ABSTRACT

Objective Many patient deaths have been reported because of administration of contaminated intravenous medicines due to incorrect aseptic techniques. Our aim was to review the literature for (1) incorrect practices in aseptic drug preparation and administration and (2) recommendations for safer practices in hospitals.

Methods A systematic literature search was conducted in PubMed covering 2007–2015. Studies were included if they concerned aseptic medicine preparation and administration in hospitals by different healthcare professionals, assessed incorrect practices and made recommendations for safer aseptic preparation and administration.

Results 26 studies were included of which 19 were original articles. 12 of the studies concerned description of incorrect practices that led to contamination. The studies reported 11 incorrect practices that increased the risk of contamination of parenteral medicines. The most reported incorrect practices were multiple use of phials and syringes (2/12 studies) and lack of overall disinfection during the aseptic preparation and administration (3/12 studies). 22 practices were recommended to avoid contamination, which were classified into six categories: equipment and medicines (7); disinfection (6); working environment (3); storing (3); catheter care (2) and quality of prepared medicines (1). The results indicate that pharmacists prepared syringes with less contamination than nurses because of the pharmacist’s aseptic skills and environmental aspects in pharmacy units.

Conclusions The review discusses many appropriate and enhanced practices in aseptic drug preparation and administration. As the change for the better in contamination rates of administered medicines seems to be challenging to achieve in hospitals, better and possibly international procedures for safe parenteral practices need to be developed.

INTRODUCTION

Administration of contaminated intravenous medicines due to incorrect aseptic techniques has been a contributing factor to many of the patient deaths that have been reported. Healthcare-associated infections are a significant cause of harm to patients and add remarkably to the healthcare costs all over the world. Intraoperative therapy is a complex process sometimes requiring the preparation of a medicine in the hospital pharmacy premises or on the ward before administration to the patient. Thus, the preparation phase is posing a potential risk for microbial contamination. Therefore, aseptic techniques must be used when handling sterile starting components for the preparation of medicines for parenteral administration in order to reduce microbial contamination risk. Aseptic techniques are methods designed to prevent contamination from microorganisms. These techniques require application of the strictest rules and best knowledge of infection prevention in order to minimize the risks for infection. Common settings where aseptic techniques for preparation of medicines are needed include surgery rooms and clinics in hospitals, pharmacies and drug industry. According to a previous study, medication errors are common related to the parenteral medicines in hospitals. At least one deviation from the aseptic techniques was observed among 19%–100% of intravenous drug preparation and administration cases of that study. Aseptic techniques alone cannot guarantee that a sterile dose will ultimately be prepared, because environmental contamination can occur during the preparation and administration. It is often argued that aseptically prepared medicines for parenteral administration should be made in a controlled environment in a pharmacy department, where the risk of environmental contamination is lower than in the clinical environment. However, there is little evidence to support this argument.

Microbial contamination of parenterally prepared medicines is quite common. According to a systematic review on microbiological contamination rates of doses prepared using aseptic techniques in different environments, 7% of prepared doses were contaminated (coverage of the evidence: 1950–2007). The contamination rates were higher when medicines were prepared in hospital wards rather than in a pharmaceutical environment. The same authors updated the systematic review and meta-analysis in 2015 to cover the evidence published in 1950–2014. The first systematic review found the overall contamination rates for doses prepared in clinical environments to be 5% for individual doses and 2% for doses prepared as part of a batch. Rates for doses prepared in pharmaceutical environments were found to be 2% for individual doses and 0% for doses prepared as part of a batch. In the recent update in 2015, there was a higher frequency of contamination of doses prepared in a clinical rather than in a pharmaceutical environment (3.7% vs 0.5%, respectively). The above-mentioned two systematic reviews by Austin and Elia compared the contamination...
rates between the different environments, but they did not focus on the different aseptic techniques applied to the preparation of parenteral medicines. The aseptic techniques can differ in many ways, for example, by practices related to working area, personal hygiene, reagents and media and handling. The aim of this systematic study was to focus on these different aseptic techniques in order to identify (1) incorrect practices in aseptic medicine preparation and administration and (2) recommendations for safer practices in hospitals.

**METHODS**

**Study design**

A systematic review based on the literature search in PubMed covering years 2007–2015 was carried out (figure 1). The quality of included studies was assessed using the GRADE system.

