

The system of aseptic preparation of intravenous drugs in clinical care settings
from a patient safety perspective

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Researcher's note: why this study?

At some point in 1999, I was asked to investigate the cause of a positive blood culture in a surgical patient. Very early on in that investigation it became clear that the cause of the positive blood culture, and the patient's life-threatening blood stream infection, was the infusion which had been prepared on the ward by a nurse. A staff nurse became curious as to what I wanted with the patient's temperature and infusion charts. It soon also became clear to the nurse that not only had an infusion caused the problem, but she was the nurse that had prepared the infusion. She was devastated; almost hysterical. She made me watch her procedure. What became obvious to me was that the organisation was asking her (and all nurses) to undertake a procedure that could not, to any degree, be guaranteed to prevent patients becoming seriously ill as a consequence of microbial contamination of infusions. This thesis is part of ongoing work to fulfil a promise to do all I could to ensure that nurses would not be put in such a position.

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This is an original piece of work which was only made possible by the contributions of others to whom I now give thanks and acknowledgment.

I thank the ward managers who bravely said I could come into their wards and scrutinise their environments and their procedures.

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Contents

1	Introduction.....	20
2	Aseptic Intravenous Drug Preparation.....	26
2.1	The opportunities for drug error in NHS Scotland.....	27
2.2	Asepsis failure: the mechanisms and micro-organisms.....	28
2.2.1	Micro-organisms and endotoxin.....	29
2.2.2	Drugs that support and encourage microbial growth	32
2.2.3	The degree of microbial contamination.....	33
2.3	Chapter 2 summary.....	36
3	Justification for this Research Proposal.....	38
3.1	Hazard to patients from infusates.....	38
3.2	Recognition of infusate contamination as a cause of BSI.....	42
3.3	The opportunities for asepsis failure.....	44
3.4	Current national guidance	47
3.4.1	Infection control guidance.....	47
3.4.2	Pharmaceutical guidance	49
3.5	Aseptic preparation procedures.....	51
3.6	Chapter 3 summary.....	54
4	The Development of a Methodological Framework for this research.....	55
4.1	The risk society	56
4.1.1	A managerial approach: high, mid and low level.....	57
4.2	The social approach to risk.....	58
4.3	Cultural Theory.....	60

4.4	Psychological approaches to risk and its measurement	61
4.5	Risk assessment methods.....	62
4.5.1	Failure Mode and Effects Analysis (FMEA)	66
4.5.2	Healthcare FMEA (HC-FMEA).....	68
4.5.3	Socio-Technical Probabilistic Risk Assessment (ST-PRA)	69
4.6	Error causation theory development.....	71
4.6.1	From humans causing errors to systems being culpable.....	73
4.7	Review of other error causation theories and approaches	75
4.7.1	Systems Engineering.....	75
4.7.2	Socio-technical systems	75
4.7.3	Normal Accident Theory	76
4.7.4	Root Cause Analysis	78
4.8	Human Errors	79
4.8.1	Human Error Theory.....	80
4.8.2	Latent conditions - Organisation	85
4.8.3	Latent conditions – Safety culture.....	86
4.8.4	Measuring the safety culture.....	89
4.8.5	Current Working Conditions.....	90
4.8.6	Current Working Conditions – Error detectability / feedback	91
4.8.7	Current Working Conditions – Procedure complexity	92
4.8.8	Current Working Conditions – A procedure profile.....	92
4.8.9	Current Working Conditions – Communication.....	96
4.8.10	Active failures in the delivery of care	98

4.8.11	Active Failures – Violations.....	101
4.8.12	System Defences and Barriers	102
4.8.13	System Defences - Redundancy Checks	103
4.9	Human Error Theory Summary	104
4.10	High-Reliability Theory	105
4.11	Patient Safety Research.....	105
4.11.1	Human Factors	108
4.12	Chapter 4 summary	109
5	The Methodological Framework used in this Thesis.....	111
6	Research Questions.....	113
6.1	Research Questions.....	113
6.2	Research Objectives	113
7	Methods.....	114
7.1	Data Collection Methods Selection.....	115
7.2	Data Collection Tools	119
7.2.1	Data Collection Tool 1 – Location Assessment	119
7.2.2	Data Collection Tool 2 – Observations of procedures.....	120
7.2.3	Data Collection Tool 3a – HCWs’ opinions on safety.....	122
7.2.4	Data Collection Tool 3b – Operators stated redundancy checks .	125
7.2.5	Validity of the Data Collection Tools	126
7.2.6	Summary of mixed methodology being used.....	129
7.3	Population and Sample	132
7.3.1	Inclusion and exclusion criteria.....	133

7.4	Ethics and Research Governance.....	133
7.4.1	Recruitment and consent.....	134
7.5	Chapter 7 summary.....	135
8	Results	138
8.1.1	Generic results applicable to all study wards.....	140
8.2	Results from the pilot ward: an Intensive Care Unit (ICU)	147
8.2.1	Data Stream 1 - Location Assessment - pilot ward.....	148
8.2.2	Data Stream 2 – Observations of drug preparations - pilot ward .	156
8.2.3	Contamination risks in the pilot ward procedure	160
8.2.4	How to reduce potential contamination risks in the pilot ward	170
8.2.5	Data Stream 4 – Procedure comparisons (pilot ward)	175
8.2.6	Data Stream 3a - Opinions on safety (pilot ward)	175
8.2.7	Summary of safety opinion questionnaire results (pilot ward).....	180
8.2.8	Summary of the pilot ward results.....	181
8.3	Results from the 2 nd ward: a bone marrow transplant unit (BMTU)	184
8.3.1	Data Stream 1 - Location Assessment 2 nd study ward.....	185
8.3.2	Data Stream 2 - Observations of drug preparations (2 nd ward)....	195
8.3.3	Contamination risks in the 2 nd ward procedure	201
8.3.4	How to reduce potential contamination risks (2 nd ward).....	206
8.3.5	Data Stream 4 – Procedure comparisons (2 nd ward)	210
8.3.6	Data Stream 3a - Opinions on Safety (2 nd ward)	211
8.3.7	Summary of the opinions of safety from the 2 nd ward	215
8.3.8	Summary of the results from the 2 nd ward	216

8.4	Results from the 3 rd ward - an Intensive Care Unit (ICU)	218
8.4.1	Data Stream - 1 Location Assessment 3 rd ward.....	219
8.4.2	Data Stream 2 Observations drug preparations (3 rd ward)	228
8.4.3	Contamination risks in the 3 rd ward procedure.....	233
8.4.4	How to reduce potential contamination risks in the 3 rd ward	239
8.4.5	Data Stream 4 – Procedure comparisons (3 rd ward).....	244
8.4.6	Data Stream 3a – Opinions on Safety 3 rd ward.....	249
8.4.7	Summary of the safety opinion results on the 3 rd ward	254
8.4.8	Summary of the results from the 3 rd ward	255
8.5	Results from the 4 th ward - A vascular surgery ward	256
8.5.1	Data Stream 1 - Location assessment.....	257
8.5.2	Data Stream 2 - Observations of drug preparations 4 th ward.....	265
8.5.3	Contamination risks in the 4 th study ward procedure	270
8.5.4	How to reduce potential contamination risks in the 4 th ward	276
8.5.5	Data Stream 4 – Procedure comparisons 4 th ward	280
8.5.6	Data Stream 3 – HCWs’ Opinions on Safety 4 th ward.....	281
8.5.7	Review of the opinions of safety on the 4 th ward.....	286
8.5.8	Summary results from the 4 th ward	287
8.6	Results from the 5 th ward – a neonatal intensive care unit (NICU)	288
8.6.1	Data Stream - 1 Location Assessment 5 th ward.....	289
8.6.2	Data Stream 2 - Observations of drug preparations 5 th ward.....	296
8.6.3	Contamination risks in the 5 th study ward procedure	302
8.6.4	How to reduce potential contamination risks in the 5 th ward	307

8.6.5	Data Stream 4 – Procedure comparisons 5 th ward	309
8.6.6	Data Stream 3a – Opinions on Safety 5 th ward.....	309
8.6.7	Summary of the safety opinions on the 5 th ward	314
8.6.8	Summary results from the 5 th ward	315
8.7	Results from the 6 th ward – medical receiving cardiology ward (MRCW)	316
8.7.1	Data Stream 1 - Location Assessment 6 th ward.....	317
8.7.2	Data Stream 3 - Observations of Drug Preparations 6 th ward.....	325
8.7.3	Contamination risks in the 6 th ward procedure.....	328
8.7.4	How to reduce potential contamination risks in the 6 th ward	332
8.7.5	Data Stream 4 – Procedure comparisons 6 th ward	336
8.7.6	Data Stream 3a – Opinions of Safety 6 th ward.....	336
8.7.7	Summary results from the 6 th ward	338
8.8	Comparative results on redundancy checks from 5 study wards.....	339
8.8.1	Summary of the redundancy check comparisons	341
8.9	Review of other information available in the study wards	347
8.9.1	Information on hand hygiene available to the nurses.....	347
8.9.2	Drug Information from the Pharmaceutical Companies	351
8.9.3	Information from the manufacturers of antiseptics	355
8.9.4	Summary of review of sundry information available to nurses	359
8.10	The system of intravenous drug preparation -how it works in practice ...	360
8.10.1	Intravenous drug preparations	360
8.10.2	The system’s error-prone characteristics	364
8.10.3	Identification of the system’s reliability characteristics	366

8.11	Summary of the results including the system profile	367
9	Discussion	368
9.1	The Location Assessments	369
9.2	The observed procedures and available equipment.....	374
9.2.1	Variation in aseptic technique	381
9.2.2	Variation in the use of gloves.....	384
9.2.3	Variation in the use of filters	386
9.2.4	Are some drugs immune from contamination?	387
9.2.5	Does the patients' immune status explain procedure variations?	389
9.3	The HCWs' opinions of safety – the safety culture	391
9.4	What is making IR-BSI invisible to nurses	393
9.4.1	How the regulatory framework contributes to IR-BSI invisibility ...	394
9.4.2	Variation between UK and US regulations.....	399
9.4.3	IR-BSI is hidden within the literature and absent from guidance .	403
9.4.4	IR-BSI is not under surveillance.....	406
9.4.5	What is making IR-BSI invisible in clinical practice	408
9.4.6	The current training.....	412
9.5	Who would be held to account should a patient suffer an IR-BSI?.....	414
9.6	What are the challenges to preventing IR-BSI?.....	415
9.7	What can be done locally to reduce the risks of IR-BSI?.....	416
9.7.1	Building human factors in to the procedure	417
9.8	How to make IR-BSI visible at a national level?	419
9.9	Review of the methods, methodological framework and the results.....	421

9.10	Assessment of the initial arguments	423
9.11	Limitations of this thesis	425
9.12	The strengths of this thesis.....	428
10	Conclusions.....	430
10.1	Conclusions related to the regulations and guidance	430
10.2	Conclusions related to the risks.....	432
10.3	Conclusions related to the system.....	433
10.4	Conclusions related to the safety culture.....	435
10.5	Conclusions as to why the system is as it is.....	436
10.6	Conclusions related to the study methods.....	437
11	Recommendations	439
11.1	Local Recommendations	439
11.2	National recommendations.....	441
11.3	Research agenda	444
12	Glossary	445
13	References	449
14	Appendices.....	491

List of Tables

Table 1	Common micro-organisms that cause IR-BSI	30
Table 2	Infusate contamination cross-transmission	35
Table 3	Operation Profile with the Study Profile.....	94
Table 4	Categories of communication error (Lingard et al. 2004))	97

Table 5	Assessing the microbial risks in the observed study procedures	120
Table 6	Statements from the HCWs' Opinions of Safety (safety culture)	124
Table 7	Error-prone, high-reliability and system profile characteristics	128
Table 8	Comparison of written and observed procedures 3 rd ward	245
Table 9	Variation in procedure with a reconstitution device	266
Table 10	How a 2 person non-interrupted procedure is performed	298
Table 11	The percentage of redundancy checks 'always done'	340

List of Figures

Figure 1	Organisation Accident Model for Intravenous Drugs Preparation	84
Figure 2	Unsafe Acts and basic error types (Reason 1990: 207)	99
Figure 3	The layout of the pilot ward	148
Figure 4	The drug preparation area in the pilot ward	152
Figure 5	The drug preparation procedures in the pilot ward	159
Figure 6	Timing from infusate contamination to IR-BSI	161
Figure 7	The sterility of equipment at the start of the procedure (pilot ward) ..	162
Figure 8	The critical surfaces during the procedure (pilot ward)	163
Figure 9	The critical surfaces just before administration (pilot ward)	164
Figure 10	Infusates posing the highest contamination risk (pilot ward)	168
Figure 11	The steps where contamination is most likely to occur (pilot ward) ..	169
Figure 12	Steps in the current procedure that could be eliminated	171
Figure 13	Integrated new steps and new system order (pilot ward)	174
Figure 14	Revised procedure (Figure 13 colour-coded)	174

Figure 15	The layout of the second study ward.....	185
Figure 16	The drug preparation room (2 nd ward).....	189
Figure 17	The drug preparation procedures (2 nd ward)	197
Figure 18	The sterility of equipment at the start of the procedure (2 nd ward) ..	201
Figure 19	The critical surfaces during the procedure (2 nd ward)	202
Figure 20	The critical surfaces just before administration (2 nd ward).....	203
Figure 21	Where contamination is most likely (2 nd ward)	205
Figure 22	What makes it difficult to ensure aseptic preparation (2 nd ward).....	205
Figure 23	Suggested amendments to the procedure (2 nd ward)	208
Figure 24	Alternative procedure (2 nd ward)	210
Figure 25	The plan of the 3 rd ward (an ICU).....	219
Figure 26	The drug preparation area in the 3 rd ward	223
Figure 27	How the drug preparation were performed in the 3 rd ward	230
Figure 28	Equipment sterility at the start of the procedure (3 rd ward).....	234
Figure 29	The critical surfaces during the procedure (3 rd Ward)	235
Figure 30	The critical surfaces just before administration (3 rd Ward)	236
Figure 31	When contamination is most likely to occur (3 rd ward)	238
Figure 32	Amended procedure for increased reliability (3 rd ward).....	243
Figure 33	Revised procedure colour-coded (3 rd ward)	244
Figure 34	The plan of the 4 th ward	257
Figure 35	The multi-purpose area where drugs are prepared 4 th ward	261
Figure 36	The drug preparation procedures 4 th ward	267
Figure 37	Use of filters preventing infusate contamination causing IR-BSI....	271

Figure 38	The sterility of equipment at the start of the procedure (4 th ward) ..	272
Figure 39	The critical surfaces during the procedure (4 th ward)	273
Figure 40	The critical surfaces just prior to administration (4 th ward)	273
Figure 41	Infusates posing the highest contamination risk (4 th ward).....	275
Figure 42	The prevention of contaminated drug infusion (4 th ward)	275
Figure 43	How the procedure could be improved on the 4 th ward	279
Figure 44	Colour-coded amended procedure on the 4 th ward	280
Figure 45	The layout of the 5th ward.....	289
Figure 46	The drug preparation area in the 5th ward	292
Figure 47	The drug preparation procedure on the 5 th ward	301
Figure 48	The sterility of equipment at the start of the procedures (5 th ward)	302
Figure 49	The critical surfaces during the procedure (5 th ward)	303
Figure 50	The critical surfaces just before administration 5 th ward.....	304
Figure 51	The limited drugs that pose an infusate risk (5 th ward).....	305
Figure 52	When is contamination of the infusate most likely to occur?	306
Figure 53	Procedure on the 5 th study ward with suggested amendment.....	308
Figure 54	The layout of the 6 th ward.....	317
Figure 55	The multi-purpose room where drugs are prepared (6 th ward).....	320
Figure 56	The drug preparation procedure on the 6 th ward	327
Figure 57	At the start of the 6 th ward procedure, what is sterile?	328
Figure 58	Critical surfaces during the procedure in the 6 th ward	329
Figure 59	Critical surfaces immediately prior to administration (6 th ward)	330
Figure 60	The drugs at highest risk of contamination on the 6 th ward	331

Figure 61	During what steps of the procedure is contamination possible	332
Figure 62	Suggested modified procedure for reliability in the 6 th ward.....	335
Figure 63	Colour-coded amended procedure for the 6 th ward.....	335
Figure 64	Stated Redundancy Checks in the pilot ward.....	342
Figure 65	Stated Redundancy Checks in the 2 nd ward.....	343
Figure 66	Stated Redundancy Checks in the 3 rd ward	344
Figure 67	Stated Redundancy Checks in the 4 th ward	345
Figure 68	Stated Redundancy Checks in the 5 th ward	346
Figure 69	Publications of IR-BSI outbreaks by year 1990-2009.....	411

List of Appendices

Appendix 1	Location Assessment Tool	492
Appendix 2	Observation of intravenous drug preparation	498
Appendix 3(a)	Operator opinions on safety; 3(b) Redundancy checks	501
Appendix 4	Ethics Permission and R&D Management Approval	504
Appendix 5	Participant Information Leaflet.....	508
Appendix 6	Consent Form.....	512
Appendix 7	Responses to Opinions of Safety Statements from the pilot ward..	513
Appendix 8	Responses to Opinions of Safety Statements from the 2nd Ward .	514
Appendix 9	Responses to Opinions of Safety Statements from the 3rd Ward ..	515
Appendix 10	Responses to Opinions of Safety Statements from the 4th Ward ..	516
Appendix 11	Responses to Opinions of Safety Statements from the 5 th ward	517
Appendix 12	Paper from the study submitted to the British Journal of Nursing..	519

Abstract

A review of the literature on blood stream infections caused by contaminated intravenous infusates which are prepared in clinical care settings found that this common nursing procedure poses at times a significant and life-threatening risk to patients. The guidance and regulations surrounding the preparation of intravenous drugs in clinical care settings suggests that this procedure is extremely complex and poses many different potential hazards to patients. This thesis set out to determine how the infection risks are being addressed in practice by asking the questions: 'What is the system of intravenous drug preparation in clinical care settings in NHS Scotland?' and, 'How does it work in practice?'

Several data sources were utilised: six locations, in specialities where the literature identified significant outbreaks had occurred, were examined for potential contamination risk. Observations (78) of infusate preparations were undertaken and, where available, written procedures were compared with observed practices. Finally, analyses were made of 71 questionnaires, completed by the nurses who prepare intravenous drugs, regarding their opinions of the procedures' safety and when they perform redundancy checks.

The conclusion of this study is that the system of preparing intravenous drugs in clinical care settings by nurses is, as a consequence of potential infusate contamination, error-prone and unreliable. The reasons for this conclusion are now detailed.

- Due to a lack of mandatory environmental standards, and the provision of poor environments, there is a risk of infusate contamination from environmental sources and consequently, a risk to patients of infusate-related blood stream infections (IR-BSI).
- Some in use equipment poses contamination risks to patients' infusates. Equipment that could reduce the contamination risk is not always available and in some instances such safety-enhancing equipment has been removed.
- There are no complete written procedures which mirror what is done in practice. At present, from a human-factors perspective, it is not easy for the nurse to do the right thing, or to be sure exactly what is the right thing to do.
- The procedure, in practice, has the required elements of an aseptic procedure, but the execution of the procedure is more often not performed aseptically.
- The procedure of intravenous drug preparation as observed is mainly an interrupted aseptic procedure and as such the recommencement of the aseptic procedure requires repeated hand hygiene.
- The nurses' opinions of safety vary, as did their assessment of the infection risk to their patients, but it is clear that intravenous drug preparation is not a much-loved nursing procedure and some nurses find it very stressful.
- There is no asepsis quality control built into the system. Aseptic steps are the least likely to be performed as a redundancy check compared to the mandatory checks of 'right patient, right drug and right dose'.

- The information available to the nurses, from the drug companies, from the makers of equipment and from national agencies does not identify with sufficient clarity the infection risks, or detail how to negate them.

Suggestions for improvement to the six procedures and environments are clear once the procedure steps are colour-coded as either aseptic or non-aseptic; validity testing of these improvements is however, still needed.

The systems' vulnerabilities observed in this research appear to stem from a chain of external influences including an underestimation of the problem size and the actions needed to prevent it in evidence-based guidelines and mandatory guidance. This leads to poor recognition of the risk of IR-BSI in clinical practice. The problem of infusate contamination causing IR-BSIs is further compounded by the fact that it is not caused by a single organism and does not always present as a disease in real time, that is, over the lifetime of the infusion. As a consequence, this presents surveillance difficulties in terms of definitions, data collection and analysis.

Finally, although the diagnosis of a blood stream infection for an individual patient remains relatively easy, it is not easy to recognise a contaminated infusate as the origin of the problem. All these challenges make both the recognition of the problem and agreement on prevention strategies, extremely challenging.

In summary, the main conclusion of this thesis is that the preparation of infusates in clinical care settings, which occurs approximately 3,000,000 times a year in NHSScotland, is from an aseptic perspective, error-prone and unreliable. Recommendations to optimise patient safety include, changing the procedure locally and, with the utmost urgency, the production of minimum environmental standards. The results of this study are relevant to all hospitals in Scotland and throughout the United Kingdom where the current regulations apply and similar procedures are performed.

1 Introduction

This thesis consists of 14 chapters in which the reasons for research into aseptic preparation of intravenous drugs are made, the methods to undertake the research are described and the results detailed. The discussion provides an evaluation to conclude that the system is at present more error-prone than reliable.

This chapter provides a synopsis of the thesis. Chapter 2 presents an understanding of the size of the potential problem. Details are specified as to the number of intravenous procedures performed each year in Scotland, the potential sources of contamination, as well as how micro-organisms in infusates cause serious life-threatening, infusate-related blood stream infections (IR-BSI). The unique properties of micro-organisms that most frequently cause IR-BSI are also discussed.

Chapter 3 describes the justification for this research, specifically, there appears to be a clear hazard to patients from the status quo, it is difficult to recognise infusate contamination as a cause of a blood stream infection (BSI), the opportunities for asepsis failure are numerous, and current guidance is extensive, yet insufficiently, focused on quality or IR-BSI prevention. Additionally, the system on paper at least, is extremely complex.

Chapter 4 provides an evaluation of the strengths, weaknesses and relevance of different approaches to risk and error causation to the thesis. This evaluation leads to the development of a methodological framework. Although risk perception and risk assessment are considered relevant to the thesis, the chapter concludes that the assessment and methodological approach best suited to assess the system of aseptic preparation of intravenous drugs is a systems approach to human error, combined with high-reliability theory, patient safety and human factors. Understanding and measuring the safety culture related to intravenous drug preparation procedures is also considered critical to the success of the thesis in understanding the system of aseptic preparation.

Chapters 5 and 6 are brief chapters. Chapter 5 describes the methodological framework used in the thesis. Patient safety is considered compromised from the inherent dangers in the procedure recognised in the literature and the guidance. The system is considered vulnerable because it is designed by, and reliant on, humans. From a systems approach to human error the need to identify unsafe acts and latent conditions that provoke errors are identified. The examination of the system is considered the means by which to identify what is required to improve safety. Human factors are involved in making sure that system changes make it easy for the healthcare workers (HCWs) to do the right thing. Chapter 6 specifies the research questions which are: What is the system of aseptic drug preparation in clinical care settings? And, How does it work in practice?

In Chapter 7 an explanation is given of the rationale for selecting each of the methods used in this thesis to answer the research questions. To reduce bias, triangulation of different data collection methods was required. Ready-to-use data collection tools were not available for this study. Four different data sources were utilised, namely, the assessment of locations where intravenous drugs are prepared, observations of the preparations of intravenous procedures being performed, comparison of written procedures with observed procedures and a survey to identify the HCWs' opinions on safety and to determine when redundancy checks are performed. Sampling for this thesis was done by identifying the most common clinical settings from which outbreaks have been reported in the literature. Five such clinical specialities were identified: neonatal and adult intensive care units, haematology-oncology units, vascular surgery wards and medical wards. It was decided to use one ward from each of these specialities with an additional pilot ward of an adult intensive care unit. The study took place in one NHS board in Scotland which is responsible for a third of all healthcare in Scotland. Details of the ethical and research governance permissions obtained are also provided in this chapter.

Chapter 8 contains the results which are presented individually and collectively. What the results show is that although there is a single training programme and a single training manual, there are 6 different procedures performed. The risk of infusate contamination varies between individual wards based on the environments, the equipment, the drugs and diluents used. No ward had a written

procedure which reflects in its entirety the procedure as performed in practice. For each of the individual areas an assessment of potential risk of asepsis failure is made along with suggestions for improvements to reliability. The procedures in all six locations contained contamination risks that are unrecognised as such by the nurses. All but 2 of the aseptic procedures are interrupted by steps that are not aseptic. In order to illustrate the interrupted nature of the procedures, and identify where the procedure should recommence with hand hygiene, each procedure is shown with colour-coding steps as either aseptic or non-aseptic.

The data from the HCWs' opinions of safety survey shows a safety culture that has characteristics of safety, such as a willingness to report errors as well as characteristics of safety vulnerability including erroneous assumptions of safety and a lack of feedback. Chapter 8 continues with the collective between-ward redundancy checks data which shows that asepsis checks are performed least frequently of all the redundancy checks. An evaluation of all the information available to the nurses who prepare the drugs indicates that the nurses are not well served by information provided from a variety of organisations including pharmaceutical companies and the World Health Organization. Infection risks in the available information are not well highlighted. A system profile is produced from the combined results showing that it is nurses who perform this common, safety-critical procedure in clinical care settings in Scotland. What is also concluded overall is that the system of aseptic drug preparation is more error-prone than reliable.

Chapter 9 provides detailed discussion of the results and the identified variations between the procedures, specifically, variations in use of gloves and filters and seeks explanations for this in the published literature. There is discussion of the results from the Location Assessments, the observed procedures and the nurses' opinions of safety data. This chapter provides analysis of why the system is vulnerable and why such variation exists. There is discourse on the differences between the regulations in the United Kingdom which are limited, and the United States regulations, where there are stringent environmental controls and a requirement for end-product testing are provided. A chain of external influences that impact on the safety of this procedure are identified and discussed. These influences include: a lack of recognition of the problem in national guidance, difficulties in extracting information in the literature, difficulties in diagnosis of a clinical case, difficulties in surveillance and a poor understanding of the significance of the problem as a clear hazard to patients. It is concluded that the primary factor as to why the preparation of intravenous drugs in clinical care settings poses such risks, and is without sufficient safeguards, is that the problem has been, and still is, considered rare. Such guidance as there is in Scotland does not recognise the infection risks from such high-risk drugs as multi-dose vials, long-term infusions (>12hours) and lipid-based drugs and as a consequence neither do the ward staff. Additionally, the minimum standard for the environmental conditions under which such procedures should be performed is not specified.

Chapter 10 lists the conclusions from the totality of the results and shows that the system of aseptic preparation of intravenous drugs in near patient settings is unreliable and lacks quality control. The cause of this unreliability is in the main outwith the hospital, where there are no specified environmental regulations and no requirement for ongoing quality control of the product. Unless the system of aseptic preparation of intravenous drugs is changed, it will continue to be under-diagnosed, under-investigated and under-reported. Suggestions for improvements are given for individual wards, but all require validation.

The recommendations from the findings of this thesis (Chapter 11) are wide-reaching and include recommendations for local procedure modifications, the need for equipment experts and for environmental risk assessment experts. With regard to national guidance, there is a need for a specification of environmental and product quality control standards in order to ensure the safety of patients when preparing intravenous drugs in clinical care settings. The research agenda is set to clarify the risk of infusate contamination and to reduce it. At present, the risk of error in this procedure cannot be accurately enumerated.

The final three chapters contain the glossary, references and appendices. The next chapter commences with an evaluation of the problem contaminated infusates and its potential size.

2 Aseptic Intravenous Drug Preparation

In this chapter data are given on the frequency with which the preparation of intravenous drugs is undertaken in clinical care settings. The opportunities for asepsis failure during this procedure, and precisely how intravenous drugs can cause IR-BSIs and catheter contamination, are also explained. The unique nature, properties and origin of some of the common micro-organisms that cause IR-BSI is specified; this includes how some of these organisms can grow in nutritionally poor conditions. The chapter also includes information on how illness can be caused by living micro-organisms and by toxins released on their death. The factors that determine whether an IR-BSI or catheter contamination will occur are in addition discussed. Finally, how cross-transmission in a healthcare setting can cause IR-BSI is specified.

Aseptic preparation and administration of intravenous drugs is a common, yet inherently dangerous, clinical procedure performed in the main by nurses in near-patient areas. A comprehensive survey of practices in a university hospital found that only 25% of intravenous drugs were prepared in an aseptic pharmacy suite – the remainder were prepared in clinical care settings (Beaney and Goode 2003). A point prevalence survey found that 28% of inpatients received one or more intravenous drugs each day (Taxis and Barber 2003). This concurs with a national prevalence study of hospital associated infections, which found that 31% of

patients had a peripheral vascular access device (Reilly et al. 2007). Extrapolating data for Scotland, and using acute occupied bed days for 2006 as the denominator (Health Protection Scotland 2007), it is estimated that in Scotland approximately 3,000,000 intravenous drugs are prepared in clinical areas each year, and, around 700,000 are prepared in aseptic pharmacy departments.

2.1 The opportunities for drug error in NHS Scotland

The opportunities for any type of drug error in this common procedure are numerous. There are potential errors of: wrong drug, wrong dose, wrong diluent, wrong route, or precipitate formation, poor mixing with administration of foreign body, for example, glass, or undissolved drug (Maki and Ringer 1991, Munro et al. 2003, Crowley et al. 2004, Cousins et al. 2005). There are also potential administration errors of wrong patient, too rapid an administration rate or air-embolism (Santell and Cousins 2005). Drug errors are acknowledged to be a significant worldwide healthcare problem (Smith 2004: 14). High-profile drug errors, which resulted in deaths, have prompted government ministers to take action and produce policies with an objective to cut drug errors by 40% (Dept. of Health 2000). Throughout NHSScotland it is policy that all drug errors, including near misses, should be reported. However, the Audit Commission acknowledges that because of variations in definitions, reporting arrangements and actual reporting, the true number of drug errors is unknown (Audit Commission 2001: 20). The national focus of drug error prevention thus far has been on the most common and obvious types of errors, and those that have the highest profile, for example,

the erroneous lethal intrathecal injection of vincristine (Dept. of Health 2000, Audit Commission 2001).

The focus of this thesis is another category of drug error that is less obvious - a failure of asepsis - which like all the errors listed previously, is potentially fatal (Vidal et al. 2003, Vonberg and Gastmeier 2007). This thesis will present several related arguments for the need for research into a systematic analysis of the safety and reliability of aseptic preparation of drugs in clinical care settings. Before presenting these arguments, an explanation of the mechanisms of asepsis failure will be given.

2.2 Asepsis failure: the mechanisms and micro-organisms

A failure of asepsis at any stage during preparation may lead to contamination of the infusate and potentially to the patient developing a blood stream infection (BSI). Pathogenesis arises following direct infusion of micro-organisms into the blood stream, and/or, low level contamination of infusate causing intra-luminal contamination of the catheter enabling biofilm formation with a BSI arising at some later date (Linares et al. 1985, Donlan 2001). Biofilm forms on any surface in contact with moisture – including all medical devices. Biofilm development begins when infused micro-organisms adhere to the surface of the catheter and protect themselves by the production of extracellular polymers. These polymers protect the micro-organisms from not only antibiotics infused through the catheter, but also from phagocytes. Over time the biofilm increases in size and complexity and

eventually small numbers of micro-organisms float off from the catheter surface entering the blood stream and resulting in a BSI (Donlan 2001). In addition to causing a BSI, in a small proportion of patients, some micro-organisms will metastasise and cause infections in other organs, particularly the heart (Giamarellou 2002).

The degree of contamination, and consequently patient ill health, will be dependent on three factors:

- The type of micro-organisms that contaminate the infusate.
- The extent to which the drug/diluent will support and encourage microbial growth.
- The degree of microbial contamination, which is dependent on the number of organisms in the initial contamination and duration of infusion.

Factors that mitigate against a BSI developing, including the use of a filter and the early removal of the catheter, will be discussed later. The three factors affecting the degree of contamination will be discussed individually:

2.2.1 Micro-organisms and endotoxin

A variety of micro-organisms can contaminate infusates and cause BSIs, including: Gram-negative micro-organisms, which are mainly part of the normal gut flora, other Gram-negative micro-organisms, which are mainly free living environmental micro-organisms, parasites that cause diseases such as malaria, and, most notably, blood borne viruses. Table 1 gives samples of the most common micro-

organisms causing BSIs from infusates. The environmental Gram-negative micro-organisms listed in Table 1 are renowned for their ability to grow well in nutritionally poor intravenous solutions (Gilat et al. 1958, Felts et al. 1972, Maki and Martin 1975). Experimental laboratory studies have found that heavily contaminated infusates, (10^6 micro-organisms per ml) did not appear cloudy to the naked eye (Gilat et al. 1958, Felts et al. 1972, Maki and Martin 1975, Macias et al. 2005). Consequently, for nurses preparing drugs there are no visual clues when infusates are contaminated. What this table further illustrates is that IR-BSI is not caused by a single organism; a consequence of which is that laboratory based surveillance and monitoring of the problem is extremely difficult and currently not done locally or nationally.

Table 1 Common micro-organisms that cause IR-BSI		
Category	Examples of micro-organisms	References
Gram-negative bacilli Part of normal gut flora / found in environment	<i>Klebsiella</i> spp <i>Enterobacter</i> spp <i>Serratia</i> spp	(Felts et al. 1972, Maki and Martin 1975, Ostrowsky et al. 2002, Siegman-Igra et al. 2005, Pan et al. 2006, Gillespie et al. 2007)
Environmental Gram-negative bacilli Mainly free living environmental micro-organisms	<i>Stenotrophomonas maltophilia</i> <i>Burkholderia cepacia</i> Non-aeruginosa pseudomonads	(Felts et al. 1972, Hsueh et al. 1998, Nasser et al. 2004, Centers for Disease Control 2005, Centers for Disease Control 2006)

Table 1 Common micro-organisms that cause IR-BSI		
Gram-positive cocci	<i>Staph. aureus</i> Coagulase negative staphylococci	(Krumholz et al. 1994, Kuehnert et al. 1997, Langevin et al. 1999)
Parasites	<i>Plasmodium falciparum</i>	(Al-Saigul et al. 2000, Jain et al. 2005)
Blood borne viruses (BBV)	Hepatitis B virus Hepatitis C virus	(Katzenstein et al. 1999, Centers for Disease Control 2003, Williams et al. 2004, Macedo de Oliveira et al. 2005)

The durability of these micro-organisms is further illustrated by researchers who found that *Pseudomonas putida* in heparinised saline could survive refrigeration for up to 35 days (Perz et al. 2005) and *Burkholderia cepacia* has the ability to grow in distilled water (Spencer 1995). These environmental micro-organisms that cause infusate contamination can arise from periodic contamination of the potable water supply and subsequent contamination of the healthcare environment (Koerner et al. 1997, Rogues et al. 2007, Cholley et al. 2008, Livni et al. 2008).

When micro-organisms, in particular the Gram-negative bacilli, are destroyed they still pose a further risk by releasing endotoxin from the break-up of their cell wall. Once in the blood stream endotoxin can induce a high fever, reduce blood pressure and cause disruption in the coagulation of the blood, leading to possible haemorrhaging within the tissues. Endotoxin is considered to be the principal

component of Gram-negative BSI responsible for initiating the patho-physiological processes resulting in the clinical features of Gram-negative sepsis and septic shock. Endotoxin can be present in an infusate in the absence of live micro-organisms (Chapman and Iredell 2008).

Gram-positive micro-organisms such as *Staphylococci* spp, which are the main cause of catheter-related BSIs, (Coello et al. 2003) can - and do - contaminate infusates (van Grafhorst et al. 2002). However, possibly because of their inability to grow in the infusates they have been implicated less as a source of IR-BSI (Sitges-Serra et al. 1984, Langevin et al. 1999, van Grafhorst et al. 2002). The vascular catheter however, can be seeded with Gram positive micro-organisms through contamination of the infusate. The extent to which this causes catheter related BSI at some time in the future is unknown.

2.2.2 Drugs that support and encourage microbial growth

Some drugs containing lipids, such as propofol, have been implicated in many outbreaks (Veber et al. 1994, Bennett et al. 1995, Halkes and Snow 2003, Trepanier and Lessard 2003). Lipid drugs can temporarily inhibit phagocytosis, and this, combined with any microbial contamination, can have a serious outcomes for patients (Krumholz et al. 1994, Langevin et al. 1999).

Heparin, a frequently used anticoagulant, can pose an infusate risk in several ways. Heparin is given as a long-term infusion (12-24 hours) or as a flush to

maintain catheter patency following administration of a drug. Most importantly however, heparin supports microbial growth. Heparin has been implicated in several IR-BSI outbreaks when given as a continuous infusion, as well as when administered as a flush solution to maintain a vascular device patency (Al-Saigul et al. 2000, Centers for Disease Control 2005, Siegman-Igra et al. 2005, Gershman et al. 2008, Yang et al. 2008, Blossom et al. 2009). There have even been reports of heparinized antibiotic lock solutions being contaminated (Safdar and Maki 2006).

2.2.3 The degree of microbial contamination

The duration of the infusion, which includes the time from preparation to completed administration, can also influence when and if a BSI will occur (Krumholz et al. 1994, Langford 2000). Longer administrations of infusions, over 12-24 hours, provide even very few micro-organisms with sufficient time to multiply to significant numbers thereby enabling a BSI to occur within the life-time of the infusion. As stated previously, rapid growth of some Gram-negative micro-organisms in infusion solutions has been demonstrated. One organism per ml of a *Klebsiella* spp inoculated into dextrose yielded a mean 1.11×10^5 micro-organisms per ml after 24 hours at room temperature (Maki and Martin 1975). Similarly, very early on in infusion therapy, during an investigation into a case series of IR-BSIs, it was shown that 10-20 causative micro-organisms inoculated into Darrow's solution at room temperature resulted in 6-8 million micro-organisms per ml 48 hours later (Gilat et al. 1958). Therefore, if an infusate is contaminated and administered over a 12-24 hour period, very few micro-organisms can proliferate and cause an IR-

BSI within the lifetime of the infusion. The higher the inoculum, the earlier the IR-BSI will manifest. Bolus infusions, or short duration infusions, with low level microbial contamination may not cause a IR-BSI immediately but, as stated previously, can contaminate the catheter surface and facilitate biofilm formation and, provided the catheter remains in situ, cause catheter-related BSI at a later date. Thus it can be concluded that there is no safe level of microbial contamination of infusates.

There are several possibly mechanisms for infusates to become contaminated in clinical care settings involving:

- Cross-transmission from healthcare worker (HCW) to patient
- Cross-transmission from patient-to-patient via HCW
- Cross-transmission from the environment-to-patient due to HCW actions or inactions.

These mechanisms are described in Table 2. What this table also illustrates is that IR-BSI can (and has been) caused by contamination arising from a variety of sources. Additionally, when such contamination occurs it is not easily detectable to the person preparing the infusate.

Table 2 Infusate contamination cross-transmission	
Cross-transmission from HCW to Patient	
A HCW infected with a BBV cuts his/her finger, which bleeds into an open ampoule. The drug along with the BBV is then drawn up and administered to the patient.	(Parker 1995)
Hand (artificial nail) contamination during preparation, contaminating the infusate directly.	(Gordin et al. 2007)
Cross-transmission from Patient-to-Patient via HCW	
“Double-dipping” A needle used on a patient infected with a BBV or a parasite, enters a drug vial. The drug (and BBV or parasite) is then subsequently used on one or more patients.	(Al-Saigul et al. 2000, Centers for Disease Control 2003, Jain et al. 2005, Macedo de Oliveira et al. 2005)
Reuse of the same administration sets which have become contaminated on serial patients.	(Halke and Snow 2003)
Cross-contamination during processing of radio-pharmaceutical specimens used for myocardial perfusion studies – transmission of BBVs.	(Patel et al. 2006)
Cross-transmission from the environment to patients due to HCW (actions / inactions) or environmental limitations	
Contamination during preparation, either from an environmental source, such as, splash contamination from a tap, contaminated surface used to prepare drugs, poor hand hygiene or poor aseptic technique, resulting in either a single patient episode, or if the contamination involves a vial which is subsequently reused, then in multiple patients becoming infected.	(Hsueh et al. 1998, Centers for Disease Control 2005, Jain et al. 2005, Centers for Disease Control 2006, Pan et al. 2006, Gillespie et al. 2007).

Table 2 Infusate contamination cross-transmission	
Contamination of the drug from the outside of the drug vial or ampoule.	(Zacher et al. 1991)
Failure to, or inadequate, decontamination of the hub pre-administration of the drug resulting in infusion of the micro-organisms contaminating the hub, as well as the infusate.	(Sitges-Serra et al. 1984, Sitges-Serra et al. 1985, Sitges-Serra et al. 1985, Doit et al. 2004, Nasser et al. 2004, Livni et al. 2008)
Active contamination of an access point by use of contaminated antiseptics for aseptic vascular catheter procedures, that is, contaminating the hubs before infusing the drug.	(Heo et al. 2008)
Illegal tampering of hanging infusates to get access to opiates introducing micro-organisms in to the infusate in the process.	(Ostrowsky et al. 2002)
Intrinsic contamination (that occurs in the manufacturer's premises) is not being considered in this thesis except where evidence from intrinsic contamination can be extrapolated and related to extrinsic contamination.	

2.3 Chapter 2 summary

In this chapter it has been shown that the opportunities for asepsis failure when preparing intravenous infusions are vast. Additionally, some of the micro-organisms that cause IR-BSI have unique properties that enable them to grow well in nutritionally poor solutions, without visible detection. Factors such as the size of contamination and duration of infusions can determine whether an IR-BSI occurs

during the life-time of the infusion or at a later date. The specifics of cross-transmission as reported in the literature and in Table 2 show how IR-BSI can occur. The next chapter will further elucidate from the literature evidence that justifies the need for additional research into the system of aseptic preparation of intravenous drugs in clinical care settings.

3 Justification for this Research Proposal

This chapter will set out and discuss the evidence supporting the need for a study into procedures for the aseptic preparation of intravenous drugs. These reasons are summarised as:

- There appears to be a clear hazard to patients from infusate contamination
- It is difficult to recognise infusate contamination as a cause of BSI
- The opportunities for asepsis failure are numerous
- Current national guidance is extensive yet insufficiently focused on asepsis failure with no requirement for ongoing quality control
- The system of aseptic preparation, on paper at least, is extremely complex.

3.1 Hazard to patients from infusates

The assessment of a clear hazard to patients comes in the main from, published case reports, outbreak reports, systematic reviews of outbreaks and epidemiological evidence. A systematic review of worldwide drug-related outbreaks between 1990 and 2005, identified 128 reports of non-blood product related outbreaks involving 2,250 patients (Vonberg and Gastmeier 2007). In these outbreaks the majority of contamination occurred in drugs prepared in near-patient areas. A significant number of these outbreaks (64/128) involved multi-dose vials (or vials that were designated single-use being used more than once). The

drugs/infusions that are most commonly reported as the source of the contamination are heparin (flush or infusion) and lipid drugs/solutions such as propofol or intralipid. The mortality from outbreaks of contaminated substances varied in the review from 0 – 25% (Vonberg and Gastmeier 2007). This is probably still an underestimate as many of the patients infected with a BBV, which may result in a fatal outcome over time, would not have been included in these data.

Outbreaks are perhaps the most visible consequence of infusate contamination and IR-BSI. A recent investigation into an outbreak of *Enterobacter aerogenes* BSIs in a neonatal intensive care unit focused quickly on infusates as the possible cause. This was because one of the patients had only been born approximately 2 hours before becoming symptomatic, and the only intervention in that time had been an infusion (Narayan et al. 2009). In all in this outbreak, a total of 10 babies developed IR-BSI over a 14 day period. Three babies died. The repeated use of saline bags as a multi-dose diluent, contaminated with *Enterobacter aerogenes* was thought to be the origin of the outbreak (Narayan et al. 2009). That the potential for outbreaks is almost ubiquitous was revealed in another study of 1,093 ward prepared infusates, which found a contamination rate of 0.9%; and two cases of IR-BSIs (Macias et al. 2008). The authors concluded that 'endemic infusate contamination may be a present danger' (Macias et al. 2008: 48). It is the environmental Gram-negative micro-organisms detailed in Table 1 that were the commonest pathogens in this study (Siegman-Igra et al. 2005).

There are additional reports that suggest infusate contamination may be implicated in causing IR-BSI, although causality was not demonstrated. Several authors have reported an increase in Gram-negative sepsis after antibiotics for Gram-positive infections (Victor et al. 1994, Ubeda et al. 1998, van Houten et al. 2001). This could be contamination of the infusate (the antibiotic), or the heparin flush used after antibiotic infusion to prevent clotting in the catheter lumen, or some, as yet unidentified, associated procedure. It is not necessarily a weakness on the part of the outbreak investigators or of the studies in not confirming the causes; often by the time the organism is identified in a patient's blood, the infusate is no longer available for sampling.

There are other outbreak reports in which there was one category of infection outcome (BSI), where the organism was a Gram-negative bacillus or polymicrobial Gram negative bacilli, (often of an environmental source), where the patients were either in an intensive care or haematology-oncology unit, where the infections were associated with vascular access device usage and poor aseptic practices were found, for example, identified use of multi-dose vials and no other plausible transmission routes found (Boktour et al. 2006, Kilic et al. 2007, Erbay et al. 2008, Kallen et al. 2008, Kilic et al. 2008, Kim et al. 2008, Mikulska et al. 2009, Nadkarni et al. 2009). These reports implicate infusates as the access route for the micro-organisms gaining entry into the patients' blood. One such example, an investigation into an outbreak of *Alcaligenes xylosoxidans* BSIs in an oncology

outpatient setting, identified gross breaches in infection prevention protocols including, insertion of catheters without gloves, storage of pre-filled syringes in the hood, use of open-undated multi-dose vials, storage of non-hygienic materials in the chemotherapy preparation hood and failure of routine hand washing (Kim et al. 2008). In this outbreak, twelve patients acquired a BSI, nine before the investigation commenced (Kim et al. 2008).

Evidence that hand contamination is not, as is usual, the main infection control suspect came in a study showing that the Gram-negative bacilli found on HCWs' hands were not associated with those found in patients' blood (Larson et al. 2005).

The World Health Organization produced sound guidance on safe single-use injection devices; the document suggests that the problem of non-aseptic preparations is worldwide, not just affecting the third world (World Health Organization 2007). This is confirmed by a report on 4 large hepatitis B and hepatitis C virus outbreaks, affecting more than 350 people, resulting from what was classified as unsafe injection practices, which occurred in outpatient settings in the United States (Centers for Disease Control 2003).

The final evidence that there is a clear hazard to patients from near-patient preparation comes from the epidemiological studies of the micro-organisms listed in Table 1. There is evidence from national centres and other epidemiologists that these micro-organisms have been increasing in recent years (Health Protection

Agency 2003, Vidal et al. 2003, Health Protection Agency 2005, Albrecht et al. 2006, Wu et al. 2006, Health Protection Agency 2007).

All of the studies in this section are relatively recent and many occur in modern health services. It is clear that BSIs as a consequence of asepsis failure and infusate contamination are life-threatening and current. The implication is that there is a clear hazard to patients' safety from the status quo.

3.2 Recognition of infusate contamination as a cause of BSI

Despite the infusate-related outbreak reports discussed previously, it is often difficult to relate a BSI back to a contaminated infusate, particularly if the infusion has been completed. The contaminated substances outbreak review noted that contamination 'might not even be noticed if only a few patients are affected on the ward' (Vonberg et al. 2007: 19). It does not seem intuitive that BSIs caused by poor intravenous procedures could go relatively undetected. However, many of the patients who require intravenous infusates are already sick and are generally vulnerable to infections; the majority of BSIs occur in intensive care units, haematology or renal units (Edgeworth et al. 1999, Zaidi et al. 2001, Jugo et al. 2002, Coello et al. 2003, Gulati et al. 2003, Ozkocaman et al. 2006). It seems that only something exceptional will alert staff to a possible contaminated infusate. A 4-year review of BSIs and risk factors was undertaken when a cluster of BSIs was found to be associated with heparin pumps (Siegman-Igra et al. 2005). These researchers found that 6% (96 patients) had a BSI for which the only identified risk

factor was an intravenous catheter. In response to this study by Siegman-Igra et al. (2005), other investigators reported similar findings, that is, IV-heparin pump related BSIs in multiple patients (Peiris et al. 2006).

Even more difficult to detect, however, is a delayed-onset IR-BSI. Infusate contamination can, as stated previously, cause biofilm production and consequently the time from infusion to symptoms extends. Investigations into a multi-state outbreak of *Serratia marcescens* found that the majority of 162 cases were identified within days of exposure although 2 patients developed IR-BSI weeks after exposure (Blossom et al. 2009). During one outbreak of BSIs caused by *Alcaligenes xylosoxidans*, the causative organisms was found in the biofilm of catheters (Kim et al. 2008). That biofilm formation causes delayed-onset BSIs was demonstrated clearly during a multi-state outbreak of heparinised saline flush contaminated intrinsically (at the manufacturers) with *Pseudomonas fluorescens*. With 47 cases identified the outbreak control team found the cause of the outbreak and instigated a product recall. The product recall was successful, however, a further 33 cases were identified post-product recall. These delayed-onset IR-BSI cases were identified between 84 and 421 days after their last exposure to the contaminated heparinised saline (Gershman et al. 2008).

What the Gershman et al. (2008) study shows is that depending on the degree of infusate contamination, the time to symptom development varies, from instantly, to possibly several months after drugs have been administered. Therefore, unless

there is an identified contamination incident, such as occurred in the Gershman et al. (2008) outbreak, it can be extremely difficult, if not impossible, to trace back contamination to a single contaminated infusate. The Gershman et al. (2008) outbreak report is not unique. During investigations into a poly-microbial outbreak of 27 IR-BSIs in an outpatient setting caused by contaminated saline bags used as multi-dose diluents (accessed via a dispensing valve), investigators found that the median time between date of last infusion and date of onset of symptoms was 5 days [range 3-14] (Watson et al. 2005). Rapid growth of micro-organisms pre-administration and delayed-onset BSI was further demonstrated in investigations into a cluster of BSIs an outpatient setting, caused by the contaminated artificial fingernail of one nurse. The nail was used to open a vial of heparin. The heparin flushes were all made up at the same time but administered through the day. Patients who received the flush in the afternoon were symptomatic immediately where as those who received the flush in the morning were symptomatic over several days (Gordin et al. 2007). Others have also reported the phenomena of delayed-onset BSI following infusate contamination (Souza Dias et al. 2008, Mauri et al. 2009).

3.3 The opportunities for asepsis failure

With approximately three million drugs prepared in near patient-areas in Scotland's hospitals every year, and with no requirement for continuing quality control of the infusates, the nurses or the environments, the opportunity for asepsis failures in

performing this procedure are vast. Even a 0.5% contamination rate would mean a 150,000 contaminated infusates administered in Scotland each year with an unknown number causing IR-BSI.

It is difficult to estimate precisely how much contamination occurs; however, several studies that have looked at different parts of the procedure indicate that asepsis failures are common. In a reliable, if small, environmental study, which followed standard microbiology methods (using air sampling and contact plates), researchers found that 10/10 surfaces where drugs were prepared in near-patient areas were contaminated (Beaney and Goode 2003). In a systematic review of published studies on all errors in intravenous drug preparation and administration, poor aseptic technique, and environmental contamination were noted to be frequently found (Crowley et al. 2004). Many of the micro-organisms listed in Table 1 can survive for long periods in the inanimate environment (Kramer et al. 2006), as well as in fluids (Langford 2000). A microbiological contamination rate of 0.9% was found in a study of in-use of 227 multi-dose vials (Mattner and Gastmeier 2004). In one outbreak involving 8 children, *Burkholderia cepacia* was identified in condensate in the underside of plastic stoppers covering infusate vials. This vial condensate contained 10^5 micro-organisms per ml of *Burkholderia cepacia* (Doit et al. 2004). Adequate decontamination of the vial tops before withdrawing the contents would have prevented contamination of the infusate, and the patients' IR-BSIs.

In a large (over 950 syringes sampled), well-designed study significant differences were identified in syringe contamination rates comparing infusates prepared in a pharmacy suite and in intensive care units. Syringes prepared from 10-ml ampoules in the intensive care units had a median contamination rate of 22%, compared with pharmacy-prepared contamination rates of 1% ($p < 0.001$) (van Grafhorst et al. 2002). Staphylococci were the main organisms identified in the study; the authors noted that infusate contamination might be the source of subsequent staphylococcal catheter-related BSI. Contamination rates were much lower when glass vials were used – this was postulated to be due to vials requiring fewer manipulations (van Grafhorst et al. 2002). In another well designed study which observed 100 nurses preparing infusates, drawing up fluids, and a further 100 nurses preparing infusates with several manipulations, Worthington et al. (2001) were able to demonstrate considerable variation in aseptic technique and significant contamination rates (8%). Higher infusate contamination rates were associated with greater required manipulations in the procedure (Worthington et al. 2001). A systematic review of microbial contamination of infusates prepared in clinical areas identified an overall 5% contamination rate (95% CI; 0.8% to 13.1%) (Austin and Elia 2009). Most conclusively, however, in a multi-centre (3 European countries including the UK), non-participant observational study, researchers found at least one deviation from aseptic technique in each of 299 observations (Cousins et al. 2005). Although there was the possibility of observer bias – different observers in different countries - what should be noted was that this was a volunteer population that had agreed to being observed. Consequently, this could

be an underestimate of general aseptic performance with the possibility that non-volunteers might not perform 'so well' and that, when unobserved, practice might be different. The study did not identify which aspects of the aseptic technique procedure were missed. In conclusion therefore, not only are the opportunities for asepsis failure, subsequent infusate contamination and BSI as a consequence immense, whenever aseptic practice has been observed the performed procedures was less than optimal to prevent contamination.

3.4 Current national guidance

A variety of specialists, organisations and authorities have produced guideline documents with the objective of increasing patient safety and reducing the risks of BSI as a consequence of asepsis failure (NHS Executive 1996, Audit Commission 2001, O'Grady et al. 2002, Royal Pharmaceutical Society 2005, Nursing and Midwifery Council 2006, National Patient Safety Agency 2007, Pratt et al. 2007, World Health Organization 2007, Healthcare Commission 2007a). However, for the majority of these documents, asepsis failure prevention is not the only, or more importantly the main, objective. As a consequence the lack of coverage and degree of importance of asepsis failure emphasised in these documents appears insufficient to achieve patient safety.

3.4.1 Infection control guidance

The United Kingdom's Dept of Health commissioned epic guidelines on the prevention of central venous catheter infections ignores infusate contamination

entirely in its synopsis of the causes of central line infections (Pratt et al. 2001, Pratt et al. 2007). The search terms used to produce these evidence-based guidelines do not include 'infusate', and there is no discussion of infusate-related BSI. The US Centres for Disease Control (CDC) guidelines state in the section on pathogenesis that 'rarely infusate contamination leads to CR-BSI [catheter-related blood stream infection]' (O'Grady et al. 2002: 5). Although the guideline cites 293 references in total, there is only one reference provided to support this statement: and this is from a book published in 1982. Neither of these two guidelines, from which many local hospital policies are based, appears to fully recognise the problem of asepsis failure causing infusate contamination. Infusates are recognised as a more common cause of sepsis in the developing world (Hsueh et al. 1998, Verghese et al. 1998, Wu et al. 2006). To illustrate how this national guidance is duplicated through current research, in a meta-analysis of randomised control trials of the efficacy of vancomycin-containing lock or flush, a group of researchers (Safdar and Maki 2006) failed to identify the contamination risks from flush solutions (Worthington et al. 2001, Centers for Disease Control 2006, Held et al. 2006). Because their meta-analysis only included randomised control trials it excluded outbreak reports of contaminated antibiotic-lock solutions causing infusate-related BSI (Held et al. 2006); including the contamination reports would have added critical information to the evaluation.

3.4.2 Pharmaceutical guidance

The first report on aseptic preparations in the NHS was The Breckenridge Report published in 1976, which identified several problems and variation in training, documentation, information, and most crucially stated that 'strict asepsis could never be assured in a ward setting' Zavery et al. (2005: 3). The Audit Commission (2001: 64) recommended in 2001 that '...the practice of making-up aseptic preparations on hospital wards should be stopped'. This recommendation has never been accepted as such. Government health departments have not issued mandates, for example, Health Department Letters to chief executives telling them to stop the practice in their facilities.

The Healthcare Commission (2007a) advocates regular competency checking for staff, regular reviews of training and regular quality control for those aseptic pharmacies that are not licensed – without ever specifying what is meant by the terms 'regular'. Also, there is no recommendation for quality control of clinical care settings. In this guidance, Trusts are correctly advised to source out 'high-risk' medicines yet in the document there is no definition of what is meant by 'high-risk' (Healthcare Commission 2007a). The Nursing and Midwifery Council (NMC) in an A-Z sheet on medicines management, does not include hand hygiene or the term aseptic technique (Nursing and Midwifery Council 2006). Another guideline on the safe and secure handling of medicines, includes sections on intravenous drugs and their preparation, but does not include warnings on multi-dose vials, heparin or advocate hand hygiene (Royal Pharmaceutical Society 2005). The need for

aseptic preparation is specified in this document, yet precisely how to do this is not discussed.

Pharmaceutical companies provide information leaflets with every drug supplied for intravenous infusion. There are no national standards with regard to the information on what is required to ensure that the drug is aseptically prepared. The drug information leaflet can be written primarily for the patient as the audience, or the HCW. Some leaflets have separate patient sections and HCW sections. There is no specific section on any leaflet dedicated to the HCW who will compound the drug. The information on HCW risks provided by drug companies was examined closely in this study and was found to be in general difficult to read and with limited infection prevention information.

There are standards, licensing and monitoring arrangements for infusates produced in aseptic pharmacy suites, as well as the environments in which they are produced (NHS Executive 1996). However, the problem is that no such standards and guidelines exist for drugs prepared in clinical care settings [in England]. In 2002, a good practice statement was produced for the NHS in Scotland (CRAG 2002). This document includes a definition of 'high-risk', 'where the hazard associated with preparation is likely to have serious consequences for the patient or operator' (CRAG 2002: 6). Examples of high-risk drugs that should be made up in an aseptic suite include cytotoxic, intralipids and intrathecal drugs. Not all high-risk drugs are recognised in this document, of note heparin, long-term

infusions and multi-dose vials are not included. The document advocates a multi-professional risk assessment of each clinical area where drug preparation is to take place. There is a recommendation for 'planned, regular, audit of personnel, environments and procedures involved in near patient areas' and a time specification, every 12-18 months (CRAG 2002: 19). Although the CRAG (2002) guidance had the objective of devising good practice statements related to, amongst other things, the environment, and recommends planned regular audit of the environment, there are no standards for a safe environment provided within the document (CRAG 2002). The authors conclude that research is required to establish validated environment standards (CRAG 2002). Microbiological testing of the environment and of infusates is also not advocated. This document is clearly a big step forward; however, the extent to which these recommendations have been implemented, if at all, is unknown.

This review of national guidance from a variety of national bodies therefore does not provide clear guidance on the prevention of asepsis failure.

3.5 Aseptic preparation procedures

The National Patient Safety Agency (NPSA) in a work competence statement for the preparation of injectable medicines, details 20 actions, incorporating a further 33 points that should be taken prior to each drug being prepared and administered. As for hand hygiene, it merely advocates compliance with local policy (National Patient Safety Agency 2007). Complexity in any system increases the risk of

failure by increasing the opportunities for failure. If a procedure has 50 steps, and each step is completed correctly 95% of the time, then only 6% of the procedures will be completed correctly (Croteau and Schyve 2000: 185). The 53 points identified by the NPSA omit the 6 steps in hand hygiene, and if hand hygiene is required a further twice during the procedure, then the procedure for the preparation and administration of IV drugs is, according to the NPSA at least 68 steps long – and very complex. Although the converse is also true, an inadequate number of steps can also lead to system failure; the emphasis needs to be how simple the procedure can be whilst still containing sufficient steps to negate omission of a critical step.

In addition to the complexity derived from the number of procedural steps, individual drugs can have particular mixing and administration requirements. There are risks associated with cross-reaction and precipitation, which means that for any given drug requiring a 68 step preparation, there will be additional and specific variations in practice required for safe administration.

With regard to patient safety during intravenous drug preparation procedures, there needs to be quality control and systems analysis to ensure that the procedures are effective, clear and as simple as possible. Additionally, any required standards must be capable of being achieved with the available resources (Pronovost et al. 2006).

Apart from the complexity of the procedure, there appears to be a good deal of advocacy of aseptic technique without clarification of precisely what it is – though this has been specified outwith a national guideline (Rowley 2001, Rowley and Sinclair 2004). The NPSA competency statement states that ‘a non-touch technique is avoiding touching areas where bacterial contamination may be introduced’ NPSA (2007: 3). The aseptic non-touch technique advocated by Rowley (2001) also focuses the procedure on non-contamination of key parts. However, as already alluded to, contamination can occur with an aseptic non-touch technique if the antiseptic or drug is already contaminated, or if splash contamination occurs during the preparation of the procedure – regardless of a non-touch technique (CRAG 2002).

With regard to the procedure itself therefore, there appears to be a lack of clarity of exactly what aseptic preparation requirements are. Worryingly for nurses, in a pseudo light-hearted analysis of the cause of infusate contamination of regional analgesia akin to a game of Cluedo®, one editor wrote: “*The nurse unwittingly did it, in the pre-induction room, with a contaminated infusate*” (Horlocker et al. 2008: 1095). Unwittingly or not, this situation is not acceptable to either the nurse or the patient.

3.6 Chapter 3 summary

The discussions in this chapter have identified that research into the system of aseptic preparation of intravenous drugs is warranted because:

- There appears to be a clear hazard to patient safety from the status quo
- It is difficult to identify infusate contamination as a cause of BSI
- The opportunities for asepsis failure are numerous
- Current national guidance is not focused on asepsis failure
- The system of aseptic preparation is extremely complex.

Research into the aseptic preparation of drugs in clinical care settings with the objective of understanding the systems involved, their reliability and the error-prone potential were clearly indicated from this review.

The next chapter explores theories of risk and error causation to aid the study design.

4 The Development of a Methodological Framework for this research

The key to understanding the system aseptic preparation of intravenous drugs is understanding the risks and the errors inherent within the procedure, and what is done, or not done, to negate them. Policies and procedures are underpinned by broader theoretical models and even when they are claims to 'theoretical' approaches this is rarely the case. Therefore, in this chapter there will be a brief discussion of the strengths, weaknesses and relevance of different approaches and theories related to risk and error for their use within a methodological framework for this thesis. Although risk perception and risk assessment are considered relevant to the thesis, the chapter concludes with the assessment that the methodological approach best suited to assess the system of aseptic preparation of intravenous drugs is a systems approach to human error, combined with high-reliability theory, patient safety and human factors approaches.

To begin, there needs to be an understanding of what is meant by risk and error as used in this thesis. Whereas a hazard can be considered as anything that might cause harm, a risk is the probability that harm (human or mechanical) actually results from the hazard (Health and Safety Executive 2006: 2). An error is an action that could lead to harm being realised. Risks and errors are therefore closely inter-linked. There are two paradigms related to the perception of risk by

individuals, a) the psychometric and b) the social and cultural which will be discussed along with an introduction on the societal perception of risk, including the relevance of a managerial approach to the thesis.

4.1 The risk society

It has been argued that there is a natural and inevitable transformation of an industrial society to a risk society as a consequence of the production of hazards beyond which society is prepared to accept (Beck 1996). What results after hazards and dangers become recognised is 'the task of redefining previously attained standards (of responsibility, safety, control, damage limitation and distribution of the consequences of loss), with reference to potential dangers' Beck (1996: 29). This can also be seen in healthcare settings related to infection prevention. An increase of healthcare associated infections emerged as a consequence of ever more risky 'industrialised' healthcare interventions, which developed without sufficient safeguards and controls. Through personal experience and press reports these infections became visible to the public. Politicians were made aware that the public viewed these infections as unacceptable and avoidable. Other healthcare tragedies, such as the increased mortality following cardiac surgery in Bristol, have resulted in similar reactions (Dept. of Health 2001). The response from the UK Departments of Health has been the setting of standards, targets and the mandatory publishing of outcome rates, for example, surgical site infections and rates of *Clostridium difficile* infection. In addition, Departments of Health are now in pursuit of a desirable, if

perhaps, unattainable 'zero tolerance' to negative healthcare outcomes (Duerden 2009, Warye and Granato 2009). The procedure discussed in this thesis is as yet in the 'industrial state' and will remain there until as Beck (1996: 29) states 'the problems produced by it exceed the basis of societal conceptions of security'. Perceived risk of IR-BSI is, for this procedure, relevant to the HCW in that the patient is probably unaware there is an infection risk. The degree to which the HCWs perceives the risk to the patient of an IR-BSI, or a personal risk as a result of the consequences (disciplinary and legal) that a contaminated infusate could result and be traced back to their procedure, is unknown. The concept of a transforming society in respect of risk, although not of direct utility to the methodological framework of this thesis, provides a useful understanding of the position of aseptic drug preparation with regard to detectable and perceived risks. As an alternative to the HCWs' perceptions of risk a managerial approach, requires evaluation.

4.1.1 A managerial approach: high, mid and low level

An illustration of the move from an industrialised society to a risk society is given in the investigations into major catastrophes, such as Piper Alpha, Three-Mile Island and The Herald of Free Enterprise which revealed the degree to which management acts and decisions directly and indirectly contributed to the events (Kemeny et al. 1979, Pate-Cornell 1993, Hurst 1998). As a consequence, legislation to make corporate leaders personally accountable was introduced (Corporate Manslaughter and Corporate Homicide Act 2007). In a review of the

role of managerial leadership in determining workplace safety, O'Dea et al. (2003), suggest that although the moral case for safety has been established, the financial one has not. Safety will not gain primacy whilst it continues to compete for attention with production, costs and other targets. There have been arguments put forward that attention should be directed more on leaders to improve their behaviours with a consequent hope of improving patient safety (Flin and Yule 2004). At the various level of management, high, middle or low, there are different responsibilities. For example, high-level management might set the overall objective and a budget. Middle and lower management levels will be responsible for seeing the object is reached and within the budget. The chosen approach for this thesis is not, however, managerial. This is because although managers / leaders clearly have a direct and indirect influence in the achievement of corporate goals and safety, in relation to this thesis, the problem has yet to be significantly recognised as such by healthcare professionals and as a consequence it can not therefore be expected to be so acknowledged by their non-clinical managers.

Having briefly discussed risk in the context of society as a whole, and a possible managerial approach, an evaluation of the anthropological (social and cultural paradigm) approaches to understanding risk will now be given.

4.2 The social approach to risk

The behaviour of the HCWs in relation to how they undertake the aseptic procedure can alter infection risks. These risks could arise not as a consequence

of objective data within the system, but more as a consequence of choice of the individual or collective HCWs. It has been argued that risk can be best understood as a social construct (Gabe 1995: 11). As stated previously, those perceiving risk as a consequence of this procedure will be those performing it. The procedure could be collectively perceived by HCWs and thus performed as at a social level. For example, if the lead nurse emphasises that the infection risk is so low as to be insignificant and does not complete accepted aseptic steps, junior nurses are likely to do similar especially, if there is no accessible evidence that this lax approach causes any detectable patient harm.

Models have been developed to understand and explain behaviour by reference to the individual's perceptions of the involved risks. Such approaches have been used in infection control. The Health Belief Model has been applied to try to understand why HCWs hand hygiene practices were low, and whether, by understanding risk perceptions, better strategies to improve compliance could be devised (Pittet 2004). The understanding that was gained from the application of this social construct assisted in the recognition and development of the World Health Organization's (WHO) hand hygiene guidance, the purpose of which was to inform those who promote hand hygiene of the most likely approaches to successfully alter attitudes and behaviour of staff towards hand hygiene (Pittet et al. 2009).

Understanding HCWs' beliefs of the risk will be important in this study. Although the behaviour of HCWs may be partially socially constructed, the procedure itself contains objective data that could have greater impact on performance and the risk to the patient of receiving an IR-BSI. This objective data includes the environment, the equipment and information available to the HCW; therefore as a consequence, using a socially constructed model would be inadequate by itself to determine how the system works.

4.3 Cultural Theory

The Cultural Theory (of risk) originated from the work of anthropologist Mary Douglas (Douglas 1992). Cultural theorists recognise that culture is 'part of the essential nature of an organisation' (Cooke 2009: 261). Culture is considered to be influenced by two dimensions, the degree of hierarchy, known as the 'Grid' and the degree of social cohesion 'Group'. Different types of grid-group values result in different perceptions of risk and different behaviours when dealing with them. For example, if an organisation had a high grid and low group position, it would result in one with strong organisation control, but where individuals were isolated with few shared values. Whilst Cultural Theory is a successful means of understanding how and why individuals and organisations are structured and behave as they do towards various risks, for this thesis, it will not aid in identifying what the system is *per se* as it omits an objective assessment of the risks from the built environment, the drugs and from the behaviours of the HCWs therein. Discussions on measuring safety culture and climate will be discussed later.

Having assessed the relevance of the social and cultural paradigms to this thesis, the second, the psychometric paradigm, will now be evaluated.

4.4 Psychological approaches to risk and its measurement

The psychological approach to risk focuses on individuals' perceptions of risk rather than the social and cultural environment in which risk perceptions are formed' (Abraham 2009). The psychometric measurement of risk perception, emerged as a means of understanding the variations of risk as perceived by the lay public and scientists (Abraham 2009). Key findings amongst the work on risk perception were that:

- Risk perception could be measured and predicted.
- The perception and toleration of risk by individuals was found to be associated with, amongst other variables, the degree of benefit gained from the risk and the degree to which the risk was voluntary (Slovic et al. 2004). [For example, car drivers take risks every time they get in a car, but these risks are outweighed by the personal benefits of driving a car. Conversely, even though the risk of a nuclear accident is much lower than the risk of accident from driving a car, taking that risk is not in the control of the individual, and consequently deemed less acceptable to them].

Risk perception measurements are subjective; they are relevant to this thesis as HCWs' behaviour may be dependent on the perceived risk of an IR-BSI to the

patient, the perceived risk of an IR-BSI being traced to their performance and the perceived benefit of aseptic technique to negate the risk. However, prior to identifying these subjective perceptions of risk, there is a requirement to identify the objective elements in the system which may impact more greatly on the outcomes of the procedure, that is, sterile or non-sterile infusates. Other than the subjective assessments of perceived risk, there are objective measures of risk that are used in risk management and risk reduction. The utility of these approaches will now be discussed.

4.5 Risk assessment methods

It has been argued that decisions about risk and safety involve choices between alternatives (Fischhoff et al. 1981). In order to make these choices there needs to be assessment; various assessment methods have evolved to enable people to make the best choices. For the process of aseptic drug preparation, assessments need to be cognisant of: what level of environmental and procedure contamination precautions are required to achieve a sterile infusate, or at least an infusate that is unlikely to cause harm to patients. This thesis is asking, in effect, if the procedure of aseptic intravenous drug administration has an acceptable level of risk for both patients and the HCWs who perform it. An understanding of the objective methods used to evaluate risk is therefore, of service to this work. The specific question of whether aseptic preparation as it is currently performed is safe, or at an acceptable safety level, is akin to the generic question: 'how safe is safe enough?', asked by Fischhoff et al. (1981: 6) and the logical follow-on question: 'how can an

acceptable risk level can be determined?’ According to Fischhoff et al. (1981: 53) risk assessments should be based on seven specific criteria. These criteria are whether the modality is: comprehensive, logically sound, practical, open to evaluation, politically acceptable, compatible with institutions and conducive to learning. Fischhoff et al. (1981) also asserts that all methods of risk assessment can be divided into three types: Professional Judgement, Bootstrapping and Formal Analysis. A brief explanation of these types and their applicability to this thesis given the criteria above are summarised as follows:

Professional judgement relies on the experience and expertise of professionals who use the process. Although professional judgements are most-considered most trustworthy for routine events, they are criticised for not including judgements of those who are receiving the outputs of the procedure, in this case the patients (Fischhoff et al. 1981: 78). For aseptic drug preparation procedures there is not just one group of health professionals involved. All healthcare specialities involve HCWs who prepare and infuse intravenous drugs as an integral part of whatever health speciality they are from. Although present in every ward and clinical area, there is no single group of intravenous drug specialists in Scotland who ‘own the process’ and who hence make the professional risk decisions. Decisions on who will prepare the infusions and what equipment they are allowed to use, appear to lie more with health service managers who govern the procedures’ budget rather than the professionals who perform the procedure. Hence professional judgement alone as a method of assessing

risk-decisions is insufficient for this thesis, but may contribute to an understanding of the issues.

Bootstrapping assumes 'that an adjustive process has produced a nearly optimal balance of risks for a social or natural environment' (Fischhoff et al. 1981: 100). There is a formal analysis process within bootstrapping but this is considered superficial and incomplete (Fischhoff et al. 1981: 100). Additionally, Fischhoff et al. (1981: 97) states that 'when clarity is lacking, bootstrapping offers no decision rule'. Potentially erroneous assumptions of safety for aseptic drug preparation procedures have already been recognised in this thesis and the situation can be said to be far from clear. Hence the procedure can thus far can be said to have evolved through a bootstrapping model, in that it is a procedure that is considered safe enough without having taken full understanding of the evidence of the potentially catastrophic patient dangers reported in the literature (Nasser et al. 2004, Mikulska et al. 2009, Nadkarni et al. 2009). Although bootstrapping perhaps describes the status of the thesis procedure is, it would not be a suitable method to detail the current risks or their assessments. The aseptic aspects of the thesis procedure have never been critically and completely assessed as being a risk, therefore, what is required now is a formal measure of system analysis.

Formal analysis: formal analysis consists of 4 steps:

- The decision problem is defined and then all potential options and their consequences are listed.
- The relationships between the options and their alternatives are defined. Complex problems are decomposed into component parts. Probabilistic assessments are made against each of these parts.
- All consequences are evaluated by some common unit, which could be money or for the purposes of this thesis, infusate contamination or infusate related blood stream infection.
- Robust testing of the process, for example, sensitivity analysis.

It has been argued that formal analysis is 'open and sound' Fischhoff et al. (1981: 119). Using a formal process has many advantages, but for this thesis the main problem from the execution of the procedure perspective is in defining the problem itself, that is, the contamination risk potential and the opportunity for contamination to cause IR-BSI. Aseptic drug preparation procedures like all healthcare procedures are dynamic and the contamination risk potential varies in different settings because the procedure varies, and the environmental risks vary. This makes the allocation of a single risk value problematic.

In order to determine their relevance to this thesis, there will now be a discussion and evaluation of three types of formal (risk) analysis, Failure Mode and Effects Analysis, Healthcare Failure Mode and Effects Analysis, and Socio-Technical Probabilistic Risk Assessment.

4.5.1 Failure Mode and Effects Analysis (FMEA)

FMEA is a tool designed for prospective systems analysis and systems improvement through risk assessment. The FMEA process produces a risk priority number for individual potential errors in a system using a three variable equation; where each variable is scored from one to ten (Marx and Slonim 2003, Stalhandske et al. 2003). The first action in a FMEA is for a team to identify all the potential problems that could arise when the system is working. Once this is done a numerical risk value is produced for how the likelihood of occurrence of each of the potential failures might occur, how severe the event might be should the failure occur, and how likely it is that the failure might be detected if it occurred. The FMEA score is calculated by multiplying the outcome severity score, the occurrence likelihood score and the likelihood failure detection score. The likelihood score of occurrence is calculated from both the literature and experience; this, however, implies that the literature is unbiased and that experience is both complete and is reliably quantifiable. There are a few key problems with this approach: firstly, it appears to apply to a static system when in reality systems continuously evolve and are subject to variations in, for example, number of tasks to be done, the time available to complete the tasks and variations

in equipment being utilised. Evolution of systems in this thesis could involve new drugs, new diluents, new legal restrictions, new connections or more complex mixing regimens. This could necessitate a new or modified FMEA every time the system evolved. The second problem with FMEA is that those assessing the system will do so from the perspective of local experience, which may be incomplete and not reflect the entire universe of potential problems experienced by workers in other places (Marx and Slonim 2003). These authors also suggest that FMEA can only identify errors as single events and not in combinations or a series of errors: FMEA does not include a way to examine if error 'a' was followed by error 'b' in another part of the system.

To carry out a FMEA once potential single failures are identified, the team can either act to reduce the probability of the failure occurring or introduce redundant safety steps to mitigate the effects of failure (Marx and Slonim 2003).

There is evidence to suggest that a FMEA enables those who perform procedures to stand back and critically analyse the systems' processes and eliminate any obvious hazards. A FMEA has been applied to the topic area of this study – intravenous drug preparation procedures (Apkon et al. 2004). However, the researchers in the Apkon et al. (2004) study failed to identify asepsis failure as a possible error, and recommended extended hang times in order to reduce errors associated with replacing infusions. The evidence cited to corroborate the safety of this recommendation is two papers, one of which is not related to prepared drugs

but administration sets for sterile fluids. None of the many papers identifying infusate-related BSI as a significant problem and long infusion times as a contributory factor are included in the Apkon et al. (2004) FMEA. The application of a FMEA process as in the Apkon et al. (2004) study may have resulted in a reduction in one recognised common medication error, but it has also resulted in increased risk of IR-BSI by erroneously recommending hang times of 72 hours. It is clear that healthcare delivery is inherently dangerous and that tools such as FMEA routinely applied could make it safer. However for this thesis procedure, a FMEA analysis alone would be insufficient with which to profile and understand the system.

4.5.2 Healthcare FMEA (HC-FMEA)

HC-FMEA has evolved from FMEA and includes a 'Hazard Scoring Matrix' this involves the calculation of the probability of an incident occurring (frequent, occasional, uncommon and remote) with the severity or effect of the incident should it arise (catastrophic, major, moderate or minor) (DeRosier et al. 2002, van Tilburg et al. 2006). HC-FMEA is a 5-step process that uses a team to interrogate a process. This involves a graphic flow diagram and the Hazard Score Matrix. Decisions are made based on the vulnerability of identified potential problems (DeRosier et al. 2002, van Tilburg et al. 2006). Like the non-healthcare version, HC-FMEA also seems to apply to linear and static systems. There are obvious strengths to the process, clearly, it is always useful to review critically a system and remove or change obvious steps that might lead to failure. But there are

weaknesses in this process too. It seems illogical to suggest that one failure category will always cause one type of serious outcome – and thereby always score the same. For example, the same asepsis failure in drug preparation will cause a range of outcomes from none to death, depending on the degree or asepsis failure, the type and number of micro-organisms on the hands of the HCW or in the environment at the time the drug was being prepared, and the duration time of the infusion. The key factor that could continuously change the risk calculations is the variation in the day to day conditions of work. For example, in extremely busy times HCWs have to evolve and adapt systems to make them as safe as possible based on the availability or restriction of resources. It is difficult to see how HC-FMEA or FMEA could anticipate all potential errors, particularly as systems are dynamic and continuously evolve. Consequently, having undertaken a HC-FMEA may lead HCWs to assume a false sense of security and safety with regard to the systems they operate.

4.5.3 Socio-Technical Probabilistic Risk Assessment (ST-PRA)

ST-PRA is another tool designed for prospective system safety analysis, (Marx and Slonim 2003). Although it is applied prospectively, in effect it is of most use in those systems that are considered to be most vulnerable to error. ST-PRA is described as a top-down tool; a hybrid between FMEA and decision support models. To visualise risk, faults trees are drawn from a single top error, for example, delivering the wrong drug to a patient. The basic events that can lead to this top error are mapped, where the errors are consequent on earlier errors, this is

indicated. Probability estimates are added to the basic events. This is a team task and grounded in experience – this has to be the case as for all estimates of risk as there are no published data on which to rely. The authors acknowledge that there may be limited information, but that the estimates must be arrived at. Once the tree is completed the team can then intervene to make the system safer, either by introducing redundant steps of double-checking, creating forcing functions designed so the system cannot be bypassed. ST-PRA has been used to reduce wrong-drug errors in long-term care facilities (Conrow Comden et al. 2004), these authors state that ST-PRA can identify systemic and behavioural elements that increase or reduce the risk of drug error. Again the analysis of systems using ST-PRA seems to negate context. None of the nine events or gates identified everything that could lead to a drug error, includes sub-optimal staffing or distraction both of which have been implicated as causes of errors (Conrow Comden et al. 2004). Others have also identified limitations to ST-PRA, including the potential for naïve analysis, reliance on expert estimation, presumption of binary statistics and tunnel vision (Wreathall and Nemeth 2004). ST-PRA clearly has advantages over FMEA. However, if during intravenous drug preparation errors are not visible and not easily recognised by operators it is difficult to see how error frequency, essential to ST-PRA, is to be calculated. The key element, a precursor to a ST-PRA or HC-FMEA, is to identify the assumptions or safety that the operators work under. For example, if infusate contamination is considered as only remotely possible, then their estimates of risk will be dangerously wrong, and the HCWs may be less likely to perform advocated safety procedures involving

hand hygiene or wrongly assume the sterility of multi-dose vials which are easily contaminated.