**Search strategy, inclusion criteria and data extraction**

A systematic literature search was conducted in PubMed covering the period from January 2007 to April 2015. This period was chosen as we wanted to focus on the most recent evidence published in peer-reviewed journals and indexed in PubMed. The search strategy, search terms and search engine from the first systematic review by Austin and Elia were applied. Studies were included if they concerned aseptic medicine preparation and administration in hospitals by different healthcare professionals, assessed incorrect practices and made recommendations for safer aseptic preparation and administration. Our inclusion criteria covered microbiological contamination (bacteria or fungi) of all parenteral products when prepared or administered to patients (also cytostatics and parenteral nutrition) in inpatient care.

We also included letters, editorials and commentaries from peer-reviewed journals because they reflect ongoing scientific debate on important issues at the time of publication. The exclusion criteria were studies not published in English, all animal studies and studies which covered food. In short, the following terms and their combinations.

<table>
<thead>
<tr>
<th>Search terms:</th>
<th>syringe, bag, infusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>In combination with:</td>
<td>microbial, microbiological, bacteria, fungi, contaminated, contamination</td>
</tr>
<tr>
<td>Combinations of infusion with bacteria and infusion with fungi were combined for an additional third term:</td>
<td>prepared, manufactured, compounded</td>
</tr>
</tbody>
</table>

Figure 1 Search strategy for PubMed indicating the used search terms and their combinations.

**RESULTS**

This systematic review is based on 26 peer-reviewed articles, of which 19 were original articles with empirical results (see online supplementary appendix 1). The key findings of the review are reported in table 1. The settings of the included articles are presented in online supplementary appendix 1. Twelve of these included articles dealt with incorrect practices and recommendations to avoid contamination. Thus, these were the key studies that provided empirical evidence to our research questions. These 12 studies concerned reasons for incorrect practices; description of incorrect practices that lead to contamination and recommendations to avoid contamination.

The majority of the included articles (69%, n=18) were graded as low quality because they were non-randomised. Three
of the original articles and all of the letters (n=2), editorial (n=1) and commentaries (n=2) were graded as very low quality because they were, for example, guidelines in their nature without empirical evidence (see online supplementary appendix 1, Objective and Study design).

Three of the 12 key studies (table 1) compared practical aseptic techniques and contamination rates between nurses and pharmacists in medicine preparation or administration. Three studies had been conducted only among nurses. The remaining studies (n=6) had been conducted among various healthcare professionals or not conducted among personnel at all. These 12 key studies had been carried out in different environments: 8 of the studies were conducted in clinical and 1 in pharmaceutical environments. Two of the studies compared clinical and pharmaceutical environments. The contamination rates varied depending on the environment, profession or administration and preparation practices, ranging from 0% to 16% (see online supplementary appendix 1). Based on the data extracted from the included articles, it is indicated that pharmacy practitioners’ aseptic skills are better than those of nurses and environmental (laminar-airflow hood in a cleanroom, drug preparation area in hospital ward or uncontrolled decentralised pharmacy in a ward) aspects in pharmacy units are cleaner than in wards.

Incorrect practices that led to contamination of parenteral medicines

From the included articles with empirical evidence (n=12, table 1), we identified 11 incorrect practices that led to contamination in aseptic preparation and/or administration of medicines in hospitals. The most common of these incorrect practices were: incorrect aseptic techniques (five studies), multiple use of syringes (one study), phials and ampoules (two studies) and environmental aspects (one study).

Incorrect aseptic technique, poor training and lack of experience (five studies)

Microbiological contamination during preparation was the most critical failure mode. Aseptic techniques are required to manipulate central venous lines and prepare doses for intravenous administration. Training and practice in the use of aseptic techniques may differ between healthcare workers, which lead to different risks of catheter-related sepsis.
Sigward et al. studied the aseptic technique of pharmacy practitioners with aseptic simulation test where all septa of the phials to be manipulated were contaminated. The aseptic simulation test or media-fill test procedure uses a sterile microbiological growth medium (tryptone soya agar) in place of the drug solution to test whether the aseptic practices are adequate to prevent contamination during actual drug production. Usually, the test is done annually in the pharmaceutical industry and in hospital pharmacies. Sigward et al. showed in their study that when a pharmacy practitioner used a correct aseptic

Table 1: The key findings and recommendations of the included articles (n=12) with empirical evidence on incorrect practices that lead to contamination in aseptic preparation and/or administration of medicines in hospitals and recommendations to avoid contamination according to the type of the recommendation (studies presented in alphabetical order)

<table>
<thead>
<tr>
<th>Study</th>
<th>Reasons/incorrect practices that lead to contamination</th>
<th>Recommendations to avoid contamination</th>
<th>Profession</th>
<th>Clinical or pharmacy-based preparation or administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disinfection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austin and Elia</td>
<td>1. Nurses did not clean the working surface or ampoule necks and did not use gloves</td>
<td>1. Cleaning the working surface with detergents and disinfectants (eg, 70% isopropyl alcohol or ethanol) with proper technique 2. Use of gloves 3. Cleaning each ampoule neck and rubber septa with alcohol swab before opening</td>
<td>Nurses and pharmacists</td>
<td>Clinic</td>
</tr>
<tr>
<td>Gargiulo et al</td>
<td>2. Lack of hand hygiene, no disinfection of phial septa or intravenous ports and multiple use of syringes</td>
<td>4. Hand washing and hand disinfection 5. Disinfection of the intravenous ports</td>
<td>Anaesthetists</td>
<td>Clinic</td>
</tr>
<tr>
<td>Gorski</td>
<td>3. Lack of infection prevention in peripheral intravenous catheter use and alternative site infusions</td>
<td>6. Skin antisepsis before catheter placement</td>
<td>Nurses</td>
<td>Clinic and home</td>
</tr>
<tr>
<td>Catheter care</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gorski</td>
<td>Lack of infection prevention in peripheral intravenous catheter use and alternative site infusions</td>
<td>1. Checking and caring the catheter site daily</td>
<td>Nurses</td>
<td>Clinic and home</td>
</tr>
<tr>
<td>Yoshida et al</td>
<td>4. Character of ward and catheter placement time</td>
<td>2. Catheter placement not more than 30 days</td>
<td>Nurses and pharmacists</td>
<td>Clinic and pharmacy departments</td>
</tr>
<tr>
<td>Equipments and medicines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bertoglio et al</td>
<td>5. Manually filled (filled by a nurse or a pharmacist in a hospital ward) syringes</td>
<td>1. Using of manufactured prefilled syringes</td>
<td>Nurses and pharmacists</td>
<td>Clinic</td>
</tr>
<tr>
<td>De Smet et al</td>
<td>6. Multiple dose phials with a high nutrient content</td>
<td>2. Single use of flushing solutions with low nutrient content</td>
<td>Nurses</td>
<td>Clinic</td>
</tr>
<tr>
<td>Buerke et al</td>
<td>7. Multiple use</td>
<td>3. Single use of syringes in automatic injectors</td>
<td>Technical and medical staff</td>
<td>CT department (clinic)</td>
</tr>
<tr>
<td>Nakataki et al</td>
<td>8. Improper handling</td>
<td>4. Aseptic handling of infusion set needles</td>
<td>Nurses</td>
<td>Clinic</td>
</tr>
<tr>
<td>Rangel-Fausto et al</td>
<td>9. Open infusion containers</td>
<td>5. Use of closed infusion containers</td>
<td>Physicians, nurses and paramedical staff</td>
<td>Clinic</td>
</tr>
<tr>
<td>Dolan et al</td>
<td>N/A</td>
<td>6. Single use of syringes, disposable tubes and connectors of automatic injectors 7. Discarding all opened phials, intravenous solutions and opened syringes</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Storing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolan et al</td>
<td>N/A</td>
<td>1. Storing medications in a clean area on a clean surface 2. Storage of needles and syringes never unwrapped 3. Preparation of IV solutions as close as possible to administration</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Working environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolan et al</td>
<td>N/A</td>
<td>1. Drug preparation in laminar flow hood 2. Avoiding to contact sterile drugs or sterile areas with non-sterile objects</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Stucki et al</td>
<td>10. Environmental aspects</td>
<td>3. Working in cleanrooms when ever possible</td>
<td>Single operator</td>
<td>Clinic and pharmacy department</td>
</tr>
<tr>
<td>Quality of prepared medications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gershman et al</td>
<td>11. No auditing for suppliers</td>
<td>1. Checking suppliers to ensure that medications ordered are produced according to manufacturing regulations</td>
<td>N/A</td>
<td>Pharmacy department</td>
</tr>
</tbody>
</table>