This brief review of methods of risk assessment has considered the possibility of this approach to evaluate the safety of the system of aseptic preparation of intravenous drugs. None of the three types of risk assessment discussed above provides, in itself, a sufficiently robust method with which to describe the system of aseptic drug preparation. Although this is one procedure by title, the procedure varies in how it is done in the individual clinical settings, and how the environments add or detract additional contamination risks. Defining the problem of contamination is at present difficult and a better understanding of the procedure as it is performed and risks within different clinical settings is a necessary step before a formal risk analysis can be undertaken.

Thus far in this chapter although relevant the risk assessment methods reviews and reviews of the two paradigms of risk perception (social and cultural, and psychometric) have not identified an approach or theory which would assist in identifying the system of aseptic drug preparation. The chapter now continues with discussions on approaches and theories of error causation.

4.6 Error causation theory development

The understanding and development of theories and approaches of error causation has progressed through four recognisable periods over the latter part of

the twentieth century (Wiegmann et al. 2002). In the first – the technical period – errors were identified as resulting from mechanical and technical failures, largely as a consequence of the preceding rapid mechanical and technical industrial developments. As the mechanical / technical equipment itself became more reliable, the second phase – human error stage – focused on the operators as the cause of failures. Logically as neither the machines nor the humans worked independently of each other, during the third stage – the sociotechnical period – research focused on the study of the interactions of both humans and machines together. The latest and current period according to Wiegmann et al. (2002) has developed following recognition that humans do not interact with machines in isolation but within a context; and that context is the organisational culture. It seems credible that another epoch has now evolved that of error prevention through the adoption of high-reliability characteristics (Hudson 2003, Wilson et al. 2005, Carroll and Rudolph 2006, Tamuz and Harrison 2006). The progression of error causation theories has followed an iterative and developmental style, but each new period did not result in an older theory being immediately and completely discarded. Consequently, some aspects of the theoretical approaches from all of these periods remain in use. It seems clear, however, that to understand the system of preparing intravenous drugs, the thesis will need to cover the technical, human and cultural factors which make up the system. A brief summary of how one error theory has been developed over time will be given.

4.6.1 From humans causing errors to systems being culpable

Heinrich (1950), in an early publication on industrial accident prevention, put forward several important axioms. These axioms have been - and continue to be - developed by, for example, Reason (1990), Dekker (2006) and Vincent (2006). The first key axiom was that injuries occur because of accidents, accidents occur because of unsafe acts of individuals or machines, unsafe acts occur because of the fault of a person and this is provoked by the social environment (Heinrich 1950: 10). These factors were illustrated as dominos; the first one to fall brought the next one down. Another axiom is 'the foundation of major injury', which states that for every injury caused by an unsafe act there are over 300 near misses (Heinrich 1950: 25). Although it is acknowledged in the text that each type of category has its own base pyramid size, the key principle is that there are always many near misses for every major injury.

Heinrich (1950: 36) places blame on individuals to a far greater extent than is done today. Unsafe acts were, for example, categorised as 'improper attitude, lack of knowledge, physical unsuitability and improper mechanical or physical environment'. More recently in what is a more logical system-centred approach Reason (1990: 207) suggests that the causes of unsafe acts should be categorised based on whether the acts were intended or unintended. Unintended actions are considered to be due to latent conditions within the system and not wilful actions of an individual. Violations, that is, deliberate acts, are considered to be a minor cause of failures and sometimes an ultra-safe act (Amalberti et al.

2006). Only by understanding the latent conditions, such as the organisation and culture, current conditions of work and system defences, can there be an understanding of why errors occur. For example, according to Dekker (2006: 70) 'A large part of understanding human error is about understanding in detail the situation in which the human was working; about the tasks he or she was carrying out; about the tools that were being used.'

Heinrich's (1950: 25) 'foundation of major injury' is pyramidal in shape, and implies that for every 300 no-injury accidents there are considered to be 29 minor injuries and 1 major injury . Although no precise size of the pyramid base is accepted today, this axiom is still considered valid. It is the basis for recognised need both to report and to understand near misses as a means of preventing major injuries. This brief discussion of the development of error theory shows that the theory has evolved from an initial focus on the individual, to a focus on the system, and that understanding is essential to understanding how to prevent major injuries. Therefore, according to Dekker (2006: 226) identifying human error should not be the end of the investigation, but the beginning. Further in-depth explanation of this approach will be discussed presently, but first, a review of other error causation theories and approaches is required.

4.7 Review of other error causation theories and approaches

4.7.1 Systems Engineering

Systems engineering (SE) is a useful multi-disciplinary approach; it is concerned with optimising the performance of any given system in the pursuit of clearly agreed goals. SE is achieved by identifying the desired state and the present state, then identifying all the ways that the desired state can be achieved and finally determining and deploying the most efficient means of getting to the desired state. SE is an effective means of improving systems; however as critics have noted, it tends to treat humans as 'components to be engineered' (Jackson 2003: 62). The thesis procedure is complex and appears to rely almost exclusively on HCWs for successful execution. Consequently, as SE does not appear to take sufficient cognisance of the human perspective, this has been rejected an approach for use in this thesis.

4.7.2 Socio-technical systems

Socio-technical systems (STS) developed as a consequence of the dilemmas faced in comprehending systems composed of people and technical systems in various contexts (Coiera 2007). This included the recognition that humans interacting with machines resulted in unpredictable outcomes – undesired as well as un-designed. Although STS is an organisational approach, it is also used to understand and optimise any system work design. This thesis procedure fits within the definition of a complex socio-technical system in that in any given environment they have multiple goals, involve multiple interacting parts and parties, and are

complex social structures which encompass uncertainties alongside complex technology. The work is highly specialised, and a variety of tools and information are used. The use of medical devices (seen as synonymous with the term technology) has been recognised as a leading case of adverse events in healthcare (Balka et al. 2007). Following a review of the literature on governance, Balka et al. (2007) advocated that greater emphasis on socio-technical systems' issues is required to reduce adverse events associated with medical devices. These authors suggest that the socio-technical tradition gives primacy to the social contexts in which humans interact with technology. An STS approach sees healthcare as a real life happening, a social process, and through which formative evaluation can be made to guide improvements in system design (Berg et al. 2003). However, despite its advocates, it has been difficult to visualise this approach as a process to be followed for this thesis or to identify the ability of an STS approach to determine error-prone and high-reliability characteristics, that is, to achieve the thesis aims; therefore, as an approach, STS is considered unsuitable.

4.7.3 Normal Accident Theory

Normal Accident Theory (NAT) draws on empirical evidence that all systems designed and run by humans are error-prone and subject to failure of any part (Perrow 1999, Tamuz and Harrison 2006). Therefore, according to NAT, accidents can be seen as 'normal' or inevitable for the system: even if they are not acceptable to the operators or customers or, as in this case, to HCWs and

patients. Criticism of NAT starts with its name. There is a growing body of injury prevention and public health advocates who argue against using the term 'accidents' because the term implies, without supporting evidence, that events were unforeseen and unpreventable (Doege 1978, Evans 1993, Doege 1999, Davis and Pless 2001, Tamuz and Harrison 2006). So strong is this new ire against the use of the word accidents that the British Medical Journal has banned it, and the Accident and Emergency Journal has been renamed the Emergency Medical Journal (Davis and Pless 2001). In this thesis it has been established that the mechanisms for infusate contamination are known, and any consequent sepsis should be considered preventable; therefore, in this thesis the term 'accident' will be avoided.

In NAT, systems are analysed for their degree of complexity / linearity and their degree of coupling; which denotes not just the system's vulnerability to fail, but also the type of failures to which they are vulnerable, for example, tightly coupled, complex systems are prone to catastrophic failures, whereas loose, linear systems are more vulnerable to component failures. The scale of complexity or linearity is identified, for example, from the degree of variation in the system procedures and the obviousness and immediacy with which errors can be identified whilst the systems are operating. Results from thesis, and from the literature review, show that there are difficulties in recognising failures whenever they manifest.

4.7.4 Root Cause Analysis

This thesis is evaluating the system and practice of aseptic preparation of intravenous drugs because the literature suggests it could be error-prone and as a direct consequence, could cause BSIs. It could be argued therefore that an incident analysis tool, such as Root Cause Analysis (RCA), would be useful for profiling the system. An RCA tool is designed to answer 3 questions: what happened, why did it happen and what can be done to prevent it happening again (Reason 2000). A presumed IR-BSI could be used as the sentinel event from which to work backwards to profile the system. Single cause analysis tools have their critics because they imply there is a single root cause and not the multiple chains of causes that have been identified by others (Vincent et al. 2004, Dekker 2006). Identifying a root cause is considered to be just a point at which the investigator decides to stop, and nominate the origin of an error (Dekker 2006: 77). This seems a reasonable argument and since all healthcare is undertaken from finite government resources and policies, all root cause analyses could ultimately and ubiquitously (albeit ineffectively and erroneously) blame the government. Studies on the effectiveness of RCA in reducing risk and improving safety are scant and it has been suggested that the investment in RCA has thus far not resulted in demonstrable reductions in harm (Wu et al. 2008). Other critics of RCA suggest that the pursuit of safety is not about identifying the causes of individual errors but about making systems robust in the face of human and operational hazards (Reason 2000).

Thus far the only approach that is relevant to the thesis is the systems approach to human error. A more in-depth review of this work and its relevance to the theory will now be given.

4.8 Human Errors

According to Dekker (2006: 226) 'human error is the inevitable by-product of the pursuit of success in an imperfect, unstable, resources-constrained world'. Reason (2000) suggests that there are two ways to understand human error; firstly from the perspective of the person and secondly from the perspective of the system. The personal perspective is the traditional view which focuses on the person who committed the last act before failure occurred. This view would assert that the people, the operational frontline workers, who commit these errors, do so as a consequence of not following rules or not taking appropriate action (Reason, 2000). The counter view to this approach is a systems error approach. The theory here is that humans are fallible and therefore expected to err. This is a view also asserted in Normal Accident Theory by Perrow (1999: 9). Errors are the result of systemic latent conditions set up in the environment, the procedures, the equipment, and the organisation and culture. Investigations of high-profile system failures have identified that systems seldom fail because of a single error; rather it is a series of errors which occur consecutively that eventually result in failure (Reason 1990, Vincent et al. 1998, Reason 2000, DeRosier et al. 2002, Vincent et al. 2004, Dekker 2006). The long numbers of recommendations following

investigations of any kind confirm this. Even the term 'lessons learned' to be included following all outbreaks is in the plural. This systems approach to understanding human errors, which as discussed earlier was developed from earlier theories, is considered the most relevant theory and approach for this thesis. Exactly why Human Error Theory is so relevant will now be described.

4.8.1 Human Error Theory

Reason's Human Error Theory is summarised as:

'Errors are consequences rather than causes, having their origins not so much in the perversity of human nature as in the upstream systemic failures.

'Adverse events are caused by a combination of active failures and latent conditions.' Reason (2000: 768).

- Active failures are the unsafe acts committed by the people who are in direct contact with the patient or the system – they take the form of slips, lapses, mistakes and violations.
- Latent conditions are the inevitable "resident pathogens" within the system. They arise from decisions made by management, they cause adverse events in two ways; firstly by producing error-provoking conditions and secondly by creating weaknesses within the system that may lay dormant for some considerable time. (Reason, 2000: 769).

Reason (2000) provides a model, the Swiss Cheese Model of Systems Accidents, to aid in the understanding of how human errors occur in a systems approach. In this model all systems has defensive layers which are represented by slices of emmental cheese. When there are holes in all the defence layers a pathway for a system failure is present. The following statements expand the understanding of the Swiss Cheese Model of Systems Accidents.

- All systems have defences, barriers and safeguards to prevent potential victims (patients) and assets from local hazards
- All defences contain weaknesses
- Holes appear in the defensive layers
- The presence of holes in one layer does not normally cause a bad outcome. When holes appear in all of the layers then and a pathway through the holes can be made – a failure occurs.

Reason (2000: 768).

In trying to provide a more complete image of potential failure, Reason (2000: 769) suggests that it is useful to consider the holes in the cheese not in fixed positions, but as ones which open, close and reopen in different places and at different times. This means that errors in one category could appear for a time and disappear followed by, or concurrent with, other types of error. Thus solutions to 'fill the holes in the cheese' can never be considered either simple or concluded – and systems should not be considered as completely examined or completely safe following individual inspection at a fixed point of time.

The premise that systems contain weaknesses is shared by others who investigate errors and systems. For example, in agreeing with the fragility of systems, Dekker (2006: 16) states that:

‘Systems are basically unsafe. People in them have to create safety by tying together the patchwork of technologies, adapting under pressure and acting under uncertainty.

‘Safety is never the only goal in systems. Multiple interacting pressures and goals are always at work. There are economic pressures, pressures that have to do with schedules, competition, customer service and public image. Trade-offs between safety and other goals sometimes have to be made when there is uncertainty and ambiguity. Goals other than safety are easy to measure. How much people borrow from safety to achieve those goals is very difficult to measure.’

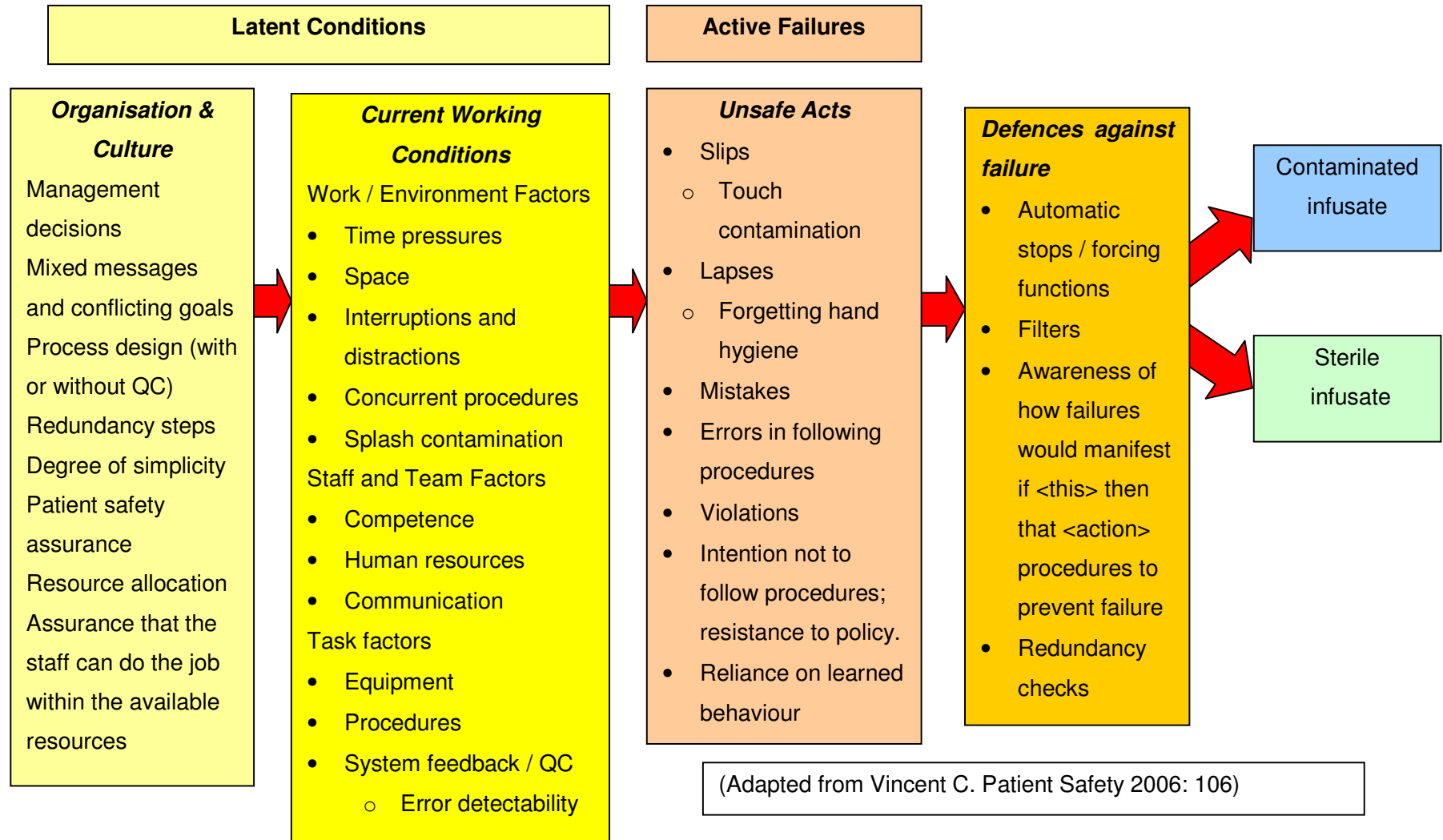
Dekker (2006: 227) also asserts that since no one sets out to chop the wrong limb off, or overdose a patient, investigators must understand why (and how) actions made sense to practitioners at the time they were performed. Even though the arguments are presented in slightly different ways, there is some overlap here between the work of Dekker (2006) and Reason (1990, 2000). Both advocate trying to understand the data that are available to the operator, and what the data indicates to the operator during procedure. Dekker (2006: 96) advocates using

these data to understand why the operator performs as s/he does, and Reason (1990: 199) to identify the systemic weaknesses in the journey to a failure.

In progressing the work of Reason (1990), a framework for analysing risk and safety has been produced (Vincent et al. 1998), and updated (Vincent 2006). This framework illustrates the latent conditions of the organisation and culture and the current conditions of work that can provoke errors and violations and the active failures related to unsafe care delivery practices that exist in a system. The number of failures that occur will be dependent on the presence and robustness of defences and barriers to stop any failure occurring.

A systems approach to human errors offers what thus far appears to be the most useful framework with which to understand and describe a system's reliability and error-prone nature. This approach includes an evaluation of the organisation and culture, the current conditions of work and all the resources available and unavailable to the HCWs who perform the procedure, as well as the system defences. This systems approach to human error was designed to understand what within a system provokes humans to err, in doing so it does what this thesis set out to do – understand the system its resilience as well as the error-prone and reliability characteristics therein. Figure 1 illustrates how IR-BSI might arise through a contaminated infusate caused by latent conditions in the organisation and culture and the current working conditions which provoke unsafe acts and without system defences lead to contaminated infusates.

Figure 1 Organisation Accident Model for Intravenous Drugs Preparation



Having identified Human Error Theory and the Swiss Cheese Model and the most useful approach to understanding the error-prone nature of the system of aseptic drug preparation, both the latent conditions (organisation and culture, current working conditions) and the active failures which include the defences will now be discussed in detail. This will begin with the most important latent condition; the Organisation and Culture.

4.8.2 Latent conditions - Organisation

Latent conditions which can provoke active errors arise because managers and designers of systems do not assume that their decisions could lead to errors and failures by front line HCWs (Leape, 1994). As errors and failures are not seen as inevitable, there is nothing in the system design to prevent or absorb them (Leape 1994). Another factor that prevents optimal design in a system is that organisations frequently have other goals that compete with safety, causing, as a consequence, fallible design decisions (Cook and Woods 1994, Carroll and Rudolph 2006). In NHSScotland one can consider the following as competing goals alongside patient safety: financial budget constraints, waiting list targets, time in accident and emergency on a trolley targets and reducing bed occupancy targets.

The decision to allow nurses to perform aseptic drug preparation procedures in clinical care settings was driven by three factors: the need to reduce junior doctor hours, the expense associated with preparation in a pharmacy and the relatively

cheap availability of nurses. It was not primarily a decision based on patient safety. If patient safety was paramount for drug preparation, one would expect to find during the examination of the systems, evidence that managers were mindful that the systems they designed or were responsible for, could fail; as a consequence there would be quality control to demonstrate defect rates and to recognise promptly signs of system failure – none of which were found in this thesis. Other organisation / system design errors, which set up the current conditions of work can manifest as deficiencies in training programmes, ignorance of the system, inadequate numbers of HCWs available to undertake the procedures, inadequacies in ongoing monitoring of performance, allocation of poor resources and poor procedures.

The organisation is responsible for setting the standards of quality control. Newhouse et al. (2005: 45) considers one of the most salient points in such evaluation to be whether the end product is free from error. End product evaluation could also be included as part of the system feedback. However, although a defective end product indicates that one or more of the production processes are awry, this is different from being able to detect a problem as it arises, in real-time. No such evaluation was found in this thesis.

4.8.3 Latent conditions – Safety culture

As discussed earlier, the safety culture in which HCWs work is recognised as being critical to safety and in determining whether errors occur. Crucial to the

safety culture is whether HCWs feel safe in reporting errors and near misses (Cuschieri 2003, Hudson 2003, Vincent et al. 2004, Tighe et al. 2006). It is only by studying and understanding error reports that the system can be modified to improve safety (Cuschieri 2003, Hudson 2003, Vincent et al. 2004, Tighe et al. 2006). If HCWs feel that punitive actions will result when they report an error or system fault, they may be tempted not to report. The attitude of managers towards this information is crucial to system safety (DeRosier et al. 2002). Hierarchical cultures have been found to be less safe as operators are too scared to report identified errors (Risser et al. 2000: 241). As an example, in two recent wrong site operations some HCWs in the theatre knew the wrong limb was being amputated but were too intimidated to inform the surgeon (Personal Communication). Systems become reliable when errors are accepted and expected and lessons are learned (Vincent et al. 1998, Glendon et al. 2006: 110).

The term 'vulnerable system syndrome' has been defined (Reason et al. 2001: ii21). This is said to exist when three interacting and self-perpetuating elements are in place, namely: 'the blaming of front-line individuals when things go wrong, denying the existence of systemic error-provoking weaknesses, and the blinkered pursuit of productive financial indicators' (Reason et al. 2001: ii21). Hence vulnerable system syndrome is the combination of three latent conditions that make the staff who directly deliver patient care doomed to fail – and, ironically – take the blame for the system's failures.

For the safety culture to be measured, and that measurement altered, there has to first be agreement on the definition and validation of measurement tools. In a thorough review of published definitions of safety culture and safety climate (Wiegmann et al. 2002) the following definition was advocated:

'Safety culture is the enduring value and priority placed on worker and public safety by everyone in every group at every level of an organisation. It refers to the extent to which individuals and groups will commit to personal responsibility for safety, act to preserve, enhance and communicate safety concerns, strive to actively learn, adapt and modify (both individual and organisational) behaviour based on lessons learned from mistakes, and be rewarded in a manner consistent with these values.' Wiegmann et al. (2002: 8).

Safety culture measures are taken at one point in time and are therefore considered to be a snapshot of the state of safety providing an indicator of the underlying safety culture (Cox and Flin 1998). A measure of the safety culture has been described as the safety climate in order to distinguish between the more enduring (safety culture) and the variable (safety climate).

The definition of safety climate was advocated as:

'Safety climate is the temporal state measure of safety culture, subject to commonalities among individual perceptions of the organisation. It is therefore situationally based, and refers to the perceived state of safety at a

particular place at a particular time, it is relatively unstable and subject to change depending on the features of the current environment or prevailing conditions.' Wiegmann et al. (2002: 10).

For ease of reading in this study, the term safety culture will be used to denote a single measure arising from the HCWs' opinions of procedure safety. The next section will discuss measurement of the safety culture.

4.8.4 Measuring the safety culture

Although as Davies et al. (2000) argue, the nature of the organisational culture has a bearing on the safety of the organisation and on performance therein, exactly how to measure 'culture' this is not well established. The report on the 1994 Chernobyl explosion for the first time cited a poor safety culture as a factor contributing to the catastrophe (Cox and Flin 1998). Since Chernobyl, there has been much research to try to understand what safety culture is and how if at all, it can be measured and improved (Flin et al. 2006, Flin 2007). At present results from studies are small in nature with limited over-time repetition and with even more limited correlation evidence of a good safety culture and positive patient outcomes (Scott et al. 2003, MacDavitt et al. 2007). However, there is more evidence of a poor safety culture being associated with negative outcomes. For example, a review of wrong site surgeries found various unsafe behaviours amongst surgeons, including a failure of formal communication, performance of tasks when fatigued and a non-compliance with established protocols (Dagi et al. 2007). In the field of healthcare safety culture measurement, validation of tools is

developing. In a cross-sectional survey of nearly 11,000 HCWs in 203 clinical settings, researchers identified a six factor model of measuring safety that could be used to measure attitudes to patient safety across organisations and settings. The six factors were the: working conditions, team working climate, safety climate, perceptions of management, job satisfaction and stress recognition (Sexton et al. 2006). Although this work was done at the level of the organisation or clinical setting, it seems reasonable to assume the factors remain relevant at the level of a single procedure and, that with minor adaptation, can be used to measure the safety culture in clinical areas related to aseptic intravenous drug preparation procedures.

The latent conditions which comprise the organisation and culture set the scene in which the procedure is performed and errors and safety are either present or absent. The next slice of the Swiss Cheese Model is the current conditions of work, which includes more variable criteria, including the procedure complexity, the staff available, how the conditions can provoke errors and how within a system they can be measured; this is covered in the next section.

4.8.5 Current Working Conditions

Current working conditions can provoke errors in a variety of ways. For example, there may be insufficient human resources on a given day to undertake the procedure correctly, the environment may not be conducive to the procedure being performed aseptically, and the operators on duty may not be competent in

undertaking the tasks (Reason 1990, Vincent et al. 1998). Specifically for drug preparation, poor current working condition failures could include: too few staff to perform the tasks, patients who have create a distracting environment, clinical leaders not stressing the importance of hand hygiene or not insisting on cleaning the environment before the procedure occurs. Error detectability will be discussed in more depth, as will a system profile to enable the current working conditions in the thesis procedure to be identified. Communication, a critical current working condition in the prevention of errors, will also be discussed separately.

4.8.6 Current Working Conditions – Error detectability / system feedback

The detectability of errors that may or may not occur throughout the procedure is provided to the operator via feedback. For feedback to be of use it should be in real-time, that is, as it happens. If slips or lapses occur during a procedure and they are immediately visible to the operator, actions can be taken from preventing failures occurring. For example, if bacteria on entering an infusate coloured it blue, it would be obvious to the HCW that an error had occurred and that the infusate was contaminated and must not be infused. The only visible detectable errors by the operator in this system are for the drug and diluent volume and presence of precipitation. The ability of the operator to detect any slips or lapses should they occur was examined in the thesis. This includes the time taken for errors to become detectable, that is, during preparation, during administration or post administration. Determining the information/feedback available to the operator

whilst the procedure is being performed was fundamental to assessing the defences of the system.

4.8.7 Current Working Conditions – Procedure complexity

It seems logical to assume that the more steps there are in a procedure, the more opportunities exist for error in recollection, and the more opportunities for distraction and consequently slips and lapses. (The contrary is also true – too few steps in a procedure can also induce failures). It has been argued that omission errors are the most common type of human error (Reason 2002). As already alluded to, the number of steps in this procedure could be as high as 68; in addition there can be variation in diluent, drug, acceptable volumes, order of administration and drug-specific actions pre and post administration. Variability of input reduces simplicity and can greatly influence the reliability of the procedure (Spath 2000: 207); the degree of simplicity / complexity in these thesis procedures will be considered. Complexity has been described as ‘the enemy of safety’ (Woods et al. 2007: 462). The procedures’ complexity will increase the procedures’ error-prone risk. In describing any procedure therefore, an understanding of its inherent complexity is also required.

4.8.8 Current Working Conditions – A procedure profile

To understand the current working conditions related to the procedure, the procedure itself requires profiling. In an attempt to expand operative safety beyond patient factors and the technical skills of the surgeon, and to provide a basis for

assessing interventions, an 'operation profile' was devised (Vincent et al. 2004). This profile includes: the surgical team, procedures, operative events, communication, technical skills, team performance, decision-making and the operative environment; that is, all of Vincent's (2006) contributory factors. The operation profile was adopted as a term to characterise the full range of factors that have been implicated in surgical outcome in the peri-operative period. Table 3 shows the comparisons between the profile written by Vincent et al. (2004) and a procedure profile for aseptic drug preparation based on the known elements from experience and published national guidance. The aseptic drug preparation procedure profile also includes communication error categories devised by Lingard et al. (2004) and as discussed in the next section. Also Included in Table 3 are the written procedures and checklists. There is growing evidence that the use of checklists can reduce omission errors – which as already stated are the most frequent human error type (Reason 2002). In a recent review, checklist use in the intensive care unit, particularly to reduce catheter related blood stream infections, was extremely effective (Hales and Pronovost 2006). The checklist used by Hales et al. (2006) detailed all the steps to be followed for safe and aseptic insertion of a catheter. It was monitored and completed by an observer and not the operator. During this thesis, all tools available to the HCWs were looked for, including checklists to memory aid and reduce omission errors – none were found. Checklists can facilitate standardisation of a system. If it is standardised, that is, always performed the same way, then according to Vincent (2006: 181) it has greater reliability by reducing human fallibility. Combining variability of input with

variability in operators may make it difficult for standardisation of the thesis procedures. One vital component to the understanding of the safety of any system is an understanding of the communications of the people working in it, which is discussed further in the next section.

Table 3 Operation Profile with the Study Profile	
Operation Profile	Aseptic Drug Procedure Profile
Patient factors Principal complaint Co-morbidities ASA, BMI, Age	Patient factors Vascular devices used Drugs to be infused
The Surgical Team <ul style="list-style-type: none"> ○ Personnel ○ Experience of previous work together ○ Familiarity with procedure ○ Fatigue, sleep loss, stress etc. 	The Infusion Team <ul style="list-style-type: none"> ○ Who is involved ○ Sufficient numbers of competent staff ○ Experience of previous work together ○ Training and competency (initial; continuing) ○ Familiarity with procedure ○ Stress
Processes and Procedures <ul style="list-style-type: none"> ○ Adequacy of notes and management plan ○ Consent and preparation ○ Anaesthetic procedures 	Processes and Procedures <ul style="list-style-type: none"> ○ Written procedures ○ Checklists ○ Rules for various situations ○ Procedures performed
Key operative events <ul style="list-style-type: none"> ○ Blood loss ○ Minor and major complications ○ Error compensation and recovery 	Key procedural events <ul style="list-style-type: none"> ○ Inability to do procedure as written ○ Complications, for example, precipitation ○ Error compensation and recovery

Table 3 Operation Profile with the Study Profile	
Operation Profile	Aseptic Drug Procedure Profile
Flow of information following patient Adequacy of notes and consent Specific communications during the procedure Hand over	Flow of information Availability of data during the procedure Confirmation of completion
	Communication (opportunities & performance) Occasion Content Purpose Audience
Technical skills Ratings of good general surgical practice Ratings of operation practice specific steps Identification of specific technical errors	Technical skills Practice as per procedure Inclusion of steps crucial to asepsis Deviations from procedures
Team performance and leadership Leadership Coordination between team members Willingness to seek advice and help Responsiveness to flexibility	Team support for the operator Who manages the team What data is used to evaluate the system (error reports, quality control, reflective procedure review) Leadership support Support from team members Willingness to seek help and advice
Decision making and situation awareness Patient limitations Operation limitations	Decision making and situation awareness Patient limitations Operator limitations Team limitations

Table 3 Operation Profile with the Study Profile	
Operation Profile	Aseptic Drug Procedure Profile
Surgeon's limitations Team limitations	
The Operative Environment Availability and adequacy of equipment Availability of notes, records Noise and lighting Distractions	The Preparation Environment Cleanliness Availability and adequacy of equipment Access to key information; procedures, drug information Access to key equipment Noise and lighting Distractions Is it easy to do the procedure right
Interruptions: Phone calls, messages, outside theatre events, etc.	Interruptions: Phone calls, messages, multi-tasking, other events

4.8.9 Current Working Conditions – Communication

Sentinel events in healthcare have been defined as the occurrence of unanticipated death or serious injury, regardless of cause (Carrico and Ramirez 2007). Investigators found that 60% of sentinel events in American hospitals involved communication errors (for some procedures it is as high as 80%), (Herndon 2005, Joint Commission on Accreditation in Hospitals Organization 2007). The aseptic preparation of intravenous drugs requires communication between different HCWs and as a consequence was considered worthy inclusion in the thesis. Communication during the thesis procedure involves: the HCW performing the procedure and the prescriber, the pharmaceutical company, the

ward manager, co-HCWs involved in any redundancy checks and, of course the patient. Lingard, et al. (2004), categorised communication errors in an operating theatre. This framework has been adapted as a guide to assess the quality of communication within the systems in this thesis (Table 4).

Table 4 Categories of communication error (Lingard et al. 2004))		
Category	Explanation	Example
Occasion Failure	Problem in the situation or context of the communication	Asking if asepsis was maintained after a drug has been infused.
Content Failure	Insufficient or inaccuracy in the information being transferred.	Asking for a drug to be given without detailing the dose or the route or infusion time.
Audience Failure	Gaps in the composition of the group engaged in the communication.	Discussions between doctors on the preparation requirements of a new drug and omitting to include the nurse who will prepare the drug in the discussions.
Purpose Failure	Communication events in which the purpose is unclear, not achieved or incomplete.	Two nurses discuss that drugs need prepared for a specific time. No one confirms that they will take responsibility for doing this.

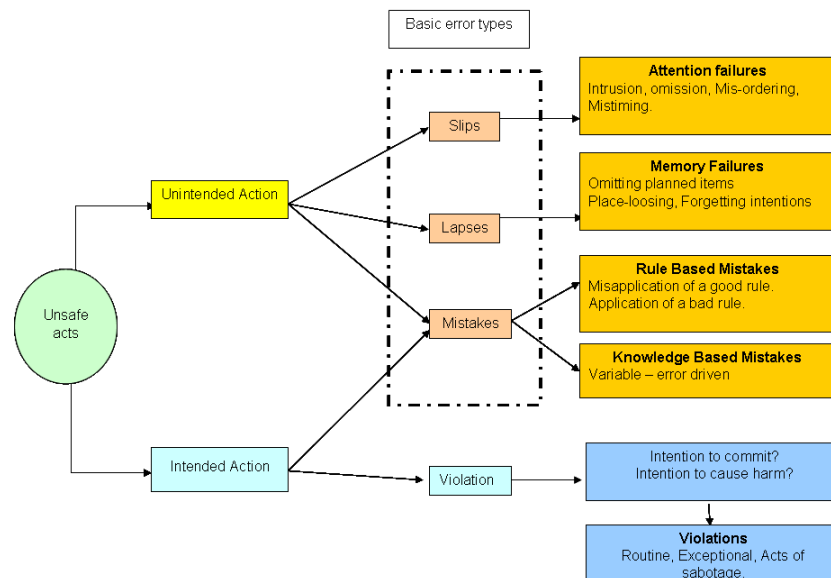
It is clear that both the opportunities for communication that occur, and the effectiveness of the communication given and received, need to be assessed.

Having discussed the latent conditions which can provoke error producing weaknesses - making up the organisation and culture and the current conditions of work - the next section will focus on the active failures which, as stated previously, are the unsafe acts committed by the people who are in direct contact with the patient or the system. Active failures take the form of slips, lapses, mistakes and violations.

4.8.10 Active failures in the delivery of care

Active failures are the unsafe acts performed by operators in practice and are usually the last acts that happen before the system fails (Figure 2.) In this thesis active failures include, for example, failure to perform hand hygiene, splash creation during preparation or the reuse of a contaminated single-use vial. According to Reason (1990: 206) unsafe acts are either intended actions or unintended actions. Intended actions have 3 basic error types: skill based, rule based and knowledge based. Skill based errors occur as slips and lapses due to attention capture through distraction or preoccupation. Rule based errors are due to either the poor application of a good rule, or the application of a wrong rule. Lastly, knowledge-based errors occur after a failure has occurred and when none of the known rules are considered applicable (Reason 1990: 86).

Figure 2 Unsafe Acts and basic error types (Reason 1990: 207)



(Reproduced with permission Cambridge University Press)

Skill-based errors are errors that arise in the execution of a procedure. They can arise as a consequence of any event, which disrupts the procedure including external distractions and internal preoccupation, for example, waiting for a drug to arrive, or delayed readiness of the patient, personal worries or stress. This is known as environmental capture – the operator who had been focused on the scheme or task in hand, fails on resumption after an interruption or delay to execute as it had been planned (Reason 1990: 71). The introduction of the use of red tabards by nurses doing drug rounds, literally as a ‘do not disturb’ notice to colleagues, is a method which aims to reduce the risk of medication errors caused by environmental capture (Scott et al. 2010). The communication errors discussed

in Table 4, fit into this category of error, in that they represent slips and lapses in attention and arise in the execution of a procedure and before a failure occurs.

Rule-based errors occur in two ways, either the application of a bad rule or a poor execution of a good rule. For rule-based errors to arise there must be rules. As the preparation of intravenous drugs are long established procedures, it would seem reasonable to assume that potential errors have been anticipated and prepared for, and there are as Reason (1990: 65) describes, if <this> situation then, that <action> rules or solutions available. Therefore, not only do the procedures of how to prepare infusions need to be available to the operator, but a series of rules that anticipate known failures and provide corrective actions should also be present. For example, to recognise and stop an IR-BSI, the following rule should be present: if during the administration of an infusate prepared on a ward, a patient unexpectedly becomes pyrexial, stop the infusion and immediately seek medical help.

Knowledge-based errors are errors that arise in addressing failures that had not been anticipated. Consequently, there are no accepted or specified ways to resolve the failure. Knowledge-based errors occur in a series, since no rules are specified in the given situation, various actions are tried to seek a solution until, if at all, an effective action is found. In essence it is the presence of knowledge-based errors, the 'not knowing what is not known' which arise in a different formats, that substantiate the criticisms of FMEA, HC-FMEA and ST-PRA in earlier

sections and further emphasise possible flaws in such methodologies. If there are no rules to lead the HCW to stop an infusion when a patient develops symptoms of an IR-BSI, then it could be expected that the patient will continue to be infused with micro-organisms until such time as either the infusate is complete or the HCW eventually considers the infusate as the possible cause and turns it off.

Unlike the active failures where the unsafe act was an unintended action, violations are active failures that they were intended by the operator, and as such they merit discussion separately.

4.8.11 Active Failures – Violations

Some active failures are violations, that is, deliberate attempts to deviate from a protocol. These violations according to Reason (1990: 195) are classified on the basis of intention: that is, the intention to commit a violation, and the intention to cause harm to the system (patient). It does not seem logical to anticipate that violations with the intent to cause harm will be committed in the presence of observers. Perversely, violations can on occasion be the safest option for the patient, for example, on finding a patient's morphine infusion pump had been administered too quickly and the patient was about to suffer a respiratory arrest, the safest option would be for the nurse to violate regulations and administer an antidote in advance of calling the doctor and having a prescription written pre administration.

Some violations become routine, such as when HCWs deliberately fail to perform hand hygiene when it is advocated. Following an extensive hand hygiene campaign, and when HCWs knew their hand hygiene practice was being observed, they still performed hand hygiene only 73% of the time (Randle et al. 2006). It would be impossible to separate violations from genuine omissions in this thesis. However, it was agreed that the researcher would make interjections if patients were considered at risk. For example, an interjection would be made if the researcher identified that prepared infusions were likely to be contaminated; no such interjections were, however, required.

4.8.12 System Defences and Barriers

Although errors may occur as a result of the latent conditions or as unsafe acts, failures can still be prevented if the system is well defended. For aseptic drug preparations there are three types of system barriers or defences that could be used to reduce aseptic failure risk these are: forcing functions, bacterial filters and redundancy checks. An automatic stop or forcing function can protect systems by routinely indicating that there have been breaches in procedures and forcing the operator to take appropriate actions. For example, if water in a modern autoclave does not reach the correct temperature, the doors lock and force the operator to call the engineer. As a consequence non-sterile packs will not be placed on shelves ready for use. The degree of automation that assists the operator to produce a safe sterile product in drug preparation procedures in this thesis has to be established.

The second type of system defence is a physical barrier of a filter capable of removing any infusate contamination without degrading any drug. Filters are available which can eliminate not just the micro-organisms but also endotoxin released from dead micro-organisms (Baumgartner et al. 1986, Horibe et al. 1990). Arguments have been put forward that in-line filters are necessary and there is evidence to support their use (Vanhaecke et al. 1989, Curran et al. 1999, Curran et al. 2000, Ball 2003). It should be noted that not all filters are capable of filtering endotoxin (Grobner et al. 2007). However, as previously stated, filters are not recommended in national (or international) guidelines, there appears to be no appetite, or more importantly budget, for their purchase. In this thesis filters were found to be in use correctly, ineffectively and not at all.

4.8.13 System Defences - Redundancy Checks

A redundancy is any duplication in procedural step introduced to increase the likelihood of it being completed successfully. Redundancies are built into a system to minimise the risk of errors. Some steps in a procedure may be considered so important or error-prone that they require a crosscheck to ensure they have been done. A frequently heard crosscheck is that issued by pilots once an aeroplane has landed 'Doors to manual and crosscheck'. In drug administration, a crosscheck that the patient is the person the prescription is written for is an accepted essential safety step. Reason (1990: 77) argues however, that certain features of the environment will with experience become increasingly significant

while others will be considered less error-prone, though this may not in fact be the reality of the situation. For example, if aseptic failure is not perceived as a significant risk, there may be no redundancy checks required on the aseptic steps of drug administration procedures. Crosschecking cannot make a system error-proof. Failures can still happen in crosschecked procedures as there can be confusion in what precisely is being crosschecked and role-hierarchy could affect a junior's willingness to speak up when an error is identified (Patterson 2007).

4.9 Human Error Theory Summary

In taking a systems approach to errors and identifying that failures arise due to a combination of both latent conditions and active failures, Reason (1990) and Vincent (2006) have provided an approach that can determine the error-prone nature of a system. This is because, included in the assessments are the objective elements of a system such as the equipment, the methods, the resources and the subjective elements. The latter include the culture and perceptions of risk, as discussed earlier. Therefore, to analyse the system of aseptic drug preparation and how it could lead to contaminated infusates, there must be analysis of the latent conditions and of how the workers perform the procedure. Although human error theory has utility in identifying the error-prone nature of a system, other theories are also necessary to identify reliability. The next section will discuss how High Reliability Theory and how patient safety and human factors approaches; can be used to determine the reliability of a system.

4.10 High-Reliability Theory

Beyond systems being reliable, a new focus on high-reliability has been defined for those organisations that have key characteristics. These characteristics are: a preoccupation with failure, a reluctance to simplify interpretations of events, sensitivity to operations, a commitment to resilience and deference to expertise (Weick et al. 1999: 81). These characteristics denote mindfulness and lead to the capability to discover and manage unexpected events, thus leading to high-reliability. What in essence Weick et al. (1999) are saying is that only by always being watchful and mindful of the fallible nature of the system can it be protected and operators prepared for and manage the unexpected. This seems intuitively correct because, if HCWs do not expect that splash contamination could pose a contamination risk for infusates (and patients) then, according to high-reliability theory, they will not act to prevent splash contamination during preparation. High-reliability is not synonymous with infallibility. Unanticipated interactions among system components which lead to system failures can never be completely forecast, averted or designed away (Tamuz and Harrison 2006). This is another warning of moving holes in slices of cheese. Evidence of the presence of these high-reliability characteristics will be looked for in this thesis.

4.11 Patient Safety Research

Patient safety is a growing research domain and indeed a movement for healthcare system change within healthcare organisations (Altman et al. 2004, Newhouse and Poe 2005, Runciman et al. 2006, Balka et al. 2007). Although there

were claims early on that iatrogenic disease caused more suffering than from all traffic collisions or industrial injuries (Illich 1974), it was not until 1999 and the publication of the Institute of Medicine's report suggesting that there were between 44,000-98,000 preventable deaths occurring in the US health care system every year, that patient safety was recognised as being seriously and routinely compromised (Institute of Medicine 1999). The Institute of Medicine's report was followed by reports into high-profile NHS systems' failures such as the Bristol Cardiac Surgery Inquiry. In summing up the failures of Bristol, Vincent (2006: 19) commented that: 'although routine, highly-skilled and complex, healthcare could be substandard to the point of being dangerous.'

The surgeons in Bristol had data which showed that performance in Bristol was worse than comparable centres; however, their poor results were erroneously explained away as the result of case mix. As recognised by Newhouse et al. (2005: 47), healthcare improvement requires continuous measurement, feedback, systems redesign and increased cooperation amongst HCWs. The Institute of Healthcare Improvement was instigated just to make healthcare safer for patients. Through campaigns designed to save 100,000 lives and avoid 5 million adverse events using rapid cycle testing, this movement has successfully progressed (Wachter and Pronovost 2006). The understanding of the error-prone nature of healthcare implicit in the movement was useful in developing the methodological framework of this thesis. Healthcare organisations have only just begun to see themselves as similar to the nuclear industry and aircraft industry; that is, as a

safety-critical organisation. The Scottish Patient Safety Programme launched in 2008 for all healthcare in Scotland, is a partnership with the Institute of Healthcare Improvement and has bold aims to reduce patient harm, including a reduction in all cause mortality by 30%.

Patient safety, although not a new concept, it is only relatively recently acknowledged as being the most important underlying premise of all healthcare.

The characteristics of patient safety have been defined as follows:

‘Patient safety is concerned primarily with the avoidance, prevention and amelioration of adverse outcomes or injuries stemming from healthcare itself. It should address events that span the continuum of ‘errors’ and ‘deviations’ to ‘failures’.

Patient safety emerges from the interaction of the components of the system. It is more than the absence of adverse outcomes and is more than avoidance of identifiable ‘preventable’ errors or occurrences. Safety does not reside in a person, device or department. Improving safety depends on learning how safety emerges from the interaction of the components.

Vincent (2006: 14).

These concepts are relevant to this thesis because the thesis is about understanding one system in healthcare so that there can be avoidance, prevention and amelioration of adverse outcomes of infusate sepsis due to contamination which occurs during the preparation and administration of

intravenous drugs. Vincent (2006: 15) also argues that the reduction of harm should be the primary goal and that patient safety should not be equated with merely preventing errors unless the errors in question are potential sources of harm.

4.11.1 Human Factors

Human factors are the relationship between human beings, the equipment they use and the environments in which they work; this includes the procedures they have to undertake. The system's design and organisational characters that influence behaviour for the purpose of minimising errors and optimising output are the essence of human factors study (Stranks 2007: 108). In a curriculum for medical students on patient safety, the WHO has defined human factors as 'the study of all the factors that make it easy to do the work in the right way' (World Health Organization 2009).

The objective in human factors science is to understand what is preventing the HCW from doing the right thing and to make it easy for the HCW to do the right thing. As such, human factors can be said to be the overarching approach in use in this study. Human factors principles that enable HCWs to do the right thing include: standardisation, simplicity, safety, consideration of the interactions of people, equipment and environment and crucially understanding when, why and how things may go wrong (Norris 2009). Examples of human factors that may make it difficult to achieve aseptic drug preparation could include: number of

procedure steps, poor environment, and difficulty in identifying the sterility of components. Conversely, making it easy for the HCW to do the right thing could involve; use of technology to reduce the number of steps, better labelling of products and the use of checklists.

4.12 Chapter 4 summary

In this chapter, theories and approaches to risk perception, risks assessment, error causation, high-reliability and patient safety were discussed and evaluated for their potential utility to the thesis. The theories and approaches which were evaluated, but rejected included: Cultural Theory, a management approach, Systems Engineering, Socio-technical Systems, Normal Accident Theory, Failure Modes Effects Analysis, Healthcare Failure Modes Effects Analysis and Socio-Technical Probabilistic Risk Assessment. These approaches were all characterised by a too narrow focus with which to view a complex dynamic system and this was the main reason for their rejection.

The theories and approaches that were considered to be of more utility to the study and discussed in-depth were; Human Error Theory, High Reliability Theory and Patient Safety research, including Human Factors. Human Error Theory, from a systems approach, asserts that failures arise not because of the unsafe acts of individuals but because of latent conditions in the system including the organisation and culture and the current working conditions. Measuring the safety culture was seen as crucial to identifying the procedure's error-proneness. The

human error approach to understanding why people do as they do is of value to this thesis because it considers not only unsafe acts, but also the latent conditions that are capable of provoking errors. However, it is not the only theory that is required for the thesis. High Reliability Theory includes the characteristics with which to identify the reliability within a system and assessing a system's reliability is also considered essential to describing it. Healthcare in Scotland is today set with patient safety as the priority context. The growing evidence base from patient safety research, which includes human factors, is also considered to be of value to this thesis in describing the system of aseptic intravenous drug preparation procedures.

From all these theories and approaches discussed in this section the methodological framework used for this thesis will be summarised in the next chapter.

5 The Methodological Framework used in this Thesis

In this brief chapter the methodological framework used in this thesis is detailed. To understand the system of aseptic preparation of intravenous drugs in clinical care settings, aspects of the system that are both error-prone and reliable need to be identified. As a consequence of the evaluations in the previous chapter, the methodological framework for use in the thesis is in the domain of Human Error Theory, High Reliability Theory, Patient Safety and Human Factors and is made up of the following specifics:

- Patient Safety: Healthcare, and in particular intravenous drug preparation, is inherently dangerous (Verghese et al. 1998, Institute of Medicine 1999, Stelfox et al. 2006, Vonberg and Gastmeier 2007).
- Patient Safety: Healthcare can be made safer by measuring and understanding performance and changing systems to make them more reliable, thereby reducing the distance between the desired goals and the achieved outcomes (Newhouse and Poe 2005).
- Human Error: All systems designed by humans are fallible. Failures arise through a combination of unsafe acts performed by frontline workers and latent conditions in the system's design. By identifying the latent conditions (organisation and culture and the current conditions of work) and how the HCWs perform the procedure, the error-prone nature of a system can be determined. (Reason 1990, Vincent et al. 1998, Reason 2000, Vincent et al. 2000, Vincent et al. 2004, Vincent 2006).

- Safety Culture: The safety culture within an organisation and within the clinical area is critical to the safety of the patients and staff therein. To measure the safety culture related to this procedure, six domains have been identified as critical to that measure: working conditions, team working climate, safety climate, perceptions of management, job satisfaction, working conditions and stress recognition (Sexton et al. 2006).
- Patient Safety and Human Error: Certain characteristics in a system can make it more error-prone, for example, complexity, variation in input, role confusion, lack of feedback, tight-coupling, time constraints, hierarchical culture, poor safety culture and erroneous assumptions of safety (Cook and Woods 1994, Spath 2000, Hudson 2003, Pronovost et al. 2006).
- High-Reliability Theory: Certain characteristics in a system can make it safer, for example; sensitivity to operations, commitment to resilience, deference to expertise, reluctance to simplify and preoccupation with failure (Hudson 2003, Carroll and Rudolph 2006, Tamuz and Harrison 2006).
- Human Factors: Understanding the system from a human factors perspective will identify what is required to enable the HCW to do the right thing (World Health Organization 2009).

In this brief chapter the methodological framework utilising Human Error, High Reliability, Patient Safety and Human Factors has been detailed. The next chapter contains the research question and objectives for the thesis.

6 Research Questions

In this chapter the research question and the overall objectives for the thesis are set out. The purpose of the thesis is to evaluate the system of preparation of intravenous drugs in clinical care settings in NHSScotland in order to identify how error-prone and how reliable the system is. The thesis is informed by the methodological framework. From the previous sections, the following emerge as the research questions and objectives.

6.1 Research Questions

- (1) What is the system of aseptic preparation of intravenous drugs in clinical care settings in Scotland?
- (2) How does the system work in practice?

6.2 Research Objectives

To produce a profile of the system of preparation of intravenous drugs in near patient areas in Scotland

- To identify the system's reliability characteristics
- To identify the system's error-prone characteristics
- To identify the challenges that HCWs face in ensuring asepsis during the preparation of intravenous drugs in clinical care settings in Scotland.

The next chapter provides a discussion on the evaluation and selection of various methods that were required to answer the research questions.

7 Methods

In this chapter the rationale for using the selected data collection methods will be given. As no single sampling method was deemed sufficient to answer the research questions, different data sources were selected; these data collection sources and methods facilitated triangulation of the data, making the data more robust and less subject to bias.

To identify the system of aseptic preparation of intravenous drugs, the following methods were identified as necessary:

- Observational assessments of each location
- Observations of drug preparations in practice
- HCWs' opinions of safety and when redundancy checks are performed
- A comparison of written procedures with observed procedures.

Six clinical settings where the literature had identified an infusate outbreak risk were selected for the research. As no existing tools were identified as being suitable, four data collections tools were devised. Details of how these tools were devised are given in this chapter. Also in this chapter, the sampling frame and recruitment process are described. The ethical and research governance considerations and procedures are given. The chapter begins with a review of the possible data sources.

7.1 Data Collection Methods Selection

The thesis set out to answer the questions: 'What is the system of aseptic preparation of intravenous drugs in clinical care settings in Scotland? And 'How does it work in practice?' The thesis was informed by the methodological framework. To complete this thesis, a variety of different data sources could have been used. The possible sources of data for this thesis included:

- The operators who carry out the procedure
- The nurses in charge of those who carry out the procedures
- The environments in which the procedures are performed
- The equipment (including guidelines / policies / checklists) to aid the procedure
- Data monitoring and feedback on the system
- Error reporting on the system

Data for this thesis could have been collected, for example, by asking HCWs about their practices, by observing HCWs practices, by surveying the environment, or examining written evidence about practice or performance. There are advantages, disadvantages and potential biases to all the various methods available for collecting the data (Parahoo 1997, Bowling 2002). It is also well-recognised that merely measuring a research phenomenon can impact on the phenomenon being measured and thus bias the results (Heisenberg 1930). For example, asking HCWs what they do using a semi-structured questionnaire might yield biased

information in that there may be a difference from what HCWs say they do from what they actually do. In addition, it is recognised that observer bias can arise when HCWs being observed change their practice as a consequence of the presence of a researcher (Parahoo 1997: 313, Bowling, 2002: 154). Discussing the procedures with HCWs whilst they are performing them has already been recognised in this review as a source of potential environmental capture and consequently a cause of omission error (Reason 1990: 71). Asking HCWs to describe the facilities or interruptions may generate a personal biased perspective. For example, a HCW may be so accommodating of poor facilities or accepting of frequent interruptions as normal, that such facilities and events might not be recognised as potential error precursors, when to an unbiased eye this would be recognised as the situation. Another important source of bias is from the researcher. Observer bias arises when, as a result of preformed opinions, what is recorded as occurring is different to what occurred (Bowling 2002: 154). To reduce this source of bias, the first ward study took place observed by a research expert. A debrief on the methods used in pilot study took place. There was agreement not to change the methods but some improvements in preparation were identified.

There are accepted methods that can minimise the risk of bias being introduced as a consequence of measuring by non-participant observation. For example, it has been shown that those being observed cannot maintain a change in practice as a consequence of being observed for long periods, in effect they return to 'type' (Parahoo 1997: 313). Therefore, in this study sufficient numbers of observations of

drug preparation procedures were required to minimise bias. None of these methods used in isolation would have provided sufficient data to answer the research questions. Observations of practice alone would have provided data on what was done, but not if it was being done as the procedure was written. Observations of practice alone would not have identified the context in which care was delivered or identification of any HCWs' assumptions of safety.

Kimchi et al. (1991) defined the term triangulation to describe a research method that uses multiple means of data collection, theory or analysis. The term is derived from the methods of finding an unknown third point from two known points, for example, as used in distance finding when map making. Triangulation in research has more recently been defined as 'the combination of two or more data sources, investigators, methodological approaches, theoretical perspectives or analytical methods within the same study' (Thurmond 2001: 253).

Triangulation has been advocated in nursing research because it negates or minimises potential bias inherent in all single methods (Kimchi et al. 1991). In this thesis there was no single data source that could have been used to answer the research question and therefore triangulation from multiple data sources was required. Triangulation of methods was used to verify data collected from different sources, minimise bias and to ensure that sufficient data was collected to answer the research question. This triangulation of data involved four different sources – detailed in the next section.

The four data sources used to answer the research question were as follows:

- Assessments of locations where the procedures are performed
- Observations of aseptic drug preparation procedures
- Survey of HCWs' opinions on safety and when they performed redundancy checks
- Comparison of written procedures with observed procedures. 'Written procedures' includes all the information available to the HCW for the purposes of achieving asepsis during drug preparations which was examined.

Reason's (1990) error categorisation (Figure 2) also provides useful information for the data collection. First, the researcher must observe the operator and not interrupt. Interruptions could cause distraction and could provoke skill-based errors. Secondly, communication before observing the procedure must not cause the operator to be anxious because, if the operator is preoccupied on what the researcher observes and reflect on this, similar slips and lapses due to environmental capture could arise. Finally, since distraction may be a part of the normal context in which operators perform such tasks, it must be looked for. A working environment that is full of operator distractions would be considered as skill-based and error-prone.

7.2 Data Collection Tools

No existing validated or un-validated tools were found in the literature that could have been used for this thesis. Consequently, data collection tools were devised for each of the data sources. The design of the tools was influenced from related research in the literature, from the extant national guidance and from the researcher's experience in performing the procedure and writing guidelines for them (CRAG 2002, Lingard et al. 2004, Vincent et al. 2004, Nursing and Midwifery Council 2006, National Patient Safety Agency 2007).

7.2.1 Data Collection Tool 1 – Location Assessment

The Location Assessment tool was devised by adapting the procedure profile produced by Vincent et al. (2004) and illustrated in Table 3. The Location Assessment was designed to identify the environmental factors related to the procedure, including: regulatory framework for aseptic drug preparation, area design of where drugs are prepared, types of patients and drugs commonly used, whether high-risk drugs such as heparin was used, what facilities available to the HCW, what training was provided and what quality control was ongoing (Appendix 1). This data collection tool was administered by the researcher with the nurse in charge of the clinical area in the clinical area where the intravenous drugs are prepared.

7.2.2 Data Collection Tool 2 – Observations of procedures

The data collection tool for the observation of each individual procedure was prepared from national guidance of the advocated steps for a safe procedure, and from the researcher’s professional experience of preparing drugs (CRAG 2002, Nursing and Midwifery Council 2006, National Patient Safety Agency 2007). The advocated steps in the procedure were listed with space for comment on exactly how the procedure was performed (Appendix 2).

The assessment of any microbial contamination was based on the following summary of evidence (Table 5).

Table 5 The evidence supporting the method of assessing the microbial risks in the observed study procedures		
Potential contamination sources	Potential cross-transmission route and subsequent infusate contamination	Supporting Evidence
Hands	Contamination of hands at any point in the procedure will facilitate contact transmission of micro-organisms to any subsequent environment or equipment surface.	(World Health Organization 2009)
Surfaces used to prepare	A contaminated surface used to prepare infusates could through contact transmit contamination to	(World Health

Table 5 The evidence supporting the method of assessing the microbial risks in the observed study procedures		
drugs	equipment or hands that will subsequently through further contact transfer the micro-organisms to the infusate.	Organization 2009)
Equipment contamination	Cross-transmission to equipment can arise by contact with a contaminated surface (human, environmental or other equipment), thus facilitating subsequent transfer to an infusate.	(Kramer et al. 2006)
Access points to diluents / drug vials	Diluent access points that are not sterile will be contaminated through exposure to the air or contact; if not decontaminated they will provide microbes with entry to the diluent/drug and thereby contaminate an infusate.	(Zacher et al. 1991)
Re-use of drug vials	Contamination will arise over time with the re-use of multi-dose or single-use vials. This will enable the direct transfer micro-organisms to any infusate prepared after contamination has occurred.	(Mattner and Gastmeier 2004)
Contaminated antiseptic	Antiseptics are weak disinfectants and unless sterile and single-use can become contaminated and subsequently contaminate environments, hands, skin or vial tops and thus an infusate.	(Nasser et al. 2004)

Table 5 The evidence supporting the method of assessing the microbial risks in the observed study procedures		
Droplet contamination	Equipment, hands, drugs or diluents exposed to water spray can become contaminated with microbes which can subsequently contaminate an infusate.	(Nasser et al. 2004)
Long term infusates	Infusates administered over 12 hours will provide micro-organisms with sufficient time to multiply to cause IR-BSI during the life-time of the infusate.	(Maki and Martin 1975)
Airborne dissemination (related to the degree of drug exposure to air)	Any drug/diluent ampoule or equipment part in contact with any drug/diluent, which is open to the air during preparation has the potential to be contaminated from the myriad of microbes which are present in air all of the time. The amount of contamination being proportionate to the amount of contamination in the air and duration of exposure.	(Eickhoff 1994)

7.2.3 Data Collection Tool 3a – HCWs’ opinions on safety

The third data collection tool (Appendix 3a), asks for the HCWs’ opinions on safety of the aseptic drug procedures and was developed from validated tools produced to measure the safety culture in clinical settings. The science of measuring safety in a clinical setting is considered immature (Pronovost et al. 2006). The majority of

safety culture tools are designed to measure organisation-wide safety culture (Scott et al. 2003, Singer et al. 2003, Pronovost et al. 2006, Sexton et al. 2006). Although some have been modified to measure safety in clinical units (Koornneef 2006), none have yet been devised to measure safety culture related to the research procedure. The majority of these safety culture tools use a Likert scale to generate quantitative data (Colla et al. 2005, Makary et al. 2006, Modak et al. 2007, Wisniewski et al. 2007).

To devise a safety culture measurement tool for the research procedure, existing tools were reviewed. Six domains of safety previously identified and included in the methodological framework, by Sexton et al. (2006) were all recognised as relevant to the study; these domains of safety were: team worker climate, safety climate, perceptions of management, job satisfaction, working conditions and stress recognition. The HCWs' opinions of safety tool (Appendix 3a) begins with three statements that measure the safety culture by assessing the HCWs assumptions of safety and the working conditions, that is,

When preparing drugs it is easy to prevent asepsis failure.

When preparing drugs it is easy to detect asepsis failure.

The procedures for preparing drugs on this ward are simple.

The first 2 of these statements relate to the safety culture and the last statement pertains to the working conditions. The remaining statements were designed to

measure the safety culture by canvassing the degree to which the HCWs consider the procedure safe based on the domains of safety (Sexton et al. 2006) Table 6.

Table 6 Statements from the HCWs' Opinions of Safety (safety culture)	
Criterion	Measuring
The resources, (time, people, equipment) on this ward makes it easy to prepare IV drugs safely	Working conditions
The environment, (space, cleanliness, lack of clutter) on this ward makes it easy to prepare IV drugs safely	Working conditions
The distractions and interruptions on this ward make it difficult to prepare IV drugs safely	Working conditions
I get feedback on the quality of my IV drug preparation performance	Safety culture
I would feel uncomfortable raising safety concerns regarding IV drug preparation on this ward	Safety culture
I can prepare IV drugs on this ward without distraction or interruption	Working conditions
Asepsis failure is a safety priority on this ward	Perceptions of management
If I recognised an error in my IV drug preparation, I would always report it	Safety culture
There is good support on this ward for those who	Teamwork culture

Table 6 Statements from the HCWs' Opinions of Safety (safety culture)	
Criterion	Measuring
prepare intravenous drugs	
To improve patient safety I am encouraged to report errors	Safety culture
Preparation of IV drugs is stressful	Stress Recognition
Preparation of IV drugs gives me job satisfaction	Job satisfaction

Evaluations of the scores on the Likert scale were used to determine if HCWs who prepare intravenous drugs consider the procedures safe and consider the likelihood of failure low. Such assumptions of safety can be poor indicators of reliability as it is only by acknowledging the propensity to fail that the system can become reliable (Hudson 2003, Carroll and Rudolph 2006, Tamuz and Harrison 2006).

7.2.4 Data Collection Tool 3b – Operators stated redundancy checks

The last part of the HCW survey relates to the redundancy checks that the HCWs perform when undertaking the thesis procedures. Again there was no tool identified from the literature that could have been used or adapted. To produce this data collection tool, the procedure of intravenous drug preparation was broken down into the component parts, and at each step in the procedure, the HCW was asked to note if they performed a redundancy step. Data from this part of the thesis was compared to that observed and that required by the written procedures.

The data showed where redundancy checks are present in aseptic and non-aseptic parts of the procedures. This data collection tool is Appendix 3b.

No data collect tool was devised for the comparison between written and observed procedures. This would have been devised from the wards' procedures.

7.2.5 Validity of the Data Collection Tools

None of the three data collection forms (Appendix 1, 2, 3a, 3b) have been field tested – though a pilot study was performed. The data collection tools were examined to ensure that the data collected would answer the research question and that they have face validity. The criteria measured by the tools were compared to the characteristics identified from the literature that denote error-prone or high reliability features. These characteristics were designated as: error-prone characteristics (EPC), high-reliability characteristics (HRC) or system profile characteristics (SPC). The characteristics within each of these data collection tools were compared against the characteristics identified from the literature to ensure that they are incorporated in at least one, and preferably more than one, of the data collection tools, facilitating triangulation of the data from different sources. Table 7 shows with an 'X' which characteristics were measured by each of the tools.

Table 7 lists all the EPC, HRC and SPC that were required in the thesis and shows which of the data collection streams they were identified from.

Table 7 Error-prone, high-reliability and system profile characteristics

	Location assessment	Preparation observations	Safety opinions / Redundancy checks	Written materials
EPC – Reliance on humans	X	X		X
EPC – Complexity	X	X		X
EPC – Variation in input	X	X		X
EPC – Role Confusion	X		X	
EPC – Lack of feedback	X	X	X	X
EPC – Tight coupling	X	X		
EPC – Time constraints		X	X	
EPC – Hierarchical culture			X	X
EPC – Poor safety culture			X	
EPC – Erroneous assumptions of safety			X	X
HRC – Sensitivity to operations		X	X	
HRC – Deference to expertise	X	X	X	
HRC - Commitment to resilience			X	
HRC: Reluctance to simplify		X	X	

Table 7 Error-prone, high-reliability and system profile characteristics

	Location assessment	Preparation observations	Safety opinions / Redundancy checks	Written materials
HRC: Preoccupation with failure			X	
SPC: Latent conditions / failures	X	X	X	X
SPC: Current working conditions	X	X		
EPC: Unsafe acts		X	X	
EPC: Absence of system defences	X	X	X	X
SPC: End product testing	X	X		

Having determined the data collection tools to be used, the remaining sections of the chapter will discuss the population and sampling as well as the ethics and research governance.

7.2.6 Summary of mixed methodology being used

In order to answer the research questions: what is the system of aseptic preparation of intravenous drugs in clinical care settings in Scotland and how does it work in practice? - a mixed methods approach to obtain both qualitative and

quantitative data was used. This approach was chosen because a holistic system description requires both numerical data and qualitative data. Merely counting the presence or absence of phenomena would not have achieved the research aims. Similarly, qualitative data alone would not have identified with sufficient clarity the opinions of safety or redundancy checks. Therefore, where the phenomena were more suited to being described numerically, then a quantitative approach was used to complement the qualitative data.

Mixed methods research is seen as a complement to traditional qualitative or quantitative research and provides a pragmatic solution to the limitations offered by either method applied individually. Proponents suggest the approach results in a more complete analysis (Cresswell et al. 2004, Johnson and Onwuegbuzie 2004). It has also been argued that a mixed methods approach enables the researcher to tackle both practice and policy issues (as was required in this study) from both the standpoint of numbers and narratives (Borkan 2004). However, others have warned that adding quantitative data, or trying to quantify qualitative data results in a loss of depth and flexibility (Driscoll et al. 2007). This argument has been countered by those who suggest that the application of mixed methods benefits the study provided that there is recognition of the pitfalls that could arise when results from both methods were not in agreement (Borkan 2004, Cresswell et al. 2004). In this study where the observed results differed from the reported results explanations were looked for. For example, reported safety opinions did not match the researcher's observed risk assessment from the procedure. This was

shown to be not a result of untrue reporting, but of an unrecognised understanding of risk from the procedure as performed.

Qualitative data was gained from the location assessments where the nurses described their wards, how they operated and how they produced the infusates. This data was then complemented with qualitative data from observations of how the nurses actually used the environment, the equipment and the information available to them. Additionally, the qualitative data included the descriptions of the context in which they worked including any distractions and risks from concurrent procedures performed by colleagues. This qualitative data was combined with quantitative data which was gained from the survey of opinions of safety and the survey of where redundancy checks were performed. Further quantitative data was gained from comparisons of the observed procedures with the written procedures, that is, comparing what was done with what was specified to be done.

Consequently, this mixed methods approach produced both qualitative and quantitative data and reduced the potential bias sources inherent in all forms of research. The data generated which were mainly qualitative, described the elements of a system in detail rather than enumerated the presence or absence of particular system elements to answer the research questions: what is the system of aseptic preparation of intravenous drugs in clinical care settings in Scotland and how does it work in practice?

7.3 Population and Sample

Three different populations were identified:

- The environment, that is, the clinical settings where the procedures were performed
- The HCWs in each of the clinical settings who prepared the intravenous drugs
- The drugs prepared in each of the settings.

It was anticipated that each individual clinical setting would have up to 20 HCWs who could prepare many different drugs for intravenous use throughout any given day. The total population of clinical settings where HCWs manipulate intravenous drugs was considered a theoretical population; the true number of such clinical settings being unknown. The population was not considered homogenous but made up of clinical settings where there is considerable variation in: the number and type of drugs prepared, the environment in terms of it being 'fit-for-purpose', and the expertise therein. Types of clinical settings were chosen based on their high-use of intravenous drugs prepared and from reports in the literature of infusate-related outbreaks or high-levels of blood stream infections (Coello et al. 2003, Vonberg and Gastmeier 2007). The following categories of ward were chosen:

1st Ward - The pilot ward: an Intensive Care Unit (adult)

2nd Ward – A bone marrow transplant unit (adult)

3rd Ward – An Intensive Care Unit (adult)

4th Ward – A Vascular Surgery ward (adult)

5th Ward – A Neonatal Intensive Care Unit (paediatric)

6th Ward – A Medical receiving ward (adult)

A quota sampling of one clinical setting from each of the target clinical settings was used. The NHS in Scotland operates as a single NHS Board system. There are 11 main NHS Boards and 3 island Boards. Data were collected from 1 NHS Board that comprises 30% of all healthcare in Scotland – NHS Greater Glasgow and Clyde.

7.3.1 Inclusion and exclusion criteria

The inclusion criteria for this study were:

- A target clinical setting
- The clinical team were willing to participate and agreed to consent
- Intravenous drugs were prepared in the clinical setting

The exclusion criteria were:

- Clinical areas not in the identified in the target list
- In a target clinical setting, but preparation of drugs in clinical care settings does not take place.

7.4 Ethics and Research Governance

A submission was made to the local Research Ethics and the Research Governance Committees for NHS Greater Glasgow and Clyde and the University

of Stirling. Ethics and Governance permission was received. The submission included the promise to maintain and assure beneficence, non-maleficence, fidelity, justice, veracity and confidentiality to all those involved in the study.

The ethical issues that could have arisen were around observations of omissions or violations that could have led to patient harm. To address this, the consent form included information on what would happen if such events were observed, that is, the researcher would inform the HCW being observed.

The researcher assured the ethical committees that the study would benefit wider patient safety; there were no interventions in the study that could cause harm to either the patients or HCWs, primacy would always be given to the normal healthcare activities which would take precedence, and the researcher's records, as discussed in the following sections of the thesis are truthful. No individual identifiable nurse or patient data were collected or disclosed. The ward managers were invited to see the results of their individual data collection.

The letter from the ethics and R&D management committees approving the study is included as Appendix 4.

7.4.1 Recruitment and consent

Recruitment was performed as specified by the Ethics Committee. A letter was sent to the Director of Nursing asking for permission to conduct the study in NHS

Greater Glasgow and Clyde and a request was made to nominate ward managers in the selected areas. Ward managers from each of the chosen clinical areas volunteered to take part.

Several managers of wards made contact requesting that more wards be used in the study – however this was not possible given the study design and its purpose.

The information leaflet used for HCWs is shown as Appendix 5

The consent form for observations is shown as Appendix 6

7.5 Chapter 7 summary

To answer the research questions, 'What is the system of aseptic preparation of intravenous drugs?' And 'How does it work in practice?', data collection tools were required that would minimise bias and describe the system. Six clinical areas were chosen (including a pilot ward) where intravenous drugs are prepared and where the literature suggests there may be risk of infusate-related outbreaks.

No single data collection source would answer the research questions and no existing data collection tools were identified to fit the methodological framework. Triangulation was used to strengthen the inferences that were gained from the data analysis and reduce the risk of bias during the data gathering or analysing.

Four data collection tools were devised. The first tool, the Location Assessment, involved the researcher examining the physical environment where the ward operates, the patients, the drugs, the procedures, the information available and the location where the drugs were prepared. The researcher completed the Location Assessment with the nurses in charge of the areas.

The second tool was an observation data collection form that collected data on how drugs were prepared in practice. This data was collected by the researcher observing, with consent, all drugs prepared on a single shift.

The third data collection tool consisted of two parts. The first part (3a) collected data on the HCWs' opinions of safety (to measure the safety culture related to the thesis procedures) and the second part (3b) collected data on when the HCWs stated they performed redundancy checks. This data collection was given to all identified persons who prepared intravenous drugs on a study ward.

A final data source, for which no data collection tool was devised, was to compare written procedures with observed procedures. All the tools required piloting. To ensure face validity, the criteria they measure were mapped to the characteristics identified from the underlying framework literature, as denoting error-prone characteristics, high reliability characteristics, system profile characteristics and the methodological framework.

Once the data collection tools were completed then ethical and research governance at a university and NHS board level were attained. Following this, volunteer wards were selected from the inclusion criteria and after discussions and agreements to participate from the ward managers, the data collection was then ready to commence.

8 Results

This chapter contains the results from all the data collected. Presented first are the generic data from the location assessments and the procedure observations that were common to all six study wards. This is followed by the individual results from the six study wards detailing: the location assessment data, the observations of procedures, the contamination risks in the procedures and the strategies for reduction of contamination risks. The comparison of observed and written procedures is given after this, followed by the results of the opinions of safety. After the individual wards' results, the final sections include collective results on redundancy checks followed by an evaluation of the information available from sources other than the NHS board.

What these results will demonstrate is that although there is a single training programme and overall single procedure manual, there are 6 very different procedures performed. The risk of infusate contamination varies between individual wards based on the environment facilities available, the equipment in use, the drugs and diluents in use, how the procedure is performed and the opinions of safety therein. There was only one written procedure which could be compared with an observed procedure. A risk assessment had not been performed on any study ward. The identified risks included: risks from splash contamination, risks of error from distraction and interruption, risks from the types of drugs used

(multi-dose vials) and risks from equipment used (Dispensing Pins). Some of the wards used equipment to defend the system, for example, reconstitution devices, which reduced possible infusate exposure to microbial contamination. Two wards used effective in-line filters to prevent infection should contamination have occurred. In all six wards there was at least one systematic error that increased the infusate contamination risk. Most notably in all of the wards, many staff did not know that tops of rubber vials were not sterile and therefore did not decontaminate them before use. Despite staff in the ICUs partaking in a national safety programme, which provided the ward with data on ventilator-associated pneumonia, and central vascular catheter-related infections, there was no IR-BSI data and no end product testing being performed in any of the study wards.

The opinions of safety questionnaire which aimed to measure the safety culture provided a mixed picture. There were opinions indicating increased safety, such as willingness to report errors, and vulnerable safety indicators, for example, erroneous assumptions of safety and some nurses finding the procedure stressful. The opinions of safety did not always concur with the researcher's assessment of risk; this underlines the importance of triangulated data. Safety culture results are available for only five of the six study wards. Insufficient responses were collected on the 6th study ward with which to assess their safety opinions. This ward had the least optimal facilities.

The redundancy checks data shows that there is again variation in when redundancy checks are done and the nature of these. The results clearly indicate that asepsis checks are the least likely checks to be performed as a redundancy check.

The final results data are an assessment of all other infection-related information available to all the HCWs who prepare drugs; these data show that the HCWs who prepare and administer intravenous drugs are not well informed about infection risks.

From all the data sources detailed above, the system profile was produced. The conclusion from the profile is that the system of aseptic drug preparation is at present more error-prone than reliable. The chapter begins with a statement on the non-existent environmental risk assessments followed by a review of the generic training and generic manual pertaining to the preparation of intravenous drugs.

8.1.1 Generic results applicable to all study wards

In none of the study wards had there been an environmental risk assessment performed to identify if the area was suitable for preparing the intravenous drugs as required by the CRAG (2002) guidance. In all the study wards it is the qualified nurses who prepare and administer the intravenous drugs.

What training do those who prepare and administer intravenous drugs receive?

Once a nurse has had sufficient time post registration, usually 6 months, and the ward manager considers the nurse ready, arrangements are made for the nurse to attend the NHS board single day (two days for ITU nurses) intravenous training programme. On completion of this training, which includes calculation testing, supervision is given until the nurse has completed 10 bolus drug preparations, 10 infusion preparations and 10 infusion pump preparations. Mentoring is provided on the wards by qualified nurse and, wherever possible, by a named individual. Nurses in-training for intravenous drug competency evidence their progress in a record book. Once the nurses' training had been completed, the written examinations passed and the supervised practice completed, the nurse is then deemed competent.

Nurses can be moved from a competent status back to one which is not competent at the request of the nurse or by one of the team leaders. This could be, for example, if a competent nurse had a run of calculation errors or near-misses related to infusion timings or cross-reactions had been identified. The nurse may have, for a time, personal problems and feel that the additional burden from drug preparation is not helping. This would be grounds for not preparing and administering intravenous drugs for a time.

What training is provided after initial training?

No further formal training is provided. However, clinical skills are developed on the wards and there is ongoing peer approval and informal assessment for all staff who prepare and administer intravenous drugs.

Are there any drugs which staff do not prepare?

None of the staff on any of the study wards are permitted to add drugs to total parenteral nutrition bags, prepare chemotherapy drugs or prepare intrathecal drugs. These drugs and additions are all prepared in the hospital's sterile pharmacy suite. The study wards all had a formulary which listed the drugs that could be given on that ward.

Were any communication failures observed during the preparation of infusates?

Observing for communication failures was done on the study wards. All redundancy checks were done with two nurses, one of whom was competent in intravenous drug administration. The following communication statements can be made for the observed procedures on all the study wards

Occasion – all drug checks were done before administration

Audience – all drug checks were done with one competent nurse and one other nurse

Content – all drug checks were read out against written instructions and confirmed

Purpose – all drug checks were done to ensure right: patient / patient prescription, drug, dose, diluent, duration, route, and timing.

Are there checklists; if so, what do they cover?

There were no available checklists for IV drug preparation and administration found in any of the study wards.

What generic information is available on the wards?

Available on all study wards was the NHS Greater Glasgow & Clyde “Intravenous Medicine Administration Self-Directed Learning Package” (NHS Greater Glasgow and Clyde 2009). The document is given to all nurses who undergo training for competency in intravenous drug competency in this NHS board.

The following information to prevent infection is given in this document:

- Hand washing (level II) prior to handling the cannula or preparing medicines
- Cleaning ports prior to use
- Changing administration sets every 72 – 96 hours
- Minimising the number of manipulations to prepare a medicine, that is, break a vial membrane once to remove the desired quantity of fluid
- Minimising the time between preparation and administration
- Minimising the length of time that the cannula is in situ. It is recommended that the cannula is changed every 72-96 hours following insertion, provided that an alternative site is available should the patient continue to need IV access
- Use of closed IV systems and reconstitution devices

What makes the above generic is the lack of specifics (for example, the requirement to change the cannula) when in fact most ICU patients will have CVCs which do not get changed every 96 hours. There is a lack of other specifics for example:

‘72 or 96 hours for change of cannula and administration set’

There is no information as to why the HCW should choose to change a cannula at 72 hours and why on occasion at 96 hours. There is no mention of the need to change it sooner if there are particular risks (for example, post blood or lipid transfusion).

‘Minimise the time between preparation and administration’

There is no specific information as to what would be an unacceptable preparation-to-administration time interval.

‘Cleaning ports prior to use’

There is no information as to which ports in particular are included here, with what they should be cleaned (sic) [decontaminated], and for how long should the antiseptic be in contact with the port surface. Finally exactly how should the antiseptic be applied to ensure that there is effective decontamination of the ports?

‘Use of a closed IV systems and reconstitution devices.’

There are no more specifics on what defines equipment as closed and why, if it is available, there is not a requirement to use it all the time.