N/A, not available.
Multiple use of syringes, phials and ampoules (three studies)

We found three studies which concerned the multiple use of syringes, phials and ampoules. A single-dose or single-use phial and syringe are a dosage forms of liquid medication intended for parenteral administration (injection or infusion) that are meant for use in a single patient for administration of a single dose. Single-dose or single-use medicines do not typically contain an antimicrobial preservative and they are licensed solely to be used as a single dose or for single use. The microbial contamination can occur after the first penetration of the single dose. Two of the included articles reported outbreaks resulting from healthcare personnel using single-dose or single-use phials for multiple patients. The multiple use of syringes, phials and ampoules (table 1) for more than one patient increases the risk of microbial contamination. The multiple use is a practice where the same syringe, phial or ampoule is used for more than once and on more than one patient. The multiple use of prefilled syringes has been imagined to save time and to be more effective. Buerke et al. showed that the time of assembly of the injection system and installation of prefilled syringes did not differ significantly between the single use protocol and multiple-use protocol and there is the risk of bacterial contamination with multiple use of syringes. Many studies on injection practices show that physicians are not aware of the risks of multiple use of syringes. A survey of 550 healthcare professionals found that 1% of clinicians reported sometimes reusing syringes and 6% reported reusing single-dose phials. According to Cozanitis and Mäkelä, syringe reuse is a very common practice among anaesthetists. Rosenberg et al. showed almost 40% of anaesthetists admitted to multiple use of syringes.

Direct influence of environmental cleanliness on the quality of end products (two studies)

One of the main factors that contributes to microbial contamination of drugs is the cleanliness of the work environment. When medicinal preparations are not prepared in an aseptic environment, it is recommended that the drug is administered soon after reconstitution to avoid microbial contamination. However, in some situations, drugs are prepared ahead of time and stored until they are needed. Stucki et al. showed that microbial contamination of prepared syringes containing sterile media correlates with the rate of environmental contamination. Working with a correct aseptic technique within a cleanroom was demonstrated to be the best way to avoid bacterial or fungal contamination of injectable drugs directly resulting in patient infections. Furthermore, working in a cleanroom is a premise if the period of drug storage is extended. But when working in hospital wards without cleanrooms, the competency and carefulness of the operator is especially important. The operator has to use safe preparation and administration practices to avoid contamination.

Recommendations for safe practices to avoid contamination of parenteral medicines (12 studies, 22 recommendations)

Twenty-two recommendations were found for safe practices to avoid microbial contamination in different operational procedures (table 1). They were categorised into the following six key recommendation categories: disinfection (six recommendations); catheter care (two recommendations); equipments and medicines (seven recommendations), storage (three recommendations), working environment (three recommendations) and quality of prepared medicines (one recommendation) (table 1).

Letters, editorials, columns, brief reports and commentaries (seven articles)

Included letters (n=2), editorials (n=1), columns (n=1), brief reports (n=1) and commentaries (n=2) reflected ongoing scientific debate on the same issues related to safe aseptic preparation and administration of parenteral medicines as evidenced in empirical studies described above. They raised the issues of multiple use of syringes and unsafe injection practices, which increase the risk of microbial contamination.

DISCUSSION

This systematic review found 11 incorrect practices that increased the risk of contamination of parenteral medicines. The most reported incorrect practices were multiple use of phials and syringes and lack of overall disinfection during the aseptic preparation and administration. Twenty-two practices were recommended to avoid contamination. Most of the recommendations relate to categories disinfection and equipments and medicines. The results indicate that pharmacists prepared syringes with less contamination than nurses because of the pharmacist’s aseptic skills and environmental aspects in pharmacy units.

Hand hygiene and hand disinfection are the most important disinfection procedures; however, careful surface, injection port, catheter, neck of ampoules, rubber septa and patient skin disinfection also decrease the risk of microbial contamination of prepared and administered parenteral medicines. The multiple use of phials and syringes should be avoided. Newly introduced procedures should be assessed to control their infection risks. These procedures could be, for example, alcohol hand hygiene and desinfection phial gums and injection ports. In the USA, the Centers for Medicare and Medicaid Services is responsible for ensuring that healthcare facilities comply with infection prevention health and safety standards, for example, that single-use phials or single-dose phials are not used for more than one patient.

Based on the data extracted from the included studies, it is indicated that pharmacy practitioner’s aseptic skills are better than those of nurse and environmental (laminar-airflow hood in a cleanroom, drug preparation area in hospital ward or uncontrolled decentralised pharmacy in a ward) aspects in pharmacy units are cleaner than in wards. The most likely reason for differences in contamination rates between nurses and pharmacists concerns their respective training and experience in aseptic techniques. In the hospital wards, the medicine preparation is often performed in patient rooms, without any protective wear, while in the hospital pharmacies the preparation is done in cleanrooms with regulating protective wear.
Environmental standards and preparation practices in hospital wards are variable. There are no national standards for ward-based aseptic preparation, while the preparation in hospital pharmacies is well instructed. Therefore, the demand for making parenterally used medicines in a pharmacy department is well founded. Recent research has started to pay attention to the aseptic techniques for all administration procedures and infusion solution/medication preparation, after incorrect aseptic techniques and environmental aspects have been identified. As a result, to prevent contamination and bloodstream infections, checklists and safety tools have been developed and used. The compliance of hospital staff with the given rules is often poor.

De Giorgi et al. showed, based on a pharmacoeconomic analysis, that the involvement of a clinical pharmacist is one of the most cost-effective interventions in reducing microbiological contamination in patient care.

Our results showed that there is lack of quality in manufactured infusates (see online supplementary appendix 1). Infections due to contaminated infusates are a serious threat. The use of contaminated solutions may lead to a large and severe epidemic, and because of that it is important that manufacturers as well as compounding pharmacies follow guidelines and regulations to guarantee the quality of preparations.

Infected control teams in organisations also play an equally important role in noting contaminated sources. Furthermore, public health entities have an important role in effectively communicating information in these kinds of cases. More co-ordination between healthcare centres and governing bodies is needed for rapid identification of contaminated solutions in the future.

Some authors believe that manual aseptic filling in flow cabinets of cleanrooms is technology nearing the end of its use as regulations have been tightened and there are many new technologies available. The fact is inevitable that human operators are the major, some would claim only, significant risk modality in aseptic processing. To continue to guarantee the quality of hand or manual aseptic filling, we have to adopt these new technologies. They include items such as in-line depyrogenation of containers, automatic weight-check, machine controls, such as no container-no fill, improved component handling, electronic adjustments and significantly separative technologies such as closed isolators. Some companies have begun to perform manufacturing under the guise of compounding. Firms are trying to capitalise on the regulatory exemptions afforded to compounded products to produce less expensive medicinal products. Thus, it is important to check out suppliers of medicinal products to ensure that medications ordered are produced according to manufacturing regulations.

Study strengths and limitations

We exploited the previous systematic review and its search strategy. We also intentionally used only PubMed as a search engine but wanted to take another approach by identifying incorrect aseptic techniques and practices that lead to contamination in preparation and administration of parenteral medications. The data extraction by titles and abstracts were conducted by one author, which has potential for a selection bias, in selection of which studies to include in review to present the most significant result. In turn, two authors evaluated the full texts, which improve the reliability of the synthesis of the evidence. The included studies applied different study designs and protocols, as well as different measures and indicators to assess the possible contamination of parenteral preparations, which make it difficult to compare and generalise their findings. Protocols in most of the included studies were designed for ward-based or pharmacy-based aseptic preparation in such a way that aseptic practices were seen as the only leading cause to contamination. Therefore, the possibility of manufacture-based contaminations might have been overlooked.

Practical implications

Our study provides the most current evidence on safety risks and possible ways to minimise the risks in aseptic preparation and administration of medicines in hospitals. Our review found differences in contamination rates between different healthcare workers in preparing medicines as has been found in the previous systematic reviews (Austin and Elia and Austin et al.). We also found many incorrect aseptic techniques and practices that should be avoided and many good techniques and practices that should be used instead. The new safer techniques and practices, for example, disinfection and hygiene aspects, should be implemented and taught to healthcare practitioners, particularly to nurses. As the change for the better in contamination rates of administered medicines seems to be challenging to achieve in hospitals, better and possibly international procedures for safe parenteral practices need to be developed.