The generic document also defines an adverse incident and what should be done if one is detected. An adverse incident is defined as:

‘any happening with or without injury (near miss)

which is not consistent with the care provided to the patient by the facility and relates to the treatment that the patient has or should have received.’

A reporting adverse incident algorithm is provided for staff – the accompanying form to be completed does not include infection signs or symptoms, infusate contamination, IR-BSI or insertion site infection, as specific listed categories. There are 22 options; number 22 is ‘other’.

In summary this generic information is just that; generic. It lacks details of precisely what should be done, when it should be done and how it should be done.

This chapter will now continue with the results on the remainder of the data that were collected and were specific to the individual study wards. The individual wards results are presented in the following order:

1st Ward - The pilot ward: an Intensive Care Unit (adult)

2nd Ward – A bone marrow transplant unit (adult)

3rd Ward – An Intensive Care Unit (adult)

4th Ward – A Vascular Surgery ward (adult)

5th Ward – A Neonatal Intensive Care Unit (paediatric)

6th Ward – A Medical receiving ward (adult)

Each individual ward result is presented in the following order:

- The Location Assessment
- The observations of drug preparations
 - An assessment of the contamination risks in each ward's procedures
 - An assessment of how the contamination risks can be reduced
- Comparison of observed procedures with written procedures
- The results of the HCWs' opinions of safety.

The individual ward's results begin with the pilot ward.

8.2 Results from the pilot ward: an Intensive Care Unit (ICU)

Data Stream 1 – Location Assessment - pilot ward

Data Stream 2 – Observation of Intravenous Drug Preparations - pilot ward

Contamination risks in the pilot ward procedure

How to reduce potential contamination risks in the pilot ward

Data Stream 4 - Comparison of observed procedures with written procedures

Data Stream 3a – Opinions of Safety - pilot ward

Study took place on Thursday 10th September 2009

Researcher Evonne Curran

Observer Dr. Kath Stoddart

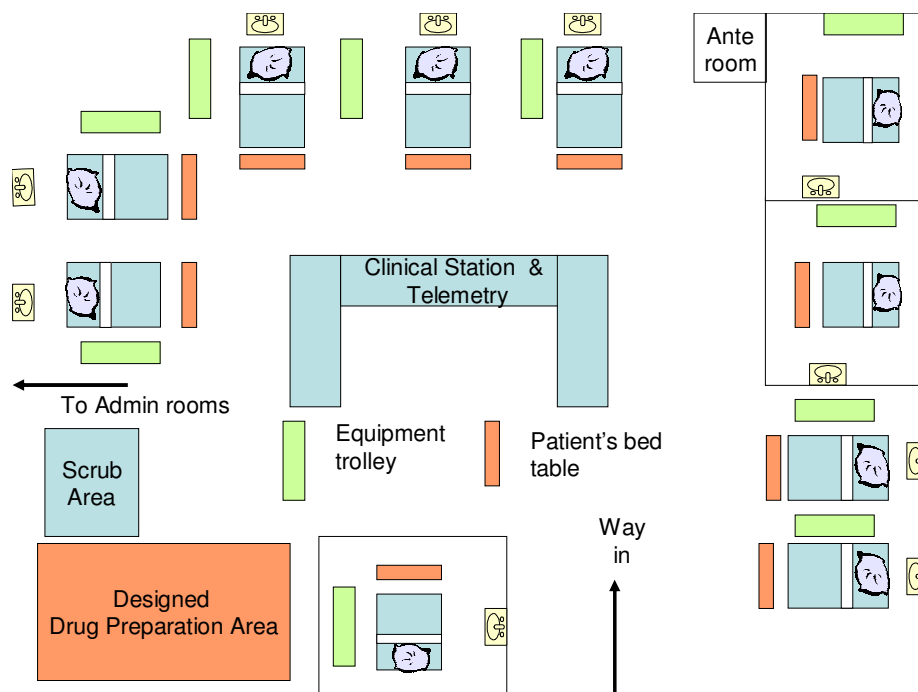
8.2.1 Data Stream 1 - Location Assessment - pilot ward

The data for the Location Assessment were obtained by interview with the ward manager and from the researcher's observations during the study period.

The unit and the patients they care for

The unit is a general intensive care unit (ICU) comprising 10 beds of which 3 are in cubicles (Figure 3). The patient population comprises patients requiring respiratory support, patients with burns and tertiary referrals patients such as those with upper gastrointestinal pathology, in particular patients with severe pancreatitis.

Figure 3 The layout of the pilot ward



What vascular devices are used for intravenous drug administration?

In the main, central vascular catheters (CVCs) are used to administer drugs. This is due to the longer term vascular access requirements of intensive care patients, the use of drugs irritant to veins and the need for immediate reliable vascular access. Some patients have peripheral vascular catheters (PVCs). Peripherally inserted central catheters (PICCs) and midline catheters would be used if they are already in situ when the patient is admitted. Swan Ganz catheters are occasionally used; patients can now be monitored without the use of this invasive device.

Approximately how many intravascular drugs are prepared in the unit?

The patients in the ICU require about 10 drugs each per day. With an average daily population of 7 patients, a conservative estimate would be that 25,500 intravascular drugs per year are prepared in the ICU.

What intravenous drugs are prepared and administered?

The main intravenous drug groups used and administered to patients are: antibiotics, anaesthetic drugs, beta-blockers, ACE inhibitors, bronchodilators and gastric ulcer prophylaxis medicines. In addition, all CVCs are flushed 4 hourly with saline and after the administration of drugs to minimise catheter blockage.

Does the unit use drugs associated with infusate sepsis?

Several drugs that have been associated with causing infusate sepsis are used within this ICU. Long-term infusions (>12hr duration) are used for drugs such as

heparin and morphine; this initially poses the risk of low level contamination then becoming high-level over the course of the infusion. There is frequent use of lipid drugs, such as the anaesthetic propofol, which is known to promote microbial growth.

Are any of the intravenous drugs prepared from multi-dose vials?

The initial response to the above question was that no multi-dose drugs are used; however, observation of the drug's cupboard identified several drugs that, although not used as multi-dose drugs, could be used as such in error. For example, Lignocaine and Propofol both come as sterile bottles with rubber tops that could inadvertently be used, contaminated and replaced on a shelf without showing obvious contamination prior to reuse. Invitingly, the Lignocaine is labelled 'with preservative'.

A bag of saline is allocated to each patient for a 24 hour period to be used as a multi-dose diluent and flush solution. It is patient-labelled and does not leave the bedside. It is accessed via a "Dispensing Pin" which enables repeated doses to be removed from the bag without the need to use multiple individual ampoules.

How long are the vascular access devices in situ for?

There is no set time for CVCs replacement. They are often removed just before transfer of a patient. They are always removed if there is redness around the insertion site or if there are signs of a catheter-related blood stream infection.

Is there a stable team that prepares and administers the intravenous drugs?

Yes. Generally the population is stable and the entire qualified nurse team is either able to prepare and give intravenous drugs or in training to be competent to do so. Intravenous drug preparation is seen as part of what they do. The off duty rota is prepared to ensure there are sufficient staff on every shift who are trained to prepare and administer IV drugs.

Are all the team familiar with all the intravenous preparing procedures?

Yes. By the time they are deemed competent their records should show that they have experience in preparing the wide variety of drugs required by ICU patients, and certainly all the usual intravenous drugs prepared by the unit.

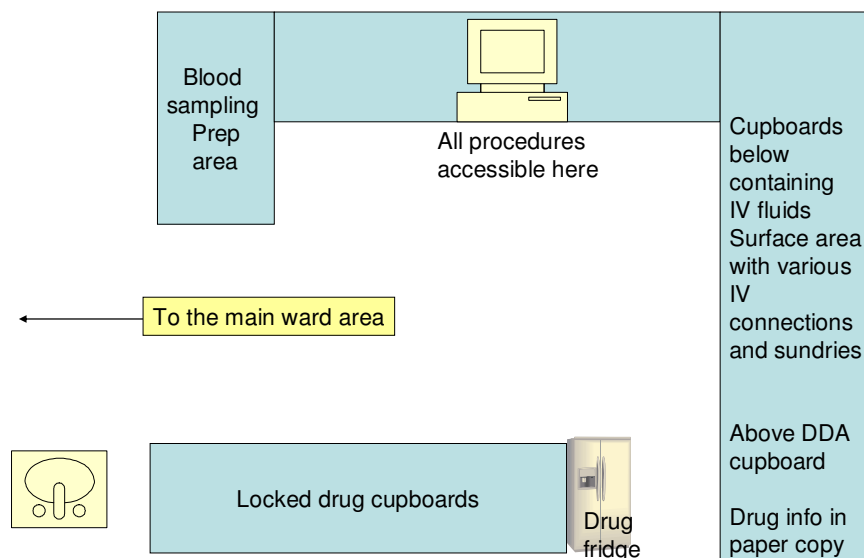
Where are the intravenous drug preparation procedures performed?

There is a designated Drug Preparation Area (Figure 4). However, this is not the area where the drugs are prepared. This is unfortunate, because it is well designed. (There are no standards for the environment of aseptic preparation areas in near patient settings, however, this area was spacious, visibly clean, not used for concurrent procedures, and not subject to splash contamination; the sink being immediately outside the area).

The reason for not using the Drug Preparation Area is that preparation of drugs in the area kept the nurses away from their intubated patients for too long – even though this was only for a few minutes at a time. This left insufficient nurses on the

floor to prevent the patients from self-extubating. The unit was opened in 2005 and before that the ICU was in a much smaller 7 bedded ward in a Victorian building. Prior to 2005, everyone and everything was close at hand – which had obvious advantages and disadvantages. Ironically, this modern well-equipped and well-designed spacious Drug Preparation Area posed an unforeseen risk to patients because it is too remote from them (Figure 3 and Figure 4). The actual areas where drugs are prepared are the table tops at the bedside (Figure 4).

Figure 4 The drug preparation area in the pilot ward



What written procedures are available?

Each bedside has a computer on the desktop which provides access to intravenous drug information for every intravenous drug that can be used in the unit. These information sheets include data on the drug, the normal dose, what other drugs it can and cannot be given with and the usual modes of administration

timing. A paper based resource of the same information is available in the Drug Preparation Area. No written aseptic drug preparation procedures could be found.

Displayed Poster Information

In a clean and uncluttered Drug Preparation Area there are a total of 20 posters or information sheets available – most referring to information that would be required rapidly, none refer to maintaining asepsis during the preparation and administration of intravenous drugs.

How often are the procedures referred to?

The nurses themselves had made the drug information accessible on the desktop of each bedside computer. These procedures were observed being frequently used.

Are the intravenous drug preparation procedures generic and drug specific?

The procedures are drug specific. However as stated previously, there are no specific procedures available to detail how to prevent contamination of the infusates.

What other procedures are done in the preparation areas?

At the bedside, a variety of procedures are done including, bed bathing, suctioning (closed), physiotherapy and dressing wounds. However because an individual nurse is allocated to an individual patient these procedures are not done

concurrently with intravenous drug preparation procedures unless there is an emergency. During emergencies, every effort is still undertaken to maintain asepsis.

What team operation support is there?

The manager feels that there is support from within the infusion team between colleagues in that they are encouraged to share problems and concerns related to intravenous drugs and the administration thereof. There is 24 hour access to pharmaceutical support for information regarding any drug.

The manager in charge of the unit is very supportive of the team and is trying to arrange IV drug preparation stations to move the drug preparation areas from the bedside to an area close by but less susceptible to splash contamination.

Is the lighting good making it easy to see to read instructions within the unit ?

Yes – there are no lighting problems. The lighting can be adjusted to suit the patient and the nurse.

What if any performance measures are available?

The ICU is clearly working hard to develop their quality improvement skills and lead with the Scottish Patient Safety Programme (SPSP). The unit has data on catheter-related blood stream infections (CR-BSI), of which it was stated there were none in the past few months. Error data are discussed at regular meetings

between lead nurses and consultants. All data available is displayed in an area of the ward frequented by nurses going to and from their breaks.

What monitoring is done outside the ward?

The SPSP data is sent to an extranet site and monitored by the SPSP team.

What ITU operator performance monitoring is done?

The majority of procedures are done in sight of colleagues in the large open plan area that is the ICU. All drugs to be administered need to have several redundancy checks. Although there is no written procedure, all procedures observed were performed to the same process. It would be extremely difficult to be a “rogue preparer” within the ICU and not be detected.

What, if any, self-assessment of performance is done?

There seemed to be a willingness by all those observed to question the process if they were in any way unsure.

How frequently are drug errors reported?

According to the ward manager all drug errors are reported. In the ICU most drugs are intravenous and therefore most of these drug errors relate to intravenous drugs. Specifics of the drug errors not related to asepsis were not part of this study. All drug errors are discussed at consultant / lead nurse meetings and

changes made. If required, more support is given to individuals. Analysis of errors is seen as a means to achieving and enhancing patient safety.

8.2.2 Data Stream 2 – Observations of drug preparations in the pilot ward

How many procedures were observed?

It was a quiet day for the intensive care unit with only 4 of the ten beds occupied. A total of 10 intravenous drug preparations were observed for 4 patients.

What procedures were observed and how many drugs were administered?

The following drugs were observed during preparation to pre administration:

Antibiotics: Metronidazole infusion; amoxicillin, Co-amoxiclav; Gentamicin,

Analgesics: Paracetamol infusion, Bronchodilator: Aminophylline

H2 antagonists: Zantac

Flush solutions were given after the above intravenous drugs.

How variable are the procedures?

The procedures do vary in terms of drug compatibility but can be represented simply as follows:

- Draw up drug; Draw up flush; Administer drug; Administer flush

Or alternatively

- Draw up diluent; Mix diluent with drug; Draw up mixture (drug and diluent);
Draw up flush; Administer mixture; Administer flush

A good deal of variation underlies this simple representation. For example, the administration can be via a continuous infusion, bolus or syringe pump. The solution may need to be administered covered (so it does not deteriorate in the light) or at a specific temperature. To maintain a specified pH, the diluent may vary. Some drugs may need to be stopped prior to administration of a second drug to prevent precipitation or a cross-reaction. The IV drug administration sheets guide those preparing and administering the infusates to prevent such drug errors.

How is the intravenous drug procedure performed?

The process of intravenous drug preparation as observed and the reported administration procedure is as follows:

- The nurse applies alcohol hand gel (AHG) to decontaminate hands and dons a clean plastic patient-specific, colour-coded apron.
- The preparation area where the drug is to be prepared is cleaned with a detergent wipe. (The first 2 steps are sometimes done in reverse order).
- All drugs and diluents and sundries are then collected for inspection and cross checking.
- Against the prescription and the patient identification the following are checked by 2 nurses (one of whom is deemed competent): the Drug (including expiry date) the Diluent (including expiry date), the Dose, the Duration of administration, that the Drug is due and has not been administered already, and that the intended Route of administration is intravenous. This first set of

checks is to ensure that the nurse is able to prepare the prescription correctly from the gathered drugs and diluents.

- One nurse then applies AHG again and dons non-sterile gloves.
- On several occasions it was observed that something had been forgotten and (with the gloves on) the nurse would go back to a draw to collect a syringe or additional needle. This would negate the benefit of the gloves.
- The packs are then opened.
- The drug is prepared as either a draw up drug then draw up flush, or, if the drug is a powder, the process is draw up diluent, mix diluent with drug, draw up mixture (drug and diluent).
- The second set of checks is to ensure that what has been drawn up is the correct dosage, the diluent is as required by the prescription and that there are not possible cross-reactions that could occur.
- A visual check for any precipitation or particulates is then done.
- Labels, if required, are then written and applied.
- A filter is then sometimes put on to the syringe - this was not always done.

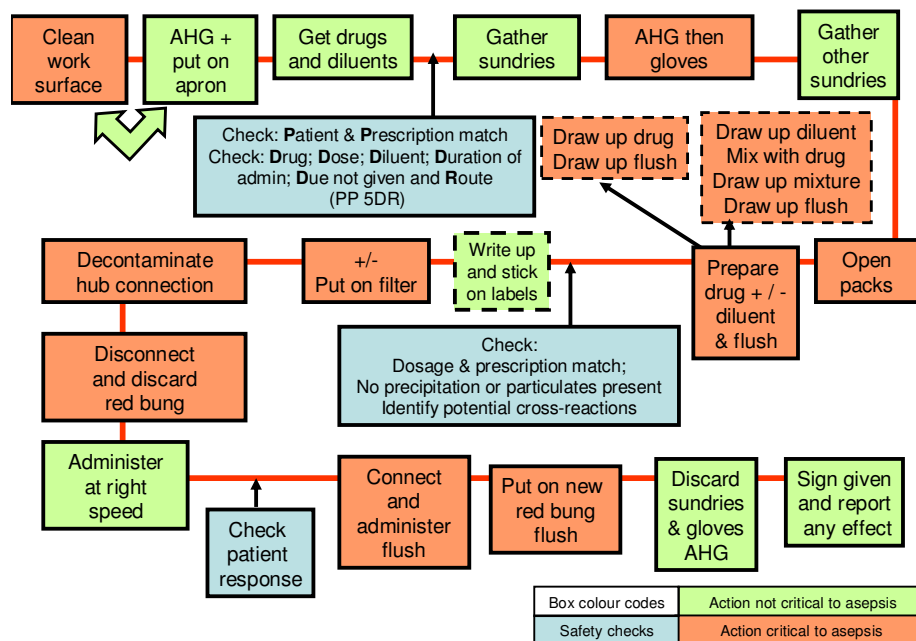
The following part of the procedure was discussed with the nurse and not observed in accordance with the ethics submission.

- The connection is decontaminated with an alcohol wipe.
- The red bung is disconnected.
- The drug is then administered followed by the diluent. Occasionally the flush would come direct from a 3-way tap via an existing infusion.

- During administration the patient is observed for abnormal reaction to the administration of the drug.
- The syringe or infusion is then disconnected and a new sterile bung is applied.
- Sundries including gloves are discarded and alcohol gel is again applied to hands
- Documentation is completed.

This procedure is illustrated as Figure 5.

Figure 5 The drug preparation procedures in the pilot ward



Was there distraction during the intravenous drug preparation procedures?

None of the 10 observed procedures were interrupted as such. One procedure, commenced during an ongoing conversation with a doctor regarding the patient's

clinical condition. All safety checks continued as required. The allocation of one-nurse to one-patient reduces the possible distractions from assessment of the care requirements of other patients. However, because of the very nature of the ICU patients and their requirement for continuous monitoring, in essence, all intravenous drug preparation procedures were considered as being undertaken concurrently with the procedures of, keeping one eye on the patient, one eye on the constant read outs of critical measurement monitors and listening for alarms. All absences from the bedside were prefixed with an agreement with a colleague to take over temporary continuous monitoring of their patient.

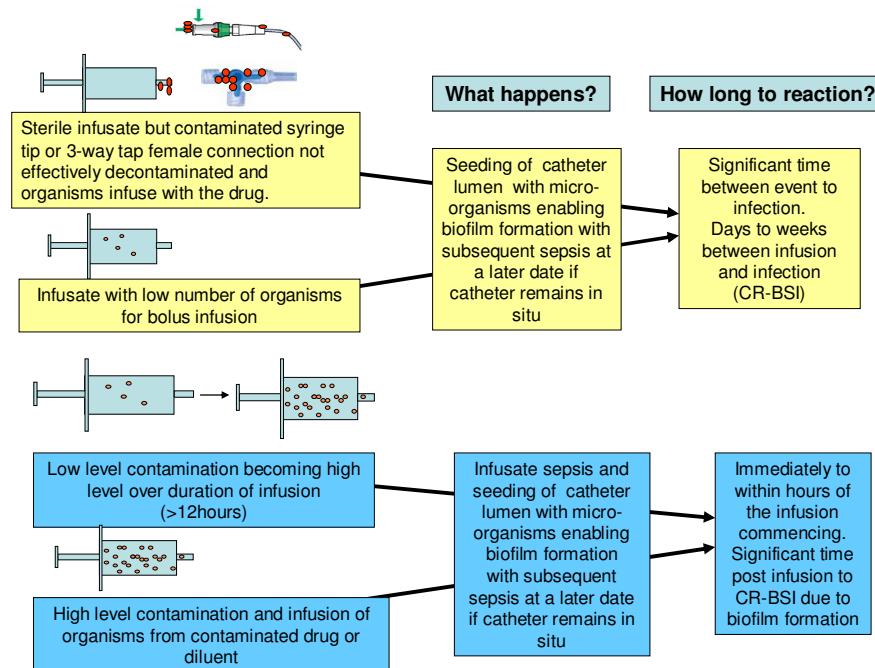
Is the equipment needed for intravenous drug preparation procedures close at hand?

Yes – kept on the same bed-side mobile table surface

8.2.3 Contamination risks in the pilot ward procedure

Figure 6 shows how long it would take in this ward for infusate contamination to cause a symptomatic patient response, that is, over days or weeks if contamination starts as a biofilm, or almost immediately if there is heavy infusate contamination. With Figure 6 as a guide, the procedures and location assessment data will be examined for their error-prone and reliability status. To do this, there is first an analysis of what is sterile/non-sterile and what are the critical parts of the equipment during preparation and immediately prior to administration.

Figure 6 Timing from infusate contamination to IR-BSI



What is sterile and non-sterile at the start of the procedure?

Figure 7 illustrates the sterile and non-sterile surfaces and materials used in the pilot ward. The sterile surfaces/materials are:

- Syringes, needles, internal contents of drugs ampoules, (internal contents to diluents if never used), Dispensing Pin, if never used, diluent if never used.

The non-sterile materials/surfaces are:

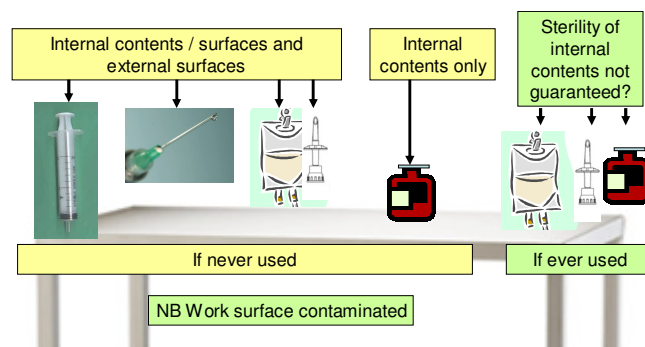
- The access point to any rubber topped vial
- Outside containers of any drug vial

Re use of the access point to the multi-dose diluent via the Dispensing Pin

Possibly the multi-dose diluent

The work surface on which the procedure is to be performed.

Figure 7 The sterility of equipment at the start of the procedure (pilot ward)



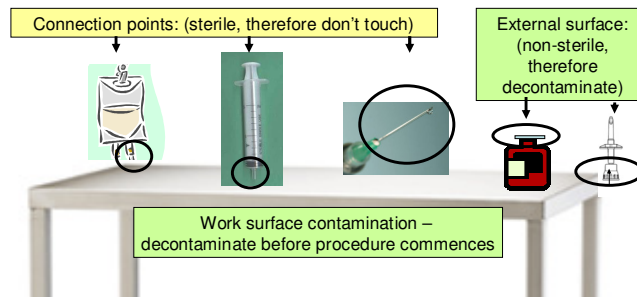
What are the critical surfaces that if contaminated, or not decontaminated, will prevent aseptic preparation?

As the work surface is not sterile, has not been decontaminated and has been open to contamination, it should be cleaned and be dry prior to the procedure starting. The critical surfaces during preparation are the connection points of the top of the syringe, the metal part of the needle that will come into contact with the drug and internal Dispensing Pin surface. These are the surfaces which, if contaminated - or not decontaminated - will prevent aseptic preparation and administration (Figure 8).

The other critical surfaces are the ampoule tops and the Dispensing Pin surfaces.

The method of using the Dispensing Pin is to remove the blue bung, clean the port with alcohol wipe, access the port, then replace the same bung.

Figure 8 The critical surfaces during the procedure (pilot ward)



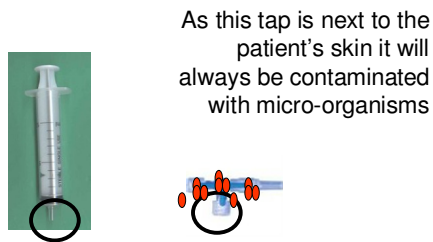
The information literature provided by the manufacturer on the Dispensing Pin confirms the status of this medical device as single-use. Therefore, re-use of the Dispensing Pin is currently contrary to the manufacturer's recommendations and MHRA (2010) regulations. It would be possible for the diluent to be contaminated when removing or replacing the Dispensing Pin bung. Contamination could also occur via bacteria bearing droplets, generated by general ICU activity, landing on the inner canal when the bung is not in situ.

Immediately before administration what are the critical surfaces that must be protected from contamination or decontaminated?

Immediately before the administration of the drug the critical surfaces are the hub, the tip of the syringe and the 3-way tap on the end of the catheter (Figure 9). As the 3-way tap is attached to the patient it, must always be considered to be

contaminated with at least with a covering of coagulase negative staphylococci, the leading cause of catheter related blood-stream infections.

Figure 9 The critical surfaces just before administration (pilot ward)



Is the equipment used for intravenous drug preparation procedures free from environmental splash contamination?

Although there is no splash from a tap as such, these portable preparation stations are situated within 1 metre of the ventilated patient's bed. The suction system used is closed and will not create splash but there is always the possibility of unplanned disconnection of the endotracheal tube from the ventilator tubing and consequent dissemination of aerosols over a couple of metres. Endotracheal secretions like all respiratory secretions, contain bacteria. There are no visual cues which signal to the nurses making up the infusion that environmental contamination may have occurred and that sterility of equipment may have been compromised.

Does the equipment aid the process of maintaining sterility of the infusate?

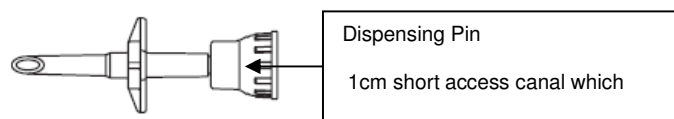
Four types of equipment appear to increase the risk of asepsis failure, these are discussed below.

a) Uncertainty over access point sterility

Some packaging of drugs clearly demonstrates a sterile access point once the access point wrapper or stopper is removed; for example, Metronidazole has a sealed peel back top. Others such as Lignocaine has a flip-off top revealing a non-sterile access point – though no information regarding this is visible and it is not obvious in the drug information literature. Other drugs are more likely to be sterile, for example, Propofol, the flip off top was sealed – again however, there was no visible label to indicate that the access point is sterile. Access points that look sterile provide an erroneous visual message that decontamination prior to access is not required.

b) The Dispensing Pin

The Dispensing Pin turns a single-use sterile infusion, such as a 0.9% saline 500ml infusion bag, into a multi-dose diluent which is used over a 24 hour period. There is no preservative in the saline infusion.



The access to the Dispensing Pin is via a short canal. It is not possible to access thoroughly this canal in order to decontaminate it. If left unprotected it will become exposed to airborne/droplet contamination throughout the 24 hour period it is used. Any item in contact with this canal, for example, the top of the syringe, could be contaminated with whatever micro-organisms are contaminating it. This contact contamination would then contaminate anything that subsequently comes into contact with the syringe. Dispensing Pins are provided with a bung to protect the canal. It was witnessed that this was sometimes replaced. It would be difficult to guarantee the sterility of the contents of the diluent due to the design of the device. Thus the Dispensing Pin could potentially contaminate the top of the syringe, which subsequently comes into contact with the top of the catheter without an intervening decontamination procedure.

Following possible contamination of the saline multi-dose diluent, then its use for a 24 hour period gives time for a single organism possibly to become millions; or at the very least to may survive and potentially contaminate the catheter lumen, facilitating biofilm formation (if not frank infusate) contamination. Figure 6 shows possible contamination outcomes depending on the degree of contamination of the infusate.

c) The filter

The access point to the catheter is defended on most observed occasions by a filter. The filter is a Millipore Millex® -OR 0.22µ filter. It has a maximum pressure

specification of 75 psi. The question that no one in the ward who was asked could answer is: what pressure is exerted during administration? There was limited knowledge regarding this product available on the ward.

The part of the syringe that was in contact with the Dispensing Pin is the part that is in contact with the filter. Therefore, if a filter is used, it does prevent contact contamination of the catheter hub from a potentially contaminated syringe tip – but not in the way it is designed to do. The manufacturer’s specification of the Millipore Millex® -OR 0.22µ filter [SLGS 025 OS] advises:

“Do not use this product as an in-line filter for intravenous administration”

It must be concluded therefore, that this filter does not achieve the effective microbial filtration as it was believed understood by those using it in the pilot ward.

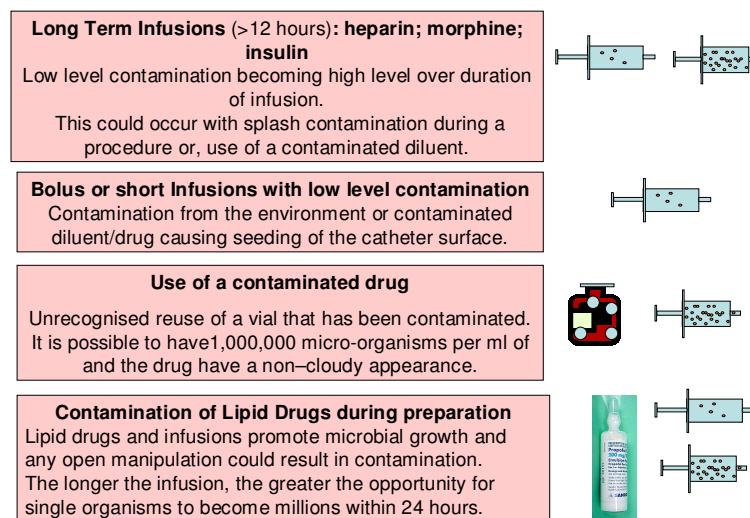
d) Single-use drugs able to be used as a multi-dose drugs

Any multi-dose drug use carries a risk of infusate contamination. The risk arises from an original non-sterile access followed by replacement of the residual drug back on the shelf for reuse. Repeat access for a subsequent patient can then produce a contaminated infusate. There is no evidence that this practice is ongoing within the unit. This risk is shown in Table 2. The four equipment risks are all dependent on other factors; for example, the access point may not be sterile, but without viable micro-organisms and a procedural step that transfers the micro-organisms, the infusate will not be contaminated. Similarly, reused single-use vials, will only contaminate an infusate if, during use, the vial has become contaminated.

What are the intravenous drugs at highest risk contamination for the Pilot ICU?

The types of drugs prepared in the ICU with the highest risk of causing infusate contamination are illustrated in Figure 10.

Figure 10 Infusates posing the highest contamination risk (pilot ward)



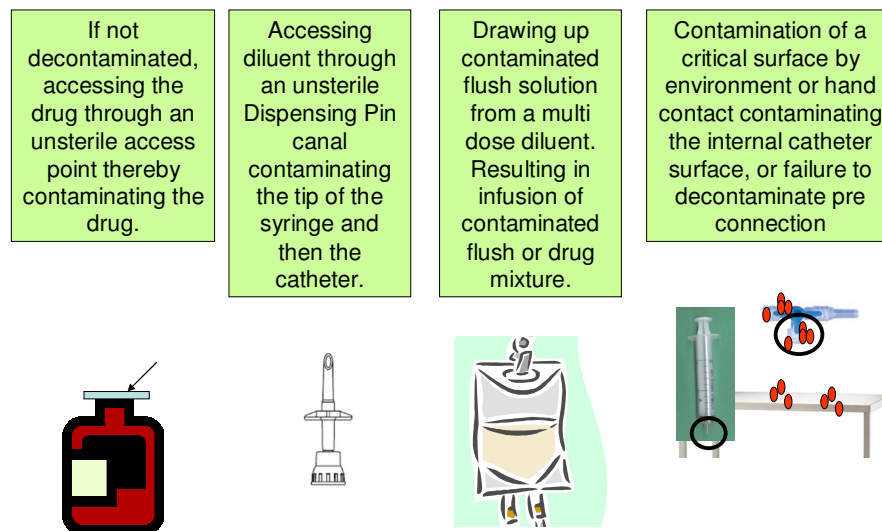
The infusates at highest risk are: long-term infusates, lipid based infusates, any infusate with low level contamination from the environment, infusates made from a contaminated drug or diluent, for example, from a multi-dose vial. Long-term infusions and lipid drugs are used frequently within the ICU; therefore the risk of asepsis failure and infusate contamination must (also) be considered high.

At which stage is the procedure likely to produce errors in aseptic preparation?

Figure 11 illustrates the steps of the procedure where, in certain circumstances, contamination could occur, these are:

- Accessing the sterile drug through a non-sterile access point contaminating the drug.
- Critical surface contamination / non decontamination:
 - Touching with unclean or gloved hands the tip of the syringe with subsequent contamination of the catheter lumen.
 - Critical surface contamination from direct contact with a contaminated environment work surface.
 - Failure to decontaminate effectively the hub prior to connection with the syringe.
- Accessing the diluent via a contaminated Dispensing Pin canal, thus contaminating the tip of the syringe
- Drawing up the diluent if it is contaminated by multi access.

Figure 11 The steps where contamination is most likely to occur (pilot ward)



All drugs prepared in the unit are prepared immediately prior to use, therefore storage post preparation with delayed administration is not an issue.

8.2.4 How to reduce potential contamination risks in the pilot ward

The procedure as performed currently can be classified as:

An interrupted aseptic procedure - performed by a single nurse with checker

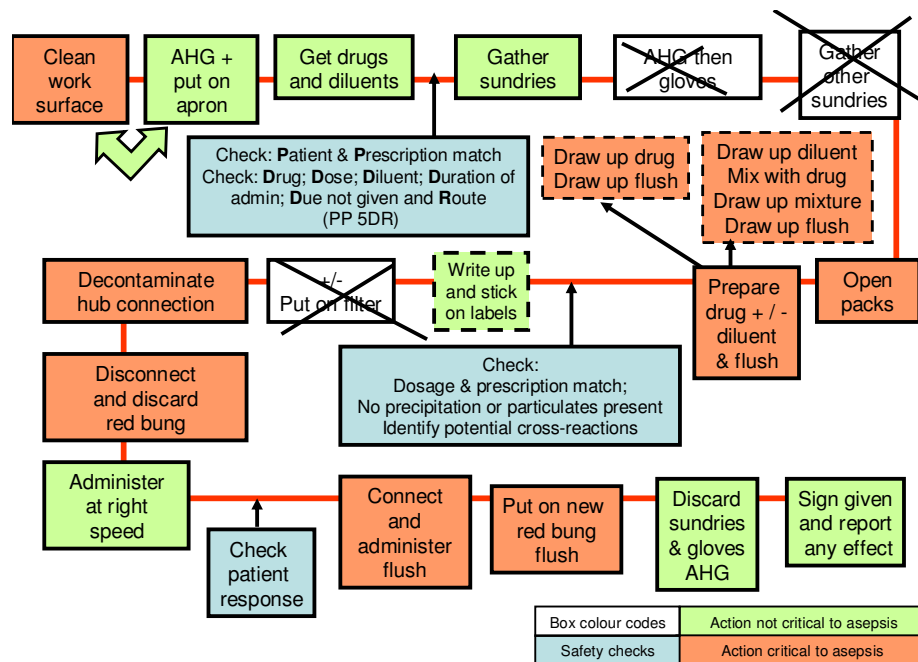
The written procedure (Figure 5) has been colour-coded with blue indicating mandatory redundancy checks, orange indicating steps critical to asepsis and green for steps essential to the procedure, but not to asepsis. From this colour-coding it can be seen that the procedure is an interrupted aseptic procedure; that is, it involves aseptic steps followed by non-aseptic steps during which there is potential contamination of gloved hands. For example, the need to apply labels as soon as a drug has been added is a non-aseptic interruption of the aseptic procedure, albeit essential for patient safety. This non-aseptic step is then followed by aseptic steps pre-administration. This interruption without subsequent hand hygiene prevents completion of the procedure as an aseptic one. (Shown in Figure 5 as orange boxes followed by blue, green and then orange boxes).

To promote reliability and reduce errors, the following steps in the procedure should be removed (Figure 12).

Change: Always start the procedure with the decontamination of the work surface

The most logical routine to start the procedure is to clean the work surface, then decontaminate hands and then don a plastic apron. The rationale for this methodology will be discussed later.

Figure 12 Steps in the current procedure that could be eliminated



Change – From use of gloves to hand hygiene at critical steps

Using gloves at the start of the procedure and then touching potentially contaminated surfaces or objects negate asepsis. It is not possible to use a single pair of gloves at the start of the procedure and maintain asepsis of the procedure. Not using gloves but instead using alcohol hand gel (AHG) to link between the interruptions in asepsis steps can restart and maintain asepsis throughout the procedure. It would seem logical, therefore, to stop using gloves and introduce

hand hygiene at any time when potential contamination of the hands may have occurred (Figure 12).

If gloves are considered critical to prevent contamination of nurses' hands by the drug, then further deliberation must be given to the equipment being used. It should be easy to prepare a drug by using equipment that does not cause splash, for example, with the use of reconstitution devices. Exposure of HCWs' skin to drug contamination should be considered under Control of Substances Hazardous to Health (COSHH) Regulations (2002) and a risk assessment carried out detailing what is required to negate or mitigate against this risk (Health and Safety Executive 2009).

Change - Stopping the Current Filter Usage

There is no benefit from the current filter as it is not designed for in-line use and therefore its use should stop (Figure 12). The overall use of filters will be discussed in the combined results.

New Step – Confirm drug and diluent are single-use sterile

During the first set of mandatory safety checks, a new check has been introduced. This is to confirm that both the drug and diluent are **single-use** and **sterile** (SUS) (Figure 13). This would mean stopping the use of the Dispensing Pin and multi-dose diluent. This is the most important change to enhance asepsis in this ward.

New Step – Identification of critical surfaces and information before preparation

As the procedure is ready to start, a new cognitive step has been introduced at which the HCW identifies the critical surfaces and essential drug information. This is to remind the nurse that the tops of drug vials are not sterile unless there is visual evidence presented to the contrary and to identify clearly what can and cannot be touched to maintain asepsis of the procedure. Also, at this point checking for critical drug information will enable appropriate steps to be taken in order to optimise safe administration.

New Step – Review possible critical surface contamination and cross-reaction risk

Prior to administration of the drug, a further cognitive step is introduced whereby the HCW reviews the performed procedure and is confident that neither critical surface contamination has occurred, nor cross-reactions are likely to occur.

Figure 13 shows the procedure with new steps included as yellow, Figure 14 is the same procedure with the colour-coding of all steps as blue for mandatory checks, orange for steps critical to asepsis and green for other steps.

These changes do not make or guarantee a validated aseptic procedure, but they do make a procedure which will not obviously cause infusate contamination from environmental, drug or diluent sources. To validate the procedure would require end product testing and greater process monitoring.

Figure 13 Integrated new steps and new system order (pilot ward)

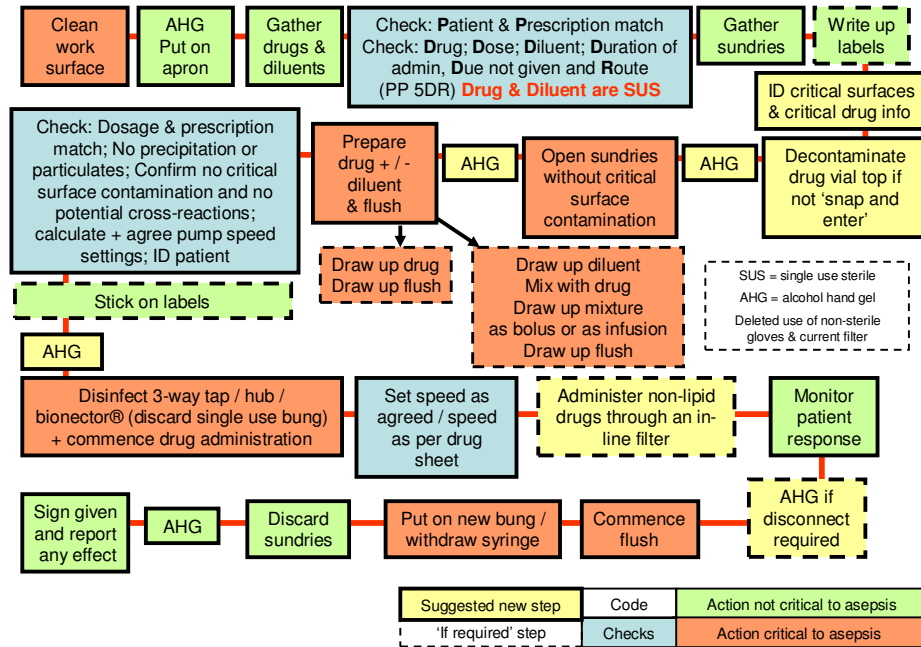
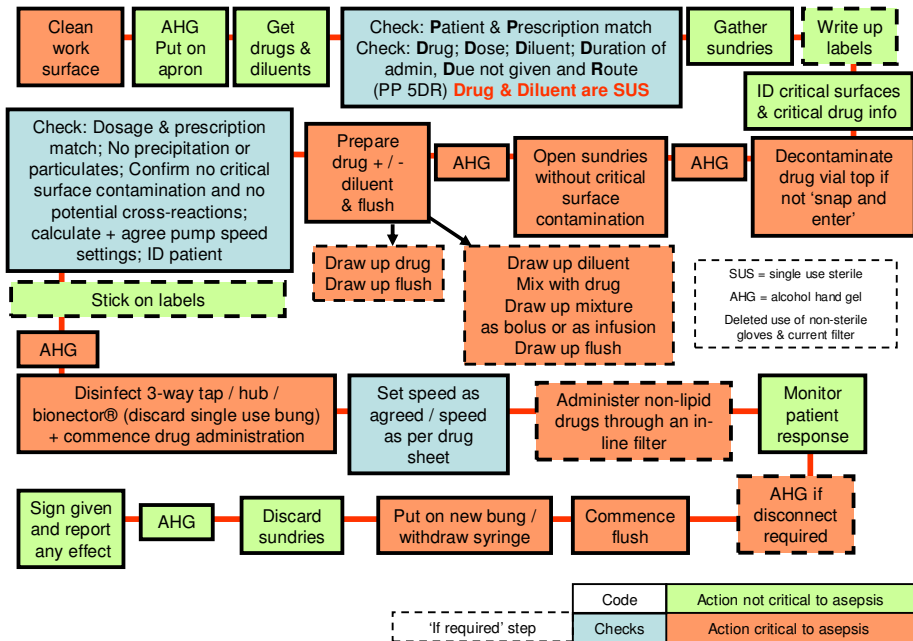


Figure 14 Revised procedure (Figure 13 colour-coded)



8.2.5 Data Stream 4 – Procedure comparisons (pilot ward)

This data could not be collected as there was an absence of written procedures with which to compare the observed procedures.

8.2.6 Data Stream 3a - Opinions on safety (pilot ward)

A total of 48 questionnaires were issued to all staff in the ICU who were competent or in training for competency in intravenous (IV) drug preparation, 17 (35%) were returned. During a repeat visit, the ward manager was asked to remind staff to complete the questionnaire and a further reminder request was issued via email.

The resulting statements on safety are given below and summarised in Appendix 7.

Statement 1 - When preparing IV drugs it is easy to prevent asepsis failure

The majority of the respondents, 11/17 (65%) agreed with this statement. However due to the equipment used, and the method of its use on this ward this was not observed to be the case.

Statement 2 - When preparing IV drugs it is easy to detect asepsis failure

To the statement on ability to detect asepsis failure, 6/17 (35%) thought it easy to detect failure, 3/17 (18%) thought it difficult and the remaining 7 (41%) could neither agree nor disagree with the statement. Although it would be easy to detect

an obvious touch contamination, contamination of the equipment or drugs is not easy to detect, as microbes are invisible to the naked eye.

Statement 3 – The procedures for preparing IV drugs on this ward are simple

The responses to this statement were variable, 3/17 (18%) strongly agreed with the statement and 2/17 (12%) strongly disagreed with it. These responses may have reflected experience. For example, more experienced nurses perhaps considering the procedures simple, and those in-training considering them complex. However, there is no data available to support this. Clearly there is variability of opinion on the simplicity statement and efforts to reduce perceived complexity are needed; this possibly reflects the degree of experience of the respondents.

Statement 4 – The resources on this ward make it easy to prepare IV drugs safely

The majority of respondents 15/17 (88%) agreed with this statement. It is possible that the respondents were referring to availability of resources and their opinions of the ease of which the equipment available facilitated drug preparation. The Dispensing Pin, for example, made it much easier to withdraw volumes of diluent; but crucially however, it also made asepsis failure more likely.

Statement 5 – The environment on this ward makes it easy to prepare IV drugs safely

There was less agreement with this statement. 2/17 (12%) disagreed with the statement and only 9/17 (53%) agreed. There was no opportunity for respondents to state what in particular about the environment was making it unsafe. Statements 4 and 5 are the reverse of what was found by the researcher. It was the equipment (resources) and how they were used that was making the procedure unsafe, not the environment as such.

Statement 6 - On this ward distractions and interruptions make it difficult to prepare IV drugs safely

The majority of respondents 10/17 (59%) agreed with this statement. Although the visit took place on a quiet ICU day, on the feedback visit with all beds occupied, the distraction from many concurrent activities and patient alarms was all too apparent.

Statement 7 – I get feedback on the quality of my IV drug preparation

Only 3/17 (18%) respondents agreed with this statement. These nurses were possibly still in training and being mentored to achieve competency. The majority disagreed with this statement; they did not get feedback on their performance. There was no standing policy to do this.

Statement 8 – I would feel uncomfortable raising safety concerns regarding preparing of IV drugs on this ward

There was variation in the responses here 11/17, (64%) disagreed with the statement and only 4/17 (24%) agreed, indicating most would be comfortable raising concerns if they were identified.

Statement 9 – I can mix drugs on this ward without distraction or interruption

Twelve of the 17 respondents (70%) disagreed with this statement, which confirms the findings of Statement 6, that distraction and interruption are frequently part of the ICU drug preparation procedure.

Statement 10 – Asepsis failure when preparing IV drugs is a safety priority on this ward

The majority of respondents agreed with this statement 11/15 (73%). There were 2 non-responses to this statement. It is difficult to assess whether this was an oversight or whether the 2 non-responders to this question genuinely could not answer it.

Statement 11 – If I recognised an error in my IV drug preparation I would report it

Thirteen of the 17 (76%) respondents agreed with statement. Only one respondent strongly disagreed. This indicates that that the majority of the nurses on the pilot ward recognised the need to report any drug errors for the safety of the

individual patient, the safety of the system, and they felt as a nurse it was safe for them to do so.

Statement 12 – There is good support to those who have to prepare IV drugs

Only 2 (12%) of respondents disagreed with this statement. 12 (71%) agreed there was good support on the ward for those who prepared drugs.

Statement 13 – To improve patient safety I am encouraged to report errors

Nearly all of the respondents 16/17 (94%) agreed with this statement, which reflected the ward manager's statements on efforts to reduce drug errors. This also confirms the findings in statement 11.

Statement 14 – I find preparing IV drugs is stressful

Six of the 17 (35%) respondents could neither agree nor disagree with this statement. Two of the 17 (12%) respondents stated IV drug preparation was stressful. This is possibly due to perceived risks from errors to their patients and to themselves as nurses or, if students, perhaps the risk of not being seen as competent in performing the task.

Statement 15 – Preparing IV drugs gives me job satisfaction

The results to this statement were varied with both strong agreement and disagreement being reported. More respondents [7/17 (41%)] disagreed with the statement than actually agreed with it [4/17 (24%)]. This indicates that nurses

chose to work in the ICU not because they prepare intravenous drugs - but in spite of it.

8.2.7 Summary of safety opinion questionnaire results on the pilot ward

The responses to the statements indicate that the factors that make the procedure error-prone on this ward are therefore:

- Erroneous assumptions of safety (Statements 1, 2)
- Complexity of the procedure (Statement 3)
- Perceived environmental difficulties (Statement 5)
- Unrecognised risk from the available resources (Statement 4)
- Lack of performance feedback (Statement 7)
- Distractions and interruptions (Statements 6 and 9)
- Stress from the procedure (Statement 14)
- Lack of job satisfaction (Statement 15)

What enhances the safety of the procedure on this ward are

- The resources available to prepare IV drugs (Statement 4)
- The willingness to report errors (Statements 8, 11)
- That asepsis failure is a priority on this ward (Statement 10)
- The support provided to the team (Statement 12)
- That staff are encouraged to report errors (Statement 13).

8.2.7.1 Additional comments from the respondents

The respondents were given space for additional comments – the following three comments were written:

“Very busy unit, sometimes to the detriment of aseptic technique – always rushing”

“My practice is very dependent on colleagues experience and workload at the time of assistance.”

“Some aspects of IV drug administration (checking overall procedure was performed aseptically), checking catheter hubs were aseptically accessed not always double checked due to time, that is, if the unit is extremely busy. Would trust colleagues to perform the points mentioned above aseptically.”

8.2.8 Summary of the pilot ward results

The Location Assessment in this ward identified potential environmental contamination risks, for example, the risk of exposing equipment to droplets from ventilator disconnections. There are also risks identified from the equipment: the filter was not designed (or labelled) to be used as in-line filter, the Dispensing Pin was labelled single-use and therefore should not have been used to turn a single-use bag of saline into a multi-use item. The procedure itself poses risks in that drug vial tops are not recognised (or well-labelled) as non-sterile items and therefore not decontaminated. Additionally, the procedure is an interrupted aseptic procedure and hand hygiene needs to be performed before commencing aseptic steps after non-aseptic steps. The use of gloves does not facilitate asepsis. The procedure observations identified the complexities and also some of what the

nurses did and did not know about what is sterile and non-sterile before and during the procedure. The statements from the opinions of safety and redundancy checks questionnaire identified that the some of HCWs' perceptions of risk are at odds with the evidence, for example, 6/17 (35%) thought it easy to detect asepsis failure when it is not. The majority 10/17 (59%), state that distractions and interruptions make it difficult to prepare intravenous drugs safely. This concurs with the researcher's observations that all procedures in the unit are done with concurrent observations of the patient's well-being, and whilst being continuously alert to the readouts from monitors and listening to all noises for patients' alarms. Indicators of safety were also identified; for example, the majority of staff stated they were encouraged to report errors, that they would report errors and that there was good support within the unit to enable them to perform the procedure. The comment by one nurse that the number of redundancy checks would vary with the business of the unit at the time, concurs with the description of systems by Dekker (2006: 16) 'People in them [systems] have to create safety by tying together the patchwork of technologies, adapting under pressure and acting under uncertainty.'

The data from all sources fitted in with the methodological framework: the procedure is dangerous and complex. The procedure relies more on humans than machines for safety. The system needs understood from the perspective of what is required to make it easier to do the right thing, and notably, by measuring and understanding performance and by changing systems healthcare can be made more reliable.

As a consequence of the pilot study results - which was performed in the presence of an observer – and the foregoing data analysis and data presentations, the data collection tools were not amended for use in the remaining 5 study wards.

8.3 Results from the 2nd ward: a bone marrow transplant unit (BMTU)

Data Stream 1 – Location Assessment 2nd study ward (BMTU)

Data Stream 2 – Observation of Intravenous Drug Preparations 2nd ward

Contamination risks in the 2nd ward procedure

How to reduce potential contamination risks in the 2nd ward

Data Stream 4 - Comparison of observed procedures with document review

Data Stream 3a – Opinions of Safety 2nd ward

Study took place on Friday 18th September 2009

Researcher Evonne Curran

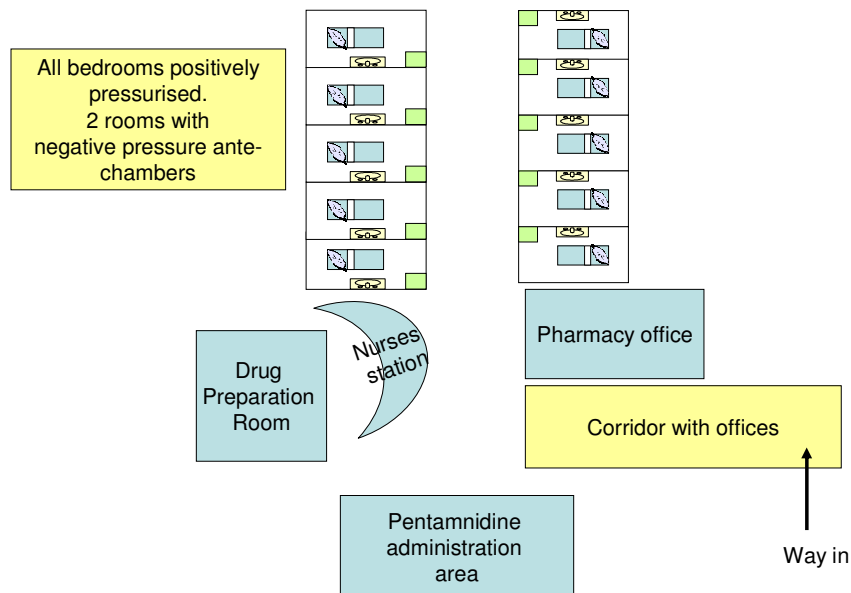
8.3.1 Data Stream 1 - Location Assessment 2nd study ward

The data for the location assessment were obtained by interview with the ward manager and from the researcher's observations during the study period.

The unit and the patients they care for

The BMTU is purpose-built and opened in 2007. It comprises 10 single cubicles, which are all positively pressured to reduce the risk of the patients developing pneumonic illnesses from airborne-pathogens. Two of the cubicles have a negative pressure ante-room, which can prevent airborne cross-transmission, should a patient have a communicable infection during a period of immuno-compromise (Figure 15).

Figure 15 The layout of the second study ward



This BMTU cares for patients before and after bone marrow transplant. In addition, the ward cares for patients with haemo-oncology diseases who cannot be accommodated in their original ward. To optimise the likelihood that bone marrow transplants will not be rejected, significant healthcare interventions are required pre transplantation. After their bone marrow transplant the patients again require intensive support to minimise the risk of bone marrow transplant rejection and to reduce the risk of infections until their transplant begins to produce sufficient effective blood cells.

What vascular devices are used for intravenous drug administration?

In the main, central vascular catheters (CVCs) of a Hickman style are used. This is due to the extremely long-term vascular access requirements of BMTU patients, the use of drugs very irritant to veins and the need for reliable vascular access. Emergency femoral lines may be used for short-term periods. Peripherally inserted central catheters (PICCs) are seldom used.

Approximately how many intravascular drugs are prepared in the BMTU?

The patients in the BMTU require about 10 – 12 drugs per patient per day. This means that about 100 intravenous drugs are prepared each day in the BMTU unit and 36,500 intravascular drugs per year.

What intravenous drugs are prepared and administered in the BMTU?

The main intravenous drug groups administered to patients are: antibiotics, immuno-suppressants, immuno-conditioning, anti-emetics, anti-fungal agents and chemotherapy drugs. To ensure that the entire drug prepared is administered, Y administration sets are frequently used. This enables a flush to be put in the second arm of the Y and the catheter flushed after the drug infusion is complete.

Does the unit use drugs associated with infusate sepsis?

Lipid drugs, such as propofol which promote microbial growth, are infrequently used in the BMTU. Long-term infusions (>12 hours duration) are used for some analgesics and other drugs. Patients in the BMTU can have poor blood clotting capabilities and therefore drugs such as heparin, which reduces clotting, are seldom required.

Are any of the intravenous drugs prepared from multi-dose vials?

No. However, if a drug is prepared for two patients at the same time one nurse would prepare both drugs to save wasting an ampoule, that is provided of course, a single ampoule contained sufficient drug for both patients. No multi dose-diluents are used.

How long are the vascular access devices in situ for?

The CVCs can be in use for a period of between 1 month to 6 weeks or for up to a period of several months for one particular group of transplant patients. The

catheters used are tunnelled; this reduces the risk of insertion site infections. It is dangerous procedure to re-site a CVC in an immuno-suppressed patient with a low platelet count. The risk of haemorrhaging during the procedure is high and therefore, if the catheter becomes infected, efforts will be made to salvage the line with the use of antibiotic locks. Line-salvage using antibiotics are not possible in lines that are in continuous use, for example, in ITU patients' lines. This is because elements of biofilm will be continuously infused along with the infusion causing the patient to be severely ill for the duration of line use. The BMTU staff are very conscious of the need to prevent CR-BSI in their patients, and are aware that if CR-BSI occurs, this could have additional life-threatening implications for the patient.

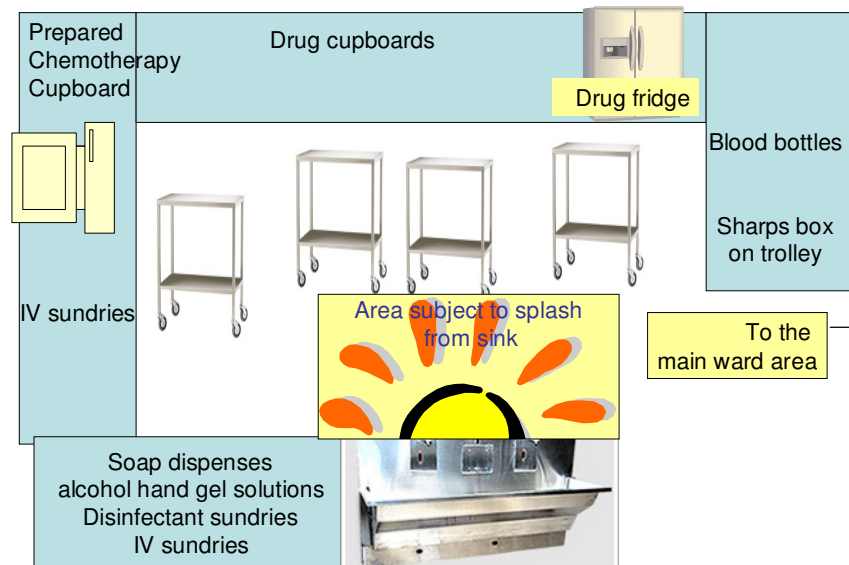
Is there a stable team that prepares and administers the intravenous drugs?

Yes. The population is stable and the entire qualified nurse team is either able to prepare and give intravenous drugs or in training to be competent to do so. Intravenous drug preparation is seen as part of what they do.

Where are the intravenous drug preparation procedures performed?

There is a designated Drug Preparation Room (Figure 16). This Drug Preparation Room is uncluttered and visibly clean.

Figure 16 The drug preparation room (2nd ward)



Preparation is done on the trolleys.

Are there any drugs which BMTU unit staff do not prepare?

The BMTU unit staff do not add drugs to total parenteral nutrition bags or prepare intrathecal drugs. Chemotherapy drugs are administered but, in the main, these drugs will have been pre-prepared in the sterile pharmacy suite.

Are all the team familiar with all the intravenous preparing procedures?

Yes. The frequency with which drugs are given in the BMTU unit means by the time nurses are deemed competent, they have attained experience in a wide range of drug preparation and administration and have had a wealth of opportunities to prepare them.

What written procedures are available?

Two written procedures for the safe administration of intravenous drugs were provided for review:

- The first – The Scrubbing Procedure
 - The scrub procedure lacks some specifics in that it states at 5.01 ‘scrub for 3-4 minutes according to the hospital infection control hand washing policy.’
 - The scrub procedure offers an alternative to the traditional antiseptic soap and water wash, with the option of an alcohol based hygiene alternative.
- The second procedure – Procedure for the safe administration of intravenous MabCampath® (a humanized rat monoclonal antibody). This drug frequently causes severe patient reactions and different infusion times are specified as a consequence between the first and subsequent infusions.
 - Although this procedure is detailed it again lacks specifics, for example, ‘set up trolley with the aforementioned equipment using aseptic technique’, exactly how to perform this aseptic technique is not specified in the procedure.

Displayed Poster Information

In a clean and uncluttered Drug Preparation Area there are a total of 20 posters or information sheets available – most referring to information on intravenous

infusions and hand hygiene. None refer to any aspect of how to maintain asepsis during preparation and administration of intravenous drugs.

How often are the written procedures referred to?

In an effort to maintain control of the procedures, they are kept in the ward manager's office. Consequently, the procedures are not referred to on a procedure-by-procedure or day-to-day basis. All the procedures contain a colour printed watermark. There is a warning on each document that unless the coloured watermark is visible then the copy is unauthorised.

Are the intravenous drug preparation procedures generic or drug specific?

The procedures are drug specific; however, as stated previously, there are no specific procedures available to detail how to prevent contamination of the infusates other than to follow 'aseptic technique.'

Do the intravenous drug preparation procedures include problem identification and if <this situation> then <that> actions?

Yes. The document on MabCampath® infusion details what to do should the patient react to the drug; that is, if the patient becomes become pyrexial and or develops a rigor. If line occlusion occurs, then there is an algorithm poster documenting what to do to optimise the likelihood of removing the occlusion without harm to the patient as a consequence.

What other procedures are done in the drug preparation room?

The only other procedure done in the drug preparation area is hand hygiene. This seems innocuous; however, observations of this procedure using the 2 person full-scrub sink will be described. There are obvious spray marks for a semi-circled area extending about 0.5 metre from the scrub sink (Figure 32). Some of the nurses who wash their hands at this sink stand to one side of the automatic taps so that their uniforms do not become drenched whilst they perform hand hygiene. Consequently, when concurrent drug preparation procedures are performed, the sterile equipment on the trolley is exposed to spray (potentially containing environmental micro-organisms from the hand hygiene procedures).

This is a particularly large spray, in part due to the design of the taps which instead of a single flow faucet have a shower style multi-stream flow. Additionally, angle at which the spray hits the upper side of the scrub sink seems responsible for the some of the large spray area. Of the 17 aseptic procedures performed, 4 were performed during concurrent hand hygiene procedures and are subject to potential spray contamination. As patients on this ward are vulnerable to infections from opportunistic environmental micro-organisms, the water supplied to the BMTU unit is filtered and of a higher quality than that supplied to general wards. Nevertheless, given the capabilities of environmental Gram negative organisms, it is to be expected that the sink will become periodically contaminated with micro-organisms that could cause infusate contamination arising from drop droplet sprays.

What team operation support is there?

There is support from within the infusion team between colleagues. The ward team are very supportive of their pharmacist and the work done by the pharmacist to assist them in preparing drugs.

Is the lighting good, making it easy to see to read instructions within the unit?

Yes – there are no lighting problems in the area.

What, if any, performance measures are available?

There was no data with regard to CR-BSI incidence. There was data on the acquisitions of MRSA and *C. difficile* acquisitions within the BMTU unit. The ward is not yet participating in the Scottish Patient Safety Programme.

What monitoring is done outside the ward?

There is no specific CR-BSI surveillance done. This does not mean that infections would not be picked up and discussed at critical incident meetings – just that there is no ongoing surveillance and performance monitoring of CR-BSI.

What in-unit operator performance monitoring is done?

The majority of procedures are done in sight of colleagues in the Drug Preparation Room which is open. Procedure preparations can be done concurrently. At one point 3 nurses were observed preparing intravenous drugs simultaneously. The preparation area could accommodate 4 concurrent preparation procedures.

Significant variations or deviations in procedures would be noted. All drugs to be administered need to have several redundancy checks. Although there is no written procedure, all procedures observed were done to the same standard. It would be extremely difficult to be a “rogue preparer” within the BMTU unit and not be detected. There seemed to be a genuine pride in the work done to prepare IV drugs.

What, if any, information is available during the preparation of intravenous drugs, and how situation-aware is the nurse?

The nurse preparing the drug has visible information on the amount of drug and diluent being prepared and whether the infusate contains particulates. The key information unavailable to the nurse is the sterile or non-sterile nature of the aseptic preparation and of the end result.

What if any self-assessment of performance is done?

All those observed showed a willingness to question aspects in the process if they were unsure.

How frequently are drug errors reported?

According to the ward manager all errors are reported. The ward manager considers that because of the extensive redundancy checks, few errors arise on the ward.

8.3.2 Data Stream 2 - Observations of drug preparations (2nd ward)

How many procedures were observed?

A total of 17 intravenous drug procedures were observed from the gathering of the equipment until the nurse entered the patients' rooms. During these 17 procedures a total of 20 drugs were prepared. During the preparation of the 17 procedures, at 7 times there were concurrent preparations by more than one nurse was ongoing in the Drug Preparation area.

What drugs were prepared and administered?

The drugs prepared and administered were:

Antibiotics: Co-trimoxazole, gentamicin, ampicillin co-amoxiclav, piperacillin with tazobactam, teicoplanin

Anti-fungals: itraconazole

Anti-virals: aciclovir,

Immune-suppressants: Hydrocortisone, ciclosporin,

Antiemetics: ondansetron,

Analgesics: diamorphine.

Antihistamine: chlorphenamine

Diuretics: furosemide

Monoclonal antibody: MabCampath®

The above drug names are generic apart from MabCampath®, this name is given as the proprietary name because all the documents on the ward refer only to the proprietary name (generic name Alemtuzumab).

How variable are the procedures?

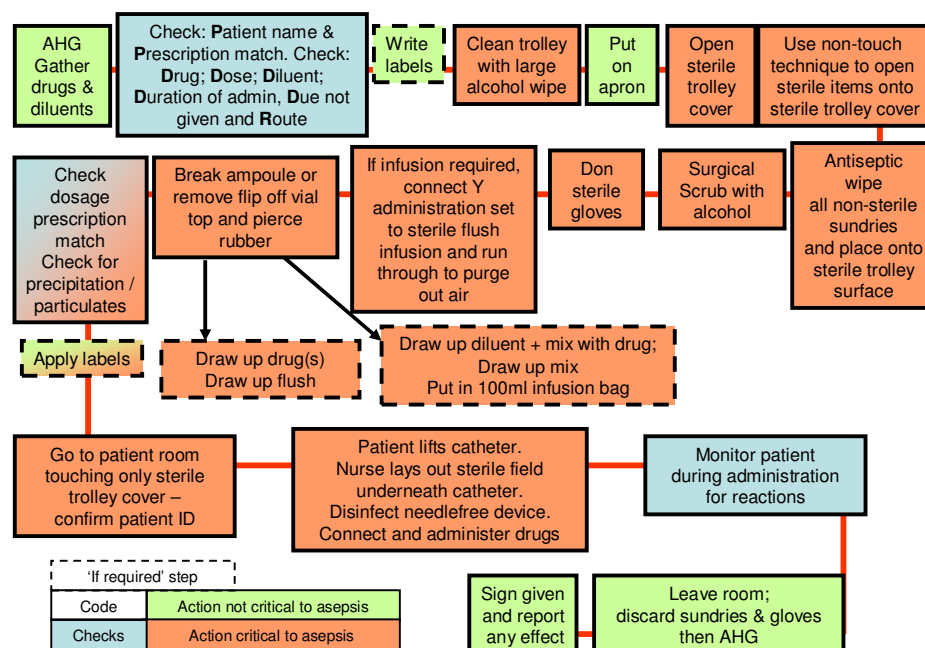
Some drugs are administered as bolus, some like diamorphine, as a long-term infusion (>12 hours). The majority are prepared and put into 100ml or larger infusion bags. The use of a diluent in this way reduced variation in the procedures. There are however, still significant variations to the procedure; for example, some drugs require the use of opaque bags so that the infusate is not exposed to the light. Chemotherapeutic agents are stored separately in a locked cupboard and sent to the unit wrapped within units.

The Hickman-style catheters have 2 lumens; a drug and a blood line. This does not mean that all the drugs go down the drug line. Sometimes half of a prescribed drug would go down one arm of the catheter and the remainder via the other lumen. For example, antibiotics to salvage an infected line are administered through both lumens.

How is the intravenous drug procedure performed?

Figure 17 shows the process of intravenous drug preparation as observed and administration procedure as reported.

Figure 17 The drug preparation procedures (2nd ward)



- The nurse applies alcohol hand gel (AHG) to decontaminate hands and then gathers together all the drugs and diluents required for the preparation.
- Against the prescription, the gathered medications are checked by the nurse who will prepare the drugs and a second nurse (one of the nurses will be deemed competent at intravenous drug preparation) that it is the correct: Drug (including expiry date), Diluent (including expiry date), Dose, Duration of administration, Due – that the drug is due and has not been given and the Route of administration. This first set of checks is to ensure that the nurse is able to prepare the prescription correctly from the gathered drugs and diluents.
- Drug addition labels are then written.
- A trolley is then cleaned with a larger 10cm by 10cm alcohol wipe to create a decontaminated surface.

- Onto this trolley surface a pack of 2 sterile water-repellent squares are placed.
- One corner of one of the sterile squares is opened to cover the entire trolley surface.
- On to this (now sterile) field, all sterile items required for preparation are placed using a non-touch technique, including, 500 ml 0.9% saline infusion bag, sterile Y type administration set, syringes, needles.
- Once all the sterile sundries have been placed on the field, the outer surfaces of all non-sterile sundries such as drug vials, labels, water for injection are wiped using an antiseptic wipe and then placed on the trolley surface.
- The nurse performs a surgical scrub (using either antiseptic soap and water or the alcohol hand rub) as per the displayed procedure.
- Sterile gloves are put on.
- The administration set is connected to the 500 ml 0.9% saline infusion bag and air purged from the tubing.
- Glass ampoules are then broken, or the flip tops of vials are removed. The drug access points of flip top vials are not decontaminated.
- The drug is drawn up (mixed with a diluent if required).
- The drug is injected into a 100ml infusion bag which is then connected to the second arm of the Y administration set
- The drug is inspected for particulates and precipitation.
- A label is applied if the drug is to be infused via infusion pump.
- If any drug prepared was in excess of that prescribed, the finished drug is then checked to be of the correct dosage.

- If additional drugs are required they are prepared in the same way.
- Once all drugs are prepared the nurse pushes the trolley touching only (with sterile gloves on) the sterile cover of the trolley. (This has been coloured within Figure 17 as orange - critical to asepsis - touching any non sterile item during this step would constitute an asepsis failure).
- The door to the patient's room is then opened without using hands.

The remainder of the procedure was unobserved in line with the ethics submission.

The BMTU staff described the following:

- The patient identification and prescription name are checked (verbal check).
- The nurse picks up the second sterile field and the patient lifts the catheter, the second sterile field is placed under the catheter.
- The nurse then decontaminates the catheter and Bionector® which presents an external rubber bung surface and can be connected directly to the administration set once decontaminated.
- A short arm extension with external clamp may be used to provide greater control of drug administration.
- As all patients are in cubicles with closed doors, some drugs require the nurse to remain with the patient during the infusion, others do not. All patients are conscious and able to call for help. There is no telemetry monitoring.
- Once the drug is administered, the Y connection is switched and the flush administered.
- The nurse leaves the patient's room, sundries including gloves are discarded and alcohol gel is again applied to hands

- Documentation is completed.

Was there distraction during the intravenous drug preparation procedures?

The nurses are conscious of distractions during drug procedures. A purple apron is used as a visual “Do Not Disturb Notice” for non-intravenous drug rounds. Once intravenous drug preparations commenced no other procedures or interruptions took precedence. The only distraction seen was sometimes from colleagues who were trying to do the same thing, that is, prepare drugs aseptically. From time-to-time due to the lack of space there was the need to move the trolleys mid-procedure. This was deemed normal and completed without apparent loss of situation awareness.

Is the equipment needed for IV drug preparation procedures close at hand?

Yes – all the required equipment is kept in the Drug Preparation Room. Of note, there were 4 different antiseptic wipes available.

General purpose environmental wipe

*Alcohol 10cm X 10cm wipe

*Clinell® wipe containing Chlorhexidine gluconate and alcohol

*Steret smaller 2.5cm X 2.5cm wipe containing alcohol

* all these three wipes were housed in the same small storage container

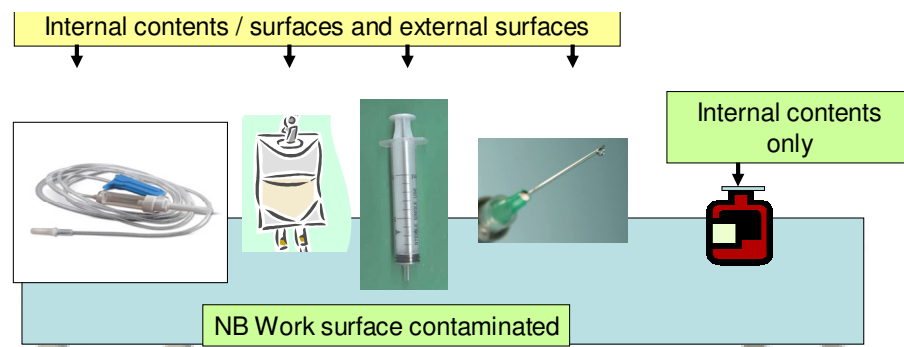
8.3.3 Contamination risks in the 2nd ward procedure

Figure 6, showing how long it would take for infusate contamination to cause infection, is also applicable to the second study ward. With this figure as a guide the procedures and location assessment data will be examined for their error-prone and reliability status. As procedures, drugs and equipment vary from place to place, for this ward there is a need to analyse for the procedure; firstly, what is sterile/non-sterile? Secondly, what are the critical parts of the equipment during preparation? And thirdly, what are the critical parts immediately prior to administration?

What is sterile and non-sterile at the start of the procedure?

Figure 18 shows the sterility of equipment and surfaces at the start of the procedure on the second ward.

Figure 18 The sterility of equipment at the start of the procedure (2nd ward)



The sterile surfaces/materials are the: trolley surface cover, syringes, needles, infusion bag and its contents, internal contents of drugs ampoules.

The non-sterile materials/surfaces are:

The access point to any rubber topped vial

Outside containers of any drug vial - including under flip off tops

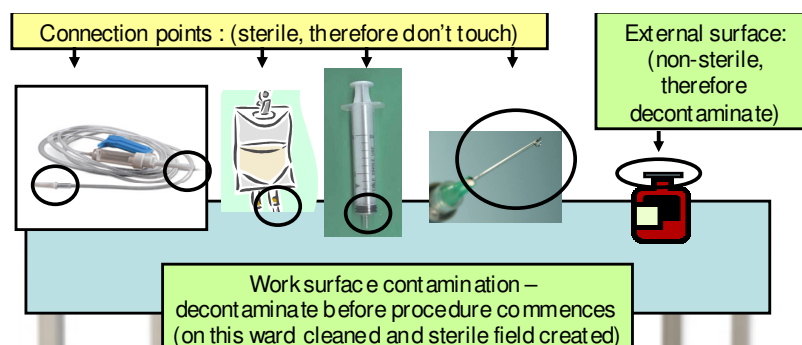
Drug addition label

The work surface (trolley top).

What are the critical surfaces during the procedure that, if contaminated or not decontaminated, will prevent aseptic preparation?

The critical surfaces during preparation are the connection points of the administration set, the tops of the syringes and the metal part of the needle that will come into contact with the drug. These surfaces should not be touched. The top of the drug ampoule vial should be considered contaminated and requiring decontamination (Figure 19). On this ward the trolley surface is cleaned and covered with a sterile drape creating a sterile field and negating contamination of critical sterile surfaces.

Figure 19 The critical surfaces during the procedure (2nd ward)



Immediately before administration what are the critical surfaces that must be protected or decontaminated?

Immediately before the administration of the drug the critical surfaces are the Bionector®, (a needle-free connector put at the end of the catheter to allow for easy administration), the top of any syringe should a bolus drug be administered and the end of the administration set to be connected to the Bionector® (Figure 20). The Bionector® access point is the only piece of equipment that requires decontamination as the other critical surfaces should be sterile; however, these sterile surfaces must not become contaminated.

Figure 20 The critical surfaces just before administration (2nd ward)



Is the equipment used for intravenous drug preparation procedures free from environmental splash contamination?

There is obvious splash contamination of the area surrounding the scrub sink as discussed earlier. Although not obvious unless looked for, there are visual cues that could signal to the nurses making up the infusion that environmental contamination may have occurred and sterility of equipment may have been

compromised. This, as explained previously, is from the spray during hand washing from the scrub sink. The most obvious safety measure here to prevent contaminated spray contaminating sterile fields is, in the short-term, not to perform hand hygiene during drug preparation. In the longer a better and better sited scrub sink area would be beneficial.

Does the equipment aid the process of maintaining sterility of the infusate?

Only one item of equipment posed a hazard during aseptic preparation – the rubber topped drug vials which, as stated previously, require decontamination prior to access to prevent potential asepsis failure.

Where is the procedure in this ward likely to produce errors in aseptic preparation?

Figures 21 and 22 illustrate the potential sources of IV contamination on the ward and what makes it difficult to assure asepsis, that is, the parts of the procedure where contamination is most likely to occur, these are:

- During preparation from spray contamination generated at the scrub sink.
- Needle piercing a non-sterile rubber topped vial contaminating the drug.
- Failing to decontaminate effectively the Bionector® pre administration.

Figure 21 Where contamination is most likely (2nd ward)

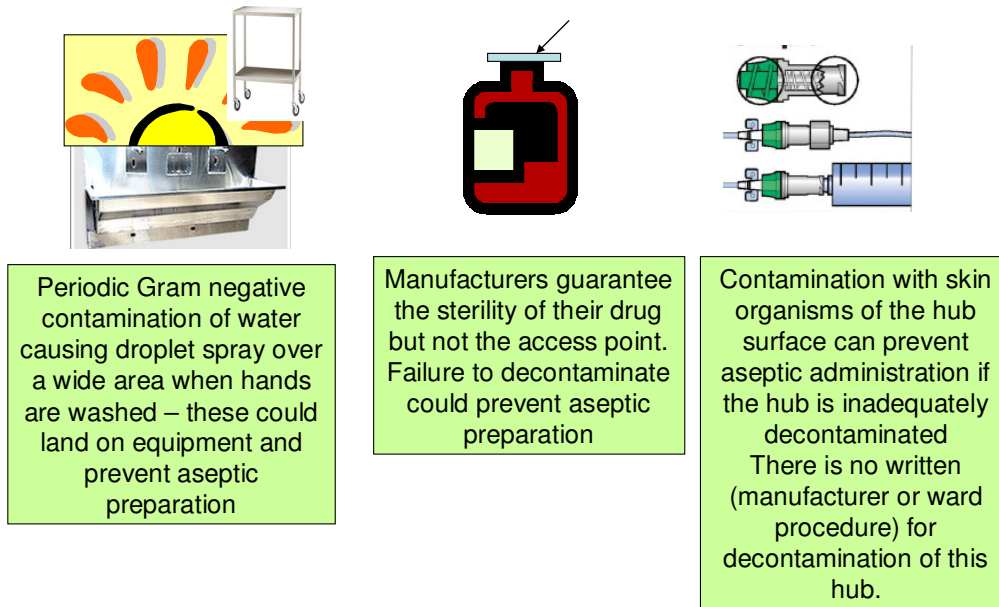
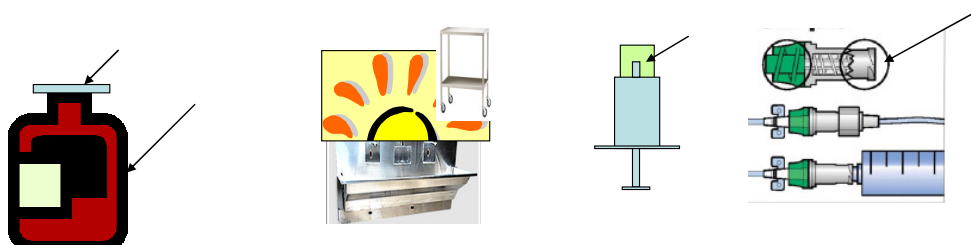


Figure 22 What makes it difficult to ensure aseptic preparation (2nd ward)

1. Unknown sterility of ampoule access points
2. Spray generated from the sink in the preparation area which may or may not contain contaminated droplets which if they land on surfaces are not detectable
3. Inability to recognise if a critical surface has been contaminated
4. Difficulty in ensuring effective decontamination of the hub pre connection of the administration set or syringe



8.3.4 How to reduce potential contamination risks (2nd ward)

This procedure can be classified as:

An uninterrupted aseptic procedure performed by a single nurse assisted, at intervals, by a second nurse to perform required redundancy checks.

The nurses on this ward have negated the natural interruption of an aseptic drug preparation procedure by a 'disinfect everything' and 'touch nothing that has not been disinfected or is sterile', methodology. The lack of quality control data on the end product or CR-BSI data means they cannot objectively assess the effectiveness of their efforts, for example, it cannot be confirmed that wiping labels with a disinfectant wipe is an effective means of decontamination. The nurse enters the patient's room alone; therefore identity checks are done by a single nurse and done verbally. Maintaining an uninterrupted aseptic procedure could therefore be said to take precedence over redundancy checks or right patient checks. Checks are performed after the drug is prepared and labels applied at the correct time, immediately post preparation; however they are done without what is considered to be interruption of the aseptic procedure – denoted on Figure 17 by double-colouring of these steps. Changes to the procedure which would reduce the risk of contamination are as follows.

Change – Remove the risk of contaminated aerosols by removing the scrub sink

Regardless of the asepsis in the steps performed by the nurse, the procedure is vulnerable due to the dissemination of potentially contaminated aerosols during concurrent hand hygiene procedures. Concurrent hand hygiene procedures should stop as a short-term step and the sink should be removed as a medium / long-term step. To reduce the risk from splash contamination, the use of the sink should be stopped during and immediately before aseptic procedures.

New step – hand hygiene after trolley cleaning

An additional hand decontamination step is introduced prior to the opening of the sterile trolley towel. This is because hands may have been contaminated during the cleaning of the trolley by transient environmental pathogenic micro-organisms and the next item they touch will be the sterile drape towel.

New step – confirm drug and diluent are single-use sterile

Although there are no multi-dose diluents or vials currently used, an additional step of confirming that drugs and diluents are single-use and sterile would still add to patient safety.

New step – decontamination of the vial tops

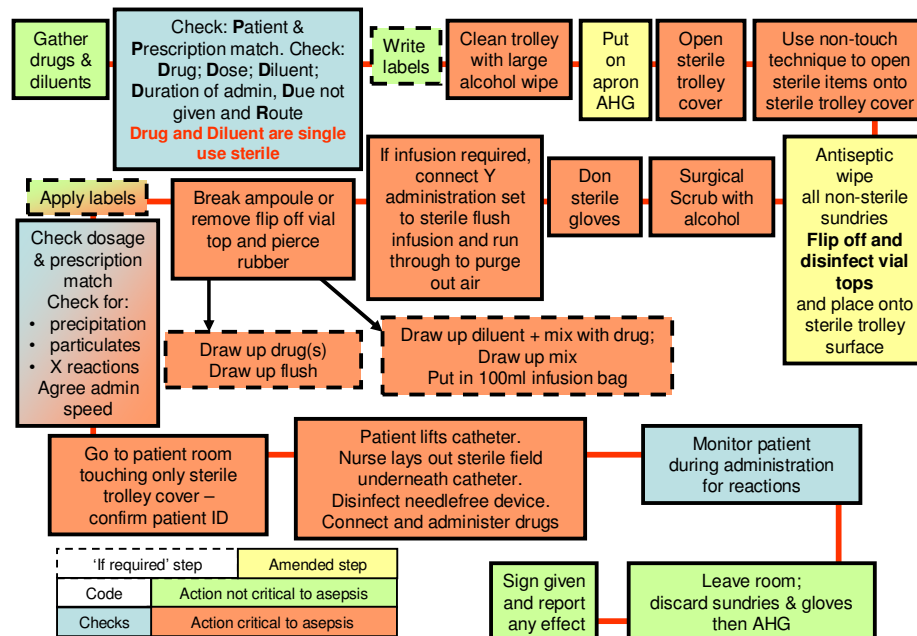
The critical point that is being missed in this procedure is the disinfection of the vial tops. To reduce the risk of error from micro-organisms entering the drug vial, the

top of the vial should be decontaminated – this amended step to the procedure is shown in Figure 23.

New step – consider cross-reactions at a set point

The drugs used on this ward tend follow a pattern depending on the patient’s progress pre and post transplant. There is a more limited drug selection used in the BMTU and therefore the opportunities for cross-reactions between the commonly used drugs are well recognised in this ward. Nevertheless a ‘stop and consider possible cross-reaction’ step before administration commences step has been introduced in the modified procedure.

Figure 23 Suggested amendments to the procedure (2nd ward)

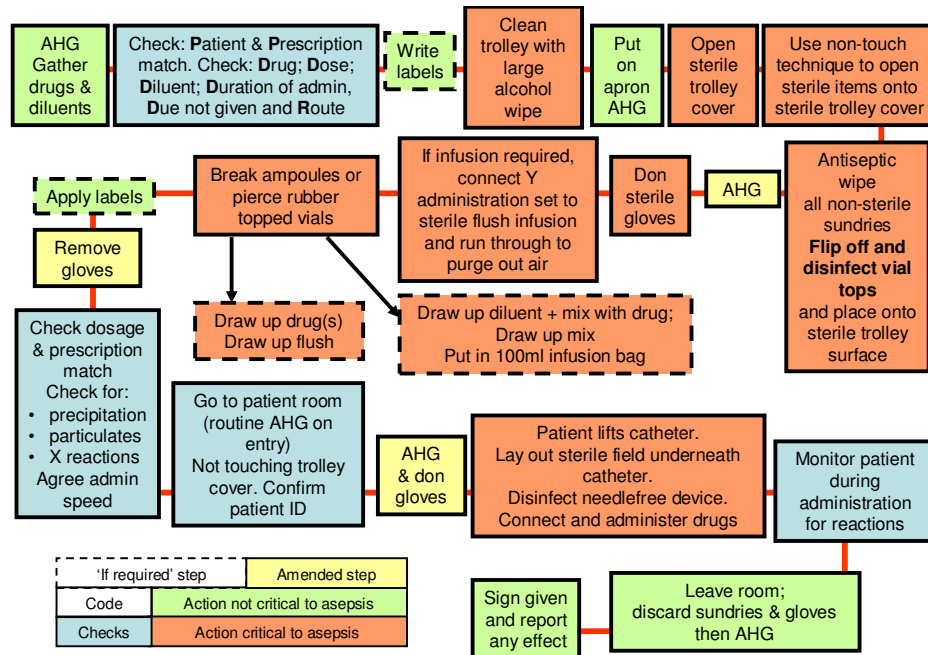


The key questions in assessing possible changes to this procedure are:

- Is a full surgical scrub antiseptic hand decontamination required?
- Would an-interrupted aseptic procedure using alcohol hand decontamination at key points better reduce the risk of contamination?
- Would the advocated changes produce benefits or disadvantages for the nurses?

An alternative amended procedure which could be tested for advantages is shown as Figure 24. It is an interrupted-aseptic procedure involving the removal of gloves when labels are stuck on bags. The aseptic procedure recommences when the nurse arrives in the patient's room. The change provides the nurse with the freedom of confirming the patient's arm band and identification by being able to touch the patient before hand hygiene to restart the aseptic procedure. The advantages of this procedure (Figure 24) need to be assessed for increased or decreased simplicity and increased or decreased use of resources as well as increased or decreased microbiological risk.

Figure 24 Alternative procedure (2nd ward)



The alternative procedure needs evaluation as it may have advantages for HCWs, including reduced exposure to antiseptics without increased risk to patients. Added to the uncertainty of the efficacy of the new procedure, there are other issues related to which antiseptic should be used and the method of antiseptic use. These matters will be discussed separately.

8.3.5 Data Stream 4 – Procedure comparisons (2nd ward)

There was no written procedure for aseptic preparation of infusates available on this ward. Consequently, no comparisons could be made.

8.3.6 Data Stream 3a - Opinions on Safety (2nd ward)

A total of 15 questionnaires issued were issued to all the staff who were either competent or who were in training to be competent within the unit; 7 responses were received (47%). This includes 2 responses received after an e-mail reminder was issued to the ward manager. The results to the statements on safety are given below (a summary of these data are given in Appendix 8).

Statement 1 – When preparing IV drugs it is easy to prevent asepsis failure

The majority of the respondents 5/7 (85%) agreed with this statement. Two neither agreed nor disagreed. However, due to the risk of splash contamination within the drug preparation area, it is, in fact difficult to prevent asepsis failure in this unit.

Statement 2 – When preparing IV drugs it is easy to detect asepsis failure

There was a variable response to this question, with strong agreement and strong disagreement noted. Three of the 7 respondents (43%) agreed that it was easy to detect asepsis failure. Two neither agreed nor disagreed indicating they were not sure whether it was easy to detect. Although it is easy to detect contact contamination failure, it is not easy to detect asepsis failure from environmental sources such as the sink.

Statement 3 – The procedures for preparing IV drugs on this ward are simple

There was no strong agreement or disagreement with this statement. Four respondents (57%) neither agreed nor disagreed with it. This possibly reflects the

variability in the procedures. Some are simple and some are extremely complicated

Statement 4 – The resources on this ward make it easy to prepare IV drugs safely

No one disagreed with this statement. The resources available and used on the ward including, antiseptics and sterile disposable trolley cloths, correlated with the view that ward staff had everything they thought necessary to prepare IV drugs safely.

Statement 5 – The environment on this ward makes it easy to prepare IV drugs safely

Only one respondent disagreed with this statement. This further emphasises that those preparing intravenous drugs did not recognise the potential environmental hazard from the scrub sink in the drug preparation area.

Statement 6 – On this ward distractions and interruptions make it difficult to prepare IV drugs safely

Once again the majority neither agreed nor disagreed with this statement. By using a dedicated Drug Preparation Area the nurses were not constantly listening for alarms and watching for patient's self-extubating as in the pilot ICU. However, the closeness to the nurses' station means that the Drug Preparation Area is the first port of call for enquiries when the station was unmanned, meaning that opportunities exist for distraction during preparation.

Statement 7 – I get feedback on the quality of my IV drug preparation

As in the pilot study, the majority 5/7 (71%) respondents disagreed with this statement. The one respondent who agreed with this statement could have been in training for competency. There was no policy statement encouraging this to be done.

Statement 8 – I would feel uncomfortable raising safety concerns regarding the preparing IV drugs on this ward

There was 7/7 (100%) disagreement with this statement, meaning that all respondents would raise any safety concern they recognised.

Statement 9 – I can mix drugs on this ward without distraction or interruption

There were variably responses to this statement, 3/7 (43%) of respondents strongly disagreed with this statement. The remainder either agreed or neither agreed or disagreed. It is possible that some members of the staff are more likely to get interrupted than others; the ward manager or daily nurse in charge, for example are more likely to be requested to accompany doctors on ward rounds.

Statement 10 – Asepsis failure when preparing IV drugs is a safety priority on this ward

The majority of respondents 5/7 (71%) strongly agreed with this statement. The procedure which involved a full surgical scrub lent weight to this statement.

Statement 11 – If I recognised an error in my IV drug preparation I would report it

The responses to this question agree with statement 8 on being comfortable with raising safety concerns. The majority here, 6/7 (86%), would self-report an error if they recognised it in their own practice.

Statement 12– There is good support to those who have to prepare IV drugs

Once again no respondents disagreed with this statement. The majority of respondents 4/7 (57%), either agreed, or strongly agreed, with the statement on available support.

Statement 13 – To improve patient safety I am encouraged to report errors

Six of the 7 respondents agreed, or strongly agreed, that they were encouraged to report errors (Figure 46). The one strong disagreement was possibly a misread. The responses to this statement otherwise concur with other statements on support and error reporting. (Statements 8, 10, 11 and 12)

Statement 14 – I find preparing IV drugs is stressful

This statement produced variable responses. An equal number agreed and disagreed with the statement. Therefore, some nurses clearly find the preparing of IV drugs stressful. This is understandable; despite the supportive environment, errors in IV drug preparation, particularly of the toxic drugs used, can be life-threatening for the patients and potentially career threatening for the nurse.

Statement 15– Preparing IV drugs give me job satisfaction

Once again there was a wide range of responses to the statement. The majority 4/7 (57%) disagreed – they did not get job satisfaction from preparing IV drugs. Therefore, despite the high volume of drugs prepared, approximately 10 per patient per day, it can be concluded again that the majority of respondents work in the BMTU not because they have to prepare IV drugs but in spite of the fact that this is the case.

8.3.6.1 Additional comments from the respondents

“Double checking depends on the business of the ward and type of drug is always with chemo or unfamiliar drug.”

“If a new junior member was under supervision I would always check every step. After a period of supervision a nurse is deemed competent only the drug, dose patient and infusion rates are checked routinely.”

“Comments are my responsibility as the one accessing the Hickman line I feel.”
(Referring to never checking the catheter hubs were accessed aseptically and the checking that hand hygiene and PPE use was appropriate).

8.3.7 Summary of the opinions of safety from the 2nd ward

Some of the responses to the statements indicate aspects of a safety culture that could make the procedure more error-prone. These are as follows:

- Erroneous assumptions of safety (Statements 1, 2)

- Complexity of the procedure (Statement 3)
- Unrecognised environmental difficulties (Statement 5)
- Lack of performance feedback (Statement 7)
- Distractions and interruptions (Statement 6, 9)
- Stress from the procedure (Statement 14)
- Lack of job satisfaction (Statement 15)

The responses which indicate positive aspects of a safety culture and therefore reduce the risk of error in the procedure are:

- The resources available to prepare IV drugs (Statement 4)
- The willingness to report errors (Statements 8,11)
- That asepsis failure is a priority on this ward (Statement 10)
- The support provided to the team (Statement 12)
- That staff are encouraged to report errors (Statement 13))

8.3.8 Summary of the results from the 2nd ward

Whilst completing the Location Assessment tool on this ward, the ward manager stated that their very vulnerable patients necessitated a procedure that includes a full (surgical) scrub technique. However, the environment posed the patients risks from the very scrub sink used to achieve safety; vast sprays of droplets frequently contaminate the nurses' sterile preparation areas. Although no specific equipment was identified that would increase risk on this ward, vial tops were not decontaminated, potentially causing another source of infusate contamination. In

this ward the attempts to prevent infusate contamination focused on preventing organisms getting into the drugs; there was no attempt to use filters to prevent contaminated drugs getting into the patients.

The opinions of safety demonstrated that the procedure was not much-loved, 4/7 (57%) did not agree that it gave them satisfaction, even though it made up a good part of the nurses' daily work load. There were indicators of a good safety culture, in that the nurses were encouraged to report errors and HCWs stated that if they noticed an error they would report it.

8.4 Results from the 3rd ward - an Intensive Care Unit (ICU)

Data Stream 1 – Location Assessment (3rd ward)

Data Stream 2 – Observation Drug Preparations (3rd study)

Contamination risks in the 3rd ward procedure

How to reduce potential contamination risks in the 3rd ward

Data Stream 4 – Comparison of observed procedures with document review

Data Stream 3a – Opinions of Safety (3rd ward an ICU)

Study took place on Monday 28th September 2009

Researcher Evonne Curran

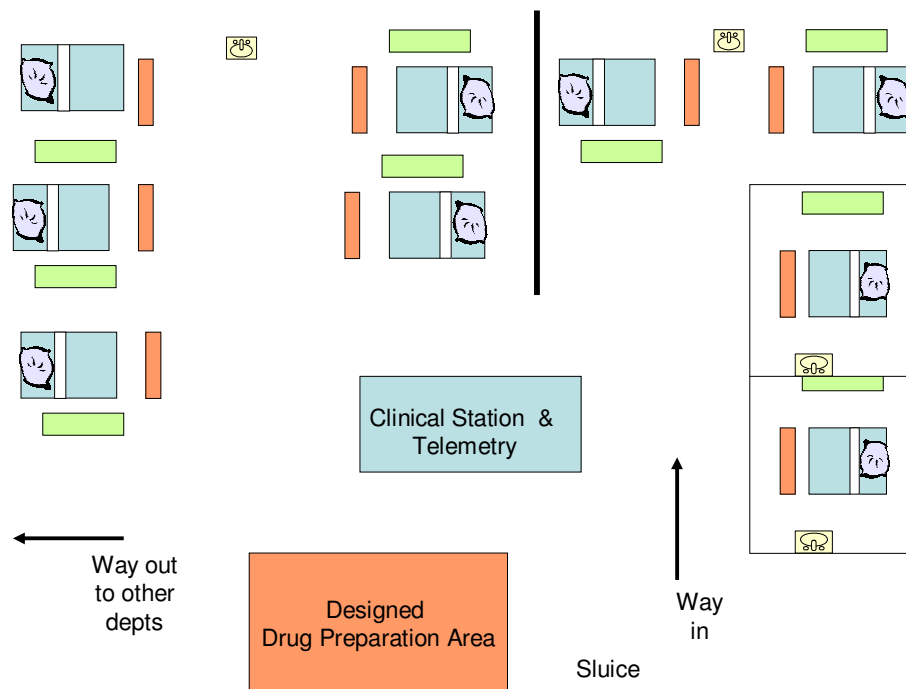
8.4.1 Data Stream - 1 Location Assessment 3rd ward

The data for the Location Assessment tool were obtained by interview with the ward manager and from the researcher's observations during the study period.

The unit and the patients they care for

The unit is a general intensive care unit (ICU) caring for patients with a wide range of severe illnesses including: renal disease, multiple trauma following road traffic accidents and respiratory failure due to many causes. The unit is a regional centre and cares for a wide range of tertiary referral patients. The ICU comprises 7 ICU beds and 2 HDU beds, or it can be used as an 8 bedded ICU with one vacant bed (Figure 25).

Figure 25 The plan of the 3rd ward (an ICU)



What vascular devices are used for intravenous drug administration?

In the main, central vascular catheters (CVCs) are used to administer intravenous drugs. This is due to the longer term vascular access requirements of intensive care patients, the use of drugs irritant to veins and the need for immediate reliable vascular access. The CVCs are sited in the internal jugular veins. Femoral veins are used when there is no alternative venous access. Occasionally patients have peripheral vascular catheters (PVCs); this is mainly the high dependency patients. Peripherally inserted central catheters (PICCs) and midline catheters are not routinely used, but would be used if they are already in situ when the patient is admitted.

Approximately how many intravascular drugs are prepared in the unit?

On average, a patient in the ICU would require between 10-12 drugs per day. Therefore, the unit can prepare and administer about 90 intravenous drugs per day and about 33,000 per year.

What intravenous drugs are prepared and administered?

The main intravenous drug groups used administered to patients are: antibiotics, inotropes, ACE inhibitors, bronchodilators, sedatives, anticoagulants and gastric ulcer prophylaxis medicines.

Does the unit use drugs associated with infusate sepsis?

There is frequent use of lipid drugs, such as propofol, which are known to promote microbial growth and are associated with infusate sepsis. Intravenous drugs are administered via bolus, syringe pump and via infusion. Long-term infusions (>12 hours) are used for insulin and diamorphine and very occasionally for heparin. These long-term infusions pose a unique risk in that they enable low numbers of micro-organisms to multiply over the duration of the infusion, eventually causing infusate sepsis.

Are any of the intravenous drugs prepared from multi-dose vials?

Propofol (anaesthetic sedative) and heparin (anticoagulant) are delivered as sterile bottles with rubber tops that could inadvertently be used, contaminated and replaced on a shelf; that is, contaminated without showing obvious contamination, and then, dangerously for patients, reused. There are some drugs, including one heparin preparation, which is prepared from multi-dose vials. The product information for this heparin states that it can be used for up to 14 days once opened. Dispensing Pins are available; these devices enable repeated doses to be removed from the bag without the need to use multiple individual ampoules.

How long are the vascular access devices in situ for?

CVCs are routinely replaced after 7 days (longer if appropriate, for example if they are required for only a few more days). The CVCs would always be removed if

there was redness around the insertion site, or if there are signs of a catheter-related blood stream infection. PVCs would be removed after 3 days.

Is there a stable team that prepares and administers the intravenous drugs?

Yes. There is a core of long-term staff on the ward who have been deemed competent for some time in relation to intravenous drug preparation.

What post initial training is provided?

A post-training consolidation pack is being prepared to provide further support for nurses and further assurance of patient safety related to drug administration. It is intended that this will reaffirm the policy. At present, no further formal training is provided. There is ongoing peer approval and assessment for all staff who prepare and administer intravenous drugs.

Are all the team familiar with all the intravenous preparing procedures?

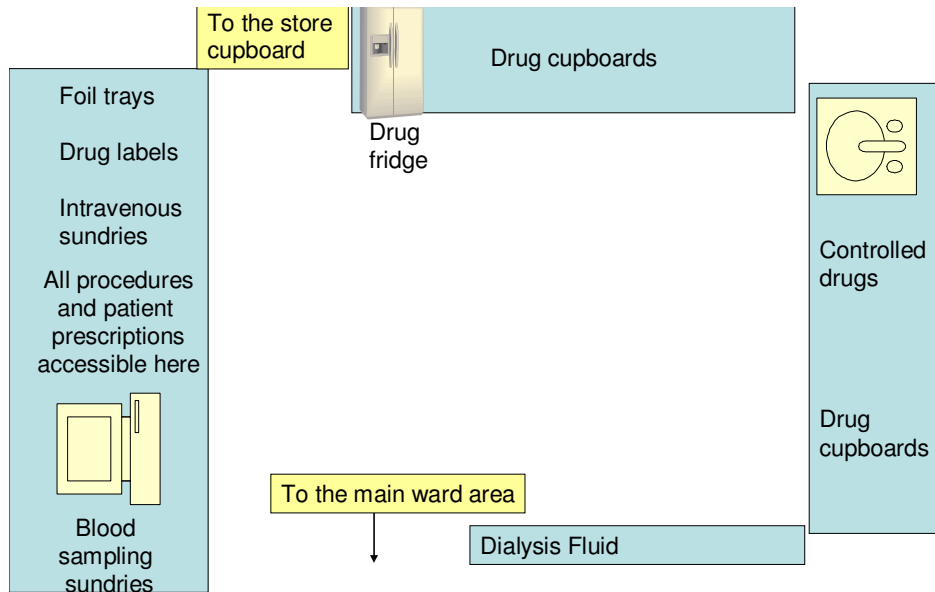
By the time team members are deemed competent, their records should show that they have experience in preparing the wide variety of drugs required by ICU patients, and certainly all the usual intravenous drugs prepared by the unit.

Where are the intravenous drug preparation procedures performed?

There is a designated Drug Preparation Area, (Figure 26). Depending on the complexity of the drug preparation and the preference of the nurse, some IV drugs are prepared here; some are prepared at the bedside.

This Drug Preparation Area is uncluttered and visibly clean. The one sink does not create splash that could contaminate drug preparation procedures (Figure 26).

Figure 26 The drug preparation area in the 3rd ward



What team operation support is there?

The ward manager has put together a resource pack for all the staff. This pack contains the policies and a variety of supplementary information to support all those who prepare intravenous drugs. This information is readily available and is kept in the drug preparation area. The manager feels that there is support from within the infusion team between colleagues, in that they are encouraged to share problems and concerns related to intravenous drugs and the administration thereof. There is unit pharmaceutical support available.

What written procedures are available?

Drug information sheets are available in a folder in the Drug Preparation area. These sheets contain information about the drug; how it can be reconstituted, compatibilities and incompatibilities, final pH. No information regarding infection risk is provided.

A manual entitled “Safe and Secure Handling of Medicines in Hospital Wards, Theatres and Departments.” is available on the unit (NHS Greater Glasgow and Clyde 2008). Section 14.5 of the above document is the ‘Administration of medicines by injection and infusion. (This is the only one of the six study wards in which this April 2008 document was identified). Within the document there is no instruction on precisely how to perform aseptic technique. The instruction available is discussed in Data Stream 4.

How often are the drug procedures and drug information referred to?

The nurses often refer to the drug information sheets. The resource pack is available and used as a resource pack rather than a procedure reference guide. The procedure (14.5) as detailed in the NHS Greater Glasgow and Clyde, Safe and Secure Handling of Medicines in Hospital Wards and Departments was not referred to on a procedure-by-procedure basis (NHS Greater Glasgow and Clyde 2008).

Are the intravenous drug preparation procedures generic or drug specific?

The drug information sheets are drug specific. However, as stated previously, there were no specific procedures available to detail how to prevent contamination of the infusates.

Do the intravenous drug preparation procedures include problem identification and if <this situation> then <that> action is required?

There is no information relating to the preventing of infusate contamination in this format.

Displayed Poster Information

In a clean and uncluttered Drug Preparation Area there are a total of 10 posters or information sheets available – most referring to information that would be required rapidly. None of these posters refers to asepsis maintenance during the preparation and administration of intravenous drugs.

What other procedures are done in the preparation areas?

In the Drug Preparation Area other preparation procedures are readied, for example, dressing procedures, control drug procedures. This area is spacious and few concurrent procedures were observed. At the bedside a variety of procedures are done including, bed bathing, suctioning (closed), physiotherapy and dressing wounds. However, because an individual nurse is allocated to an individual patient,

these procedures are not performed concurrently with intravenous drug preparation procedures unless there is an emergency. During emergencies, every effort is still undertaken to maintain asepsis.

Is the lighting good, making it easy to see to read instructions within the unit ?

Yes – there are no lighting problems. The lighting can be adjusted to suit the patient and the nurse.

What if any performance measures are available?

The ICU is clearly working hard to develop their quality improvement skills and lead with the Scottish Patient Safety Programme (SPSP); the unit has data on catheter-related blood stream infections (CR-BSI), of which it was stated there had been 82 days since their last infection.

All data available is displayed in an area where the nurses and members of the public come through the unit. Error data is discussed at regular meetings with the clinical team.

What in-ward operator performance monitoring is done?

The majority of procedures are done in sight of colleagues in the large relatively open plan area that is the ICU. All drugs to be administered need to have several redundancy checks. Although there is no written procedure, the majority of procedures are done to a similar process. There were some observed and

reported variations, for example, one nurse was observed using alcohol gel on gloved hands, the ends of the catheters could be connected with either a 3-way tap or Bionector®. There was an option to use Dispensing Pins although all observed procedures were performed by the ward nurses using single-use diluents. However, the elements of the procedures were similar – the order in which they were performed seemed to be operator dependent. It would be extremely difficult to be a ‘rogue preparer’ within the ICU and not be detected.

What if any information is available during the preparation of intravenous infusion and how situation aware is the nurse?

The nurse preparing the drug can tell the amount of drug and diluent being prepared and what is required; the nurse is also aware of whether there is undissolved drug, or particulates such as visible glass particles present in the infusate. The only information unavailable to the nurse is the sterile or non-sterile nature of the drug (also, if the Dispensing Pin is used, it is not known whether there is contamination of the diluent, the Dispensing Pin canal, the syringe tip and the catheter connection point).

What monitoring is done outside the ward?

Data on CR-BSIs and compliance with vascular care procedures are sent to the SPSP extranet site and monitored by the SPSP team as well as being reviewed and acted up on internally.

How frequently are drug errors reported?

The ward manager reported that clinical incidents involving medications are reported on average 250 times per month throughout NHS Greater Glasgow and Clyde.

According to the ward manager all drug errors are reported. Error reporting is seen as a means to achieve safety.

8.4.2 Data Stream 2 Observations drug preparations (3rd ward)

How many procedures were observed?

In a busy ICU a total of 17 procedures were observed. These 17 procedures involved 22 drug preparations.

What procedures were observed and how many drugs were administered?

A variety of procedures were observed; drugs prepared for bolus, for syringe driver and for administration via infusion.

The infusates prepared included:

Analgesics: Paracetamol

Anaesthetics/sedatives: Propofol, Fentanyl, Diazemuls

Antibiotics: Clarithromycin, Ampicillin, Cefotaxime, Amoxicillin

Steroids: Hydrocortisone, dexamethasone

Others: Potassium chloride, insulin, proton-pump inhibitors, acyclovir, phenytoin.

How variable are the procedures?

The procedures do vary in terms of drug compatibility but can be represented simply as follows:

- Draw up drug; Draw up flush; Administer drug; Administer flush;

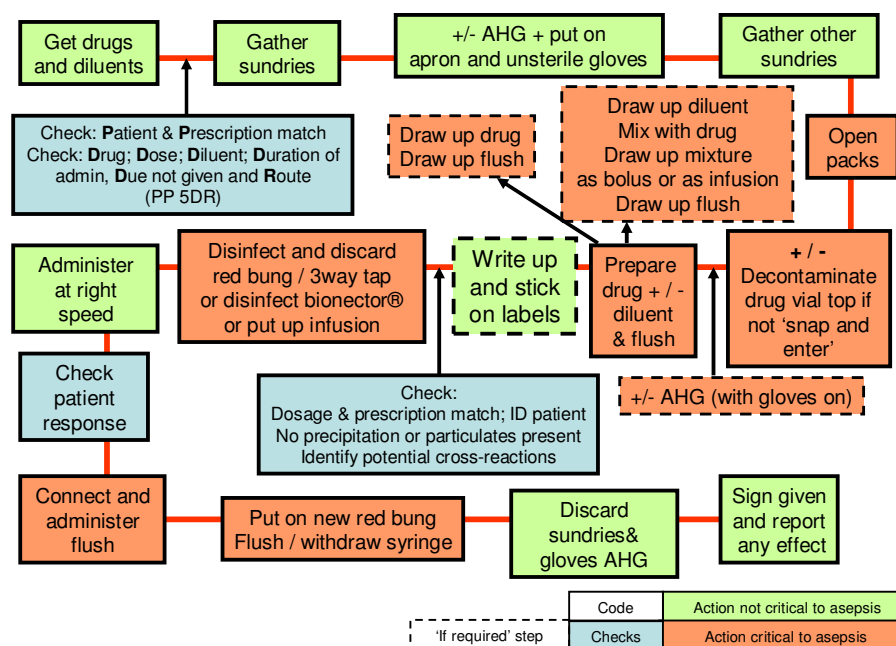
Or alternatively

- Draw up diluent; Mix diluent with drug; Draw up mixture (drug and diluent); Draw up flush; Administer mixture; Administer flush.

Underlying this simplification there is a good deal of variation. The solution may need to be administered covered, so it does not deteriorate in the light, or may require to be administered at a specific temperature. To maintain a specified pH, the diluent may vary. Additionally, some drugs may need to be stopped prior to administration of a second drug to prevent precipitation or cross-reaction. The IV drug administration sheets help ensure the procedure minimises such risks.

The procedure is illustrated in Figure 27. Observed variations in the procedure are denoted by a '+/-' sign.

Figure 27 How the drug preparation were performed in the 3rd ward



How is the intravenous drug procedure performed?

Figure 27 shows the process of intravenous drug preparation as observed and administration procedure as reported as follows:

- That the nurse gathers all drugs and diluents.
- Against the prescription (which is on a computer screen) the following are checked by 2 nurses (one of whom is deemed competent):
 - The patient and prescription match.
 - The Drug (including expiry date), the Diluent (including expiry date), the Dose, the Duration of administration; that the drug is Due and has not been given and the Route of administration. This first set of checks is to

ensure that the nurse is able to prepare the prescription correctly from the gathered drugs and diluents.

- Sundries (needles, syringes and administration sets) are then gathered.
- Alcohol hand gel may then be applied; a plastic apron and non-sterile gloves are put on.
- As in the pilot ICU, it is often recognised at this stage that something has been forgotten and, with the gloves on, going back to a drawer to collect a syringe or additional needle. This would negate any infection control benefit from the gloves.
- The packs are then opened.
- The drug access points of rubber-topped vials are sometimes decontaminated. ('Snap and enter' vials are frequently used into which the needle can be inserted to collect the drug without the need to pierce a bung. These vials do not require decontamination).
- The drug is prepared as either a draw up drug, draw up flush, or a draw up diluent. The procedure is then to mix the diluent with drug, and then to draw up the mixture (drug and diluent).
- The second set of checks is to ensure that what has been drawn up is the correct dosage, the diluent is as required by the prescription and that there are not possible cross-reactions that could occur. A visual check for any precipitation is done.
- Pre-written labels are then applied to syringes or infusions (Labels are sometimes written at this point).

The following part of the procedure was discussed with the nurse and not observed as per the ethics submission.

- The connection is decontaminated with an alcohol wipe.
- The red bung is disconnected.
- The drug is then administered (by bolus / syringe or infusion) followed by the diluent. Occasionally the flush would come direct from a 3-way tap via an existing infusion.
- During administration the patient is observed for abnormal reaction to the administration.
- The syringe or infusion is then disconnected and a new sterile bung is applied.
- Sundries including gloves are discarded and alcohol gel is again applied to hands.
- Documentation is completed.

One nurse applied alcohol hand gel to gloved hands, a clear recognition that the gloved hands had become contaminated and something needed to be done. However, gloves are not designed to be decontaminated in the same way as hands.

Was there distraction during the intravenous drug preparation procedures?

It was not unusual for a nurse to be disturbed during the preparation of a drug but this was not seen to result in the omission of a step. As noted previously in an ICU, when the nurse is at the bedside there are concurrent procedures of watching the patient, listening for alarms and intermittent monitoring of the telemetry.

Is the equipment needed for intravenous drug preparation procedures close at hand?

Equipment is kept in the patient's own equipment trolley or in the drug preparation area.

8.4.3 Contamination risks in the 3rd ward procedure

Figure 6 illustrates again for this ward how long infusate contamination would take to cause a symptomatic response in a patient; that is, almost immediately if there is heavy infusate contamination, or over days or weeks if contamination causes biofilm formation to start. With this figure as a guide, the procedures and location assessment data will be examined for their error-prone and reliability status. To do this there is first an analysis of what is sterile/non-sterile and what are the critical parts of the equipment during preparation and immediately prior to administration.

What is sterile and non-sterile at the start of the procedure?

No Dispensing Pins were seen in use, although I was informed they could be used and they were seen to be available on the shelves. Figure 28 illustrates the sterile and non-sterile surfaces and materials used in the pilot ward. The sterile surfaces/materials are:

Syringes, needles, internal contents of drug ampoules, (internal contents to diluents if never used), Dispensing Pin (if never used), diluent (if never used).

The non-sterile materials/surfaces are:

The access point to any rubber topped vial

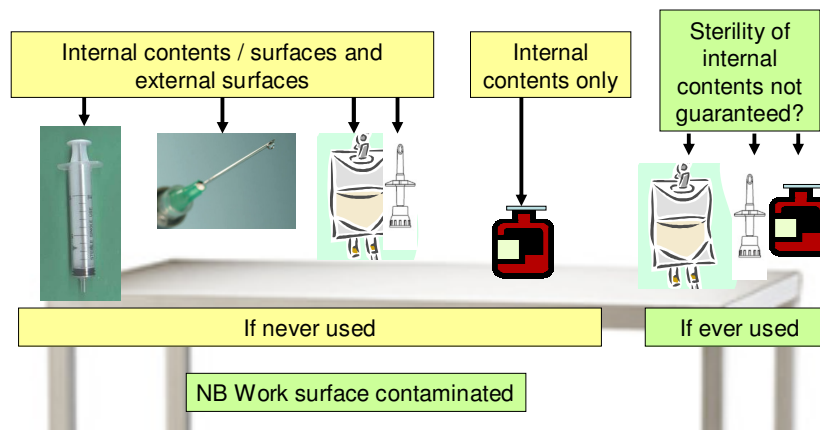
Outside containers of any drug vial

Reuse of the access point to the multi-dose diluent via the Dispensing Pin

Possibly the multi-dose diluent if a Dispensing Pin is used

The surface on which the drugs are to be prepared.

Figure 28 Equipment sterility at the start of the procedure (3rd ward)

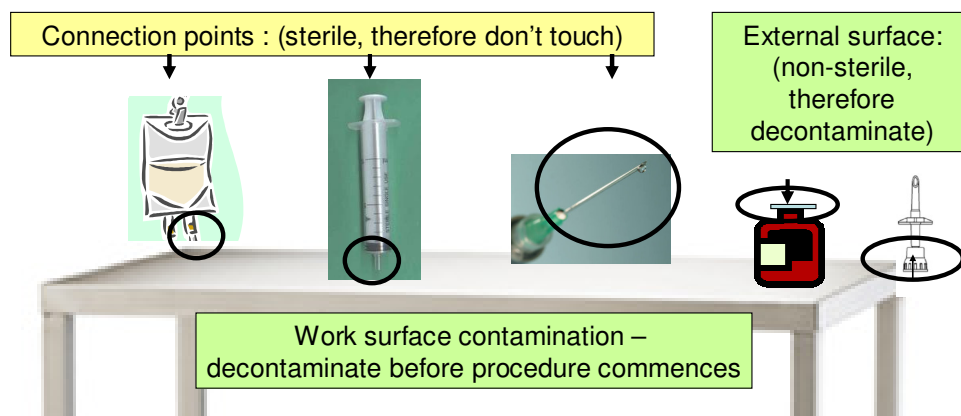


What are the critical surfaces that if, contaminated or not decontaminated, will prevent aseptic preparation?

As the work surface is not sterile, has not been decontaminated and has been open to contamination, it should be cleaned and be dry prior to the procedure starting.

The critical surfaces during preparation are the connection points of the top of the syringe, the metal part of the needle that will come into contact with the drug and internal Dispensing Pin surface. These surfaces should not be touched (Figure 29). The other critical surface is the top of the ampoule.

Figure 29 The critical surfaces during the procedure (3rd Ward)



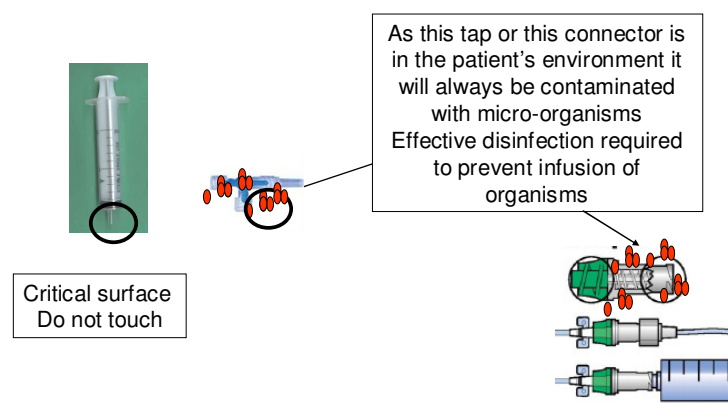
As identified on the pilot ward, Dispensing Pins are designated single-use equipment. It would be possible for the diluent to be contaminated by the bung being contaminated when removed and then replaced or after non-immediate replacement of the bung or by droplet contamination from general ICU activity. There is no mechanism to identify whether multi-dose vials are contaminated.

Immediately before administration, what are the critical surfaces that must be protected from contamination or decontaminated?

Immediately before the administration of the drug the critical surfaces are the hub, the tip of the syringe and the 3-way tap on the end of the catheter (Figure 30). As

the 3-way tap is attached to the patient, it must always be considered to be contaminated and to be covered with at least coagulase negative staphylococci, the leading cause of catheter related blood-stream infections.

Figure 30 The critical surfaces just before administration (3rd Ward)



Is the equipment used for intravenous drug preparation procedures free from environmental splash contamination?

There is no possible splash from a sink during drug preparations. At the bedside, although a closed suction system is used there is always the possibility of unplanned ventilator disconnection resulting in aerosols being disseminated over a couple of metres; this would (since endotracheal secretions are always contaminated) contain bacteria. There are no visual cues which signal to the nurses making up the infusion that environmental contamination may have occurred and sterility of equipment may have been compromised.

Is the equipment adequate; that is, does it aid the process of maintaining sterility of the infusate?

Three types of equipment appeared to pose possible asepsis challenges for the nurses: Sterile or non-sterile access points, Dispensing Pins and the use of potentially contaminated multi dose vials. The mechanisms by which this equipment poses a risk have been discussed previously.

What are the infusates at highest risk of contamination for the 3rd ward?

Figure 10 highlights the infusates at highest risk of contamination in this ward. In this ITU there is high use of lipid drugs, which promote microbial growth. Also, there is a high use of infusions of >12 hours duration which can enable microbial growth over the lifetime of the infusion. Such infusions in this ICU could include heparin, diamorphine or insulin. Finally, there could be unintentional use of contaminated diluents, or contaminated multi-dose vials on this ward.

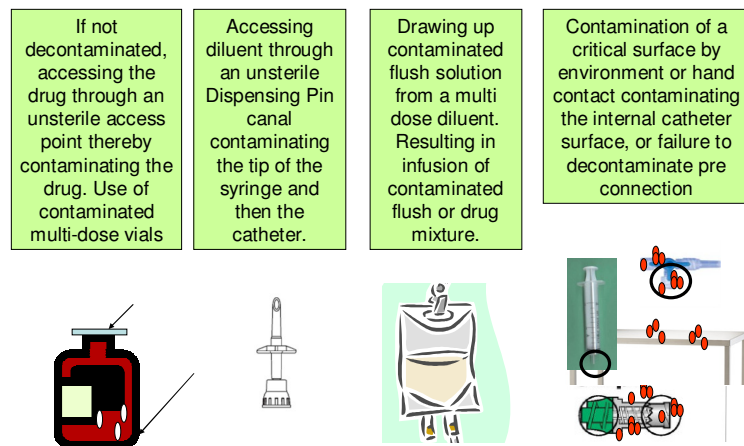
Where is the procedure likely to produce errors in aseptic preparation?

Figure 31 illustrates the stages of the procedure at which contamination is most likely to occur; these are the same as in the pilot ward:

- Accessing the sterile drug through a non-sterile access point with resulting contamination of the drug.
- Critical surface contamination / non-decontamination:
 - Touching (with unclean or gloved hands) the tip of the syringe with subsequent contamination of the catheter lumen.

- Critical surface contamination from direct contact with a contaminated environment work surface.
- Failure to decontaminate effectively the hub pre connection with the syringe.
- Accessing the diluent via a contaminated Dispensing Pin canal thus contaminating the tip of the syringe
- Drawing up the diluent if it is contaminated through multi access.
- Using a contaminated multi-dose vial.

Figure 31 When contamination is most likely to occur (3rd ward)



8.4.4 How to reduce potential contamination risks in the 3rd study ward

The procedure at present can be classified as:

An interrupted aseptic procedure performed by a single nurse with checker

That is, there are aseptic steps followed by non-aseptic steps followed by aseptic steps (Figure 27). The interrupted aseptic nature of the procedure is illustrated by colour-coding the steps: blue for mandatory checks, green for essential steps but not critical to asepsis, orange for steps critical to asepsis (Figure 27). Changes that would promote reliability and reduce errors in this procedure are highlighted below.

New step - Cleaning the work surface preparation area

The procedure should commence with cleaning of the work surface preparation area with either a detergent or disinfectant wipe. The surface should be allowed to dry before any items are placed on it. This should be followed by hand hygiene and then donning of the plastic apron. A visibly clean work surface does not denote microbiological 'cleanliness'. Pathogenic environmental and skin organisms, that could cause infusate contamination, can survive for long periods of time on surfaces. Through direct contact, equipment and then the infusate itself could become contaminated. Therefore, the preparation surface should be cleaned before starting the procedure to reduce the risk of equipment contamination or contamination of the HCWs' hands. The area should be dry before any items are placed on it. This step should be considered critical to asepsis.

New step - Introducing hand hygiene after cleaning of the preparation area

As the cleaning of the surface could itself result in contamination of the nurses' hands by the same transient environmental micro-organisms, the second step is to decontaminate hands by using an alcohol based hand gel. The last preliminary step is donning the plastic apron to prevent contamination from the uniform causing contamination of the preparation area. This preliminary procedure assumes that hands are visibly clean before commencing the task and that cleaning the surface does not result in visibly dirty hands, if it does, hand washing would be required.

New step - Confirm drugs and diluents are single-use sterile

All drugs and diluents should be confirmed as single-use sterile (SUS) at the start of the procedure. This means that the use of Dispensing Pins should be stopped. In addition, all multi-dose vials, even of heparin with preservative, should be stopped. Once all the equipment has been gathered, an additional cognitive step of considering for each procedure what is sterile and what is critical throughout the procedure will help guide practice. At this point checking for critical drug information will reduce other patient safety hazards associated with intravenous drug administration.

Changed step - from glove use to hand hygiene at critical points

There was a lack of clarity as to why gloves are used for this procedure. Gloves could be being used to prevent microbial contamination from nurses' hands to the

sterile equipment during the procedure, to prevent contamination of the nurses' skin by the drug or just because it is custom and practice. If gloves are to be used effectively, that is changed if ever contaminated during any stage of the procedure, then as the procedure is an interrupted aseptic procedure they should be replaced every time the gloved-hands come in contact with a potentially contaminated surface (therefore pairs would be required for this procedure [the first before gathering sundries, the second after touching contaminated drug ampoule surfaces and the third pair before administration]). Gloves are not designed to be decontaminated in the same ways as hands, that is, by hand-washing or using alcohol hand gel.

If glove use is to prevent hand contamination from the drug, then they should be used before drug manipulation and removed after drug is drawn into the syringe; this is the last opportunity for skin contamination. This type of glove use, that is, to protect the nurses' skin, requires a Control of Substances Hazardous to Health Regulations 2002 (COSHH) risk assessment be completed, to determine what risk is present and how it can be negated or mitigated against (Health and Safety Executive 2009). Assuming that gloves are not used prevent a hazardous exposure to the nurses' skin, the amended procedure replaces glove use by more frequent hand decontamination to increase the likelihood of an aseptic procedure being achieved.

The tops of all drug vials not marked sterile should be decontaminated with a disinfectant wipe. Alcohol hand gel should then be applied after sundries have been opened – this is because during the opening of the vials, or flipping off of lids, hands may have become contaminated.

Sticking labels on to infusion bags as soon as the drug is added is a critical patient safety step which interrupts the aseptic procedure. Therefore, in order to recommence the aseptic procedure, hand hygiene should be performed after the label has been applied to the infusate bag/syringe. Alcohol hand gel should also be reapplied once more if there is a requirement to disconnect the line before flushes.

New step – Review possible critical surface contamination and cross-reaction risk

As in the pilot ward, prior to administration of the drug, a further cognitive step is introduced. At this point the nurse reviews the performed procedure and is confident that neither critical surface contamination has occurred nor cross-reactions are likely to occur. There is also the opportunity to undertake the critical non-aseptic check of considering what steps, if any, are required to prevent cross-reactions or precipitation.

The procedure as done currently is shown as Figure 27, the new steps in the procedure are shown as Figure 32, and are colour-coded in Figure 33. The colour-

coding of the procedure enables staff to identify what steps are critical to asepsis and what are critical to patient safety, for example, sticking on of labels.

Figure 32 Amended procedure for increased reliability (3rd ward)

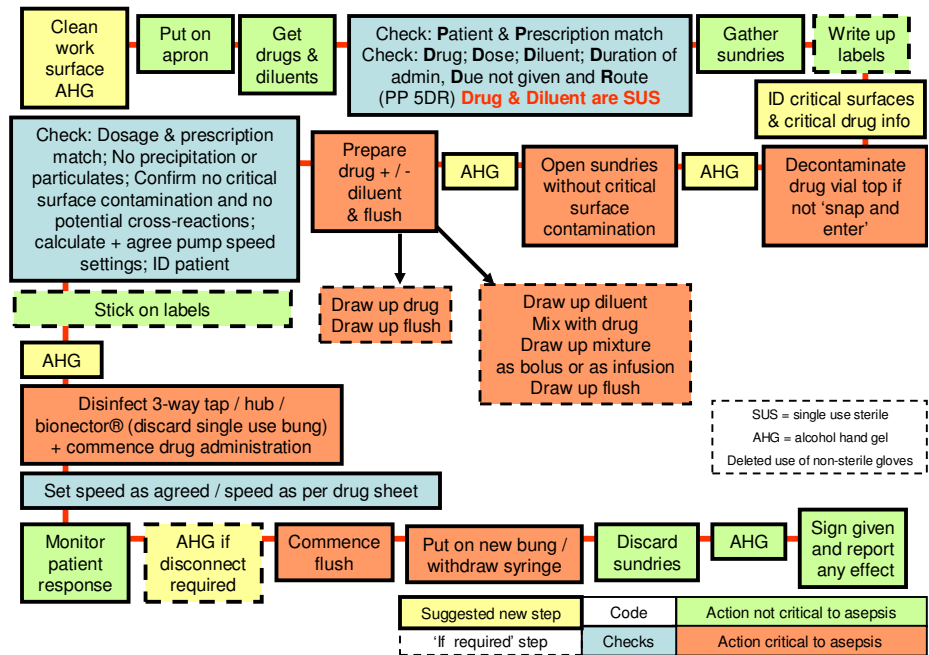
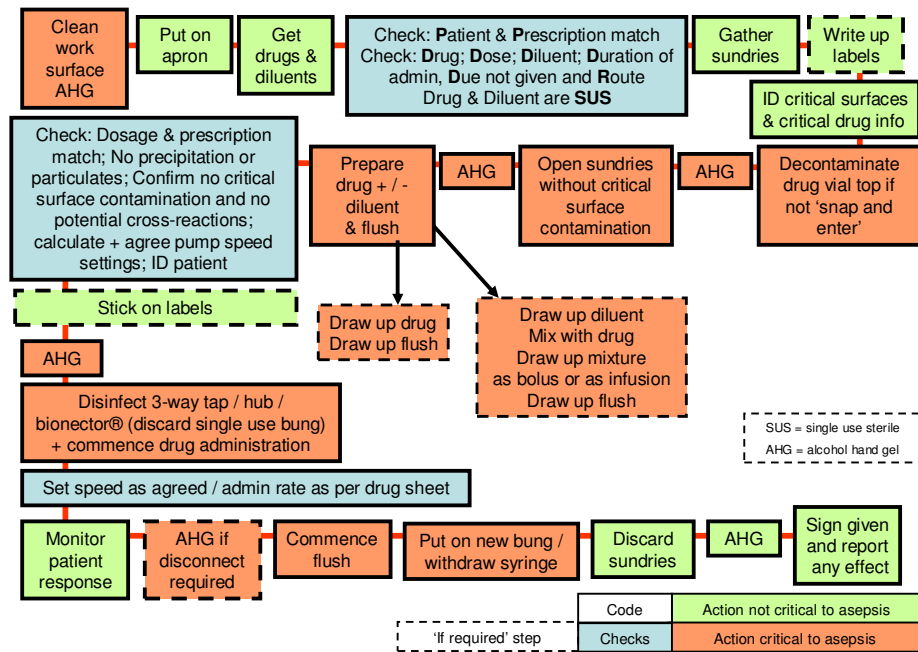


Figure 33 Revised procedure colour-coded (3rd ward)



The recommended changes attempt to achieve an aseptic procedure, without end product validation, it is not possible to confirm that this modified aseptic procedure will reliably achieve a sterile product.

8.4.5 Data Stream 4 – Procedure comparisons (3rd ward)

This ward has a written procedure and the following table (Table 8) iterates the step in the procedure, the purpose of the step and whether it was observed.

Table 8 Comparison of written and observed procedures 3rd ward		
Procedure	Purpose	Observed
Has a clear, uncluttered surface for preparation	To prevent contamination	Yes
Has adequate space	To enable the procedure to be performed correctly	Yes
Is quiet, away from distractions	To prevent errors	Not always possible
Has a surface that can be cleaned	To prevent contact contamination	It has a surface that can be cleaned, but it was not physically cleaned before each procedure
Has access to hand washing facilities (medicine preparation, however, should not be carried out adjacent to sinks)	To prevent splash contamination	Yes
Is well lit	To reduce errors	Yes

Table 8 Comparison of written and observed procedures 3rd ward		
Procedure	Purpose	Observed
If available, a ready-to-use form of injection should be used in preference to one prepared at ward/pharmacy level	To reduce errors	Unable to tell what was available in pharmacy
Injections for one patient only should be prepared at a time and administered before preparing any injections or infusions for another patient	To reduce errors	Done, but one patient had 5 drugs being prepared during the same procedure
Injections must be clearly identifiable at all stages during preparation and administration	To reduce errors	Yes, as far as is practical.
The additive label for syringes and infusions (excluding syringes prepared for immediate use as a bolus) must be prepared before starting preparation of the injection / infusion so that it is affixed immediately after preparation is	To promote the correct procedure and reduce errors	Yes, note this procedure interrupts the aseptic steps in the procedure

Table 8 Comparison of written and observed procedures 3rd ward		
Procedure	Purpose	Observed
complete. The label must specify the patient, name, additive, strength, diluent, route, date and time prepared, initials of staff involved in preparation and expiry date		
In wards / theatres / departments, if an injection is to be given by bolus, the name of the medicine must be affixed to the syringe (for example, using an additive label or specific drug-name label). The finished preparation and original containers must be kept in an individual tray between preparation and administration to patient	To reduce errors	All drugs were given as soon as prepared – negating this risk
All prepared infusions / injections must be labelled with an appropriately sized label so as not to obliterate the name of the	To enable rate checks	Yes the label was applied so that although adhered, it could

Table 8 Comparison of written and observed procedures 3rd ward		
Procedure	Purpose	Observed
infusion and to allow inspection of the solution and volume. For syringe drives, the label must be attached in such a way to avoid obliterating the graduations on the syringe		be lifted to identify the dosage
On no account should prepared injections / infusions be administered that contain particulate matter	To prevent complications	Yes – drugs were checked to be clear of particulates
Infusion bags must not be routinely used as multi-dose containers for the preparation of injections. In some clinical areas, devices are available that facilitate the use of infusion bags as multiple use containers for a restricted time period (for example, for drawing up small quantities to flush lines / use as a diluent). These devices should	To prevent infusate contamination	Not seen done but available for use on the ward

Table 8 Comparison of written and observed procedures 3rd ward		
Procedure	Purpose	Observed
only be used after local risk assessment has been undertaken and procedures put in place that ensure patient safety at all time		

The procedure does not specify any asepsis checks. The procedure does specify the criteria which must be met to allow use of Dispensing Pins. However, this requirement is not in line with the MHRA (2010) guidance on single-use equipment. From the researcher's perspective, it is difficult to see how patient safety can be assured at all with the use of Dispensing Pins.

8.4.6 Data Stream 3a – Opinions on Safety 3rd ward

A total of 45 questionnaires were issued to staff in the ICU who were competent, or were in training for competency, in intravenous (IV) drug preparation; and a total of 19 (42%) were returned. A summary of these data are given in Appendix 9.

Statement 1 - When preparing IV drugs it is easy to prevent asepsis failure

The majority of respondents 15/19 (79%) thought that is easy to prevent asepsis failure on this wards. However, in fact given the risk of splash contamination, use of high-risk drugs and variability in procedure it is not easy to prevent asepsis failure on the ward.

Statement 2 - When preparing IV drugs it is easy to detect asepsis failure

The responses to this statement were more variable. Less than half the respondents 9/19 (97%) agreed with the statement that it is easy to detect asepsis failure. As stated previously, it is easy to detect touch contamination. However, given that micro-organisms and significant microbial contamination can not be seen with the naked eye, it is not easy to detect asepsis failure.

Statement 3 – The procedures for preparing IV drugs on this ward are simple

Despite the observed complexity in the procedures, the majority of respondents 15 (79%) stated that they thought the procedures on the ward were simple.

Statement 4 – The resources on this ward make it easy to prepare IV drugs safely

Again the majority of respondents were in agreement with this statement, 15 (79%). Three could not agree or disagree with this statement and one respondent strongly disagreed with it.

Statement 5 – The environment on this ward makes it easy to prepare IV drugs safely

Fourteen respondents (74%), agreed with this statement. The unit differed from the pilot ICU in size. It was much smaller and the drug preparation area could be used as it was much closer to the patients. Also, the next patient and therefore their nurse, was also much closer to hand and this nearby nurse was therefore able to

provide cover more easily should one nurse be away from the bedside to prepare drugs.

Statement 6 - On this ward distractions and interruptions make it difficult to prepare IV drugs safely

Only 6 respondents (32%) agreed with this statement. As many drugs were prepared in the drug preparation area (Figure 57) there was less distraction from the concurrent monitoring of the patient whilst preparing the drug and performing drug calculations. This diversity of response showed that some nurses find it difficult to avoid interruption and distraction when preparing drugs.

Statement 7 – I get feedback on the quality of my IV drug preparation

Again there was diversity in responses to this statement, with strong agreement and strong disagreement to it. On this ward the ward manager was working on additional supporting materials, such as a resource pack and specifications for continued education that perhaps influenced the respondents. A slight majority 10 (53%) disagreed with the statement.

Statement 8 – I would feel uncomfortable raising safety concerns regarding preparing of IV drugs on this ward

In agreeing with this statement 4 of the respondents (21%) stated they would be uncomfortable in raising safety concerns. Only 13 (68%) of the respondents would feel comfortable in raising safety concerns. These 4 respondents could be recently

qualified nurses who were had not yet felt confident enough, experienced an open invitation to express any concerns re safety.

Statement 9 – I can mix drugs on this ward without distraction or interruption

More respondents disagreed with the statement that they could prepare drugs without distraction or interruption. Eight (42%) of the respondents could neither agree nor disagree with it.

Statement 10 – Asepsis failure when preparing IV drugs is a safety priority on this ward

The majority 12 (63%) agreed that asepsis failure was a safety priority on this ward. What influenced 3 respondents to disagree with this statement is unknown.

Statement 11 – If I recognised an error in my IV drug preparation I would report it

There most frequent response to this statement was strong agreement. Thirteen respondents (68%) stated they would report a personal error. This was not a universal response and 2 respondents strongly disagreed with the statement whilst 4 neither agreed nor disagreed with it, indicating they were unsure what they would do should the situation arise.

Statement 12 – There is good support to those who have to prepare IV drugs

A clear majority 15 (79%) stated that there was good support on the ward to those who prepare intravenous drugs. This evidence of support was observable in the resource pack made available from all the staff on the ward.

Statement 13 – To improve patient safety I am encouraged to report errors

There was strong agreement with this statement. No one disagreed with it. So although not everyone stated they would report drug errors (Statement 11), no one disputed that there were not encouraged to do so.

Statement 14 – I find preparing IV drugs is stressful

Only 2 respondents agreed with the statement. The majority of respondents disagreed with this statement; they did not find IV drug preparation stressful. This may reflect the responses to statement 12, in which where the majority of respondents thought the support to those who prepare IV drugs.

Statement 15 – Preparing IV drugs gives me job satisfaction

The most frequent response was neither agreement nor disagreement. Yet again however, 4 (21%) or the respondents stated they did not get satisfaction from IV drug preparation procedures.

8.4.6.1 Additional comments on the questionnaires

“If interrupted during drug mixing, for example, telephoning, cardiac arrest – restart again.”

“Having previously made a drug error, I tend to be more cautious.”

8.4.7 Summary of the safety opinion results on the 3rd ward

The results from this safety questionnaire again indicate several aspects where there is an indication of a positive safety culture and others where the procedure could be at risk because of poor safety culture characteristics.

Responses that indicate a positive safety culture include:

- Procedures are not considered complex (Statement 3)
- Resources on this ward are considered good (Statement 4)
- Environment resources are considered good (Statement 5)
- Willingness to raise safety concerns (Statements 8 and 11)
- Asepsis is considered a safety priority (Statement 10)
- Good support on the ward (Statement 12)
- Encouragement to report errors (Statement 13)

Responses that indicate a poor safety culture include:

- Erroneous assumptions of safety (Statements 1 and 2)
- Distractions and interruptions (Statements 6 and 9)
- Lack of feedback on performance (Statement 7)

- Some willingness / concerns about returning errors (Statement 8)
- Procedure found stressful by some (Statement 14)
- Lack of job satisfaction from the procedure (Statement 15).

8.4.8 Summary of the results from the 3rd ward

The results from the 3rd study ward again identify infusate contamination risks that are present in the environment, the equipment, the drugs, the diluents and the very execution of the procedure which were not recognised as such by those who prepare the infusates. For example, there is a risk of splash from drugs prepared at the bedside, there is a risk of environmental contamination of drugs and diluents (particularly as multi-dose vials are routinely used), and the interrupted nature of the procedure poses a risk of touch contamination.

The opinions of safety present a mixed safety culture picture with some statements indicating a positive attitudes towards safety, for example, the staff are encouraged to, and most stated they would, report errors However, other statements create a different picture, the majority stated they did not get feedback, there were continuous interruptions and distractions and some found it stressful. Additionally the results showed that opinions on the safety of the procedure, in the ability to prevent and detect asepsis failure, were at odds with the evidence.

8.5 Results from the 4th ward - A vascular surgery ward

Data Stream 1 – Location Assessment (4th ward)

Data Stream 2 – Observation of Intravenous Drug Preparations (4th ward)

Contamination risks in the 4th study ward procedure

How to reduce potential contamination risks in the 4th ward

Data Stream 4 - Comparison of observed procedures with document review

Data Stream 3a – Opinions of Safety (4th ward)

Study took place on Tuesday 13th October 2009

Researcher Evonne Curran

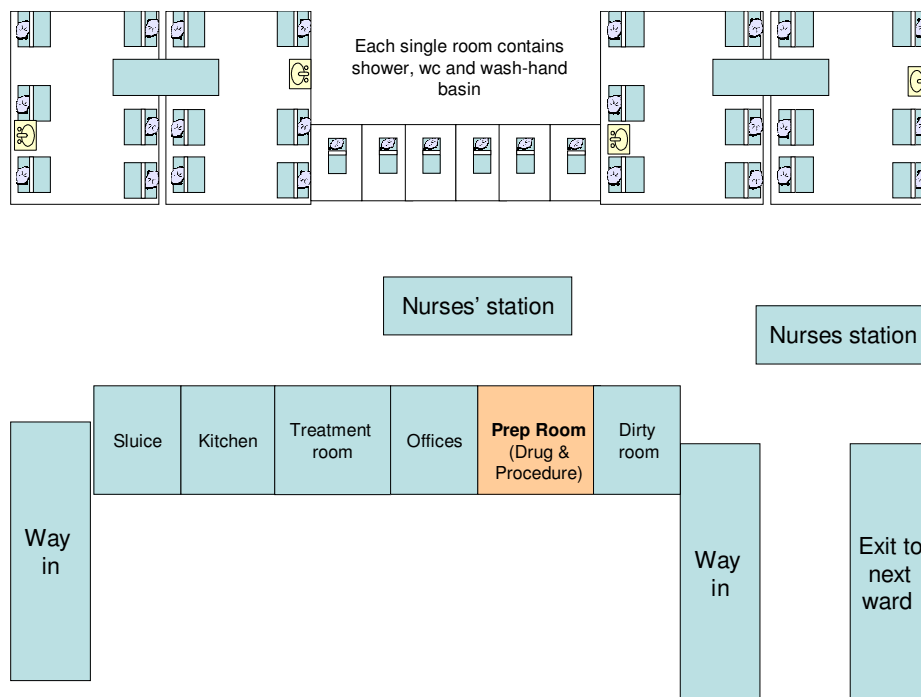
8.5.1 Data Stream 1 - Location assessment

The data for the location assessment were obtained by interview with the ward manager and from the researcher's observations during the study period.

The ward and the patients they care for

The ward is a 30 bedded vascular surgery ward. The beds are in four, 6-bedded areas and there are six single rooms (Figure 34).

Figure 34 The plan of the 4th ward



The staff on this ward care for patients before and after vascular surgery, and for patients with leg ulcers caused by vascular diseases. The main healthcare interventions are vascular graft implants and the promotion of tissue viability through improved vascular circulation and advanced wound healing. Consequently, the ward cares for patients at extreme risk of infection; that is,

patients post aortic bifurcation graft and patients with chronic ulcers who will be colonised with, and shed into the ward environment, vast numbers of micro-organisms such as *Staphylococcus aureus*.

What vascular devices are used for intravenous drug administration?

The main vascular access devices used to administer intravenous drugs are peripheral vascular catheters. Some patients have central vascular catheters. Individual patients on this ward do not require long-term vascular access devices and the drugs used are not highly-irritant to the vein. Peripherally inserted central catheters (PICCs) and Midline catheters are not routinely used.

Approximately how many intravascular drugs are prepared in the ward?

On average, approximately 18-20 intravenous drugs are prepared and administered in the fourth study ward each day. This averages to around 6,500 drugs per year prepared in the ward.

What intravenous drugs are prepared and administered?

The main intravenous drug groups prepared for administration to patients are: antibiotics, anticoagulants, (for example, heparin), analgesia, (for example, morphine), insulin and steroids.

Does the ward use drugs associated with causing infusate sepsis?

Several drugs prepared within the ward are recognised as being associated with infusate sepsis. Heparin, morphine and insulin are given via long-term infusion pumps of >12 hours duration which, if they are even minimally contaminated provides the micro-organisms with sufficient time to cause an IR-BSI over the lifetime of the infusate. There is infrequent use of lipid drugs such as propofol which are known to promote microbial growth.

Are any of the intravenous drugs prepared from multi-dose vials?

No drugs were issued in vials that could be used in a multi dose way. Most drugs are provided in snap-top plastic or glass vials. The drugs issued in rubber-topped vials required reconstitution.

How long are the vascular access devices in situ for?

The peripheral vascular catheters are in situ for a maximum of 72 hours. The central vascular catheters are left in situ with no set removal time.

Is there a stable team that prepares and administers the intravenous drugs?

Yes. Generally the population of nurses in the ward is stable. The off-duty is prepared to ensure there are sufficient staff on every shift who are trained to prepare and administer IV drugs.

Are all of the team familiar with all of the intravenous preparing procedures?

Compared to the intensive care units, there is a more limited selection of drugs requiring preparation to meet the needs of their patients. By the time they are deemed competent, the nurses' records should show that they have experience in preparing all of the frequently used ward drugs.

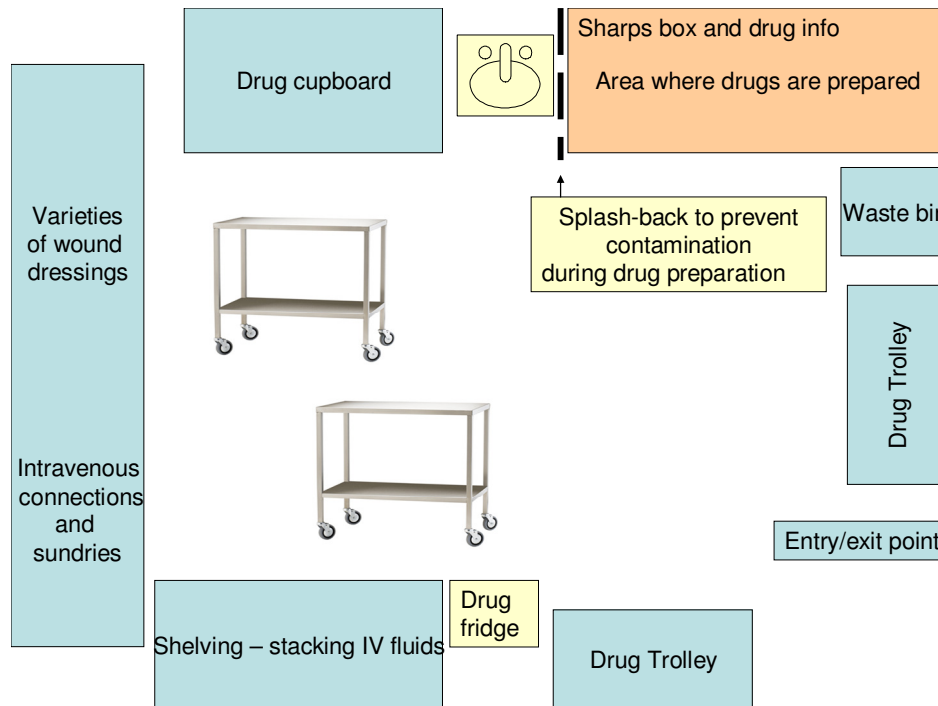
Are there any drugs which vascular nursing staff do not prepare?

The vascular nursing staff do not add drugs to total parenteral nutrition bags, prepare chemotherapy drugs or prepare intrathecal drugs. Potassium and magnesium additions to infusions are also not permitted.

Where are the intravenous drug preparation procedures performed?

There is a designated area within a generic preparation area which should be used solely for the preparation of intravenous drugs. It has a splash guard to protect it from splashes from the wash-hand basin, which it is adjacent to. (Figure 35). This Drug Preparation Area is small but uncluttered and visibly clean. The ward managers designed the area designated for drug preparation, including addition of the splash board to protect the drugs from wash-hand basin splash.

Figure 35 The multi-purpose area where drugs are prepared 4th ward



What written procedures are available?

There are written procedures which are available in the ward manager’s office and in the drug preparation area. The procedures include 14 data items but none related to asepsis risk. Other policies are available pertaining IV drug administration but these relate to permissions, self-certification, core drugs. They do not refer to asepsis except in the vaguest terms, for example, ‘Observe aseptic technique’. There is one intravenous nursing standard which includes the process’s specification: ‘The drug will be prepared aseptically and safely in a clean quiet area.’ How to achieve this is not specified.

Displayed Poster Information

A variety of poster information is available in the drug preparation area providing instructions on, for example, hand hygiene, dressing usage, blood transfusion and use of filters for IV drug administration. There is no poster detailing how to ensure asepsis during intravenous drug preparation.

How often are the procedures referred to?

The nurses frequently refer to the individual information on drugs regarding the compatibility of the drug and the method of administration. This occurs mainly when the drug is not often used on the ward.

Are the intravenous drug preparation procedures generic or drug specific?

The information sheets are drug specific. There is no procedure which specifically details the process of using the ward-available equipment, for example, the reconstitution device. There is a poster for use of the in-line filter.

Do the intravenous drug preparation procedures include problem identification and if <this situation>, then <that action> should be done?

The key, **if** this situation, then **that** action, is provided in the drug administration protocol which ends with:

‘If a nurse has reasonable grounds to question the accuracy or completeness of the above information, she has a duty to question the prescription.’

There are other 'if this situation, then that action' statements, for example, on the "Quick Guide to Blood Transfusion"

- If any discrepancy – do not proceed
- If transfusion reaction – stop transfusion and report to medical staff immediately

What other procedures are done in the preparation areas?

The area where the drugs are prepared is a generic preparation area for dressing procedures and preparation area for other aseptic procedures such as catheterisation. The controlled drugs cupboard is also in this area as are 2 drug trolleys. Consequently, during intravenous drug preparation concurrent procedures are performed frequently. However, apart from hand hygiene, none involve possible splash contamination, although they can and do involve disruption and general disturbance of the intravenous drug preparation procedure (Figure 35).

What team operation support is there?

There is seldom additional support available from out with the ward when, for example, there are an unusually high number of intravenous drugs to be prepared. At present there is no regular ward pharmacist.

Is the lighting good making it easy to see to read instructions within the unit?

Yes – there are no lighting problems. The lighting can be adjusted to suit the patient and the nurse.

What, if any, performance measures are available?

The ward is not yet taking part in the Scottish Patient Safety Programme. At present the ward has no performance measures, such as catheter related blood stream infection data, with which to judge performance.

Is there end product evaluated for sterility?

There is no end product monitoring, that is, no guarantee that the drugs being prepared are sterile.

What in-ward operator performance monitoring is done?

The main part of the procedure is done by a single nurse not necessarily in sight of others. All checks are done with two persons as previously specified.

What if any information is available during the preparation of intravenous infusion and how situation aware is the nurse?

The nurse preparing the drug knows the amount of drug and diluent being prepared and what is required and whether there is undissolved drug, or particulates such as visible glass particles. The only information unavailable to the nurse is the sterile or non-sterile nature of the drug and the diluent.

How frequently are drug errors reported?

Drug administration errors are reported at a rate of approximately 1 per year.

8.5.2 Data Stream 2 - Observations of drug preparations 4th ward

How many procedures were observed?

It was a quiet day for ward with only 16 of the 30 beds occupied. A total of 5 intravenous drug preparations were observed for 2 patients.

What procedures were observed and how many drugs were administered?

The following drugs were observed during preparation to pre administration of antibiotics: Flucloxacillin x 2, Benzylpenicillin x 2, Piperacillin / Tazobactam 1.

How variable are the procedures?

When a drug required reconstitution, and the drug was available in a rubber topped vial, a reconstitution device was used. This device considerably reduces any procedure variation. The reconstitution device (a shielded double-needle), reduces the amount of preparation and administration steps and effectively turns the procedure into a closed procedure.



Reconstitution device –
facilitating closed system
preparation of IV drugs

Table 9 shows the difference between the steps with and without a reconstitution device.

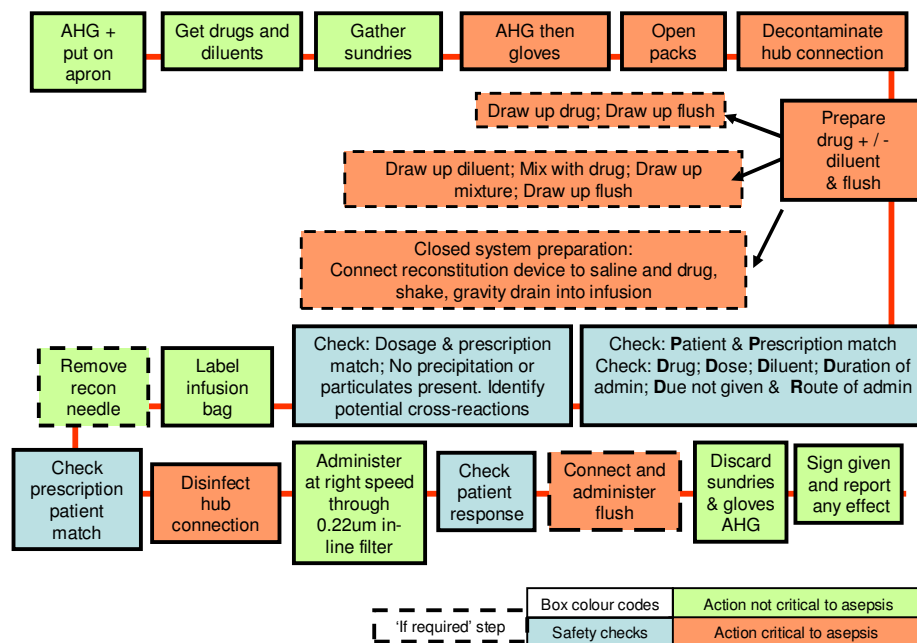
Table 9 Variation in procedure with a reconstitution device	
Procedure with reconstitution device	Procedure without reconstitution device
Expose bung of saline infusion	Expose bung of saline infusion
Disinfect bung of saline infusion	Disinfect bung of saline infusion
Open reconstitution device	Open needle
Connect reconstitution device to saline infusion bag	Open syringe
Disinfect rubber top of drug vial	Connect needle to syringe
Connect reconstitution device to drug vial	Draw up flush
Shake and mix – invert to drain drug into infusion bag	Disinfect rubber top of drug vial
	Inject flush into drug
	Shake and mix
	Re-insert needle to draw up drug
	Inject drug into saline infusion bag

The reconstitution device can only be used when the diluent is sodium chloride 0.9%. If the diluent is water, the drug preparation is as per the right-hand column. The difference may seem like only 4 steps – but it equates to a couple of minutes preparation time; when several drugs are to be prepared this represents a considerable amount of time. Furthermore as, the bulk of drugs used on this ward

are antibiotics which require reconstitution, the reconstitution device method is seen by staff as a considerable benefit. This essentially creates a closed system and also negates the problem of aseptic tasks being interrupted by mandatory non-aseptic tasks, which are followed by further aseptic tasks.

The ward also uses a simple 'draw up drug, draw up flush' for direct bolus injections, but this is less common than preparing the drug as either a syringe infusion or infusion bag. There is less variation on this ward as the drugs used are less complex and require fewer specifics. The procedure is illustrated in Figure 36.

Figure 36 The drug preparation procedures 4th ward



Administration of the drugs to the patient was not observed, according to the research protocol. However, the nurses reported that all drugs are infused via a

three-way tap in front of which is a 0.22µm in-line filter. To minimise a contamination risk during disconnection and reconnection, the filter includes an integral short arm extension and external clamp.

How is the intravenous drug procedure performed?

Figure 36 shows the process of intravenous drug preparation as seen and the reported administration procedure:

- The nurse applies alcohol hand gel (AHG) to decontaminate hands and dons a clean plastic apron.
- All drugs and diluents are gathered.
- All sundry equipment is then gathered.
- Alcohol hand gel (AHG) is then applied and non-sterile gloves put on.
- The drug vial is then decontaminated with an alcohol impregnated wipe.
- A reconstitution device (shielded double needle) is then applied to the drug vial.
- The second part of the reconstitution device is then connected to a 100ml infusion of sodium chloride 0.9%.
- With the drug vial still attached the liquid is inverted to mix the infusion with the drug.
- Once the drug has been checked for complete dissolution, it is drained using a combination of gravity and the vacuum within the infusion bag.
- A second nurse then checks the prescription for the following:
 - The correct Drug (including expiry date) the Diluent (including expiry date), the Dose, the Duration of administration, that the drug is Due (and

has not been administered) and that the intended Route of administration is intravenous.

- If the prepared drug is in excess of the prescribed drug it is then discarded with both nurses present. [This type of preparation would not be done via a reconstitution type preparation].
- At this point the mixed solution is checked for precipitation and residual particulates.
- Once the checks are completed, the first nurse dismantles the drug vial and to reconstitution needle is discarded.
- The label is then completed and signed by 2 nurses. This is then applied to infusion bag.
- Gloves are then removed and sundries discarded.
- The infusion bag and prescription are taken to the bedside to check that there is a match.

The following part of the procedure was discussed with the nurse and not observed, as per the ethics submission.

- The infusion bag with drug is then connected to the administration set in the same way any infusion bag would be connected. The connection for the administration set is separate to the port used for the reconstitution needle.
- The drug is then administered followed by the diluent. Occasionally the flush would come direct from a 3-way tap via an existing infusion.
- During administration the patient is observed for abnormal reaction to the administration.

- The syringe or infusion is then disconnected and a new sterile bung is applied.
- Sundries including gloves are discarded and alcohol gel is again applied to hands
- Documentation is completed.

Was there distraction during the intravenous drug preparation procedures?

There were no observed distractions during intravenous drug preparations, possibly because the ward was quiet

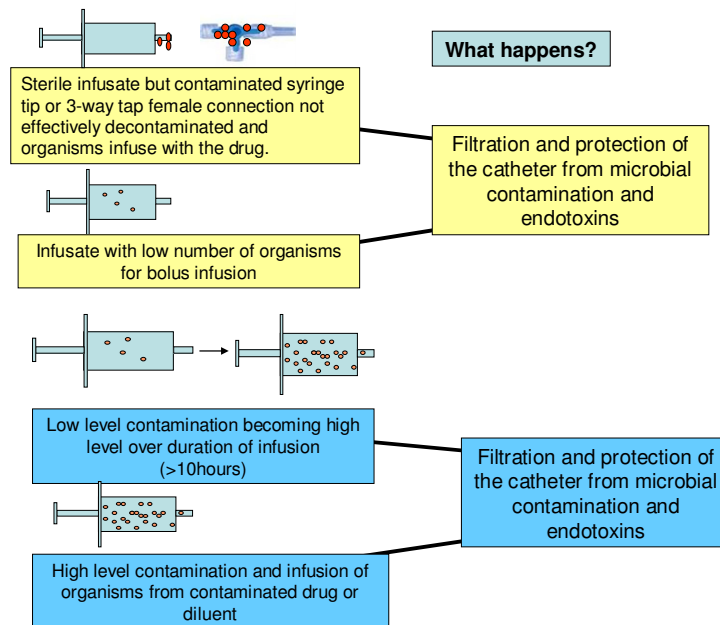
Is the equipment needed for intravenous drug preparation procedures close at hand?

All equipment is kept within the generic preparation area (Figure 35).

8.5.3 Contamination risks in the 4th study ward procedure

This ward has a system which, even if contamination arises, would prevent organisms and / or their toxins being infused into the patient. Figure 37 shows how infusate contamination on this ward will not cause infection because of routine use of in-line filtration by a filter capable of removing bacterial contamination and endotoxins over the lifetime of the peripheral vascular catheter (up to 96 hours). Correctly from a patient safety perspective, the process of preparing drugs on this ward does not proceed on the basis that it is well defended, therefore requiring of less care. The procedure still aims to prevent primary contamination of the infusate.

Figure 37 Use of filters preventing infusate contamination causing IR-BSI



The filter used is a Vygon™ 96 hour in-line filter 0.22µm pore size. Manufacturer's specification: 0807.01

“A self priming 96 hour 0.22µm endotoxin retentive air eliminating filter. Supplied with a pre attached microbore PVC extension line with injection site and clamp and day change labels. Filter not suitable for use with lipids or blood products.”

What is sterile and non-sterile at the start of the procedure?

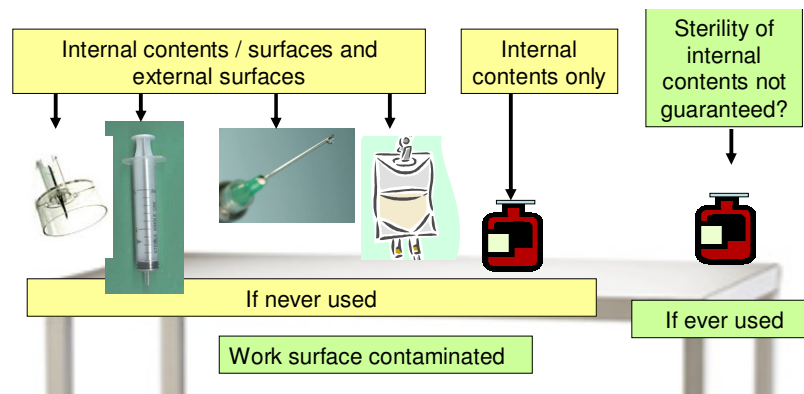
Figure 38 illustrates the sterile and non-sterile surfaces and materials used in the 4th ward at the start of the procedure. The sterile surfaces/materials are:

Syringes, needles, internal contents of drugs ampoules, (internal contents of diluents, reconstitution device

The non-sterile materials/surfaces are:

The access point to any rubber topped vial, Outside containers of any drug vial and the surface on which the drugs are prepared.

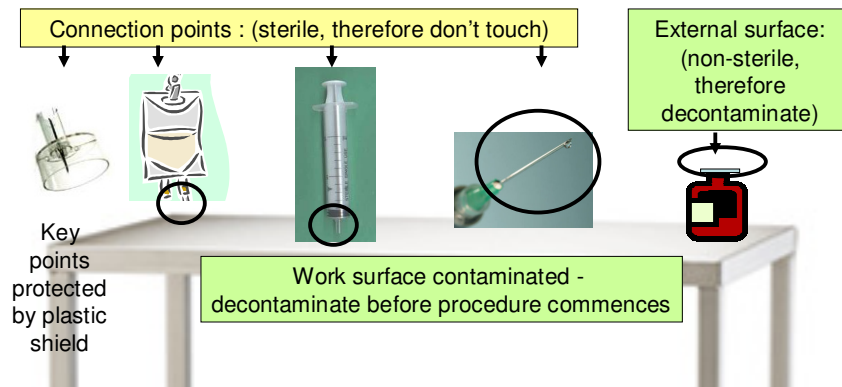
Figure 38 The sterility of equipment at the start of the procedure (4th ward)



What are the critical surfaces that if contaminated, or not decontaminated, will prevent aseptic preparation?

The critical surfaces during preparation are the connection points of the top of the syringe, the metal part of the needle that will come into contact with the drug. These surfaces should not be touched (Figure 39). The work surface should be considered contaminated and should be cleaned and be dry before the procedure commences.

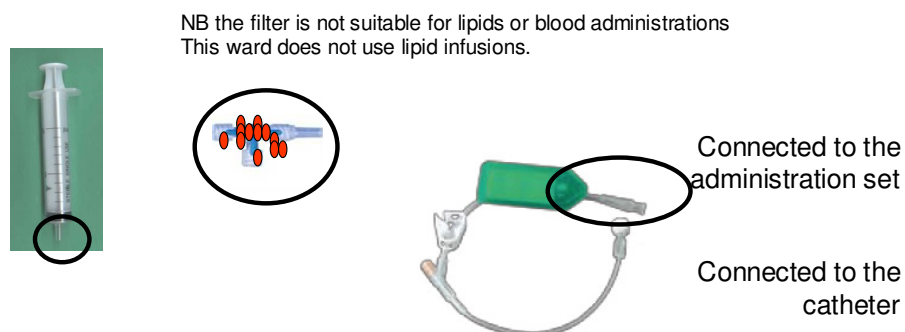
Figure 39 The critical surfaces during the procedure (4th ward)



Immediately before administration what are the critical surfaces that must be protected from contamination or decontaminated?

Immediately before the administration of the drug the critical surfaces are the hub, the tip of the syringe and the 3-way tap on the end of the catheter (Figure 40). As the 3-way tap is attached to the patient it must always be considered to be contaminated and to be covered with at least coagulase negative staphylococci, the leading cause of catheter related blood-stream infections.

Figure 40 The critical surfaces just prior to administration (4th ward)



Is the equipment used for intravenous drug preparation procedures free from environmental splash contamination?

There were no observed procedures that resulted in splash in the area during intravenous drug preparation. The closed system reduces the risk of potential contaminated splashes reaching the infusate.

Is the equipment adequate, that is does it aid the process of maintaining sterility of the infusate?

The use of a reconstitution device reduces the risk of touch contamination; this is further reduced by an aseptic technique. Effective filtering prevents unidentified contamination from reaching the patient. All access points of drug vials were decontaminated, so potential risk of upper surface contamination being transferred to the infusate was negated.

What are the intravenous drugs at highest risk contamination for the 4th ward?

This ward at present has a procedure which is double-defended. The infusate is defended from contamination by a reconstitution device, and even if contamination of the infusate occurs, the patient is protected by a device for filtration of any microbial contamination including infusates. The drugs at highest risk on this ward are the infusions of >12 hours duration, but this risk is much lower than on other wards due to the procedure having 2 layers of defences. Such long-term infusions could include: heparin, diamorphine and insulin. Figure 41 illustrates the drugs and drug preparations at highest risk of contamination on this ward, and Figure 42

shows the effect of filtration as a defence barrier against microbial contamination and contamination with endotoxins negating these risks.

Figure 41 Infusates posing the highest contamination risk (4th ward)

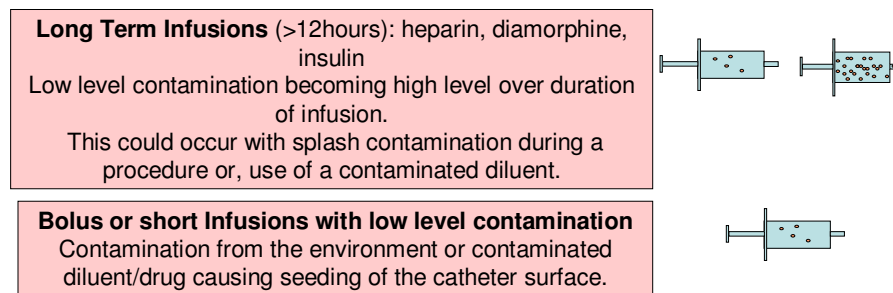
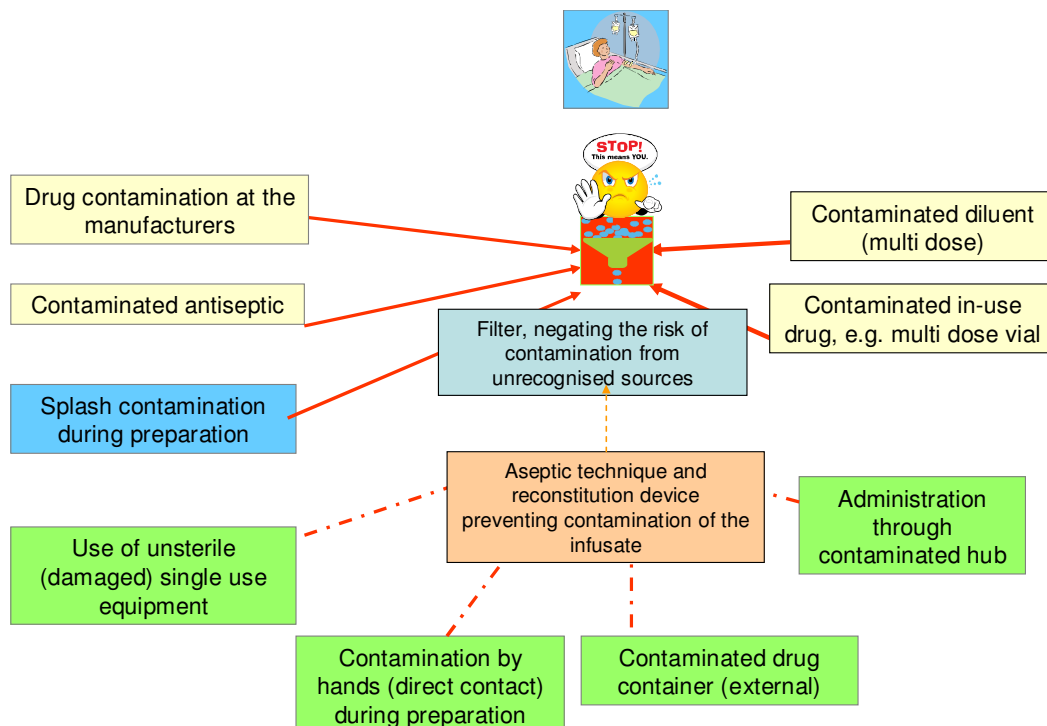


Figure 42 The prevention of contaminated drug infusion (4th ward)



Where is the procedure likely to produce errors in aseptic preparation?

With a reconstitution device acting as a closed system, potential microbial contamination is significantly reduced as there is little opportunity for microbial access to the system. Microbial contamination of a long-term infusion is possible. However, as stated previously, with an effective in-line filter it should be possible to prevent microorganisms or their toxins harming the patient.

8.5.4 How to reduce potential contamination risks in the 4th study ward

The procedure as performed and shown in Figure 36 can be classified as:

An interrupted (closed) aseptic procedure – performed by a single nurse with checker

Colour-coding the written procedure (Figure 36), highlights the steps that are crucial to asepsis (orange), the steps that contain mandatory checks (blue) and other required steps that are not critical to asepsis (green). This enables the procedure to be seen as interrupted aseptic procedure and therefore identify when hand decontamination is required after steps which may contaminate hands.

Overall, from what has been described and shown in the Figures (36-42), it can be seen that this is a double-defended procedure; the reconstitution device protects the infusate and the filter protects the patient. There are however, no data to show that the procedure results in a sterile product, but the equipment used does provide plausibility of a sterile product. Although the reconstitution device cannot be used for all drugs, as no lipid drugs are used in this ward, the filter can. For

optimal patient safety, however, the procedure should be assessed as though the defence (in-line filter) was not there. As a consequence the following changes should improve the overall safety of the procedure.

New step - decontamination of the work surface area

To reduce the risk of contamination of critical surfaces of sterile equipment, the surface area where the drugs are prepared should be cleaned before the start of every procedure. This will prevent transfer of organisms from the surface to the hands of the nurse. This will also prevent transfer of organisms to the patients' environments.

New step - confirm drug and diluent are single-use sterile

The addition of a new check to confirm that the drug and diluent are single-use sterile will reduce the risk of a single-use vial being inadvertently reused, and remind staff that diluents should also be single-use. Identifying critical drug information at this time, that is, before preparation commences should make the nurse alert to possible variations in procedure required to maintain patient safety. For example, whether the tops of vials are or are not sterile.

Changed step - from glove use to hand hygiene at critical steps

There is no additional asepsis benefit gained from the use of gloves and if the gloves come into contact with non-sterile surfaces they could, like hands, become contaminated. Although hands can be decontaminated, gloved hands cannot.

Hand hygiene, using an alcohol based hand gel, can be performed if an aseptic step is interrupted by a non-aseptic step followed by an aseptic step, for example, injecting drug to an infusion bag, applying a label, and then injecting another drug into a second bag. Therefore, replacing gloves with hand hygiene at critical points would reduce opportunities for contamination of the infusate. Alcohol based hand gel has been identified as being required after packs are opened, before disinfection of the hub and if disconnection is required, prior to administration of a flush before the disconnection.

New step – confirm no critical surface contamination

In addition to the checks of dosage and precipitation, an additional cognitive step of the nurse reflecting on the procedure and considering and confirming that there was no critical surface contamination before proceeding to administer, would again add to patient safety. Fixing the cross-reaction check at this point would introduce consistency.

Changed step - when checks are performed

In other areas the first set of checks are performed before the drug preparation steps of the procedure begin. In this ward with the reconstitution device the checks are done as a single set of checks (Figure 43). This is patient safe as the drug vials remain attached to the infusate and the person checking can be assured that what is used to prepare the drug. The amended procedure places the checks

before the drug preparation because, when the reconstitution device cannot be used, this is when the patient safety checks should occur.

All the new steps are highlighted in Figure 43 and the entire procedure with colour-coded steps is shown as Figure 44.

Figure 43 How the procedure could be improved on the 4th ward

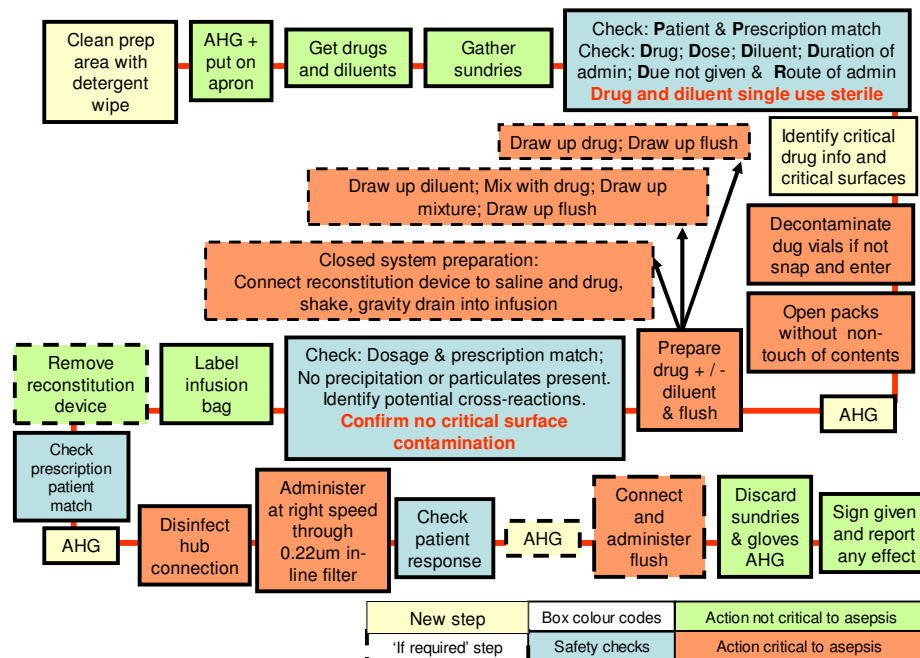
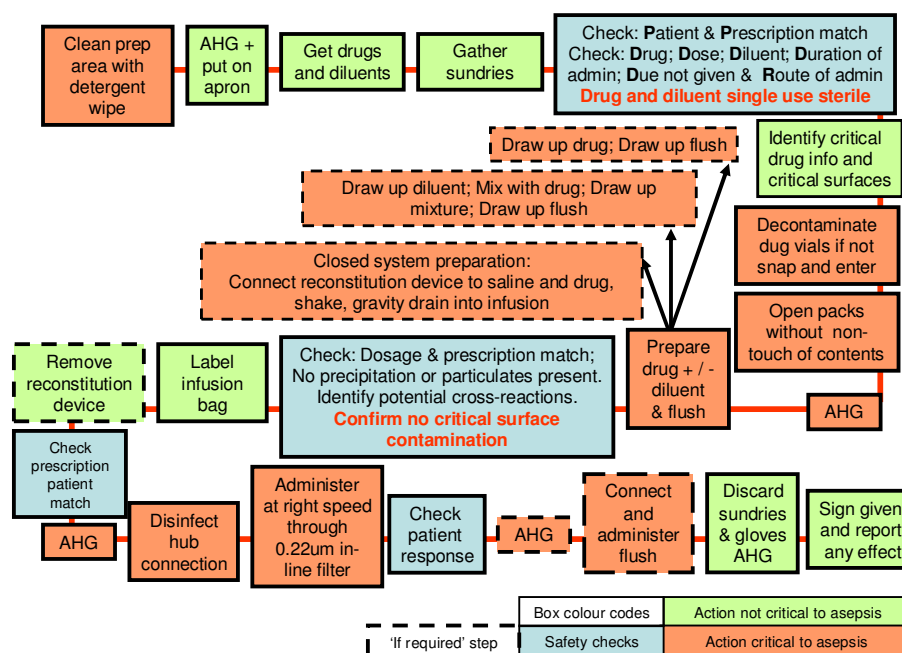


Figure 44 Colour-coded amended procedure on the 4th ward



The ward staff have been recently informed that as a cost-saving measure they should no longer require use in-line filters. Therefore, these assessments are only valid at the time of writing.

8.5.5 Data Stream 4 – Procedure comparisons 4th ward

This ward did have procedures; they were of an older type (circa 1996) and did not include the equipment or procedure being followed; that is, preparation with a reconstitution device, and thus direct comparison could not be made. This older type of procedure was the closest of all the study wards to clear guidance on how to perform an aseptic procedure. Another anachronistic aspect of the procedure which made it outmoded is the reference to hand washing, when the evidence

suggests that alcohol based hand gels are as effective and less irritant to the nurses' skin.

8.5.6 Data Stream 3 – HCWs' Opinions on Safety 4th ward

A total of 15 questionnaires on the HCWs' opinions of safety and redundancy checks were issued to all the nurses who prepared intravenous drugs on the 4th study ward; 8 (53%) were completed. A repeat reminder was issued to the ward manager via email – which resulted in 2 questionnaires being received and these have been included in the total. A summary of these data are given in Appendix 10. The responses to the statements for this ward are as follows:

Statement 1 - When preparing IV drugs it is easy to prevent asepsis failure

No respondents disagreed with this statement and the majority 7/8 respondents (88%) agreed that on this ward it is easy to prevent asepsis failure. On this ward with the use of reconstitution devices this statement is correct. The closed system used for the majority of drugs make it easy to prevent asepsis failure.

Statement 2 - When preparing IV drugs it is easy to detect asepsis failure

There was a less uniform response to the second statement. Two nurses strongly agreed that it was easy to detect asepsis failure, and 2 disagreed with it. Four respondents (50%) neither agreed nor disagreed with the statement. Whilst it is easy to detect an obvious contact contamination microbial contamination, it is not easy to detect contamination from other sources, such as the environment.

Statement 3 – The procedures for preparing IV drugs on this ward are simple

Seven of the 8 respondents (88%) stated that the procedures for preparing IV drugs on the 4th study ward are simple. With the use of the reconstitution device, the observations made by the researcher concur with these opinions.

Statement 4 – The resources on this ward make it easy to prepare IV drugs safely

All 8 respondents (100%) agreed with this statement that the resources on the ward make it easy to prepare IV drugs. Again this probably refers to the availability of the reconstitution device.

Statement 5 – The environment on this ward makes it easy to prepare IV drugs safely

There was less agreement with regard to the environment on the 4th ward. Four respondents (50%), neither agreed nor disagreed and a further 4 nurses were equally divided in agreeing and disagreeing with the statement that the environment make it easy to prepare IV drugs safely. These responses reflect the environment available for preparing drugs. The ward manager has tried to create a safe environment – but it is a small, shared space.

Statement 6 - On this ward distractions and interruptions make it difficult to prepare IV drugs safely

Once again with there was a disagreement with responses to the statement. Four respondents (50%) agreed with the statement that distractions and interruptions make it difficult to prepare IV drugs. However, an equal number disagreed with the statement. It is possible that certain nurses, for example, the nurse in charge are more likely to be interrupted as holders of the ward keys.

Statement 7 – I get feedback on the quality of my IV drug preparation

All the respondents on this ward were in agreement with this statement, in stating that they did not get feedback on the quality of their IV drug preparation.

Statement 8 – I would feel uncomfortable raising safety concerns regarding preparing of IV drugs on this ward

There were positive responses to this statement with 7/8 respondents (88%) disagreeing with this statement; therefore the nurses on this ward would feel comfortable in raising concerns regarding the preparing of intravenous drugs on the 4th study ward. No one agreed with the statement.

Statement 9 – I can mix drugs on this ward without distraction or interruption

Only 2 respondents (25%) agreed with this statement, 4 (50%) strongly disagreed with it stating they could not prepare IV drugs without distraction or interruption. This concurs with the responses to statement 6.

Statement 10 – Asepsis failure when preparing IV drugs is a safety priority on this ward

The most frequent response 4 (50%) to the statement on to whether asepsis failure is a safety priority on the ward was neither agreement nor disagreement. Three respondents (38%) agreed that it was a safety priority and the remaining response was disagreement. This may have been explained by the lack of performance data on the efficacy of the procedure and by the lack of outcome data (catheter related blood stream infection data).

Statement 11 – If I recognised an error in my IV drug preparation I would report it

Critical for patient safety, all the respondents on this ward 8/8 (100%) stated that if they recognised a drug error in their drug preparation they would report it.

Statement 12 – There is good support to those who have to prepare IV drugs

Again critical for patient safety, and in spite of a challenging environment, no respondents disagreed with the statement on good support being available on the ward for those who prepare IV drugs.

Statement 13 – To improve patient safety I am encouraged to report errors

There was no disagreement with this statement and the most popular response 4/8 (50%) was strong agreement, that is, to improve patient safety the nurses on the ward were personally encouraged to report errors to improve patient safety.

Statement 14 – I find preparing IV drugs is stressful

Although 2/8 (25%) respondents stated they strongly disagreed, 2 also stated that they agreed with the statement and found it stressful. This might reflect practice, competence and / or confidence with the procedure. It might also however, reflect that even when the procedure is at its simplest with the use of a reconstitution device, because of the potential consequences to patients and to themselves, the procedure is stressful for some nurses.

Statement 15 – Preparing IV drugs gives me job satisfaction

On this ward no respondents found preparing IV drugs gave job satisfaction. The reasons for this are unclear and no background comments related to this were made. It is possible that the reconstitution device, in reducing the procedure to as safe and simple as it can be in a ward setting, leaves the nurse with little to get satisfaction from.

8.5.6.1 Additional comments provided

“Time constraints forcing haste. Time and personal constraints generally prohibit double checking the administration of IV drugs (excluding heparin and insulin infusions). Preparation is always double checked for drug / dose / expiry. ”

“If I check an IV drug with a colleague I usually don’t stand and watch them make it up (unless I’m training them). It’s the duty of the individual nurse to ensure the procedure was aseptic.”

8.5.7 Review of the opinions of safety on the 4th ward

Because of the use of reconstitution devices and in-line filters, the responses on this ward with regard to the HCWs safety opinions were more in agreement with the researcher; for example, it was easy to prevent asepsis failure on this ward. The overall scores as positive and negative indicators of a safety culture are listed below.

Positive opinions of safety related to this procedure include:

- It easy on this ward to prevent asepsis failure (Statement 1)
- The procedures for preparing drugs are easy on this ward (Statement 2)
- The resources on the ward make it easy to prepare IV drugs (Statement 3)
- Willingness to raise concerns and report personal errors (Statement 8 and 11)
- Encouragement to report errors (Statement 13)

Negative opinions of safety related to this procedure:

- It is difficult to detect asepsis failure (Statement 2)
- The environment does not make it easy to prepare IV drugs (Statement 5)
- Distractions and interruptions do not make it easy (Statements 6 and 9)
- There is no feedback on performance (Statement 7)
- The procedure for some is stressful (Statement 14)
- Preparing IV drugs does not give satisfaction (Statement 15).

8.5.8 Summary results from the 4th ward

The nurses on this ward do not use drugs or diluents in multi-dose vials that increase the risk of contamination and do use equipment that would reduce contamination. Should contamination occur, an in-line filter capable of protecting the patient is used even the infusate is administered over a long period. The system is double-defended. Although the ward has thus far the smallest preparation area available, the nurse in charge tried to make the area and procedure as safe as possible, for example by use of the splash protection guard. The main recommendation on this ward is to clean the area before preparation begins and to consider replacing gloves with repeated hand hygiene at designated steps. There are several indicators of a good safety culture, including all the respondents saying that the resources make it easy to prepare IV drugs safely. Although this ward has the safest procedure reviewed thus far, they have been told to stop using filters to reduce cost and therefore this procedure will not be as safe or well defended in the future.

8.6 Results from the 5th ward – a neonatal intensive care unit (NICU)

Data Stream 1 – Location Assessment (5th ward)

Data Stream 2 – Observation of Intravenous Drug Preparations (5th ward)

Contamination risks in the 5th ward procedure

How to reduce potential contamination in the 5th ward

Data Stream 4 – Procedure comparisons (written with observed)

Data Stream 3a – Opinions of Safety (5th ward)

Study took place on Thursday 15th October 2009

Researcher Evonne Curran

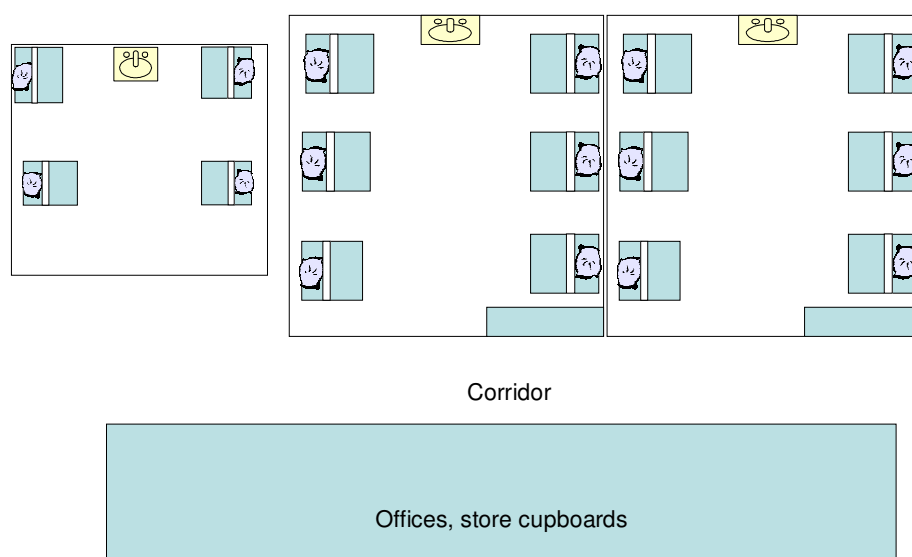
8.6.1 Data Stream - 1 Location Assessment 5th ward

The data for the Location Assessment were obtained by interview with the ward manager and from the researcher's observations during the study period.

The unit and the patients they care for

This unit is a specialist neonatal intensive care unit (NICU) which cares for very small babies with a wide range of critical illnesses requiring medical and surgical interventions. Babies are not admitted to the NICU for being low-birth weight as such but rather, when specialist medical or surgical interventions are required after delivery of low-birth weight babies. The unit provides a variety of national and tertiary services including extracorporeal membrane oxygenation (ECMO). The unit provides regional cardiac services. The NICU comprises two 6-cot bays and one, 4-cot bay NICU (Figure 106).

Figure 45 The layout of the 5th ward



What vascular devices are used for intravenous drug administration?

A variety of vascular access devices are used to administer intravenous drugs including: central vascular catheters, umbilical catheters, peripherally inserted central catheters and peripheral vascular catheters.

Approximately how many intravascular drugs are prepared in the unit?

A baby in the NICU could require between 10-12 drugs per day. An average of 10 babies requiring this volume of drugs would give rise to approximately 100 intravenous drugs per day and approximately 36,500 intravascular drugs requiring preparation within the unit each year.

What intravenous drugs are prepared and administered?

A variety of different intravenous drugs are required by the babies including: analgesia, anti-coagulants, steroids, heparin, sedation, antibiotics and cardiac drugs.

Does the unit use drugs associated with infusate sepsis?

The unit does use drugs associated with causing sepsis. Many drugs are infused over long time periods (>12hrs). Drugs such as heparin and lipids, which promote microbial growth, are also used.

Are any of the intravenous drugs prepared from multi-dose vials?

The unit does not use drugs from designated multi-dose vials. Sometimes, because of the small volumes used from a prepared drug vial, there is considerable volume of paediatric drug dose remaining. In such instances, if another patient were on the same drug at the same time, the ampoule would be re-used. This can be achieved without additional risk to the second baby, though technically the drug mix would be designated single-use.

How long are the vascular access devices in situ for?

As venous access is both difficult and critical for the babies in this unit, there is no planned routine replacement of catheters on this ward.

Who prepares intravenous drugs for administration in the NICU?

Any registered nurse, who has been through the approved NHS Greater Glasgow and Clyde training programme and has completed their assessment and examination, including a rigorous calculation test, can prepare and administer drugs on this ward.

Is there a stable team that prepares and administers the intravenous drugs?

Yes. There is a core team of long-term staff on the ward who have been deemed competent for sometime in intravenous drug preparation. The unit has become even larger recently due to amalgamation with another neonatal unit.

Are all the team familiar with all the intravenous preparing procedures?

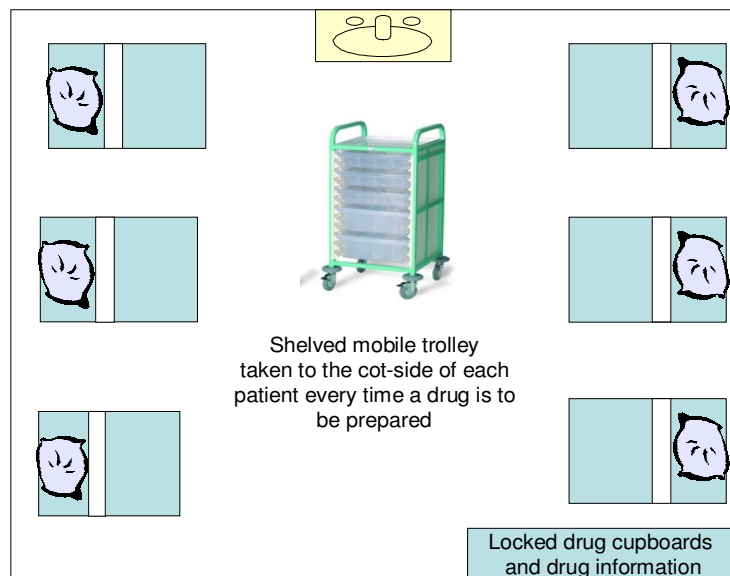
By the time the nurses are deemed competent their records should show that they have experience in preparing the wide variety of drugs required by babies on the neonatal intensive care unit.

Are there any drugs which NICU staff do not prepare?

The unit staff can if required, add drugs to parenteral nutrition but not to the lipid preparations. Due to the increased risk with intrathecal drugs, such drugs are also not prepared by unit staff.

Where are the intravenous drug preparation procedures performed?

Figure 46 The drug preparation area in the 5th ward



The drug preparation procedures are performed on a mobile trolley which is used for one procedure, cleaned and then available for the next procedure (Figure 46). Drugs are dispensed from cupboards in the 6-cot area. These drug cupboards are topped up from a central store daily.

What written procedures are available?

The following instructions are available in the neonatal intensive care unit.

Guidelines to safe administration:

- Medical prescriptions must contain the prescribed medicine dose to be infused appropriate for weight.
- Calculations of the drug must be done by 2 nurses independently.
- Expiry dates of the drug and diluent must be checked.
- The nurse must check the prescription has not already been administered.
- The drug must not be administered if it is not free of particulates.
- The drug must be of the correct quantity.
- The line must be patent.

‘A strict aseptic technique must be followed for all drug preparations to be given via central venous catheters.

Aseptic technique must be used for all peripheral catheters’.

The ward manager stated that all intravenous drugs were given using a strict aseptic technique regardless of the catheter type.

There was no specific written procedure for a 'strict' or (non-strict) aseptic technique available on the ward. Drug information sheets detailing: diluents, pH, osmolarity, compatibilities and incompatibilities were available for all drugs used in each of the 3 rooms where the patients were nursed and where the drugs were prepared and administered.

Displayed Poster Information

There are a few posters on hand hygiene within the 6-cot areas but, as this is a small patient area rather than an overt clinical preparation area, the poster displays are more limited.

How often are the drug procedures and drug information referred to?

The nurses often refer to the drug information sheets.

Are the intravenous drug preparation procedures generic and drug specific?

The drug information sheets are drug specific. However as stated previously, there are no specific written procedures available to detail how to prevent contamination of the infusates.

Do the intravenous drug preparation procedures include problem identification and if <this situation> then <that> action?

No such presentation of information is available.

What other procedures are done in the preparation areas?

Apart from surgical procedures, all procedures are performed at the cot-side. However, while drug procedures are being performed no other procedures are ongoing for individual patients.

What team operation support is there?

There is good team support from within the unit and support from the ward pharmacist.

Is the lighting good, making it easy to see for reading instructions within the unit?

The lighting is good. However, to prevent the babies becoming irritated by the light and to facilitate a calm atmosphere, lighting is sometimes dimmed. (This can affect the ability of the nurse to visualise clearly the drug amount, presence of particulates or precipitation during checking procedures).

What, if any, performance measures are available?

There are no catheter-related blood stream infection (CR-BSI) data as yet. The unit is not yet taking part in the Scottish Patient Safety Programme.

What in-ward operator performance monitoring is done?

All intravenous drug preparation procedures are done with 2 nurses in attendance throughout. There is therefore no opportunity to do other than follow the accepted procedure.

What monitoring is done outside the ward?

The microbiology department undertakes routine laboratory based surveillance of all blood stream infections – this is not sufficient to facilitate CR-BSI surveillance.

What, if any, self-assessment of performance is done?

The unit is not as yet participating in the Scottish Patient Safety Programme. They are aware of their infection challenges related to blood stream infections. These are CR-BSI due to coagulase negative staphylococci. No specific data on this was available.

How frequently are drug errors reported?

According to the ward manager all errors are reported. No specific data was available.

8.6.2 Data Stream 2 - Observations of drug preparations 5th ward

How many procedures were observed?

In a full ward, a total of 11 procedures were observed involving 19 drugs. Although no timing measures were done, the procedures on this ward seem to take longer and involve more manipulations and more cross-checking than any procedure observed thus far.

What procedures were observed?

The intravenous drug preparations included:

Antibiotics: vancomycin, metronidazole, cefotaxime, gentamicin,

H₂ antagonists: ranitidine, Analgesia: paracetamol, morphine

Sedatives: Midazolam, Diuretics: furosemide

How variable are the procedures?

The procedures do not vary extensively. Drug volumes are comparatively small and the babies' veins delicate; therefore the procedures all involve careful calculations and dilution. Although the procedures in the neonatal unit are more involved they are not more variable.

How is the intravenous drug procedure performed?

The procedures on this ward are undertaken by 2 nurses throughout; one IV preparation nurse and one nurse assisting.

The procedure is performed as follows:

- The work surface of the trolley is cleaned using a detergent wipe.
- Sundries and drugs are gathered from the shelves of the trolley below the locked drug cupboard within the 6-cot area.
- The initial set of checks is done to determine that the drug can be prepared from the collected drugs, diluents and sundries. The two nurses check that:
 - The prescription matches the name of the patient.

- The Drug [including expiry date], Dose [calculated independently by 2 nurses], the Diluent [including expiry date], that the drug is Due and has not been given, the Duration of administration and that the Route prescribed is intravenous.
- Labels are written.
- A sterile pack containing a sterile towel is opened and tipped onto the cleaned trolley surface. The sterile towel is opened to cover the trolley surface. Table 10 shows how the procedure is performed with 2 nurses taking turns to progress the procedure.

Table 10 How a 2 person non-interrupted procedure is performed	
IV Preparation Nurse	Assistant Nurse
Put on apron	
Wash hands	Hand hygiene
	Open sterile gloves on to trolley surface
Put on sterile gloves	
	Open all sterile contents and tip on to trolley surface
Connect syringes to needles	
	+/- decontaminate bung, or snap vial top
	Present vial or ampoule
Aspirate drug without touching	



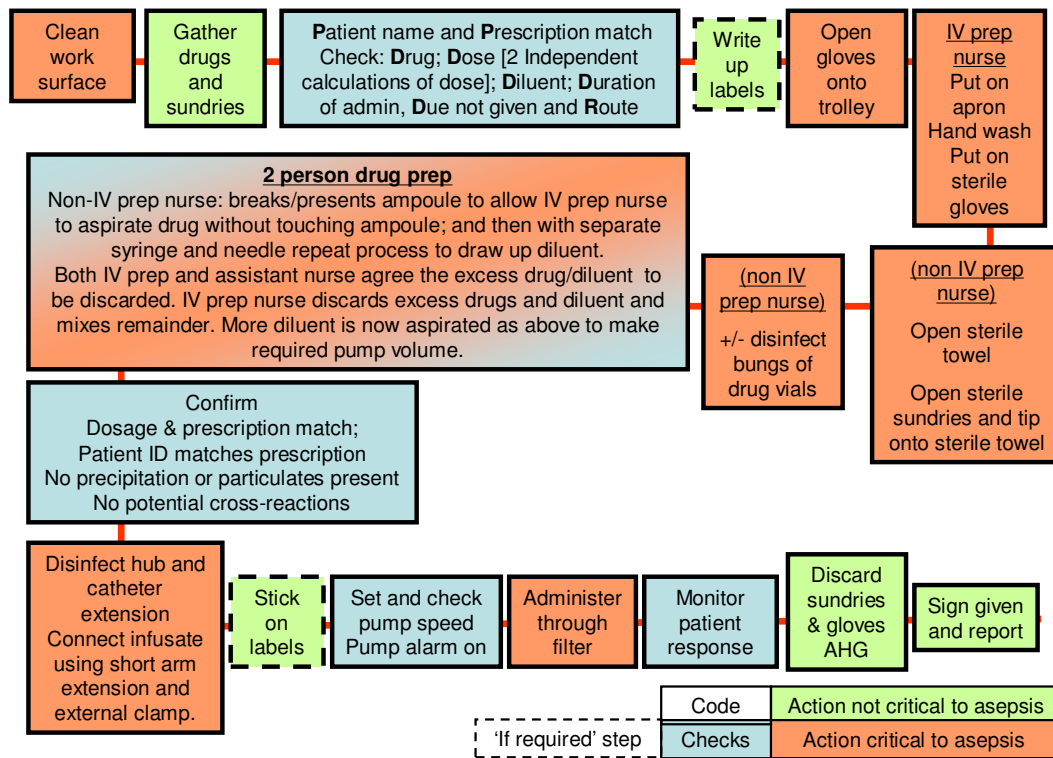
Table 10 How a 2 person non-interrupted procedure is performed	
IV Preparation Nurse	Assistant Nurse
outside of vial/ampoule	
Both nurses agree the excess drug over the prescribed dose to be discarded.	
Discard excess drug.	
Both nurses confirm correct drug volume in syringe	
	Snap diluent vial
	Present vial
Aspirate diluent without touching outside of vial	
Both nurses agree the amount of diluent to be discarded.	
Discard excess diluent	
Both nurses confirm excess diluent discarded	
Mix drug and diluent in same syringe	
Both nurses then agree the amount of mixed drug to be discarded.	
Discard excess mixed drug	
Both nurses agree the correct volume of mixed drug in the syringe	
	Present vial
Aspirate diluent to the remaining drug to dilute to the finished infusion volume.	
Both nurses then complete a second set of checks	

Table 10 How a 2 person non-interrupted procedure is performed	
IV Preparation Nurse	Assistant Nurse
<ul style="list-style-type: none"> • The dosage and prescription match • The prescription matches the patient's identification • There are no particulates or precipitation in the infusion • There are no potential cross-reactions with the concurrent infusions. 	
Disinfect hub, catheter extension and catheter near the hub, connect infusion	
Stick on label	
<p>Both nurses agree the speed and settings of the infusion pump.</p>	

- Unless the drug is a lipid, the administration is through a filter.
- The patient remains continuously monitored.
- Sundries are discarded.
- Personal Protective Equipment is removed.
- Hands are decontaminated.

This procedure is illustrated in Figure 47.

Figure 47 The drug preparation procedure on the 5th ward



Was there distraction during the intravenous drug preparation procedures?

The nurses who performed the above procedures were all focused on the trolley, its contents and the prescription. There were no observed interruptions. These nurses remained alert throughout, in particular to alarm calls from the various monitors. There are several notices pertaining to the need to create and maintain a calm environment for the benefit of the babies.

Is the required equipment needed close at hand?

All the required equipment is on the trolley. With two nurses present throughout, the assistant forgetting a syringe or needle does not negate or interrupt the aseptic procedure, as the IV preparation nurse is always ably assisted.

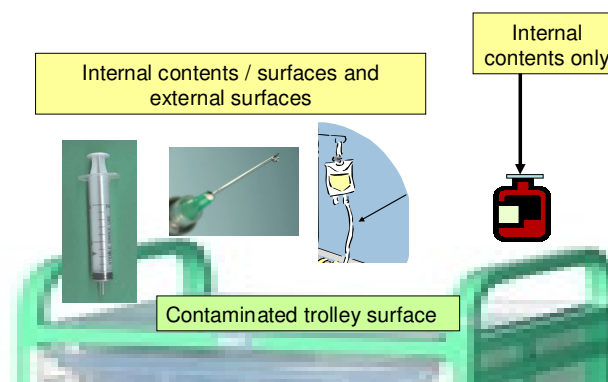
8.6.3 Contamination risks in the 5th study ward procedure

Figure 6 is also applicable in this ward, and illustrates how long it takes for infusate contamination to cause symptomatic infection in patients. With Figure 6 as a guide, the procedures and data from the Location Assessment will be examined for their error-prone and reliability status. To do this, there is first an analysis of what is sterile/non-sterile, and of the critical parts of the equipment during preparation and immediately prior to administration.

What is sterile and non-sterile at the start of the procedure?

Figure 48 illustrates the sterile and non-sterile surfaces and materials used in the neonatal intensive care unit.

Figure 48 The sterility of equipment at the start of the procedures (5th ward)



.At the start of the procedure the sterile products are:

- All syringes, needles, administration sets, sterile trolley cover.
- The internal contents of the drug vials.

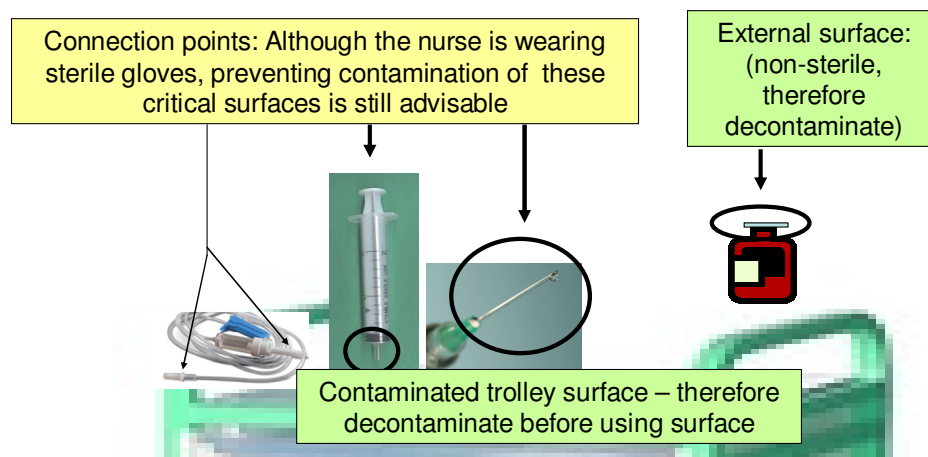
The non-sterile products at the start of the equipment are:

- The external surface of the drug vials and the trolley surface.

During the procedure, what are the critical surfaces that, if contaminated or not decontaminated, will prevent aseptic preparation?

The critical surfaces during preparation are the connection points of the top of the syringe and the metal part of the needle that will come into contact with the drug. These surfaces should not be touched, or in the case of the drug ampoules, should be decontaminated (Figure 49).

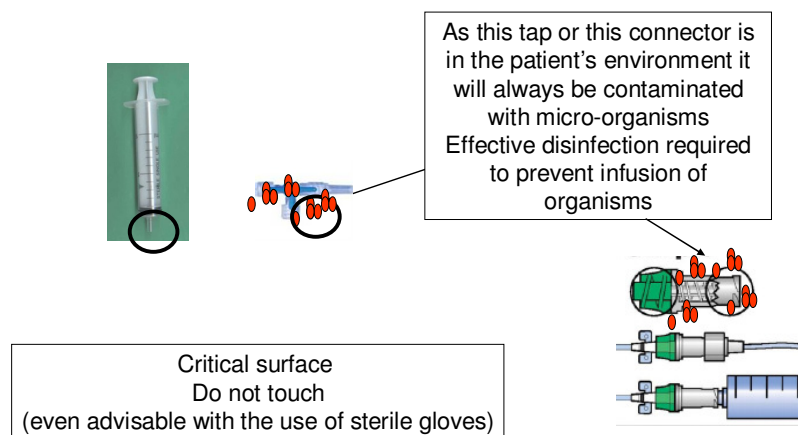
Figure 49 The critical surfaces during the procedure (5th ward)



Immediately before administration, what are the critical surfaces that must be protected from contamination or decontaminated?

Immediately before the administration of the drug, the critical surfaces are the hub, the tip of the syringe and the needlefree device (Figure 50). As the needlefree device is attached to the patient, it must always be considered to be contaminated and covered with (at least) coagulase negative staphylococci, the leading cause of catheter related blood-stream infections.

Figure 50 The critical surfaces just before administration 5th ward



Is the equipment used for intravenous drug preparation procedures free from environmental splash contamination?

There is no possible splash from a sink during drug preparations.

Does the equipment aid the process of maintaining sterility of the infusate?

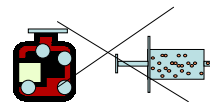
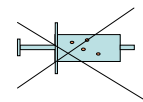
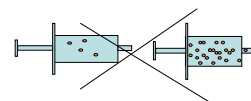
Although not everyone decontaminated the rubber vial tops, all of the equipment employed, was used in a way to prevent asepsis failure and to prevent the disruption of an aseptic procedure. The filter used is a paediatric 96hr in-line filter, capable of removing microbial contents and endotoxins.

What are the intravenous drugs at highest risk contamination for the 5th ward?

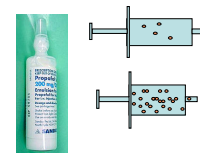
Assuming the filter remains functioning throughout the duration of all infusates, the drugs at highest risk of contamination are lipids (Figure 51). These drugs cannot be filtered and are excellent growth media for micro-organisms.

Figure 51 The limited drugs that pose an infusate risk (5th ward)

Full aseptic procedure – including decontamination of vial tops and use of a filter, negates risk of contamination of the infusate.



Contamination of Lipid Drugs during preparation
Lipid drugs and infusions promote microbial growth and any open manipulation could result in contamination. The longer the infusion, the greater the opportunity for single organisms to become millions within 24 hours. Lipids cannot be infused via filters.

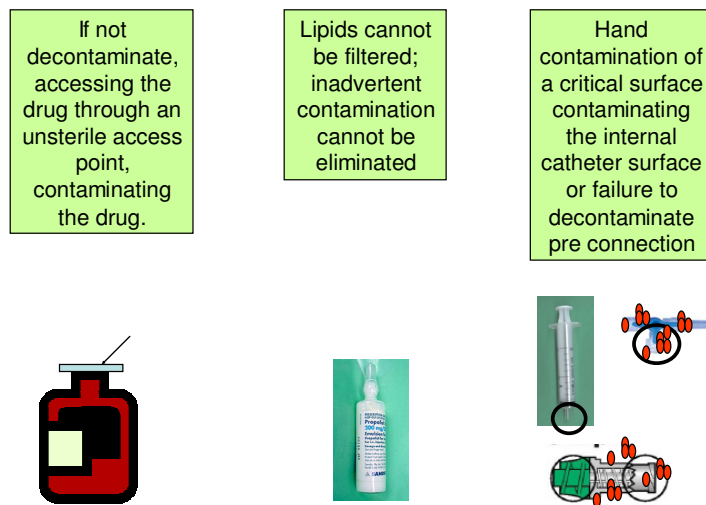


Where is the procedure likely to produce errors in aseptic preparation?

Figure 52 illustrates the stages of the procedure at which contamination is most likely to occur, these are:

- Accessing the sterile drug through a non-sterile access point with resulting contamination of the drug.
- Preparing lipid drugs.
- Immediately prior to administration.

Figure 52 When is contamination of the infusate most likely to occur?



8.6.4 How to reduce potential contamination risks in the 5th ward

This procedure can be classified as:

A 2-person, uninterrupted aseptic procedure performed at the cot-side

Because of the comparatively tiny patients, this procedure requires more manipulations and is far more complex than adult procedures. Some steps are done independently, for example, the independent drug calculations. Possibly due to the nature of paediatric drug doses, there appears to be no reconstitution devices or other similar equipment that could reduce the open nature of the procedure or the number of drug manipulations.

The procedure is single-defended by an in-line filter but should be and is performed aseptically as though the filter is not present. The use of two persons enables the aseptic procedure to be performed uninterrupted.

As the procedure is performed on a sterile surface and all equipment is free from touch contamination, there is no requirement for an additional identification of the critical surfaces. The only recommended changes to this procedure are as follows:

New step - add hand hygiene after cleaning of trolley surface

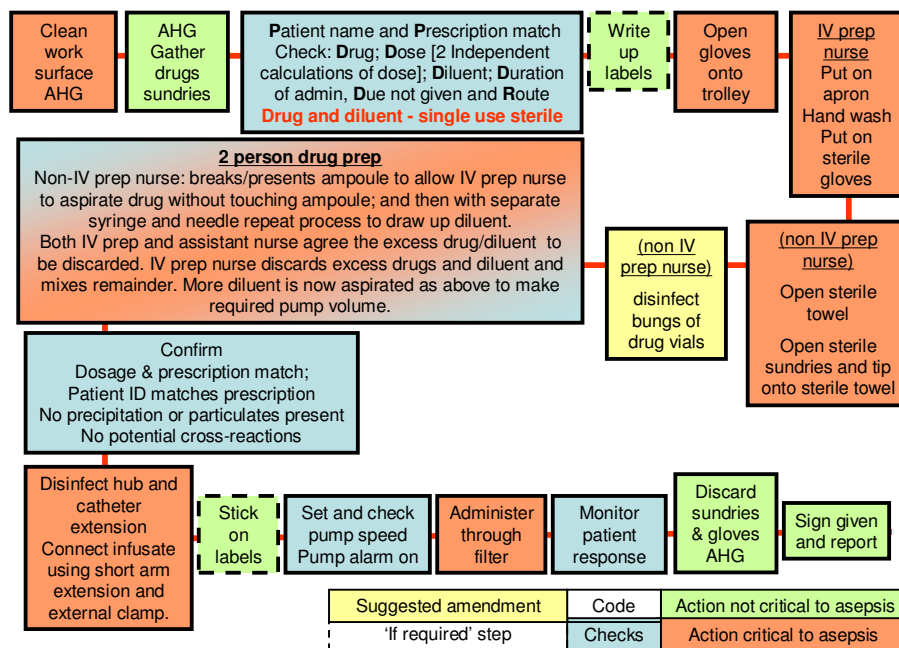
Although there is less opportunity on this ward for the trolley surface to be contaminated with environmental organisms, hand hygiene after the trolley surface

is cleaned will ensure that the procedure will not result in hand contamination and subsequent cross-contamination of equipment, the environment or the patient.

New step - always decontaminate vial tops

Although there is an in-line filter, always decontaminating the vial top would increase the reliability of this procedure. There is no indication that the filter is working. The drug could be inadvertently connected before the filter. The altered procedure is shown as Figure 53.

Figure 53 Procedure on the 5th study ward with suggested amendment



New step - add confirmation of sterility of drug and diluent

For further patient safety, add a confirmation that drug and diluent are single-use sterile prior to preparing drugs.

Consideration of lighting modification

To aid the nurses checking drug information, consider additional trolley lighting for when there is dim lighting in the unit for the comfort of babies.

8.6.5 Data Stream 4 – Procedure comparisons 5th ward

This is one of the 4 data streams; this question could not be answered as there were no written procedures which specify the aseptic procedure.

8.6.6 Data Stream 3a – Opinions on Safety 5th ward

A total of 45 questionnaires were issued to staff in the NICU who were competent or in training for competency in intravenous (IV) drug preparation; a total of 18 (40%) responses were received. A summary of these data are given in Appendix 11. The results to the statements on safety are given below

Statement 1 - When preparing IV drugs it is easy to prevent asepsis failure

Most of the respondents 15/18 (83%) agreed with the statement on the ease of preventing asepsis failure on this ward. This is not surprising since it is a 2-person, uninterrupted aseptic procedure. Only 1 person disagreed with this statement.

Statement 2 - When preparing IV drugs it is easy to detect asepsis failure

A high proportion of staff 13/18 (72%) thought it easy to detect asepsis failure. Obvious errant contact failures are easy to detect, but micro-organisms being invisible to the naked eye, asepsis failure is, in fact difficult to detect.

Statement 3 – The procedures for preparing IV drugs on this ward are simple

Fewer than half 8/18 (42%) thought that preparing IV drugs on the ward was simple. The procedures on this ward were the most complex of all the observed procedures. Nevertheless, only 3 respondents disagreed with the statement.

Statement 4 – The resources on this ward make it easy to prepare IV drugs safely

Nine of the 17 respondents [53%] (1 non-response) thought that the resources on the ward made it easy to prepare IV drugs safely.

Statement 5 – The environment on this ward makes it easy to prepare IV drugs safely

Only 6 respondents (33%) agreed with this statement. There were no comments as to what in particular within the environment increased the risk to their drug preparation procedures. The researcher observed light – or the lack of light – as posing a potential risk. Further exploration of this may be useful.

Statement 6 - On this ward distractions and interruptions make it difficult to prepare IV drugs safely

Seven of the 18 respondents (39%) agreed with this statement. The most popular response was to neither agree nor disagree with the statement.

Statement 7 – I get feedback on the quality of my IV drug preparation

Sixteen of the 18 respondents (89%) disagreed with this statement. Feedback on individual performance of IV drug preparation is not provided.

Statement 8 – I would feel uncomfortable raising safety concerns regarding preparing of IV drugs on this ward

Most of the respondents 14/18 (78%) disagreed with this statement; that is they would feel comfortable in raising safety concerns on the ward. However, 4 (22%) respondents stated they would feel uncomfortable raising safety concerns.

Statement 9 – I can mix drugs on this ward without distraction or interruption

Ten of the 18 respondents (56%) disagreed with this statement (Figure 117). They stated that they could not prepare IV drugs without interruption and distraction. The responses to this statement mirror the responses to statement 6.

Statement 10 – Asepsis failure when preparing IV drugs is a safety priority on this ward

Fifteen of the 18 respondents (83%) agreed with this statement. No respondents disagreed with it. What was observed in practice agrees with these responses.

Statement 11 – If I recognised an error in my IV drug preparation I would report it

Thirteen of the 18 respondents (72%) strongly agreed with this statement. Only 2 respondents disagreed with it.

Statement 12 – There is good support to those who have to prepare IV drugs

Only 8 of the 18 respondents (44%) thought that there was good support to those who prepare IV drugs. Three respondents disagreed with the statement.

Statement 13 – To improve patient safety I am encouraged to report errors

The majority of respondents 11/18 (61%) agreed with this statement, that they were encouraged to report errors. Three respondents did not feel that this was the case.

Statement 14 – I find preparing IV drugs is stressful

Only 2/18 (11%) of respondents found IV drug preparations stressful; this is surprising considering the complex nature of the procedures, the consequences of any error to the patient and their family and, of course, to themselves. Stress may

have been reduced because they use a 2-person, non-interrupted aseptic procedure.

Statement 15 – Preparing IV drugs gives me job satisfaction

Almost as many respondents agreed as disagreed with this statement. Six of 18 respondents 33% stated that did not get job satisfaction from preparing drugs and only 5/18 (28%) agreed. Clearly the respondents do not work in the NICU because they prepare IV drugs, but for some of the nurses it is in spite of the fact that they have to prepare IV drugs.

8.6.6.1 Additional comments on the questionnaire

“IV drug prep/admin is stressful when there is not enough experienced staff on duty. Also not having enough decent equipment, for example, pumps, is a real pain. So time the drug administration is like juggling balls. Availability of the medical staff to take levels is also an issue.”

“Experienced neonatal nurses generally know when a dose which has been prescribed is not within normal and will check this using formulary if it seems high/low. Every dose of every drug would not be checked in this way.”

“There are now differences in the way each ward makes up their drugs and infusions even though there is a monograph, there is a difference between PD + NICU and ITU.”

8.6.7 Summary of the safety opinions on the 5th ward

The responses to the statements indicate some positive indicators of safety as well as negative indicators. The opinions of safety which are negative indicators are as follows:

- Asepsis failure is considered easy to detect when, in fact, it is not easily detected (Statement 2).
- The procedures themselves are not simple (Statement 3).
- The staff do not feel the environment makes it easy to perform IV drug procedures safely (Statement 5).
- There is no individual feedback on performance (Statement 7).
- The majority of nurses feel that they cannot prepare IV drugs without interruption or distraction (Statements 6 and 9).
- Some nurses who prepare IV infusions do not feel that they are well supported (Statement 12).
- Not everyone feels encouraged to report errors (Statement 13).
- The nurses do not derive job satisfaction from the procedure (Statement 15).

The positive indicators of safety from the statements are:

- Most feel it is easy to prevent asepsis failure (Statement 1).
- Staff stated they have good resources on the ward to prepare IV drugs (Statement 4).
- The majority would feel comfortable raising safety concerns (Statement 8).
- Asepsis failure is felt to be a safety priority on the ward (Statement 10).
- The majority of staff would report an error if they identified it (Statement 11).

- In the main it is not a stressful procedure (Statement 14).

8.6.8 Summary results from the 5th ward

The procedure on this ward is performed differently to the previously 4 study wards in that 2 nurses perform the procedure together. The 2 nurses performing the procedure become, as far as is possible, oblivious to the world outside and concentrate on the multiple manipulations and calculations required to ensure the correct drug and an aseptic infusate. The only environmental risk is from a lack of light, created for patient comfort. There was no additional risk from equipment and no multi-dose drugs or diluents are used. The system is defended by filters. Again however, and much to the surprise of the nurse manager, there are no written step-by-step aseptic procedures. The main safety concerns on this ward relate to the complexity of the procedure required to achieve a safe and correct drug, and not all the nurses feel supported.

8.7 Results from the 6th ward – a medical receiving cardiology ward (MRCW)

Data Stream 1 – Location Assessment (MRCW) 6th ward

Data Stream 2 – Observation of Intravenous of Drug Preparations (MRCW)

Contamination risks on the 6th ward procedure

How to reduce potential contamination risks in the 6th ward

Data Stream 4 – Procedure comparison (written and observed) (MRCW)

Data Stream 3a – Opinions of Safety (MRCW) 6th ward

Study took place on Tuesday 27th October 2009 and Saturday 23rd January 2010

Researcher Evonne Curran

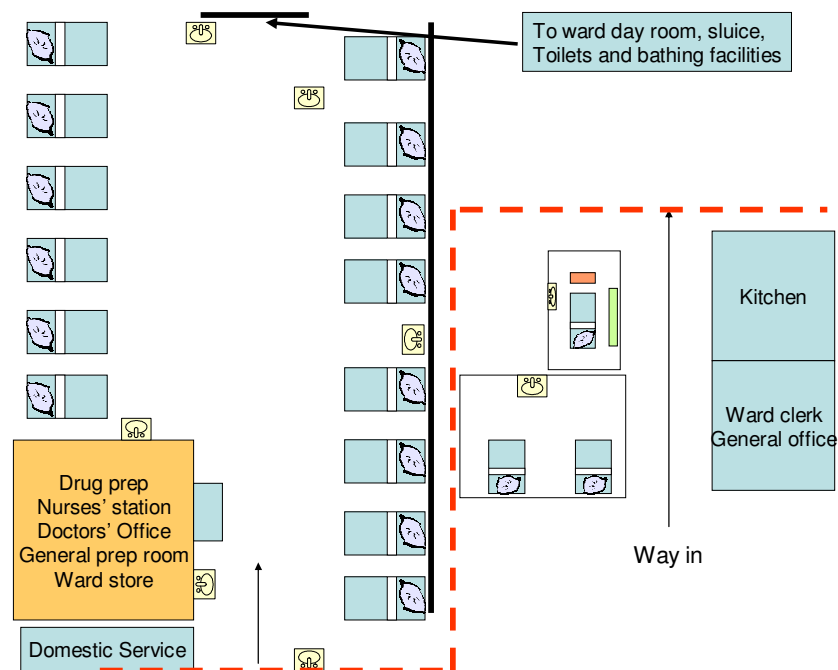
8.7.1 Data Stream 1 - Location Assessment 6th ward

The data for the Location Assessment were obtained by interview with the ward manager and from the researcher's observations during the study period.

What patients does the unit care for?

The ward is a 17 bed medical receiving cardiology ward. Fourteen beds are in Nightingale position, there is one cubicle (not en-suite) and one room of two beds (Figure 54). The population comprises emergency admission patients with chest pain following myocardial infarct, patients for angiogram, patients awaiting transfer to the Golden Jubilee hospital before cardiac surgery and the same patients on return from cardiac surgery.

Figure 54 The layout of the 6th ward



What vascular devices are used for intravenous drug administration?

The main vascular access devices used to administer drugs are peripheral vascular catheters. Some patients have central vascular catheters (CVCs). Individual patients on this ward do not require long-term vascular access and the drugs used are not highly-irritant to veins. Peripherally inserted central catheters (PICCs) are occasionally used.

Approximately how many drugs are used per day?

On an average day approximately 40 drugs are required by the patients on the ward. This is highly variable – there are days when no drugs are required (the first, second and third planned visit dates were postponed as there were no required drugs for intravenous administration).

What intravenous drugs are prepared and administered?

The main intravenous drug groups used and administered to patients are: cardiac drugs, inotropic drugs, glycerol trinitrate, antibiotics, insulin, anticoagulants, (for example, heparin), analgesia, (for example, morphine) and paracetamol.

Does the unit use drugs associated with infusate sepsis?

Heparin, morphine and insulin are given via long-term infusion pumps of over 12 hours duration which, if they are even minimally contaminated, makes them vulnerable to becoming highly contaminated over the lifetime of the infusion. There

is no use of lipid drugs (such as propofol) which are known to promote microbial growth. The heparin and insulin infusions are prepared from multi-dose vials.

How long are the vascular access devices in situ for?

The PVCs are in situ for a maximum of 72hours. CVCs would be left in situ with no set removal time.

Is there a stable team that prepares and administers the intravenous drugs?

Yes. All the nurses on the ward are currently trained in the preparation and administration of intravenous drugs.

What mentoring is done?

Staffing levels do not permit 1:1 mentoring, although there is supervision when required. (At the time of the visit, all staff had been deemed competent in drug preparation).

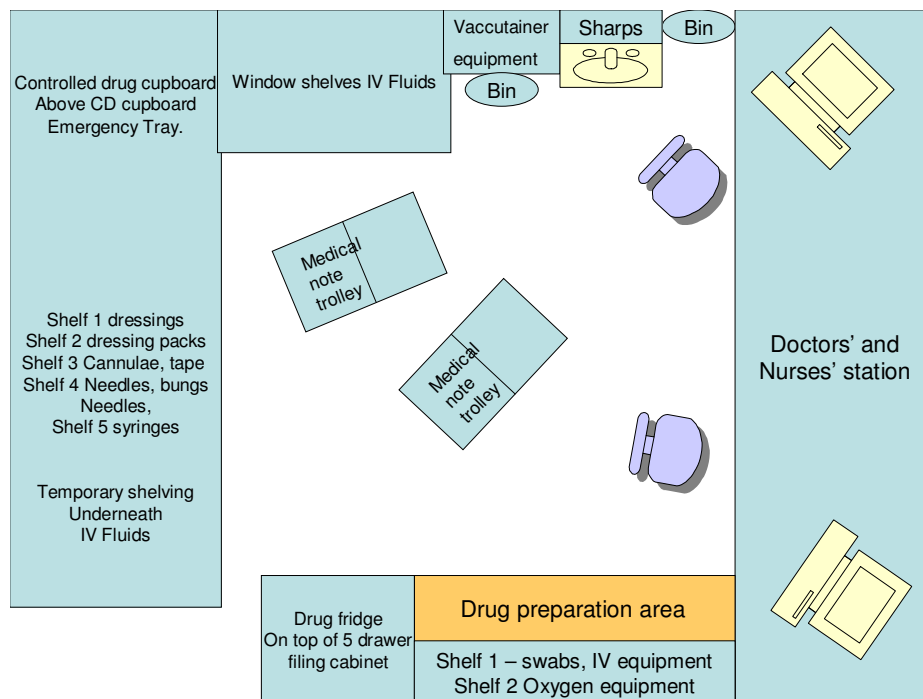
Are all the team familiar with all the intravenous preparing procedures?

Yes. Once competent, the nurse can prepare and administer all the drugs in the IV Drug Monographs Folder held within the ward. (There are 153 drugs listed in this folder).

Where are the IV drug preparation procedures done?

The intravenous drugs are prepared in a multi-purpose area of a combined nurses' station, doctors' station, drug preparation area, sundry storage, patient note trolley storage and general preparation area (Figure 55). As a consequence of the above, the Drug Preparation Area is visibly clean - but cluttered.

Figure 55 The multi-purpose room where drugs are prepared (6th ward)



Are there any written procedures?

There are a few general guidelines and intravenous drug monographs, but according to the ward manager there are no written procedures showing or illustrating how to make up intravenous drugs using an aseptic procedure. There is information on the use of reconstitution devices, but this has not been included

here as these devices have been removed from the ward. There is also information on the 153 drugs in the ward formulary, but none relate to asepsis.

The folder containing the information on the 153 drug monographs includes the following disclaimer:

Disclaimer

The information within the document has been carefully written and reviewed by a team of pharmacists and practice development representatives within the Southern General Hospital and the Victoria Infirmary. However no responsibility can be accepted for any errors or omissions within the document. It is assumed that the users possess the necessary training skills and competence to interpret this information appropriately and to obtain information appropriately and to obtain specific advice when necessary.

This 6th and final study ward had the least available resources in terms of environment and equipment. This disclaimer, in effect, says that if the authors got it wrong it's the fault of the person using the information and not of those writing it. This is an example of blaming frontline workers for active failures caused by latent conditions and does not to the researcher seem reasonable.

The standard warning on each monograph is as follows:

All vials and ampoules and infusions are for single-use only unless otherwise stated.

Administer reconstituted medicines immediately.

There is no information provided on infection risk.

What posters are available in the generic preparation area?

There are a total of 57 posters, the highest number in all of the study wards, in the generic preparation area. There is no poster detailing how to ensure asepsis during intravenous drug preparation.

How often are the procedures referred to?

The nurses frequently refer to the individual information on drugs regarding the compatibility of the drug and the method of administration.

Are the intravenous drug preparation procedures generic and drug specific?

The information sheets are drug specific.

Do the intravenous drug preparation procedures include problem identification and if <this> then <that> action?

The only information provided in this format is a generic:

'If unsure then ask.'

What other procedures are done in the preparation areas?

There is no restriction of concurrent procedures being performed when a nurse is preparing intravenous drugs. The full range of possible procedures is as follows:

Preparation of dressings, catheters or other aseptic technique

Controlled drug checking and preparation.

Intramuscular drug checking and preparation.

Office bustle including telephone calls (nursing and medical)

Writing up of notes.

Reviewing of X-rays on the computer.

The preparation room is seldom empty. As the ward is a receiving ward, activity can increase rapidly; at such times numerous intravenous drug preparations will be required immediately, there will also be lots of admissions, lots of note writing, specimen sending, relatives calling and general healthcare activity.

What team operation support is there?

The ward manager feels there is little support here, from management or pharmacy staff.

Is the lighting good making it easy to see to read instructions within the unit ?

Yes – there are no lighting problems.

What, if any, performance measures are available?

The ward is not yet taking part in the Scottish Patient Safety Programme. At present the ward has no performance measures, such as catheter related blood stream infection data, with which to judge performance.

What in-ward operator performance monitoring is done?

The drug preparation area is small and cluttered; although the ward manager tries to keep an overview of all her staff, it is difficult to do this when the observation of intravenous drug preparation is obscured by other concurrent activities.

What, if any, information is available during the preparation of intravenous infusion and how situation aware is the nurse?

The nurse preparing the drug can tell the amount of drug and diluent being prepared, what drug / dose is required and whether there is undissolved drug or particulates such as visible glass particles. The only information unavailable to the nurse is the sterile or non-sterile nature of the drug and the diluent.

What monitoring is done outside the ward?

None.

What, if any, self-assessment of performance is done?

There is no ongoing self assessment of performance. Unlike other wards, the paucity of space makes it extremely difficult to watch the person preparing drugs.

How frequently are drug errors reported?

No data were available on reported drug errors.

8.7.2 Data Stream 3 - Observations of Drug Preparations 6th ward

How many procedures were observed?

On the first visit of 6 hours no intravenous drugs were prepared.

During a second visit - 3 intravenous drugs were prepared the total number of intravenous drugs on that shift.

What procedures were observed?

The following procedures were observed:

Antibiotics: Amoxicillin; metronidazole

Analgesics: Paracetamol

How variable are the procedures?

The ward manager feels the drug procedures are not particularly variable. A narrow set of drugs is commonly used – despite the 153 monographs in the folder.

How is the intravenous drug procedure performed?

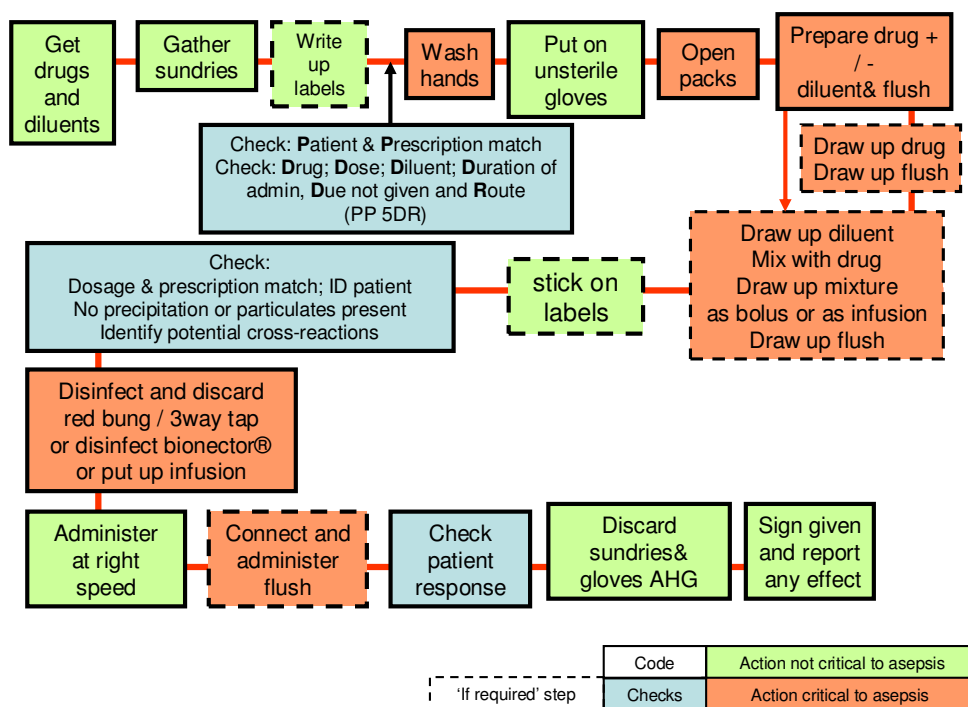
Figure 56 shows the process of intravenous drug preparation as observed and reported, after observations stopped (at the time the nurse was ready to go to the bedside).

- The nurse collected the drugs and diluents and sundries to prepare the infusate.
- The label is written for application to the infusate immediately the drug is prepared.
- The nurse checks with a colleague that the Patient and Prescription details matched those for whom the infusate is being prepared, and that it is the correct drug, diluent, the planned duration of administration, the route and that the drug is due and had not been given.
- The nurse washes her hands and puts on non-sterile gloves.
- The nurse opens the packs, syringes and needles.
- The top of the rubber vials are flipped off and accessed without decontamination.
- The drug is mixed with a prepared diluent.
- The drug and diluent are then injected into a 100ml infusion bag.
- The written label is then applied to the bag.

The next part of the procedure was not observed as per the ethics submission but reported to take place as follows:

- The needlefree access bung was disinfected (alcohol wipe).
- The administration speed was checked.
- A flush solution would be administered if required.
- The patient's response was checked throughout.
- Sundries were discarded and hands decontaminated
- Documentation was then completed.

Figure 56 The drug preparation procedure on the 6th ward



Was there distraction during the intravenous drug preparation procedures?

At this point in time (Saturday 5pm) the ward was quiet and there were no distractions. It was clear, however, that the need for intravenous drugs on this ward was highly unpredictable.

Is the equipment needed for intravenous drug preparation procedures close at hand?

Yes. The equipment is all kept within the generic preparation area (Figure 55).

8.7.3 Contamination risks in the 6th ward procedure

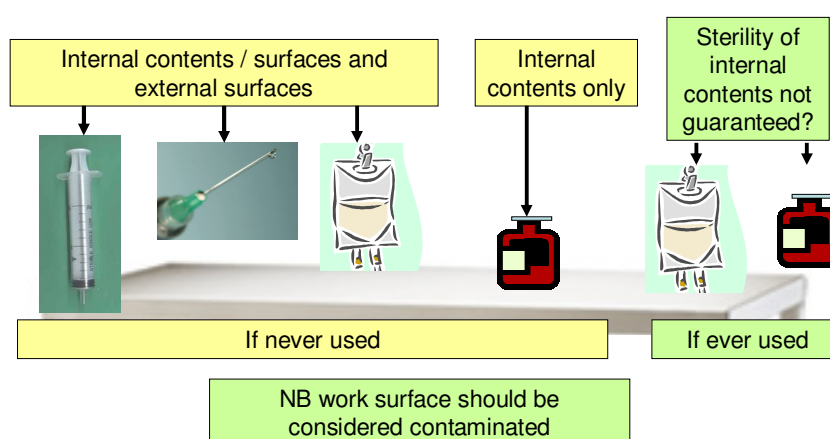
Figure 6 is again applicable for this ward; this illustrates how infection could arise from contamination of either equipment or infusate and shows the length of interval before this is likely to become apparent, that is, over days or weeks if contamination starts as a biofilm or, almost immediately if there is heavy infusate contamination.

What is sterile and non-sterile at the start of the procedure?

Figure 57 illustrates the sterile and non-sterile surfaces and materials used in the 6th ward. The sterile surfaces/materials are:

- The internal contents of any diluents
- The external and internal surfaces of sterile needs and syringes
- The internal contents of single-use vials (that have been used once).

Figure 57 At the start of the 6th ward procedure, what is sterile?



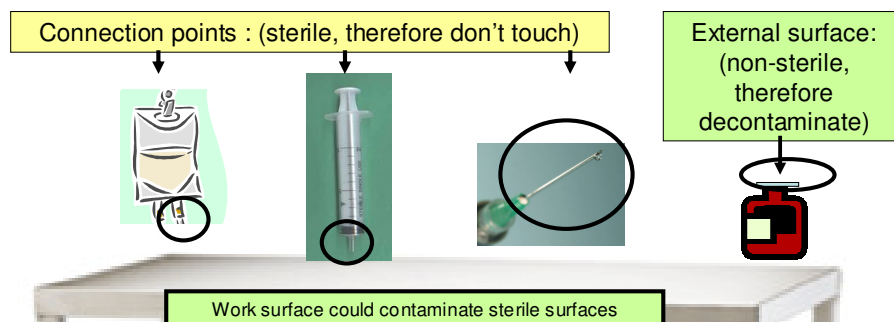
The non-sterile materials/surfaces are:

- The surface on which the procedure is performed
- Internal contents of multi-dose vials
- The external surface of rubber topped vials

What are the critical surfaces that, if contaminated or not decontaminated, will prevent aseptic preparation?

Figure 58 illustrates what should be avoided at the start of the procedure and what is contaminated and requires decontamination. The work surface requires decontamination before the procedure commences. Surfaces on the top of vials also require decontamination. If ever the sterile contents cannot be guaranteed they should not be used.

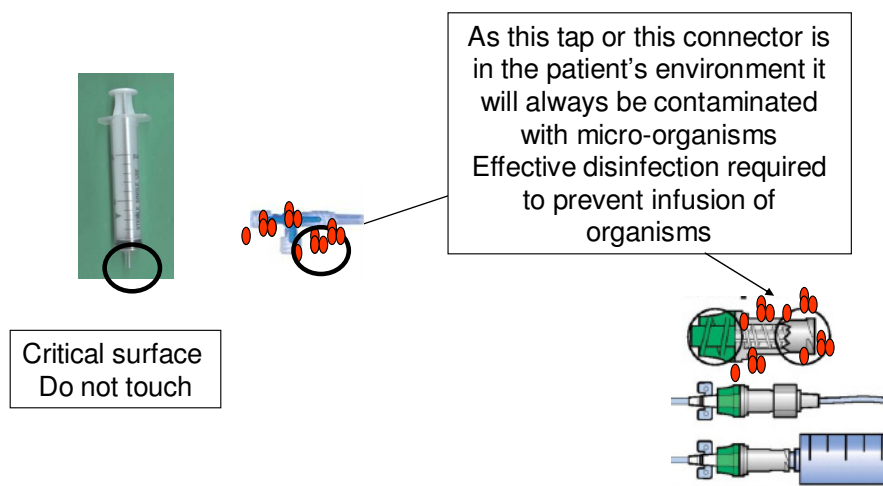
Figure 58 Critical surfaces during the procedure in the 6th ward



Immediately before administration what are the critical surfaces that must be protected from contamination or decontaminated?

Immediately before the administration of the drug, the critical surfaces are the hub, the tip of the syringe and the 3-way tap on the end of the catheter (Figure 59). As the 3-way tap is attached to the patient, it must always be considered to be contaminated and to be covered with (at least) coagulase negative staphylococci, the leading cause of catheter related blood-stream infections.

Figure 59 Critical surfaces immediately prior to administration (6th ward)



Is the equipment used for intravenous drug preparation procedures free from environmental splash contamination?

There is a sink, which could create splash, in the same multi-purpose area where the drugs are maintained – no splash was seen during the observations.

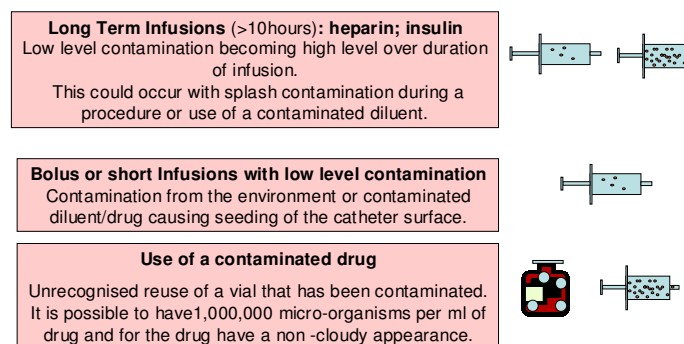
Does the equipment aid the process of maintaining sterility of the infusate?

Multi-dose vials increase the risk of infusate contamination on this ward. These vials are mainly used for heparin infusions.

What are the intravenous drugs at highest risk contamination for the 6th ward?

The high-risk drug preparations are the infusions of >12 hours duration or longer. These pose a risk of sufficient time for heavy growth of micro-organisms from an original contamination of a very few organisms. Such infusions on this ward would include heparin and insulin. Figure 60 illustrates the drugs and drug preparations at highest risk of contamination.

Figure 60 The drugs at highest risk of contamination on the 6th ward

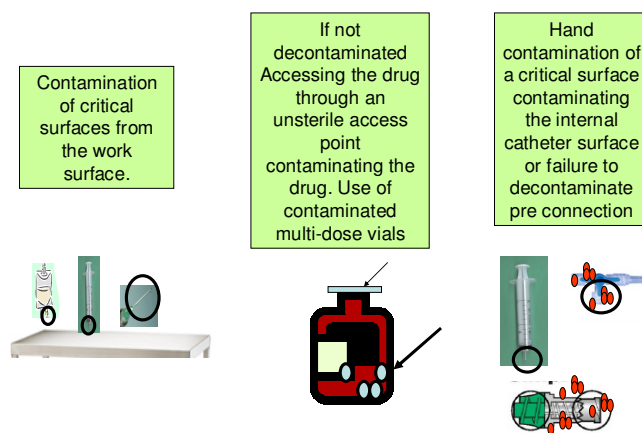


Where is the procedure likely to produce errors in aseptic preparation?

There are three parts of the procedure which are likely to cause contamination. Firstly, the non-decontamination of the work surface area could lead to potential contamination of the critical surfaces. Secondly, failure to decontaminate rubber

vial surfaces could lead to contamination of the drug. Repeated access and use of multi-dose vials would contaminate the drug and thus the infusate. Lastly, failure to decontaminate the needle-free device / catheter hub will lead to infusion of organisms along with the infusate.

Figure 61 During what steps of the procedure is contamination possible



8.7.4 How to reduce potential contamination risks in the 6th ward

The researcher questions whether, regardless of changes to the procedure, the preparation of intravenous drugs could be performed safely in this ward environment. Assuming, therefore, that a suitable place could be found, the following amendments are suggested to increase patient safety.

This procedure as observed was:

A single person, interrupted aseptic procedure performed with a checker.

The main suggestions for change in this procedure (apart from a change of the environment), are a reordering of steps, an increase in hand hygiene, decontamination of the work surface at the start of the procedure and decontamination of rubber vial tops (Figure 62). These changes are indicated as yellow steps in the written procedure. The reason for these changes is to reduce the likelihood of contamination from equipment and hands.

Increase of hand hygiene is suggested, as opposed to the use of gloves, as the gloves can become contaminated and, once contaminated, cannot be decontaminated. If gloves are being used to prevent skin contamination with drug, then using them immediately before accessing the drugs would prevent skin contamination. Removing them after this step, and using alcohol hand gel after all non-aseptic steps, would allow completion of an aseptic procedure.

Due to the lack of space on this ward, the infusates are extremely vulnerable to contamination; therefore as previously used in this ward reinstating reconstitution devices would clearly reduce the risk of contamination by closing the procedure and reducing the opportunities for contamination, such as occur when a syringe and ampoule are open to airborne contamination. Stopping the use of multi-dose vials would significantly reduce the risk of infusate contamination. The same drugs

are available in non-multi-dose vial format in other wards within the NHS board. Confirming at the start of the procedure, that all drugs and diluents are single-use sterile could be done to confirm this.

The procedure, as witnessed, contains the elements of an aseptic procedure but it is not performed as one. By following the reordering, adding the hand hygiene, and by confirming that drugs and diluents are single-use sterile the contamination risk would be reduced. Significant risk reduction would be added by performing the procedure in a better environment with adequate space.

Colour-coding the written procedure, as discussed with the other study wards, will identify for the nurses the points at which the aseptic procedure is interrupted, and consequently, where hand hygiene is required. Figure 63 shows the modified written procedure with the changes colour-coded to show clearly when there is an interruption in asepsis and, consequently, a need to restart the aseptic procedure with hand hygiene.

Figure 62 Suggested modified procedure for reliability in the 6th ward

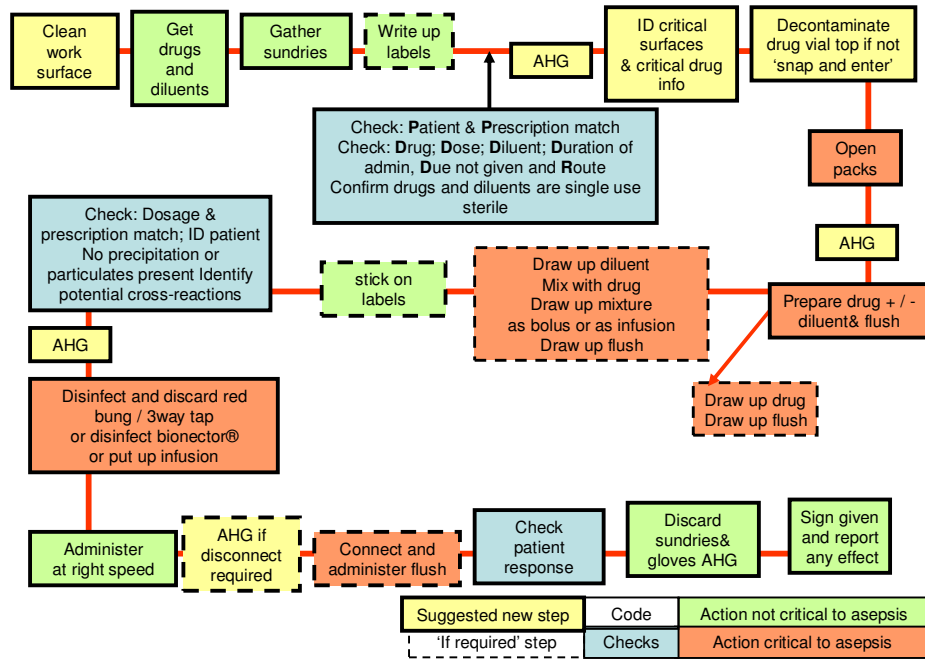
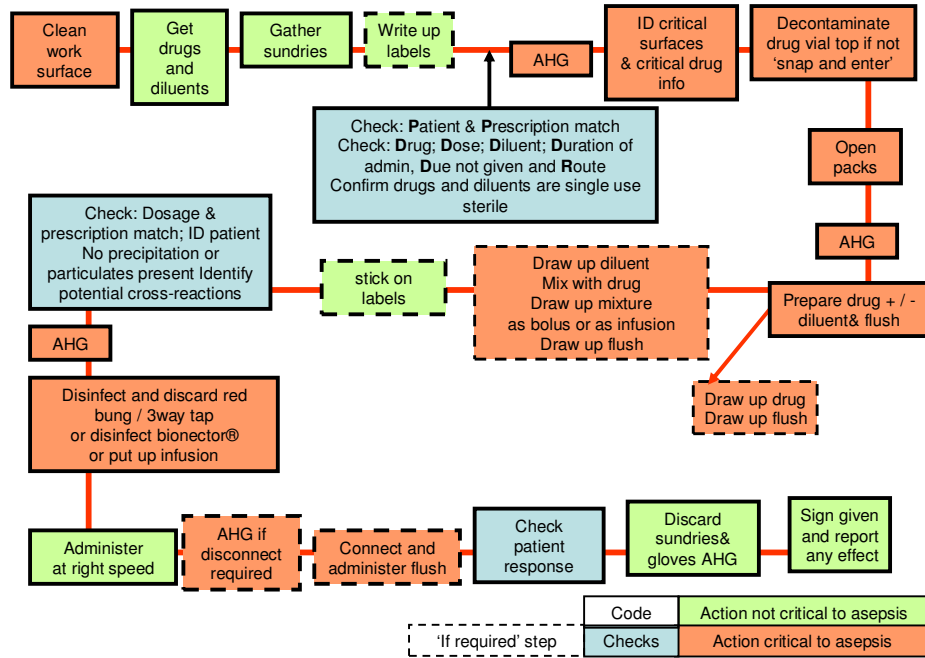


Figure 63 Colour-coded amended procedure for the 6th ward



8.7.5 Data Stream 4 – Procedure comparisons 6th ward

This analysis could not be undertaken because there are no written procedures which included the aseptic steps available on the ward.

8.7.6 Data Stream 3a – Opinions of Safety 6th ward

As on all the study wards and in compliance with the ethics submission, the manager was given the questionnaires to disseminate to her staff who are deemed competent to prepare and administer intravenous drugs. The questionnaires were contained with a letter of introduction and information regarding the research and a stamped addressed envelop. I was informed there 'were about 15' staff who could prepare and administer drugs. The ward manager appeared willing to disseminate the information to her colleagues. Only 2 questionnaires were returned completed. During the second visit, a repeat sample of 15 forms, letters, stamped addressed envelopes was left and the senior staff nurse assured me they would be distributed to all those who could prepare intravenous drugs. No further responses were received.

This ward was the least rich in resources and equipment space. This ward's procedure was least rich in steps for asepsis, for example, the surface, small though it was, was not cleaned before the procedure began, a plastic apron was not worn and, non-sterile gloves were used, but it was unclear why. It is possible that the nurses were not prepared to state when they did and did not do

redundancy checks, as this would implicate their practice as being poorer than others. The following information was gained from the 2 respondents:

- The respondents differed in how difficult they thought it was to prevent asepsis failure (one considered it difficult, one neither agreed nor disagreed)
- Both agreed strongly that it was easy to detect asepsis failure
- Both agreed strongly that the procedures on the ward were simple
- Both agreed strongly that the resources on the ward made it easy to prepare IV drugs safely
- Both agreed strongly that they were encouraged to report errors
- Both agreed that distractions and interruptions made it difficult to make up drugs safely [concurred with statement 9]
- Both agreed strongly that they did not get feedback on their performance
- Both agreed that asepsis failure a priority on the ward
- Both agreed strongly that they would report errors
- Both agreed strongly that they are encouraged to report errors
- Differed in finding the procedure stressful (one strong agreement one neither agreed nor disagreed)
- Differed in the degree of job satisfaction from the procedure (one strong agreement and one selected neither agree nor disagree).

8.7.7 Summary results from the 6th ward

The infusates in this ward are at a higher risk of contamination because of the environment, the procedures and the equipment. There is a risk from environmental splash from a nearby sink, the multi-purpose room is inadequate in size and creates multiple distractions when it is busy. Long-term infusions are prepared from multi-dose vials and there is a lack of defences. Safety equipment (reconstitution devices) has been removed. Additionally, there are no filters used. Of all the study wards, this ward is least rich in terms of resources, equipment and facilities. One of the reasons for volunteering to be included in the study was, according to the manager, 'the hope of better facilities'. On this ward, only 2 nurses completed the opinions of safety questionnaire; this is perhaps not surprising, given the paucity of facilities and the equipment available to them. There are no data available to the ward staff to indicate their level of performance.

8.8 Comparative results on redundancy checks from 5 study wards

The questionnaire on opinions of safety also contained the questions on redundancy checks, Appendix 3b. The respondents were asked whether they 'always, sometimes or never' performed a redundancy check at various stages of the procedure. There were 71 respondents from the six study wards. The data is analysed by ward. On the 6th study ward only 2 questionnaires were returned and therefore this data was deemed too unrepresentative to analyse separately and unsuitable for adding to another ward's data for analysis.

The redundancy checks were divided into three categories as follows:

- mandatory checks of right drug, right dose, right diluent and right patient
- technical checks related to the infusate being free from precipitation and particulates and the infusion being administered at the right speed
- asepsis checks including the aseptic access of the ampoules or vials, decontamination of catheter hubs, hand hygiene and glove use as well as a catch-all of the overall procedure being performed aseptically.

The numbers of respondents in each ward varied (range 7 – 19). Larger numbers of responses were from wards where more nurses were able and required to give intravenous drugs; specifically the adult and neonatal ICUs. The response rates for individual wards have been presented in the individual ward results for Data

Stream 3a. The responses agree with the researcher’s observations, suggesting that what is reported as being done equates to what is actually done. It is possible that the nurses would perform differently when the researcher was not present, but given the number of procedures observed, this is considered unlikely. The results are presented in a table of the average percentage of the ‘always’ responses in each of the categories; mandatory checks, technical checks and aseptic checks. Figures 64-68 show the responses to each opportunity for a redundancy checks in the 5 study wards with sufficient responses.

Table 11 The percentage of redundancy checks ‘always done’

	Percentage of redundancy checks always done				
	1st ward	2nd ward	3rd ward	4th ward	5th ward
Number of questionnaires on redundancy checks	n = 17	n = 7	n = 19	n = 8	n = 18
Mandatory checks (4)	85%	54%	97%	75%	100%
Technical checks (4)	51%	28%	57%	56%	94%
Aseptic checks (5)	18%	10%	29%	28%	90%

χ^2 square test not valid

The key points from these results are:

- The highest frequency of ‘always done’ redundancy checks is of the mandatory checks (range 54-100%). Only one ward, the NNICU, (the 5th study ward), performed 100% of the mandatory checks. This is a non-interrupted 2-person aseptic technique.
- The second highest frequency of ‘always done’ redundancy checks if of the technical checks (range 28-94%). Again the highest number of checks was in the 5th study ward.

- The lowest frequency of 'always done' redundancy checks is of the asepsis checks, (range 10-90%).
- The 2 person non-interrupted aseptic procedure performed on the 5th study ward is the only procedure with 100% of reported 'always done' mandatory redundancy checks.
- All patients in the 2nd ward are in cubicles and this explains why there is a lower number of reported redundancy checks on the patient in this ward – average of always done mandatory redundancy checks – 54%.

8.8.1 Summary of the redundancy check comparisons

The number of steps in the procedure of aseptic preparation of intravenous drugs makes it difficult, if not impossible, to perform a redundancy check at every opportunity. What these results show, however, is that aseptic steps are not considered as high a priority as the mandatory or technical redundancy checks, and unless a 2 person uninterrupted procedure is undertaken they do not get performed.

These results also show that the environment, for example all patients being in single rooms, can affect whether a redundancy check of 'right patient' is done.

Figure 64 Stated Redundancy Checks in the pilot ward

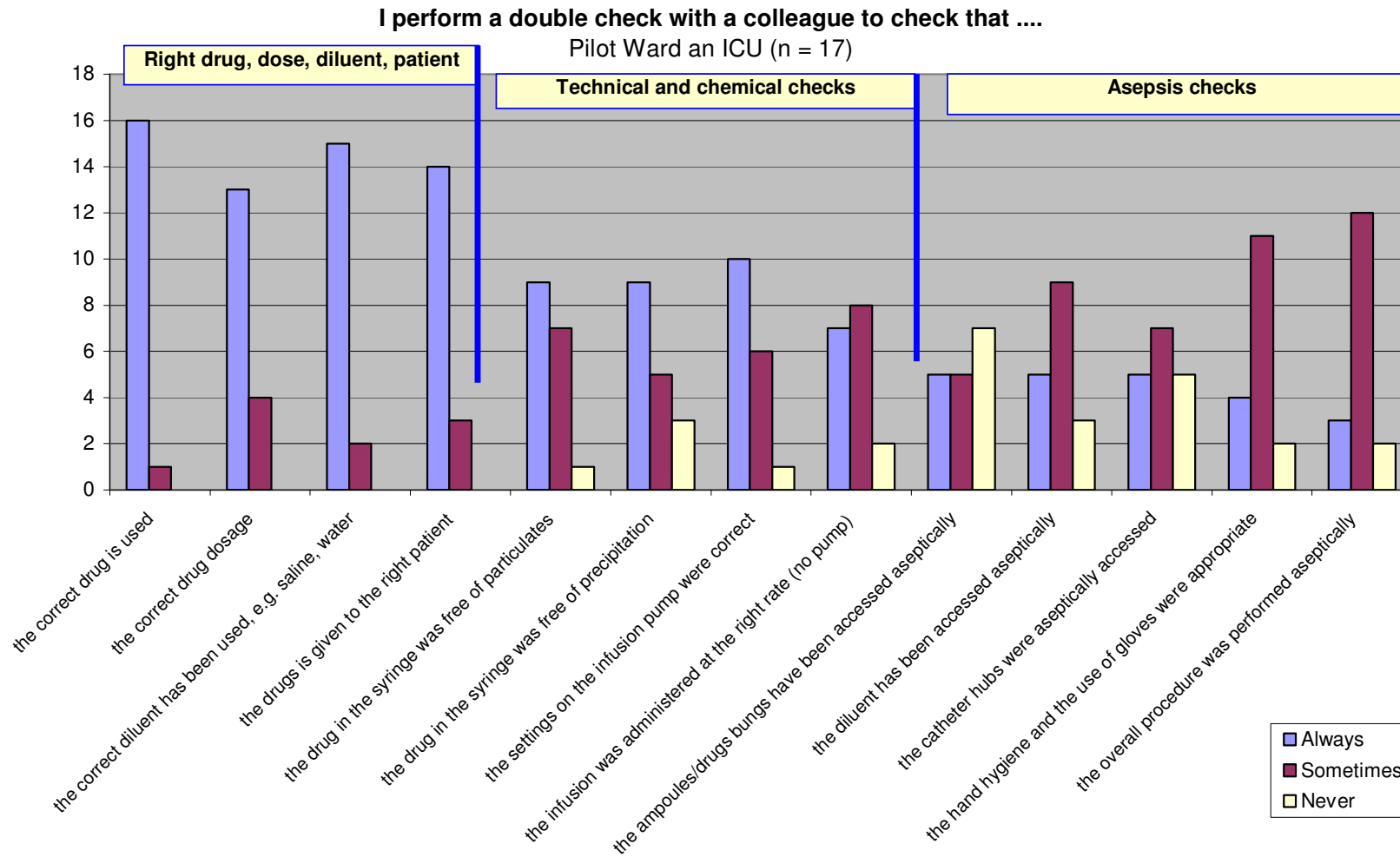


Figure 65 Stated Redundancy Checks in the 2nd ward

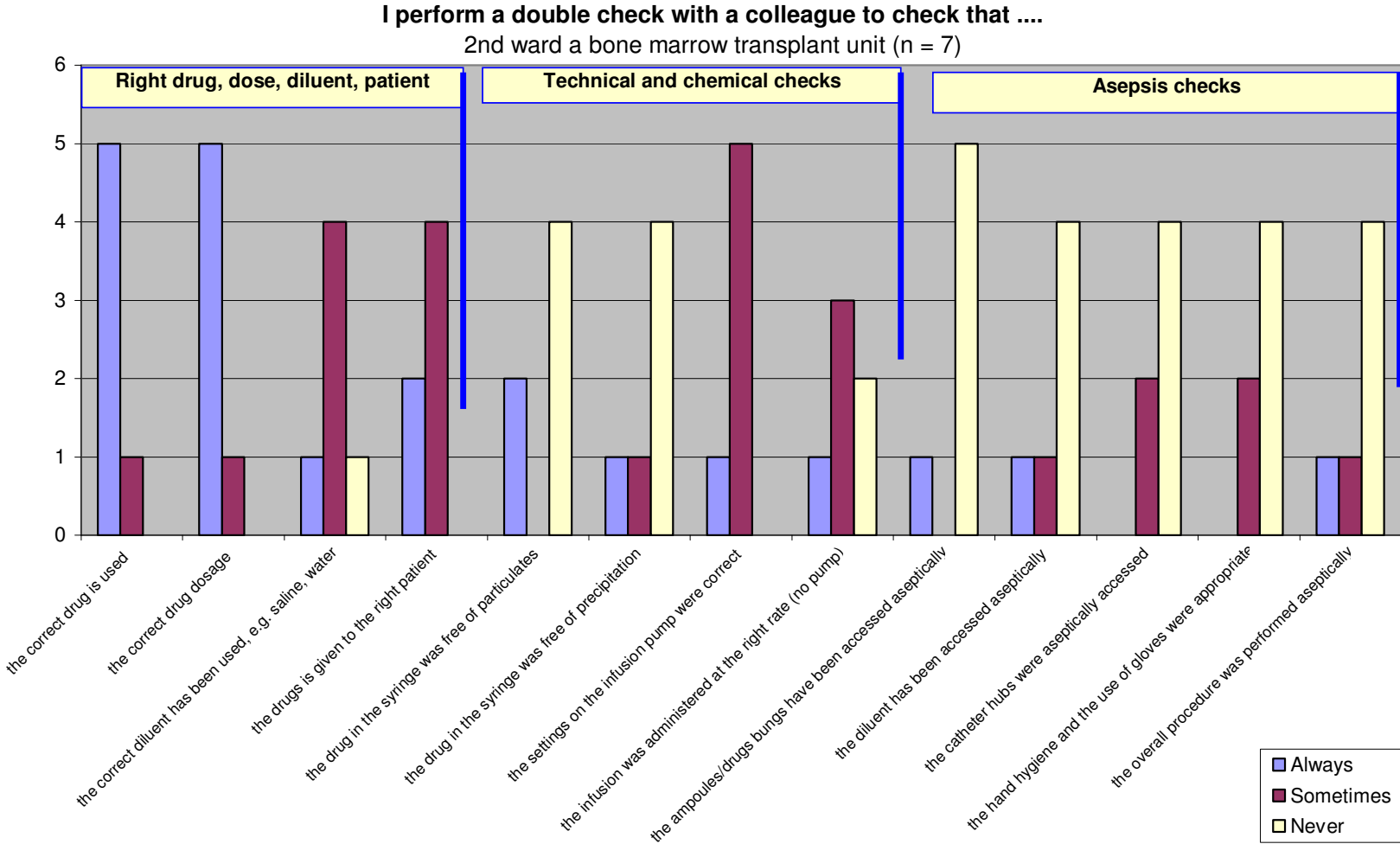


Figure 66 Stated Redundancy Checks in the 3rd ward

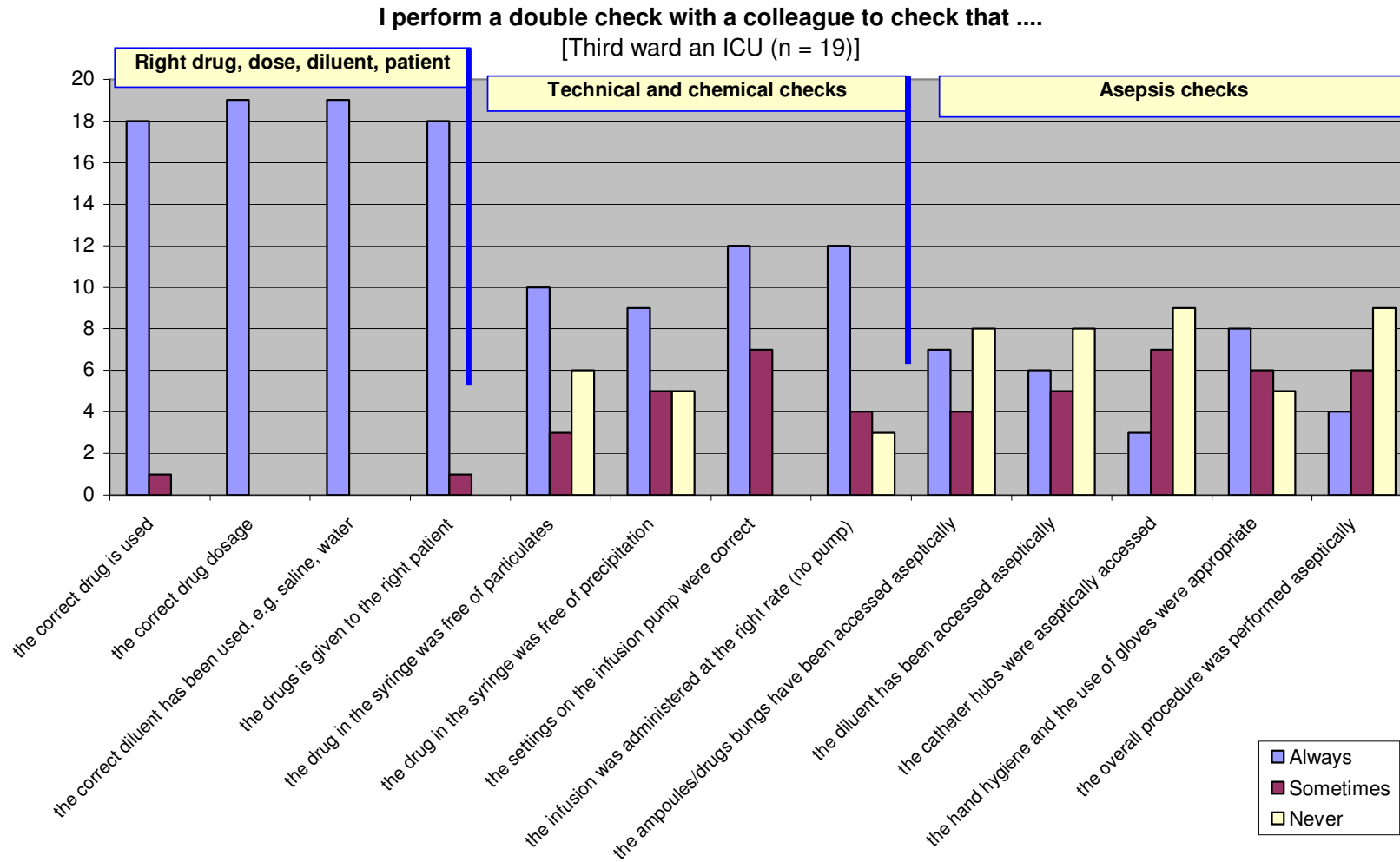


Figure 67 Stated Redundancy Checks in the 4th ward

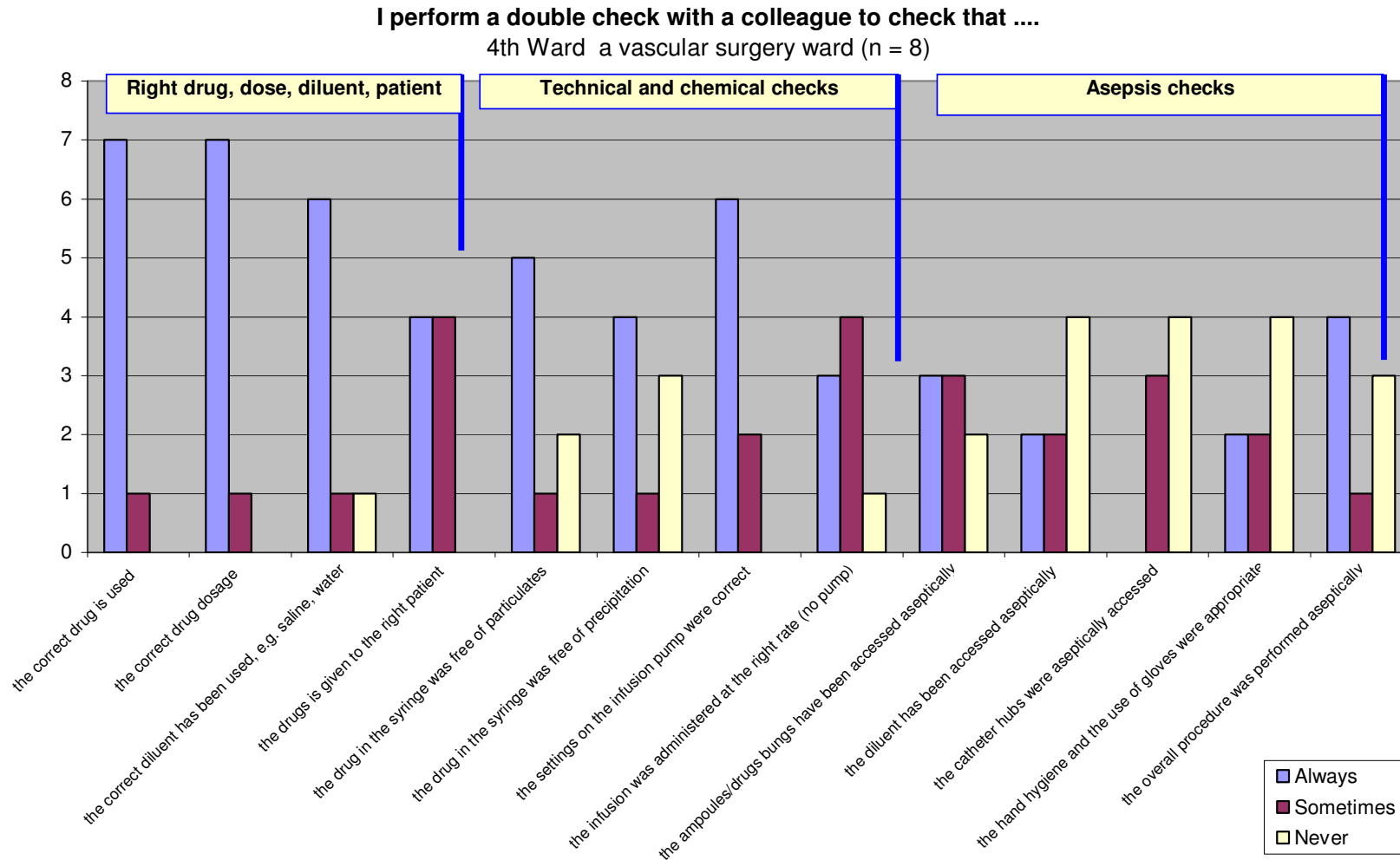
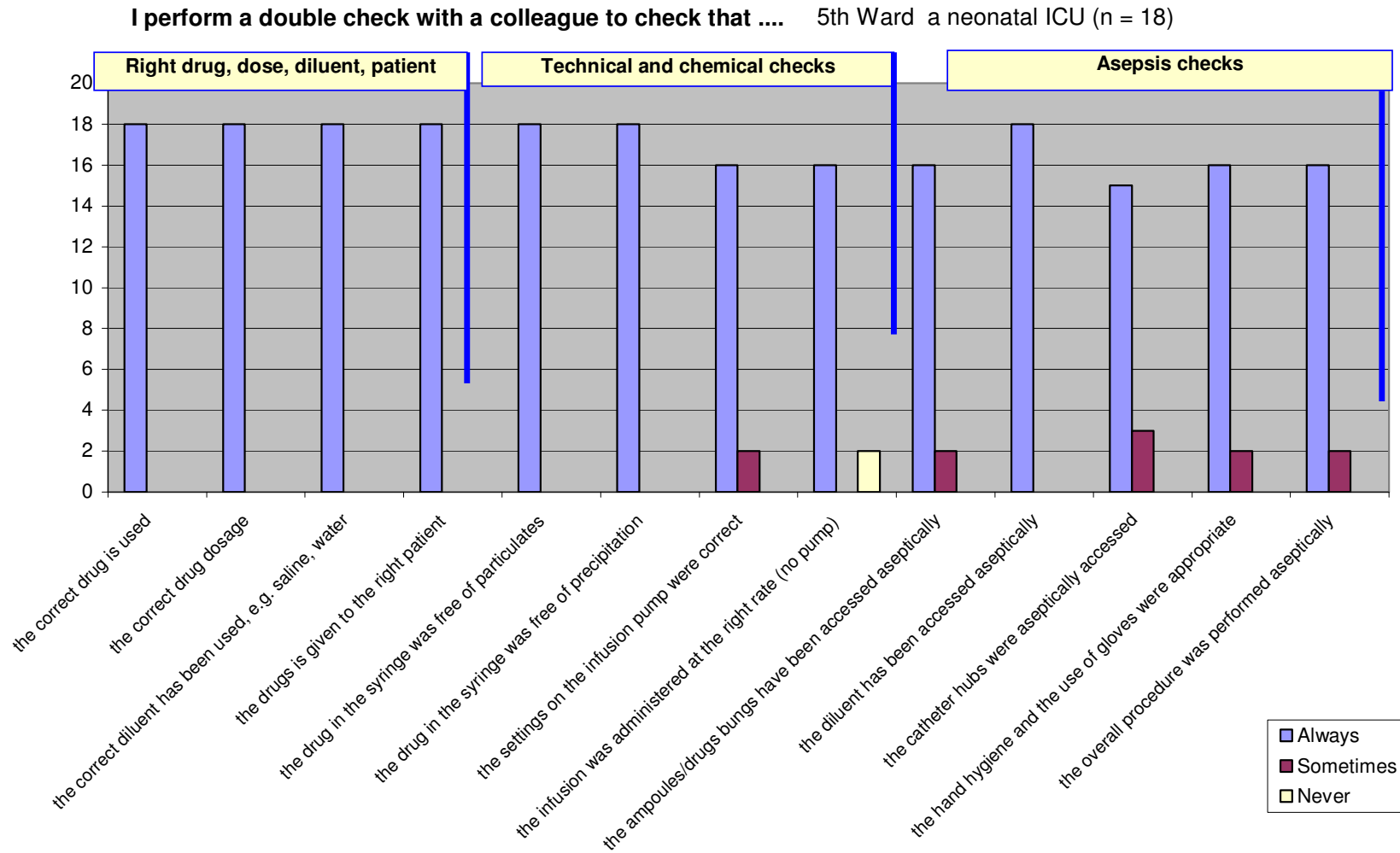


Figure 68 Stated Redundancy Checks in the 5th ward



8.9 Review of other information available in the study wards

Although the wards differ in design and in how the procedures are performed, certain other information is common to the nurses in all wards. This section reviews the common information available to the nurses and is divided into 4 sections: the hand hygiene guidance, information from the pharmaceutical companies, information on the use of antiseptics and information available on infusate labels. This review presents evidence that the nurses are not equipped with sufficient information to warn them of the potential risks of infusate contamination and of IR-BSI detection.

8.9.1 Information on hand hygiene available to the nurses

Posters from the World Health Organization (WHO) showing how and when to perform hand hygiene, which have been incorporated into the Health Protection Scotland Hand Hygiene campaign and Hand Hygiene Model Policy (Health Protection Scotland 2009), were seen in all of the study wards, in particular in the areas where drugs for intravenous infusion were prepared. As this information is so immediately available and present this section will assess whether the WHO guidance on hand hygiene is sufficient to prevent asepsis failure.

As part of the patient safety challenge *Clean Care is Safer Care*, the WHO began working on international guidelines for hand hygiene in August 2004. The theory and methodology were published in advance of the guidance, which was issued finally in May 2009 (Sax et al. 2007, World Health

Organization 2009). The guidelines contain contributions from more than 100 international experts and are intended for implementation in any situation in which healthcare is delivered (Pittet et al. 2009). There is an extensive literature review accompanying the guidance, which also takes cognisance of behavioural science and human factors, with an objective to produce guidelines for safe practice that are easy to remember, to comprehend and to visualise. As a consequence, it was hoped the guidance would also be easy to audit and enable the production of compliance reports. The guidance, like the methodological framework for this thesis, therefore considers the human factors required to enable the nurses to do the right thing.

The WHO guidance, on when to perform hand hygiene to minimise the risk of one of the 4 negative outcomes occurring, has been reduced to just 5 moments:

- Before touching a patient

- Before a clean/aseptic procedure

- After body fluid exposure risk

- After touching a patient

- After touching patient surroundings (World Health Organization 2009).

The WHO guidelines divide the healthcare environment into 2 zones the *patient zone* and the *healthcare zone*. The patient zone contains the patient and their immediate surroundings. The healthcare zone contains all surfaces in the healthcare setting outside the patient zone. Within the patient zone

there are 4 *critical site* categories, one of these critical site categories is 'device associated' and specifically includes vascular catheter hubs (World Health Organization 2009). The WHO guidelines are based on two key assumptions, that all objects going in and out of the patient zone are cleaned, and that everything within the patient zone is potentially contaminated with the patient's own micro-flora (World Health Organization 2009).

The questions raised by the WHO guidance in relation to the task of aseptic preparation of intravenous drugs are:

- If followed, would this guidance be sufficient to prevent asepsis failure in the preparation of intravenous drugs?
- If followed, would this guidance facilitate aseptic administration of intravenous drugs?

In trying to prevent asepsis failure in the preparation of intravenous drugs, the document does not provide hand hygiene guidance for interrupted aseptic tasks performed initially outside the patient zone, with subsequent entry into the patient zone; for example, aseptic preparation in a drug preparation area with drug administration within the patient zone. The only moment that could be said to apply is moment 2, *before an aseptic task*. However, since most procedures outwith the patient zone are still interrupted aseptic procedures, then to perform hand hygiene for aseptic preparation only before commencing a task would be insufficient to prevent asepsis failure. The assumption that all objects going into the patient zone are 'cleaned' is not the reality for aseptic

preparation outside the patient zone, where critically, the contents of the syringe should be sterile.

For aseptic administration all five of the moments could be involved. Critically, the document specifies that for moment 2, before aseptic procedure, hand hygiene should take place between the *last* exposure to a surface and immediately before access to a critical site with infection risk for the patient. To this extent, the hand hygiene would be effective in preventing contamination from the hands of the nurse administrator to the catheter hub, assuming this part of the procedure was uninterrupted – as in the 5th study ward. If there were interruptions in the procedure, as in the 1st, 2nd, 3rd, 4th, and 6th study wards, (that is, aseptic steps followed by non-aseptic steps), followed by aseptic steps, repeated hand hygiene would be required if subsequent contamination occurred. This repeat step is not specified in the WHO 5 moments. As important, however, is the concept that hand hygiene performed as per the WHO 5 moments within the patient zone will not prevent the micro-organisms on the outside of the hub being infused along with the patient. How to decontaminate the hub is not included in this hand hygiene guidance. HCWs are not advised to seek other guidance at this point.

In dealing with a single procedure (hand hygiene) and a single mode of transmission (contact via hands – both direct and indirect) this vast guidance does not cover the risks associated with splash contamination, the need for decontamination of other items such as hubs and with aseptic procedures

performed outside the patient zone which can have life-threatening consequences to the patient. In reading this WHO guidance, HCWs could be led to the erroneous assumption that 'hand contact' is the only mode of transmission relevant during aseptic procedures. This is not the case. Adherence to the WHO 5 moments for hand hygiene as specified in the WHO guidelines is therefore insufficient of itself to facilitate aseptic preparation or aseptic administration of intravenous drugs.

8.9.2 Drug Information from the Pharmaceutical Companies

The pharmaceutical literature provided for each of the high-risk drugs identified (heparin and propofol) was reviewed. Three of four heparin leaflets made by Leo contain no information related to possible risk from microbial contamination and subsequent infection. There is no instruction to use an aseptic technique during preparation of the drug. The drug could be used as a multi-dose vial as there is a clear instruction to do so up to 14 days post first use. There is no space on the vial to mark the opening date. The flush heparin made by Wockhardt, includes a warning to use an aseptic technique with this drug; 'Aseptic techniques should be used at all times during [this drug's] use to avoid contamination.' The product information states 'Any portion of the contents not used at once should be discarded.' Therefore, this product should be considered single-use.

These leaflets have all been written as if the primary readers were the patient. There is no indication here that heparin is associated with infusate

contamination, as has been published in the literature. The heparin information from Leo printed in 2008 provides less warning on infection risk than that prepared in 2002. Information is not provided to validate the safety of these multi-dose vials which can be pierced as often as drug remains in the vial until the expiry date is reached. Even with a 14 day usage, there needs to be clear instruction to label the vial so that the date the vial is to be discarded is visible to subsequent users. There is no indication of the validity of the 14 day usage, that is, what rates of deliberate contamination have been used to challenge the preservatives, and whether there was endotoxin within the vial thereafter. Of note, contamination of multi-dose heparin vials containing preservative has been reported (Nogler-Semenitz et al. 2007). The information on all 4 heparin leaflets is of an easily readable print size.

Information leaflets reviewed:

- Leo Heparin (mucous) Injection BP 1,000 and 5,000 and 25,000 Units/ml: 2002
- Leo Heparin (mucous) Injection BP 1,000 and 5,000 and 25,000 Units/ml: 2008
- Leo Heparin sodium 10 IU/ml I.V. flush solution: 2007
- Wockhardt Heparin sodium 10 I.U. ml Flushing solution for maintenance of patency of intravenous devices: 2007.

8.9.2.1 Drug Information from drugs at high-risk of infusate contamination

Propofol (Diprivan®) 10mg/ml Injectable emulsion

The pharmaceutical information on propofol is provided on 3.5 sides of A4 in a very small font which is not easily readable. It is written for the prescriber and contains detailed information on the pharmacokinetics. There is a warning on the sterile nature of the drug, how easily it can be contaminated and how it can provide a medium for micro-organisms to flourish and what to do to prevent asepsis failure:

‘Strict aseptic technique must always be maintained during handling. Diprivan injectable emulsion is a single-use parenteral product which contains 0.005% disodium edentate to retard the rate of growth of micro-organisms as it is not an antimicrobially preserved product under USP standards. Accordingly, strict aseptic technique must be adhered to. Do not use if contamination is suspected. Discard unused portions as directed within the required time limits. There have been reports in which failure to use aseptic technique when handling Diprivan injectable emulsion was associated with microbial contamination of the product and with fever, infection/sepsis, other life-threatening illness and or death.

Prepare for use just prior to initiation of each anaesthetic/sedative.

Complete administration within 6 hours.

Change administration lines after use.’

Comment on the propofol information

The information required by any nurse preparing propofol is available as a stark warning. This is essential, given the outbreaks that have occurred as a consequence of propofol contamination (Krumholz et al. 1994, Veber et al. 1994, Bennett et al. 1995, Kuehnert et al. 1997, Langevin et al. 1999, Trepanier and Lessard 2003). There is, however, one problem with the provided information; although emboldened, the information is in very small print on the second side (4th column) of the leaflet. As such, for all it is emboldened, typographically, it is also de-emphasised.

8.9.2.2 Other drug information leaflets reviewed

A review of a selection of 8 other drug information leaflets available in the study wards found: In only 1 of the 8 leaflets is there instruction to use aseptic technique, is it stated the product is sterile and is there instruction on when and how to decontaminate a drug vial. In only four of the eight leaflets did it state 'single-use' product.

Drug information leaflets read:

Flucloxacillin (CP pharmaceuticals); Lidocaine 1% (TARO); Vancomycin (Wockhardt); Ceftriaxone (Wockhardt); Lidocaine hydrochloride 2% (Hameln); Benzylpenicillin (Genus pharmaceuticals); Cefotaxime (Wockhardt); Meropenem (AstraZenica UK Ltd).

8.9.2.3 Comment on additional drug information leaflets

It is clear from reviewing this small selection of pharmaceutical information that critical information related to infection risk is not made readily-available nor sufficiently well highlighted to those who, when preparing intravenous drugs, should take special actions and require to follow steps to prevent contamination.

8.9.3 Information from the manufacturers of antiseptics

For aseptic preparation of intravenous drugs, several antiseptics were observed being used as follows:

- Steret® - Isopropyl Alcohol BP70%v/v
- Clinell® Chlorhexidine gluconate 2% BP & Isopropyl alcohol 70% ‘
- Alcowipe® Isopropyl Alcohol BP70%v/v

All the antiseptics were dispensed in the form of an impregnated wipe, presented in a sealed single-use package. The antiseptics observed used contained a paucity of information ‘use wipe to clean site’, ‘use as directed’ and ‘For external use only’.

There is a paucity of information related to disinfection in terms of which disinfectant should be used, how the disinfectant should be applied and crucially, when the disinfectant should be applied. In addition, there are no

visible clues to show the nurse preparing the drug that sufficient disinfection has been applied and disinfection as such has been achieved.

Disinfection is not as effective a process as sterilization, that is, the removal of all micro-organisms. Disinfection, according to the Medicines and Healthcare products Regulatory Agency (MHRA) (2010: 7), is 'a process used to reduce the number of viable infectious agents but which may not necessarily inactivate some microbial agents, such as certain viruses and bacterial spores'. Chemical disinfectants, can under defined conditions, achieve disinfection, but are the least effective means of achieving disinfection (heat is the most effective). Chemical disinfectants, however, are used when heat poses a hazard to either the integrity of the equipment being disinfected or the safety of the patient. Antiseptics are the least effective of the chemical disinfectants; antiseptics are disinfectants that are safe to use on skin (and some mucous membranes). As antiseptics are weak disinfectants it is not surprising that some outbreak reports have cited contaminated disinfectant as a cause (Nasser et al. 2004, Weber et al. 2007, Romero-Gomez et al. 2008). As a consequence, the majority of antiseptics used in healthcare are dispensed or packaged as single-use products.

There are parameters set for the purpose of validating both sterilisation and disinfection processes which take account of the variety of unknowns prior to either process commencing. For chemical disinfectants to achieve disinfection

and not themselves cause harm to the equipment or the patients, these unknowns include:

- What type(s) and how many micro-organisms are likely to be present?
- What organic material is present and how will this affect the antiseptic–surface contact and consequently the kill times of the micro-organisms present?
- How the chemical disinfectant should be manoeuvred to ensure sufficient contact with the surface?
- How long the chemical disinfectant needs to remain in contact with the surface?
- What environmental conditions need to be maintained prior to the surface being considered disinfected?
- Is type of surface being disinfected compatible with the disinfection?

Antiseptics are required several times during the thesis procedure:

- To decontaminate the surface on which the procedure will be performed
- To decontaminate the bungs on the top of vials and all ampoules that do not have sterile access points,

And although not part of the observed study,

- To decontaminate the bung / needlefree device or three-way tap and distal catheter section, immediately prior to the drug being administered.

There is an evidenced-based guidance on information relating to the application of disinfectants to the skin, prior to the insertion of the catheter and for application to the skin for cleansing prior to the application of dressings. The epic2 (Pratt et al. 2007), provide information on when antiseptics should be used. However, there is no evidence-based recommendation for the use of antiseptics for the preparation of a surface area or pertaining to the decontamination of vials and ampoules. In addition, epic2 (Pratt et al. 2007) does not include specifics on how long the antiseptic should be left in contact with a surface or what type of contact should occur. The makers of antiseptics do not also make the catheters or the sundry equipment to which disinfectants require to be applied. Giving more specific information in their literature about disinfectants and disinfection application could leave the antiseptic manufacturers open to litigation should a device failure occur as a consequence of antiseptic application. This paucity of information does not help the nurses who want to identify and perform evidence-based practice.

8.9.3.1 Infusate Additive Labels

The labels added to intravascular-drugs vary in size but not in the information which requires to be completed. This information includes details of the drug, the patient, the diluent, the batch number, the expiry date and time and the route of administration. The labels contain an implied warning “Discontinue if cloudiness or precipitate develops”. The implication here is that it is only cloudy infusates which pose a risk. As previously discussed, infusates can be

heavily contaminated with $>10^6$ micro-organisms without making the fluid appear cloudy (Gilat et al. 1958, Maki and Martin 1975).

Errors have been reported where labels were not used and confusion had arisen as to what drug was being administered. It is these errors that led to the standing instruction to adhere a label immediately a drug had been added to an infusion and not before. It is the addition of this label at this time, which for most clinical areas, changes the antiseptic procedure from an uninterrupted procedure to an interrupted procedure.

8.9.4 Summary of review of sundry information available to nurses

This review of the sundry information available to nurses to assist them to perform evidence based procedures shows that the information is poor, poorly presented or absent altogether. The drug information does not include known infection risks and when it does include them, such information is deemphasised. The antiseptic information lacks an evidence-base and contains no specifics. The infusate label hints that only cloudy infusates are contaminated when this is not the case. These can be seen as latent conditions which could lead the nurses to erroneous assumptions of safety and consequently to unsafe acts.

From all these cumulative evidence sources the system profile of aseptic preparation of intravenous drugs has been produced.

8.10 The system of intravenous drug preparation and how it works in practice

The objectives of this thesis are to produce a procedure profile of the system of aseptic preparation of intravenous drugs and to identify the system's error-prone and reliability characteristics. The system profile described below is derived from a synthesis of all of the results. What the system profile shows is that this common, safety-critical, complex procedure is performed by nurses in environments which pose contamination risks, with equipment that can either increase or decrease contamination risks, and using methods that need to be modified for safety. The information provided to the nurses, from multiple sources, is insufficient to alert and inform them about contamination risks and how to prevent them. Additionally, there is minimal system feedback at a personal level on performance and no data is available on the quality of the end product, or the frequency of IR-BSI. However, despite the system being, at present, more error-prone than reliable, it is clear that the nurses and ward managers are committed to patient safety and to doing the best they can with all of the resources available to them.

8.10.1 Intravenous drug preparations

The preparation of intravenous drugs is a common, complex, safety-critical procedure performed by nurses approximately 3,000,000 times a year in clinical care settings. The way the procedure is performed varies depending on the drug, the need for a diluent, the equipment which is accessible and

whose use is understood, and the preferences and ways of working that have evolved over time in individual clinical areas. The procedure can be likened to a magic trick; the objective is to remove sterile contents from one or more containers and transfer them to another container without contaminating the contents – the infusate. This is difficult because although the internal contents of a drug vial should be sterile, the air, the environment and the usually gloved hands of the nurse preparing the infusate are not. It is expected that an aseptic technique will enable the nurse to achieve this. However, there is no written procedure for aseptic technique and there are no visual or audible indications at the end of the procedure as to whether the objective has been achieved. Additionally, there are no quality control data to confirm achievement of the objective.

The procedure is performed differently in different clinical settings, for example:

Single person interrupted procedure (with checker) 1st, 3rd 6th wards

Single person (closed) interrupted procedure (with checker) 4th ward

Single person non-interrupted procedure (with checker) 2nd ward

Two person non-interrupted procedure (including checker) 5th ward

All procedures include several redundancy checks of right: drug, dose, diluent, due not given, duration of administration and route of administration. There is no written requirement to undertake redundancy checks on asepsis steps.

The complexity of the procedure varies between the wards because of the different types of drugs that patients with different clinical conditions require. The procedures in the ICUs, where patients frequently have multiple critical conditions and often require many drugs at the same time, are more complex than the drug procedures on the general wards. The neonatal ICU procedures are most complex of all, involving mixing, dilution and discarding of excess drug pre administration. But, even in the non-ICUs, patients require a myriad of drugs which require different diluents, different calculations and different flush regimens. There are also various methods of administration, for example, by syringe driver, bolus injection or gravity drop infusion, which add to the complexity. In addition there may be post-administration instructions, which create further variation in the procedure. General drug preparation instructions are available on computers, in manuals and on posters, but also mainly in the individual memory of those who regularly prepare them. Instructions to prevent asepsis are not visible. In the ICUs and the BMTU a significant proportion of most days are spent preparing intravenous drugs.

The clinical care environments where the procedures are performed also vary. Some procedures were observed to be done at the bedside / cot-side, others in a designated drug preparation area and 2 were performed in a small designated area within a multi-purpose room. In one area where there was a purpose designed facility this was so far away from patients that it had been found to be unsafe to use it as the staff were away from their patients for too long.

There had been no risk assessments of the environments where drugs are prepared in any of the study wards; the ward managers themselves are left to design and create areas safety. All of the environments in the study wards include at least one latent condition which increases the risk of unsafe acts. Study wards 1, 2, 3, 4 and 6 have a risk from possible splash contamination. Study ward 5 has a risk of error of misreading resulting from low lighting for patient comfort.

All of the environments where the drugs were prepared were visibly clean; only one was not free from clutter. Non-bedside / cot-side preparations varied considerably in the amount of space available to the nurse preparing the infusions from, a single shelf in 2 study wards, to a large open plan room or a single designated procedure room. None of the facilities had access to a drug preparation cabinet which would have removed airborne particles or droplets.

Not only do the procedures vary, but the equipment varies also. Only in the 4th study ward are drugs prepared using a reconstitution device, which saves time and reduces the risk of contamination. Another ward had previously used them, but these had been removed by the management due to cost. The nurses using the reconstitution devices on the 4th study ward consider that they could not do without them, whilst 3 other wards had not heard of them. Two wards use filters, capable of removing endotoxin and micro-organisms 3 others did not (one uses an inappropriate filter). Dispensing pins are used to

save time and money, but this use poses an unrecognised infection risk to patients by turning a sterile diluent into a multi-dose vial and potentially contaminating infusates. The variability in the use of equipment engenders variable levels of infusate contamination risk.

The use of drugs prepared from multi-dose vials is prevalent on some wards and completely absent on others. The risk of infusate contamination of multi-dose vials is not well-recognised by the nurses. This is possibly because the manufacturers state that the vials can be used for 14 days and also because there can be significant contamination without changes in the visual appearance of the drug within the vial.

To train the nurses in this procedure they are provided with a single day or two day course followed by supervised practice in the clinical area. Once deemed competent, no further training is mandatory at present; although this is under review in one ward. Many nurses are unaware of critical information about safety, for example, the need to decontaminate vial tops. For some nurses, the task is reported as being stressful and some receive no job satisfaction from it. It seems to be a necessary chore rather than a much-loved nursing procedure.

8.10.2 The system's error-prone characteristics

There are many latent conditions relating to the way this procedure is performed that make the nurses undertaking it more prone to performing

unsafe acts. These latent conditions begin with the lack of a written procedure that is easy to follow and that reflects what is done and what equipment is used. The quality control of this procedure is achieved by one competent nurse checking that another competent nurse is following the same local procedure. There is no reassurance that the drugs, diluents or completed infusates are sterile. There are no visual clues that could indicate that the infusates are contaminated. Due to a lack of visual clues, and possibly the lack of a procedure telling them to do so, accessing the drugs through a non-sterile bung is not routinely preceded by decontamination, potentially introducing contamination into the drug. Not all errors that could occur were recognised as such, for example, there are no instructions to consider an infusate the source of sepsis should the patient develop a pyrexia.

Nurses who prepare drugs in the adult ICUs are in effect multi-tasking, in that they also continue to observe their patients and are attuned to several monitoring alarms for signals that their patients' critical signs are deteriorating. Concurrent procedures are allowed in all three of the facilities where drugs were prepared away from the bedside / cot-side, increasing the risk of distraction and interruptions and possible loss of situation awareness.

The ward managers also commented that there is an inability of the system to respond to capacity surges. If the wards are busy, with more dependent patients and more requirements for intravenous drugs, there are seldom additional staff to assist in undertaking the additional workload.

There is clearly a lack of overall organisational control on what equipment could, should and should not be used to enhance safety and reduce costs. For example, the pilot ward should not use either Dispensing Pins or inappropriate filters. The 6th study ward with the poorest facilities could have used reconstitution devices to improve safety. The accessibility of safety equipment was based on the individual ward budget dependent and not on any safety risk assessment. Finally, the lack of recognition of infusate contamination as a listed adverse incident also downplays its significance.

8.10.3 Identification of the system's reliability characteristics

It is more difficult to identify reliability characteristics with regard to the environment, the equipment and the way the procedure is performed in the context of a procedure with latent conditions which could potentially produce errors. However, the nurses were committed to being safe; this is evidenced by them volunteering for this study in the hope of improving their facilities and procedures. The data from the opinions of safety survey also confirms that nurses were encouraged to report errors, and that they would report personal errors in order to make the system safer. However, because infusate contamination and IR-BSI are not listed adverse events, even if they did recognise a contaminated infusate as causing an IR-BSI, it is uncertain if it would be recognised and reported as an adverse drug error. The procedure within each study ward is performed reliably, that is, it is performed the same way, and was checked to ensure it was performed the same way. The

problem with these 'reliable' methods was that the same way was itself unreliable in terms of being able to guarantee a sterile product.

8.11 Summary of the results including the system profile

The results from all the data sources have enabled the production of a profile of the system of intravenous drug preparation in clinical settings. This system profile indicates that this common, complex, safety-critical procedure is performed by nurses in environments which could pose contamination risks, with equipment and drugs which can either increase or decrease contamination risks, and using various methods that can be modified to decrease the risk of contamination. The information provided to the nurses does not indicate to them with sufficient clarity the infusate risks. Consequently, the nurses who perform these procedures are largely unaware of the contamination risks posed by the equipment, the drugs, the environment or the methods they use.

Despite all the identified latent conditions rendering the system at present more error-prone than reliable, there is evidence that patient safety is a priority for those who perform the procedure. The next chapter will discuss these results and identify what is making the system unsafe and what makes it perform as it does.

9 Discussion

In this chapter the results from all the data sources, including the system profile set out in the previous chapter, are discussed to answer the research questions: ‘What is the system of intravenous drug preparation in clinical care settings in NHS Scotland?’ and, ‘How does it work in practice?’ This discussion will thereby identify what makes the system of aseptic preparation of intravenous drugs error-prone and vulnerable to contamination in individual clinical care settings. How these findings relate to the methodological framework set out in chapter 4 is also discussed. This chapter is set out as follows: the results from the Location Assessments, the observations and the opinions of safety are discussed first. Explanations for the variability in the observed procedures, with particular reference to the variations in aseptic technique, the use of gloves and the use of filters, are then given. This will be followed by a review of what is making IR-BSI invisible. This section will show that IR-BSI prevention is not well specified in the regulatory framework, that national guidance does not include IR-BSI prevention in sufficient detail, that IR-BSI reports are difficult to find in the literature, and that the information presented to those who prepare infusates does not highlight with sufficient clarity the problem of IR-BSI. The section thereafter includes discussion on who will be held to account for IR-BSI, the challenges that HCWs face and what can be done to reduce IR-BSI locally and nationally. The final section demonstrates that this thesis has confirmed the stated assumptions regarding

the system's vulnerability, and shown the utility of the methodological framework needed to undertake this research. To counter this, recognition of the limitations of the study are provided. This chapter concludes that the system is error-prone and that unless the system changes, IR-BSI will remain under-diagnosed, under-investigated and under-reported.

To identify the system of aseptic preparation of intravenous drugs in clinical care settings different data sources were used. Six locations where drugs were prepared in 5 different hospitals in Glasgow were examined, 78 intravenous drug preparations were observed, the opinions of safety of 71 nurses who prepare intravenous drugs were considered, data on when the nurses stated they perform redundancy checks were collected and, finally, observed practice was reviewed in the context of all the information available to those preparing the drugs. The data from each of these sources are presented in 3 sections: The Location Assessments, The Procedures Performed and the HCWs' Opinions of Safety (safety culture measure).

9.1 The Location Assessments

Data from the Location Assessments identified that the environments in which the nurses prepare intravenous drugs vary significantly in terms of suitability as determined by the available space, the multi-purpose use of the space, the proximity to a sink and the potential for direct infusate contamination. More importantly, however, the contamination risks posed by these environments are not recognised as such by the nurses. The 4th study ward and the 6th

study ward are afforded a shelf in a multi-purpose room (Figures 35 and 55) on which to perform the procedure. These wards' procedures are exposed to splash contamination from close-by sinks. Distractions in the busy multi-purpose overcrowded room on the 6th study ward indicate a clear risk of environmental capture. It is difficult to see how this space could ever be considered safe enough for the preparation of intravenous drugs.

The 2nd study ward is the only ward where the nurses always used a designated room (Figure 16). However, in this ward droplet spray from a scrub sink is a potential contamination risk, but is not recognised as such. The droplet spray itself was recognised by the nurses, they stand sideways when washing their hands so they do not get wet, but the potential contamination hazard from droplet spray to the infusates is not recognised. Consequently, on this ward where a full scrub is performed before each procedure, sterile towels are used to prevent contamination from the trolley surface and all sundry equipment is decontaminated before placement on the trolley, the environmental contamination risk has not been identified.

Procedures performed at the bedside in the adult ICUs (1st and 3rd wards) are exposed to a lesser extent from potential spray contamination from ventilators and thereby pose a risk of contaminated surfaces on which they prepare drugs – these surfaces are not always decontaminated before the procedure commences. There was less risk of spray contamination in the 5th study ward, the neonatal ICU, where spray from disconnected ventilators would be

minimal. Lighting here makes reading and visible detection of contamination difficult.

Concurrent procedures are permitted during the preparation of intravenous drugs, in the 1st, 3rd, 4th and 6th study wards; this increases the risk of distractions and leading to the nurses potentially losing situation awareness. During these concurrent procedures other contamination could occur, for example, via droplet contamination to the preparation areas. In the 2nd ward, where IV drugs were prepared in a separate area, so many drugs were prepared concurrently by different nurses that distractions and interruptions were inevitable. The separate preparation room in the 2nd study ward was also the first place to look for a nurse, which was another distraction risk. This inability of being able to prepare IV drugs without distraction or interruption, was also highlighted in the survey of opinions of safety; the majority response of staff in all 6 wards to the statement 'I can prepare drugs on this ward without interruption or distraction', was to disagree with it. This is corroborated by responses to statement 9, 'On this ward distractions and interruptions make it difficult to prepare IV drugs safely', with which most respondents agreed.

Although it is easy to criticise these environments from an infection control risk potential, it is not those who perform the procedure who determine the environments they have at their disposal; it is the organisation's responsibility to provide safe environments. These environments have created latent

conditions capable of provoking unsafe acts during the preparation of infusates; this is as described in human error theory and as included in the methodological framework (Chapters 5 and 6). As stated previously, the CRAG (2002: 17) statement on the environment is that aseptic preparation of intravenous drugs should be carried out in a 'suitable' environment without specification of what is meant by 'suitable'. Without specification of environmental standards that can be measured, there can be no guarantee of safety or awareness of how remote from safety a particular environment is. The NPSA recommend that the environment be 'uncluttered and free from interruption and distraction' (National Patient Safety Agency 2007), the RCN guidance does not include environmental standards (RCN IV Therapy Forum 2003). What is clear from this study is that an environment free from interruption and distraction is not always available in the NHS in Scotland. In the ICUs, the nurses were also multi-tasking, monitoring their patients and their patients' alarms whilst preparing intravenous drugs.

Nurses who are specialists in intensive care, or bone marrow transplant care, are not necessarily specialists in hazards posed by plumbing equipment. Consequently, a formal risk assessment against set environment standards performed by those who are experts, is the only way to ensure recognition and negation of risks posed from the environment. Had the CRAG (2002) document set standards for the environment, rather than providing a vague objective 'suitable', this situation may not have been allowed to prevail. The environment is one key determinant of whether the drug is likely to be

contaminated. What the results show, in particular in the 2nd study ward, is that it is possible to have a safe procedure performed in a poor environment, thus exposing the infusate to potential contamination. The need for a minimum standard for the environment in terms of space, and negation of any potential hazards within the space, is clearly indicated for patient safety. Viewing the ward layouts and drug preparation areas (Figures 3- 4, 15 - 16, 25 -26, 34 - 35, 45 - 46 and 55 - 56) some wards, in particular the 4th and 6th wards, (Figures 34 and 56) may not have sufficient space within the ward that would meet set criteria. There is also a clear requirement that national guidelines should not, without specification, use terms such as 'safe', 'appropriate' or 'suitable'. Additionally, given that environments cannot (at least at present) be guaranteed interruption free or distraction free, exactly how nurses are assisted to negate such hazards needs to be addressed. Of note, the 1st ward had a well designed environment that was so far away from the patients as to be effectively out of useful reach. It can be concluded, therefore, that at the design stage, testing the practicalities of environments should be considered before building commences.

The data from the Location Assessments supports the human error theory put forward in the methodological framework, in that there are latent conditions in the system design which provoke errors by frontline workers – the nurses. In this case, the environments in which the nurses have to prepare intravenous infusions can provoke loss of situational awareness through distractions and can result in contaminated infusates through droplet contamination. What can

be concluded is that whilst nurses were observed trying to achieve safety, during the procedures, there were systematic flaws in the observed environments in all clinical settings making their aseptic preparations prone to error and microbial contamination. The next section will discuss the results from the observed procedures and assessment of equipment available to perform them.

9.2 The observed procedures and available equipment

Having discussed how the different environments vary in their potential to increase the risk of contamination, similar differences in the observed procedures and equipment available to perform them will now be discussed. The procedures also vary markedly in how they are performed depending on the type of ward. The contamination risks in the observed procedures vary depending on the type of equipment used, whether multi-dose vials or diluents are used and whether defences are built into the system.

The procedure which appears to pose least contamination risk is performed on the 5th ward. This procedure is performed by 2 nurses who are present throughout. The second nurse assists the nurse preparing the infusate by, for example, holding vials for piercing as well as by being present to perform redundancy checks – including asepsis-related redundancy checks (Figures 47, 68 and Table 10). Additionally, there are no multi-dose vials or diluents on this ward and, finally, the system was defended by the use of an effective in-line filter. Reconstitution devices cannot be used on this ward (equipment size

not available). Therefore, should contamination arise on this ward, defences are present to prevent contamination of the infusate causing an IR-BSI. The one flaw in this procedure, which is seen in all wards, is that the nurses did not know that the tops of vials were non-sterile and therefore do not always decontaminate the top of the vial.

Because of the risk of drug calculation error on the 5th study ward, it has been agreed that 2 nurses should be present throughout and that all calculations will be done independently by 2 nurses. Therefore, the 2-person procedure on this ward, done in the main to ensure right drug and right dose facilitates an uninterrupted aseptic technique. Other wards are less well staffed.

Although performed in a multi-purpose room, the nurses on the 4th study ward (Figure 35) use a procedure that negates risks and is well defended. Risks are firstly negated by the use of a reconstitution device which closed the system to potential contamination from, for example, droplets from the nearby sink. Additionally, the nurses on this ward use snap-top ampoules of high-risk drugs such as heparin, and do not use multi-dose vials. Finally, the system is defended, should contamination occur, by an in-line filter capable of removing microbial contamination. Should these defences fail, then there were real contamination risks, (Figures 36 and 37). The preparation surface is not cleaned before the procedure begins and, again, decontamination of vial tops is not routinely performed.

The single person, non-interrupted procedure on the BMTU (2nd study ward) poses potential contamination risks due to the lack of decontamination of vial tops. Additionally, there are no data to confirm their decontamination of everything going onto the trolley is effective at decontamination (Figure 17). Filters are not used on the infusates in this ward.

The two ICUs (1st and 3rd) wards use similar single person, interrupted procedures, similar equipment and consequently their procedures pose similar risks (Figures 5 and 27). The multi-use diluent on the 1st ward and intermittent use on the 3rd ward, facilitated by the Dispensing Pin, turns a sterile diluent into a potentially contaminated one available for use over a 24 hour period. As previously stated, outbreaks have been caused by use of multi-use diluents (Narayan et al. 2009). On the 3rd ward, multi-dose vials of heparin are used which pose an unrecognised risk. Filters used on the 1st ward are of an unsuitable type and consequently it can not be considered that any microbial protection is afforded by them. On these wards (1st and 3rd), the procedure has the ingredients of an aseptic technique but it is not performed in a way that ensures it. For example, the purpose of the use of non-sterile gloves is not clear. Putting on of gloves and then collecting equipment means that the aseptic steps are interrupted. This was acknowledged by one nurse who decontaminated gloved hands in an attempt to maintain an aseptic procedure. The need to stick on labels immediately a drug has been added is critical to safety. This is because the failure to do so has resulted in erroneous administration of drugs. This safety-critical step interrupts the aseptic nature of

the procedure (the label is not sterile) and poses an additional risk of asepsis failure by interrupting asepsis. However, as has been shown by suggested amendments to procedures, it can be overcome (Figures 14 and 33) by recommencing the procedure with hand hygiene. Again, as on all wards, the decontamination of vial tops is not performed as part of the aseptic technique. This is not surprising, given the lack of information provided by the manufacturers of drugs who do not highlight that the vial tops are non-sterile and require decontamination prior to access.

The 6th ward which, as already stated, is at risk from environmental contamination and distractions causing loss of situational awareness, is also at contamination risk from the use of multi-dose vials. This single person, interrupted procedure is performed without the use of reconstitution devices or filters to defend the system (Figure 56). Vial tops are not decontaminated. However, the nurses do the best possible with the very limited resources available to them. Their reason for taking part in the project was the possibility of improving the facilities for this procedure.

Aseptic technique for drug preparation has clearly evolved within the six study wards differently. The 5th study ward uses a 2-person procedure which, is perhaps, the original model. Other ward procedures have evolved based on what resources and equipment are, and are not, available. The requirements in this procedure, of right drug, right dose, right patient, stick on label as soon as drug added, all compete with performing an aseptic technique. At present,

from a human-factors perspective, it is not easy for the nurse to do the right thing, or to be sure exactly what is the right thing to do. Colour-coding of written procedural steps as either 'critical to asepsis', or 'mandatory checks' or 'required but not for asepsis or a check', enables for the first time all the steps to be visible and to ensure they are all performed at optimal times for patient safety, making it easy for the nurses to do the right thing.

The requirement to stick on a label as soon as a drug is added to an infusion bag or syringe is a safety-critical step that interrupts all procedures. The 2nd ward tries to negate an interruption at this step by wiping the sticker with an antiseptic wipe. The 5th study ward prevents interruption of asepsis by having a second person do it. The 4th study ward has a closed-system and therefore the need for asepsis at this point is negated, but the remaining wards carry on regardless with 'aseptic' steps. The aseptic procedure in the 1st, 3rd, 4th and 6th wards is naturally interrupted at the point where the label is stuck on. The colour-coded figures (14, 33, 44 and 62) show that, by re-introducing hand hygiene after the sticker is adhered, an antiseptic procedure can subsequently be restarted. Colour-coding the step, as either aseptic or non-aseptic, provides a visual check of when the procedure is interrupted and when hand hygiene needs to recommence.

What the colour-coding does for the first time is to allow the critical non-aseptic steps of the procedure to be reviewed concurrently with the aseptic steps and not as a separate procedure. In this way, the elements of the

procedure can be seen and agreed on with managers and infection control teams. It can be used to teach the procedure and it can be modified and examined for optimal safety as new equipment or variations of the procedure are deemed necessary. Additionally, if the procedure for any given unit is accompanied by periodic culture of infusates, then it could also be validated. The critical checks of right drug, right dose, right duration, right diluent, due and not already administered, and right route are fundamental to patient safety; however they are arguably no more important to patient safety than right aseptic technique. Focusing on right drug, right dose, right patient, has deemphasised the risks posed by failure of aseptic technique.

The acceptance in some wards of the risks posed by the use of multi-dose drugs and diluents reflects the lack of emphasis on such risks in national and local guidance. What is also striking is the degree to which the systems are and are not defended, or are exposed to contamination risk. To some extent these variations can be explained again by a lack of specifics in the national guidance. As stated in Chapter 4, the Healthcare Commission (2007a) recommends regular competency checking, and regular quality control without specifying what is meant by the term 'regular'. The Nursing and Midwifery Council (2006) negates to specify when hand hygiene is required in their statement on medicines management. The Royal Pharmaceutical Society (2005) fails to mention multi-dose vials as posing a special risk. Even the CRAG (2002: 6) guidance defines the term 'high-risk' loosely 'Where the hazard associated with preparation is likely to have a serious risk.' The NPSA

competency statement (2007), in specifying that aseptic technique means avoid touching areas where bacterial contamination may be introduced, again lacks specifics. The evidence that multi-dose vials and in particular heparin pose a risk is abundant in the literature (Katzenstein et al. 1999, Al-Saigul et al. 2000, Nasser et al. 2004, Centers for Disease Control 2005, Perz et al. 2005, Siegman-Igra et al. 2005, Centers for Disease Control 2006, Held et al. 2006, Pan et al. 2006, Peiris et al. 2006, Safdar and Maki 2006, Gordin et al. 2007, Grobner et al. 2007, Nogler-Semenitz et al. 2007, Vonberg and Gastmeier 2007, Gershman et al. 2008, Souza Dias et al. 2008, Yang et al. 2008, Blossom et al. 2009, Motamedifar and Askarian 2009, National Patient Safety Agency 2009, Ross et al. 2009).

There are several sources of written material available to the nurses from the organisation, from the pharmaceutical information, from the World Health Organisation on hand hygiene. None of these sources provides clear, accessible information on what the nurses needed to do and not do to prevent possible contamination of infusates. There is no written procedure on any ward which described what is done on the wards for aseptic preparation of intravenous drugs. One ward manager spent several hours on the ward searching for an aseptic procedure that, to her disappointment and disbelief, does not exist.

To try to explain some of the variation in the observed procedures on the study wards, three aspects are discussed further: variation in aseptic

technique, variation in the use of gloves and variation in the use of filters. Additionally, there is discussion as to whether specifics in drugs or patients can explain variations in the procedures. To begin with, a brief discussion of the possible reasons for variation in the observed aseptic technique is given.

9.2.1 Variation in aseptic technique

Aseptic technique is a method of carrying out procedures so that there is a minimum risk of microbial contamination and subsequent infection. It is achieved by the sterility of equipment and a non-touch method (Cape and Dobson 1974, Boakes 2009). According to a leading manual of nursing practice, it is a set of specific practices and procedures performed under carefully controlled conditions with the goal of minimising contamination by pathogens (Dougherty and Lister 2004). Both, these definitions are clear that aseptic technique is not like sterilisation, an absolute term, but more like disinfection, a way of achieving something which it is hoped will not expose the patient to harm. It is a title bestowed on a selection of procedures, such as dressing changes, insertion of urinary catheters and operative procedures. The findings from this thesis indicate that there has been what can be called 'procedure drift'; and, that the time has come to revisit such definitions and agree the specific environmental conditions and usage of equipment which are sufficient to prevent contamination and the patient from acquiring infection.

There is clearly a lack of standardisation in the performance of aseptic technique in the six study wards. There is also a lack of written procedures to remind staff exactly what requires to be done and when in the procedure it should be performed. A standardised and visually appealing version of aseptic technique is available. Aseptic non-touch technique™ (ANTT™) was first published as an evidence-based theory to practice development in 2001 (Rowley 2001). ANTT™ comes with pictorial presentations of the individual steps of the procedure which are visually appealing. This technique has clear advantages over the existing and often variable practices. Indeed one of the goals of ANTT™ was to reduce variation in practice. Other advantages derived from a standardised approach include reduction in cost, decrease in poor practice and removal of unnecessary, labour intensive practices; these benefits are similarly laudable. However, there are problems with ANTT™. Rowley (2001: VI) explains that the theoretical framework on which it is based is that '10% of all endemic infections in hospital are airborne... therefore it is reasonable to assume that the airborne route is small in comparison to direct contact'. This assumption is referenced to two papers. The first paper does estimate nosocomial airborne infections at 10%; though this work relates more to airborne infections such as tuberculosis (Eickhoff 1994). The second paper suggests that the reported increase in Gram positive organisms, which are resistant to desiccation, may indicate an increased role of airborne dissemination in micro-organisms (Schaal 1991). However, what is also absent from the theory for ANTT™ is the use of the literature on the pathogenesis of catheter-related sepsis, including infusate contamination, of

which none is included. The routes of infusate contamination discussed in Table 2 are also absent from Rowley's (2001) work.

In later work, the theory has developed and there is now acknowledgement that, as micro-organisms are present in the air, sterility is not achievable in healthcare settings (Rowley and Clare 2009). The authors of ANTT™ choose to accept that environmental contamination risks are present without an evaluation of how big a risk they pose or what can be done to negate them; there are categories of cabinet that can negate environmental risk.

Recently, ANTT™ has been registered as a trademark and become an advocated procedure in parts of England. ANTT™ is a condensed procedure compared to the 50 plus steps in the NPSA statement (2007) and there is much to be welcomed in this approach. However, the crucial flaw is that in the Rowley (2001: VIII) steps 'gather all the equipment and drugs' and 'prepare the drug aseptically' there is a paucity of information and no mention that the drugs, diluents and sundries need to be and to remain sterile, There is also no ANTT™ requirement to decontaminate vial tops (Rowley 2001). There are specifics missing that might be in other materials produced by Rowley, however these are available through a commercial route. ANTT™ is better for the patients and more cost effective for organisations than what has gone before – but real safety has yet to be demonstrated. There is no evidence of outcome validation, that is, infusions made following ANTT™ being sterile; as such it is difficult to advocate this as an evidence-based approach. Aseptic

technique is a system designed by humans and, as stated in the methodological framework, systems designed by humans are fallible. One of the key issues with the aseptic procedure of preparing a sterile infusate is that it is performed concurrently with the procedure of administering a drug safely to the right patient. Therefore, to ensure that all of these procedures are performed without error, the instructions need to be written and described as combined procedures. Such an approach would result in improved patient safety through reduced human error. Again this is recognised in the methodological framework in the statements on patient safety, human error and human factors. Another variation in the observed procedures will now be discussed, the use of gloves.

9.2.2 Variation in the use of gloves

The use of gloves during the procedure in the study wards is also variable. In wards where non-sterile gloves are used (1st, 3rd, 4th and 6th wards), it is difficult to determine why they are being used at all. That is whether it is to protect the nurse from drug contamination, or whether it is to protect the infusate from contamination. Once gloves are put on however, the difficulty in performing an aseptic procedure is clear, particularly if an additional piece of equipment is required. Rowley, (2001) in describing ANTT™, advocated gloves as a requirement under the Control of Substances Hazardous to Health Regulations (Rowley 2001). However, this requires more explanation than is given. If there is a hazard from the preparation of drugs which requires the use of gloves, precisely what that hazard is not specified. If the risk is from

drug spill onto hands, then gloves may protect the nurse. However, if the risk is from unexpected drug spray during a disconnect, then the risk will be to a greater surface area than the hands, for example, the forearms and such sprays could also be inhaled. COSHH regulations mandate that, wherever practical, people should be protected from the recognised hazard (Health and Safety Executive 2009). For example, this could be by the use of equipment that negates the risk of spray, such as reconstitution devices. If the risk of unintended drug contact cannot be negated, then control measures must be used, in this case the gloves or, via the use of cabinets which control the preparation conditions. Additionally, there is a requirement to monitor any residual exposure (Health and Safety Executive 2009). As stated previously, there is no evidence in any of the 4 study wards that used non-sterile gloves that they know why they are wearing them. They also do not appear to know whether a risk assessment of personal contact with drug during preparation has been done, and whether the use of gloves is an effective means of negating any such risk. To enable clarification of risk, a full risk assessment of possible unintentional drug exposures to those preparing infusates and the measures to reduce such exposure should they occur, is necessary. It would be better if this risk assessment were done by specialists, as drug contamination is not easy to visualise, and at a clinical area the required expertise may be absent.

9.2.3 Variation in the use of filters

Incorrect use of in-line filters were seen used in the 4th and 5th wards. Those seen used in the 1st ward were not in-line filters and therefore not effective in removing contaminants. Use of inappropriate filters has been associated with an outbreak of *Ralstonia mannitolilytica*. This occurred in an oncology ward where Mini-spike Plus® filters (0.2 µm) were in use (Grobner et al. 2007). It was found that the outbreak micro-organism could pass through this filter. The Mini-spike Plus® filter is not an in-line filter, but a filter used with a combined dispensing pin to prevent transfer of organisms and particulates from a diluent to an infusate.

There are no national pharmaceutical or infection control guidance documents that recommend the use of in-line filters to negate the risks of infusate contamination. However, from the evidence in the literature, and from the observations made in this thesis, there is a good case to be made for their use. IR-BSI is caused by contaminated infusates (Vonberg and Gastmeier 2007). The environments where nurses prepare drugs can be exposed to splashes which are a recognised source of environmental Gram negative organisms that have caused outbreaks. (Deliere et al. 2000, Grobner et al. 2007, Kilic et al. 2007, Ceyhan et al. 2008, Cholley et al. 2008, Erbay et al. 2008). The duration of some infusions provides sufficient time for the organisms to multiply to significant numbers causing IR-BSI (Siegman-Igra et al. 2005, Peiris et al. 2006). Multi-dose vials remain in use and they are a recognised risk of IR-BSI (Vonberg and Gastmeier 2007). IR-BSI is difficult to

detect as it can arise some time after an infusion is started or even after it has finished (Centers for Disease Control 2006). Finally, in a recent review of the all the arguments for filter use, the case for the use of filters was considered strong and the authors questioned whether it would be lawyers or practitioners who would eventually make the successful case for their use (Ball 2003). Therefore, in the absence of data showing that sterile infusates can be produced in clinical care settings, there is a need for defence of the catheter (and thereby the patient) from micro-organisms which grow well in nutritionally poor fluids, and from the endotoxins the micro-organisms produce.

Having described the need for filters to prevent contaminated infusates from being administered, the next section will demonstrate that no drugs can be considered immune from contamination.

9.2.4 Are some drugs immune from contamination?

Although some infusates are antibiotics, this does not make them immune from contamination. Antibiotics usually act against a particular range of micro-organisms and other classes of micro-organism are unharmed - and can even flourish - in such an infusate (van Houten et al. 2001, Blot et al. 2002, Safdar and Maki 2006).

Some of the heparin supplied to the 3rd study ward is provided as multi-dose vials which contain a preservative (manufactured by Leo). A study of in-use multi-dose vial contamination showed found 4 of 96 vials were contaminated

(Nogler-Semenitz et al. 2007). Three of these contaminated vials contained preservatives; therefore preservatives cannot be considered as a guarantee of internal content sterility. Multi-dose vials with a preservative are usually given an in-use shelf-life. On the 3rd study ward the shelf life was stated as 14 days. Of note, the multi-dose vial contamination study also found that 28% of the multi-dose vials that were in-use were not marked with a date of opening, highlighting the potential error of use beyond the stated shelf-life (Nogler-Semenitz et al. 2007). Failure to note a start date was also seen on the 3rd study ward's multi-dose vials.

An outbreak of IR-BSI has also been reported in chemotherapy drugs which are noted for their toxicity to humans (Mauri et al. 2009). There were multiple errors noted during the investigations, but what perhaps facilitated this outbreak was extremely long hang times of up to 48hours (Mauri et al. 2009). There are no drugs that can be considered immune to microbial contamination, and all drugs can thus cause IR-BSI. What is required is equipment, environments, skilful participants and procedures that prevent this event from happening.

This section has highlighted the no drugs can be considered immune from contamination and that some drugs, such as multi-dose vials, are more at risk of contamination than others. Additionally there are visual clues that erroneously suggest that drugs should be considered sterile when that is not

the case. There are several aspects of the methodological framework which are relevant, but key are the following 2 bullet points.

- Patient safety – it is not safe for patients that the nurses cannot determine the sterility of drugs.
- Human error / human factors – it is easy for the HCW to use a non-sterile drug without recognising this.

The next section will discuss whether drug preparations for some patients require additional precautions.

9.2.5 Does the patients' immune status explain procedure variations?

The final explanation which needs to be explored with regard to the variations in procedure is whether patients with a poor immune status require a higher standard of aseptic technique. Infusate contamination will not discriminate between patients. More robust immune systems will not protect against a direct infusion of micro-organisms. However, patients with an immature or defective immune system may suffer greater ill-health, being less able to mount an immune response. What is more important for patients who require vascular access for long periods (months), is that the catheter becomes a lifeline; IR-BSI can result in immediate sepsis as well as longer term problems due to biofilm formation and low level seeding of micro-organisms following a flush or administration of a contaminated drug. The immune suppressed patients in the bone marrow transplant unit (2nd ward) will have problems because of their poor immune responses, and low platelet counts. Low

platelet numbers causes poor clotting and, as a consequence, replacing infected catheters in these patients could result in severe haemorrhage.

The longer the catheter remains in situ, the greater the risk of potential exposure to infusate contamination. Arguments can be made for greater 'asepsis' for these patients. However, as stated throughout this research thesis, there can be no acceptable level of contamination; the question is not what extra precautions are required for certain types of patients, but what level of precautions will provide microbiologically sterile infusates for all patients. These arguments on risk and the acceptable level of risk, as discussed in Chapter 4 and as set out by Fischhoff et al. (1981) are difficult to assess in this context as there are no surveillance or IR-BSI data and no process data in any of the study wards. All wards should be using sufficient asepsis precautions to prevent contamination of both the infusate and the patient. This required level of asepsis and environmental controls cannot be specified without further research. The risk of infusate contamination and IR-BSI, as stated throughout this document, increases with the use of multi-dose vials, certain drugs and longer term infusates; these can be easily removed or defended against by the use of filters.

Having discussed the variations in performed procedures and possible explanations for this, the next section will comment on the results from the safety culture survey of the nurses' opinions of safety.

9.3 The HCWs' opinions of safety – the safety culture

This is the first time the HCWs' opinions of the safety of a specific procedure have been canvassed to produce a measure of the procedure safety culture and as such the data must be interpreted with caution. What can be concluded, however, is that in each ward with sufficient results, some characteristics of safety are prevalent alongside other characteristics that denote system vulnerability. For example, staff on all 5 wards said they were encouraged to report errors and they would report errors; these are positive safety characteristics. However, they also reported that they did not get feedback on their procedure, that there were frequent interruptions and distractions, that the procedure was stressful, and when it got really busy, they did not get support or additional help. These latter factors denote potential weakness in the systems' safety. It is possibly better therefore, to consider these results not as a composite safety culture measure, but like a spider graph with the individual components denoting safety and procedure vulnerability clearly identified.

The vast majority of nurses in five study wards stated that they would report a drug error and that they felt comfortable in reporting personal drug errors. This shows a strong commitment to safety. Much work has been ongoing to create such an environment where errors are seen as a way to improve safety and not to blame individuals. However, what has to be recognised is that drug errors related to IR-BSI are extremely difficult to detect. As such, willingness

to report in the absence of a detectable error will not be an effective means of achieving safety. Additionally, some nurses stated that felt that it was easy to prevent and detect asepsis failure when on their particular ward this was not the case. Therefore, as an indicator of a system's risk or vulnerability such safety culture measures should be considered as data requiring verification from other sources.

Only two nurses on the 6th ward completed the questionnaire despite repeated requests to do so. This is the ward with the poorest facilities and the lowest level of personal protective equipment. On this ward the procedure is performed without the safety checks observed in the other wards. It is possible that the staff in the 6th study ward were unwilling to state what they did and did not do in relation to redundancy checks or state how they felt about the procedure. But the comment made on one of the two returned forms 'we have nothing here' seems a fair reflection.

The methodological framework described a measure of the safety culture as being critical to the overall safety of the procedure. More research on the utility and validity of such measurements is clearly needed. However, there was very useful data gained from the respondents in this study, in that nurses demonstrated erroneous assumptions of safety and highlighted that this is not a much loved nursing procedure.

It is clear from the data collected in the Location Assessments - the observations of procedures, the opinions of safety and review of all existing information available - that the procedure is variably performed, lacking standardisation and quality control. Moreover, there appears to be a complete lack of risk assessment pertaining to the procedure, from both the nurse preparing the infusion, and the patient receiving the infusion. Additionally, to the nurses who prepare drugs, IR-BSI is almost invisible. Before identifying what can be done to reduce IR-BSI locally, there needs to be a full understanding of what is making IR-BSI invisible to nurses.

The results of the Location Assessments, observations of practice and opinions of safety have identified the system of aseptic drug preparation and concluded that there are multiple factors in the environment, the equipment and the methods that make the system error-prone. This next section explores what is making the system perform as it does.

9.4 What is making IR-BSI invisible to nurses

There is a chain of external influences which contribute significantly to rendering of IR-BSI invisible to those who prepare, administer and manage systems. If there is a single primary external influence from which all others stem, it is perhaps that historically IR-BSI was considered so rare and of such low significance that it has continued to remain under-recognised as an important factor in infusion therapy (O'Grady et al. 2002). Other external influences flow from this history of under-recognition of the problem which

include, a lack of specification in the regulatory framework, IR-BSI prevention is not well specified in the national guidance, IR-BSI reports are not easy to identify and extract from epidemiological studies in scientific literature, IR-BSI is not under surveillance and would be difficult to survey should the need for surveillance be recognised and, finally, IR-BSI as a risk is not well explained or well recognised by those who prepare intravenous drugs. There is a chasm between the US and UK with respect to the requirements and the environments for the preparation of intravenous drugs. All of these links in the chain provide an understanding as to why the system of aseptic drug preparation is, as has been described, error-prone.

The following section will begin with a discussion of the regulatory framework, including the differences between the US and UK regulations. This will be followed by explanations of why IR-BSI is invisible in the national guidance, invisible in the literature, currently not under surveillance and invisible in clinical practice.

9.4.1 How the regulatory framework contributes to IR-BSI invisibility

There are strict regulations in the UK that govern the aseptic pharmacies which produce intravenous medications under licence in sterile suites. These are the same regulations that also govern pharmaceutical companies manufacturing any drugs (MHRA 2007). The aseptic pharmacies and pharmaceutical companies produce aseptic drugs under licence from the MHRA. The MHRA works under various European Directives that have been

transposed into UK law. All of the regulations which must be adhered to in order to gain and maintain a manufacturer's licence from the MHRA are summarised in the Rules and Guidance for Pharmaceutical Manufacturers and Distributors (MHRA 2007).

The MHRA (2007) guidance is extensive, covering all aspects of the process from drug preparation to the storage and delivery of the sterile drugs (MHRA 2007). The guidance includes specification of the environment, including the air-quality within the room, the air-quality within the cabinet where the drugs are made, the air-locks as staff enter the preparation area, the location of sinks in the preparation area itself, specification of the decontamination of the cabinet, the standard and use of personal protective equipment to be worn by those preparing the drugs, the markings on the product packaging, the quality control on the products, the training of staff who produce the products and the filtration processes of the final product. None of these EU Directives and MHRA rules applies to the intravenous drugs seen prepared on the wards in this study. The only guidance available for HCWs preparing intravenous drugs in clinical care settings in Scotland, are the 'Good Practice Statements for the preparation of injections in near-patient areas' which have been produced by an expert group under the auspices of the Clinical Research Audit Group (CRAG 2002). One statement from CRAG (2002) is that 'Injections prepared in near-patient areas should be administered immediately' (CRAG, 2002: 18). There is an assumption here that by giving the infusion immediately, there will be no time for micro-organisms to multiply and infect the catheter or the

patient. However, as already explained, drugs may be commenced immediately but, if being administered by a pump at 1ml per hour, a 20ml syringe will take 20 hours to infuse. This is sufficient time for very small numbers of micro-organisms to multiply exponentially and cause IR-BSI over the lifetime of the infusion. The outbreak reports related to heparin pumps illustrate the lack of safety in the CRAG statement (Siegman-Igra et al. 2005, Peiris et al. 2006). This instruction for immediate administration is additionally recommended by the NPSA (National Patient Safety Agency 2007). The NMC's A-Z advice sheet for medicines management contains no specification for immediate administration (Nursing and Midwifery Council 2006). The advice sheet has now been superseded by Standards for Medicines Management, Standard 20 of which related to intravenous medication; this standard now only refers to the need for two registrants to check the medication. For all other aspects of intravenous medication, registrants are referred to the RCN's document on intravenous standards (RCN IV Therapy Forum 2003, Nursing and Midwifery Council 2009). Section 8.1 of the RCN Standards for IV therapy contains no specific requirement for immediate administration and states that any drug added to an infusion bag should be discarded after 24hours (RCN IV Therapy Forum 2003). There is a clear failure in all the available national guidance to recognise the risk from medicines prepared in a clinical care area that are not completed until 20 hours post preparation, regardless of whether they are commenced immediately.

One final omission from the CRAG (2002) guidance is the failure to recognise the unique risks posed by drugs such as heparin and propofol, long-term infusions and multi-dose vials. Risks associated with these infusions can be easily reduced by making HCWs understand the problem, banning multi-dose vials and having long-term infusions prepared under truly aseptic conditions. The large outbreaks in the US related to contamination of heparin, for example, are the result of systematic errors in aseptic preparation on a sizeable level due to a lack of quality control and quality in production (Nasser et al. 2004, Centers for Disease Control 2005, Centers for Disease Control 2006, Held et al. 2006, Gershman et al. 2008, Blossom et al. 2009). These outbreaks are a direct result of trying to find the cheapest components, without ensuring sufficient safety controls.

The good practice statements from CRAG can only be considered the starting point of what is required for the safe preparation of drugs in clinical care settings. The expert group, in stating that national environmental standards need to be devised, acknowledges the deficits within the CRAG guidance (CRAG 2002). Additionally, the standard operating procedure included as an appendix to the CRAG guidance does not contain the latest evidence base on hand hygiene, instead stating that hand washing rather than hand decontamination with alcohol should be used. There are several opt outs in which the reader is referred elsewhere. For example, when referring to the need to use gloves it states 'in all cases staff should refer to local policies' CRAG (2002: 29). The document does, however, clearly identify the need to

decontaminate rubber vial tops, which was not seen done and not clearly recommended, in all pharmaceutical information leaflets, despite being necessary for asepsis CRAG (2002: 30).

There are several other problems with the CRAG (2002) document, and the RCN IV Therapy Forum's guidance (2003). Firstly, the process by which the evidence to support the standards was gathered is not stated (CRAG 2002, RCN IV Therapy Forum 2003). For the CRAG document, the distribution list for the document is not included, there are no responsibilities allocated to specific professionals for any of the standards and, most notably, there is no implementation plan or implementation money to accompany it. Therefore, there can be little surprise to find that the evidence supporting the statements is incomplete, not all risks have been identified, (for example, removing multi-dose vials, increased risks with long-term infusions and the good practice statements have not been implemented in the study wards). The inadequacy in the supporting literature is exposed with the statement that '...most [microbial] contamination does not lead to sepsis' (CRAG 2002). Only one paper supports this statement and none of the recent papers highlighting delayed-onset IR-BSI are recognised. This is an erroneous assumption of safety and hints at an acceptable level of contamination, when the latest evidence of delayed-onset IR-BSI clearly supports a zero acceptable level of contamination. The CRAG (2002) guidance identifies an aspirational contamination rate of 0.1%; it does not provide a road-map to achieve this.

With regard to the cornucopia of pharmaceutical and infection control guidance (discussed in section 3.4) that is available to produce local guidance, what can be concluded is that it merely illustrates the complexity and risks associated with the procedures, but provides minimal assistance to enable those carrying out the procedure to do so safely. The voluminous content does not make it easy, or sometimes even possible, for the HCW to do the right thing. The UK guidance needs to be evaluated in the context of the US guidance, where as stated previously, infusate contamination has been described as rare (O'Grady et al. 2002). This is discussed below.

9.4.2 Variation between UK and US regulations

There is significant variation between aseptic pharmacy (MHRA, 2007) regulations in the UK and the regulations for compounding pharmacies in the United States of America. The key difference is that in the United States the regulations apply to all practice settings where intravascular drugs are compounded (Kastango and Bradshaw 2004). These US regulations apply not only to pharmacists but to whoever compounds drugs, which would include nurses in clinical care settings and all the drugs observed being prepared in this study. The US regulations became law in 2004 and are known as United States Pharmacopeia (USP) National Formulary, chapter 797. The purpose of chapter 797 is:

'To prevent harm and fatality to patients that could result from microbial contamination (non sterility), excessive bacterial

endotoxins, large content errors in strength of correct ingredients and incorrect ingredients in compounding sterile preparations (CSPs).' (Kastango and Bradshaw 2004).

The responsibilities of those compounding drugs are stated and include maintaining appropriate cleanliness as well as providing labelling and supplementary instructions for the proper clinical administrations of CSPs (Kastango and Bradshaw 2004). Chapter 797 classifies all drugs into one of three levels of risk. The drugs observed being made in clinical care settings in this study would fall into chapter 797 category of low-risk. If preparing low-risk level drugs in the US the following requirements must, by law, be met:

- The preparations must be compounded from sterile commercial drugs using sterile commercial devices
- Compounding must take place in a class 5 environment at all times
- Compounding procedures involve only a few closed-system, basic simple aseptic transfers and manipulations
- Routine disinfection and air-quality testing is used to maintain a class-5 clean room
- Adequate personnel garb for sterile preparation
- Correct identification and quantification of components reviewed before and after compounding
- Final visual inspection for each CSP
- Annual media-fill test procedure for each person who compounds, performed to validate proper aseptic technique.

(Kastango and Bradshaw 2004)

The training for personnel who compound sterile preparations under chapter 797 is not specified in terms of the number of hours that should be included in the education programmes, but on one key outcome measure is specified, in that the programme should include, as well as a written examination, a practice evaluation of aseptic technique using growth media. This ensures that those compounding drugs, and the procedures they use, are capable of producing a sterile product.

All finished CSPs must be checked by a pharmacist before they are dispensed to ensure that the preparation is sterile and accurate. Methods to do this include: physical visual inspection and verification of compounding accuracy by a second person.

There are, however, two key exceptions to chapter 797. Chapter 797 does not apply to what are classified as 'immediate use' CSPs. Immediate use CSPs, which are exempt from all the chapter 797 regulations, includes all emergency drugs such as those used in cardiopulmonary resuscitation, or in the emergency room. The is one additional exemption, in what seems to be a possible (complete) escape clause, is that, low-risk drugs may be classified as 'immediate use' when only simple aseptic measuring and transfer are needed, no more than two entries are made to any container and administration starts within one hour of preparation (United States Pharmacopeia 2009). There is no limit on finish time. The degree to which this exemption clause is used is unknown. Informal discussions with a leading member of the American

Practitioners in Infection Control have revealed that it is only in out patient settings that there is difficulty in applying chapter 797 regulations in America (Personal Communication). Compliance with chapter 797 in hospital ward settings is good; that is, wards have access to compounded sterile drugs.

The United States Pharmacopeia have set legally enforceable environmental controls and standards for drug compounding in clinical care settings far in advance of those in Scotland or the rest of the UK. In providing exceptions of low-risk drugs commenced within the hour, they have omitted to consider drugs which, although commenced within the hour, are not completed for up to 20 hours later (for example, heparin or morphine infusions). However, although there are some exemptions, it seems that there are standards, environmental controls, processes and checks to ensure the sterility of drugs prepared in hospitals, regardless of who prepares them. There is a conundrum here, in that the United States Pharmacopeia considers such standards and controls to be necessary when the assessment of the hazard from infusates in the Centres for Disease Control Guidance is that IR-BSI is a rare event (O'Grady et al. 2002). The United States Pharmacopeia clearly regards the risk of microbial and or endotoxin contamination of infusates as much more real than do the Centre's for Disease Control's Hospital Infection Control Practices Advisory Committee, and unlike the UK, have decided exactly what should be done about it (O'Grady et al. 2002, Kastango and Bradshaw 2004).

It is clear that there is a chasm between the regulations in the US, where there is quality control, environmental specification, validated processes and general standards, and Scotland, where there are no environmental standards and good practice statements which are more of a wish list than a national policy, and where the quality of the end product is untested and not validated. It has been argued that anything other than compliance with chapter 797 would not be scientifically, morally or ethically acceptable (Kastango and Bradshaw 2004). Explorations into any public health implications of a lack of regulatory framework in the UK should be fully evaluated.

National guidance documents, as discussed in this section, are derived from evidence in the scientific literature. How the scientific literature is influencing the invisibility of IR-BSI will now be discussed.

9.4.3 IR-BSI is hidden within the literature and absent from guidance

Evidence contained within the scientific literature is extrapolated and forms the basis of evidence based guidance, detailing how best to undertake clinical practice for patient health and patient safety. What has become clear in searching for the literature for this thesis is that there are many different aspects to IR-BSI causation and prevention. Currently, and perhaps erroneously, IR-BSI is included under the umbrella domain of the prevention of central vascular catheter (CVC) sepsis - this is problematic. IR-BSI occurs via drugs that are infused through peripheral vascular catheters as well as intrathecal catheters. Therefore, looking at the CVC literature alone would be

incomplete. Epidural infusates have, alarmingly, been found to have a contamination rate of 1.5% (Yuan et al. 2008). Recently an extensive review of the literature and risks associated with peripheral vascular catheters (PVC) concluded similarly that PVC-related BSIs is under recognised as a problem in clinical practice by those in infection prevention and control (Zingg and Pittet 2009). PVC-related BSIs can be caused by infusates.

Although this study focused on extrinsic infusate contamination, many lessons were learned from the literature on intrinsic contamination, for example, the delayed onset IR-BSI of up to 481 days after the last contaminated exposure identified by Gershman et al. (2008). Extrinsic contamination causing IR-BSI outbreaks often involves contamination resulting from mass-production and therefore the outbreaks are larger and occur over wider geographical areas. Large outbreaks necessitate more detailed investigations and greater understanding of what happens when infusates are contaminated (regardless of where that contamination occurs). Once an outbreak is recognised, investigators also know the particular organism they are looking for and can request microbiologists to report a specific organism should it be isolated from blood cultures (Perz et al. 2005, Held et al. 2006, Gershman et al. 2008, Souza Dias et al. 2008, Blossom et al. 2009). Consequently, when preparing guidance for the prevention of extrinsic contamination causing IR-BSI, the pathogenesis of intrinsic contamination causing IR-BSI should also be considered.

Despite using multiple different searches of different databases (Medline, CINHALL, EMBASE and Cochrane) the majority of reports of infusate-related outbreak were still only found in the references of other infusate-related reports and not in the searched database outputs. There seems to be a lack of uniformity in the use of the index of Medical Subject Headings (MESH) terms, for example. some papers whose primary purpose was to report an outbreak of IR-BSI or discuss factors related to it, omitted in their key words the terms 'infusate' and 'contamination' (Macias et al. 2005, Nogler-Semenitz et al. 2007, Mauri et al. 2009).

If producing evidence-based guidance to prevent an infusate contamination, then the first step should be to fully understand the disease and its epidemiology; where the micro-organisms come from and how the micro-organisms gain entry to the infusate as well as how infusate contamination can be prevented.

From the identification of the literature for this thesis, it appears the only complete way to ensure all necessary papers are identified is to use a search strategy with the impossibly over sensitive terms of 'bacteraemia' or 'septicaemia' or 'blood stream infection' and 'drug' or 'infusion' or 'infusate' or 'heparin' or 'propofol' or 'flush' or 'outbreak'. (A continuous search of these terms has been ongoing during this thesis.) The epic2 guidance, however, being a systematic evidence based guideline, listed the search terms used, crucially, the omission of the terms 'infusate' and 'microbial contamination', led

the authors to make erroneous conclusions regarding risks from contaminated infusates (Pratt et al. 2007). The epic2 team have asked the researcher for key words prior to new guidance being produced. It can be concluded thus far that IR-BSI is poorly prevented by recommendations in the national guidance, and poorly reported and indexed in the scientific literature. To be included in national guidance, IR-BSI must be extractable from the literature; to get into the literature, IR-BSI must be reported.

In relation to this topic, the literature comprises mainly outbreak reports; the next section highlights the properties of IR-BSI which add to the detection difficulties and thereby its surveillance and entry into the literature.

9.4.4 IR-BSI is not under surveillance

Reductions in the rates of *Clostridium difficile* infection (CDI) illustrates what can be achieved if an infection is under surveillance. The early years of this millennium were marked by significant outbreaks of CDI (Healthcare Commission 2007b). One of the many recommendations of an external report on a high-profile outbreak of CDI was that the illness must be treated as a disease in its own right. The specific comments relating to this were:

‘The diagnosis of *C. difficile* needs to be respected as a diagnosis in its own right, with proper continuity of management for patients with this illness. When the diagnosis is made, the condition needs to be taken seriously, as a

potentially life-threatening condition. Investigations should be carried out.' Healthcare Commission (2007b: 112).

The need for the external outbreak review came about because the public and politicians became increasingly concerned about a disease that healthcare professionals noted was mounting, but were not controlling effectively. Patients with CDI were found to have been treated so poorly that they were dying when, if they had received aggressive resuscitation and specialist interventions, they may have survived. Since the widespread publication of these outbreak reports, there has been production of national guidance on the prevention and control of CDI and the setting of individual NHS Boards' CDI reduction targets, all of which has resulted in sustained decreases in CDI incidence. This reflects the findings of Beck (1996) (discussed in Chapter 4) as a move from an industrialised society to a risk society. CDI has one clear advantage over IR-BSI - it can be counted. By being counted, the high-profile nature of CDI is maintained, CDI can be kept under both local and national surveillance and the impact of control measures on the incidence can be determined. Benchmarking NHS board against NHS board can motivate HCWs to take actions to improve local situations. Executives can be held to account if they do not have effective systems to achieve the national targets. All of this can, and is, being done because CDI can be counted.

IR-BSI cannot be counted. It is not caused by one organism, but by a myriad of micro-organisms that do not even form a recognised microbiological group (Table 1). It can be easily missed as a clinical diagnosis, as there is no

available information on the clinical picture it presents. Delayed-onset presentations mean that unless there is a recognised outbreak and tracking of a specific organism, cause and effect are often not established.

As IR-BSI cannot be counted, it is difficult to see how success from any interventions or system changes could be measured. System changes will also require significant investment. It should be noted that equipment that would reduce the risk of this IR-BSI had been, or is about to be removed, from two of the study wards because it was deemed unnecessary and of no cost-benefit (6th ward had reconstitution devices removed, 4th ward to stop using filters). Doubtless, as there is no guidance available to the contrary, the managers thought their actions were a boon to prevent waste in the NHS.

Having identified that IR-BSI is difficult to identify and survey, to get reported in the literature and to extract from the literature for use in national guidance, the next step is to identify what in clinical practice is making IR-BSI invisible.

9.4.5 What is making IR-BSI invisible in clinical practice

There are subtle warnings that IR-BSI could arise as a consequence of intravenous drug preparation; for example, in the six study wards' available policies there is a requirement to 'follow aseptic technique' and on the study wards' drug addition labels, it reads 'DISCONTINUE IF CLOUDINESS OR PRECIPITATE DEVELOPS'. These warnings, as they exist, are inadequate. As already stated, 10^6 micro-organisms per ml of solution will not appear

cloudy (Gilat et al. 1958, Felts et al. 1972, Maki and Martin 1975, Macias et al. 2005). It should be noted that it would be difficult to detect opacity in syringe contents with a large yellow label on the syringe set against the background of the pump holder. Additionally there is no acknowledgement of the existence of infusate contamination in the listed drug errors in the six study wards' documentation. There are also no clinical descriptions of what symptoms to be observant for and what should be done if these symptoms are present; that is, stop the infusion, seek medical help, sample both the infusate and the patient's blood and start a new infusion through a new catheter.

Reports of IR-BSI in the scientific literature are published in specialist infection prevention and control journals, thus de-emphasising the problem to clinicians and reducing further its likely recognition in clinical settings. There are significant reports of IR-BSI, but they are scattered uncoordinatedly throughout the literature and are incapable of mounting the sustained presence necessary for full notification and action. Consequently, as there is no clear effective guidance available promoting IR-BSI as a possible clinical outcome, IR-BSI is invisible in clinical practice.

It has been noted that if problems are invisible to HCWs they are considered trivial (Berwick 2003); this may explain the lack of focus on this topic to date. Vincent (2006: 154) argues that the hardest problems to solve are the ones that are not recognised as problems. The difficulties in recognising a potentially contaminated infusate as a cause of a BSI has significant

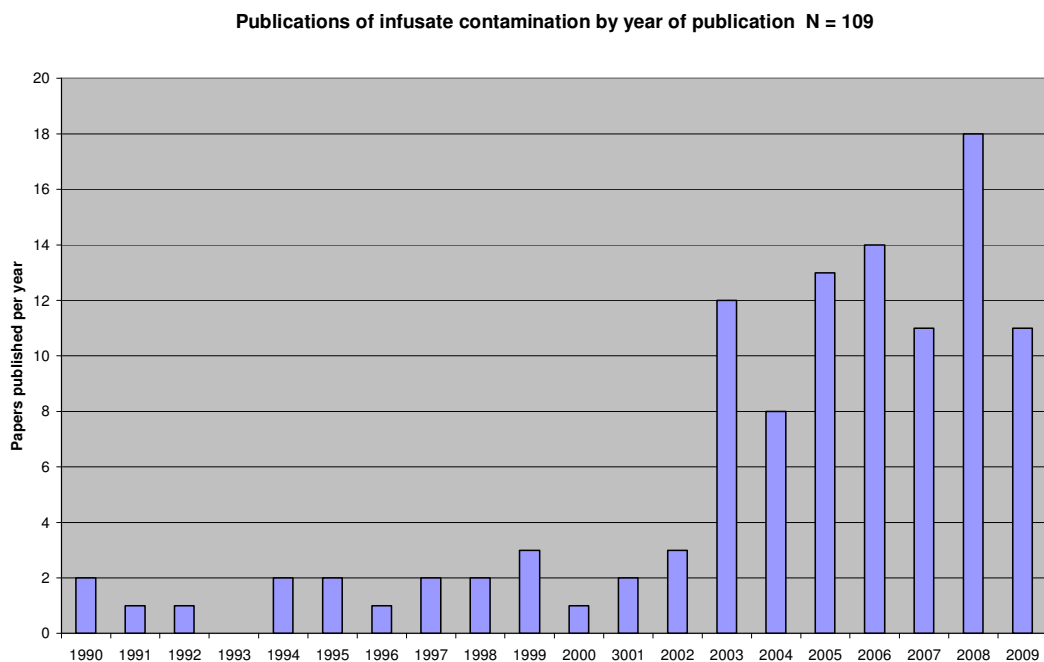
implications for practice. HCWs in the study wards, and in general, are currently not directed to consider infusate contamination in patients with significant pyrexia and thereby may not move to stop a contaminated infusion, leaving the patient to suffer the life-threatening implications of a BSI without removing the cause – the contaminated infusate. This situation is similar to that of another life-threatening nosocomial disease which was initially frequently under diagnosed – Legionnaires' disease.

In 6 hospitals where Legionnaires' disease had never been reported, researchers asked the hospital executives if they would be willing to allow microbiological sampling of their hospitals' water supplies. The researchers found *Legionella* spp in the water supplies of 5 out of the 6 hospitals. In 3 hospitals with positive water supplies that allowed the study to continue, cases of Legionnaires' disease were found when appropriate samples were taken from patients (Goetz et al. 1998). These findings emphasise the fact that there needs to be a belief or recognition of the possibility that a disease may occur before it is likely that the disease is diagnosed. Legionnaires' disease outbreak investigations have shown that, although not detected, cases were present before the outbreaks began (Goetz et al. 1998).

As a first step to the prevention of IR-BSI, there must be: recognition that IR-BSI is a disease, recognition that IR-BSI could happen anywhere that drugs are prepared, recognition of what causes IR-BSI and recognition of how to diagnose and treat IR-BSI. This is supported by the reports of heparin

infusions being unexpectedly associated with BSIs, and the look-back exercises that identified more, previously missed incidents (Siegman-Igra et al. 2005, Peiris et al. 2006). The clinical significance of IR-BSI needs to be brought to the attention of all HCWs who prepare infusates and those who care for patients receiving infusates. Awareness should be raised of the clinical signs and symptoms which should trigger an assessment as to whether a contaminated infusate could be the source of the patient's symptoms. Education is required to ensure HCWs are aware of the immediate action necessary for patient safety. Plotting IR-BSI outbreak reports from the literature by year of publication as shown in the graph below, highlights the possibility that perhaps IR-BSI is becoming more visible. The extent to which this is due to reporting bias is, as yet, unknown.

Figure 69 Publications of IR-BSI outbreaks by year 1990-2009



9.4.6 The current training

This thesis did not set out to evaluate the training programme. However, another of the external influences that prevent optimal practice of intravenous drug preparation within the study wards is the national guidance on the correct preparation of intravenous drugs (RCN IV Therapy Forum 2003, Nursing and Midwifery Council 2006, National Patient Safety Agency 2007, Nursing and Midwifery Council 2009) which impacts on the NHS board's education programme. The mandatory training and its content, a single day or two days for ITU staff, together with mentored practice, at present reflects the perceived level of risk of IR-BSI; that is, the risk is low. The instructions and training at present focus on drug calculations to prevent wrong drugs, or drugs being given to the wrong patient. Only one page of the NHS board's 43 page training document is dedicated to aseptic technique and preventing infection (NHS Greater Glasgow and Clyde 2009). This prevention of infection includes generic principles only. For example, it states that 'infection is serious and can be prevented by, hand washing, cleaning of ports, changing of administration sets, minimising the number of manipulations to prepare a medicine and use of closed system (reconstitution devices)' (NHS Greater Glasgow and Clyde 2009). Given that there is a clear recommendation in this package to use reconstitution devices it is difficult to understand why they could have been removed from the 6th study ward.

What is also difficult to understand, however, is how a single standardised education programme could result in the very different procedures as seen in the six study wards; for example, the variety of personal protective equipment, aprons and gloves used, variation in performance of redundancy checks and the variation of equipment utilised within the wards, are all worthy of note. The training as it exists at present is clearly focused on principles and lacking in specifics. The board's training document gives no indication as to how infection develops in a patient and what to do should the patient present with symptoms of infection that may be related to an infusate (NHS Greater Glasgow and Clyde 2009). Those writing the document have built in failures at the knowledge-based level, specifically, 'selectivity' not including all the things that can go wrong and the 'availability heuristic', ignoring that which is not visible (Reason 1990: 88).

The local training document and the training and the mentorship that follows, is insufficient to prevent IR-BSI. Increased training and competency assessment, involving microbiological testing of infusates, will not be required unless and until IR-BSI is recognised for what it is; a real and present danger to patients, which needs to be prevented by adequate training and validation of procedures' efficacy.

Having identified that there is poor national guidance, difficulties in extracting data from the literature, difficulties in determining the size of the problem through surveillance and reporting, difficulties in recognising the problem in

clinical practice and also a lack of specifics in infection prevention training, accountability for IR-BSI should it occur will now be examined.

9.5 Who would be held to account should a patient suffer an IR-BSI?

If a patient were to develop an IR-BSI or worse, there was an outbreak of IR-BSI, the question of who would be held to account needs to be examined. IR-BSI outbreaks are different to other healthcare related outbreaks in that, although many outbreaks result from a failure to wash hands, precisely by whom, at which point and for which procedure hands were not washed can never usually be identified. However, finding which infusate was implicated and who prepared it is much easier for IR-BSI – the person who prepared it will have recorded a signature to that effect. Internationally, criminal investigations have been commenced following outbreaks of IR-BSI (Macias et al. 2005). In a short paper, the question was asked: *Is it safe for nurses to prepare intravenous drugs?* to start debate on this issue, considering the implications for nurses from a UK perspective (Curran et al. 1999). This question still needs to be fully debated and answered: would it be the nurse who has performed the unsafe act, or would corporate responsibility fall to those who wrote inadequate procedures that could not guarantee sterile infusions? Would it be managers who did not provide, or removed safety devices, or would it be those who wrote national guidance which from an aseptic perspective are insufficient to prevent IR-BSI? It could be all of those

described above. Any individual nurse would probably have difficulty in proving that the IR-BSI arose not because he or she that did not follow the aseptic procedure, but because the procedure itself was insufficient to prevent infusate contamination.

9.6 What are the challenges to preventing IR-BSI?

The final objective of this thesis was to detail the challenges that HCWs face in the aseptic preparation of intravenous drugs. It can be concluded that these challenges are that they work in sub-optimal environments, have poor local procedure guidance and have poor product guidance from manufacturers, there are time constraints, equipment constraints and their human resources are finite. If it becomes busy, then they too have to get busy without additional support. It is not the complexity of any given procedure that seems to be the problem, but the factors that work in combination. The guidance that is available is, at times, undoable; for example, to prepare drugs in a quiet area free of distraction. Such areas do not always exist in the NHS in Scotland. Crucially, if an infusate is contaminated, then the nurses will not be able to detect this, and if it causes patient harm - an IR-BSI - nurses may not have the skills or guidance to enable them to recognise it. From these results it can be concluded that the procedure of aseptic drug preparation of intravenous drugs is more error-prone than reliable.

9.7 What can be done locally to reduce the risks of IR-BSI?

For each ward a process map has been provided optimising the procedure within the current available resources (Figures 14, 24, 33, 45, 53 62). Each ward manager was provided with the assessments of their ward and it was suggested that these assessments be shared with the local infection control team. If re-ordering the steps of the procedure to reduce potential contamination will reduce risk from asepsis failure, the second easy step to reducing risk for the patients is to alert all nurses as to the possibility of IR-BSI, the best early detection measures and appropriate early actions. These are clear infection control improvements, but they are not validated and a process of validation is needed.

Those who prepare and administer intravenous drugs should be made aware of IR-BSI and how the condition presents. Most importantly they should know the actions required if a patient becomes pyrexial whilst receiving intravenous drugs, that is, immediate reporting to medical staff, consideration of stopping and replacing the infusion, sending the infusate off for culture along with blood cultures from the patient and continuous monitoring of symptoms. Infusate contamination and IR-BSI should be added to the list of drug errors in all clinical areas.

The definition of high-risk drugs prepared in near patient areas should be extended to include long-term infusions and lipid infusions. If these drugs could arrive on the ward in a ready to administer form safety would be

significantly enhanced. Additionally, the removal of all multi-dose vials would also considerably enhance patient safety.

It has been suggested that certain organisms, such as *Burkholderia cepacia*, isolated in patients who receive intravenous therapy and do not have any additional risk factors, should indicate the possibility of contaminated intravenous products (Held et al. 2006). The results from the six study wards concur with this assertion; that is, monitoring for possible IR-BSI through investigation of positive blood cultures could provide a trigger for a more in-depth investigation of systems. Exactly how infection control teams should investigate IR-BSI needs to be determined; the notion that infusate contamination may be an intermittent problem must be considered when investigations are deemed necessary; ergo, a single infusate which is shown not to be contaminated is not a guarantee of batch-free contamination (Austin and Elia 2009, Blossom et al. 2009).

9.7.1 Building human factors in to the procedure

Included within the methodological framework of this study are human factors. This is crucial because the study procedure is designed by humans and heavily reliant on humans – and as a consequence vulnerable. As stated previously, human factors study is about making it easy for the HCW to do the right thing. There are many steps already discussed which could be taken to make it easier for the HCWs to perform aseptic preparation of intravenous drugs. The main human factors that would help the HCWs are firstly, a written

procedure that is simple to follow and combines all of the aseptic, non-aseptic and mandatory checks. Use of checklists and posters which pictorially illustrate the steps and use colour codes to denote steps that identify the steps critical to asepsis would enhance the overall safety of the procedure and also allow discussions of change to take place when, for example, consideration is given to using a new piece of equipment. Like the drug safety information, this should be available where the drugs are prepared. It would also aid teaching and thus potentially increase reliability by being easy to remember and refer to. Secondly, the environment and workflow require expert assessment. These assessors should have the power to designate areas as unfit for the preparation of intravenous drugs if deemed necessary. The environmental assessments need to be performed at a time when drugs are being prepared and when the wards are at their busiest.

The third change to facilitate aseptic preparation of infusates would be to review all available sundries and use equipment throughout that reduces the number of steps as equipment to reduce the opportunity for microbial entry to a system. To do this there needs to be a multi-disciplinary team approach including clinical experts, practice development, infection control, management, procurement and pharmacy staff. It is impossible for the ward staff to have optimal safe systems without this level of support.

A more radical approach would be to start again and consider whether drugs should be made up in clinical areas at all. Examination is required as to

whether a separate area off the ward, with delivery of drugs to the ward in ready-to-administer form would be safer for both patients and staff. Perhaps 'who prepares drugs' is also a question which needs to be asked again. Nurses inherited this role but, from a patient safety perspective, it may be better done by HCWs whose only task is to prepare intravenous medications rather than the continuously multi-tasking nurses.

What is not currently achievable locally is the recommendation by the Audit Commission that aseptic preparation of intravenous drugs at ward level should cease (Audit Commission 2001). However what is not acceptable, is a ward-prepared infusate contamination rate of 5% (CI 0.8-13.1); this was identified in a recent systematic review of the infusate contamination involving 19 published studies (Austin and Elia 2009). None of the wards in this study participated in any end product testing. Clearly, some level of validation of end product is required to guarantee patient safety.

9.8 How to make IR-BSI visible at a national level?

The recommendations to reduce locally the risk of IR-BSI are also relevant nationally. To transform IR-BSI into a disease that is visible within the literature requires the scientific community to agree a uniformity of reporting MESH terms for IR-BSI. Healthcare related outbreak reports differ from other reports in the scientific literature in that they do not always produce new science, but what they do is highlight that healthcare remains unsafe, and more requires to be done to prevent the problem as it has arisen. IR-BSI

needs better recognition firstly, within the infection control community and secondly, in the guidance produced to prevent vascular access device related infections (peripheral and central) a sub-set of which are IR-BSI. The frontline healthcare community looks to scientists in infection prevention and control for evidence-based guidance on the prevention of infection. This is the opportunity that must be grasped to explain and highlight IR-BSI. National agencies such as Health Protection Scotland, who receive data from all laboratories in Scotland, should look at available blood culture data to determine if evidence is already available to enable detection of at least some organisms that cause IR-BSI.

Guidance on environmental standards with minimum specifications must be set and an understanding of why there are such variances in international guidance developed.

This invisible disease cannot be prevented until it is made visible. Although no single organism indicates an IR-BSI, infection control teams should, in particular, consider which environmental Gram-negative organisms isolated from blood should trigger an 'alert organism' response; that is, an infection control nurse investigating to determine whether the primary source of the BSI was an infusate. Finally, research is required to better understand the nature of IR-BSI and how to prevent it.

9.9 Review of the methods, methodological framework and the results

The methodological framework set out in Chapter 6 of this thesis has proven invaluable. The results have shown that ,from a patient safety perspective, the preparation of intravenous drugs in clinical care settings is inherently dangerous. From a human error and human factors perspective this system designed by humans is fallible. The unsafe acts that can cause infusate contamination in the preparation of intravenous drugs are provoked by the current conditions of work, specifically the environments, staffing, invisibility of IR-BSI as a significant problem, training, equipment and the methods used.

The HCWs' opinions of safety provided useful data showing indicators of safety and indicators of vulnerability within the system which have been. It is difficult to see the utility of this data as a composite safety measure or safety culture score. Making interpretation of the data more difficult is the finding that the opinions of safety of those who perform the procedure do not always equate to the evaluation of the safety of the procedure by the researcher. More research is required here to understand how such surveys can add to the understandings of safety related to an individual procedure.

Patient safety and human error characteristics that make the system more error-prone included procedure complexity, procedure variation, lack of feedback, time constraints and erroneous assumptions of safety. Characteristics that make the system reliable have also been identified; these

included the commitment of staff to performing a safe procedure and the reason for volunteering for the study – to improve their local systems.

Having measured and understood the procedures, and considered the human factors of how it can be made easier for the nurses to do the right thing, improvements can be identified in all six study wards. The nurses were pleased with the simplification of the colour-coded presentations and how they can be used to enhance safety. Measures of output are more difficult to identify as there is currently no validation of the end product.

With regard to the methods used, it is clear that no single data stream, for example, observations of practice, survey of opinions of safety or Location Assessments would have given so complete a picture of the system. Additionally, the system needs to be assessed at the level of the individual working, that is, ward-by-ward and not at a higher level. Individual wards varied and are likely to continue to vary significantly in their resources, their environments and their procedures.

The Location Assessment tool developed from the Vincent et al. (2004) profile has been shown to have utility and could provide the skeleton framework for the study of any dynamic system.

Measuring the opinions of safety related to a single complex procedure may prove useful for other types or procedure undertaken by specific healthcare

worker groups. There are lessons to be learned for the NHS Board in the results from the opinions and redundancy checks data. These issues pertain to what level of redundancy checks they would be happy to achieve for their patients, and whether what they think needs doing is what is actually done or understood by those performing the procedure.

On completion of the thesis minor amendments could be made on improvement of all of the data collection forms, but these are minor, on the whole they proved extremely valuable and could be used by others to examine systems.

9.10 Assessment of the initial arguments

This evaluation of the system of aseptic preparation of intravenous drugs in clinical care settings confirms the arguments put forward at the beginning of the study, but expands on their importance, namely:

- There is and will continue to be a hazard to patients from the status quo.
- It is even more difficult than initially considered to recognise infusate contamination as a cause of BSI.
- The opportunities for asepsis failure are numerous and the prevention strategies are limited.
- Current national guidance and local guidance is extensive yet insufficiently focused on asepsis failure, with no requirement for ongoing quality control.

- The system of aseptic preparation is extremely complex and that complexity is increasing.
- The financial climate means that safety equipment is being withdrawn from service with unrecognised potential consequences.

All six study wards use the same error reporting system which is biased towards the frontline worker being at fault. It is the frontline worker who will have prepared the drug erroneously or missed out steps. But, as highlighted by the nurses from time to time, they have to increase capacity of workload without an increase in capacity of workers, thus increasing the likelihood of accidents; this is without recognition that the system is at increased risk. The role of understaffing being associated with CVC-related BSI has been reported (Fridkin et al. 1996). Reason (2005) identified the term 'vulnerable system syndrome' this is indicated by three perpetuating elements: the blaming of frontline workers when things go wrong, denying the existence of systemic error-provoking weaknesses and the blinkered pursuit of financial indicators. Aseptic drug preparation in Scotland fits into this definition because:

- When errors occur it is the last act (active failure) by the nurse that is considered the error. This was evidenced in this thesis by, for example, the error reporting systems used throughout and by the disclaimer on information provided by pharmacists in the 6th study ward.
- There are systemic error-provoking weaknesses, for example, there are poor environments, insufficient staff when patient-dependency

increases, multi-tasking, and resulting lack of ability to comply with available guidance.

- The pursuit of low costs by the removal of safety devices due to potential cost savings at the expense of patient safety. This was evidenced in the 4th and 6th study wards.

In defence of managers, the professional bodies have not produced clear guidance to counter the last two of these points.

The conclusion of this thesis is that, as long as the perception of IR-BSIs is that it is a rare problem and while specific guidance and equipment to prevent it are absent, infusate contamination and IR-BSI will remain under-diagnosed, under-investigated and under-reported.

9.11 Limitations of this thesis

This thesis set out to identify the system of aseptic preparation of intravenous drug preparation in Scotland, with the objectives of identifying the systems' reliability and error-prone characteristics. To undertake this task, a variety of data sources have been used including assessments of the locations where drugs are prepared, observations of drugs being prepared and collection of the opinions of nurses who performed the procedure. As a consequence of the results of this research in one large NHS board, the system of aseptic drug preparation in clinical care settings is described as more error-prone than reliable. It could be assumed that if more data were to be gathered from other NHS boards, different conclusions could be made. However, the NHS board

where the research was undertaken comprises a third of all healthcare in Scotland. Because the national guidance has been reviewed alongside the system evaluation, it is reasonable to assume that other NHS boards could be advocating similar methods and providing similar environments. The findings of this study are that environments where drugs are prepared can pose a risk of contamination, some of the equipment used increases the risk, and the ward staff are not familiar with what is and what is not sterile at the start of the procedure; therefore, the likelihood that some proportion of drugs are contaminated and that IR-BSI occurs seems logical. The problem might be rare, but even a 0.5% contamination rate – which is optimistic – would mean approximately 150,000 contaminated drugs are infused each year. The proportion that would go on to cause IR-BSI is unknown.

The procedures were observed from the initial step of gathering the equipment until the nurse went to administer the infusate. It is clear, however, that the administration of the infusate is another part of the procedure where asepsis can be interrupted by, for example, identification of the patient (particularly if the patient is unable to assist the nurse).

This research did not include the identification of the response of infection control teams to the isolation of an organism, for example, from environmental Gram negative organisms, the type noted in the literature for causing IR-BSI. In effect, this could have been seen as part of the system of preparation of intravenous drugs.

The arguments that lead to the assessment of the thesis procedure being considered a hazard to patients rely in the main on published outbreak and case reports, and as such this could be considered a limitation. This is because for ethical considerations, there can be few randomised control trials performed in the in the field of infection prevention and control. However, even when available, evidence from randomised control trials seldom provides a complete picture. For example, Safdar and Maki (2006) undertook a systematic review of the randomised control trials to determine the efficacy of vancomycin-containing lock solutions. This review had three fundamental errors, namely, infusate contamination was not listed as a cause of CVC-related BSI, 'infusate' was not one of the search terms used, and lastly, because their search was limited to randomised control trials and incomplete search terms were used, they excluded a report of an outbreak with the very solution they were looking to evaluate the efficacy (Held et al. 2006).

Lastly, it could be considered that the Location Assessment data, observations of drug preparations and survey of opinions are insufficient in number from which to draw wider conclusions. However, because of the lack of national environmental guidelines, it seems reasonable to assume similar systems to those examined are prevalent elsewhere in NHS Scotland.

This study was designed to describe a system and did not use microbiology methods although opportunities for such investigations presented themselves.

For example, the sampling of infusates produced with and without using reconstitution devices and or dispensing pins would have yielded useful data. However, the system being described was not known before the study began and therefore this line of investigation was not possible as ethical permission had not been sought in advance, and funding for microbiology had not been secured. Additionally, such investigations would require a much larger study powered to produce rates of contamination with small confidence intervals. Such work could be undertaken in the future to enhance the knowledge base around this topic.

Information on the significant variation of equipment used in the different clinical areas arose during the study. Several assertions were made regarding the utility of the different types of equipment and potential risks / benefits including time, cost, safety and reliability. The need for a full cost-benefit evaluation of the different equipment was not considered before the study began and ethical permission was not requested for this. Therefore, as no cost-benefit analysis was done this limits the overall evaluation of the equipment information provided. This work should be done in the future.

9.12 The strengths of this thesis

The strengths of this research lie in the methodological framework, which enables a complete systems approach to be applied to the thesis procedure. The methodological framework included elements of patient safety, human error and human factors study, as well as the safety culture. Most importantly

however, the complete systems approach includes the people, the environment, the methods and the available and (unavailable) equipment. By focusing the study on the areas where intravenous drugs are prepared in high-quantities and which the evidence from the literature has identified as posing a risk of outbreak, the likelihood of recognising system elements which could provoke weaknesses has been increased.

As a nurse who has professionally prepared intravenous infusions and investigated IR-BSI, the researcher was able to bring a unique insider perspective to devising of the data collection tools and to the analysis of the data.

This approach could be repeated in different settings or modified for different procedures. Those who volunteered to take part in the study did so because they hoped the procedure would result in affirmation that their procedures were sound or that the outcome would result in improved safety for the patients who receive the drugs. The nurse managers all stated they found the outputs useful. If required to start again, there is little that the researcher would change in the way the research was performed.

This study has identified perspectives from which to view the procedures in order to enable greater safety to be embedded by those preparing intravenous drugs.

10 Conclusions

Despite a willingness by nurses and by ward managers to provide safe systems, and a readiness report errors in order to improve the safety of procedures, it must be concluded that aseptic intravenous drug preparations are safety-critical procedures (performed approximately 3,000,000 times a year in NHSScotland) at times without optimal environments, without optimal equipment, with minimal asepsis guidance and without quality control. As a consequence this procedure is error-prone and from a safety perspective is unreliable.

10.1 Conclusions related to the regulations and guidance

As there are no national environmental standards and risks of potential environmental contamination were detected in five of the six study wards, it seems reasonable to assume that other hospitals will be allowing preparation of drugs in similar sub-optimal environments and using similar sub-optimal procedures.

Despite extensive documentation, the local guidance available for those preparing intravenous drugs to prevent infusate contamination is limited. The standards within the guidance available were also in part not achievable and failed to take account of the circumstances in which the nurses worked; on the

basis of the environments sampled, quiet areas free from distraction and interruption do not appear to exist in NHSScotland.

There is a lack of recognition in the national and local guidance of the risks posed by specific infusates, for example, long-term infusions, infusates made from multi-dose vials (even if containing preservative) and by certain drugs such as heparin and propofol.

There is no extant national guidance which considers IR-BSI as a real and present danger to patients. Guidance that is available uses non-specific terms such as 'appropriate', 'safe', and 'suitable' which are inadequate for those providing the environments or trying to perform the procedures safely.

In both local and national guidance, IR-BSI is not considered a drug error, the signs and symptoms to look for are not well known or highlighted to the clinical teams who prepare and infuse drugs.

The manufacturers' drug labels need to be improved to indicate clearly to those preparing infusates whether the drug is accessed through a sterile or non-sterile port and whether the individual drug poses a significant infection risk.

Manufacturers' guidance on the use of antiseptics should clarify how long the antiseptic needs to be applied to the device, or to the skin, in order to achieve decontamination.

In the UK there is no published standard aseptic procedure or mandatory guidance specific for intravenous drug preparation which takes account of the risks from the environment, external drug vial surfaces, internal contents of drug vials and the necessary interruptions of the procedure caused by the need for mandatory checks or application of labels.

There is significant variance in regulation and quality control between UK and US guidance with the US mandating wide-ranging environmental and quality assurance controls. The rationale for this variance needs to be examined and explained. Either the US is over-regulated and over-cautious or in the UK the NHS is exposing patients to unnecessary risk.

10.2 Conclusions related to the risks

As there is no ongoing surveillance of IR-BSI or of infusate contamination rates, the degree of infusate contamination and IR-BSI that occurs as a consequence of these procedures is unknown. However, the risks identified in this research show that the risk of contamination is real, even if the size of the risk is yet to be quantified. In future research it would be useful to correlate specific environment-related microbiological data with data on infusate contamination rates.

Without instruction to the contrary, managers can and do remove safety devices that protect patients from IR-BSI.

10.3 Conclusions related to the system

Overall, aseptic preparation in clinical areas can be considered as meeting the criteria for a 'vulnerable system syndrome' in that the front-line workers are blamed for errors, there are unrecognised systemic error-provoking weaknesses, and cost is used as a reason to reduce safety precautions.

In relation to Human Error Theory, HCWs could easily perform unsafe acts when completing intravenous drug preparation procedures because of latent conditions in the organisation and culture and the current conditions of work. Additionally from a Human Factors perspective, it is not easy for the HCWs to do the right thing or to be sure what is the right thing to do.

The study has identified systematic errors about which the nurses who prepare the drugs were unaware in each of the six study wards visited in relation to either the environment and or the procedure.

Although, this is, in theory, a single procedure, it has evolved very differently on different wards. It varies due to the environment, the equipment available for use and the perceived risk to the patient, even though the risk of an IR-BSI

is not dependent on the patient's underlying condition. The variations in individual procedures enhance the error-prone nature of the system.

The nurses in this study have made the best of the environmental resources available to them and want to know how to make their systems better.

The majority of aseptic procedures performed are interrupted by, for example, the need to put a label on the infusate as soon as the drug had been added or the need to undertake mandatory checks which involve touching non-sterile items. The need to recommence the aseptic procedure is not preceded by hand hygiene and therefore there is, as a consequence, the potential to contaminate the infusate. By considering the procedure as interrupted, and by colour-coding steps as either aseptic or non-aseptic, the nurse can be logically guided to perform hand hygiene as required. [This is not required for 2-person non-interrupted procedures].

Gloves are routinely used by many nurses who prepare drugs, but there is confusion regarding why the gloves are used and what they are achieving. Gloves can prevent asepsis as effective hand hygiene cannot be achieved with gloved hands.

At present low priority is given to preventing asepsis failures by the use of redundancy checks; this is evidenced by asepsis redundancy checks being

performed, less frequently than the mandatory checks of right drug, right dose, right diluent and right patient.

10.4 Conclusions related to the safety culture

Measuring the nurses' opinions of safety gives a more complete systems analysis of this procedure. The data gathered in this project can be used locally to identify what is needed to enhance safety, for example, feedback on performance and increasing knowledge regarding the capability to detect asepsis failure.

The nurses' perceptions of the risk of infusate contamination and of their ability to detect it should it occur are at variance with reality; for example, they are more likely to believe they can prevent and detect asepsis failure when this is not the case.

Aseptic preparation of drugs is not a well-liked procedure and some nurses find it stressful. Nurses work where they work not because they like to undertake intravenous drug preparation procedures, but in spite of the fact they have to prepare them. Why this is so is yet to be determined.

The nurses' commitment to safety was demonstrated by a stated willingness to report errors should they occur.

There is no drug that can be considered immune to contamination and thus any drug can potentially cause IR-BSI. Necessary equipment, environments and procedures that minimise the risk of contamination from occurring are required. Training is needed to alert nurses to the risks associated with preparing intravenous drugs and how to minimise these risks. Additionally, training should include how to look for and recognise IR-BSI and what to do should it be suspected.

10.5 Conclusions as to why the system is as it is

The lack of a reliable error-free procedure performed, with quality control, in hospitals in NHSScotland relates directly to a chain of external influences as highlighted below:

- Infusate contamination causing IR-BSI is considered rare, although there is evidence in the literature to suggest the problem occurs more frequently than is recognised. Additionally, the clinical presentations of IR-BSI, which can occur during the infusion, a short time after the infusion, or many months after the infusion, leads to difficulties in relating IR-BSI back to a contaminated infusate. Reports such as exist in the scientific literature are not uniformly indexed, making systematic searches difficult to achieve. Therefore, at present, IR-BSI is under-recognised and under-reported.
- IR-BSI is also difficult to quantify and to survey because it is not a disease caused by a single micro-organism or even a single group of micro-organisms.

10.6 Conclusions related to the study methods

If other researchers decide to undertake a systems' analysis of intravenous drug preparation then it should be done, as in this study, at the level of individual units, inclusive of all system elements and not at a divisional or board level. This study has shown that there are significant variations in environments, resources and procedures and thus significant variations in risk of contamination.

Examination of any intravenous drug preparation system must also take place from the perspective of both the patient and the individual who must prepare the infusate. The procedure which the nurse is asked to perform must itself be capable of producing a sterile infusate. The nurse must be afforded all the required resources to complete the procedure as required, including most importantly, sufficient time. This is imperative because even though systems may be at fault, it is individuals who are held to account.

This research has investigated the procedure of intravenous drug preparation in clinical care settings principally to determine if the system is patient-safe. At present the system is error-prone, some environments are poor and safety equipment is not always available. Consequently, from an aseptic perspective, this frequently performed procedure cannot be considered safe and reliable. The system lacks asepsis quality control. As long as the perception of IR-BSI is that it is a rare problem, and specific guidance and surveillance to prevent

and detect it are absent, then infusate contamination and IR-BSI will remain under-diagnosed, under-investigated and under-reported. However, patients requiring drugs prepared in clinical areas will continue to be exposed to possible infusate contamination and potentially to IR-BSI.

11 Recommendations

Based on the conclusions from the data in this research project, recommendations are offered to improve the system of aseptic preparation of intravenous drugs in clinical care settings. These recommendations focus on improving systems by reducing risks. These recommendations have been divided into local and national categories.

11.1 Local Recommendations

To render the local system of aseptic preparation of intravenous drugs more reliable and less error-prone, the following recommendations are made:

- The board should undertake a risk-assessment of all clinical areas where drugs are prepared.
- There is a need for the environmental risk-assessment to involve experts in environmental microbiological risks. It must be acknowledged that some clinical areas as currently configured may not be suitable for intravenous drug preparation procedures.
- Local procedures should be optimised to ensure that any interruptions in aseptic technique are followed by recommencement of the procedure by hand hygiene.
- Each clinical area should have a written procedure of what should be done, wherever possible using pictures to illustrate clearly how and in what order the steps should be performed. This written procedure

should be reviewed and amended each time new equipment is purchased.

- There is need for a risk-assessment of the exposure of nurses to drug contamination during this procedure. As a consequence of this assessment, the requirement for gloves and other personal protective equipment should be reassessed.
- The risk-assessment should ensure that the procedure is capable of achieving a sterile infusate and the nurses have the resources required to achieve this.
- There is a need for better local guidance which can make it easier for the nurses to do the right thing.
- The risk of IR-BSI and how it manifests clinically needs to be brought to the attention of all staff.
- IR-BSI should be a listed adverse event and recognised as a drug error.
- All those who prepare infusates must be made aware what is sterile at the start of the procedure and how sterility is best maintained throughout.
- The need to decontaminate vial tops must be made clear in all written procedures.
- Drugs at high-risk of infusate contamination need to be identified on all wards; replacements to reduce risk should be purchased where possible.
- Use of multi-dose vials should cease.

- Equipment that can reduce the risk of infusate contamination should be identified and utilised based on expert advice.
- Wherever possible reconstitution devices should be used.
- Infection control teams should add environmental Gram negative micro-organisms, isolated from blood, to the list of alert organisms requiring specific investigations.
- Some level of quality control should commence.
- A review of the education and training needs should be undertaken to ensure patient safety through the production of sterile infusates.

11.2 National recommendations

To make the system of aseptic preparation of intravenous drugs locally more reliable and less error-prone nationally, the following recommendations are made:

- Environment specifications, including the minimum standards for safe preparation of IR-BSI must be set.
- The risk of infusate contamination from long-term infusions, lipid drugs, multi-dose vials should be reappraised.
- There should be greater recognition of the problem of IR-BSI in national guidance, including methods to be used to identify and to report it.
- The burden put on nurses by this task needs to be understood by those who prepare national guidance and those who ask them to perform it.

- The procedures and steps advocated in national guidance should be tested for their utility and resource requirement before being advocated.
- There should be recognised MESH terms for infusate contamination reports.
- Those producing evidence-based guidance should be alert to the difficulties of identifying infusate contamination reports in the literature.
- There should be recommendations within national guidance of what the system must provide to ensure that the organisation and the culture and the current conditions of work do not engender error-provoking weaknesses.
- The problem of IR-BSI needs to be better recognised by the infection control community.
- Surveillance of IR-BSI should be tested.
- Drug information should include the infection risks in readable text.
- Antiseptic information must be more comprehensive and should include application times and recommended modes of application.
- Drug packaging should clearly identify what is sterile and what is not sterile with regard to the drug and the drug container.
- A validated aseptic procedure to prepare intravenous drugs in clinical settings requires to be developed. This procedure must take account of all the potential contamination sources.

These recommendations include the making the problem of IR-BSI more well known. To that end a paper has been submitted to the British Journal of

Nursing entitled 'Intravenous drugs prepared in near-patient areas pose significant, but insufficiently recognised, infection risks. This paper is included as Appendix 12.

11.3 Research agenda

As a consequence of this research project, the following research questions should be considered as necessary to the safety of patients in Scotland:

- How can safe intravenous drug preparation procedures be achieved and demonstrated in Scotland?
- Are the environmental standards in the US essential for patient safety?
- What are the most cost-effective methods of IR-BSI surveillance?
- Are nurses exposed to drug contamination during preparation and, if present, how can this exposure risk be minimised?
- How useful are safety culture assessments for individual procedures?
- What are the optimal training and competency requirements for safe intravenous drug preparation procedures?

12 Glossary

Term	Definition
Adverse event	Unintended outcome caused by medical management rather than the disease process and which is sufficiently serious to lead to prolongation of hospitalisation, or to temporary or permanent impairment, or disability to the patient.
Ampoule	A small sealed glass container for drugs used mainly for parenteral administration.
Antibiotic lock	An antibiotic that is injected into the catheter but not flushed through to reduce the proliferation of biofilm.
Aseptic non-touch technique ANTT™	A trademarked procedure for various aseptic techniques advocated as a means to achieve standardisation of process.
Aseptic technique	A method of performing a procedure without introducing a risk of infection to the patient.
Biofilm	The development on the surface of a vascular access device (but any surface in contact with moisture) of micro-organisms and polymers producing a sticky substance that protects and enables micro-organisms to flourish.

Term	Definition
Endotoxin	A toxin liberated on the death of micro-organisms, particular the Gram-negative bacilli. Endotoxin in the blood stream can give rise to a severe life-threatening condition – endotoxic shock. The patient experiences fever, blood pressure is reduced and coagulation of blood can be interrupted.
Extrinsic contamination	Contamination occurring after manufacture.
Gram stain in relation to Gram negative and Gram positive organisms	All micro-organisms are colourless and difficult to see, even under a microscope, without application of stains. Gram's stain differentiates between micro-organisms of a similar shape but with different cell wall thickness. Bacteria with thin cell walls do not retain the stain (Gram negative) and those with thicker cell walls retain the stain (Gram positive). The difference in cell wall thickness has implications for antibiotic therapy and can aid in the preliminary 'best guess' identification of the organism.
Intravenous administration	The giving of a drug directly into the blood stream via a vein.
Intravenous infusate	Any intravenous drug prepared in clinical areas by nurses for intravenous administration.
Infusate	The contamination of an infusate with any micro-organism

Term	Definition
contamination	or endotoxin that could potentially cause a blood stream infection or vascular device infection.
Intrinsic contamination	Contamination occurring at the manufacturers.
<i>Plasmodium falciparum</i>	The parasite that causes malaria.
Scrub sink	A deep metal washing facility which enables the arm from finger tips to elbow to be rinsed.
Sentinel event	Unanticipated death or serious injury related to healthcare.
Sp and Spp	Accepted abbreviations for species Sp species singular; Spp species pleural
Vascular catheters	A cannula which facilitates a temporary direct access to the blood stream via a plastic tube.
Vial	A small rubber sealed glass container containing a drug.
Violation	An intended action which can be caused by an individual intending to cause harm or intending to enhance safety.

Drug Glossary	
ACE inhibitors	Drugs used in the treatment of hypertension
Aminophylline	Drugs used to aid patient breathing (broncho-dilator)
Analgesia	Drugs used to relieve pain
Antibiotics	Drugs used to prevent multiplication of micro-organisms within the body.
Propofol Diprivan®	An anaesthetic agent prepared in lipid emulsion, known for its ability to promote microbial growth.
Heparin	A drug used to reduce clotting (anticoagulant)
Inotropes	Drugs used to strengthen the heart contraction.
Protein pump inhibitors	Drugs used to reduce gastric acid and thereby heartburn.

13 References

Abraham A (2009) Risk and outbreak communication: lessons from alternative paradigms. *Bulletin World Health Organization* 87 604-607.

Albrecht SJ, Fishman NO, Kitchen J, Nachamkin I, Bilker WB, Hoegg C, Samel C, Barbagallo S, Arentzen J, Lautenbach E (2006) Reemergence of gram-negative health care-associated bloodstream infections. *Archives of Internal Medicine* 166 (12) 1289-1294.

Al-Saigul AM, Fontaine RE, Haddad Q (2000) Nosocomial malaria from contamination of a multidose heparin container with blood. *Infection Control Hospital Epidemiology* 21 (5) 329-330.

Altman DE, Clancy C, Blendon RJ (2004) Improving patient safety - five years after the IOM report. *New England Journal of Medicine* 351 (20) 2041-2043.

Amalberti R, Vincent C, Auroy Y, de Saint Maurice G (2006) Violations and migrations in health care: a framework for understanding and management. *Quality and Safety in Health Care* 15 Suppl 1 i66-71.

Apkon M, Leonard J, Probst L, DeLizio L, Vitale R (2004) Design of a safer approach to intravenous drug infusions: failure mode effects analysis. *Quality and Safety in Health Care* 13 (4) 265-271.

Audit Commission (2001) *A spoonful of sugar: medicines management in NHS hospitals*. London, Audit Commission.

Austin PD, Elia M (2009) A systematic review and meta-analysis of the risk of microbial contamination of aseptically prepared doses in different environments. *Journal of Pharmacy and Pharmaceutical Sciences* 12 (2) 233-242.

Balka E, Doyle-Waters M, Lecznarowicz D, Fitzgerald JM (2007) Technology, governance and patient safety: Systems issues in technology and patient safety. *International Journal of Medical Informatics* 76 Suppl 1 35-47.

Ball PA (2003) Intravenous in-line filters: filtering the evidence. *Current Opinions in Clinical Nutrition and Metabolic Care* 6 (3) 319-325.

Baumgartner TG, Schmidt GL, Thakker KM, Sitren HS, Cerda JJ, Mahaffey SM, Copeland EM, 3rd (1986) Bacterial endotoxin retention by inline intravenous filters. *American Journal of Hospital Pharmacy* 43 (3) 681-684.

Beaney A, Goode J (2003) A risk assessment of the ward-based preparation of parenteral medicines. *Hospital Pharmacist* 10 306-308.

Beck U (1996) Risk society and the provident state. In: Lash S, Szerezynski, S, Wynne B (eds). *Risk, Environment and Modernity: Towards a New Ecology*. 27-43. London, Sage.

Bennett SN, McNeil MM, Bland LA, Arduino MJ, Villarino ME, Perrotta DM, Burwen DR, Welbel SF, Pegues DA, Stroud L, Zeitz PS, Jarvis WR (1995) Postoperative infections traced to contamination of an intravenous anesthetic, propofol. *New England Journal of Medicine* 333 (3) 147-154.

Berg M, Aarts J, van der Lei J (2003) ICT in health care: sociotechnical approaches. *Methods of Information in Medicine* 42 (4) 297-301.

Berwick DM (2003) Errors today and errors tomorrow. *New England Journal of Medicine* 348 (25) 2570-2572.

Blossom D, Noble-Wang J, Su J, Pur S, Chemaly R, Shams A, Jensen B, Pascoe N, Gullion J, Casey E, Hayden M, Arduino M, Budnitz DS, Raad I, Trenholme G, Srinivasan A (2009) Multistate outbreak of *Serratia marcescens* bloodstream infections caused by contamination of prefilled heparin and isotonic sodium chloride solution syringes. *Archives of Internal Medicine* 169 (18) 1705-1711.

Blot S, Vandewoude K, De Bacquer D, Colardyn F (2002) Nosocomial bacteremia caused by antibiotic-resistant gram-negative bacteria in critically ill

patients: clinical outcome and length of hospitalization. *Clinical Infectious Diseases* 34 (12) 1600-1606.

Boakes E (2009) Using foresight in safe nursing care. *Journal of Nursing Management* 17 (2) 212-217.

Boktour M, Hanna H, Ansari S, Bahna B, Hachem R, Tarrand J, Rolston K, Safdar A, Raad I (2006) Central venous catheter and *Stenotrophomonas maltophilia* bacteremia in cancer patients. *Cancer* 106 (9) 1967-1973.

Borkan JM (2004) Mixed methods studies: a foundation for primary care research. *Ann Fam Med* 2 (1) 4-6.

Bowling A (2002) *Research Methods in Health: investigating health and health services*. 2nd edition. Maidenhead, Open University Press.

Cape BF, Dobson P (1974) (eds) *Baillier's Nurses' Dictionary*. 18th edition. Baillier Tindall, London.

Carrico R, Ramirez J (2007) A process for analysis of sentinel events due to health care-associated infection. *American Journal of Infection Control* 35 (8) 501-507.

Carroll JS, Rudolph JW (2006) Design of high reliability organizations in health care. *Quality and Safety in Health Care* 15 Suppl 1 i4-9.

Centers for Disease Control (2003) Transmission of hepatitis B and C viruses in outpatient settings - New York, Oklahoma, and Nebraska, 2000-2002. *Morbidity and Mortality Weekly Report* 52 (38) 901-906.

Centers for Disease Control (2005) *Pseudomonas* Bloodstream infections associated with a heparin/saline flush Missouri, New York, Texas and Michigan 2004-5. *Morbidity and Mortality Weekly Report* 54 (11) 269-272.

Centers for Disease Control (2006) Update: Delayed onset *Pseudomonas fluorescens* bloodstream infections after exposure to contaminated heparin flush Michigan and South Dakota 2005-6. *Morbidity and Mortality Weekly Report* 55 (35) 961-963.

Ceyhan M, Yildirim I, Tekeli A, Yurdakok M, Us E, Altun B, Kutluk T, Cengiz AB, Gurbuz V, Barin C, Bagdat A, Cetinkaya D, Gur D, Tuncel O (2008) A *Chryseobacterium meningosepticum* outbreak observed in 3 clusters involving both neonatal and non-neonatal pediatric patients. *American Journal of Infection Control* 36 (6) 453-457.

Chapman S, Jr., Iredell JR (2008) Gram-negative sepsis in the intensive care unit: avoiding therapeutic failure. *Current Opinions in Infectious Diseases* 21 (6) 604-609.

Cholley P, Thouverez M, Floret N, Bertrand X, Talon D (2008) The role of water fittings in intensive care rooms as reservoirs for the colonization of

patients with *Pseudomonas aeruginosa*. *Intensive Care Medicine* 34 (8) 1428-1433.

Coello R, Charlett A, Ward V, Wilson J, Pearson A, Sedgwick J, Borriello P (2003) Device-related sources of bacteraemia in English hospitals - opportunities for the prevention of hospital-acquired bacteraemia. *Journal of Hospital Infection* 53 (1) 46-57.

Coiera E (2007) Putting the technical back into socio-technical systems research. *International Journal of Medical Informatics* 76 Suppl 1 98-103.

Colla JB, Bracken AC, Kinney LM, Weeks WB (2005) Measuring patient safety climate: a review of surveys. *Quality and Safety in Health Care* 14 (5) 364-366.

Conrow Comden S, Marx D, Murphy-Carley M, Hale M (2004) Using probabilistic risk assessment to model medication system failures in long-term care facilities. *Advances in Patient Safety: From Research to Implementation: Cognition, Systems and Risk*. 2. 395-407. Available: <http://www.ahrq.gov/qual/advances/> [Accessed 7 September 2010].

Cook RI, Woods DD (1994) Operating at the Sharp End: The Complexity of Human Error. In: Bogner M S (ed). *Human error in medicine* 255-309. Hillsdale NJ, Lawrence Erlbaum Associates.

Cooke H (2009) Theories of risk and safety: what is their relevance to nursing? *Journal of Nursing Management* 17 (2) 256-264.

Corporate Manslaughter and Corporate Homicide Act (2007) Corporate Manslaughter and Corporate Homicide Act 2007 (Amendment of Schedule 1) Order 2008.

Cousins DH, Sabatier B, Begue D, Schmitt C, Hoppe-Tichy T (2005) Medication errors in intravenous drug preparation and administration: a multicentre audit in the UK, Germany and France. *Quality and Safety in Health Care* 14 (3) 190-195.

Cox S, Flin R (1998) Safety Culture: Philosopher's stone or man of straw? *Work and Stress* 12 (3) 93-104.

CRAG (2002) *Good practice statement for the preparation of injections in near-patient areas, including clinical and home environments*. Clinical Resource and Audit Group (CRAG), Edinburgh. Scottish Executive.

Cresswell JW, D. FM, Ivankova NV (2004) Designing a mixed methods study in primary care. *Annals of Family Medicine* 2 (1) 7-12.

Croteau RJ, Schyve MD (2000) Proactively error-proofing health care processes. Ch. 7. In: *Spath PL (ed) Error Reduction in Health Care. A systems approach to improving patient safety*. San Francisco, Jossey-Bass.

Crowley C, Scott D, Duggan C, Whittlesea C (2004) Describing the frequency of IV medication preparation and administration errors. *Hospital Pharmacist* 11 330-336.

Curran E, McNamee S, Kirkpatrick P, Jackson B, Hood J, Thakker B (1999) Is it safe for nurses to make up I.V. infusions? *British Journal of Nursing* 8 (21) 1413.

Curran ET, Coia JE, Gilmour H, McNamee S, Hood J (2000) Multi-centre research surveillance project to reduce infections/phlebitis associated with peripheral vascular catheters. *Journal of Hospital Infection* 46 (3) 194-202.

Cuschieri A (2003) Medical errors, incidents, accidents and violations. *Minimally Invasive Therapy and Allied Technologies* 12 (3) 111-120.

Dagi TF, Berguer R, Moore S, Reines HD (2007) Preventable errors in the operating room--part 2: retained foreign objects, sharps injuries, and wrong site surgery. *Current Problems in Surgery* 44 (6) 352-381.

Davis RM, Pless B (2001) BMJ bans "accidents". *British Medical Journal* 322 (7298) 1320-1321.

Dekker S (2006) *The Field Guide to Understanding Human Error*. Aldershot, Ashgate.

Deliere E, Vu-Thien H, Levy V, Barquins S, Schlegel L, Bouvet A (2000) Epidemiological investigation of *Ochrobactrum anthropi* strains isolated from a haematology unit. *Journal of Hospital Infection* 44 (3) 173-178.

Dept. of Health (2000) *An Organisation with a Memory, Report of an expert working group on adverse events in the NHS chaired by the Chief Medical Officer*. The Stationary Office, London.

Dept. of Health (2001) *Learning from Bristol: the report of the public enquiry into the management of care of children requiring complex heart surgery at the Bristol Royal Infirmary*. The Stationary Office, London.

DeRosier J, Stalhandske E, Bagian JP, Nudell T (2002) Using health care Failure Mode and Effect Analysis: the VA National Center for Patient Safety's prospective risk analysis system. *Joint Commission Journal of Quality Improvement* 28 (5) 248-267, 209.

Doerge TC (1978) Sounding board. An injury is no accident. *New England Journal of Medicine* 298 (9) 509-510.

Doerge TC (1999) Eschewing accidents. *Journal of the American Medical Association* 282 (5) 427.

Doit C, Loukil C, Simon AM, Ferroni A, Fontan JE, Bonacorsi S, Bidet P, Jarlier V, Aujard Y, Beaufils F, Bingen E (2004) Outbreak of *Burkholderia*

cepacia bacteremia in a pediatric hospital due to contamination of lipid emulsion stoppers. *Journal of Clinical Microbiology* 42 (5) 2227-2230.

Donlan RM (2001) Biofilms and device-associated infections. *Emerging Infectious Diseases* 7 (2) 277-281.

Dougherty L, Lister Se (2004) *The Royal Marsden Hospital Manual of Clinical Nursing Procedures*. Chapter 4. 6th edition. Oxford, Blakewell Publishing.

Douglas M (1992) *Risk and Blame: Essays in Cultural Theory*. London, Routledge.

Driscoll DL, Appiah-Yeboah A, Salib P, Rubert DJ (2007) Merging qualitative and quantitative data in mixed methods research: how to and why not. *Ecological and Environmental Anthropology* 3 (1) 19-27.

Duerden BI (2009) Responsibility for managing healthcare-associated infections: where does the buck stop? *Journal of Hospital Infection* 73 (4) 414-417.

Edgeworth JD, Treacher DF, Eykyn SJ (1999) A 25-year study of nosocomial bacteremia in an adult intensive care unit. *Critical Care Medicine* 27 (8) 1421-1428.

Eickhoff TC (1994) Airborne nosocomial infection: a contemporary perspective. *Infection Control Hospital Epidemiology* 15 (10) 663-672.

Erbay A, Kanyilmaz D, Us E, Mumcuoglu I, Karahan ZC, Gozel G, Balaban N, Bodur H (2008) A cluster of *Klebsiella pneumoniae* bacteremia in a radiation oncology ward. *American Journal of Infection Control* 36 (9) 678-680.

Evans L (1993) Medical accidents: no such thing? *British Medical Journal* 307 (6917) 1438-1439.

Felts SK, Schaffner W, Melly MA, Koenig MG (1972) Sepsis caused by contaminated intravenous fluids. Epidemiologic, clinical, and laboratory investigation of an outbreak in one hospital. *Annals of Internal Medicine* 77 (6) 881-890.

Fischhoff B, Lichtenstein S, Slovic P, Derby SL, Keeney RL (1981) *Acceptable Risk*. New York, Cambridge University Press.

Flin R (2007) Measuring safety culture in healthcare: A case for accurate diagnosis. *Safety Science* 45 633-637.

Flin R, Burns C, Mearns K, Yule S, Robertson EM (2006) Measuring safety climate in health care. *Quality and Safety in Health Care* 15 (2) 109-115.

Flin R, Yule S (2004) Leadership for safety: industrial experience. *Quality and Safety in Health Care* 13 Suppl 2 ii45-51.

Fridkin SK, Pear SM, Williamson TH, Galgiani JN, Jarvis WR (1996) The role of understaffing in central venous catheter-associated bloodstream infections. *Infection Control Hospital Epidemiology* 17 (3) 150-158.

Gabe J (1995) (ed) *Medicine, Health and Risk: Sociological Approaches*. Cambridge, Blackwell Publications.

Gershman MD, Kennedy DJ, Noble-Wang J, Kim C, Gullion J, Kacica M, Jensen B, Pascoe N, Saiman L, McHale J, Wilkins M, Schoonmaker-Bopp D, Clayton J, Arduino M, Srinivasan A (2008) Multistate outbreak of *Pseudomonas fluorescens* bloodstream infection after exposure to contaminated heparinized saline flush prepared by a compounding pharmacy. *Clinical Infectious Diseases* 47 (11) 1372-1379.

Giamarellou H (2002) Nosocomial cardiac infections. *Journal of Hospital Infection* 50 (2) 91-105.

Gilat T, Hertz M, Altmann G (1958) Severe shock syndrome due to contaminated infusions. *British Medical Journal* 1 (5079) 1104-1106.

Gillespie EE, Bradford J, Brett J, Kotsanas D (2007) *Serratia marcescens* bacteremia - an indicator for outbreak management and heightened surveillance. *Journal of Perinatal Medicine* 35 (3) 227-231.

Glendon AI, Clarke SG, McKenna EF (2006) *Human safety and risk management*. 2nd edition. Florida, CRC Press.

Goetz AM, Stout JE, Jacobs SL, Fisher MA, Ponzer RE, Drenning S, Yu VL (1998) Nosocomial legionnaires' disease discovered in community hospitals following cultures of the water system: seek and ye shall find. *American Journal of Infection Control* 26 (1) 8-11.

Gordin FM, Schultz ME, Huber R, Zubairi S, Stock F, Kariyil J (2007) A cluster of hemodialysis-related bacteremia linked to artificial fingernails. *Infection Control Hospital Epidemiology* 28 (6) 743-744.

Grobner S, Heeg P, Autenrieth IB, Schulte B (2007) Monoclonal outbreak of catheter-related bacteraemia by *Ralstonia mannitolilytica* on two haemato-oncology wards. *Journal of Hospital Infection* 55 (6) 539-544.

Gulati S, Sahu KM, Avula S, Sharma RK, Ayyagiri A, Pandey CM (2003) Role of vascular access as a risk factor for infections in hemodialysis. *Renal Failure* 25 (6) 967-973.

Hales BM, Pronovost PJ (2006) The checklist--a tool for error management and performance improvement. *Journal of Critical Care* 21 (3) 231-235.

Halkes MJ, Snow D (2003) Re-use of equipment between patients receiving total intravenous anaesthesia: a postal survey of current practice. *Anaesthesia* 58 (6) 582-587.

Health and Safety Executive (2006) *Five steps to risk assessment*. Health and Safety Executive. INDG 163(rev2) 1-8. Available: www.hse.gov.uk/pubns/indg163.pdf [Accessed 9 September 2010].

Health and Safety Executive (2009) Working with substances hazardous to health. What you need to know about COSHH. *Health and Safety Executive* INDG 136(rev4). revised 06/09. Available: www.hse.gov.uk/pubns/indg136.pdf [Accessed 13 September 2010].

Health Protection Agency (2003) *Klebsiella, Enterobacter, Serratia and Citrobacter* spp bacteraemias, in England, Wales and Northern Ireland 2002. *Communicable Disease Report Weekly* 13 (20) 5-9.

Health Protection Agency (2005) *Pseudomonas* spp and *Stenotrophomonas maltophilia* bacteraemia: England, Wales and Northern Ireland: 2004. *Communicable Disease Report Weekly* 15 (39) 1-7.

Health Protection Agency (2007) Klebsiella, Enterobacter, Serratia and Citrobacter spp bacteraemia - trends in total reports 2002-6. Available: http://www.hpa.org.uk/infections/topics_az/jesc/trends.htm [Accessed 6 June 2008].

Health Protection Scotland (2009) Hand Hygiene Policy and Procedure (an element of Standard Infection Control Precautions). *Health Protection Scotland* September 2009. Available: <http://www.hps.scot.nhs.uk/haic/ic/guidelinedetail.aspx?id=31220> [Accessed 10 September 2009].

Healthcare Commission (2007a) *The best medicine The management of medicines in acute and specialist trusts*. Commission for Healthcare Audit and Inspection.

Healthcare Commission (2007b) *Investigation into outbreaks of Clostridium difficile at Maidstone and Tunbridge Wells NHS Trust*. Commission for Healthcare Audit and Inspection.

Heisenberg W (1930) *Die Physikalischen Prinzipien der Quantenmechanik (Leipzig: Hirzel)*. English translation *The Physical Principles of Quantum Theory*. Chicago, University of Chicago Press.

Held MR, Begier EM, Beardsley DS, Browne FA, Martinello RA, Baltimore RS, McDonald LC, Jensen B, Hadler JL, Demby LM (2006) Life-threatening

sepsis caused by *Burkholderia cepacia* from contaminated intravenous flush solutions prepared by a compounding pharmacy in another state. *Pediatrics* 118 (1) e212-215.

Heo ST, Kim SJ, Jeong YG, Bae IG, Jin JS, Lee JC (2008) Hospital outbreak of *Burkholderia stabilis* bacteraemia related to contaminated chlorhexidine in haematological malignancy patients with indwelling catheters. *Journal of Hospital Infection* 70 (3) 241-245.

Herndon JH (2005) 2004 ABJS Earl McBride lecture: patient safety: past, present, and future. *Clinical Orthopaedics and Related Research* 440 242-250.

Horibe K, Mashima Y, Tashiro T, Yamamori H, Okui K (1990) Evaluation of the endotoxin retention capabilities of inline intravenous filters. *Journal of Parenteral and Enteral Nutrition* 14 (1) 56-59.

Horlocker TT, Weiss WT, Olson CA (2008) Whodunit: the mysterious case of mediastinitis after continuous interscalene block. *Anesthesia and Analgesia* 107 (4) 1095-1097.

Hsueh PR, Teng LJ, Pan HJ, Chen YC, Sun CC, Ho SW, Luh KT (1998) Outbreak of *Pseudomonas fluorescens* bacteremia among oncology patients. *Journal of Clinical Microbiology* 36 (10) 2914-2917.

Hudson P (2003) Applying the lessons of high risk industries to health care. *Quality and Safety in Health Care* 12 Suppl 1 i7-12.

Hurst NW (1998) *Risk Assessment: The Human Dimension* Cambridge, The Royal Society of Chemistry.

Illich I (1974) Medical Nemesis. *Lancet* 1 (7863) 918-921.

Institute of Medicine (1999) *To err is human: Building a better health care system*. Washington DC, National Academy Press.

Jackson M (2003) *Hard Systems Thinking In: Systems Thinking: Creative Holism for Managers*. Chichester, Wiley.

Jain SK, Persaud D, Perl TM, Pass MA, Murphy KM, Pisciotta JM, Scholl PF, Casella JF, Sullivan DJ (2005) Nosocomial malaria and saline flush. *Emerging Infectious Diseases* 11 (7) 1097-1099.

Johnson R, Onwuegbuzie A (2004) Mixed Methods Research: A research paradigm whose time has come. *Educational Researcher* 33 (7) 14-26.

Joint Commission on Accreditation in Hospitals Organization (2007) Sentinel Event Statistics 2006. Available at: http://www.jointcommission.org/NR/rdonlyres/FA465646-5F5F-4543-AC8F-E8AF6571E372/0/root_cause_se.jpg [Accessed 5 February 2008].

Jugo J, Kennedy R, Crowe MJ, Lamrock G, McClurg RB, Rooney PJ, Morris TC, Johnston PG (2002) Trends in bacteraemia on the haematology and oncology units of a UK tertiary referral hospital. *Journal of Hospital Infection* 50 (1) 48-55.

Kallen AJ, Lederman E, Balaji A, Trevino I, Petersen EE, Shoulson R, Saiman L, Horn EM, Gomberg-Maitland M, Barst RJ, Srinivasan A (2008) Bloodstream infections in patients given treatment with intravenous prostanoids. *Infection Control Hospital Epidemiology* 29 (4) 342-349.

Kastango ES, Bradshaw BD (2004) USP chapter 797: establishing a practice standard for compounding sterile preparations in pharmacy. *American Journal of Health-System Pharmacy* 61 (18) 1928-1938.

Katzenstein TL, Jorgensen LB, Permin H, Hansen J, Nielsen C, Machuca R, Gerstoft J (1999) Nosocomial HIV-transmission in an outpatient clinic detected by epidemiological and phylogenetic analyses. *Aids* 13 (13) 1737-1744.

Kemeny JG, Babbitt B, Haggerty PE, Lewis C, Marks PA, Marrett CB, McBride L, McPherson HC, Peterson RW, Pigford TH, Taylor TB, Trunk AD (1979) Report of the President's Commission of the Accident at Three Mile Island. The need for change: The legacy of TMI. Washington DC, US Government Printing Office.

Kilic A, Li H, Mellmann A, Basustaoglu AC, Kul M, Senses Z, Aydogan H, Stratton CW, Harmsen D, Tang YW (2008) *Acinetobacter septicus* sp. nov. association with a nosocomial outbreak of bacteremia in a neonatal intensive care unit. *Journal of Clinical Microbiology* 46 (3) 902-908.

Kilic A, Senses Z, Kurekci AE, Aydogan H, Sener K, Kismet E, Basustaoglu AC (2007) Nosocomial outbreak of *Sphingomonas paucimobilis* bacteremia in a hemato/oncology unit. *Japanese Journal of Infectious Diseases* 60 (6) 394-396.

Kim M, Bancroft E, Lehnkering E, Donlan D, Mascola L (2008) *Alcaligenes xylooxidans* blood stream infections in outpatient oncology practice. *Emerging Infectious Diseases* 14 (7) 1046-1052.

Kimchi J, Polivka B, Stevenson JS (1991) Triangulation: operational definitions. *Nursing Research* 40 (6) 364-366.

Koerner RJ, Morgan S, Ford M, Orr KE, McComb JM, Gould FK (1997) Outbreak of gram-negative septicaemia caused by contaminated continuous infusions prepared in a non-clinical area. *Journal of Hospital Infection* 36 (4) 285-289.

Koornneef E (2006) Measuring quality in services for children with an intellectual disability. *International Journal of Health Care Quality Assurance Incorporating Leadership Health Services* 19 (4-5) 400-408.

Kramer A, Schwebke I, Kampf G (2006) How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infectious Diseases* 6 130.

Krumholz W, Endrass J, Hempelmann G (1994) Propofol inhibits phagocytosis and killing of *Staphylococcus aureus* and *Escherichia coli* by polymorphonuclear leukocytes in vitro. *Canadian Journal of Anaesthesia* 41 (5 Pt 1) 446-449.

Kuehnert MJ, Webb RM, Jochimsen EM, Hancock GA, Arduino MJ, Hand S, Currier M, Jarvis WR (1997) *Staphylococcus aureus* bloodstream infections among patients undergoing electroconvulsive therapy traced to breaks in infection control and possible extrinsic contamination by propofol. *Anesthesia and Analgesia* 85 (2) 420-425.

Langevin PB, Gravenstein N, Doyle TJ, Roberts SA, Skinner S, Langevin SO, Gulig PA (1999) Growth of *Staphylococcus aureus* in Diprivan and Intralipid: implications on the pathogenesis of infections. *Anesthesiology* 91 (5) 1394-1400.

Langford S (2000) Microbial survival in infusion fluids - the relevance to the management of aseptic facilities. *Hospital Pharmacist* 7 (8) 228-236.

Larson EL, Cimiotti JP, Haas J, Nesin M, Allen A, Della-Latta P, Saiman L (2005) Gram-negative bacilli associated with catheter-associated and non-

catheter-associated bloodstream infections and hand carriage by healthcare workers in neonatal intensive care units. *Pediatric Critical Care Medicine* 6 (4) 457-461.

Leape LL (1994) Error in medicine. *Journal of the American Medical Association* 272 (23) 1851-1857.

Linares J, Sitges-Serra A, Garau J, Perez JL, Martin R (1985) Pathogenesis of catheter sepsis: a prospective study with quantitative and semiquantitative cultures of catheter hub and segments. *Journal of Clinical Microbiology* 21 (3) 357-360.

Lingard L, Espin S, Whyte S, Regehr G, Baker GR, Reznick R, Bohnen J, Orser B, Doran D, Grober E (2004) Communication failures in the operating room: an observational classification of recurrent types and effects. *Quality and Safety in Health Care* 13 (5) 330-334.

Livni G, Yaniv I, Samra Z, Kaufman L, Solter E, Ashkenazi S, Levy I (2008) Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. *Journal of Hospital Infection* 70 (3) 253-258.

MacDavitt K, Chou SS, Stone PW (2007) Organizational climate and health care outcomes. *Joint Commission Journal of Quality Improvement* 33 (11 Suppl) 45-56.

Macedo de Oliveira A, White KL, Leschinsky DP, Beecham BD, Vogt TM, Moolenaar RL, Perz JF, Safranek TJ (2005) An outbreak of hepatitis C virus infections among outpatients at a hematology/oncology clinic. *Annals of Internal Medicine* 142 (11) 898-902.

Macias AE, de Leon SP, Huertas M, Maravilla E, Romero C, Montoya TG, Munoz JM, Lopez-Vidal Y (2008) Endemic infusate contamination and related bacteremia. *American Journal of Infection Control* 36 (1) 48-53.

Macias AE, Munoz JM, Galvan A, Gonzalez JA, Medina H, Alpuche C, Cortes G, Ponce-de-Leon S (2005) Nosocomial bacteremia in neonates related to poor standards of care. *Pediatric Journal of Infectious Disease* 24 (8) 713-716.

Makary MA, Sexton JB, Freischlag JA, Holzmueller CG, Millman EA, Rowen L, Pronovost PJ (2006) Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. *Journal of the American College of Surgeons* 202 (5) 746-752.

Maki DG, Martin WT (1975) Nationwide epidemic of septicemia caused by contaminated infusion products. IV. Growth of microbial pathogens in fluids for intravenous infusions. *Journal of Infectious Diseases* 131 (3) 267-272.

Maki DG, Ringer M (1991) Risk factors for infusion-related phlebitis with small peripheral venous catheters. A randomized controlled trial. *Annals of Internal Medicine* 114 (10) 845-854.

Marx DA, Slonim AD (2003) Assessing patient safety risk before the injury occurs: an introduction to sociotechnical probabilistic risk modelling in health care. *Quality and Safety in Health Care* 12 Suppl 2 ii33-38.

Mattner F, Gastmeier P (2004) Bacterial contamination of multiple-dose vials: a prevalence study. *American Journal of Infection Control* 32 (1) 12-16.

Mauri D, Roumbkou S, Michalopoulou S, Tsali L, Spiliopoulou A, Panou C, Valachis A, Panagopoulos A, Polyzos NP (2009) Port central venous catheters-associated bloodstream infection during outpatient-based chemotherapy. *Medical Oncology* (e-publication ahead of print) Available: <http://www.springerlink.com/content/q7g6877033l8w07x/> [Accessed 7 September 2010].

MHRA (2007) Rules and Guidance for Pharmaceutical Manufacturers and distributors 2007 (The Orange Guide). Medicines and Healthcare products Regulatory Agency. London.

Mikulska M, Durando P, Pia Molinari M, Alberti M, Del Bono V, Dominiotto A, Raiola AM, Van Lint MT, Bregante S, Orengo G, Bacigalupo A, Viscoli C (2009) Outbreak of *Ralstonia pickettii* bacteraemia in patients with

haematological malignancies and haematopoietic stem cell transplant recipients. *Journal of Hospital Infection* 72 (2) 187-188.

Modak I, Sexton JB, Lux TR, Helmreich RL, Thomas EJ (2007) Measuring safety culture in the ambulatory setting: the safety attitudes questionnaire - ambulatory version. *Journal of General Internal Medicine* 22 (1) 1-5.

Motamedifar M, Askarian M (2009) The prevalence of multidose vial contamination by aerobic bacteria in a major teaching hospital, Shiraz, Iran, 2006. *American Journal of Infection Control* 37 (9) 773-777.

Munro M, Millar B, Radley S (2003) A risk assessment of the preparation of parenteral medicines in clinical areas. *Hospital Pharmacist* 10 (3003-5).

Nadkarni AS, Schliep T, Khan L, Zeana CB (2009) Cluster of bloodstream infections caused by KPC-2 carbapenemase-producing *Klebsiella pneumoniae* in Manhattan. *American Journal of Infection Control* 37 (2) 121-126.

Narayan SA, Kool JL, Vakololoma M, Steer AC, Mejia A, Drake A, Jenney A, Turton JF, Kado J, Tikoduadua L (2009) Investigation and control of an outbreak of *Enterobacter aerogenes* bloodstream infection in a neonatal intensive care unit in Fiji. *Infection Control Hospital Epidemiology* 30 (8) 797-800.

Nasser RM, Rahi AC, Haddad MF, Daoud Z, Irani-Hakime N, Almawi WY (2004) Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an alcohol skin antiseptic. *Infection Control Hospital Epidemiology* 25 (3) 231-239.

National Patient Safety Agency (2007) *Preparation of injectable medicines. Work competence statement.* Available: www.nrls.npsa.nhs.uk/EasySiteWeb/getresource.axd?AssetID [Accessed 7 September 2010].

National Patient Safety Agency (2009) *Risks with intravenous heparin flush solutions.* Rapid Response Alert. NPSA/2008/RRR002. Available: <http://www.nrls.npsa.nhs.uk/resources/?EntryId45=59892> [Accessed 7 September 2010].

Newhouse R, Poe S (2005) *Measuring Patient Safety.* Sudbury MA, Jones & Bartlett.

NHS Executive (1996) *Aseptic Dispensing in NHS Hospitals.* Professional Letter - Chief Pharmaceutical Officer. PHL/CPhO (1996) 2.

NHS Greater Glasgow and Clyde (2008) *Safe and Secure Handling of Medicines in Hospital Wards, Theatres and Departments. Version 1 2008.* NHS Greater Glasgow and Clyde.

NHS Greater Glasgow and Clyde (2009) Intravenous Medicine Administration Self-directed learning package. *Undated*.

Nogler-Semenitz E, Lass-Flörl C, Nogler M, Speer G, Dierich MP (2007) Bacterial contamination of solutions for parenteral administration for single- and multiple-dose vials after multiple use in the hospital. *Wiener Medizinische Wochenschrift* 157 (15-16) 398-401.

Norris B (2009) Human factors and safe patient care. *Journal of Nursing Management* 17 (2) 203-211.

Nursing and Midwifery Council (2006) Medicines Management: A-Z advice sheet. *Nursing & Midwifery Council* Available: www.positive-options.com/.../NMC - Medicines management A-Z advice sheet - 2006.pdf [Accessed 7 September 2010].

Nursing and Midwifery Council (2009) *Standards for medicines management*. Available: <http://www.nmc-uk.org/aArticle.aspx?ArticleID=2995> [Accessed 11 February 2010].

O'Grady NP, Alexander M, Dellinger EP, Gerberding JL, Heard SO, Maki DG, Masur H, McCormick RD, Mermel LA, Pearson ML, Raad, II, Randolph A, Weinstein RA (2002) Guidelines for the prevention of intravascular catheter-related infections. *Morbidity and Mortality Weekly Report. Recommendations and Reports* 51 (RR) 1-26. Available:

<http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5110a1.htm> [Accessed 7 September 2010].

Ostrowsky BE, Whitener C, Bredenberg HK, Carson LA, Holt S, Hutwagner L, Arduino MJ, Jarvis WR (2002) *Serratia marcescens* bacteremia traced to an infused narcotic. *New England Journal of Medicine* 346 (20) 1529-1537.

Ozkocaman V, Ozcelik T, Ali R, Ozkalemkas F, Ozkan A, Ozakin C, Akalin H, Ursavas A, Coskun F, Ener B, Tunali A (2006) *Bacillus* spp. among hospitalized patients with haematological malignancies: clinical features, epidemics and outcomes. *Journal of Hospital Infection* 64 (2) 169-176.

Pan A, Dolcetti L, Barosi C, Catenazzi P, Ceruti T, Ferrari L, Magri S, Roldan EQ, Soavi L, Carnevale G (2006) An outbreak of *Serratia marcescens* bloodstream infections associated with misuse of drug vials in a surgical ward. *Infection Control Hospital Epidemiology* 27 (1) 79-82.

Parahoo K (1997) *Nursing Research: Principles, Process and Issues*. London, McMillan.

Parker MR (1995) The use of protective gloves, the incidence of ampoule injury and the prevalence of hand laceration amongst anaesthetic personnel. *Anaesthesia* 50 (8) 726-729.

Pate-Cornell ME (1993) Learning from the Piper Alpha Accident: A Postmortem Analysis of Technical and Organizational Factors. *Risk Analysis*. 13 (2) 215-232.

Patel PR, Larson AK, Castel AD, Ganova-Raeva LM, Myers RA, Roup BJ, Farrell KP, Edwards L, Nainan O, Krick JP, Blythe D, Fiore AE, Roche JC (2006) Hepatitis C virus infections from a contaminated radiopharmaceutical used in myocardial perfusion studies. *Journal of the American Medical Association* 296 (16) 2005-2011.

Patterson ESW, D.D. Cook, R.I. Render, M.L (2007) Collaborative cross-checking to enhance resilience. *Cognition, Technology and Work* 9 155-162.

Peiris K, Gee TM, Boswell TC (2006) Bloodstream infection related to heparin infusion caused by *Agrobacterium tumefaciens*. *Journal of Hospital Infection* 62 (2) 250-251.

Perrow C (1999) *Normal Accidents: living with high-risk technologies*. New Jersey, Princeton University Press.

Perz JF, Craig AS, Stratton CW, Bodner SJ, Phillips WE, Jr., Schaffner W (2005) *Pseudomonas putida* septicemia in a special care nursery due to contaminated flush solutions prepared in a hospital pharmacy. *Journal of Clinical Microbiology* 43 (10) 5316-5318.

Pittet D (2004) The Lowbury lecture: behaviour in infection control. *Journal of Hospital Infection* 58 (1) 1-13.

Pittet D, Allegranzi B, Boyce J (2009) The World Health Organization Guidelines on Hand Hygiene in Health Care and their consensus recommendations. *Infection Control Hospital Epidemiology* 30 (7) 611-622.

Pratt RJ, Pellowe C, Loveday HP, Robinson N, Smith GW, Barrett S, Davey P, Harper P, Loveday C, McDougall C, Mulhall A, Privett S, Smales C, Taylor L, Weller B, Wilcox M (2001) The epic project: developing national evidence-based guidelines for preventing healthcare associated infections. Phase I: Guidelines for preventing hospital-acquired infections. Department of Health (England). *Journal of Hospital Infection* 47 Suppl S3-82.

Pratt RJ, Pellowe CM, Wilson JA, Loveday HP, Harper PJ, Jones SR, McDougall C, Wilcox MH (2007) epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *Journal of Hospital Infection* 65 Suppl 1 S1-64.

Pronovost P, Holzmueller CG, Needham DM, Sexton JB, Miller M, Berenholtz S, Wu AW, Perl TM, Davis R, Baker D, Winner L, Morlock L (2006) How will we know patients are safer? An organization-wide approach to measuring and improving safety. *Critical Care Medicine* 34 (7) 1988-1995.

Pronovost PJ, Holzmueller CG, Martinez E, Cafeo CL, Hunt D, Dickson C, Awad M, Makary MA (2006) A practical tool to learn from defects in patient care. *Joint Commission Journal of Quality Improvement* 32 (2) 102-108.

Randle J, Clarke M, Storr J (2006) Hand hygiene compliance in healthcare workers. *Journal of Hospital Infection* 64 (3) 205-209.

RCN IV Therapy Forum (2003) *Standards for infusion therapy* Available: www.rcn.org.uk/_data/assets/pdf_file/0005/78593/002179.pdf [Accessed 15 July 2008].

Reason J (1990) *Human Error*. New York, Cambridge University Press.

Reason J (2000) Human error: models and management. *The Western Journal of Medicine* 172 (6) 393-396.

Reason J (2002) Combating omission errors through task analysis and good reminders. *Quality and Safety in Health Care* 11 (1) 40-44.

Reason JT, Carthey J, de Leval MR (2001) Diagnosing "vulnerable system syndrome": an essential prerequisite to effective risk management. *Quality Health Care* 10 Suppl 2 ii21-25.

Risser TR, Simon R, Rice MM, M.L S (2000) A structured Teamwork system to reduce clinical errors. Ch 9. In: *Spath PL (ed) Error Reduction in Health*

Care. *A systems approach to improving patient safety*. San Francisco, Jossey-Bass.

Rogues AM, Boulestreau H, Lasheras A, Boyer A, Gruson D, Merle C, Castaing Y, Bebear CM, Gachie JP (2007) Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a medical intensive care unit. *Journal of Hospital Infection* 67 (1) 72-78.

Romero-Gomez MP, Quiles-Melero MI, Pena Garcia P, Gutierrez Altes A, Garcia de Miguel MA, Jimenez C, Valdezate S, Saez Nieto JA (2008) Outbreak of *Burkholderia cepacia* bacteremia caused by contaminated chlorhexidine in a hemodialysis unit. *Infection Control Hospital Epidemiology* 29 (4) 377-378.

Ross RS, Viazov S, Khudyakov YE, Xia GL, Lin Y, Holzmann H, Sebesta C, Roggendorf M, Janata O (2009) Transmission of hepatitis C virus in an orthopedic hospital ward. *Journal of Medical Virology* 81 (2) 249-257.

Rowley S (2001) Theory to practice. Aseptic non-touch technique. *Nursing Times* 97 (7) VI-VIII.

Rowley S, Clare S (2009) Improving standards of aseptic practice through an ANTT trust-wide implementation process: a matter of prioritisation and care. *Journal of Infection Prevention* 10 (1) S18-S23.

Rowley S, Sinclair S (2004) Working towards an NHS standard for aseptic non-touch technique. *Nursing Times* 100 (8) 50-52.

Royal Pharmaceutical Society (2005) *The safe and secure handling of medicines: a team approach*. Royal Pharmaceutical Society. Available: www.rpsgb.org.uk/pdfs/safsechandmeds.pdf [Accessed 7 September 2010].

Runciman WB, Williamson JA, Deakin A, Benveniste KA, Bannon K, Hibbert PD (2006) An integrated framework for safety, quality and risk management: an information and incident management system based on a universal patient safety classification. *Quality and Safety in Health Care* 15 Suppl 1 i82-90.

Safdar N, Maki DG (2006) Use of vancomycin-containing lock or flush solutions for prevention of bloodstream infection associated with central venous access devices: a meta-analysis of prospective, randomized trials. *Clinical Infectious Diseases* 43 (4) 474-484.

Santell JP, Cousins DD (2005) Medication errors involving wrong administration technique. *Joint Commission Journal of Quality Improvement* 31 (9) 528-532.

Sax H, Allegranzi B, Uckay I, Larson E, Boyce J, Pittet D (2007) 'My five moments for hand hygiene': a user-centred design approach to understand, train, monitor and report hand hygiene. *Journal of Hospital Infection* 67 (1) 9-21.

Schaal KP (1991) Medical and microbiological problems arising from airborne infection in hospitals. *Journal of Hospital Infection* 18 Suppl A 451-459.

Scott J, Ingram J, Mackenzie F (2010) The effectiveness of drug round tabbards in reducing incidence of medication errors. *Nursing Times* 106 (34) 13-15.

Scott T, Mannion R, Marshall M, Davies H (2003) Does organisational culture influence health care performance? A review of the evidence. *Journal of Health Services Research and Policy* 8 (2) 105-117.

Sexton JB, Helmreich RL, Neilands TB, Rowan K, Vella K, Boyden J, Roberts PR, Thomas EJ (2006) The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research. *BMC Health Services Research* 6 44.

Siegman-Igra Y, Jacobi E, Lang R, Schwartz D, Carmeli Y (2005) Unexpected hospital-acquired bacteraemia in patients at low risk of bloodstream infection: the role of a heparin drip. *Journal of Hospital Infection* 60 (2) 122-128.

Singer SJ, Gaba DM, Geppert JJ, Sinaiko AD, Howard SK, Park KC (2003) The culture of safety: results of an organization-wide survey in 15 California hospitals. *Quality and Safety in Health Care* 12 (2) 112-118.

Sitges-Serra A, Linares J, Garau J (1985) Catheter sepsis: the clue is the hub. *Surgery* 97 (3) 355-357.

Sitges-Serra A, Linares J, Perez JL, Jaurrieta E, Lorente L (1985) A randomized trial on the effect of tubing changes on hub contamination and catheter sepsis during parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* 9 (3) 322-325.

Sitges-Serra A, Puig P, Linares J, Perez JL, Farrero N, Jaurrieta E, Garau J (1984) Hub colonization as the initial step in an outbreak of catheter-related sepsis due to coagulase negative staphylococci during parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* 8 (6) 668-672.

Slovic P, Finucane ML, Peters E, MacGregor DG (2004) Risk as analysis and risk as feelings: some thoughts about affect, reason, risk, and rationality. *Risk Analysis* 24 (2) 311-322.

Smith J (2004) Building a safer NHS for patients: improving medication safety. Department of Health. Available: http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4084961.pdf [Accessed 7 September 2010].

Souza Dias MB, Habert AB, Borrasca V, Stempliuk V, Ciolli A, Araujo MR, Costa SF, Levin AS (2008) Salvage of long-term central venous catheters during an outbreak of *Pseudomonas putida* and *Stenotrophomonas*

maltophilia infections associated with contaminated heparin catheter-lock solution. *Infection Control Hospital Epidemiology* 29 (2) 125-130.

Spath PL (2000) *Error Reduction in Health Care: A systems approach to improving patient safety*. San Francisco, Jossey-Bass.

Spencer RC (1995) The emergence of epidemic, multiple-antibiotic-resistant *Stenotrophomonas (Xanthomonas) maltophilia* and *Burkholderia (Pseudomonas) cepacia*. *Journal of Hospital Infection* 30 Suppl 453-464.

Stalhandske E, DeRosier J, Patail B, Gosbee J (2003) How to make the most of failure mode and effect analysis. *Biomedical Instrumentation and Technology* 37 (2) 96-102.

Stelfox HT, Palmisani S, Scurlock C, Orav EJ, Bates DW (2006) The "To Err is Human" report and the patient safety literature. *Quality and Safety in Health Care* 15 (3) 174-178.

Stranks J (2007) *Human Factors and Behavioural Safety*. Amsterdam, Butterworth-Heinemann.

Tamuz M, Harrison MI (2006) Improving patient safety in hospitals: Contributions of high-reliability theory and normal accident theory. *Health Services Research* 41 (4 Pt 2) 1654-1676.

Taxis K, Barber N (2003) Ethnographic study of incidence and severity of intravenous drug errors. *British Medical Journal* 326 (7391) 684.

Thurmond VA (2001) The point of triangulation. *Journal of Nursing Scholarship* 33 (3) 253-258.

Tighe CM, Woloshynowych M, Brown R, Wears B, Vincent C (2006) Incident reporting in one UK accident and emergency department. *Accident and Emergency Nursing* 14 (1) 27-37.

Trepanier CA, Lessard MR (2003) Propofol and the risk of transmission of infection. *Canadian Journal of Anaesthesia* 50 (6) 533-537.

Ubeda P, Salavert M, Giner S, Jarque I, Lopez-Aldeguer J, Perez-Belles C, Gobernado M (1998) Bacteremia caused by *Stenotrophomonas maltophilia*: a clinical-epidemiological study and resistance profile. *Revista espanola de quimioterapia* 11 (3) 205-215.

United States Pharmacopeia (2009) USP General Chapter <797> Frequently Asked Questions. *United States Pharmacopeia* 1-19. Available: www.usp.org/audiences/pharmacist/797FAQs.html [Accessed on line 30/12/2009].

van Grafhorst JP, Foudraine NA, Nootboom F, Crombach WH, Oldenhof NJ, van Doorne H (2002) Unexpected high risk of contamination with

staphylococci species attributable to standard preparation of syringes for continuous intravenous drug administration in a simulation model in intensive care units. *Critical Care Medicine* 30 (4) 833-836.

van Houten MA, Uiterwaal CS, Heesen GJ, Arends JP, Kimpen JL (2001) Does the empiric use of vancomycin in pediatrics increase the risk for Gram-negative bacteremia? *Pediatric Infectious Disease Journal* 20 (2) 171-177.

van Tilburg CM, Leistikow IP, Rademaker CM, Bierings MB, van Dijk AT (2006) Health Care Failure Mode and Effect Analysis: a useful proactive risk analysis in a pediatric oncology ward. *Quality and Safety in Health Care* 15 (1) 58-63.

Vanhaecke E, De Muynck C, Remon JP, Colardyn F (1989) Endotoxin removal by end-line filters. *Journal of Clinical Microbiology* 27 (12) 2710-2712.

Veber B, Gachot B, Bedos JP, Wolff M (1994) Severe sepsis after intravenous injection of contaminated propofol. *Anesthesiology* 80 (3) 712-713.

Vergheze SL, Padmaja P, Koshi G (1998) Central venous catheter related infections in a tertiary care hospital. *Journal of the Associations Physicians of India* 46 (5) 445-447.

Victor MA, Arpi M, Bruun B, Jonsson V, Hansen MM (1994) *Xanthomonas maltophilia* bacteremia in immunocompromised hematological patients. *Scandinavian Journal of Infectious Diseases* 26 (2) 163-170.

Vidal F, Mensa J, Almela M, Olona M, Martinez JA, Marco F, Lopez MJ, Soriano A, Horcajada JP, Gatell JM, Richart C (2003) Bacteraemia in adults due to glucose non-fermentative Gram-negative bacilli other than *P. aeruginosa*. *QJM: An International Journal of Medicine* 96 (3) 227-234.

Vincent C (2006) *Patient Safety*. Edinburgh, Churchill Livingstone.

Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW (2004) Systems approaches to surgical quality and safety: from concept to measurement. *Annals of Surgery* 239 (4) 475-482.

Vincent C, Taylor-Adams S, Chapman EJ, Hewett D, Prior S, Strange P, Tizzard A (2000) How to investigate and analyse clinical incidents: clinical risk unit and association of litigation and risk management protocol. *British Medical Journal* 320 (7237) 777-781.

Vincent C, Taylor-Adams S, Stanhope N (1998) Framework for analysing risk and safety in clinical medicine. *British Medical Journal* 316 (7138) 1154-1157.

Vonberg RP, Gastmeier P (2007) Hospital-acquired infections related to contaminated substances. *Journal of Hospital Infection* 65 (1) 15-23.

Wachter RM, Pronovost PJ (2006) The 100,000 Lives Campaign: A scientific and policy review. *Joint Commission Journal of Quality Improvement* 32 (11) 621-627.

Warye K, Granato J (2009) Target: zero hospital-acquired infections. *Healthcare Financial Management* 63 (1) 86-91.

Watson JT, Jones RC, Siston AM, Fernandez JR, Martin K, Beck E, Sokalski S, Jensen BJ, Arduino MJ, Srinivasan A, Gerber SI (2005) Outbreak of catheter-associated *Klebsiella oxytoca* and *Enterobacter cloacae* bloodstream infections in an oncology chemotherapy center. *Archives of Internal Medicine* 165 (22) 2639-2643.

Weber DJ, Rutala WA, Sickbert-Bennett EE (2007) Outbreaks associated with contaminated antiseptics and disinfectants. *Antimicrobial Agents and Chemotherapy* 51 (12) 4217-4224.

Wiegmann DA, Zhang H, von Thaden T, Sharma G, Mitchell AA (2002) A Synthesis of Safety Culture and Safety Climate Research. University of Illinois Aviation Research Lab Technical report . ARL-02-03/FAA-02-2. Available: www.aaafoundation.org/pdf/WiegmannVonThadenGibbons.pdf [Accessed 7 September 2010].

Williams IT, Perz JF, Bell BP (2004) Viral hepatitis transmission in ambulatory health care settings. *Clinical Infectious Diseases* 38 (11) 1592-1598.

Wilson KA, Burke CS, Priest HA, Salas E (2005) Promoting health care safety through training high reliability teams. *Quality and Safety in Health Care* 14 (4) 303-309.

Wisniewski AM, Erdley WS, Singh R, Servoss TJ, Naughton BJ, Singh G (2007) Assessment of safety attitudes in a skilled nursing facility. *Geriatric Nursing* 28 (2) 126-136.

Woods DD, Patterson ES, Cook RI (2007) *Behind Human Error: Taming complexity to improve patient safety*. In: Carayon P (ed). Handbook of human factors and ergonomics in health care and patient safety. Mahwah, NJ, Lawrence Erlbaum Associates.

World Health Organization (2007) Single use of injection devices. *Patient Safety Solutions* 1. Solution 8 1-4 Available: www.who.int/entity/patientsafety/solutions/patientsafety/PS-Solution8-LowRes.pdf [Accessed 7 September 2010].

World Health Organization (2009) WHO Guidelines on Hand Hygiene in Health Care: First Global Patient Safety Challenge Clean Care is Safer Care. *World Health Organization* May 2009. Available: <http://www.who.int/gpsc/5may/background/5moments/en/index.html> [Accessed 12 June 2009].

World Health Organization (2009) WHO Patient Safety Curriculum Guide for Medical Students: Topic 2 What is human factors and why is it important to patient safety. *World Health Organization*. 100-107. Available: www.who.int/entity/patientsafety/education/curriculum/who_mc_topic-2.pdf [Accessed 9 April 2010].

Worthington T, Tebbs S, Moss H, Bevan V, Kilburn J, Elliott TS (2001) Are contaminated flush solutions an overlooked source for catheter-related sepsis? *Journal of Hospital Infection* 49 (1) 81-83.

Wreathall J, Nemeth C (2004) Assessing risk: the role of probabilistic risk assessment (PRA) in patient safety improvement. *Quality and Safety in Health Care* 13 (3) 206-212.

Wu AW, Lipshutz AK, Pronovost PJ (2008) Effectiveness and efficiency of root cause analysis in medicine. *Journal of the American Medical Association* 299 (6) 685-687.

Wu CJ, Lee HC, Lee NY, Shih HI, Ko NY, Wang LR, Ko WC (2006) Predominance of Gram-negative bacilli and increasing antimicrobial resistance in nosocomial bloodstream infections at a university hospital in southern Taiwan, 1996-2003. *Journal of Microbiology, Immunology and Infection* 39 (2) 135-143.

Yang CJ, Chen TC, Liao LF, Ma L, Wang CS, Lu PL, Chen YH, Hwan JJ, Siu LK, Huang MS (2008) Nosocomial outbreak of two strains of *Burkholderia cepacia* caused by contaminated heparin. *Journal of Hospital Infection* 69 (4) 398-400.

Yuan HB, Zuo Z, Yu KW, Lin WM, Lee HC, Chan KH (2008) Bacterial colonization of epidural catheters used for short-term postoperative analgesia: microbiological examination and risk factor analysis. *Anesthesiology* 108 (1) 130-137.

Zacher AN, Zornow MH, Evans G (1991) Drug contamination from opening glass ampules. *Anesthesiology* 75 (5) 893-895.

Zaidi Y, Hastings M, Murray J, Hassan R, Kurshid M, Mahendra P (2001) Quinolone resistance in neutropenic patients: the effect of prescribing policy in the UK and Pakistan. *Clinical and Laboratory Haematology* 23 (1) 39-42.

Zingg W, Pittet D (2009) Peripheral venous catheters: an under-evaluated problem. *International Journal of Antimicrobial Agents* 34 Suppl 4 S38-42.

14 Appendices

- Appendix 1** Data collection tool 1 – Location assessment
- Appendix 2** Data collection tool 2 – Observation of intravenous drug preparation
- Appendix 3** 3a) Operator opinions on safety; 3b) Redundancy checks
- Appendix 4** Ethics and R&D governance committees' approval
- Appendix 5** Participant Information Leaflet
- Appendix 6** Consent Form
- Appendix 7** Responses to Statements Appendix 3a from the Pilot ward
- Appendix 8** Responses to Statements Appendix 3a from the Second Ward
- Appendix 9** Responses to Statements Appendix 3a from the Third Ward
- Appendix 10** Responses to Statements Appendix 3a from the Fourth Ward
- Appendix 11** Responses to Statements Appendix 3a from the Fifth Ward

There were only 2 responses from the 6th study ward and consequently these are not summarised displayed.

Appendix 1 Location Assessment Tool

Location	
Ward	
Specialty	
Date	
Regularity framework	What are the rules regarding who can prepare IV drugs on this ward
	How it IV drug administration monitored at an institutional level
	Has a risk assessment been performed on the locations where drugs are prepared on this ward?

To be completed by the nurse in charge of the clinical area and the researcher

Category	Study Profile	Response
Patient factors	<ul style="list-style-type: none"> • What clinical conditions are patients on this ward admitted with? 	
	<ul style="list-style-type: none"> • Through what type of vascular devices are drugs infused in this unit? 	PVC: CVC: (Tunnelled / not) PICC
	<ul style="list-style-type: none"> • What types of drugs are infused on this unit? 	Include flush
	<ul style="list-style-type: none"> • What is the typical duration of the vascular devices in: <ul style="list-style-type: none"> ○ short-term <72 hours; ○ medium term > 72 hrs < 1 week ○ long-term >1 week ○ Permcath - months 	PVC: CVC: (Tunnelled / not) PICC
The Infusion Team	<ul style="list-style-type: none"> • Who can prepare IV drugs in this unit? 	
	<ul style="list-style-type: none"> • Is the team who prepare IV drugs stable or are there often new members who can prepare / infuse drugs, e.g. when new doctors arrive in February / August? 	

Category	Study Profile	Response
	<ul style="list-style-type: none"> • What education and training is required before a HCW is deemed competent to prepare IV drugs <ul style="list-style-type: none"> ○ initial training, ○ experience, ○ competency assessment 	Initial Training: Experience Competency Assessment:
	<ul style="list-style-type: none"> • What if any post-initial training experience competency assessments are required for HCWs to retain their competency status for preparing IV drugs? 	Post initial training (required / invitation) Competency reassessment
	<ul style="list-style-type: none"> • Are the team familiar with all the IV preparing procedures on the ward? List of drugs can be done by individuals 	
	<ul style="list-style-type: none"> • What if any preparing limits are imposed? , e.g. no intrathecal drugs, no chemotherapy 	
Processes and Procedures	<ul style="list-style-type: none"> • How often on average are intravenous drugs prepared on this ward in a day 	
	<ul style="list-style-type: none"> • Are there written procedures? (get copies) include 	
	<ul style="list-style-type: none"> • Where are the written procedures kept in terms of accessibility to the operator whilst preparing? 	
	<ul style="list-style-type: none"> • How often are the written procedures referred to? 	

Category	Study Profile	Response
	<ul style="list-style-type: none"> • Are the written procedures <ul style="list-style-type: none"> ○ Generic ○ Drug Specific ○ Both 	
	<ul style="list-style-type: none"> • Do the procedures include problem identification and actions - if <this> then <that> action? 	
	<ul style="list-style-type: none"> • Are there checklists? 	
	<ul style="list-style-type: none"> • What aspects of the procedure do the checklists cover? 	
	<ul style="list-style-type: none"> • Where are the checklists in terms of accessibility to the operator? 	
	<ul style="list-style-type: none"> • How variable are the procedures that are done <ul style="list-style-type: none"> ○ Same drugs diluents ○ Lots of variations 	
Team support for the operator	<ul style="list-style-type: none"> • Is there support for the infusion team <ul style="list-style-type: none"> ○ Within the team ○ From outside the team <ul style="list-style-type: none"> ▪ pharmacist; ▪ general managers 	
The Preparation Environment/ equipment	<ul style="list-style-type: none"> • Has the area been risk assessed as suitable (get copy)? 	

Category	Study Profile	Response
	<ul style="list-style-type: none"> • What other procedures are done where drugs are prepared? 	
	<ul style="list-style-type: none"> • Is the equipment required close at hand? 	
	<ul style="list-style-type: none"> • Is equipment stored free from possible splash contamination? 	
	<ul style="list-style-type: none"> • Is the equipment adequate – fit for purpose? 	
	<ul style="list-style-type: none"> • Is it easy to see to read - light? 	
	<ul style="list-style-type: none"> • Are concurrent procedures permitted during preparing? 	
Evaluation of performance	<ul style="list-style-type: none"> • What if any performance measures for the procedure are available? (formal, informal) 	
	<ul style="list-style-type: none"> • Is the end product evaluated for sterility? 	
	<ul style="list-style-type: none"> • What in-ward operator performance monitoring is done 	

Category	Study Profile	Response
	<ul style="list-style-type: none"> • What in-ward clinical team performance monitoring is done 	
	<ul style="list-style-type: none"> • What monitoring of the system outside of the ward is done of in ward performance (study procedure) 	
	<ul style="list-style-type: none"> • What if any self assessment of performance occurs formally or informally? 	
	<ul style="list-style-type: none"> • What if any buddy monitoring occurs formally or informally? 	
	<ul style="list-style-type: none"> • What is the procedure should an error occur? 	
	<ul style="list-style-type: none"> • How frequently are errors reported? 	
	<ul style="list-style-type: none"> • Is there any error feedback? 	

Plan of the area where drugs are prepared:

Appendix 2 Observation of intravenous drug preparation

Date Location Ward Designation

Criteria	Particulars	Observations
Clean / clutter	Visible inspection	
Cleaning environment before start	What area cleaned	
	What cleaned with	
Hand hygiene	How done ; How often; When done	
Jewellery	Stoned rings; Wrist watches	
PPE	Sterile Single-use	
Drug	Type ID cause of infusate sepsis	
Drug purpose	Flush Therapy / Inv	
Diluent (SU MU)	Designated single-use Used singly Double dipping with patient needle	
Planned duration of infusion	Bolus; < 10hours; >10 hours	
Single or batched procedure	Making more than one drug for more than one patient	
Container (MDV; SDV ampoule)		
Aseptic access to drug	With what	
Aseptic access to diluent	With what	
Unexpected events	Precipitation Deviations from procedures	
Delays	From preparing to infusion Planned / unplanned	
Information flow	Before the procedure During the procedure	
Communication (opportunities and performance*)	Occasion Content Audience	

	Purpose	
Supervision	(non-redundancy checks)	
Technical skills	Deviations from procedures Practice as per procedure	
Asepsis failure prevention	Non touch of critical points (needle; syringe hub)	
	Non touch contaminated sites	
Catheter type	CVC; PCV	
Interruptions	Examples: Phone calls Change to other procedures Opinion requested	
Distractions	Examples: Noise Patient activities	
Location traffic	Examples People in the space Workarounds	
In procedure QC / feedback/monitoring	Observations of infusate for precipitation / cloudiness / particulates /	
Filters (defence)		
Redundancy checks	Right drug	
	Right dose	
	Aseptic ampoule access	
	Diluent correct	
	Aseptic diluent access	
	Aseptic procedure total	
	No particulates	
	No precipitation	
	Aseptic catheter hub access	
	HH & use of PPE	
	Right patient	
	Infusion pump settings	
	Infusion rate (no pump)	
Ongoing patient monitoring	4 hourly temp / inf duration	

Categories of communication error that could occur during aseptic preparing.
Adapted from (Lingard et al. 2004)

Type of failure	Explanation	Example
Occasion Failure	Problem in the situation or context of the communication	Asking if a safety check has been done after subsequent actions have occurred, for example asking if asepsis was maintained after a drug has been infused.
Content Failure	Insufficient or inaccuracy in the information being transferred.	Asking for a drug to be given without detailing the dose or the route or infusion time.
Audience Failure	Gaps in the composition of the group engaged in the communication.	Discussions between the doctor and nurse on how to prepare a drug that had not been prepared before, and omitting to include the pharmacist in the discussions.
Purpose Failure	Communication events in which the purpose is unclear, not achieved or incomplete.	Two nurses discuss that drugs need preparing for a specific time. No one confirms that they will take responsibility for it.

Appendix 3(a) Operator opinions on safety; 3(b) Redundancy checks

Please read each statement and circle the number that most accurately denotes the degree to which you agree with the statement.

	Strongly disagree			Strongly agree	
When preparing IV drugs it is easy to prevent asepsis failure	1	2	3	4	5
When preparing IV drugs it is easy to detect asepsis failure	1	2	3	4	5
The procedures for preparing IV drugs on this ward are simple	1	2	3	4	5
The resources on this ward makes it easy to prepare IV drugs safely	1	2	3	4	5
The environment on this ward makes it easy to prepare IV drugs safely	1	2	3	4	5
On this ward distractions and interruptions make it difficult to prepare IV drugs safely.	1	2	3	4	5
I get feedback on the quality of my IV drug preparation performance	1	2	3	4	5
I would feel uncomfortable raising safety concerns regarding the preparing of IV drugs on this ward	1	2	3	4	5
I can mix drugs on this ward without distraction or interruption	1	2	3	4	5
Asepsis failure when preparing IV drugs is a safety priority on this ward	1	2	3	4	5
If I recognised an error in my IV drug preparation, I would report it	1	2	3	4	5
There is good support to those who have to prepare IV drugs.	1	2	3	4	5
To improve patient safety I am					

encouraged to report errors.	1	2	3	4	5
I find preparing IV drugs is stressful.	1	2	3	4	5
Preparing IV drugs give me job satisfaction	1	2	3	4	5

Some steps in a procedure are more error prone, or more hazardous for patients if they are missed/not done correctly. Double-checking with a colleague is a frequent procedural requirement to make sure that such steps are done, and have been done correctly. For which steps in the mixing and administering drugs do you perform double checks?

I perform a double check with a colleague....			
to check the correct drug is used	Always	Never	Sometimes
to check the correct drug dosage	Always	Never	Sometimes
to check the ampoules/drug bungs have been accessed aseptically	Always	Never	Sometimes
to check the correct diluent has been used, e.g. saline, water,	Always	Never	Sometimes
to check the diluent has been accessed aseptically	Always	Never	Sometimes
to check the overall procedure was performed aseptically	Always	Never	Sometimes
to check the drug in the syringe / Infusion was free of particulates	Always	Never	Sometimes
to check the drug in the syringe / Infusion was free of precipitation	Always	Never	Sometimes
to check the catheter hubs were aseptically accessed	Always	Never	Sometimes
to check hand hygiene and the use of gloves was appropriate	Always	Never	Sometimes
to check the drug is given to the right patient	Always	Never	Sometimes
to check the settings on the infusion pump were correct	Always	Never	Sometimes

to check the infusion was administered at the right rate (no pump)	Always	Never	Sometimes
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Please comment if you wish on any aspect of drug mixing / administration:

Appendix 4 Ethics Permission and R&D Management Approval

Primary Care Division



Research Ethics
Primary Care, Community & Mental Health REC
R&D Directorate
1st Floor – The Tennent Institute
Western Infirmary
38 Church Street
Glasgow G11 6NT
www.nhsqgc.org.uk

Ms Evonne Curran
Student Stirling University - (Nurse
Consultant Infection Control)
Student at Stirling University
Dept. of Nursing and Midwifery
Stirling FK9 4LA

Date 22 December 2008
Your Ref
Our Ref
Direct line 0141 211 2123
Fax 0141 211 2811
E-mail Liz.Jamieson@ggc.scot.nhs.uk

Dear Ms Curran

Full title of study: The system of aseptic preparation of intravenous drugs in clinical care settings from a patient safety perspective
REC reference number: 08/S0701/114

Thank you for your letter of 04 December 2008, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information was considered at the meeting of the Sub-Committee of the REC held on 18 December 2008. A list of the members who were present at the meeting is attached.

However this favourable opinion is subject to the following being confirmed in writing through the Committee Co-ordinator:

- *Recruitment should not be a direct approach from the Heads of Nursing. The Heads of Nursing can forward the letters etc on behalf of the Researcher without being named.*

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission at NHS sites ("R&D approval") should be obtained from the relevant care organisation(s) in accordance with NHS research governance arrangements. Guidance on applying for NHS permission is available in the Integrated Research Application System or at <http://www.rdforum.nhs.uk>.



D370787

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

<i>Document</i>	<i>Version</i>	<i>Date</i>
University of Stirling Research Governance		
Assessment Tool 3		
Assessment Tool 2		
Assessment Tool 1		
Participant Consent Form		
Letter of invitation to participant		
Protocol		04 September 2008
Investigator CV		
Application		10 September 2008
Response to Request for Further Information		04 December 2008
Participant Information Sheet: PIS for Ward Managers	Version 2	04 December 2008
Participant Information Sheet	Version 2	04 December 2008

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Now that you have completed the application process please visit the National Research Ethics Website > After Review

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

The attached document "After ethical review –guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

We would also like to inform you that we consult regularly with stakeholders to improve our service. If you would like to join our Reference Group please email referencegroup@nres.npsa.nhs.uk.

08/S0701/114	Please quote this number on all correspondence
---------------------	---

With the Committee's best wishes for the success of this project

Yours sincerely



Liz Jamieson
On behalf of Dr Paul Fleming, Chair

Enclosures: List of names and professions of members who were present at the meeting
"After ethical review – guidance for researchers"

Copy to: Dr. Kathleen Stoddart
R&D office for NHS care organisation at lead site

NHS

**Greater Glasgow
and Clyde**

Coordinator/administrator: Maureen Travers
Telephone Number: 0141 211 6389
Fax Number: 0141 211 2811
E-Mail: Maureen.travers@ggc.scot.nhs.uk

R&D Management Office
Western Infirmary
Tennent Institute
1st Floor, 38 Church Street
Glasgow, G11 6NT

27 August 2009

Ms Yvonne Curran
Health Protection Scotland
Cadogan Square
Cadogan Street
Glasgow, G3 7HF

R&D Management Approval

Dear Yvonne,

Project Title: The system of aseptic preparation of intravenous drugs in clinical care settings from a patient safety perspective
Chief Investigator: Ms Yvonne Curran
R&D Reference: GN09PH007
Protocol no: Amended 04/09/2008

I am pleased to confirm that Greater Glasgow & Clyde Health Board is now able to grant **Management Approval** for the above study.

As a condition of this approval the following information is required during the lifespan of the project:

1. SAES/SUSARS – If the study is a **Clinical Trial** as defined by the Medicines for Human Use Clinical Trial Regulations, 2004 (CTIMP only)
2. Recruitment Numbers on a quarterly basis (not required for commercial trials)
3. Any change of Staff working on the project named on the ethics form
4. Change of CI
5. Amendments – Protocol/CRF etc
6. Notification of when the Trial / study has ended
7. Final Report
8. Copies of Publications & Abstracts

Please add this approval to your study file as this letter may be subject to audit and monitoring.

Yours sincerely,



Ross Nicol
Research Co-ordinator

Delivering better health

www.nhsggc.org.uk

Information about the research – preparing intravenous drugs in clinical care settings



**UNIVERSITY OF
STIRLING**

DEPARTMENT OF
NURSING AND MIDWIFERY

I am a student of Stirling University undertaking a research project for a Nursing Doctorate and would like to ask you to take part in the study. You need to understand why the research is being done and what it would involve for you, before you decide whether to take part. (All information gathered in this study will be treated in confidence). Please take time to read the following information carefully. Talk to your colleagues about the study if you wish. The leaflet tells you the purpose of the study and what will happen if you take part. Please take time to decide if you wish to take part.

What is the purpose of the study?

The research project is a study to describe the system of preparing intravenous drugs in ward areas. The system includes looking at the environment, the equipment, the methods and the people – in short everything involved in preparing intravenous drugs at ward level. The overall objective is to assess the reliability in the system and find out where errors could occur for the purposes of optimising patient safety.

Why have I been invited?

In order to examine the system, as well as observing the environment, the methods and the equipment, I need to observe people preparing drugs for intravenous infusions. Your ward has been chosen because it has a high use of drugs prepared

in the ward. And you have been invited to be observed as you are one of the people qualified to prepare drugs for intravenous administration.

Do I have to take part?

It is up to you to decide. I will describe the study and go through this information sheet which I will then give you. You will then be asked to sign a consent form to show you have agreed to being observed preparing intravenous drugs. You can ask me to stop observing at any time.

What will happen if I take part?

With agreement of the ward manager, I will visit the ward for one day shift and find out from the nurse in charge that day some basic information about the ward, the patients, the intravenous drugs used on the ward, all the equipment available for preparing drugs and where they are prepared. This will be done once and should take about 30 minutes.

With consent I will watch – but not interrupt – healthcare workers preparing intravenous drugs, from the collection of equipment until the drug is ready for administration. I will be available to watch all drugs prepared in a single shift – for which the healthcare workers give permission.

I will ask all healthcare workers who prepare intravenous drugs on the ward to complete a questionnaire on their opinions of safety and on where they normally perform a double-check in the procedure. The questionnaire is on 2 sides of A4 paper and should take about 10 minutes to complete.

I will review all written materials available to healthcare workers who prepare drugs, e.g. policies, procedures and checklists.

What are the benefits of taking part?

I cannot promise the study will help you but the information gathered will help advance patient safety when receiving intravenous drugs. The study will give the ward an objective opinion on the safety of intravenous drugs preparation and you the opportunity to share your opinions on patient safety on this topic.

What if there is a problem?

Any complaint about the way you have been dealt with during the study will be addressed.

Will my taking part in the study be kept confidential?

Yes.

No identifiable details of any individual will be recorded or communicated in any way.

Data will be collected at a systems level, e.g. data will be collected on the process of preparing intravenous drugs but not the individual who prepared them. Likewise data will be collected on the training provided to healthcare workers who prepare intravenous drugs but not on the training provided to an individual.

Data will be collected from 6 different clinical settings including a pilot ward.

All information collected during the course of this study will be held securely and discarded after use.

Who is organising this research?

The research is being undertaken as part of my clinical doctorate study.

Who has reviewed this study?

This study has been reviewed by:

My supervisors at the University of Stirling

The Ethics Committee at NHS Greater Glasgow & Clyde

Are there any risks to your participation?

It can be very nerve-racking knowing that you are being watched doing what you do. But this study is about the system and not individuals.

What if bad practice is observed?

The study is not designed to catch anyone out but to identify the current system. There is, however, a duty on all nurses to do all they can to prevent patient harm. If bad practice is observed then there is a duty of care to report this. This is no different to the duty of care placed on all nurses through the (Nursing and Midwifery Council)

NMC Code – Standards of Conduct, Performance and Ethics for Nurses and Midwives. To reassure those who may wish to take part in this study, bad practice would not for instance cover a nurse forgetting a step in a procedure, but, for example, would cover a deliberate intention to violate procedures and harm a patient.

What happens afterwards?

I would be happy to come back to the ward when the project is complete to explain any findings.

Further Information:

More detailed information is available from me at:

Evonne Curran

Doctorate Student

Department of Nursing and Midwifery

University of Stirling

0141 300 1151

Appendix 6 Consent Form



UNIVERSITY OF STIRLING

DEPARTMENT OF
NURSING AND MIDWIFERY

Preparing intravenous drugs in clinical care settings

Researcher: Evonne Curran

I confirm that I have read and understand the information sheet dated September 2008 Version 1 for the above study. I have had the opportunity to consider the information and ask questions and have had these questions answered. Yes No

I understand that my participation is voluntary and that I am free to stop the researcher observing at any time without giving any reason.

I agree to being observed while preparing intravenous drugs.

Name of healthcare worker Date Signature

Name of person taking consent Date Signature

Appendix 7 Responses to Opinions of Safety Statements from the pilot ward

* numbers differ due to a non-response to a statement

	Pilot Ward Safety Opinions Summary	1	2	3	4	5	Total
1	When preparing IV drugs it is easy to prevent asepsis failure	0	0	6	8	3	17
2	When preparing IV drugs it is easy to detect asepsis failure	0	3	8	5	1	17
3	The procedures for preparing IV drugs on this ward are simple	2	2	5	5	3	17
4	The resources on this ward make it easy to prepare IV drugs safely	0	1	1	13	2	17
5	The environment on this ward makes it easy to prepare IV drugs safely	0	2	6	7	2	17
6	On this ward distractions and interruptions make it difficult to prepare IV drugs safely	0	3	4	6	4	17
7	I get feedback on the quality of my IV drug preparation	7	4	3	2	1	17
8	I would feel uncomfortable raising safety concerns regarding the preparing of IV drugs on this ward	6	5	2	2	2	17
9	I can mix drugs on this ward without distraction or interruption	4	8	4	1	0	17
10	Asepsis failure when preparing IV drugs is a safety priority on this ward	1	2	1	7	4	17
11	If I recognised an error in my IV drug preparation I would report it	1	0	3	6	7	17
12	There is good support to those who have to prepare IV drugs	0	2	3	8	4	17
13	To improve patient safety I am encouraged to report errors	0	0	1	7	8	16*
14	I find preparing IV drugs is stressful	3	5	6	2	0	16*
15	Preparing IV drugs gives me job satisfaction	4	3	6	3	1	17

Appendix 8 Responses to Opinions of Safety Statements from the Second Ward

	2nd Study Ward Safety Opinions Summary	1	2	3	4	5	Total
1	When preparing IV drugs it is easy to prevent asepsis failure	0	0	2	2	3	7
2	When preparing IV drugs it is easy to detect asepsis failure	1	1	2	2	1	7
3	The procedures for preparing IV drugs on this ward are simple	0	1	4	2	0	7
4	The resources on this ward make it easy to prepare IV drugs safely	0	0	4	2	1	7
5	The environment on this ward makes it easy to prepare IV drugs safely	0	1	2	4	0	7
6	On this ward distractions and interruptions make it difficult to prepare IV drugs safely	0	1	4.5	1.5	0	7
7	I get feedback on the quality of my IV drug preparation	1	4	1	1	0	7
8	I would feel uncomfortable raising safety concerns regarding the preparing of IV drugs on this ward	4	3	0	0	0	7
9	I can mix drugs on this ward without distraction or interruption	3	0	3	1	0	7
10	Asepsis failure when preparing IV drugs is a safety priority on this ward	0	1	1	0	5	7
11	If I recognised an error in my IV drug preparation I would report it	0	0	1	3	3	7
12	There is good support to those who have to prepare IV drugs	0	0	3	2	2	7
13	To improve patient safety I am encouraged to report errors	1	0	0	3	3	7
14	I find preparing IV drugs is stressful	1	2	1	3	0	7
15	Preparing IV drugs gives me job satisfaction	2	2	1	1	1	7

Appendix 9 Responses to Opinions of Safety Statements from the Third Ward

	3 rd Study Ward Safety Opinions Summary	1	2	3	4	5	Total
1	When preparing IV drugs it is easy to prevent asepsis failure	1	1	2	10	5	19
2	When preparing IV drugs it is easy to detect asepsis failure	2	4	4	3	6	19
3	The procedures for preparing IV drugs on this ward are simple	1	0	3	9	6	19
4	The resources on this ward make it easy to prepare IV drugs safely	1	0	3	6	9	19
5	The environment on this ward makes it easy to prepare IV drugs safely	1	0	5	5	8	19
6	On this ward distractions and interruptions make it difficult to prepare IV drugs safely	3	3	7	6	0	19
7	I get feedback on the quality of my IV drug preparation	5	5	2	5	2	19
8	I would feel uncomfortable raising safety concerns regarding the preparing of IV drugs on this ward	8	5	2	3	1	19
9	I can mix drugs on this ward without distraction or interruption	3	5	6	1	4	19
10	Asepsis failure when preparing IV drugs is a safety priority on this ward	2	1	4	5	7	19
11	If I recognised an error in my IV drug preparation I would report it	2	0	4	4	9	19
12	There is good support to those who have to prepare IV drugs	1	0	3	8	7	19
13	To improve patient safety I am encouraged to report errors	0	0	3	5	11	19
14	I find preparing IV drugs is stressful	5	8	4	1	1	19
15	Preparing IV drugs gives me job satisfaction	0	4	8	4	2	18*

Appendix 10 Responses to Opinions of Safety Statements from the Fourth Ward

	4 th Study Ward Safety Opinions Summary	1	2	3	4	5	Total
1	When preparing IV drugs it is easy to prevent asepsis failure	0	0	1	5	2	8
2	When preparing IV drugs it is easy to detect asepsis failure	0	2	4	0	2	8
3	The procedures for preparing IV drugs on this ward are simple	0	0	1	4	3	8
4	The resources on this ward make it easy to prepare IV drugs safely	0	0	0	6	2	8
5	The environment on this ward makes it easy to prepare IV drugs safely	0	2	4	2	0	8
6	On this ward distractions and interruptions make it difficult to prepare IV drugs safely	0	4	0	2	2	8
7	I get feedback on the quality of my IV drug preparation	6	2	0	0	0	8
8	I would feel uncomfortable raising safety concerns regarding the preparing of IV drugs on this ward	4	3	1	0	0	8
9	I can mix drugs on this ward without distraction or interruption	4	0	2	2	0	8
10	Asepsis failure when preparing IV drugs is a safety priority on this ward	0	1	4	2	1	8
11	If I recognised an error in my IV drug preparation I would report it	0	0	0	2	6	8
12	There is good support to those who have to prepare IV drugs	0	0	3	4	1	8
13	To improve patient safety I am encouraged to report errors	0	0	1	3	4	8
14	I find preparing IV drugs is stressful	2	1	3	1	1	8
15	Preparing IV drugs gives me job satisfaction	1	2	5	0	0	8

Appendix 11 Responses to Opinions of Safety Statements from the 5th study ward

	5th Study Ward Safety Opinions Summary	1	2	3	4	5	Total
1	When preparing IV drugs it is easy to prevent asepsis failure	0	1	2	11	4	18
2	When preparing IV drugs it is easy to detect asepsis failure	1	0	4	8	5	18
3	The procedures for preparing IV drugs on this ward are simple	1	2	7	5	3	18
4	The resources on this ward make it easy to prepare IV drugs safely	0	1	7	7	2	17*
5	The environment on this ward makes it easy to prepare IV drugs safely	1	3	8	5	1	18
6	On this ward distractions and interruptions make it difficult to prepare IV drugs safely	0	3	8	6	1	18
7	I get feedback on the quality of my IV drug preparation	10	6	2	0	0	18
8	I would feel uncomfortable raising safety concerns regarding the preparing of IV drugs on this ward	8	6	0	3	1	18
9	I can mix drugs on this ward without distraction or interruption	4	6	5	3	0	18
10	Asepsis failure when preparing IV drugs is a safety priority on this ward	0	0	3	8	7	18
11	If I recognised an error in my IV drug preparation I would report it	0	2	2	1	13	18
12	There is good support to those who have to prepare IV drugs	1	2	7	5	3	18
13	To improve patient safety I am encouraged to report errors	0	2	5	5	6	18
14	I find preparing IV drugs is stressful	2	8	6	1	1	18
15	Preparing IV drugs gives me job satisfaction	3	3	7	3	2	18

Appendix 12 First Paper from the study submitted to the British Journal of Nursing

Intravenous drugs prepared in near-patient areas pose significant, but insufficiently recognised, infection risks

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Abstract

The preparation of intravenous drugs is a common, yet inherently dangerous nursing procedure. The many potential errors associated with this procedure include wrong drug, wrong dose and wrong route of administration. As a consequence of these known risks a variety of checks are used to optimise safety. This paper explores the literature around another intravenous drug preparation problem, that of infusate contamination, which can cause infusate related-blood stream infection (IR-BSI). In this paper, the mechanisms of infusate contamination are discussed, details of the types of micro-organisms that cause contamination are given and the types of drugs that enable proliferation of micro-organisms are explained. Additionally, deficits within current guidance are revealed. The paper concludes that IR-BSI is a significant but under-recognised risk to patients. As microbial contamination sufficient to cause IR-BSI is not detectable to the naked eye, those who prepare intravenous drugs must be more cognisant of the contamination risks and how to reduce them.

Key words: Infusate contamination; microbial contamination, intravenous drugs

Introduction

Preparation of intravenous drugs is a common nursing procedure performed most frequently in near-patient areas. The procedure can involve simply drawing up a drug from a glass ampoule, or more complicatedly, drawing up a drug, drawing up a diluent, mixing the drug and diluent, discarding any excess and then aseptically administering the infusate to the patient. During the procedure the infusate can be exposed to microbial contamination from a variety of sources. Infusate contamination can cause infusate related blood-stream infection (IR-BSI) as well as microbial

contamination of the catheter with infection manifesting at a later time through the development of biofilm (Lindsay and von Holy 2006). Key to understanding IR-BSI is an understanding of how micro-organisms gain access to the infusates.

How micro-organisms gain access to infusates

Micro-organisms gain access to infusates either intrinsically, during the drugs' manufacture, or extrinsically, during drug preparation in near-patient areas. This paper is about the extrinsic contamination risks; however, where the lessons learned from intrinsic IR-BSI outbreaks are relevant they will be discussed. Table 1 lists the three routes of cross-transmission for extrinsic infusate contamination.

Table 1 Routes of cross-transmission for extrinsic infusate contamination:	
○	Healthcare worker (HCW)-to-patient
○	Patient-to-patient via HCW (related to equipment use/misuse)
○	Environment-to-patient (usually related to unrecognised risks)

HCW to patient cross-transmission could arise when, for example, a HCW with a blood borne virus (BBV) cuts a finger when opening a glass ampoule and minute droplets of blood (and BBV) contaminate the infusate (Parker 1995). The infusate and BBV is then inadvertently administered to the patient. Basic hand hygiene failure causing HCW-to-patient cross-transmission was clearly demonstrated when an organism was found in patients' blood and a nurse's artificial nail: the nail was used to flip off drug vial lids (Gordin et al. 2007).

Patient-to-patient via HCW cross-transmission occurs when a HCW (knowingly or unknowingly) reuses contaminated equipment or drug vials. Such breaches in basic

infection control have resulted in cross-transmission of BBVs, bacteria and parasites (Al-Saigul et al. 2000, Centers for Disease Control 2003, Jain et al. 2005). One recent review estimated that as a consequence of a failure to perform safe injection practices, in 35 reported outbreaks, more than 100,000 patients had been exposed to BBVs (Dolan et al. 2010).

Environment-to-patient cross-transmission arises when small aerosols containing micro-organisms are liberated, e.g. during any procedure involving a tap. The aerosols land on the equipment preparation area and are subsequently transferred into the infusate. The micro-organisms arising from this route are usually opportunistic environmental pathogens, e.g., *Burkholderia capeczia* (Hsueh et al. 1998, Doit et al. 2004). Having explained the routes of cross-transmission, the properties of specific types of micro-organisms and infusates that promote IR-BSI will now be described.

Properties of micro-organisms and infusates that increase the risk of IR-BSI

Some micro-organisms such as the BBVs and parasites do not multiply in the infusate but cause infection by direct infusion of a minimal (invisible to the naked eye) inoculum. Gram-positive micro-organisms such as *Staphylococci* spp, which are the main cause of catheter-related BSIs, (Coello et al. 2003) can, and do contaminate infusates (van Grafhorst et al. 2002). However, possibly because of their inability to grow rapidly in the infusates they have been implicated less as a source of IR-BSI. These organisms can seed the catheter lumen and cause infection, through biofilm development, at a later date. The time from infusion to catheter infection in these situations can be so delayed that retrospective detection of infusate contamination becomes impossible.

Gram-negative micro-organisms are renowned for their ability to grow well in nutritionally poor intravenous solutions. Of paramount importance for those preparing infusions is the fact that heavily contaminated infusates (10^6 micro-organisms per ml) do not appear cloudy to the naked eye (Gilat et al. 1958, Felts et al. 1972, Maki and Martin 1975).

Drugs associated with IR-BSI

Although any drug can become contaminated lipids and heparin contamination is more widely reported. Drugs containing lipids, such as propofol, have been implicated in several outbreaks (Bennett et al. 1995, Halkes and Snow 2003, Trepanier and Lessard 2003). Heparin (as an infusion or flush) has been implicated in IR-BSI outbreaks (Al-Saigul et al. 2000, Siegman-Igra et al. 2005, Gershman et al. 2008, Blossom et al. 2009). There have even been reports of heparinised antibiotic lock solutions being microbially contaminated (Safdar and Maki 2006).

The time from infusion to IR-BSI developing

Symptoms of an IR-BSI can arise immediately a contaminated infusion is commenced, over the life-time of the infusion or shortly thereafter, or as a delayed-onset presentation, days, weeks or even months after an infusion is completed. Delayed-onset IR-BSI was eloquently illustrated during a multi-state *Pseudomonas fluorescens* outbreak caused by contaminated heparinised saline. With 47 cases identified the outbreak control team instigated a product recall. The product recall was successful, however, a further 33 cases were identified post-product recall. These delayed-onset IR-BSIs, which were caused by biofilm proliferation on the catheter lumen; were identified between 84 and 421 days after their last exposure to

the contaminated heparinised saline (Gershman et al. 2008). The above report shows clearly that no level of contamination can be considered safe. The infusates at highest risk of contamination are shown in the table 2 below.

Table 2 The infusates at the highest risk of causing IR-BSI by environmental sources are those where:
○ The procedure is open to environmental contamination
○ The drug supports microbial growth
○ The infusate is infused over 12hours enabling small numbers of micro-organisms present to proliferate exponentially.

The size of the IR-BSI problem

A systematic review of worldwide drug-related outbreaks between 1990 and 2005, identified 128 reports of non-blood product related outbreaks involving 2,250 patients (Vonberg and Gastmeier 2007): the majority occurred by drugs prepared in near-patient areas. A significant number of these outbreaks 64/128 involved multi-dose vials (or vials that were designated single-use used more than once).

The potential for IR-BSI was revealed in another study of 1,093 ward prepared infusates, which found a contamination rate of 0.9%; and two cases of IR-BSIs (Macias et al. 2008). The authors concluded that 'endemic infusate contamination may be a present danger' Macias et al., (2008: 48).

IR-BSI outbreaks are the most visible consequence of infusate contamination, because an infection control alert would be recognised when the same organism occurred in more than one patient. However, single IR-BSI episodes, of which there

are probably many more than outbreaks, may not create an alert signal and may go undetected. Vonberg and Gastmeier (2007: 19) agree that IR-BSI 'might not even be noticed if only a few patients are affected on the ward'. It does not seem intuitive that IR-BSIs could be undetected. However, many of the patients who require intravenous infusates are already sick and are generally vulnerable to infections; the majority of BSIs occur in intensive care units, haematology or renal units (Edgeworth et al. 1999, Coello et al. 2003, Gulati et al. 2003). It seems that something exceptional has to happen to alert staff to a possible contaminated infusate. A 4-year review of BSIs and risk factors was undertaken when a cluster of BSIs was found to be associated with heparin pumps (Siegman-Igra et al. 2005). These researchers found that 6% (96 patients) had a BSI for which the only identified risk factor was an intravenous catheter.

It is difficult to estimate precisely how much contamination occurs; however, several studies that examined different parts of the procedure found that asepsis failures are common. In a small environmental study, which followed standard microbiology methods (using air sampling and contact plates), researchers found that 10/10 surfaces where drugs were prepared in near patient areas were contaminated (Beaney and Goode 2003). In a systematic review of published studies on all errors in intravenous drug preparation and administration, poor aseptic technique, and environmental contamination, were noted to be frequently found (Crowley et al. 2004). A microbiological contamination rate of 0.9% was found in a study of in-use of 227 multi-dose vials (Mattner and Gastmeier 2004).

In another study Worthington et al., (2001) observed 100 nurses preparing infusates drawing up fluids, and a further 100 nurses preparing infusates with several

manipulations. These researchers demonstrated considerable variation in aseptic technique and significant contamination rates (8%). Higher infusate contamination rates were associated with greater required manipulations in the procedure (Worthington et al. 2001). A systematic review of microbial contamination of infusates prepared in clinical areas identified an overall 5% contamination rate (95% CI; 0.8% to 13.1%) (Austin and Elia 2009) found at least one deviation from aseptic technique in each of 299 observations. Therefore, not only are the opportunities for asepsis failure, subsequent infusate contamination and IR-BSI as a consequence immense, whenever aseptic practice has been observed the performed procedures was less than optimal to prevent contamination.

What guidance and regulations is there to help nurses recognise and prevent IR-BSI?

The Nursing and Midwifery Council sets and updates standards related to medicines management (Nursing and Midwifery Council 2010). With regard to intravenous medications, the relevant standard relates to a two-person checking procedure. Registrants are referred to other agencies (National Patient Safety Agency [NPSA], and the Royal College of Nursing) for other aspects of this procedure (Nursing and Midwifery Council 2010).

The NPSA in a work competence statement for the preparation of injectable medicines details a complex procedure. As for hand hygiene, it merely advocates compliance with local policy (NPSA 2007). Apart from the complexity of the procedure, there appears to be a good deal of advocating aseptic technique without clarification of what it is – though this has been specified out with a national guideline (Rowley 2001, Rowley and Sinclair 2004). The aseptic non-touch technique

advocated by Rowley (2001) also focuses the procedure on non-contamination of 'key parts'. However, as already discussed, contamination can occur with an aseptic non-touch technique if the antiseptic or drug is already contaminated or if splash contamination occurs during the preparation of the procedure – regardless of a non-touch technique.

The Royal College of Nursing has produced detailed advice on intravenous procedures (RCN IV Therapy Forum 2010). However, this guidance is not systematically produced and a lot of the advice therein refers the reader back to local policy. There is insufficient weighting of the evidence with which to guide those having to write local procedures. Despite the risks demonstrated in this paper there are as yet no minimal environmental standards for the preparation of infusates in the UK.

The US Centres for Disease Control guidelines, states that infusate contamination is a rare cause of blood stream infection (O'Grady et al. 2002). Although the guideline cites 293 references in total, there is only one reference provided to support this statement: and this is to a book published in 1982. The United Kingdom's Dept of Health *epic2* guidelines on the prevention of central venous catheter infections does not include infusate contamination in its synopsis of the causes of central line infections (Pratt et al. 2007).

Although the risk IR-BSI is not recognised by everyone, it certainly is recognised by some. In an overly concise summary of one outbreak investigation report, which hints that all investigations reveal similar causes, one editor wrote of the cause of infusate contamination akin to a game of Cluedo®: "*The nurse unwittingly did it, in the pre-*

induction room, with a contaminated infusate" (Horlocker et al. 2008: 1095).

Unwittingly or not, this situation is not acceptable to either the nurse or the patient.

Conclusions

The evidence from outbreak reports, prospective evaluation of infusates and procedure observations combined, indicate that IR-BSI is a real risk to patients but at present it is under-recognised as such.

What is required now to optimise patient safety is:

- The sources of infusate contamination and the risk of IR-BSI must become more widely recognised.
- Aseptic technique related to the preparation of infusates needs amended to negate contamination risks.
- National guidance and standards are required so that HCWs who follow procedures do not unwittingly cause their patients harm.

Key phrases

Infusates can be contaminated from the HCW themselves, from the misuse of equipment and from environmental sources.

IR-BSI is an under-recognised risk to patients and current guidance is insufficiently focused on its cause, its recognition and its prevention.

There are at present no extant environmental standards in the UK, no requirement for quality assurance of prepared drugs and no ongoing surveillance of the outcome

References:

- Al-Saigul AM, Fontaine RE, Haddad Q (2000) Nosocomial malaria from contamination of a multidose heparin container with blood. *Infection Control Hospital Epidemiology* 21(5):329-30
- Austin PD, Elia M (2009) A systematic review and meta-analysis of the risk of microbial contamination of aseptically prepared doses in different environments. *Journal of Pharmacy and Pharmaceutical Sciences* 12(2):233-42
- Beaney A, Goode J (2003) A risk assessment of the ward-based preparation of parenteral medicines. *Hospital Pharmacist* 10(306-308)
- Bennett SN, McNeil MM, Bland LA et al. (1995) Postoperative infections traced to contamination of an intravenous anesthetic, propofol. *New England Journal of Medicine* 333(3):147-54
- Blossom D, Noble-Wang J, Su J et al. (2009) Multistate outbreak of *Serratia marcescens* bloodstream infections caused by contamination of prefilled heparin and isotonic sodium chloride solution syringes. *Archives of Internal Medicine* 169(18):1705-11
- Centers for Disease Control (2003) Transmission of hepatitis B and C viruses in outpatient settings - New York, Oklahoma, and Nebraska, 2000-2002. *Morbidity and Mortality Weekly Report* 52(38):901-6
- Coello R, Charlett A, Ward V et al. (2003) Device-related sources of bacteraemia in English hospitals - opportunities for the prevention of hospital-acquired bacteraemia. *Journal of Hospital Infection* 53(1):46-57
- Crowley C, Scott D, Duggan C, Whittlesea C (2004) Describing the frequency of IV medication preparation and administration errors. *Hospital Pharmacist* 11(330-36)

Doit C, Loukil C, Simon AM et al. (2004) Outbreak of *Burkholderia cepacia* bacteremia in a pediatric hospital due to contamination of lipid emulsion stoppers. *Journal of Clinical Microbiology* 42(5):2227-30

Dolan SA, Felizardo G, Barnes S et al. (2010) APIC position paper: safe injection, infusion, and medication vial practices in health care. *American Journal of Infection Control* 38(3):167-72

Edgeworth JD, Treacher DF, Eykyn SJ (1999) A 25-year study of nosocomial bacteremia in an adult intensive care unit. *Critical Care Medicine* 27(8):1421-8

Felts SK, Schaffner W, Melly MA, Koenig MG (1972) Sepsis caused by contaminated intravenous fluids. Epidemiologic, clinical, and laboratory investigation of an outbreak in one hospital. *Annals of Internal Medicine* 77(6):881-90

Gershman MD, Kennedy DJ, Noble-Wang J et al. (2008) Multistate outbreak of *Pseudomonas fluorescens* bloodstream infection after exposure to contaminated heparinized saline flush prepared by a compounding pharmacy. *Clinical Infectious Diseases* 47(11):1372-9

Gilat T, Hertz M, Altmann G (1958) Severe shock syndrome due to contaminated infusions. *British Medical Journal* 1(5079):1104-6

Gordin FM, Schultz ME, Huber R, Zubairi S, Stock F, Kariyil J (2007) A cluster of hemodialysis-related bacteremia linked to artificial fingernails. *Infection Control Hospital Epidemiology* 28(6):743-4

Gulati S, Sahu KM, Avula S, Sharma RK, Ayyagiri A, Pandey CM (2003) Role of vascular access as a risk factor for infections in hemodialysis. *Renal Failure* 25(6):967-73

Halkes MJ, Snow D (2003) Re-use of equipment between patients receiving total intravenous anaesthesia: a postal survey of current practice. *Anaesthesia* 58(6):582-

Horlocker TT, Weiss WT, Olson CA (2008) Whodunnit: the mysterious case of mediastinitis after continuous interscalene block. *Anesth Analg* 107(4):1095-7

Hsueh PR, Teng LJ, Pan HJ et al. (1998) Outbreak of *Pseudomonas fluorescens* bacteremia among oncology patients. *Journal of Clinical Microbiology* 36(10):2914-7

Jain SK, Persaud D, Perl TM et al. (2005) Nosocomial malaria and saline flush. *Emerging Infectious Diseases* 11(7):1097-9

Lindsay D, von Holy A (2006) Bacterial biofilms within the clinical setting: what healthcare professionals should know. *Journal of Hospital Infection* 64(4):313-25

Macias AE, de Leon SP, Huertas M et al. (2008) Endemic infusate contamination and related bacteremia. *American Journal of Infection Control* 36(1):48-53

Maki DG, Martin WT (1975) Nationwide epidemic of septicemia caused by contaminated infusion products. IV. Growth of microbial pathogens in fluids for intravenous infusions. *Journal of Infectious Diseases* 131(3):267-72

Mattner F, Gastmeier P (2004) Bacterial contamination of multiple-dose vials: a prevalence study. *American Journal of Infection Control* 32(1):12-6

NPSA (2007) Preparation of injectable medicines. *Work competence statement* March 2007 (available at: www.npsa.nhs.uk/health/alerts)

Nursing and Midwifery Council (2010) Standards for Medicines Management. *Standard 20: Intravenous Medication* PB-STMM-A5-0410(108)

O'Grady NP, Alexander M, Dellinger EP et al. (2002) Guidelines for the prevention of intravascular catheter-related infections. The Hospital Infection Control Practices Advisory Committee, Centers for Disease Control and Prevention, U.S. *Pediatrics* 110(5):e51

Parker MR (1995) The use of protective gloves, the incidence of ampoule injury and the prevalence of hand laceration amongst anaesthetic personnel. *Anaesthesia* 50(8):726-9

Pratt RJ, Pellowe CM, Wilson JA et al. (2007) epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *Journal of Hospital Infection* 65 Suppl 1(S1-64

RCN IV Therapy Forum (2010) Standards for Infusion Therapy. 3rd edition. *Royal College of Nursing*

Rowley S (2001) Theory to practice. Aseptic non-touch technique. *Nursing Times* 97(7):VI-VIII

Rowley S, Sinclair S (2004) Working towards an NHS standard for aseptic non-touch technique. *Nursing Times* 100(8):50-2

Safdar N, Maki DG (2006) Use of vancomycin-containing lock or flush solutions for prevention of bloodstream infection associated with central venous access devices: a meta-analysis of prospective, randomized trials. *Clinical Infectious Diseases* 43(4):474-84

Siegmán-Igra Y, Jacobi E, Lang R, Schwartz D, Carmeli Y (2005) Unexpected hospital-acquired bacteraemia in patients at low risk of bloodstream infection: the role of a heparin drip. *Journal of Hospital Infection* 60(2):122-8

Trepanier CA, Lessard MR (2003) Propofol and the risk of transmission of infection. *Canadian Journal of Anaesthesia* 50(6):533-7

van Grafhorst JP, Foudraïne NA, Nootboom F, Crombach WH, Oldenhof NJ, van Doorne H (2002) Unexpected high risk of contamination with staphylococci species attributable to standard preparation of syringes for continuous intravenous drug administration in a simulation model in intensive care units. *Critical Care Medicine* 30(4):833-6

Vonberg RP, Gastmeier P (2007) Hospital-acquired infections related to contaminated substances. *Journal of Hospital Infection* 65(1):15-23

Worthington T, Tebbs S, Moss H, Bevan V, Kilburn J, Elliott TS (2001) Are contaminated flush solutions an overlooked source for catheter-related sepsis? *Journal of Hospital Infection* 49(1):81-3