CONCLUSION

This systematic review identified many incorrect and unsafe practices and disregarded given rules in aseptic preparation and administration of parenteral medicines. This study indicates that current preparation and administration systems for parenteral therapy do not minimise patient safety risks. As a consequence, both theoretical knowledge and practical skills required in safe preparation and administration of parenteral medications should be improved among healthcare practitioners. As the change for the better in contamination rates of administered medicines seems to be challenging to achieve in hospitals, better and possibly international procedures for safe parenteral practices need to be developed.

Contributors The following contributorship statement applies to each author of this manuscript: substantial contributions to the analysis of data for the work; revising the work critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding Eva Suvikas-Peltonen was supported by the state research funding granted by Satakunta Hospital District when completing the review.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

7 Austin PD, Hand KS, Elia M. Systematic review and meta-analysis of the risk of microbial contamination of parenteral doses prepared under aseptic techniques in

8 Guyatt GH, Oxman AD, Kurtz R, et al. What is “quality of evidence” and why is it
9 Mohr D, Libarati A, Tetzaff J, et al. Preferred reporting items for systematic reviews
10 Austin P, Elia M. Improved aseptic technique can reduce variable contamination
11 Bertoglio S, Rezzo R, Merlo FD, et al. Pre-filled normal saline syringes to reduce
totally implantable venous access device-associated bloodstream infection: a single
efficiency of use of automatic MDC! injectors with prefilled syringes: results of a
13 Chemaly RF, Rathod DB, Sikka MK, et al. Serratia marcescens bacteremia because
of contaminated prefilled heparin and saline syringes: a multi-state report. Am
14 Crill CM, Hak EB, Robinson LA, et al. Evaluation of microbial contamination
associated with different preparation methods for neonatal intravenous fat emulsion.
of the injectable medication process in the paediatric and neonatal intensive care
16 De Smet B, Veng C, Kruy L, et al. Outbreak of Burkholderia cepacia bloodstream
infections traced to the use of Ringer lactate solution as multiple-dose vial for
17 Souza Dias MB, Habert AB, Bonasca V, et al. Salvage of long-term central venous
catheters during an outbreak of Pseudomonas putida and Stenotrophomonas
maltophilia infections associated with contaminated heparin catheter-lock solution.
18 Dolan SA, Felizardo G, Barnes S, et al. APIC position paper: safe injection, infusion,
19 Gargiulo DA, Sheridan J, Webster CS, et al. Anaesthetic drug administration as a
potential contributor to healthcare-associated infections: a prospective
simulation-based evaluation of aseptic techniques in the administration of
20 Greshman MD, Kennedy DJ, Noble-Wang J, et al. Multistate outbreak of
Pseudomonas fluorescens bloodstream infection after exposure to contaminated
heparinized saline flush prepared by a compounding pharmacy. Clin Infect Dis
21 Gorski LA. Central venous access device associated infections: recommendations
22 Ishart CM, McCall KL, Kretschmer D, et al. Parenterals laboratory course to
reduce microbial contamination rates in media fill test performed by pharmacy
23 Kerenyi M, Borza Z, Czontos C, et al. Impact of medications on bacterial growth in
24 Rangel-Fauisto MS, Higuera-Ramirez F, Martinez-Soto J, et al. Should we use closed
or open infusion containers for prevention of bloodstream infections? Ann Clin
microorganism for validation of pharmacy operations. Am J Health Syst Pharm
26 Stucki C, Sautter AM, Fawet J, et al. Microbial contamination of syringes during
preparation: the direct influence of environmental cleanliness and risk manipulations
2008;14:399–403.
28 Younger G, Khan M. Setting up and priming an intravenous infusion. Nurs Stand
22:53.
31 Chemaly RF, Rathod DB, Raad II. A tertiary care cancer center experience of the
2007 outbreak of Serratia marcescens bloodstream infection due to prefilled
32 Cozantitis DA, Mikaela P. The contaminated syringe: harming the patient’s good.
evolution of aseptic processing technology. PDA J Pharm Sci Technol
34 Kuehn BM. Unsafe injection practices plague US outpatient facilities, harm patients.
35 Pugliese G, Gosnell C, Bartley JM, et al. Injection practices among clinicians in
36 Rosenberg AD, Bernstein DB, Bernstein RL, et al. Accidental needlesticks: do
anesthesiologists practise proper infection control precautions? Am J Anaesthesiol
37 Simmons BP, Hooton TM, Wong ES, et al. Centers for disease control guidelines on
infection control: guidelines for prevention of intravascular infections. Atlanta: