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epic2: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England

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Executive Summary National evidence-based guidelines for preventing healthcare-associated infections (HCAI) in National Health Service (NHS) hospitals in England were commissioned by the Department of Health (DH) and developed during 1998-2000 by a nurse-led multi-professional team of researchers and specialist clinicians. Following extensive consultation, they were published in January 2001.[1] These guidelines describe the precautions healthcare workers should take in three areas: standard principles for preventing HCAI, which include hospital environmental hygiene, hand hygiene, the use of personal protective equipment, and the safe use and disposal of sharps; preventing infections associated with the use of short-term indwelling urethral catheters; and preventing infections associated with central venous catheters.

The evidence for these guidelines was identified by multiple systematic reviews of experimental and non-experimental research and expert opinion as reflected in systematically identified professional, national and international guidelines, which were formally assessed by a validated appraisal process. In 2003, we developed complementary national guidelines for preventing HCAI in primary and community care on behalf of the National Collaborating Centre for Nursing and Supportive Care (National Institute for Health and Clinical Excellence).[2]

A cardinal feature of evidence-based guidelines is that they are subject to timely review in order that new research evidence and technological advances can be identified, appraised and, if shown to be effective in preventing HCAI, incorporated into amended guidelines. Periodically updating the evidence base and guideline recommendations is essential in order to maintain their validity and authority.

Consequently, the DH commissioned a review of new evidence published following the last systematic reviews. We have now updated the evidence base for making infection prevention and control recommendations. A critical assessment of the updated evidence indicated that the original epic guidelines published in 2001 remain robust, relevant and appropriate but that adjustments need to be

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made to some guideline recommendations following a synopsis of the evidence underpinning the guidelines.
These updated national guidelines (epic2) provide comprehensive recommendations for preventing HCAI in hospitals and other acute care settings based on the best currently available evidence. Because this is not always the best possible evidence, we have included a suggested agenda for further research in each section of the guidelines. National evidence-based guidelines are broad principles of best practice which need to be integrated into local practice guidelines. To monitor implementation, we have suggested key audit criteria for each section of recommendations.
Clinically effective infection prevention and control practice is an essential feature of protecting patients. By incorporating these guidelines into routine daily clinical practice, patient safety can be enhanced and the risk of patients acquiring an infection during episodes of healthcare in NHS hospitals in England can be minimised.

1 Introductory section

1.1 Guideline Development Team

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1.2 Guideline Advisory Group

- Daphne Colpman, Continence Advisor, University College London Hospitals NHS Foundation Trust.
- Andrew Jackson, Nurse Consultant (Intravenous Therapy), Rotherham District General Hospital, South Yorkshire.
- Royal College of Nursing Intravenous Therapy Forum.
- Liz Simcock, Clinical Nurse Specialist for Central Venous Access, Cancer Services, University College London Hospitals NHS Foundation Trust.
- Dr. Godfrey W Smith, Consultant, Royal Liverpool and Broadgreen University Hospitals NHS Trust and the University of Liverpool.

1.3 Acknowledgements

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1.4 Source of Funding

The Department of Health (England)

1.5 Conflict of Interest

None

1.6 Relationship of Author(s) with Sponsor

The Department of Health (England) commissioned the authors to update the evidence and guideline recommendations previously developed by them and published as the epic guidelines in the *Journal of Hospital Infection* in 2001.

1.7 Responsibility for Guidelines

The views expressed in this publication are those of the authors and, following extensive consultation, have been endorsed by the Department of Health (England).

1.8 Summary of Guidelines

Standard Principles for preventing healthcare-associated infections in hospital and other acute care settings

This guidance is based on the best critically appraised evidence currently available. The type and class of supporting evidence explicitly linked to each recommendation is described. All recommendations are endorsed equally and none is regarded as optional. These recommendations are not detailed procedural protocols and need to be incorporated into local guidelines.

This guidance on infection control precautions should be applied by all healthcare practitioners to the care of every patient. Job descriptions should reflect this and annual appraisal evidence should be available to support continuing engagement of each member of staff. The recommendations are divided into four distinct interventions:

1. Hospital environmental hygiene;
2. Hand hygiene;
3. The use of personal protective equipment; and
4. The safe use and disposal of sharps.

These guidelines do not address the additional infection control requirements of specialist settings, such as the operating department.

Hospital environmental hygiene

SP1	The hospital environment must be visibly clean, free from dust and soilage and acceptable to patients, their visitors and staff.	*Class C*
SP2	Increased levels of cleaning should be considered in outbreaks of infection where the pathogen concerned survives in the environment and environmental contamination may be contributing to spread.	*Class D*
SP3	The use of hypochlorite and detergent should be considered in outbreaks of infection where the pathogen concerned survives in the environment and environmental contamination may be contributing to spread.	*Class D*
SP4	Shared equipment used in the clinical environment must be decontaminated appropriately after each use.	*Class D*
SP5	All healthcare workers need to be aware of their individual responsibility for maintaining a safe care environment for patients and staff. Every healthcare worker needs to be clear about their specific responsibilities for cleaning equipment and clinical areas (especially those areas in close proximity to patients).They must be educated about the importance of ensuring that the hospital environment is clean and that opportunities for microbial contamination are minimised.	*Class D*

Hand hygiene

SP6	Hands must be decontaminated immediately before each and every episode of direct patient contact/care and after any activity or contact that potentially results in hands becoming contaminated.	*Class C*

SP7 Hands that are visibly soiled or potentially grossly contaminated with dirt or organic material (i.e. following the removal of gloves) must be washed with liquid soap and water. *Class A*

SP8 Hands should be decontaminated between caring for different patients or between different care activities for the same patient. For convenience and efficacy an alcohol-based handrub is preferable unless hands are visibly soiled. Local infection control guidelines may advise an alternative product in some outbreak situations. *Class A*

SP9 Hands should be washed with soap and water after several consecutive applications of alcohol handrub. *Class D/GPP*

SP10 Before a shift of clinical work begins, all wrist and ideally hand jewellery should be removed. Cuts and abrasions must be covered with waterproof dressings. Fingernails should be kept short, clean and free from nail polish. False nails and nail extensions must not be worn by clinical staff. *Class D*

SP11 An effective handwashing technique involves three stages: preparation, washing and rinsing, and drying. Preparation requires wetting hands under tepid running water before applying the recommended amount of liquid soap or an antimicrobial preparation. The handwash solution must come into contact with all of the surfaces of the hand. The hands must be rubbed together vigorously for a minimum of 10-15 seconds, paying particular attention to the tips of the fingers, the thumbs and the areas between the fingers. Hands should be rinsed thoroughly prior to drying with good quality paper towels. *Class D*

SP12 When decontaminating hands using an alcohol-based handrub, hands should be free of dirt and organic material. The handrub solution must come into contact with all surfaces of the hand. The hands must be rubbed together vigorously, paying particular attention to the tips of the fingers, the thumbs and the areas between the fingers, until the solution has evaporated and the hands are dry. *Class D*

SP13 Clinical staff should be aware of the potentially damaging effects of hand decontamination products. They should be encouraged to use an emollient hand cream regularly, for example, after washing hands before a break or going off duty and when off duty, to maintain the integrity of the skin. *Class D*

SP14 If a particular soap, antiseptic hand wash or alcohol-based product causes skin irritation, review methods as described in Recommendation SP11 and 12 before consulting the occupational health team. *Class D*

SP15 Near patient alcohol-based hand rub should be made available in all healthcare facilities. *Class D*

SP16 Hand hygiene resources and individual practice should be audited at regular intervals and the results fed back to healthcare workers. *Class D*

SP17 Education and training in risk assessment, effective hand hygiene and glove use should form part of all healthcare workers' annual updating. *Class D*

The use of personal protection equipment

SP18 Selection of protective equipment must be based on an assessment of the risk of transmission of microorganisms to the patient or to the carer, and the risk of contamination of the healthcare practitioners' clothing and skin by patients' blood, body fluids, secretions or excretions. *Class D/H&S*

SP19 Everyone involved in providing care should be educated about standard principles and trained in the use of protective equipment. *Class D/H&S*

SP20 Adequate supplies of disposable plastic aprons, single use gloves and face protection should be made available wherever care is delivered. Gowns should be made available when advised by the infection control team. *Class D/H&S*

SP21 Gloves must be worn for invasive procedures, contact with sterile sites, and non-intact skin or mucous membranes, and all activities that have been assessed as carrying a risk of exposure to blood, body fluids, secretions and excretions; and when handling sharp or contaminated instruments. *Class D/H&S*

SP22 Gloves must be worn as single use items. They are put on immediately before an episode of patient contact or treatment and removed as soon as the activity is completed. Gloves are changed between caring for different patients, or between different care/treatment activities for the same patient. *Class D/H&S*

SP23 Gloves must be disposed of as clinical waste and hands decontaminated, ideally by washing with liquid soap and water after the gloves have been removed. *Class D/H&S*

SP24 Gloves that are acceptable to healthcare personnel and CE marked must be available in all clinical areas. *Class D/H&S*

SP25 Sensitivity to natural rubber latex in patients, carers and healthcare personnel must be documented and alternatives to natural rubber latex must be available. *Class D/H&S*

SP26 Neither powdered nor polythene gloves should be used in health care activities. *Class C/H&S*

SP27 Disposable plastic aprons must be worn when close contact with the patient, materials or equipment are anticipated and when there is a risk that clothing may become contaminated with pathogenic microorganisms or blood, body fluids, secretions or excretions, with the exception of perspiration. *Class D/H&S*

SP28 Plastic aprons/gowns should be worn as single-use items, for one procedure or episode of patient care, and then discarded and disposed of as clinical waste. Non-disposable protective clothing should be sent for laundering. *Class D/H&S*

SP29 Full-body fluid-repellent gowns must be worn where there is a risk of extensive splashing of blood, body fluids, secretions or excretions, with the exception of perspiration, onto the skin or clothing of healthcare personnel (for example when assisting with childbirth). *Class D/H&S*

SP30 Face masks and eye protection must be worn where there is a risk of blood, body fluids, secretions or excretions splashing into the face and eyes. *Class D/H&S*

SP31 Respiratory protective equipment, i.e., a particulate filter mask, must be correctly fitted and used when recommended for the care of patients with respiratory infections transmitted by airborne particles. *Class D/H&S*

The safe use and disposal of sharps

SP32 Sharps must not be passed directly from hand to hand and handling should be kept to a minimum. *Class D/H&S*

SP33 Needles must not be recapped, bent broken or disassembled after use. *Class D/H&S*

SP34 Used sharps must be discarded into a sharps container (conforming to UN3291 and BS 7320 standards) at the point of use by the user. These must not be filled above the mark that indicates the bin is full. *Class D/H&S*

SP35 All sharps bins should be positioned out of the reach of children at a height that enables safe disposal by all members of staff. They should be secured to avoid spillage. *Class D/H&S*

SP36 All staff both clinical and non clinical must be educated about the safe use and disposal of sharps. *Class D/H&S /GPP*

SP37 Consider the use of needlestick-prevention devices where there are clear indications that they will provide safe systems of working for healthcare practitioners. *Class B/H&S*

SP38 Conduct a rigorous evaluation of needlestick-prevention devices to determine their effectiveness, acceptability to practitioners, impact on patient care and cost benefit prior to widespread introduction. *Class D*

Guidelines for preventing infections associated with the use of short-term indwelling urethral catheters

This guidance is based on the best critically appraised evidence currently available. The type and class of supporting evidence explicitly linked to each recommendation is described. All recommendations are endorsed equally and none is regarded as optional. These recommendations are not detailed procedural protocols and need to be incorporated into local guidelines.

These guidelines apply to adults and children aged 1 year and older and should be read in conjunction with the guidance on Standard Principles. The recommendations are divided into five distinct interventions:

1. Assessing the need for catheterisation;
2. Selection of catheter type and system;
3. Catheter insertion;
4. Catheter maintenance; and
5. Education of patients, relatives and healthcare workers.

Assessing the need for catheterisation

UC1 Only use indwelling urethral catheters after considering alternative methods of management. *Class D/GPP*

UC2 Document the need for catheterisation, catheter insertion and care. *Class D/GPP*

UC3 Review regularly the patient's clinical need for continuing urinary catheterisation and remove the catheter as soon as possible. *Class D/GPP*

Selection of Catheter Type

UC4 Choice of catheter material will depend on clinical experience, patient assessment and anticipated duration of catheterisation. *Class D*

UC5 Select the smallest gauge catheter that will allow free urinary outflow. A catheter with a 10 ml balloon should be used in adults. Urological patients may require larger gauge sizes and balloons. *Class D*

Catheter Insertion

UC6 Catheterisation is an aseptic procedure. Ensure that health care workers are trained and competent to carry out urethral catheterisation. *Class D*

UC7 Clean the urethral meatus with sterile normal saline prior to the insertion of the catheter. *Class D*

UC8 Use an appropriate lubricant from a sterile single use container to minimise urethral trauma and infection. *Class D*

Catheter Maintenance

UC9 Connect indwelling urethral catheters to a sterile closed urinary drainage system. *Class A*

UC10 Ensure that the connection between the catheter and the urinary drainage system is not broken except for good clinical reasons, e.g., changing the bag in line with manufacturer's recommendation. *Class A*

UC11 Decontaminate hands and wear a new pair of clean, non-sterile gloves before manipulating a patient's catheter and decontaminate hands after removing gloves. *Class D*

UC12 Obtain urine samples from a sampling port using an aseptic technique. *Class D/GPP*

UC13 Position urinary drainage bags below the level of the bladder on a stand that prevents contact with the floor. *Class D/GPP*

UC14 Empty the urinary drainage bag frequently enough to maintain urine flow and prevent reflux. Use a separate and clean container for each patient and avoid contact between the urinary drainage tap and container. *Class D/GPP*

UC15 Do not add antiseptic or antimicrobial solutions into urinary drainage bags. *Class A*

UC16 Do not change catheters unnecessarily or as part of routine practice except where necessary to adhere to the manufacturer's guidance. *Class D/GPP*

UC17 Routine daily personal hygiene is all that is needed to maintain meatal hygiene. *Class A*

UC18 Bladder irrigation, instillation or washouts should not be used to prevent catheter-associated infection. *Class A*

Education of patients, relatives and healthcare workers

UC19 Healthcare workers must be trained in catheter insertion and maintenance. *Class D/GPP*

UC20 Patients and relatives should be educated about their role in preventing urinary tract infection. *Class D/GPP*

Guidelines for preventing infections associated with the use of central venous access devices (CVAD)

This guidance is based on the best critically appraised evidence currently available. The type and class of supporting evidence explicitly linked to each recommendation is described. All recommendations are endorsed equally and none is regarded as optional. These recommendations are not detailed procedural protocols and need to be incorporated into local guidelines.

These guidelines apply to adults and children aged one year and older and should be read in conjunction with the guidance on Standard Principles. The recommendations are divided into 9 distinct interventions:

1. Education of healthcare workers and patients;
2. General asepsis;
3. Selection of catheter type;
4. Selection of catheter insertion site;
5. Maximal sterile barrier precautions during catheter insertion;
6. Cutaneous antisepsis;
7. Catheter and catheter site care;
8. Catheter replacement strategies; and
9. General principles for catheter management.

Education of healthcare workers and patients

CVAD 1 Healthcare workers caring for a patient with a central venous access device should be trained, and assessed as competent in using and consistently adhering to the infection prevention practices described in this guideline. *Class D*

CVAD 2 Before discharge from hospital, patients with a central venous access device and their carers should be taught any techniques they may need to use to prevent infection and safely manage their device. *Class D/GPP*

General asepsis

CVAD 3 An aseptic non-touch technique (ANTT) must be used for catheter site care and for accessing the system. *Class B*

CVAD 4 Before accessing or dressing a central venous access device, hands must be decontaminated either by washing with an antimicrobial liquid soap and water, or by using an alcohol handrub. *Class A*

CVAD 5 Hands that are visibly soiled or contaminated with dirt or organic material must be washed with liquid soap and water before using an alcohol handrub. *Class A*

CVAD 6 Following hand antisepsis, clean gloves and an ANTT, or sterile gloves should be used when changing the insertion site dressing, line manipulation or intravenous drug administration. *Class D*

Selection of Catheter Type

CVAD 7 Use a single-lumen catheter unless multiple ports are essential for the management of the patient. *Class A*

CVAD 8 If a multilumen catheter is used, identify and designate one port exclusively for hyperalimentation to administer parenteral nutrition. *Class D/GPP*

CVAD 9 Use a tunnelled or implanted central venous access device (one with a subcutaneous port) for patients in whom long-term (more than 3-4 weeks) vascular access is anticipated. *Class A*

CVAD 10 Consider the use of an antimicrobial impregnated central venous access device for adult patients who require short-term (1 to 3 weeks) central venous catheterisation and who are at high risk for catheter-related bloodstream infection (CR-BSI) if rates of CR-BSI remain high despite implementing a comprehensive strategy to reduce rates of CR-BSI. *Class A*

Selection of Catheter Insertion Site

CVAD 11 In selecting an appropriate insertion site, assess the risks for infection against the risks of mechanical complications. *Class D/GPP*

CVAD 12 Unless medically contraindicated, use the subclavian site in preference to the jugular or femoral sites for nontunnelled catheter placement. *Class C*

CVAD 13 Use implantable access devices for patients who require long-term, intermittent vascular access. For patients requiring regular or continuous access, a tunnelled central venous access device is preferable. *Class C*

Maximal Sterile Barrier Precautions during Catheter Insertion

CVAD 14 Use maximal sterile barriers, including a sterile gown, sterile gloves, and a large sterile drape, for the insertion of central venous access devices. *Class C*

Cutaneous Antisepsis

CVAD 15 Decontaminate the skin site with a single patient use application of alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) prior to the insertion of a central venous access device. *Class A*

CVAD 16 Use a single patient use application of alcoholic povidone-iodine solution for patients with a history of chlorhexidine sensitivity. Allow the antiseptic to dry before inserting the central venous access device. *Class D/GPP*

CVAD 17 Do not apply organic solvents, e.g., acetone, ether, to the skin before the insertion of a central venous access device. *Class D/GPP*

CVAD 18 Do not routinely apply antimicrobial ointment to the catheter placement site prior to insertion. *Class D/GPP*

Catheter and Catheter Site Care

CVAD 19 Preferably, a sterile, transparent, semi-permeable polyurethane dressing should be used to cover the catheter insertion site. *Class D*

CVAD 20 Transparent dressings should be changed every 7 days, or sooner if they are no longer intact or moisture collects under the dressing. *Class D*

CVAD 21 If a patient has profuse perspiration or if the insertion site is bleeding or oozing, a sterile gauze dressing is preferable to a transparent, semi-permeable dressing. *Class D/GPP*

CVAD 22 The need for a gauze dressing should be assessed daily and changed when inspection of the insertion site is necessary or when the dressing becomes damp, loosened or soiled. A gauze dressing should be replaced by a transparent dressing as soon as possible. *Class D/GPP*

CVAD 23 Dressings used on tunnelled or implanted catheter insertion sites should be replaced every 7 days until the insertion site has healed, unless there is an indication to change them sooner. *Class D*

CVAD 24 An alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) should be used to clean the catheter insertion site during dressing changes, and allowed to air dry. An aqueous solution of chlorhexidine gluconate should be used if the manufacturer's recommendations prohibit the use of alcohol with their product. *Class A*

CVAD 25 Individual single use sachets of antiseptic solution or individual packages of single use antiseptic-impregnated swabs or wipes should be used to disinfect the insertion site. *Class D/GPP*

CVAD 26 Do not apply antimicrobial ointment to catheter insertion sites as part of routine catheter site care. *Class D/GPP*

CVAD 27 Healthcare workers should ensure that catheter-site care is compatible with catheter materials (tubing, hubs, injection ports, luer connectors and extensions) and carefully check compatibility with the manufacturer's recommendations. *Class D/GPP*

Catheter Replacement Strategies

CVAD 28 Do not routinely replace catheters as a method to prevent catheter-related infection. *Class A*

CVAD 29 Use guide wire assisted catheter exchange to replace a malfunctioning catheter, or to exchange an existing catheter only if there is no evidence of infection at the catheter site or proven catheter-related bloodstream infection. *Class A*

CVAD 30 If catheter-related infection is suspected, but there is no evidence of infection at the catheter site, remove the existing catheter and insert a new catheter over a guide wire; if tests reveal catheter-related infection, the newly inserted catheter should be removed and, if still required, a new catheter inserted at a different site. *Class A*

CVAD 31 Do not use guide wire assisted catheter exchange for patients with catheter-related infection. If continued vascular access is required, remove the implicated catheter, and replace it with another catheter at a different insertion site. *Class A*

CVAD 32 Replace all fluid administration tubing and connectors when the central venous access device is replaced. *Class D/GPP*

General Principles for Catheter Management

CVAD 33 A single patient use application of alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) should be used and allowed to dry when decontaminating the injection port or catheter hub before and after it has been used to access the system, unless contraindicated by the manufacturer's recommendations, in which case either aqueous chlorhexidine gluconate or aqueous povidone iodine should be used. *Class D/GPP*

CVAD 34 In-line filters should not be used routinely for infection prevention purposes. *Class D*

CVAD 35 Antibiotic lock solutions should not be used routinely to prevent catheter-related bloodstream infections. *Class D*

CVAD 36 Do not routinely administer intranasal or systemic antimicrobials before insertion or during the use of a central venous access device to prevent catheter colonisation or bloodstream infection. *Class A*

CVAD 37 Preferably, a single-lumen catheter should be used to administer parenteral nutrition. If a multilumen catheter is used, one port must be exclusively dedicated for hyperalimentation and all lumens must be handled with the same meticulous attention to aseptic technique. *Class D*

CVAD 38 Preferably, sterile 0.9 percent sodium chloride for injection should be used to flush and lock catheter lumens that are in frequent use. *Class A*

CVAD 39 When recommended by the manufacturer, implanted ports or opened-ended catheter lumens should be flushed and locked with heparin sodium flush solutions. *Class D*

CVAD 40 Systemic anticoagulants should not be used routinely to prevent catheter-related bloodstream infection. *Class D*

CVAD 41 The introduction of new intravascular devices that include needle-free devices should be monitored for an increase in the occurrence of device associated infection. If an increase in infection rates is suspected, this should be reported to the Medicines and Healthcare products Regulatory Agency [http://www.mhra.gov.uk] *Class D/GPP*

CVAD 42 If needle-free devices are used, the manufacturer's recommendations for changing the needle-free components should be followed. *Class D/GPP*

CVAD 43 When needle-free devices are used, healthcare workers should ensure that all components of the system are compatible and secured, to minimise leaks and breaks in the system. *Class D/GPP*

CVAD 44 When needle-free devices are used, the risk of contamination should be minimised by decontaminating the access port before and after use with a single patient use application of alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) unless contraindicated by the manufacturer's *Class D*

	recommendations, in which case aqueous povidone iodine should be used.	
CVAD 45	In general, solution administration sets in continuous use need not be replaced more frequently than at 72 hour intervals unless they become disconnected or a central venous access device is replaced.	*Class A*
CVAD 46	Administration sets for blood and blood components should be changed when the transfusion episode is complete or every 12 hours (whichever is sooner), or according to the manufacturer's recommendations.	*Class D*
CVAD 47	Administration sets used for total parenteral nutrition infusions should generally be changed every 24 hours. If the solution contains only glucose and amino acids, administration sets in continuous use do not need to be replaced more frequently than every 72 hours.	*Class D*

1.9 Introduction – the epic2 Guidelines

National evidence-based guidelines for preventing healthcare-associated infections (HCAI) in NHS hospitals were commissioned by the Department of Health (England) (DH) and developed during 1998-2000 by a nurse-led multi-professional team of researchers and specialist clinicians. They were intended to provide reliable best evidence for the development of local infection prevention and control guidelines and protocols and facilitate clinically effective practice. Having been developed within the '*epic* initiative' in the Richard Wells Research Centre at Thames Valley University, they became known as the 'epic' guidelines. Following extensive consultation, they were published in January 2001.[1] Two years later, under the auspices of the National Institute for Health and Clinical Excellence (NICE), a complementary set of national evidence-based guidelines were developed by the *epic* initiative, focused on preventing HCAI in primary and community care.[2]

An evidence review in 2004 indicated the necessity to amend and update some of the original epic guideline recommendations to ensure that they continue to reflect new and emerging evidence, remain relevant to infection control and prevention practice and enjoy the confidence of practitioners and patients.[3,4]

Additional updating systematic reviews were conducted in 2005 and the original *epic* guidelines have now been revised. They are referred to in this publication as the *epic2* infection prevention guidelines, which now replace the original 2001 guidelines.

What are national evidence-based guidelines?
These are systematically developed broad statements (principles) of good practice. They are driven by practice need, based on evidence and subject to multi-professional debate, timely and frequent review, and modification. National guidelines are intended to inform the development of detailed operational protocols at local level and can be used to ensure that these incorporate the most important principles for preventing HCAI in NHS hospitals and other acute care health services.

Why do we need national guidelines for preventing healthcare-associated infections?
During the past two decades, HCAI have become a significant threat to patient safety. The technological advances made in the treatment of many diseases and disorders are often undermined by the transmission of infections within healthcare settings, particularly those caused by anti-microbial-resistant strains of disease-causing microorganisms that are now endemic in many healthcare environments. The financial and personal cost of these infections, in terms of the economic consequences to the NHS and the physical, social and psychological costs to patients and their relatives, have increased both government and public awareness of the risks associated with healthcare interventions, especially that of acquiring a new infection.

Although not all HCAI can be prevented, many can. Clinical effectiveness, i.e., using prevention measures that are based on reliable evidence of efficacy, is a core component of an effective strategy designed to protect patients from the risk of infection.

What is the purpose of the guidelines?
These guidelines describe clinically effective measures that are used by healthcare workers for preventing infections in hospital and other acute care health services.

What is the scope of the guidelines?
Three sets of guidelines were originally developed and have now been updated. They include:

- Standard infection control principles include best practice recommendations for hospital environmental hygiene, effective hand hygiene, the appropriate use of personal protective equipment, and the safe use and disposal of sharps;

- Guidelines for preventing infections associated with the use of short-term indwelling urethral catheters; and
- Guidelines for preventing infections associated with the use of central venous access devices.

What is the evidence for these guidelines?
The evidence for these guidelines was identified by multiple systematic reviews of experimental and non-experimental research. In addition, evidence from expert opinion as reflected in systematically identified professional, national and international guidelines was considered following formal assessment using a validated appraisal process.[5,6] All evidence was critically appraised for its methodological rigour and clinical practice applicability and the best available evidence influenced the guideline recommendations.

Who developed these guidelines?
The *epic2* guidelines were developed by a nurse-led team of researchers, senior infection control nurses and a Director of Microbiology and Infection Prevention and Control in a large NHS Teaching Hospital Trust (see 1.1).

Who are these guidelines for?
These guidelines can be appropriately adapted and used by *all* hospital practitioners. They will inform the development of more detailed local protocols and ensure that important standard principles for infection prevention are incorporated. Consequently, they are aimed at hospital managers, members of hospital infection control teams, and individual health care practitioners. At an individual level, they are intended to influence the quality and clinical effectiveness of infection prevention decision-making. The dissemination of these guidelines also help patients understand the standard infection prevention precautions recommended to protect them from HCAI.

How are these guidelines structured?
Each set of guidelines follows an identical format, which consists of:

- a *resume of the systematic review process;*
- the *intervention heading*;
- a *headline statement* describing the key issues being addressed;
- a *synthesis* of the related evidence;
- an *economic opinion*, where appropriate;
- *guideline recommendation*(s) classified according to the strength of the underpinning evidence.

Finally, at the end of each section there is a description of areas for *further research* and suggested *audit criteria*. All evidence is referenced in section 5.

How frequently are the guidelines reviewed and updated?
A cardinal feature of evidence-based guidelines is that they are subject to timely review in order that new research evidence and technological advances can be identified, appraised and, if shown to be effective in preventing HCAI, incorporated into amended guidelines. The evidence base for these guidelines will be reviewed in two years (2009) and the guidelines will be updated approximately four years after publication (2011).

How can these guidelines be used to improve your clinical effectiveness?
In addition to informing the development of detailed local operational protocols, these guidelines can be used as a benchmark for determining appropriate infection prevention decisions and, as part of reflective practice, to assess clinical effectiveness. They also provide a baseline for clinical audit, evaluation and education, and facilitate ongoing quality improvements.

How much will it cost to implement these guidelines?
Significant additional costs are not anticipated in implementing these guidelines. However, where current equipment or resources do not facilitate the implementation of the guidelines, or where staff levels of adherence to current guidance are poor, there may be an associated increase in costs. Given the social and economic costs of HCAI, the consequences associated with not implementing these guidelines would be unacceptable to both patients and health care professionals.

Consultation process
These guidelines have been subject to extensive external consultation with key stakeholders, including Royal Colleges, professional societies and organisations, including patients, and trades unions (Appendix A.1).

1.10 Guideline Development Methodology

The guidelines were developed using a systematic review process (Appendix A.2). In each set of guidelines a resume of the relevant guideline development methodology is provided.

Search Process

Electronic databases were searched for national and international guidelines and research studies published during the period 01 January 1999 to 31 August 2005. A two-stage search process was used.

Stage 1: Identification of systematic reviews and guidelines

For each set of epic guidelines, an electronic search was conducted for systematic reviews of randomised controlled trials and current national and international guidelines. The following data bases were searched:

- Cochrane Library;
- National Guideline Clearinghouse;
- National Electronic Library of Health;
- National Institute for Health and Clinical Excellence.

Guidelines were retrieved and subjected to critical appraisal using the AGREE Instrument,[6] an evaluation method used in Europe for assessing the methodological quality of clinical practice guidelines.

Following appraisal, accepted guidelines were included as part of the evidence base supporting guideline development. They were also used to verify professional consensus and in some instances, as the primary source of evidence.

Stage 2: Systematic search for additional evidence

Review questions for the systematic reviews of the literature were then developed for each set of epic guidelines following recommendations from expert advisors.

Searches were constructed using relevant MeSH (medical subject headings) and free-text terms. On completion of the main search, an economic filter was applied. The following databases were searched:

- Medline;
- Cumulated Index of Nursing and Allied Health Literature;
- Embase;
- The Cochrane Library.

Abstract review – identifying studies for appraisal

Search results were downloaded into a Reference Manager™ database and titles and abstracts printed for preliminary review. Reviewers identified and retrieved all studies where the title or abstract: addressed one or more of the review questions; identified primary research or systematically conducted secondary research; indicated a theoretical/clinical/ in use study. No research designs were specifically excluded but wherever possible, in use rather than *in vitro* studies were retrieved.

Where no abstract was available and the title indicated one or more of the above criteria, the study was retrieved. Due to the limited resources available for this review, foreign language studies were not reviewed.

All full-text studies retrieved were independently assessed by two experienced reviewers who identified those studies meeting the above inclusion criteria for critical appraisal.

Quality Assessment and Data Extraction

Included studies were appraised using an adapted data extraction process based on systems developed by the Scottish Intercollegiate Guideline Network for study quality assessment.[7] Due to the limited resources available for this review, studies were not double-blind appraised. However, all studies were appraised and data extracted by one experienced reviewer and then checked by a second experienced reviewer. Any disagreement between reviewers was resolved through discussion. Evidence tables were constructed from the quality assessments and the studies summarised in the evidence reports. The evidence was classified using methods adopted by the National Institute for Health and Clinical Excellence (NICE) from The Scottish Intercollegiate Guideline Network (SIGN) (Table 1).[8,9] This system differs from that used in the previous epic and NICE infection prevention guidelines.[1,2]

The evidence tables and reports were presented to the advisors for discussion. At this stage, expert advice derived from seminal works and appraised national and international guidelines were considered. Following extensive discussion the guidelines were drafted.

Factors influencing the guideline recommendations included:

- the nature of the evidence;
- the applicability of the evidence to practice;
- costs and knowledge of healthcare systems.

The classification scheme adapted by NICE from SIGN was used to define the strength of recommendation (Table 2).[8,9]

The complete series of evidence tables are posted on the epic website at: [http://www.epic.tvu.ac.uk].

Table 1. Levels of Evidence for Intervention Studies[8]

Level of evidence	Type of evidence
1^{++}	High-quality meta-analyses, systematic reviews of randomised controlled trials (RCT), or RCT with a very low risk of bias
1^{+}	Well-conducted meta-analyses, systematic reviews of RCT, or RCT with a low risk of bias
1^{-}	Meta-analyses, systematic reviews of RCT, or RCT with a high risk of bias*
2^{++}	High-quality systematic reviews of case–control or cohort studies High-quality case–control or cohort studies with a very low risk of confounding, bias or chance and a high probability that the relationship is causal
2^{+}	Well-conducted case–control or cohort studies with a low risk of confounding, bias or chance and a moderate probability that the relationship is causal
2^{-}	Case–control or cohort studies with a high risk of confounding bias, or chance and a significant risk that the relationship is not causal*
3	Non-analytic studies (for example, case reports, case series)
4	Expert opinion, formal consensus

*Studies with a level of evidence '-' should not be used as a basis for making a recommendation

Table 2. Classification of Recommendations[8]

Class	Evidence
A	At least one meta-analysis, systematic review, or randomised controlled trial (RCT) that is rated as 1++, and is directly applicable to the target population, or A systematic review of RCT or a body of evidence that consists principally of studies rated as 1+, is directly applicable to the target population and demonstrates overall consistency of results Evidence drawn from a NICE technology appraisal
B	A body of evidence that includes studies rated as 2++, is directly applicable to the target population and demonstrates overall consistency of results, or Extrapolated evidence from studies rated as 1++ or 1+
C	A body of evidence that includes studies rated as 2+, is directly applicable to the target population and demonstrates overall consistency of results, or Extrapolated evidence from studies rated as 2++
D	Evidence level 3 or 4, or Extrapolated evidence from studies rated as 2+, or Formal consensus
D (GPP)	A good practice point (GPP) is a recommendation for best practice based on the experience of the Guideline Development Group

IP: Recommendation from NICE Interventional Procedures guidance

1.11 Consultation Process

The draft guidelines were circulated to stakeholders for comment (see Appendix A.1). The list of stakeholders included all those consulted for the phase 1 guidelines and others agreed by the DH (England).

Comments were requested on:

- the format;
- the content;
- practice applicability of the guidelines;
- specific sections or recommendations.

All comments received were collated in an MS Word™ table for consideration by the guideline developers and advisors who agreed any changes to the draft recommendations.

2 Standard Principles for preventing healthcare-associated infections in hospital and other acute care settings

2.1 Introduction

This guidance is based on the best critically appraised evidence currently available. The type and class of supporting evidence explicitly linked to each recommendation is described. All recom-

mendations are endorsed equally and none is regarded as optional. These recommendations are not detailed procedural protocols and need to be incorporated into local guidelines.

Standard infection control precautions need to be applied by all healthcare practitioners to the care of all patients, i.e., adults, children and neonates. The recommendations are divided into four distinct interventions:

1. Hospital environmental hygiene;
2. Hand hygiene;
3. The use of personal protective equipment; and
4. The safe use and disposal of sharps.

These guidelines do not address the additional infection control requirements of specialist settings, such as the operating department or for outbreak situations.

2.2 Systematic Review Process

We have previously described the systematic review process in Section 1.10. For detailed descriptions of previous systematic reviews which have contributed to the evidence base underpinning these guidelines, readers should consult the original guidelines,[1] the guidelines for the prevention of health-care associated infections in primary and community care[2] and our interim report in 2004 on changes in the evidence base.[3] Search questions were developed from advice received from our specialist advisors and the results of the searches are found in Section 2.10. The process outlined in Section 2.10 refers only to the most recent systematic review of the literature undertaken in 2005.

Following our reviews, guidelines were drafted which described 38 recommendations within the below intervention categories:

1. Hospital environmental hygiene;
2. Hand hygiene;
3. Personal protective equipment; and
4. Safe use and disposal of sharps.

2.3 Hospital Environmental Hygiene

Good hospital hygiene is an integral and important component of a strategy for preventing healthcare-associated infections in hospitals

This section discusses the evidence upon which recommendations for hospital environmental hygiene are based. Hospital environmental hygiene encompasses a wide range of routine activities including: cleaning and decontamination; laundry and housekeeping; safe collection and disposal of general and clinical waste; and kitchen and food hygiene. Guidelines are provided here for:

- cleaning the general hospital environment;
- cleaning items of shared equipment; and
- education and training of staff.

Maintain a clean hospital environment

Our initial systematic review concluded that there was little research evidence of an acceptable quality upon which to base guidance related to the maintenance of hospital environmental hygiene.[1] However, there was a body of clinical evidence, derived from case reports and outbreak investigations, which suggested an association between poor environmental hygiene and the transmission of microorganisms causing healthcare-associated infections in hospital.[10,11]

Attention had been drawn to perceived falling standards in the cleanliness of hospitals since the introduction of compulsory comprehensive tendering and the internal market. This concern was addressed by the Infection Control Nurses Association and the Association of Domestic Managers, resulting in the adoption and publication by the Department of Health of quality standards for hospital cleanliness[12,13] and more recently the NHS Healthcare Cleaning Manual.[14] In addition, existing regulations,[15-17] specialist advice,[18,19] and clinical governance guidance,[20] all provide a framework within which hospital environmental hygiene can be improved and monitored. The NHS Code of Practice on the Prevention and Control of Healthcare Associated infection came into effect in October 2006.[21] The purpose of this Code of Practice is to help NHS bodies plan and implement strategies for the prevention and control of HCAI. It sets out criteria by which managers of NHS organisations and other healthcare providers should ensure that patients are cared for in a clean environment, where the risk of HCAI is kept as low as possible. Failure to comply with the Code may result in an Improvement Notice being issued or other measures.

There is new evidence highlighting that the hospital environment can become contaminated with microorganisms responsible for HCAI.[22-27] Transmission of microorganisms from the environment to patients may occur through direct contact with contaminated equipment, or indirectly as a result of touching by hands. Meticillin

resistant *Staphylococcus aureus* (MRSA) and other pathogens have been recovered from a range of surfaces commonly touched, such as door handles,[23,28] computer keyboards,[29] soap dispensers,[30,31] and sink taps,[22,26,30] and sites where dust is allowed to accumulate.[24,32] However, whilst the presence of the same strain of microorganism in the environment as those infecting/colonising patients demonstrates that the environment becomes contaminated with microorganisms from patients, it does not provide confirmation that the environment is responsible for contamination of patients. Evidence suggesting that contamination of the environment is responsible for the transmission of HCAI is therefore not conclusive. Nevertheless, the evidence that pathogens responsible for HCAI can be widely found in the hospital environment and hence readily acquired on hands by touching surfaces, does demonstrate the importance of decontaminating hands before every patient contact.

Many microorganisms recovered from the hospital environment do not cause HCAI. Cleaning will not completely eliminate microorganisms from environmental surfaces and reductions in their numbers will be transient.[24] There is some evidence that improved cleaning regimens are associated with the control of outbreaks of HCAI. In one study, the control of an outbreak of an epidemic strain of MRSA was linked with increased cleaning hours and an emphasis on the removal of dust.[32] However, often a range of interventions are introduced in order to control an outbreak and it is difficult to clearly distinguish the effect of a single component such as cleaning.

Some evidence suggests that routine cleaning methods may not be sufficient to eliminate surface contamination with MRSA.[26,32] Disinfectants have been recommended for cleaning of the hospital environment but a systematic review failed to confirm a link between disinfection and the prevention of HCAI, though contamination of detergent and inadequate disinfection strength could have been an important confounder.[33] The use of hypochlorite for cleaning has been associated with a reduction in incidence of *Clostridium difficile* infection in one study but this was in the absence of a detectable change in environmental contamination when either detergent or hypochlorite was used.[25] In laboratory tests a combination of cleaning with detergent followed by hypochlorite was required to consistently eliminate norovirus from surfaces and prevent cross contamination.[23] Dusting and cleaning using detergent was reported to have no effect on the number of MRSA isolated from the hospital environment, but the organism was virtually eliminated by exposure to hydrogen peroxide vapour.[26]

Indicators of cleanliness based on levels of microbial or adenosine triphosphate (ATP) contamination have been proposed but are based on arbitrary standards of acceptable contamination and do not distinguish between normal environmental flora and pathogens responsible for HCAI.[22,34] The relationship between these proposed standards and the risk of acquiring infection through contact with the environment have not been established. Since cleaning will only have a transient effect on the numbers of microorganisms, regular cleaning of hospital surfaces will not guarantee complete elimination. Hand decontamination before every patient contact is therefore required to ensure that pathogens acquired by touch are not transferred to patients.

SP1	The hospital environment must be visibly clean, free from dust and soilage and acceptable to patients, their visitors and staff.	*Class C*
SP2	Increased levels of cleaning should be considered in outbreaks of infection where the pathogen concerned survives in the environment and environmental contamination may be contributing to spread.	*Class D*
SP3	The use of hypochlorite and detergent should be considered in outbreaks of infection where the pathogen concerned survives in the environment and environmental contamination may be contributing to spread.	*Class D*

Shared equipment must be decontaminated after use

There is some evidence demonstrating that shared clinical equipment becomes contaminated with pathogens. One study found that more than 50% of commodes tested were contaminated with *Clostridium difficile*.[25] A systematic review identified a number of studies demonstrating that pathogens can be recovered from a range of non-invasive clinical equipment, including stethoscopes, lifting equipment, and ultrasound probes. None of these studies demonstrated a link between the contamination and infection in a patient.[22]

Shared clinical equipment used to deliver care in the clinical environment comes into contact with intact skin and is therefore unlikely to introduce infection. However it can act as a vehicle by which microorganisms are transferred between patients, which may result in infection.[35] This equipment should therefore be appropriately decontaminated after each use with detergent

and water. In some outbreak situations hypochlorite and detergent should be considered.

SP4 Shared equipment used in the clinical environment must be decontaminated appropriately after each use. *Class D*

Hospital hygiene is everybody's business

Three studies in a systematic review of healthcare workers' knowledge about MRSA and/or frequency of cleaning practices indicated that staff were not utilising appropriate cleaning practices with sufficient frequency to ensure minimisation of MRSA contamination of personal equipment.[22] Staff education was lacking on optimal cleaning practices in the clinical areas. Knowledge deficits may hinder the application of cleaning practices and monitoring and evaluation was indicated. This is further reinforced by an observational study which noted that lapses in adhering to the cleaning protocol were linked with an increase in environmental contamination with isolates of *Acinetobacter baumannii*.[24] A second systematic review of four cohort studies comparing the use of detergents and disinfectants on microbial contaminated hospital environmental surfaces suggested that a lack of effectiveness was, in many instances due inadequate strengths of disinfectants, probably resulting from a lack of knowledge.[33] A national blended e-learning programme on preventing HCAI is available for all healthcare workers.[36]

SP5 All healthcare workers need to be aware of their individual responsibility for maintaining a safe care environment for patients and staff. Every healthcare worker needs to be clear about their specific responsibilities for cleaning equipment and clinical areas (especially those areas in close proximity to patients).They must be educated about the importance of ensuring that the hospital environment is clean and that opportunities for microbial contamination are minimised. *Class D*

2.4 Hand Hygiene

The following section provides the evidence for recommendations concerning hand hygiene practice. The difficulty in designing and conducting robust, ethical, randomised controlled trials in the field of hand hygiene means that recommendations in these areas are based on evidence from non-randomised controlled trials (NRCT), quasi-experimental studies and expert opinion derived from systematically retrieved and appraised professional, national and international guidelines. The areas discussed include:

- assessment of the need to decontaminate hands;
- the efficacy of hand decontamination agents and preparations;
- the rationale for choice of hand decontamination practice;
- technique for hand decontamination;
- care required to protect hands from the adverse effects of hand decontamination practice;
- promoting adherence to hand hygiene guidelines.

Why is hand decontamination crucial to the prevention of healthcare-associated infection?

Cross-transmission, the transfer of microorganisms between humans, which occurs directly via hands, or indirectly via an environmental source, such as a commode or wash-bowl, occurs all the time in hospitals. It is the antecedent factor to cross-infection that can result in severe clinical outcomes. Overviews of epidemiological evidence conclude that hand-mediated cross-transmission is a major contributing factor in the current infection threats to hospital in-patients.[1] Cross-transmission via hands has been identified as contributing to hospitals outbreaks involving both meticillin-sensitive and meticillin-resistant *Staphylococcus aureus* (MRSA/MSSA), multi-resistant Gram-negative microorganisms, such as *Acinetobacter spp* and vancomycin resistant enterococci (VRE).[1]

Hand-mediated cross-transmission from resident flora (microorganisms that are present on the hands most of the time) and transient flora (micro-organisms that are acquired during healthcare activity and without hand hygiene can be deposited directly on to vulnerable patients) presents a direct clinical threat to patients. When these micro-organisms are cross transmitted onto susceptible sites, such as surgical wounds, endo-tracheal tubes during pulmonary ventilation, intravascular cannulation sites, enteral feeding systems or urinary catheter drainage systems, etc., serious life-threatening infections can arise. Even the cross-transmission to non-vulnerable sites can still leave a patient colonised with more pathogenic and resistant hospital microorganisms which may, if opportunity arises, result in a healthcare associated infection at sometime in the future.

Current evidence-based guidelines conclude that in both outbreak and non-outbreak situations contaminated hands are responsible for cross-transmission of microorganisms and that effective and effective hand decontamination can significantly reduce both cross-transmission and cross-infection rates for the majority of HCAI in all healthcare settings.[1]

A recent case control study, conducted during an outbreak of *Klebsiella pneumoniae* in a neonatal intensive care unit, demonstrated an association between being cared for by a nurse with positive hand cultures for the outbreak strain and infants developing infection or colonisation.[37]

Descriptive studies of the dynamics of bacterial hand contamination demonstrate an association between patient care activities that involve direct patient contact and hand contamination.[38,39] In an observational study of hand contamination during routine patient care in a large teaching hospital, high levels of hand contamination were associated with direct patient contact, respiratory care and handling body fluids.[38] A further descriptive study of healthcare workers' hand contamination during routine neonatal care demonstrated that hands become increasingly contaminated and that gloves do not fully protect healthcare workers' hands from becoming contaminated.[39]

The association between hand decontamination and reductions in infection have been confirmed by two additional clinically-based trials[40,41] and two descriptive studies.[42,43] A NRCT introducing the use of alcohol-based hand gel to a long term elderly care facility, demonstrated a reduction of 30% in HCAI over a period of 34 months when compared with the control unit.[40] A further NRCT, demonstrated a 45% reduction in respiratory illness in the post-intervention period following the introduction of a hand washing programme.[41] One descriptive study conducted over a four year period during which alcohol-based handrub was introduced for routine hand hygiene demonstrated a reduction in HCAI from 16.9% to 9.9%.[42] A second study that compared rates of HCAI caused by MRSA, vancomycin-resistant enterococci (VRE) and *Clostridium difficile* (*C. difficile*) in the three years prior to the introduction of alcohol-based handrub showed reductions of 21% in MRSA and 41% decrease in VRE. Rates of *C. difficile* remained unchanged throughout the intervention period.[43]

Current national and international guidance consistently identify that effective hand decontamination results in significant reductions in the carriage of potential pathogens on the hands and logically decreases the incidence of preventable HCAI leading to a reduction in patient morbidity and mortality.[1,44]

When *must* you decontaminate your hands in relation to patient care?

Decontamination refers to a process for the physical removal of blood, body fluids, and the removal or destruction of microorganisms from the hands,[44] Current national and international guidance suggests that in deciding when it is necessary to decontaminate hands prior to patient contact, four key factors need to be considered:[1,44]

- the level of the anticipated contact with patients or objects;
- the extent of the contamination that may occur with that contact;
- the patient care activities being performed;
- the susceptibility of the patient.

Patients are put at risk of developing a HCAI when informal carers or healthcare workers caring for them have contaminated hands. Hands must be decontaminated before every episode of care that involves direct contact with patients' skin, their food, invasive devices or dressings. Current expert opinion recommends that hands need to be decontaminated after completing an episode of patient care and following the removal of gloves to minimise cross contamination of the environment.[1,44]

SP6	Hands must be decontaminated immediately before each and every episode of direct patient contact/care and after any activity or contact that potentially results in hands becoming contaminated.	*Class C*

Is any one hand cleaning preparation better than another?

Current national and international guidelines[1,44] consider the effectiveness of various preparations for the decontamination of hands using liquid soap and water, antiseptic handwash agents, and alcohol-based handrubs. Overall there is no compelling evidence to favour the *general* use of antiseptic handwashing agents over soap, or one antiseptic agent over another.[1,44]

Systematic reviews conducted to underpin guidelines for community and primary care and update the 2001 epic guidance[2,3] identified nineteen studies comparing hand hygiene preparations including alcohol-based handrubs and gels, antiseptic hand washes and liquid soap. Five randomised controlled trials (RCT) were conducted in clinical settings and compared the use of

alcohol-based preparations with other agents.[45-49] Four RCTs demonstrated alcohol-based preparations to be a more effective hand hygiene agent than non-medicated soap and antiseptic handwashing agents,[45-48] while a fifth study found no statistical difference between the use of alcohol-based preparations and antiseptic soap.[49] A clinical crossover trial conducted over 11 months within a neonatal intensive care unit demonstrated no statistical difference between infection rates during the hand washing and handrub phases of the trial.[50] Three clinically based, quasi-experimental studies[51-53] and nine controlled laboratory experiments[54-62] also demonstrated an association between reductions in microbiological flora and the use of alcohol-based preparations. These studies underpin a growing trend to adopt the use of alcohol-based handrubs and gels in clinical practice. However, two of the above laboratory studies highlight the need for continued evaluation of the use of alcohol-based handrubs within the clinical environment to ensure staff adherence to guidelines and effective hand decontamination.[61,62] The first study, using European Union (EU) reference standards raises the possibility that alcohol-based gels may not be as effective as handrubs for short durations of use.[61] The second laboratory study, comparing 14 different hand hygiene agents used for a 'clinically realistic' 10 second hand hygiene episode, suggests that some alcohol-based handrubs may lose efficacy after 10 consecutive uses.[62] One clinically-based quasi-experimental study compared the use of 4% chlorhexidine gluconate and 1% triclosan antiseptic handwash preparations in reducing MRSA hand carriage in a specialist surgical ward.[63] Both preparations effectively reduced total hand bacterial counts but 1% triclosan was more effective at eliminating MRSA.

Choice of decontamination: is it always necessary to wash hands to achieve decontamination?

Choosing the method of decontaminating hands will depend upon the assessment of what is appropriate for the episode of care, the available resources, what is practically possible and, to some degree, personal preferences based on the acceptability of preparations or materials.

In general, effective handwashing with a liquid soap will remove transient microorganisms and render the hands socially clean. This level of decontamination is sufficient for general social contact and most clinical care activities.[1,3,44] The use of a liquid soap preparation that contains an antiseptic will reduce both transient microorganisms and resident flora.[1,44] The effective use of alcohol-based handrubs will also successfully remove transient microorganisms and substantially reduce resident microorganisms. However, alcohol is not effective against some microorganisms such as *C. difficile*, will not remove dirt and organic material and may not be effective in some outbreak situations.[43,63] When deciding which hand decontamination preparation to use, the practitioner must consider the need to remove transient and/or resident hand flora. Preparations containing certain antiseptics that exert a residual effect on skin flora can be useful in situations where prolonged reduction in microbial flora on the skin is required e.g. surgery and some invasive procedures. They are not normally necessary for everyday clinical practice but may be used in outbreak situations.

National and international guidelines suggest that the acceptability of agents and techniques is an essential criterion for the selection of preparations for hand hygiene.[1,44] Acceptability of preparations is dependent upon the ease with which the preparation can be used in terms of time and access together with their dermatological effects. Due to their efficacy and ease of use, alcohol-based handrubs are recommended for *routine* use and offer a practical and acceptable alternative to handwashing when hands are not grossly soiled.[44]

There are no robust economic evaluations of the comparative costs associated with different hand hygiene agents and rates of HCAI. In an unpublished study of the potential cost savings associated with a national hand hygiene campaign the cost of a single HCAI is estimated at over £3,000. The authors hypothesise that even a small reduction in infections through the use of alcohol-based handrubs, would result in a cost saving.[64]

SP7	Hands that are visibly soiled or potentially grossly contaminated with dirt or organic material (i.e. following the removal of gloves) must be washed with liquid soap and water.	*Class A*
SP8	Hands should be decontaminated between caring for different patients or between different care activities for the same patient. For convenience and efficacy an alcohol-based handrub is preferable unless hands are visibly soiled. Local infection control guidelines may advise an alternative product in some outbreak situations.	*Class A*
SP9	Hands should be washed with soap and water after several consecutive applications of alcohol handrub.	*Class D/GPP*

Is hand decontamination technique important?
Investigations into the technique of hand decontamination are limited and observational in design. Two studies were identified that focused on different aspects of hand hygiene technique.[37,65] The first study proposes that there is an association between effective hand decontamination and the wearing of rings by healthcare staff for clinical care.[65] It suggests that the removal of rings should result in decreased frequency of hand carriage of pathogens before and after the performance of hand hygiene. In a case control study, conducted during an outbreak of *Klebsiella pneumoniae* in a neonatal intensive care unit, investigators suggest an association between being cared for by a nurse who wore false nails and had positive hand cultures for the outbreak strain, and infants developing infection or colonisation.[37]

Systematic reviews conducted to underpin guidelines for community and primary care and update the 2001 epic guidance[2,3] identified one RCT comparing different durations of handwashing and handrubbing on bacterial reduction that found no significant differences between the two study groups.[45] In addition a laboratory study conducted following a period of clinical observation of hand hygiene technique identified that practitioners on average applied a product for 11.6 seconds and concluded that some alcohol-based handrubs become less effective following 10 consecutive hand hygiene episodes. The authors suggest that periodic decontamination of hands, using liquid soap and water, is advisable throughout a shift.[62]

Two small-scale laboratory studies investigating methods of hand drying were identified. One found no statistically significant differences between the four methods studied[66] and the other suggests that warm air drying, when the hands are not rubbed simultaneously, may be more effective at reducing the numbers of bacteria on the hands following hand washing than the use of paper towels.[67]

Due to the methodological limitations of the above studies, recommendations continue to be based on existing expert opinion that the duration of hand decontamination, the exposure of all aspects of the hands and wrists to the preparation being used, the use of vigorous rubbing to create friction, thorough rinsing in the case of handwashing, and ensuring that hands are completely dry are key factors in effective hand hygiene and the maintenance of skin integrity.[1,44]

SP10 Before a shift of clinical work begins, all wrist and ideally hand jewellery should be removed. Cuts and abrasions must be covered with waterproof dressings. Fingernails should be kept short, clean and free from nail polish. False nails and nail extensions must not be worn by clinical staff. *Class D*

SP11 An effective handwashing technique involves three stages: preparation, washing and rinsing, and drying. Preparation requires wetting hands under tepid running water before applying the recommended amount of liquid soap or an antimicrobial preparation. The handwash solution must come into contact with all of the surfaces of the hand. The hands must be rubbed together vigorously for a minimum of 10-15 seconds, paying particular attention to the tips of the fingers, the thumbs and the areas between the fingers. Hands should be rinsed thoroughly prior to drying with good quality paper towels. *Class D*

SP12 When decontaminating hands using an alcohol-based handrub, hands should be free of dirt and organic material. The handrub solution must come into contact with all surfaces of the hand. The hands must be rubbed together vigorously, paying particular attention to the tips of the fingers, the thumbs and the areas between the fingers, until the solution has evaporated and the hands are dry. *Class D*

Does hand decontamination damage skin?
Expert opinion concludes that skin damage is generally associated with the detergent base of the preparation and/or poor handwashing technique.[1] However, the frequent use of hand hygiene agents may cause damage to the skin and alter normal hand flora. Excoriated hands are associated with increased colonisation of potentially pathogenic microorganisms and increase the risk of infection.[1,44] In addition, the irritant and drying effects of hand preparations have been identified as one of the reasons why healthcare practitioners fail to adhere to hand hygiene guidelines.[1,44]

Systematic reviews conducted to underpin guidelines for community and primary care and update the 2001 epic guidance[2,3] identified ten studies of which four were RCT conducted in clinical settings.[46,47,50,68] They compared the use of alcohol-based preparations with liquid soap and water using self-assessment of skin condition by nurses. In these studies a greater level of irritation was associated with the use of soap. Three further studies, one clinically-based quasi-experimental study, one descriptive clinical study and one non-clinical experimental study concluded that

alcohol-based handrubs caused less skin irritation.[53,69,70] In addition, one longitudinal study of the introduction and subsequent use of alcohol-based handrub over a seven year period observed no reports of irritant and contact dermatitis associated with the use of alcohol-based handrubs.[42] A laboratory study demonstrated a strong relationship between the frequency of handwashing with a chlorhexidine preparation and dermatitis.[71]

Current national and international guidance suggests that skin care, through the appropriate use of hand lotion or moisturizers added to hand hygiene preparations, is an important factor in maintaining skin integrity, encouraging adherence to hand decontamination practices and assuring the health and safety of healthcare practitioners.[1,44]

SP13	Clinical staff should be aware of the potentially damaging effects of hand decontamination products. They should be encouraged to use an emollient hand cream regularly, for example, after washing hands before a break or going off duty and when off duty, to maintain the integrity of the skin.	*Class D*
SP14	If a particular soap, antiseptic hand wash or alcohol-based product causes skin irritation, review methods as described in Recommendation SP11 and 12 before consulting the occupational health team.	*Class D*

How can adherence to hand hygiene guidance be promoted?

National and international guidelines emphasise the importance of adherence with hand hygiene guidance and provide an overview of the barriers and factors that impact on hand hygiene compliance.[1,44]

In a systematic review of 21 studies of interventions to improve hand hygiene compliance reviewers concluded that:

- Single interventions have a short-term influence on hand hygiene;
- Reminders have a modest but sustained effect;
- Feedback increases rates of hand hygiene but must be regular;
- Near patient alcohol-based preparations improve the frequency with which healthcare workers clean their hands;
- Multi-faceted approaches have a more marked effect on hand hygiene and rates of HCAI.[72]

Recent observational studies of multimodal interventions involving the introduction of alcohol-based handrubs support findings that the use of near patient alcohol-based handrub is consistently associated with greater compliance by healthcare staff.[42,73-77]

However, observational studies identify that staff fail to assess risk appropriately and therefore make inappropriate choices in relation to hand hygiene and glove use.[78-82] One study suggests that the use of motivational strategies, for example feedback may be beneficial.[81] There is some evidence from small-scale observational studies that providing patient information and actively involving patients in hand hygiene improvement programmes has a positive effect on hand hygiene compliance.[73,83,84] In addition, a national blended e-learning programme on preventing HCAI is available for all healthcare workers.[36]

SP15	Near patient alcohol-based hand rub should be made available in all healthcare facilities.	*Class D*
SP16	Hand hygiene resources and individual practice should be audited at regular intervals and the results fed back to healthcare workers.	*Class D*
SP17	Education and training in risk assessment, effective hand hygiene and glove use should form part of all healthcare workers' annual updating.	*Class D*

2.5 Personal Protective Equipment

This section discusses the evidence and associated recommendations for the use of personal protective equipment (PPE) by healthcare workers in general care settings and includes the use of aprons, gowns, gloves, eye protection and face masks. Where appropriate, in addition to the classification of the evidence underpinning the recommendations, there is an indication of a Health and Safety (H&S) requirement.

Infection control dress code - protect your patients and yourself!

Expert opinion suggests that the primary uses of PPE are to protect staff and reduce opportunities for transmission of microorganisms in hospitals.[1,18,85] A trend to eliminate the inappropriate wearing of aprons, gowns and masks in general care settings has evolved over the past twenty years due to the absence of evidence that they are effective in preventing HCAI.[1,85]

The decision to use or wear personal protective equipment must be based upon an assessment of

the level of risk associated with a specific patient care activity or intervention and take account of current health and safety legislation.[18,86-88] However, several studies have identified that both a lack of knowledge of guidelines and non-adherence to guideline recommendations are widespread and on going in-service education and training is required.[81,89-91] A national blended e-learning programme on preventing HCAI is available for all healthcare workers.[36]

SP18	Selection of protective equipment must be based on an assessment of the risk of transmission of microorganisms to the patient or to the carer, and the risk of contamination of the healthcare practitioners' clothing and skin by patients' blood, body fluids, secretions or excretions.	*Class D/H&S*
SP19	Everyone involved in providing care should be educated about standard principles and trained in the use of protective equipment.	*Class D/H&S*
SP20	Adequate supplies of disposable plastic aprons, single use gloves and face protection should be made available wherever care is delivered. Gowns should be made available when advised by the infection control team.	*Class D/H&S*

Gloves: their uses and abuses

Since the mid-1980s the use of gloves as an element of PPE has become an every-day part of clinical practice for healthcare workers.[1] Expert opinion agrees that there are two main indications for the use of gloves in preventing HCAI:[1,85]

1. to protect hands from contamination with organic matter and microorganisms; and
2. to reduce the risks of transmission of microorganisms to both patients and staff.

To glove or not to glove?

Gloves should not be worn unnecessarily as their prolonged and indiscriminate use may cause adverse reactions and skin sensitivity.[1,85] As with all items of PPE the need for gloves and the selection of appropriate materials must be subject to careful assessment of the task to be carried out and its related risks to patients and health care workers.[1,85] Risk assessment should include consideration of:

- who is at risk (whether it is the patient or the healthcare worker) and whether sterile or non-sterile gloves are required;
- the potential for exposure to blood, body fluids, secretions and excretions;
- contact with non-intact skin or mucous membranes during general care and invasive procedures.

Gloves must be discarded after each care activity for which they were worn in order to prevent the transmission of microorganisms to other sites in that individual or to other patients. Washing gloves rather than changing them is not safe.[1]

Gloves leak!

Our previous systematic review provided evidence that gloves used for clinical practice may leak when apparently undamaged.[1,85] In terms of leakage, gloves made from natural rubber latex (NRL) performed better than vinyl gloves in laboratory test conditions. Revised standards (BSI 2000) relating to the manufacture of medical gloves for single use have been devised and implemented.[92-94] These standards require gloves regardless of material to perform to the same standard.

Expert opinion supports the view that the integrity of gloves cannot be taken for granted and additionally, hands may become contaminated during the removal of gloves.[1,85] An additional study provided evidence that vancomycin resistant enterococcus remained on the hands of healthcare workers after the removal of gloves.[95] Therefore, the use of gloves as a method of barrier protection reduces the risk of contamination but does not eliminate it and hands are not necessarily clean because gloves have been worn.

SP21	Gloves must be worn for invasive procedures, contact with sterile sites, and non-intact skin or mucous membranes, and all activities that have been assessed as carrying a risk of exposure to blood, body fluids, secretions and excretions; and when handling sharp or contaminated instruments.	*Class D/H&S*
SP22	Gloves must be worn as single use items. They are put on immediately before an episode of patient contact or treatment and removed as soon as the activity is completed. Gloves are changed between caring for different patients, or between different care/treatment activities for the same patient.	*Class D/H&S*
SP23	Gloves must be disposed of as clinical waste and hands decontaminated, ideally by washing with liquid soap and water after the gloves have been removed.	*Class D/H&S*

Making choices

Expert opinion is quite clear about when gloves *must* be used by healthcare workers in general clinical practice.[1,85] Having decided that gloves should be used for a healthcare activity, the healthcare worker must make a choice between the use of:

- sterile or non-sterile gloves, based on contact with susceptible sites or clinical devices;
- surgical or examination gloves, based on the aspect of care or treatment to be undertaken.

NHS Trusts need to provide gloves that conform to European Standard, and which are acceptable to health care practitioners.[1,85] Gloves are available in a variety of materials, the most common being natural rubber latex (NRL) and synthetic materials. NRL remains the material of choice due to its efficacy in protecting against bloodborne viruses and properties that enable the wearer to maintain dexterity.[1,85] The problem of patient or health care practitioner sensitivity to NRL proteins must be considered when deciding on glove materials.

Synthetic materials are generally more expensive than NRL and due to certain properties may not be suitable for all purposes.[1] Nitrile gloves have the same chemical range as NRL and may also lead to sensitivity problems. Vinyl gloves made to European Standards provide the same level of protection as NRL.[1] Polythene gloves are not suitable for clinical use due to their permeability and tendency to damage easily.[1] A study comparing the performance of nitrile, latex, copolymer and vinyl gloves under stressed and unstressed conditions found that nitrile gloves had the lowest failure rate, adding further evidence that nitrile gloves are a suitable alternative to latex, providing there are no sensitivity issues. Importantly, the study noted variation in performance of the same type of glove produced by different manufacturers and propose a test and rating system to assist healthcare workers.[96]

SP24	Gloves that are acceptable to healthcare personnel and CE marked must be available in all clinical areas.	*Class D/H&S*
SP25	Sensitivity to natural rubber latex in patients, carers and healthcare personnel must be documented and alternatives to natural rubber latex must be available.	*Class D/H&S*
SP26	Neither powdered nor polythene gloves should be used in health care activities.	*Class C/H&S*

Aprons or gowns?

We identified four small scale observational studies that investigated the potential for uniforms to become contaminated during clinical care. However none of these studies established an association between contaminated uniforms and HCAI.[97-99] A further study demonstrated high levels of contamination of gowns, gloves and stethoscopes with vancomycin-resistant enterococci (VRE) following examination of patients known to be infected.[100]

A systematic review of eight studies reporting outcomes of 3,811 babies to assess the effects of wearing and gowning by attendants and visitors in newborn nurseries found no evidence to suggest that over gowns are effective in reducing mortality, clinical infection or bacterial colonisation in infants admitted to newborn nurseries.[101] One quasi-experimental study investigated the use of gowns and gloves as opposed to gloves only in preventing the acquisition of VRE in a medical intensive care unit setting.[102] A further prospective observational study investigated the use of a similar intervention in a medical intensive care unit.[103] These studies suggest that the use of gloves and gowns may minimise the transmission of VRE when colonisation pressure is high.

National and international guidelines recommend that protective clothing should be worn by all healthcare workers when close contact with the patient, materials or equipment may lead to contamination of uniforms or other clothing with microorganisms or, when there is a risk of contamination with blood, body fluids, secretions, or excretions (with the exception of perspiration).[1,85,104] Disposable plastic aprons are recommended for general clinical use.[1,85,104] However, unused aprons need to be stored in an appropriate area away from potential contamination.[97] Full body gowns need only be used where there is the possibility of extensive splashing of blood, body fluids, secretions or excretions and should be fluid repellent.[1,85,104]

SP27	Disposable plastic aprons must be worn when close contact with the patient, materials or equipment are anticipated and when there is a risk that clothing may become contaminated with pathogenic microorganisms or blood, body fluids, secretions or excretions, with the exception of perspiration.	*Class D/H&S*
SP28	Plastic aprons/gowns should be worn as single-use items, for one procedure or episode of patient care, and then discarded and disposed of as clinical	*Class D/H&S*

waste. Non-disposable protective clothing should be sent for laundering.

SP29 Full-body fluid-repellent gowns must be worn where there is a risk of extensive splashing of blood, body fluids, secretions or excretions, with the exception of perspiration, onto the skin or clothing of healthcare personnel (for example when assisting with childbirth). *Class D/H&S*

When is a facemask, respiratory protection and eye protection necessary?

Healthcare workers (and sometimes patients) may use standard surgical facemasks to prevent respiratory droplets from the mouth and nose being expelled into the environment. Facemasks are also used, often in conjunction with eye protection, to protect the mucous membranes of the wearer from exposure to blood and/or body fluids when splashing may occur. Our previous systematic review failed to reveal any robust experimental studies that demonstrated that healthcare workers wearing surgical facemasks protected patients from HCAI during routine ward procedures, such as wound dressing or invasive medical procedures.[1]

Facemasks are also used to protect the wearer from inhaling minute airborne respiratory particles. As surgical facemasks are not effective in filtering out such small respiratory particles, specialised respiratory protective equipment is recommended for the care of patients with certain respiratory diseases, e.g. active multiple drug-resistant pulmonary tuberculosis,[105] Severe Acute Respiratory Syndrome (SARS), pandemic influenza. The filtration efficiency of these masks (sometimes called 'respirators') will protect the wearer from inhaling small respiratory particles but to be effective, they must fit closely to the face to minimise leakage around the mask.[1,106,107] Although the advice to use particulate filter masks is based on expert opinion, there is evidence from one study that staff exposed to patients with SARS acquired the infection when they did not use particulate filter masks.[108] Another study demonstrated a lack of knowledge about guidance on using particulate respirator masks among staff caring for patients with SARS and suggests that focused training on the use of personal protective equipment and the transmission risk of SARS is required.[109]

Our previous systematic review indicated that different protective eyewear offered protection against physical splashing of infected substances into the eyes (although not on all occasions) but that compliance was poor.[1] Expert opinion recommends that face and eye protection reduce the risk of occupational exposure of healthcare workers to splashes of blood, body fluids, secretion or excretions.[1,85,104]

SP30 Face masks and eye protection must be worn where there is a risk of blood, body fluids, secretions or excretions splashing into the face and eyes. *Class D/H&S*

SP31 Respiratory protective equipment, i.e., a particulate filter mask, must be correctly fitted and used when recommended for the care of patients with respiratory infections transmitted by airborne particles. *Class D/H&S*

2.6 The Safe Use and Disposal of Sharps

This section discusses the evidence and associated recommendations for the safe use and disposal of sharps in general care settings and include minimising the risks associated with sharps use and disposal, and the use of needle protection devices. Where appropriate, in addition to the classification of evidence underpinning the recommendations, there is an indication of a Health and Safety (H&S) legislation requirement.

Sharps injuries – what's the problem?

The safe handling and disposal of needles and other sharp instruments forms part of an overall strategy of clinical waste disposal to protect staff, patients and visitors from exposure to bloodborne pathogens.[110] In 2003 the National Audit Office found that needlestick injuries ranked alongside moving and handling, falls, trips and exposure to hazardous substances as the main types of accidents experienced by NHS staff.[111] In 2001 the Royal College of Nursing (RCN) launched its *Be Sharp Be Safe* campaign aimed at reducing sharps injuries. A component of the campaign is surveillance using the software EPINet™. Fifteen sites contributed to the RCN 2002 survey and reported a total of 1,445 injuries.[112] Although many injuries (52.6%) were superficial, 44.6% (n = 626) ranked moderate, including some bleeding, and 2.8% (n = 39) were severe. Nurses were the group with the highest proportion of sharps injuries, accounting for 41.2% of all reported injuries.

A new report in 2006 from the Health Protection Agency confirms that healthcare workers are still being exposed to bloodborne virus infections, even though such exposures are largely preventable. The number of reported occupational exposures

increased by 49% in three years from 206 in 2002 to 306 in 2005, with almost half of all exposures occurring in nurses. [113] The report draws attention to the need for NHS Trusts to provide local protocols and information on the risk of bloodborne viruses in the work place and to ensure that healthcare workers are adequately trained on how to prevent injuries.

The average risk of transmission of bloodborne viruses following a single percutaneous exposure from an infected person, in the absence of appropriate post exposure prophylaxis has been estimated to be:[113,114]

- hepatitis B virus (HBV) 33.3% (1 in 3)
- hepatitis C virus (HCV) 1.8-1.9% (1 in 50)
- human immunodeficiency virus (HIV) 0.3% (1 in 300)

National and international guidelines, are consistent in their recommendations for the safe use and disposal of sharp instruments and needles.[18,115-117] As with many infection prevention and control policies, the assessment and management of the risks associated with the use of sharps is paramount and safe systems of work and engineering controls must be in place to minimise any identified risks, e.g., positioning the sharps bin as close as possible to the site of the intended clinical procedure.[88] Any healthcare worker experiencing an occupational exposure to blood or body fluids needs to be assessed for the potential risk of infection by a specialist practitioner, e.g., physician, occupational health nurse and offered testing, immunisation and post-exposure prophylaxis if appropriate.[118]

Avoiding sharps injuries is everybody's responsibility

All healthcare workers must be aware of their responsibility in avoiding needlestick injuries. This should be a part of induction programmes for new staff and on-going in-service education. A national blended e-learning programme on preventing HCAI is available for all healthcare workers.[36] In addition, the Centers for Disease Control and Prevention has developed an online programme focused on implementing and evaluation a sharps injury prevention programme.[114]

SP32	Sharps must not be passed directly from hand to hand and handling should be kept to a minimum.	*Class D/H&S*
SP33	Needles must not be recapped, bent broken or disassembled after use.	*Class D/H&S*
SP34	Used sharps must be discarded into a sharps container (conforming to UN3291 and BS 7320 standards) at the point of use by the user. These must not be filled above the mark that indicates the bin is full.	*Class D/H&S*
SP35	All sharps bins should be positioned out of the reach of children at a height that enables safe disposal by all members of staff. They should be secured to avoid spillage.	*Class D/H&S*
SP36	All staff both clinical and non clinical must be educated about the safe use and disposal of sharps.	*Class D/H&S /GPP*

Do needle protection devices reduce *avoidable* injuries?

Many agencies, including the Department of Health and National Health Service Employees encourage health care providers and their employees to pursue safer methods of working through considering the benefits of new safety devices.[119,120] The incidence of sharps injuries has led to the development of needlestick-prevention devices in many different product groups.[121] They are designed to minimise the risk of operator injury during needle use as well as so-called "downstream" injuries that occur after disposal, often involving the housekeeping or portering staff responsible for the collection of sharps disposal units.

Our previous systematic reviews[1,2] failed to identify any convincing evidence that needlestick-prevention devices were responsible for any significant impact on injury rates. This was primarily due to the lack of well-designed, controlled intervention studies. More recent studies have shown significant reductions in injuries associated with the use of safety devices in cannulation,[122,123] phlebotomy[124-126] and injections.[127]

It would seem to be logical that where needle-free or other protective devices are used, there should be a resulting reduction in sharps injuries. A review of needlestick injuries in Scotland suggested that 56% of injuries would 'probably' or 'definitely' have been prevented if a safety device had been used.[128] However, some studies identify a range of barriers to the expected reduction in injuries, including staff resistance to using new devices, complexity of device operation or improper use, and poor training.[1] A comprehensive report and product review conducted in the United States of America (USA) provides background information and guidance on the need for and use of needlestick-prevention devices but also gives advice on establishing and evaluating a

sharps injury prevention program.[121] The report identifies that all devices have limitations in relation to cost, applicability and/or effectiveness. Some of the devices available are more expensive than standard devices, may not be compatible with existing equipment, and may be associated with an increase in bloodstream infection rates.[129]

In the USA, the Occupational Safety Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) suggest that a thorough evaluation of any device is essential before purchasing decisions are made.[117,130] Similarly in the United Kingdom, the National Health Service Purchasing and Supply Agency identifies that meaningful evaluations are paramount in assessing user acceptability and clinical applicability of any needle safety devices.[131] The evaluation should ensure that the safety feature works effectively and reliably, that the device is acceptable to health care practitioners and that it does not adversely affect patient care.

SP37	Consider the use of needlestick-prevention devices where there are clear indications that they will provide safe systems of working for healthcare practitioners.	*Class B/H&S*
SP38	Conduct a rigorous evaluation of needlestick-prevention devices to determine their effectiveness, acceptability to practitioners, impact on patient care and cost benefit prior to widespread introduction.	*Class D*

2.7 Areas for Further Research

Adherence / behaviour change
Action research studies to explore the use of behavioural and quality management sciences to improve adherence of health care professionals to infection prevention guidelines, specifically in relation to:

- Hand hygiene;
- The effect of different products, e.g., gels, foams and lotions on improving adherence to recommended hand hygiene regimens;
- Standard principles for the prevention of the transmission of bloodborne pathogens;
- Cleanliness of the hospital environment;
- Trials of the effectiveness of different educational methods to increase adherence to guidelines;
- Development and evaluation of appropriate strategies for auditing adherence to infection prevention guidelines.

Staffing
- Investigate the relationship between health care workers' staffing levels, workload and skill mix and risk for nosocomial infections.

Surveillance
- Develop appropriate and realistic methods and tools to facilitate local surveillance of hospital-acquired infections.
- The role of screening for HCAI microorganisms as a means of controlling HCAI.
- Further research on community MRSA colonisation and its impact on acute care.

Needle Safety Devices
- Studies to establish the cost-effectiveness, acceptability and efficacy of needle safety devices.

Organisational change
- Studies to link improvement in infection control practice, patient outcome and cultural change;
- Studies to assess performance monitoring of mandatory infection control standards linked to government improvement practice
- The role of inter ward and inter hospital transfers on spread of HCAI

2.8 Key Audit Criteria

Aim	Criteria
To ensure all healthcare workers have access to appropriate hand decontamination equipment and protective clothing whenever they deliver care	All healthcare areas should have an appropriate supply of hand decontamination equipment, gloves, aprons and protective clothing in their care setting. Standard 100% Data collection: self audit*
Ensure that all healthcare workers are trained and competent in hand decontamination and risk assessment.	All healthcare workers involved in care are trained and updated in hand decontamination. Standard 100% Data collection: review of staff education records
To ensure that all healthcare workers respond appropriately to any sharps injury	All healthcare workers should be aware of their local sharps injury policy and how to access appropriate help should they sustain a sharps injury. Standard 100% Data collection: direct questioning

*The Department of Health. *Self assessment tools: The delivery programme to reduce Healthcare associated infections including MRSA: Essential steps to safe, clean care*. 2006. Available from http://www.dh.gov.uk Saving Lives Delivery Programme
Other useful audit criteria is available at http://www.nhsggc.org.uk/icmanual

2.9 The use of hazard analysis critical control points (HACCP) in hospital environmental hygiene

Hazard analysis critical control points (HACCP) has been used for many years in the food industry to identify and control hazards in food production. It is a systems approach involving a seven stage process starting with the development of a flow-chart describing the process, identifying areas (critical control points) where a hazard may occur and then establishing monitoring and control procedures.

Clinical governance introduced audit and quality improvement into the NHS. Winning Ways recommended the use of HACCP in preventing HCAIs and the introduction of HACCP is particularly suitable for hospital environmental hygiene.[132] Within the catering industry there are several good examples of cleaning and disinfection HACCP flowcharts, which could be adapted for acute care settings. However all processes need to be defined locally in order to address the particular hazards within the organisation and the people responsible for monitoring them.[133] In adapting these guidelines into local protocols, one should also consider the use of HACCP. Courses on HACCP and hospital hygiene are currently available at the Royal Institute of Public Health [http://www.riph.co.uk].

2.10 Standard Principles Systematic Review Process

Hospital Hygiene - Systematic Review Process

Systematic Review Questions

1. What is the evidence that inadequate hospital hygiene contributes to rates of hospital acquired infection?
2. What are the most effective methods and agents for: -terminal disinfection, decontamination of spills of blood or other, potentially infectious body substances?
3. Is there any evidence that routine use of disinfectants as opposed to detergents for environmental cleaning is more efficacious at preventing healthcare associated infection?
4. How effective is hydrogen peroxide vapour for environmental or terminal cleaning?
5. Is there any cost effectiveness evidence relating to the above?
6. What are the training and education implications for staff and patients?

Databases and Search Terms Used

DATABASES
MEDLINE, CUMULATED INDEX OF NURSING AND ALLIED HEALTH LITERATURE (CINAHL), EMBASE, NELH GUIDELINE FINDER, NATIONAL INSTIRURE FOR HEALTH AND CLINICAL EXCELLENCE, THE COCHRANE LIBRARY, US GUIDLEINES CLEARNING HOUSE
MeSH TERMS
infection control; cross infection; universal precautions, equipment contamination; disease transmission; disinfection; disinfectants; soaps; anti-infective agents; surface-active agents; hospital housekeeping
THESAURUS AND FREE TEXT TERMS
Risk assessment; occupational accident; hospital hygiene; hospital housekeeper

Search Results

Total number of articles located = 7830

Sift 1 Criteria

Abstract indicates that the article: relates to infections associated with hospital hygiene, is written in English, is primary research or a systematic review or a meta-analysis, and appears to inform one or more of the review questions.

Articles Retrieved

Total number of articles retrieved from sift 1 = 34

Sift 2 Criteria

Full Text confirms that the article relates to infections associated with hospital hygiene is written in English, is primary research or a systematic review or a meta-analysis, and informs one or more of the review questions.

Articles Selected for Appraisal

Total number of articles selected for appraisal during sift 2 = 5

Critical Appraisal

All articles which described primary research, a systematic review or, a meta-analysis and met the sift 2 criteria were independently critically appraised by two appraisers. Consensus and grading was achieved through discussion.

Accepted and Rejected Evidence

Total number of articles accepted after critical appraisal = 5
Total number of articles rejected after critical appraisal = 0

Evidence Tables

Evidence tables for accepted and rejected studies were generated and used to create **evidence summary reports**. The summary reports were, in turn, used as the basis for guideline writing.

Hand hygiene - Systematic Review Process

Systematic Review Questions

1. What is the evidence that contaminated hands are a cause of healthcare associated infection?
2. Which hand disinfection agents are the most effective at removing / reducing organisms responsible for healthcare associated infection?
3. When must hands be disinfected in relation to patient care activities?
4. What is the most effective hand washing technique for removing / reducing organisms responsible for healthcare associated infection?
5. Which hand disinfection agents are least toxic to users?
6. Which hand disinfection agents are associated with greatest compliance among healthcare workers?
7. Is there any cost effectiveness evidence relating to the above?
8. What are the training and education implications for staff and patients?

Databases and Search Terms Used

DATABASES
MEDLINE, CUMULATED INDEX OF NURSING AND ALLIED HEALTH LITERATURE (CINAHL), EMBASE, NELH GUIDELINE FINDER, NATIONAL INSTIRURE FOR HEALTH AND CLINICAL EXCELLENCE, THE COCHRANE LIBRARY, US GUIDLEINES CLEARNING HOUSE

MeSH TERMS
infection control; cross infection; universal precautions, equipment contamination; disease transmission; disinfectants; chlorhexidine; soaps; anti-infective agents; surface active agents

THESAURUS AND FREE TEXT TERMS
Handwashing; skin; epidermis; nails; antisepsis; decontamination

Search Results

Total number of articles located = 32,088

Sift 1 Criteria

Abstract indicates that the article: relates to infections associated with hand hygiene, is written in English, is primary research or a systematic review or a meta-analysis, and appears to inform one or more of the review questions.

Articles Retrieved

Total number of articles retrieved from sift 1 = 194

Sift 2 Criteria

Full Text confirms that the article relates to infections associated with hand hygiene is written in English, is primary research or a systematic review or a meta-analysis, and informs one or more of the review questions.

Articles Selected for Appraisal

Total number of articles selected for appraisal during sift 2 = 31

Critical Appraisal

All articles which described primary research, a systematic review or, a meta-analysis and met the sift 2 criteria were independently critically appraised by two appraisers. Consensus and grading was achieved through discussion.

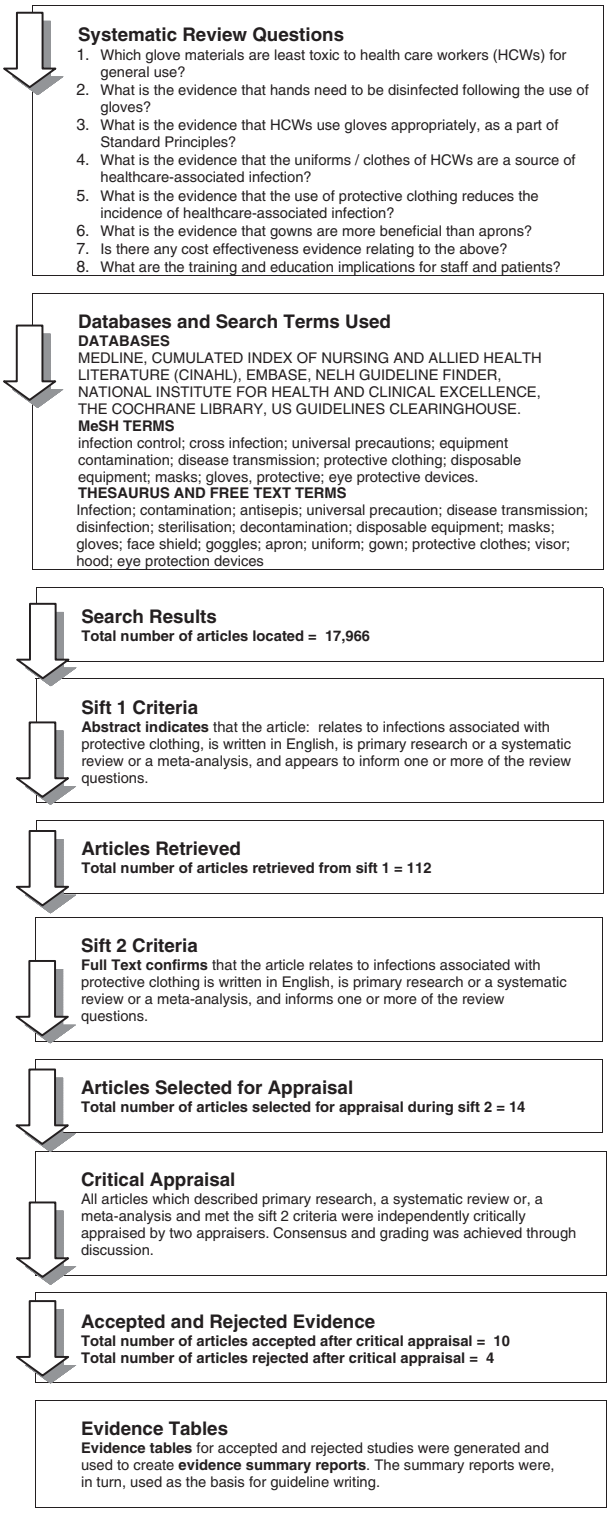
Accepted and Rejected Evidence

Total number of articles accepted after critical appraisal = 25
Total number of articles rejected after critical appraisal = 6

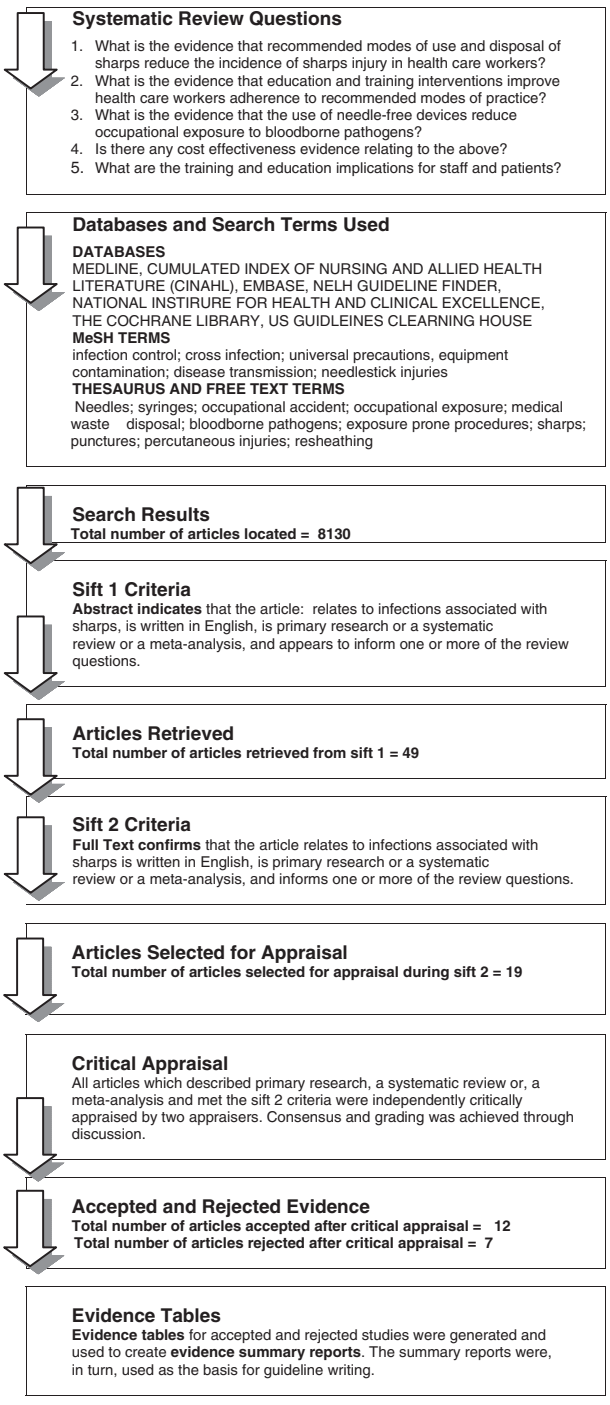
Evidence Tables

Evidence tables for accepted and rejected studies were generated and used to create **evidence summary reports**. The summary reports were, in turn, used as the basis for guideline writing.

Personal Protective Equipment - Systematic Review Process



Sharps - Systematic Review Process



3 Guidelines for preventing infections associated with the use of short-term indwelling urethral catheters

3.1 Introduction

This guidance is based on the best critically appraised evidence currently available. The type and class of supporting evidence explicitly linked to each recommendation is described. All recommendations are endorsed equally and none is regarded as optional. These recommendations are not detailed procedural protocols and need to be incorporated into local guidelines.

These guidelines apply to adults and children aged one year and older and should be read in conjunction with the guidance on Standard Principles. The recommendations are divided into five distinct interventions:

1. Assessing the need for catheterisation;
2. Selection of catheter type and system;
3. Catheter insertion;
4. Catheter maintenance; and
5. Education of patients, relatives and healthcare workers.

Background and context of the Guidelines
Catheter associated urinary tract infection (CAUTI) is the most common nosocomial infection in hospitals. Most bacteria causing infection associated with catheterisation gain access to the urinary tract either extraluminally or intraluminally. Extraluminal contamination may occur as the catheter is inserted, by contamination of the catheter from the health care worker's hands or from the patient's own colonic or perineal flora. Extraluminal contamination is also thought to occur by microorganisms ascending from the perineum. Intraluminal contamination occurs by reflux of bacteria from a contaminated urine drainage bag.

Bacteria quickly develop into colonies known as biofilms which adhere to the catheter surface and drainage bag. A biofilm forms when bacteria attach to a surface and subsequently encase themselves in an exopolymeric material. Such bacteria are morphologically and physiologically different from free-living planktonic bacteria. Bacteria in biofilms have considerable survival advantages over free-living microorganisms, being extremely resistant to antibiotic therapy.

These biofilms cause further problems if the bacteria produce the enzyme urease, such as *Proteus mirabilis*. The urine then becomes alkaline, causing the crystallisation of calcium and magnesium phosphate within the urine, which then is incorporated into the biofilm resulting in encrustation of the catheter over a period of time. Encrustation is generally associated with long-term catheterisation, since it has a direct relationship with the length of catheterisation.

3.2 Systematic Review Process

We have previously described the systematic review process in Section 1.10. For detailed descriptions of previous systematic reviews which have contributed to the evidence base underpinning these guidelines readers should consult the original guidelines,[1] the guidelines for the prevention of healthcare associated infections in primary and community care[2] and our interim report.[3] Search questions were developed from advice received from our specialist advisors and the results of the searches are found in Section 3.10. The process outlined in Section 3.10 refers only to the most recent systematic review of the literature undertaken in 2005.

3.3 Assessing the Need for Catheterisation

Catheterising patients places them in significant danger of acquiring a urinary tract infection. The longer a catheter is in place, the greater the danger
There is consistent evidence that a significant number of healthcare-associated infections in hospital are related to urinary catheterisation.[115,134-136] The risk of infection is associated with the method and duration of catheterisation, the quality of catheter care and host susceptibility. Urinary catheterisation is a frequent intervention during clinical care in hospital affecting a significant number of patients at any one time. The highest incidence of infection is associated with indwelling urethral catheterisation.[137] The per day risk of the development of bacteriuria appears comparable throughout catheterisation (3-6 percent) but the cumulative risk increases with duration of catheterisation.[137-139] Consequently, around 50 percent of hospitalised patients catheterised longer than 7-10 days contract bacteriuria.[137] Although frequently asymptomatic, 20-30 percent of patients with catheter-associated bacteriuria will develop

symptoms of CAUTI.[137] Many of these infections are serious and lead to significant morbidity and mortality. Of patients with a CAUTI, 1-4 percent develops bacteraemia and, of these, 13-30 die.[137,140] Duration of catheterisation is strongly associated with risk of infection, i.e., the longer the catheter is in place, the higher the incidence of urinary tract infection.[137,140]

Advice from best practice emphasises the importance of documenting all procedures involving the catheter or drainage system in the patient's records and providing patients with adequate information in relation to the need for catheterisation and details of the insertion, maintenance and removal of their catheter.[115,141] There is some evidence to suggest that computer management systems improve documentation and in so doing reduce the length of time catheters are in situ.[142]

UC1	Only use indwelling urethral catheters after considering alternative methods of management.	*Class D/GPP*
UC2	Document the need for catheterisation, catheter insertion and care.	*Class D/GPP*
UC3	Review regularly the patient's clinical need for continuing urinary catheterisation and remove the catheter as soon as possible.	*Class D/GPP*

3.4 Selection of Catheter Type

Is one catheter better than another?

Current evidence-based guidelines[1] identified three experimental studies that compared the use of latex with silicone catheters.[143-145] No significant difference in the incidence of bacteriuria was found. Four studies compared the use of silver coated (silver alloy or silver oxide) catheters with silicone, hydrogel or Teflon latex.[146-149] A systematic review and meta-analysis of these and other studies found that silver alloy (but not silver oxide) catheters were associated with a lower incidence of bacteriuria.[140,150]

New evidence related to the efficacy of using urinary catheters coated or impregnated with antiseptic or antimicrobial agents has emerged since our original review in 2000. Two subsequent reviews,[2,3] together with the current update review undertaken by us, have identified four systematic reviews and one meta-analysis that have examined this issue.[150-154] In general, all of these five studies suggest antiseptic impregnated or antimicrobial-coated urinary catheters can significantly prevent or delay the onset of CAUTI when compared to standard untreated urinary catheters. The consensus in these five reviews of evidence however, is that the individual studies reviewed are generally of poor quality; for instance in one case only 8 studies out of 117 met the inclusion criteria and in another, of the six reports describing 7 trials included, only one scored 5 in the quality assessment the other five scored only 1.[150,154]

Studies investigating a wide range of coated or impregnated catheters are explored in the new evidence including: catheters coated or impregnated with: silver alloy[150,151,154-161]; silver oxide[150]; gendine[162]; gentamicin[163] and silver-hydrogel[164-166]; minocycline[167]; rifampicin[167]; chlorhexidine–silver sulfadiazine[166]; chlorhexidine-sulfadiazine-triclosan[166]; nitrofurazone[166]; and nitrofuroxone.[168]

New evidence suggests that catheters coated with silver alloy are clinically effective in reducing the incidence of CAUTI, but many studies are of poor methodological quality. Consequently there remains inconclusive evidence to recommend their use in preference to other types of catheter at this time. Despite their unit cost, there is a suggestion that these devices might be a cost-effective option if overall numbers of infections are significantly reduced through their use. The few studies that have explored the cost benefit/effectiveness of using these devices have, however, also been inconclusive.[157,159,161,165]

Evidence from best practice indicates that the incidence of CAUTI in patients catheterised for a short time (up to one week) is not influenced by any particular type of catheter material.[136,169] However, many practitioners have strong preferences for one type of catheter over another. This preference is often based on clinical experience, patient assessment, and which materials induce the least allergic response. Smaller gauge catheters with a 10 ml balloon minimise urethral trauma, mucosal irritation and residual urine in the bladder, all factors that predispose to CAUTI.[135,170] However, in adults that have recently undergone urological surgery, larger gauge catheters may be indicated to allow for the passage of blood clots.

UC4	Choice of catheter material will depend on clinical experience, patient assessment and anticipated duration of catheterisation.	*Class D*
UC5	Select the smallest gauge catheter that will allow free urinary outflow. A catheter with a 10 ml balloon should be used in adults. Urological patients may require larger gauge sizes and balloons.	*Class D*

3.5 Catheter Insertion

Catheterisation is a skilled aseptic procedure
Despite evidence from one systematic review[153] which suggests that the use of aseptic technique has not demonstrated a reduction in the rate of CAUTI, principles of good practice, clinical guidance[115,134] and expert opinion[135-137,171-174], together with findings from another systematic review[140] agree that urinary catheters must be inserted using sterile equipment and an aseptic technique.

Expert opinion indicates that there is no advantage in using antiseptic preparations for cleansing the urethral meatus prior to catheter insertion.[153,173] Urethral trauma and discomfort will be minimised by using an appropriate sterile, single-use lubricant or anaesthetic gel. Ensuring healthcare practitioners are trained and competent in the insertion of urinary catheters will minimise trauma, discomfort and the potential for CAUTI.[115,135,173,174]

UC6	Catheterisation is an aseptic procedure. Ensure that health care workers are trained and competent to carry out urethral catheterisation.	*Class D*
UC7	Clean the urethral meatus with sterile normal saline prior to the insertion of the catheter.	*Class D*
UC8	Use an appropriate lubricant from a sterile single use container to minimise urethral trauma and infection.	*Class D*

3.6 Catheter Maintenance

Leave the closed system alone!
Maintaining a sterile, continuously closed urinary drainage system is central to the prevention of CAUTI.[115,134,135,173,175,176] The risk of infection reduces from 97 percent with an open system to 8-15 percent when a sterile closed system is employed.[136,174,177] Breaches in the closed system such as unnecessary emptying of the urinary drainage bag or taking a urine sample, will increase the risk of catheter-related infection and should be avoided.[115,136,178] Hands must be decontaminated and clean, non-sterile gloves worn before manipulation. A systematic review suggests that sealed (e.g., taped, pre-sealed) drainage systems contribute to preventing bacteriuria.[153]

There is limited evidence as to how often catheter bags should be changed. One study showed higher rates of symptomatic and asymptomatic CAUTI were associated with a three day urinary drainage bag change regimen when compared to no routine change regimen.[179] Best practice suggests changing only when necessary, i.e., according to either the manufacturers' recommendations or the patient's clinical need.[115,134] Reflux of urine is associated with infection and consequently, drainage bags should be positioned in a way that prevents back-flow of urine.[115,135] It is also recommended that urinary drainage bags should be hung on an appropriate stand that prevents contact with the floor.[136]

A number of studies have investigated the addition of disinfectants and antimicrobials to drainage bags as a way of preventing CAUTI.[140] Three acceptable studies from our original systematic review demonstrated no reduction in the incidence of bacteriuria following the addition of hydrogen peroxide or chlorhexidine to urinary drainage bags.[1,180-182] A systematic review supports these findings in that it suggests that adding bacterial solutions to drainage bags has no effect on catheter associated infection.[153]

UC9	Connect indwelling urethral catheters to a sterile closed urinary drainage system.	*Class A*
UC10	Ensure that the connection between the catheter and the urinary drainage system is not broken except for good clinical reasons, e.g., changing the bag in line with manufacturer's recommendation.	*Class A*
UC11	Decontaminate hands and wear a new pair of clean, non-sterile gloves before manipulating a patient's catheter and decontaminate hands after removing gloves.	*Class D*
UC12	Obtain urine samples from a sampling port using an aseptic technique.	*Class D/GPP*
UC13	Position urinary drainage bags below the level of the bladder on a stand that prevents contact with the floor.	*Class D/GPP*
UC14	Empty the urinary drainage bag frequently enough to maintain urine flow and prevent reflux. Use a separate and clean container for each patient and avoid contact between the urinary drainage tap and container.	*Class D/GPP*
UC15	Do not add antiseptic or antimicrobial solutions into urinary drainage bags.	*Class A*
UC16	Do not change catheters unnecessarily or as part of routine practice except where necessary to adhere to the manufacturer's guidance.	*Class D/GPP*

Appropriate maintenance minimises infections

Meatal cleansing with antiseptic solutions is unnecessary

Our original systematic review considered six acceptable studies that compared meatal cleansing with a variety of antiseptic/antimicrobial agents or soap and water.[1] No reduction was demonstrated in bacteriuria when using any of these preparations for meatal care compared with routine bathing or showering.[183-188] Our subsequent reviews[2,3] revealed two studies[153,189] that support these findings in that the outcomes indicate that the use of antiseptics provides no benefit in respect of meatal/peri-urethral hygiene.

Expert opinion[134-136] and another systematic review[140] support the view that vigorous meatal cleansing is not necessary and may increase the risk of infection and that daily routine bathing or showering is all that is needed to maintain meatal hygiene.

UC17	Routine daily personal hygiene is all that is needed to maintain meatal hygiene.	*Class A*

Irrigation, instillation and washout do not prevent infection

None of our systematic review evidence demonstrates any beneficial effect of bladder irrigation, instillation or washout with a variety of antiseptic or antimicrobial agents in preventing CAUTI.[1,140,190-199] Three studies, however, suggest that an acid washout solution (Suby G) is effective in reducing catheter encrustation.[196,198,200]

Evidence from best practice supports the findings in respect of bladder irrigation, instillation and washout and indicates that the introduction of such agents may have local toxic effects and contribute to the development of resistant microorganisms. However, continuous or intermittent bladder irrigation may be indicated during urological surgery or to manage catheter obstruction.[115,134-136,140]

UC18	Bladder irrigation, instillation or washouts should not be used to prevent catheter-associated infection.	*Class A*

3.7 Education of Patients, Relatives and Healthcare Workers

Given the frequency of urinary catheterisation in hospital patients and the associated risk of urinary tract infection, it is important that patients, their relatives and healthcare workers responsible for catheter insertion and management are educated about infection prevention. All those involved must be aware of the signs and symptoms of urinary tract infection and how to access expert help when difficulties arise. Healthcare professionals must be confident and proficient in procedures associated with preventing CAUTI.

UC19	Healthcare workers must be trained in catheter insertion and maintenance.	*Class D/GPP*
UC20	Patients and relatives should be educated about their role in preventing urinary tract infection.	*Class D/GPP*

3.8 Areas for Further Research

In developing the recommendations we identified several areas that were inadequately addressed in the literature. We recommend further research in the following areas.

Intervention 1: Assessing the need for catheterisation

Epidemiological studies of the prevalence and incidence of bacteriuria/urinary tract infection during short-term catheterisation in different populations and different care settings. These should at least encompass the predominant populations, i.e. older people and those undergoing surgery. There needs to be clear definition of the 'cases' and the populations from which they are drawn.

Intervention 2: Selection of catheter type

Randomised controlled trials of the efficacy of antiseptic/antimicrobial coated/impregnated urethral catheters for short-term use. These need to be high quality studies, using the hospital's actual catheter-associated UTI prevalence rather than national data, and appropriate follow-up.

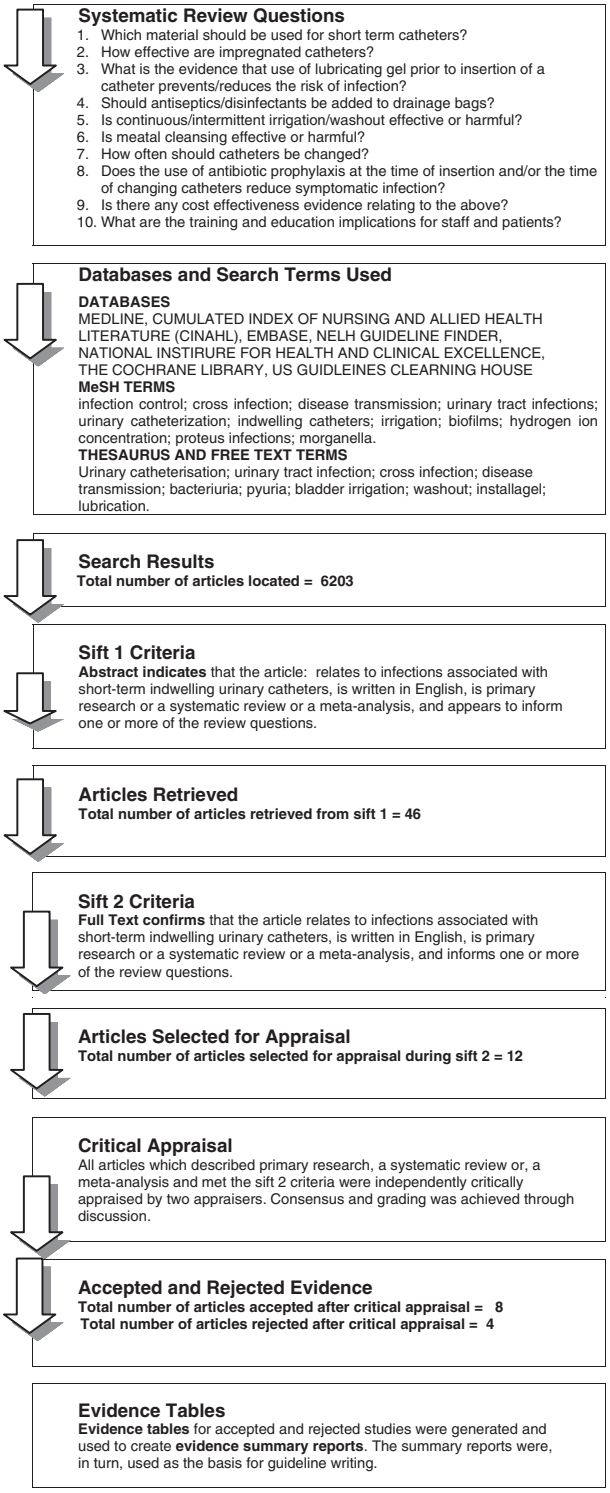
Intervention 4: Catheter maintenance

Randomised controlled trials of strategies to establish how often catheters and catheter bags need to be changed.

3.9 Key Audit Criteria

Aim	Criteria
Identify all patients with indwelling urinary catheters, their clinical need for catheterisation, assessed and documented.	All patients should have a patient record that documents the reason for catheterisation, type of catheter, catheter insertion, changes and care. Standard 100% Data collection: review of patient notes
Ensure that all healthcare workers are trained and competent in urinary catheterisation.	Healthcare workers receive training and updates in the management of urinary catheters. Standard 100% Data collection: review of staff education records
To prevent catheter-associated urinary tract infections (CAUTI)	All healthcare workers decontaminate their hands and wear a new pair of non-sterile gloves before manipulating the system. Standard 100% Data collection: observation/ self audit
To reduce the incidence of CAUTI by maintaining a closed system.	All catheters must be connected to a sterile closed drainage system or valve. Standard 100% Data collection: observation
To ensure patients and relatives are informed and educated about catheter management	All patients and carers are aware of the need to: • Decontaminate their hands; • Keep the system closed. Standard 100% Data collection: direct patient questioning of patients and carers.

3.10 Urinary Catheter Systematic Review Process



4 Guidelines for preventing infections associated with the use of central venous access devices (CVAD)

4.1 Introduction

This guidance is based on the best critically appraised evidence currently available. The type and class of supporting evidence explicitly linked to each recommendation is described. All recommendations are endorsed equally and none is regarded as optional. These recommendations are not detailed procedural protocols and need to be incorporated into local guidelines.

Background and context to the Guidelines

Bloodstream infections associated with the insertion and maintenance of central venous access devices (CVAD) are among the most dangerous complications of healthcare that can occur, worsening the severity of the patient's underlying ill health, prolonging the period of hospitalisation and increasing the cost of care.[201-204] Approximately 3 in every 1000 patients admitted to hospital in the UK acquires a bloodstream infection, and nearly one third of these infections are related to central venous access devices.[205]

Catheter related blood stream infection (CR-BSI) involves the presence of systemic infection and evidence implicating the CVAD as its source, i.e., the isolation of the same microorganism from blood cultures as that shown to be significantly colonising the CVAD of a patient with clinical features of bacteraemia. Catheter colonization refers to a significant growth of microorganisms on either the endoluminal or the external catheter surface beneath the skin in the absence of systemic infection.[206-208]

The microorganisms that colonise catheter hubs and the skin adjacent to the insertion site are the source of most CR-BSI. Coagulase-negative staphylococci, particularly *Staphylococcus epidermidis*, are the most frequently implicated microorganisms associated with CR-BSI. Other microorganisms commonly involved include *Staphylococcus aureus*, Candida species and enterococci.[208]

CR-BSI is generally caused either by skin microorganisms at the insertion site that contaminate the catheter during insertion and migrate along the cutaneous catheter track, or microorganisms from the hands of healthcare workers that contaminate and colonise the catheter hub during care interventions.[206] Infusate contamination or haematogenous seeding from site of infection elsewhere in the body is more rarely implicated as a cause of CR-BSI.

What is the evidence for these guidelines?
Evidence upon which practice can be based is derived from a range of sources and through varying processes. These guidelines are primarily based upon an expert review of evidence-based guidelines for preventing intravascular device-related infections developed at the Centers for Disease Control and Prevention (CDC) in the United States of America by the Healthcare Infection Control Practices Advisory Committee (HICPAC)[208] which were updated in 2002.[209] Using a validated guideline appraisal instrument developed by the AGREE collaboration,[6] three experienced appraisers independently reviewed the updated guidelines, taking into consideration supplementary information provided by HICPAC at our request. We concluded that the development processes were valid and that the guidelines were evidence-based, categorised to the strength of the evidence examined, reflective of current concepts of best practice, and acknowledged as the most authoritative reference guidelines currently available. They were subsequently used by us as the principal source of evidence for updating the first version of the epic guidelines.[1]

4.2 Systematic review process

Following our expert review, we systematically searched, retrieved and appraised additional supporting evidence published since the 2002 HICPAC guidelines were developed. Previously, we had updated the systematic review we conducted in 2000 for the first version of the epic guidelines[1] for the development of complementary national evidence-based guidelines for preventing HCAI in primary and community care (published in 2003 by the National Institute for Health and Clinical Excellence),[2] and again in 2004.[3,4] Comprehensive descriptions of the methodologies for the above systematic reviews can be found in the original guidelines which are downloadable from the epic website [http://www.epic.tvu.ac.uk].

In preparing the epic2 guidance, we conducted a final updating systematic review which is described in Section 4.14.

This search was confined to elements of infection prevention where expert members of the Guideline Advisory Group indicated new developments or changes in technology had occurred, or where pertinent new experimental trials or systematic reviews had been published.

Following our reviews, guidelines were drafted which described 47 recommendations within the 9 intervention categories listed below:

1. Education of healthcare workers and patients;
2. General asepsis;
3. Selection of catheter type;
4. Selection of catheter insertion site;
5. Maximal sterile barrier precautions during catheter insertion;
6. Cutaneous antisepsis;
7. Catheter and catheter site care;
8. Catheter replacement strategies; and
9. General principles for catheter management.

These guidelines apply to caring for all adults and children over the age of 1 year in NHS acute care settings with a CVAD which is being used for the administration of fluids, medications, blood components and/or total parenteral nutrition (TPN). They should be used in conjunction with the recommendations on Standard Principles for Preventing HCAI previously described in these guidelines.

Although these recommendations describe general principles of best practice that apply to all patients in hospital in which a CVAD is being used, they do not specifically address the more technical aspects of the care of infants under the age of 1 year or those children or adults receiving haemodialysis, who will generally have their CVAD managed in dialysis centres.

Because these recommendations describe broad general statements of best practice, they need to be adapted and incorporated into local practice guidelines.

4.3 Education of Healthcare Workers and Patients

To improve patient outcomes and reduce healthcare costs, it is essential that everyone involved in caring for patients with CVAD is educated about infection prevention. Healthcare workers in hospitals need to be confident and proficient in infection prevention practices and to be aware of the signs and symptoms of clinical infection. Well-organised educational programmes that enable healthcare worker to provide, monitor, and evaluate care and to continually increase their competence are critical to the success of any strategy designed to reduce the risk of infection. Evidence reviewed by HICPAC consistently demonstrated that the risk of infection declines

following the standardisation of aseptic care and increases when the maintenance of intravascular catheters is undertaken by inexperienced healthcare workers.[209] Additional evidence demonstrates that relatively simple education programmes focused on training healthcare workers to adhere to local evidence-based CVAD protocols may decrease the risk to patients of CR-BSI.[210-214]

CVAD 1	Healthcare workers caring for a patient with a central venous access device should be trained, and assessed as competent in using and consistently adhering to the infection prevention practices described in this guideline.	*Class D*
CVAD 2	Before discharge from hospital, patients with a central venous access device and their carers should be taught any techniques they may need to use to prevent infection and safely manage their device.	*Class D/GPP*
CVAD 3	An aseptic non-touch technique (ANTT) must be used for catheter site care and for accessing the system.	*Class B*
CVAD 4	Before accessing or dressing a central venous access device, hands must be decontaminated either by washing with an antimicrobial liquid soap and water, or by using an alcohol handrub.	*Class A*
CVAD 5	Hands that are visibly soiled or contaminated with dirt or organic material must be washed with liquid soap and water before using an alcohol handrub.	*Class A*
CVAD 6	Following hand antisepsis, clean gloves and an ANTT, or sterile gloves should be used when changing the insertion site dressing, line manipulation or intravenous drug administration.	*Class D*

4.4 General Asepsis

Good standards of hand hygiene and antiseptic technique can reduce the risk of infection
Because the potential consequences of catheter-related infections (CR-infections) are so serious, enhanced efforts are needed to reduce the risk of infection to the absolute minimum. For this reason, hand antisepsis and proper aseptic non-touch technique (ANTT) are required for changing catheter dressings and for accessing the system.[44,209]

Hand antisepsis can be achieved by washing hands with an antimicrobial liquid soap and water or by using an alcohol-based handrub.[44] When hands are visibly dirty or contaminated with organic material, such as blood and other body fluids or excretions, they must first be washed with liquid soap and water if alcohol-based handrubs are going to be used to achieve hand antisepsis.

Appropriate ANTT does not necessarily require sterile gloves; a new pair of disposable non-sterile gloves can be used in conjunction with a non-touch technique, for example, in changing catheter site dressings.[209] The Standard Principles for Preventing HCAI previously described in these guidelines gives additional advice on hand decontamination, the use of gloves and other protective equipment.

4.5 Selection of Catheter Type

Selecting the right catheter for the right patient can minimise the risk of infection
Different types of CVAD are available, i.e.:

- made of different materials;
- have one or more lumens;
- coated or impregnated with antimicrobial or antiseptic agents or heparin-bonded;
- cuffed and designed to be tunnelled;
- having totally implantable ports.

The selection of the most appropriate CVAD for each individual patient can reduce the risk of subsequent CR-related infection (CR-infection).

Catheter material
Although catheter material may be an important determinant of CR-infection, evidence available to HICPAC when developing their guidelines was inconclusive and they were unable to draw any specific conclusions about the contribution of catheter material to CR-infections.[209,215]

Teflon® and polyurethane catheters have been associated with fewer infections than catheters made of polyvinyl chloride or polyethylene. There is no additional evidence that demonstrates conclusively that CR-infection rates vary with different materials.[206] In England, short-term CVAD are almost always made of polyurethane and long-term tunnelled catheters are usually made of silicone.

Number of catheter lumens

Clinicians often prefer multi-lumen CVAD because they permit the concurrent administration of various fluids and medications, hyperalimentation, and haemodynamic monitoring among critically ill patients. HICPAC examined several randomised controlled trials and other studies which suggested that multi-lumen catheters were associated with a higher risk of infection than were single lumen catheters.[208,216-220] However, other studies examined by HICPAC failed to demonstrate a difference in the rates of CR-BSI.[221,222]

HICPAC noted that multi-lumen catheter insertion sites may be particularly prone to infection because of increased trauma at the insertion site or because multiple ports increase the frequency of CVAD manipulation.[218,219] HICPAC also noted that although patients with multi-lumen catheters tend to be more ill than those without such catheters, the infection risk observed with these catheters may have been independent of the patient's underlying disease severity.[220]

Two additional studies were identified from our systematic reviews. A systematic review and quantitative meta-analysis focused on determining the risk of CR-BSI and catheter colonisation in multilumen catheters compared with single-lumen catheters.[223] Reviewers reported that although CR-BSI was more common in patients with multilumen when compared with single-lumen catheters, when confined to high quality studies that control for patient differences, there is no significant difference in rates of CR-BSI. This analysis suggests that multilumen catheters are not a significant risk factor for increased CR-BSI or local catheter colonisation compared with single-lumen CVAD.

Another systematic review and quantitative meta-analysis tested whether single versus multilumen CVAD had an impact on catheter colonisation and CR-BSI.[224] Study authors concluded that there is some evidence from 5 randomised controlled trials (RCTs) with data on 530 CVAD, that for every 20 single-lumen catheters inserted, one CR-BSI will be avoided which would have occurred had multi-lumen catheters been used. As authors were only able to analyze a limited number of trials, further large RCTs of adequate power and rigour are needed to confirm these findings. In the meantime, it may be reasonable for patients who need a CVAD to choose a single-lumen catheter whenever there is no indication for a multi-lumen catheter.

CVAD 7 Use a single-lumen catheter unless multiple ports are essential for the management of the patient. *Class A*

CVAD 8 If a multilumen catheter is used, identify and designate one port exclusively for hyperalimentation to administer parenteral nutrition. *Class D/GPP*

Tunnelled and totally implantable ports

Surgically implanted (tunnelled) CVAD, e.g., Hickman® catheters, are commonly used to provide vascular access (and stable anchorage) to patients requiring long-term intravenous therapy. Alternatively, totally implantable intravascular devices, e.g., Port-A-Cath,® are also tunnelled under the skin but have a subcutaneous port or reservoir with a self-sealing septum that is accessible by needle puncture through intact skin.

In developing their 1996 guidelines, HICPAC examined multiple studies that compared the incidence of infection associated with long-term tunnelled CVAD and/or totally implantable intravascular devices with that from percutaneously (non-tunnelled) inserted CVAD.[208] Although in general most studies reported a lower rate of infection in patients with tunnelled CVAD,[225-233] some studies (including one randomised controlled trial) found no significant difference in the rate of infection between tunnelled and non-tunnelled catheters.[234,235] However, most studies examined by HICPAC concluded that totally implantable devices had the lowest reported rates of CR-BSI compared to either tunnelled or non-tunnelled CVAD.[236-246]

Additional evidence was obtained from studies of efficacy of tunnelling to reduce CR-infections in patients with short-term CVAD. One randomised controlled trial demonstrated that subcutaneous tunnelling of short-term CVAD inserted into the internal jugular vein reduced the risk for CR-BSI.[247] In a later randomised controlled trial, the same investigators failed to show a statistically significant difference in the risk for CR-BSI for subcutaneously tunnelled femoral vein catheters.[248]

An additional meta-analysis of randomised controlled trials focused on the efficacy of tunnelling short-term CVAD to prevent CR-infections.[249] Data synthesis demonstrated that tunnelling decreased catheter colonisation by 39% and decreased CR-BSI by 44% in comparison with non-tunnelled placement. The majority of the benefit in the decreased rate of catheter-sepsis came from one trial of CVAD inserted at the internal jugular site. The reduction in risk was not significant when pooled with data from five subclavian catheter trials. Tunnelling was not associated with increased risk of mechanical complications from placement or technical difficulties during placement; these outcomes

were not rigorously evaluated. This meta-analysis concluded that tunnelling decreased CR-infections. However, a synthesis of the evidence in this meta-analysis does not support routine subcutaneous tunnelling of short-term subclavian venous catheters and this cannot be recommended unless efficacy is evaluated at different placement sites and relative to other interventions.

Neither we nor HICPAC identified any additional evidence in updating our systematic reviews.

CVAD 9 Use a tunnelled or implanted central venous access device (one with a subcutaneous port) for patients in whom long-term (more than 3-4 weeks) vascular access is anticipated. *Class A*

Antimicrobial impregnated Catheters and Cuffs

Some catheters and cuffs are marketed as anti-infective and are coated or impregnated with antimicrobial or antiseptic agents, e.g., chlorhexidine/silver sulfadiazine, minocycline/rifampin, platinum/silver, and ionic silver in subcutaneous collagen cuffs attached to CVAD. Evidence reviewed by HICPAC indicated that the use of antimicrobial or antiseptic-impregnated CVAD in adults whose catheter is expected to remain in place for more than 5 days can decrease the risk for CR-BSI.[250-260] This may be cost-effective in high risk patients (intensive care, burn and neutropenic patients) and in other patient populations in which the rate of CR-BSI exceeds 3.3 per 1,000 catheter days despite implementing a comprehensive strategy to reduce rates of CR-BSI.[250]

A more recent meta-analysis analysed 23 RCTs published between 1988-1999 and which included data on 4,660 catheters (2,319 anti-infective and 2,341 control).[261] Eleven of the trials in this meta-analysis were conducted in Intensive Care Unit settings; 4 among oncologic patients, 2 among surgical patients; 2 among patients receiving TPN; 4 among other patient populations. Study authors concluded that antibiotic and chlorhexidine-silver sulfadiazine coatings are anti-infective for short (approximately 1 week) insertion time. For longer insertion times, there are no data on antibiotic coating, and there is evidence of lack of effect for first generation chlorhexidine-silver sulfadiazine coating. For silver-impregnated collagen cuffs, there is evidence of lack of effect for both short- and long-term insertion.

Second generation chlorhexidine/silver sulfadiazine catheters with chlorhexidine coating both the internal and external luminal surfaces are now available. The external surface of these catheters has three times the amount of chlorhexidine and extended release of the surface bound antiseptics than that in the first generation catheters (which are coated with chlorhexidine/silver sulfadiazine only on the external luminal surface). Early studies indicated that the prolonged anti-infective activity associated with the second generation catheters improved efficacy in preventing infections.[262]

The most recent appraisal of all of the evidence for the clinical and cost-effectiveness of CVAD treated with antimicrobial agents in preventing CR-BSI is a systematic review and economic evaluation recently conducted by the Liverpool Reviews and Implementation Group (LRiG).[263] Study authors conclude that rates of CR-BSI are statistically significantly reduced when an antimicrobial CVAD was used. Studies report the best effect when catheters were treated with minocycline/rifampin, or internally and externally treated with silver or chlorhexidine/silver sulfadiazine. A trend to statistical significance was seen in catheters only extraluminally coated. Investigation of other antibiotic treated catheters is limited to single studies with non-significant results.

HICPAC guidelines recommend the use of an antimicrobial or antiseptic-impregnated CVAD in adults whose catheter is expected to remain in place for more than 5 days if, after implementing a comprehensive strategy to reduce rates of CR-BSI, the CR-BSI rate remains above the goal set by the individual institution based on benchmark rates and local factors.[209]

CVAD 10 Consider the use of an antimicrobial impregnated central venous access device for adult patients who require short-term (1 to 3 weeks) central venous catheterisation and who are at high risk for catheter-related bloodstream infection (CR-BSI) if rates of CR-BSI remain high despite implementing a comprehensive strategy to reduce rates of CR-BSI. *Class A*

4.6 Selection of Catheter Insertion Site

Selecting the best insertion site for the patient can minimise the risk of infection

Several factors need to be assessed when determining the site of CVAD placement, including:

- patient-specific factors (e.g., pre-existing CVAD, anatomic deformity, bleeding diathesis, some types of positive pressure ventilation);

- relative risk of mechanical complications (e.g., bleeding, pneumothorax, thrombosis);
- the risk of infection.

HICPAC concluded that the site at which a CVAD is placed can influence the subsequent risk of CR-infection because of variation in both the density of local skin flora and risk of thrombophlebitis. CVAD are generally inserted in the subclavian, jugular or femoral veins, or peripherally inserted into the superior vena cava by way of the major veins of the upper arm, i.e., the cephalic and basilar veins of the antecubital space.

Subclavian, jugular and femoral placements

Multiple studies examined by HICPAC concluded that CVAD inserted into subclavian veins had a lower risk for CR-infection than those inserted in either jugular or femoral veins, but none of these was a randomised controlled trial. HICPAC stated that internal jugular insertion sites may pose a greater risk for infection because of their proximity to oropharyngeal secretions and because CVAD at this site are difficult to immobilise. They noted, however, that mechanical complications associated with catheterisation might be less common with internal jugular than with subclavian vein insertion.

HICPAC noted that no RCT satisfactorily has compared CR-infection rates for catheters placed in jugular, subclavian, and femoral sites. However, both previous and new evidence examined by HICPAC demonstrated that catheters inserted into an internal jugular vein have been associated with higher risks for CR-infection than those inserted into a subclavian or femoral vein.[252,264,265] Femoral catheters have been demonstrated to have relatively high colonization rates when used in adults and should be avoided because they are presumed to be associated with a higher risk of deep vein thrombosis (DVT) and CR-infection than are internal jugular or subclavian catheters.[266-271] Thus, in adult patients, a subclavian site is preferred for infection control purposes, although other factors, e.g., the potential for mechanical complications, risk for subclavian vein stenosis, and catheter-operator skill, should be considered when deciding where to place the catheter. HICPAC cited a meta-analysis of 8 studies and guidelines from the National Institute for Health and Clinical Excellence (NICE) indicate that the use of bedside ultrasound for the placement of CVAD substantially reduced mechanical complications compared with the standard landmark placement technique.[272,273] Consequently, the use of ultrasound may indirectly reduce the risk of infection by facilitating mechanically uncomplicated subclavian placement.

Antecubital placement

Peripherally inserted CVAD (PICC) may be used as an alternative to subclavian or jugular vein catheterisation. These are inserted into the superior vena cava by way of the major veins of the upper arm. HICPAC stated that they are less expensive, associated with fewer mechanical complications, e.g., thrombosis, haemothorax, infiltration and phlebitis, and easier to maintain than short peripheral venous catheters, i.e., a reduced need for frequent site rotation. Additionally, previous evidence examined by HICPAC suggested that PICC are associated with a lower rate of infection than that associated with other non-tunnelled CVAD, perhaps because the skin at the antecubital fossa is less moist and oily and colonised by fewer microorganisms than the chest and neck.[234,274,275] HICPAC also noted that an antecubital placement removes the catheter away from endotracheal and nasal secretions. Finally, they noted that further studies were needed to adequately determine how long PICC could be safely left in place and to determine whether routine replacement influenced the risk of associated infection.

Systematic Review Evidence

We examined a prospective cohort study using data from two randomized trials and a systematic review published in 2005.[276] In the review the authors reported a rate of PICC-BSI of 2.1 per 1,000 PICC-days. This was comparable to the rates reported in their prospective cohort study (2.1 to 3.5 per 1,000 catheter-days) and similar to that reported with prospectively studied, short-term non-cuffed CVAD placed percutaneously in the internal jugular, subclavian or femoral veins in inpatients (approximately 2.3 per 1,000 days). Investigators concluded that PICC used in high-risk hospitalised patients are associated with a rate of CR-BSI similar to conventional CVAD placed in the internal jugular or subclavian veins (2 to 5 per 1,000 catheter-days). This rate is much higher than with PICC used exclusively in the outpatient setting (approximately 0.4 per 1,000 catheter-days). They question whether the growing trend in many hospital haematology and oncology services to switch from the use of cuffed and tunnelled CVAD to PICC is justified, particularly since PICC are more vulnerable to thrombosis and dislodgment, and are less useful for drawing blood specimens. Moreover, PICC are not advisable in patients with renal failure and impending need for

dialysis, in whom preservation of upper-extremity veins is needed for fistula or graft implantation. Furthermore: '…the assumption that PICC are safer than conventional CVAD with regard to the risk of infection is in question and should be assessed by a larger, adequately powered randomized trial that assesses peripheral vein thrombo-phlebitis, PICC-related thrombosis, and premature dislodgment, as well as CR-BSI.'

CVAD 11	In selecting an appropriate insertion site, assess the risks for infection against the risks of mechanical complications.	*Class D/GPP*
CVAD 12	Unless medically contraindicated, use the subclavian site in preference to the jugular or femoral sites for nontunnelled catheter placement.	*Class C*
CVAD 13	Use implantable access devices for patients who require long-term, intermittent vascular access. For patients requiring regular or continuous access, a tunnelled central venous access device is preferable.	*Class C*

4.7 Maximal Sterile Barrier Precautions during Catheter Insertion

Using maximal sterile barrier precautions during CVAD placement will significantly reduce the risk of infection

The primacy of strict adherence to hand decontamination and aseptic technique as the cornerstone for preventing CR-infection is widely accepted. Although this is considered adequate for preventing infections associated with the insertion of short peripheral venous catheters, it is recognised that central venous catheterisation carries a significantly greater risk of infection. However, the level of barrier precautions needed to prevent infection during CVAD insertion was controversial at the time of the development of the HICPAC guidelines.[208]

Studies examined by HICPAC concluded that if maximal sterile barrier precautions (MSB) were used during CVAD insertion, catheter contamination and subsequent CR-infections could be significantly minimised.[264,277-279]

One of these studies was a prospective randomised trial that tested the efficacy of maximal sterile barriers to reduce infections associated with long-term nontunnelled subclavian silicone catheters.[279] When MSB were compared with routine procedures, they significantly decreased the risk of CR-BSI.[279]

MSB involve wearing sterile gloves and gown, a cap, mask and using a large sterile drape during insertion of the catheter as opposed to routine infection prevention procedures that involve wearing only sterile gloves and the use of a small drape. However, there is no specific evidence that wearing a facemask or cap during catheter insertion is important in preventing CR-BSI.

It has been generally assumed that CVAD inserted in the operating theatre posed a lower risk of infection than did those inserted on inpatient wards or other patient care areas.[208] Data examined by HICPAC from two prospective studies suggests that the difference in risk of infection depended largely on the magnitude of barrier protection used during catheter insertion, rather than the surrounding environment, i.e., ward versus operating room.[264,279]

Previous expert reviewers who have examined the above evidence agree that maximal sterile barrier precautions are essential during CVAD placement to reduce the risk of infection.[115,207,280-282]

Systematic Review Evidence

A systematic review published in 2004 aimed to determine the value of MSB to prevent CVAD-related infection.[283] MSB were defined as: person inserting the CVAD wear a head cap, facemask, sterile body gown, and sterile gloves and uses a full-size sterile drape. Their search identified 95 articles discussing the prevention of CVAD-related infections. The majority of these articles were review articles or consensus statements. Only three primary research studies comparing infection outcomes using MSB with less stringent barrier techniques were identified and included in the review. Authors identified no additional unpublished or ongoing primary studies. All three studies included in the review concluded that the use of MSB resulted in a reduction in catheter-related infections. The studies differed notably in their patient populations, research designs, and healthcare settings. Study authors concluded that using MSB has been found to decrease transmission of microorganisms, to delay colonization, and to reduce the rate of hospital-acquired infections. They suggest that biological plausibility and the available evidence support using MSB during routine insertion of a CVAD to minimise the risk of infection. They recommend that given the lack of adverse patient reactions, the relatively low cost of MSB, and the high cost of CR-BSI, it is probable that MSB will prove to be a cost-effective or even a cost-saving intervention.

CVAD 14 Use maximal sterile barriers, including a sterile gown, sterile gloves, and a large sterile drape, for the insertion of central venous access devices. *Class C*

4.8. Cutaneous Antisepsis

Appropriate preparation of the insertion site will reduce the risk of catheter-related infection

Microorganisms that colonise catheter hubs and the skin surrounding the CVAD insertion site are the cause of most CR-BSIs.[206,260,284] The risk of infection increases with the density of micro-organisms around the insertion site. Skin cleansing/antisepsis of the insertion site is therefore one of the most important measures for preventing CR-infection.[208] An important prospective randomised trial of agents used for cutaneous antisepsis demonstrated that 2% aqueous chlorhexidine was superior to either 10% povidone-iodine or 70% alcohol for preventing central venous and arterial CR-infections.[285] An additional study has since confirmed the superior efficacy of 2% aqueous chlorhexidine compared to povidone iodine in substantially reducing central venous catheter colonisation.[286]

Direct comparisons of aqueous versus alcoholic solutions of chlorhexidine have not been undertaken in relation to cutaneous antisepsis for preventing CR-infections. However, an alcoholic solution of chlorhexidine combines the benefits of rapid action and excellent residual activity.[287]

The application of organic solvents, such as acetone or ether, to 'defat' (remove skin lipids) the skin before catheter insertion and during routine dressing changes had been a standard component of many hyperalimentation protocols. However, there was no evidence available to HICPAC to show that the use of these agents provided any protection against CR-infection and their use could greatly increase local inflammation and patient discomfort.[208]

Several studies were examined that focused on the application of antimicrobial ointments to the catheter site at the time of catheter insertion, or during routine dressing changes, to reduce microbial contamination of catheter insertion sites.[284] Reported efficacy in preventing CR-infections by this practice yielded contradictory findings.[288-293] There was also concern that the use of polyantibiotic ointments that were not fungicidal could significantly increase the rate of colonisation of the catheter by *Candida* species.[292,294]

Systematic Review Evidence

A meta-analysis published in 2004 assessed studies that compared the risk for CR-BSI following insertion-site skin care with either any type of chlorhexidine gluconate (CHG) solution versus povidone iodine (PI) solution.[295] This analysis indicated that the use of CHG rather than PI can reduce the risk for CR-BSI by approximately 49% (risk ratio, 0.51 [CI, 0.27 to 0.97]) in hospitalised patients who require short-term catheterisation, i.e., for every 1000 catheter sites disinfected with CHG rather than PI, 71 episodes of catheter colonization and 11 episodes of CR-BSI would be prevented. In this analysis, several types of CHG solutions were used in the individual trials, including 0.5 percent or 1 percent CHG alcohol solution and 0.5 percent or 2 percent CHG aqueous solution. All of these solutions provided a concentration of CHG that is higher than the minimal inhibitory concentration (MIC) for most nosocomial bacteria and yeasts. Subset analysis of aqueous and non-aqueous solutions showed similar effect sizes, but only the subset analysis of the five studies that used alcoholic CHG solution produced a statistically significant reduction in CR-BSI. Because few studies used CHG aqueous solution, the lack of a significant difference seen for this solution compared with PI solution may be a result of inadequate statistical power.

A prospective randomised trial in Germany and published in 2004 investigated the optimal disinfection regimen at the time of catheter insertion to avoid catheter colonisation, comparing skin disinfection performed with either povidone-iodine 10% (PVP-iodine), chlorhexidine 0.5% propanol 70%, or chlorhexidine 0.5% propanol 70% followed by PVP-iodine 10%.[296] Investigators found that significantly fewer catheter tips were colonized following skin disinfection of the insertion site with propanol/chlorhexidine followed by PVP-iodine ($p = 0.006$). Study authors concluded that skin disinfection with sequential application of propanol/chlorhexidine followed by PVP-iodine was superior in the prevention of microbial CVAD colonisation compared to either of the regimens alone.

A randomised prospective multiple unit cross-over trial conducted in France and published in 2004 compared the effectiveness in preventing central venous catheter colonization and infection of two protocols for pre-insertion cutaneous antisepsis using aqueous 10% povidone-iodine (PVP-I) or a solution of 5% PVP-I in 70% ethanol.[297] Investigators found that the incidence of catheter colonization was significantly lower in the alcoholic PVP-I solution protocol than in the

aqueous PVP-I solution protocol (relative risk, 0.38: 95% confidence interval, 0.22-0.65, p < 0.001), and so was the incidence of CR-infection (relative risk, 0.34: 95% confidence interval, 0.13-0.91, p < 0.04). Study authors concluded that the use of alcoholic PVP-I rather than aqueous PVP-I can significantly reduce the incidence of catheter-tip colonization and nosocomial catheter-related infection in intensive care units.This study was designed to demonstrate the superiority of alcoholic PVP-I over aqueous PVP-I in preventing CVAD colonization. However, the weight of evidence in the majority of studies appraised in our review favours alcoholic chlorhexidine for pre-insertion cutaneous antisepsis.

CVAD 15	Decontaminate the skin site with a single patient use application of alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) prior to the insertion of a central venous access device.	*Class A*
CVAD 16	Use a single patient use application of alcoholic povidone-iodine solution for patients with a history of chlorhexidine sensitivity. Allow the antiseptic to dry before inserting the central venous access device.	*Class D/GPP*
CVAD 17	Do not apply organic solvents, e.g., acetone, ether, to the skin before the insertion of a central venous access device.	*Class D/GPP*
CVAD 18	Do not routinely apply antimicrobial ointment to the catheter placement site prior to insertion.	*Class D/GPP*

4.9. Catheter and Catheter Site Care

Infections can be minimised by good catheter and insertion site care

The safe maintenance of a CVAD and relevant care of the insertion site are essential components of a comprehensive strategy for preventing CR-infections. This includes good practice in caring for the patient's catheter hub and connection port, the use of an appropriate CVAD site dressing regimen, and using flush solutions to maintain the patency of the CVAD.

Choose the right dressing for insertion sites to minimise infection

Following CVAD placement, a dressing is used to protect the insertion site. Because occlusive dressings trap moisture on the skin, and provide an ideal environment for the rapid growth of local microflora, dressings for insertion sites must be permeable to water vapour.[206] The two most common types of dressings used for insertion sites are sterile, transparent, semi-permeable polyurethane dressings coated with a layer of an acrylic adhesive ('transparent dressings'), and gauze and tape dressings. Transparent dressings, e.g., Opsite® IV3000, Tegaderm IV®, are permeable to water vapour and oxygen, and impermeable to microorganisms.

HICPAC reviewed the evidence related to which type of dressing provided the greatest protection against infection and found little difference.[209] They concluded that the choice of dressing can be a matter of preference. If blood is oozing from the catheter insertion site, a gauze dressing might be preferred.

Gauze dressings are not waterproof and require frequent changing in order to inspect the catheter site. They are rarely useful in patients with long-term CVAD. Sterile transparent, semi-permeable polyurethane dressings have become a popular means of dressing catheter insertion sites. They reliably secure the CVAD, permit continuous visual inspection of the catheter site, allow patients to bathe and shower without saturating the dressing, and require less frequent change than that required for standard gauze and tape dressings, thus saving personnel time.

Systematic Review Evidence

A Cochrane Review of gauze and tape versus transparent polyurethane dressings for CVAD concluded that there was no evidence demonstrating any difference in the incidence of CR-related infections between any of the dressing types compared in this review.[298] Each of these comparisons was based on no more than 2 studies and all of these studies reported data from a small patient sample. Therefore it is probable that the findings of no difference between dressing types is due to the lack of adequate data. They further concluded that because there is a high level of uncertainty regarding the risk of infection associated with the CVAD dressings included in this review, at this stage it appears that the choice of dressing for CVAD can be based on patient preference.

CVAD 19	Preferably, a sterile, transparent, semi-permeable polyurethane dressing should be used to cover the catheter insertion site.	*Class D*
CVAD 20	Transparent dressings should be changed every 7 days, or sooner if they are no longer intact or moisture collects under the dressing.	*Class D*

CVAD 21	If a patient has profuse perspiration or if the insertion site is bleeding or oozing, a sterile gauze dressing is preferable to a transparent, semi-permeable dressing.	*Class D/GPP*
CVAD 22	The need for a gauze dressing should be assessed daily and changed when inspection of the insertion site is necessary or when the dressing becomes damp, loosened or soiled. A gauze dressing should be replaced by a transparent dressing as soon as possible.	*Class D/GPP*
CVAD 23	Dressings used on tunnelled or implanted catheter insertion sites should be replaced every 7 days until the insertion site has healed, unless there is an indication to change them sooner.	*Class D*

Use an appropriate antiseptic agent for disinfecting the catheter insertion site during dressing changes

HICPAC described compelling evidence that aqueous chlorhexidine 2% was superior to either 10% povidone iodine or 70% alcohol in lowering CR-BSI rates when used for skin antisepsis prior to CVAD insertion.[209,285] They made no recommendation for the use of any disinfectant agent for cleaning the insertion site during dressing changes.

Studies focused on the use of antimicrobial ointment applied under the dressing to the catheter insertion site to prevent CVAD-related infection do not clearly demonstrate efficacy.[289,294]

Systematic Review Evidence

A recent meta-analysis assessed studies that compared the risk for CR-BSI following insertion-site skin care with either any type of chlorhexidine gluconate (CHG) solution versus povidone iodine (PI) solution.[295] This analysis indicated that the use of CHG rather than PI can reduce the risk for CR-BSI by approximately 49% (risk ratio, 0.51 [CI, 0.27 to 0.97]) in hospitalised patients who require short-term catheterisation, i.e., for every 1000 catheter sites disinfected with CHG rather than PI, 71 episodes of catheter colonization and 11 episodes of CR-BSI would be prevented. In this analysis, several types of CHG solutions were used in the individual trials, including 0.5 percent or 1 percent CHG alcohol solution and 0.5 percent or 2 percent CHG aqueous solution. All of these solutions provided a concentration of CHG that is higher than the minimal inhibitory concentration (MIC) for most nosocomial bacteria and yeasts. Subset analysis of aqueous and non-aqueous solutions showed similar effect sizes, but only the subset analysis of the five studies that used alcoholic CHG solution produced a statistically significant reduction in CR-BSI. Because few studies used CHG aqueous solution, the lack of a significant difference seen for this solution compared with PI solution may be a result of inadequate statistical power.

Most modern CVAD and other catheter materials are generally alcohol-resistant, i.e., they are not damaged by contact with alcohol. However, alcohol and other organic solvents and oil-based ointments and creams may damage some types of polyurethane and silicon CVAD tubing, e.g., some catheters used in haemodialysis. The manufacturer's recommendations for only using disinfectants that are compatible with specific catheter materials must be followed.

CVAD 24	An alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) should be used to clean the catheter insertion site during dressing changes, and allowed to air dry. An aqueous solution of chlorhexidine gluconate should be used if the manufacturer's recommendations prohibit the use of alcohol with their product.	*Class A*
CVAD 25	Individual single use sachets of antiseptic solution or individual packages of single use antiseptic-impregnated swabs or wipes should be used to disinfect the insertion site.	*Class D/GPP*
CVAD 26	Do not apply antimicrobial ointment to catheter insertion sites as part of routine catheter site care.	*Class D/GPP*
CVAD 27	Healthcare workers should ensure that catheter-site care is compatible with catheter materials (tubing, hubs, injection ports, luer connectors and extensions) and carefully check compatibility with the manufacturer's recommendations.	*Class D/GPP*

4.10 Catheter Replacement Strategies

When and how catheters are replaced can influence the risk of infection

A catheter replacement strategy is composed of two elements; the frequency and the method of catheter replacement.

Frequency

HICPAC noted that with short peripheral venous catheters, the risk of phlebitis and catheter colonisation, both associated with CR-infection, could be reduced by catheter replacement and

site rotation every 48-72 hours.[208] However, decisions regarding the frequency of CVAD replacement were more complicated. They considered evidence that showed duration of catheterisation to be a risk factor for infection and which advocated routine replacement of CVAD at specified intervals as a measure to reduce infection.[222,265,299,300] Other studies, however, suggested that the daily risk of infection remains constant and showed that routine replacement of CVAD, without a clinical indication, does not reduce the rate of catheter colonisation or the rate of CR-BSI.[301,302] Conclusions from a systematic review agree that exchanging catheters by any method every three days was not beneficial in reducing infections, compared with catheter replacement on an as-needed basis.[303]

Methods

Two methods are used for replacing CVAD; placing a new catheter over a guide wire at the existing site, or percutaneously inserting a new catheter at another site. Guide wire insertion has been the accepted technique for replacing a malfunctioning catheter (or exchanging a pulmonary artery catheter for a CVAD when invasive monitoring was no longer needed) as they are associated with less discomfort and a significantly lower rate of mechanical complications than those percutaneously inserted at a new site. Studies of the risks for infection associated with guide wire insertions examined by HICPAC yielded conflicting results. One prospective study showed a significantly higher rate of CR-BSI associated with catheters replaced over a guide wire compared with catheters inserted percutaneously.[301] However, three prospective studies (two randomised) showed no significant difference in infection rates between catheters inserted percutaneously and those inserted over a guide wire.[302,304,305] Since these studies suggest that the insertion of the new catheter at a new site does not alter the rate of infectious complications per day but does increase the incidence of mechanical complications, guide wire exchange is recommended. Most studies examined by HICPAC concluded that, in cases where the catheter being removed is known to be infected, guidewire exchange is contra-indicated.[302,304-307]

A systematic review concluded that, compared with new site replacement, guidewire exchange was associated with a trend toward a higher rate of subsequent catheter colonisation, regardless of whether patients had a suspected infection at the time of replacement. Guidewire exchange was also associated with trends toward a higher rate of catheter exit-site infection and CR-BSI. However, guidewire exchange was associated with fewer mechanical complications relative to new-site replacement.[303]

Methods are available and techniques have been described which allow a diagnosis of CR-BSI to be made without the need for catheter removal.[308] Such approaches could be used prior to the replacement of a new catheter over a guide wire in order to reduce the subsequent risk of CR-infection.[308,309]

CVAD 28	Do not routinely replace catheters as a method to prevent catheter-related infection.	*Class A*
CVAD 29	Use guide wire assisted catheter exchange to replace a malfunctioning catheter, or to exchange an existing catheter only if there is no evidence of infection at the catheter site or proven catheter-related bloodstream infection.	*Class A*
CVAD 30	If catheter-related infection is suspected, but there is no evidence of infection at the catheter site, remove the existing catheter and insert a new catheter over a guide wire; if tests reveal catheter-related infection, the newly inserted catheter should be removed and, if still required, a new catheter inserted at a different site.	*Class A*
CVAD 31	Do not use guide wire assisted catheter exchange for patients with catheter-related infection. If continued vascular access is required, remove the implicated catheter, and replace it with another catheter at a different insertion site.	*Class A*
CVAD 32	Replace all fluid administration tubing and connectors when the central venous access device is replaced.	*Class D/GPP*

4.11 General Principles for Catheter Management

Aseptic technique is important when accessing the system

HICPAC considered evidence demonstrating that contamination of the catheter hub is an important contributor to intraluminal microbial colonisation of catheters, particularly long-term catheters.[310-316]

In a relatively recent overview, additional evidence from a prospective cohort study suggested that frequent catheter hub manipulation increases the risk for microbial contamination.[260,317] During prolonged catherisation, catheter hubs are accessed more frequently, increasing the likeli-

hood of a CR-BSI emanating from a colonised catheter hub rather than the insertion site.[316] Consequently, the reviewer commented that hubs and sampling ports should be disinfected before they are accessed and noted that both povidone-iodine and chlorhexidine are effective.[250,318,319]

Systematic Review Evidence

In a recent randomized prospective clinical trial conducted in England, the microbial contamination rate of luers of CVAD with either PosiFlow® needleless connectors or standard caps attached was investigated.[320] The efficacy of: chlorhexidine gluconate 0.5% w/v in industrial methylated spirit (IMS) BP 70% w/w spray (*Hydrex DS*®); Sterile isopropyl alcohol (IPA) 70% w/w spray (*Spiriclens*®); *and* 10% (w/v) aqueous povidone-iodine (*Betadine*®) was assessed for the disinfection of intravenous connections. Patients were designated to receive chlorhexidine/alcohol, isopropyl alcohol or povidone–iodine for pre-CVAD insertion skin preparation and disinfection of the connections. After 72 h in situ the microbial contamination rate of 580 luers, 306 with standard caps and 274 with needleless connectors attached, was determined. The microbial contamination rate of the external compression seals of 274 needleless connectors was also assessed to compare the efficacy of the three disinfectants. The internal surfaces of 55 out of 306 (18%) luers with standard caps were contaminated with microorganisms, whilst only 18 out of 274 (6.6%) luers with needleless connectors were contaminated ($p < 0.0001$). Of those needleless connectors disinfected with isopropyl alcohol, 69.2% were externally contaminated with microorganisms compared with 30.8% disinfected with chlorhexidine/alcohol ($p < 0.0001$) and 41.6% with povidone–iodine ($p < 0.0001$). These results suggest that the use of needleless connectors may reduce the microbial contamination rate of CVAD luers compared with the standard cap. Furthermore, disinfection of needleless connectors with either chlorhexidine/alcohol or povidone–iodine significantly reduced external microbial contamination. Both these strategies may reduce the risk of catheter-related infections acquired via the intraluminal route.

Although now generally alcohol-resistant, some CVAD and catheter hub materials may be chemically incompatible with alcohol or iodine and the manufacturer's recommendations must be complied with.

CVAD 33 A single patient use application of alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) should be used and allowed to dry when decontaminating the injection port or catheter hub before and after it has been used to access the system, unless contraindicated by the manufacturer's recommendations, in which case either aqueous chlorhexidine gluconate or aqueous povidone iodine should be used. *Class D/GPP*

Inline filters do not help prevent infections

Although in-line filters reduce the incidence of infusion-related phlebitis, HICPAC could find no reliable evidence to support their efficacy in preventing infections associated with intravascular catheters and infusion systems. Infusate-related BSI is rare and HICPAC concluded that filtration of medications or infusates in the pharmacy is a more practical and less costly way to remove the majority of particulates. Furthermore, in-line filters might become blocked, especially with certain solutions, e.g., dextran, lipids, mannitol, thereby increasing the number of line manipulations and decreasing the availability of administered drugs.[209] In our systematic review we found no additional good quality evidence to support their use for preventing infusate-related CR-BSI. However, there may be a role for the use of in-line filtration of parenteral nutrition solutions for reasons other than the prevention of infection but these are beyond the scope of these guidelines.

CVAD 34 In-line filters should not be used routinely for infection prevention purposes. *Class D*

Antibiotic lock solutions have limited uses in preventing infection

Antibiotic lock prophylaxis, i.e., flushing and then filling the lumen of the CVAD with an antibiotic solution and leaving it to dwell in the lumen of the catheter, is sometimes used in special circumstances to prevent CR-BSI, e.g., in treating a patient with a long-term cuffed or tunnelled catheter or port who has a history of multiple CR-BSI despite optimal maximal adherence to aseptic technique. Evidence reviewed by HICPAC demonstrated the effectiveness of this type of prophylaxis in neutropenic patients with long-term CVAD.[209] However, they found no evidence that routinely using this procedure in all patients with CVAD reduced the risk of CR-BSI and may lead to

an increase in antimicrobial resistant micro-organisms.

CVAD 35 Antibiotic lock solutions should not be used routinely to prevent catheter-related bloodstream infections. *Class D*

Systemic antibiotic prophylaxis does not reliably prevent CR-BSI

No studies appraised by HICPAC demonstrated that oral or parenteral antibacterial or antifungal drugs might reduce the incidence of CR-BSI among adults. However, among low birth weight infants, two studies reviewed by HICPAC had assessed vancomycin prophylaxis; both demonstrated a reduction in CR-BSI but no reduction in mortality. They noted that because the prophylactic use of vancomycin is an independent risk factor for the acquisition of vancomycin-resistant enterococci (VRE), the risk for acquiring VRE probably outweighs the benefit of using prophylactic vancomycin.[209]

Systematic Review Evidence

A Cochrane Review published in 2003 concluded that prophylactic antibiotics or catheter flushing with vancomycin and heparin may help cancer patients at high risk of catheter-related infections.[321] Patients with cancer often need to be given drugs and other treatments intravenously, so are frequently fitted with long-term tunnelled CVAD. Infections sometimes occur. Clinical trial evidence shows it may be useful to give prophylactic antibiotics prior to inserting a tunnelled CVAD or to flush the catheter with combined vancomycin and heparin, but microbial resistance may occur unless this practice is limited to high-risk patients.

CVAD 36 Do not routinely administer intranasal or systemic antimicrobials before insertion or during the use of a central venous access device to prevent catheter colonisation or bloodstream infection. *Class A*

A dedicated catheter lumen is needed for parenteral nutrition

HICPAC reviewed evidence from a prospective epidemiologic study examining the risk for CR-BSI in patients receiving Total Parenteral Nutrition (TPN). They concluded that either using a single lumen catheter or a dedicated port in a multi-lumen catheter for TPN would reduce the risk of infection.[209]

CVAD 37 Preferably, a single-lumen catheter should be used to administer parenteral nutrition. If a multilumen catheter is used, one port must be exclusively dedicated for hyperalimentation and all lumens must be handled with the same meticulous attention to aseptic technique. *Class D*

Maintaining CVAD patency and preventing catheter thrombosis may help prevent infections

Indwelling central venous and pulmonary artery catheters are thrombogenic. Thrombus forms on these catheters in the first few hours following placement and may serve as a nidus for microbial colonization of intravascular catheters.[322,323] Thrombosis of large vessels occurs after long-term catheterisation in 35 to 65% of patients.[324-328] Prophylactic heparin and warfarin have been widely used to prevent catheter thrombus formation and catheter related complications, such as deep venous thrombosis (DVT).[209,329]

Two types of heparin can be used: unfractionated (standard) heparin and low molecular weight heparins. Although more expensive, low molecular weight heparins have a longer duration of action than unfractionated heparin and are generally administered by subcutaneous injection once daily. The standard prophylactic regimen of low molecular weight heparins are at least as effective and as safe as unfractionated heparin in preventing venous thrombo-embolism and does not require laboratory monitoring.[330]

Systemic Anticoagulation

A meta-analysis of randomised controlled trials evaluating the benefit of infused prophylactic heparin through the catheter, given subcutaneously or bonded to the catheter in patients with CVAD found that prophylactic heparin:

- was associated with a strong trend for reducing catheter thrombus (RR, 0.66; 95% confidence interval [CI], 0.42, 1.05). The test for heterogeneity of variance was not significant ($p = 0.681$);
- significantly decreased central venous catheter-related venous thrombosis by 57% (RR, 0.43; 95% CI, 0.23, 0.78). The test for heterogeneity of variance was not significant ($p = 0.526$). Significant reduction of deep venous thrombosis was still present after excluding one trial of heparin-bonded catheters (RR, 0.44; 95% CI, 0.22, 0.87);
- significantly decreased bacterial colonisation of the catheter (RR, 0.18; 95% CI, 0.06, 0.60).

The test for heterogeneity of variance was not significant (p = 0.719). The significant benefit for heparin remained after excluding one trial of heparin-bonded catheters (RR, 0.19; 95% CI, 0.04, 0.86).

- showed a strong trend for a reduction in CR-BSI (RR, 0.26; 95% CI, 0.07, 1.03). The test for heterogeneity of variance was not significant (p = 0.859); This trend decreased when one trial of heparin-bonded catheters was excluded (RR,0.33; 95% CI, 0.07, 1.56).[329]

The authors of this meta-analysis concluded that heparin administration effectively reduces thrombus formation and may reduce catheter-related infections in patients who have central venous and pulmonary artery catheters in place. They suggest that various doses of subcutaneous and intravenous unfractionated and low molecular weight heparins and new methods of heparin bonding need further comparison to determine the most cost-effective strategy for reducing catheter-related thrombus and thrombosis.

There are many different preparations and routes of administration of heparin, and as yet there is no definite evidence that heparin reduces the incidence of CR-BSI, but this may reflect the heterogeneity of heparin and its administration.

Warfarin has also been evaluated as a means for reducing catheter-related thrombosis. A controlled trial of 82 patients with solid tumours were randomised to receive or not to receive low-dose warfarin (1 mg a day) beginning 3 days prior to catheter insertion and continuing for 90 days. Warfarin was shown to be effective in reducing catheter-related thrombosis.[331] In this study, warfarin was discontinued in 10% of patients due to prolongation of the prothrombin time.

Heparin versus Normal Saline Intermittent Flushes

Although many clinicians use low dose intermittent heparin flushes to fill the lumens of CVAD locked between use in an attempt to prevent thrombus formation and to prolong the duration of catheter patency, the efficacy of this practice is unproven. Despite its beneficial antithrombotic effects, decreasing unnecessary exposure to heparin is important to minimise adverse effects associated with heparin use, e.g., autoimmune-mediated heparin-induced thrombocytopenia, allergic reactions and the potential for bleeding complications following multiple, unmonitored heparin flushes.[332] The risks of these adverse effects can be avoided by using 0.9 percent sodium chloride injection instead of heparin flushes. A systematic review and meta-analysis of randomised controlled trials evaluating the effect of heparin on duration of catheter patency and on prevention of complications associated with the use of peripheral venous and arterial catheters concluded that heparin at doses of 10 U/ml for intermittent flushing is no more beneficial than flushing with normal saline alone.[333] This finding was in agreement with two other meta-analyses.[334,335] Manufacturers of implanted ports or opened-ended catheter lumens may recommend heparin flushes for maintaining catheter patency and many clinicians feel that heparin flushes are appropriate for flushing CVAD that are infrequently accessed.

HICPAC reviewed all of the evidence for intermittent heparin flushes and systemic heparin and warfarin prophylaxis and concluded that no data demonstrated that their use reduces the incidence of CR-BSI and did not recommend them for infection prevention purposes.[209,322-329,331-335] Although their use for preventing CR-BSI remains controversial, patients who have CVAD may also have risk factors for DVT and systemic anti-coagulants may be prescribed for DVT prophylaxis. In addition, heparin flush solutions may be useful in helping to maintain patency in catheter lumens that are infrequently accessed and may also be recommended by manufacturers of implantable ports and for CVAD used for blood processing, e.g., haemodialysis or apheresis.

We did not identify and further new evidence when updating our systematic review.

CVAD 38	Preferably, sterile 0.9 percent sodium chloride for injection should be used to flush and lock catheter lumens that are in frequent use.	*Class A*
CVAD 39	When recommended by the manufacturer, implanted ports or opened-ended catheter lumens should be flushed and locked with heparin sodium flush solutions.	*Class D*
CVAD 40	Systemic anticoagulants should not be used routinely to prevent catheter-related bloodstream infection.	*Class D*

Needle-free devices require vigilance

Needle-free infusion systems have been widely introduced into clinical practice to reduce the incidence of sharp injuries and the potential for the transmission of bloodborne pathogens to healthcare worker. HICPAC examined evidence that these devices may increase the risk for CR-BSI and concluded that when they are used according to the manufacturers' recommendations, they do not substantially affect the incidence of CR-BSI.[209]

Some of the devices available are more expensive than standard devices, may not be compatible with existing equipment, and may be associated with an increase in bloodstream infection rates.[129]

CVAD 41 The introduction of new intravascular devices that include needle-free devices should be monitored for an increase in the occurrence of device associated infection. If an increase in infection rates is suspected, this should be reported to the Medicines and Healthcare products Regulatory Agency [http://www.mhra.gov.uk] *Class D/GPP*

CVAD 42 If needle-free devices are used, the manufacturer's recommendations for changing the needle-free components should be followed. *Class D/GPP*

CVAD 43 When needle-free devices are used, healthcare workers should ensure that all components of the system are compatible and secured, to minimise leaks and breaks in the system. *Class D/GPP*

CVAD 44 When needle-free devices are used, the risk of contamination should be minimised by decontaminating the access port before and after use with a single patient use application of alcoholic chlorhexidine gluconate solution (preferably 2% chlorhexidine gluconate in 70% isopropyl alcohol) unless contraindicated by the manufacturer's recommendations, in which case aqueous povidone iodine should be used. *Class D*

Change intravenous administration sets appropriately

The optimal interval for the routine replacement of intravenous (IV) solution administration sets has been examined in three well-controlled studies reviewed by HICPAC. Data from each of these studies reveal that replacing administration sets no more frequently than 72 hours after initiation of use is safe and cost-effective. When a fluid that enhances microbial growth is infused, e.g., lipid emulsions, blood products, more frequent changes of administration sets are indicated as these products have been identified as independent risk factors for CR-BSI.[209]

CVAD 45 In general, solution administration sets in continuous use need not be replaced more frequently than at 72 hour intervals unless they become disconnected or a central venous access device is replaced. *Class A*

CVAD 46 Administration sets for blood and blood components should be changed when the transfusion episode is complete or every 12 hours (whichever is sooner), or according to the manufacturer's recommendations. *Class D*

CVAD 47 Administration sets used for total parenteral nutrition infusions should generally be changed every 24 hours. If the solution contains only glucose and amino acids, administration sets in continuous use do not need to be replaced more frequently than every 72 hours. *Class D*

4.12 Areas for Further Research

This is a well researched area and few realistic research needs were identified in developing these guidelines. The following investigations, along with a health economic assessment, may inform future clinical practice.

Current issues

The effectiveness of subcutaneous low molecular weight heparins or low dose warfarin to prevent catheter thrombus, colonisation and CR-BSI.

The infection risks associated with the use of peripherally inserted central catheters (PICC).

The impact of nurse consultants (intravenous therapy) and/or intravenous therapy teams on hospital CR-BSI rates.

Emerging Technologies

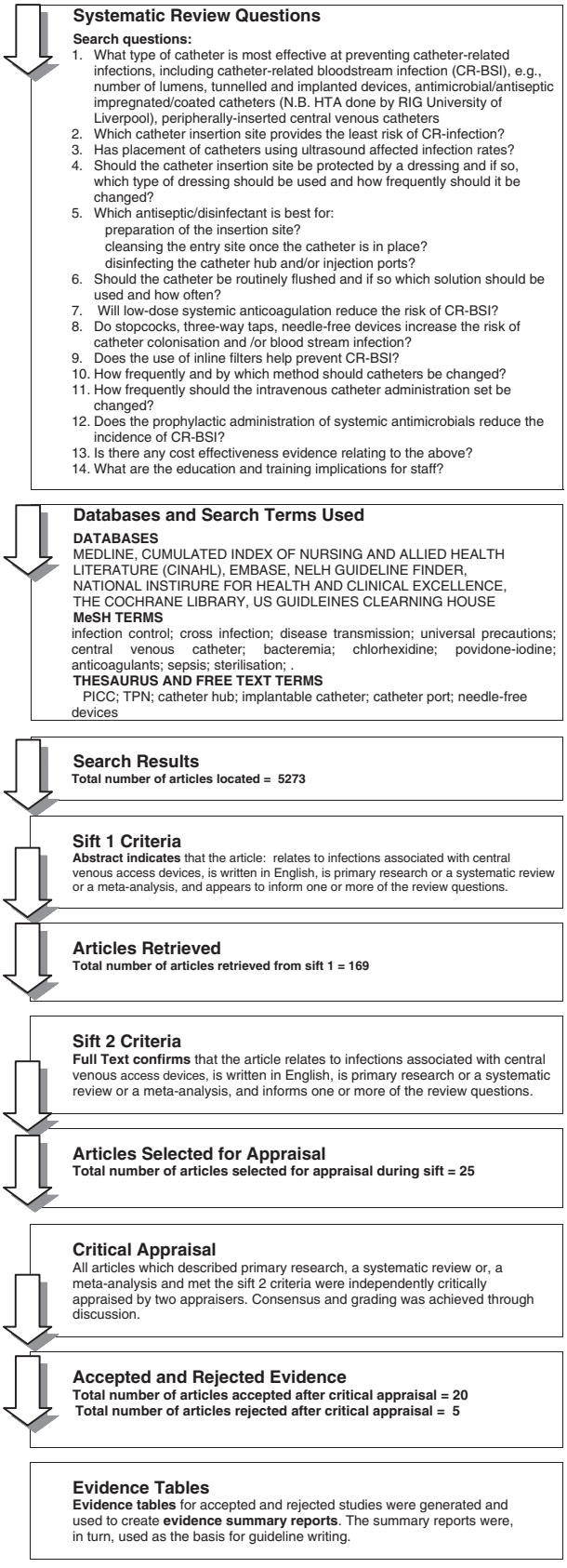
The efficacy and cost-effectiveness of anti-microbial impregnated CVAD to provide sustained protection against CRBSI in hospital patients with long term catherisation.

The efficacy and cost-effectiveness of anti-microbial impregnated catheter site dressings in preventing catheter colonisation and CR-BSI.

4.13 Key Audit Criteria

Aim	Criteria
Identify all patients with central venous catheters.	All patients should have a patient record that documents the reason for CVAD placement, type of catheter, catheter insertion site, catheter replacements and care. Standard 100% Data collection: Review of patient notes
Ensure that all healthcare workers are trained to implement these guidelines and assessed as competent. Support healthcare workers to consistently adhere to guideline recommendations.	All healthcare worker involved in the care of people with CVAD receive training and updates in the management of CVAD. Standard 100% Data collection: Review of staff education records/direct observation/self-audit
Assess the need for continuing venous access on a regular basis and remove a CVAD as soon as clinically possible in order to reduce the risk for infection.	Evidence of regular and frequent assessment of the need for CVAD and catheter discontinuation rates when the catheter is no longer essential for medical management. Standard 100% Data collection: Review of patient notes

4.14 Central Venous Access Device Systematic Review Process



5 References

1. Pratt RJ, Pellowe C, Loveday HP, Robinson N, Smith GW, and the epic guideline development team; Barrett S, Davey P, Harper P, Loveday C, McDougall C, Mulhall A, Privett S, Smales C, Taylor L, Weller B, Wilcox M. The epic Project: Developing National Evidence-based Guidelines for Preventing Healthcare associated Infections. Phase 1: Guidelines for Preventing Hospital-acquired Infections. *Journal of Hospital Infection* 2001;**47**(Supplement): S1–S82.
2. Pellowe CM, Pratt RJ, Harper P, Loveday HP, Robinson N, Jones S, MacRae ED, and the Guideline Development Group: Mulhall A, Smith G, Bray J, Carroll A, Chieveley Williams S, Colpman D, Cooper L, McInnes E, McQuarrie I, Newey JA, Peters J, Pratelli N, Richardson G, Shah PJR, Silk D, Wheatley C. Infection Control: Prevention of healthcare-associated infection in primary and community care. *Journal of Hospital Infection* 2003;**55**(Supplement 2):1–127 and *British Journal of Infection Control* 2003;**4** (Supplement):1–100.
3. Pellowe CM, Pratt RJ, Loveday HP, Harper P, Robinson N, Jones SRLJ. The *epic* project. Updating the evidence-base for national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England: a report with recommendations. *British Journal of Infection Control* 2004;**5**:10–15.
4. Pellowe CM, Pratt RJ, Loveday HP, Harper P, Robinson N, Jones SRLJ. The *epic* project. Updating the evidence-base for national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England: a report with recommendations [letter]. *Journal of Hospital Infection* 2005;**59**:373–374.
5. Centers for Disease Control and Prevention. *CDC Guidelines: Improving the Quality*. Atlanta: Centers for Disease Control and Prevention; 1996.
6. The Agree Collaboration. *Appraisal of Guidelines for Research and Evaluation (AGREE) Instrument*. St Georges Hospital Medical School; June 2001 [http://www.agreecollaboration.org].
7. SIGN. *A guideline developers' handbook (SIGN 50)*. Scottish Intercollegiate Guideline Network. 2001 (last updated May 2004) [http://www.sign.ac.uk/guidelines/fulltext/50/index.html].
8. NICE. *Guideline Development Methods: Information for National Collaborating Centres and Guideline Developers*. National Institute for Health and Clinical Excellence February 2004 (updated 2005) [www.nice.org.uk].
9. Harbour R, Miller JA. A new system for grading recommendations in evidence based guidelines. *British Medical Journal* 2001;**323**:334–336.
10. Dancer SJ. Mopping up hospital infection. *Journal of Hospital Infection* 1999;**43**:85–100.
11. Garner JS, Favero MS. CDC Guideline for Handwashing and Hospital Environmental Control, 1985. *Infection Control* 1986;**7**:231–235.
12. Working Party for Standards for Environmental Cleanliness in Hospitals. *Standards for Environmental Cleanliness in Hospitals*. Infection Control Nurses Association and the Association of Domestic Management; 1999.
13. NHS Estates. *Standards for environmental cleanliness in hospitals*. London: The Stationery Office; 2000.
14. NHS Estates. *The NHS Healthcare Cleaning Manual*. London: Department of Health; 2004.
15. Health and Safety Executive. *Safe Disposal of Clinical Waste*. London: HSE; 1999.

16. National Health Service Executive. *Hospital Laundry Arrangements for Used and Infected Linen*. HSG (95)18 Leeds: NHSE; 1995.
17. National Health Service Executive. *Hospital Catering, Delivering a Quality Service*. London: HMSO; 1989.
18. Expert Advisory group on AIDS and the Advisory group on Hepatitis. *Guidance for clinical health care workers: Protection against infection with bloodborne viruses*. London: Department of Health; 1998.
19. Microbiology Advisory Committee. *Decontamination of equipment, linen or other surfaces contaminated with Hepatitis B and/or human immunodeficiency viruses*. HC(91) 33 London: Department of Health; 1991.
20. National Health Service Executive. *A First Class Service: Quality in the new NHS*. Leeds: Department of Health; 1998.
21. Department of Health. *The Health Act 2006: Code of Practice for the Prevention and Control of Health Care Associated Infections*. London: Department of Health; 2006.
22. Griffiths R, Fernandez R, Halcomb E. Reservoirs of MRSA in the acute hospital setting: A systematic review. *Contemporary Nurse* 2002;**13**:38–49.
23. Barker J, Vipond IB, Bloomfield SF. Effects of cleaning and disinfection in reducing the spread of Norovirus contamination via environmental surfaces. *Journal of Hospital Infection* 2004;**58**:42–49.
24. Denton M, Wilcox MH, Parnell P, Green D, Keer V, Hawkey PM, Evans I, Murphy P. Role of environmental cleaning in controlling an outbreak of *Acinetobacter baumannii* on a neurosurgical unit. *Journal of Hospital Infection* 2004;**56**: 106–110.
25. Wilcox MH, Fawley WN, Wigglesworth N, Parnell P, Verity P, Freeman J. Comparison of the effect of detergent versus hypochlorite on environmental contamination and incidence of *Clostridium difficile* infection. *Journal of Hospital Infection* 2003;**54**:109–114.
26. French GL, Otter JA, Shannon KP, Adams NMT, Watling D, Parks MJ. Tackling contamination of the hospital environment by methicillin-resistant *Staphylococcus aureus* (MRSA): a comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination. *Journal of Hospital Infection* 2004;**57**:31–37.
27. Boyce JM, Potter-Bynoe G, Chenevert C, King T. Environmental contamination due to methicillin-resistant *Staphylococcus aureus*: possible infection control implications. *Infection Control and Hospital Epidemiology* 1997;**18**:622–627.
28. Oie S, Hosokawa I, Kamiya A. Contamination of room door handles by methicillin – sensitive/methicillin-resistant *Staphylococcus aureus*. *Journal of Hospital Infection* 2002;**51**:140–143.
29. Schultz M, Gill J, Zubairi S, Huber R, Gordin F. Bacterial contamination of computer keyboards in a teaching hospital. *Infection Control and Hospital Epidemiology* 2003;**24**:302–303.
30. Griffith CJ, Cooper RA, Gilmore J, Davies C, Lewis M. An evaluation of hospital cleaning regimes and standards. *Journal of Hospital Infection* 2000;**45**:19–28.
31. Brooks SE, Walczak MA, Hameed R. Chlorhexidine resistance in antibiotic resistant bacteria isolated from the surfaces of dispensers of soap containing chlorhexidine. *Infection Control and Hospital Epidemiology* 2002;**23**:692–695.
32. Rampling A, Wiseman S, Davis L, Hyett AP, Walbridge AN, Payne GC, Cornaby AJ. Evidence that hospital hygiene is important in the control of methicillin-resistant *Staphylococcus aureus*. *Journal of Hospital Infection* 2001;**49**:109–116.
33. Dettenkofer M, Wenzler S, Amthor S, Antes G, Motschall E, Daschner FD. Does disinfection of environmental surfaces influence nosocomial infection rates? A systematic review. *American Journal of Infection Control* 2004;**32**:84–89.
34. Malik RE, Cooper RA, Griffith CJ. Use of audit tools to evaluate the efficacy of cleaning systems in hospitals. *American Journal of Infection Control* 2003;**31**:181–187.
35. Microbiological Advisory Committee to the Department of Health. *Sterilisation, disinfection and cleaning of medical equipment*. London: Department of Health; 2006. ISBN 1-85-839518-6.
36. Available free of charge at: http://www.infectioncontrol.nhs.uk
37. Gupta A, Della-Latta P, Todd B, San Gabriel P, Haas J, Wu F, Rubenstien D, Saiman L. Outbreak of extended beta lactamase-producing Klebsiella pneumoniae in a neonatal intensive care unit linked to artificial nails. *Infection Control and Hospital Epidemiology* 2004;**25**:210–215.
38. Pittet D, Dharan S, Touveneau S, Sauvan V, Perneger T. Bacterial contamination of the hands of hospital staff during routine patient care. *Archives of Internal Medicine* 1999;**159**:821–826.
39. Pessoa-Silva CL, Dharan S, Hugonnet S, Touveneau S, Posfay-Barbe K, Pfister R, Pittet D. Dynamics of bacterial hand contamination during routine neonatal care. *Infection Control and Hospital Epidemiology* 2004;**25**: 187–188.
40. Fendler EJ, Ali Y, Hammond BS, Lyons MK, Kelley MB, Vowell NA. The impact of alcohol hand sanitizer use on infection rates in an extended care facility. *American Journal of Infection Control* 2002;**30**:226–233.
41. Ryan MAK, Christian RS, Wohlrabe J. Handwashing and respiratory illness among young adults in military training. *American Journal of Preventative Medicine* 2001;**21**:79–83.
42. Pittet D, Hugonnet S, Harbarth S, Mourouga P, Sauvan V, Touveneau S. Effectiveness of a hospital wide programme to improve compliance with hand hygiene. *Lancet* 2000; **356**:1307–1312.
43. Gordin FM, Schulz ME, Huber RA, Gill JA. Reduction in nosocomial transmission of drug resistant bacteria after introduction of an alcohol-based hand rub. *Infection Control and Hospital Epidemiology* 2005;**26**:650–653.
44. Centers for Disease Control and Prevention. Guidelines for hand hygiene in health-care settings. Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *Morbidity and Mortality Weekly Report* 2002;51(No.RR-16):1-45 [http://www.cdc.gov/mmwr/PDF/rr/rr5116.pdf]
45. Lucet J-C, Rigaud M-P, Mentre F, Kassis N, Deblangy C, Andremont A Bouvet E. Hand contamination before and after different hand hygiene techniques: a randomised clinical trial. *Journal of Hospital Infection* 2002;**50**:276–280.
46. Winnefeld M, Richard MA, Drancourt M, Grob JJ. Skin tolerance and effectiveness of two hand decontamination procedures in everyday hospital use. *British Journal of Dermatology* 2000;**143**:546–550.
47. Larson E, Aiello AE, Bastyr J, Lyle C, Stahl J, Cronquist A, *et al*. Assessment of two hand hygiene regimens for intensive care unit personnel. *Critical Care Medicine* 2001;**29**:944–951.
48. Girou E, Loyeau S, Legrand P, Oppein F, Brun-Buisson C. Efficacy of handrubbing with alcohol based solution versus standard handwashing with antiseptic soap: randomised clinical trial. *British Medical Journal* 2002;**325**:362–365.

49. Zaragoza M, Salles M, Gomez J, Bayas JM, Trilla A. Hand-washing with soap or alcoholic solutions? A randomized clinical trial of its effectiveness. *American Journal of Infection Control* 1999;**27**:258–261.
50. Larson EL, Cimiotti J, Haas J, Parides M, Nesin M, Della-Latta P, Saiman L. Effect of antiseptic handwashing vs alcohol sanitizer on health care- associated infections in neonatal intensive care units. *Archives of Paediatric and Adolescent Medicine* 2005;**159**:377–383.
51. Herruzo-Cabrera R, Garcia-Caballero J, Martin-Moreno JM, Graciani-Perez-Regadera MA, Perez-Rodriguez J. Clinical assay of N-duopropenide alcohol solution on hand application in newborn and pediatric intensive care units: Control of an outbreak of multiresistant *Klebsiella pneumoniae* in a newborn intensive care unit with this measure. *American Journal of Infection Control* 2001;**29**: 162–167.
52. Herruzo-Cabrera R, Garcia-Caballero J, Fernandez-Acenero MJ. A new alcohol solution (N-duopropenide) for hygienic (or routine) hand disinfection is more useful than classic handwashing: in vitro and in vivo studies in burn and other intensive care units. *Burns* 2001;**27**:747–752.
53. Larson E, Silberger M, Jakob K, Whittier S, Lai L, Latta PD, *et al*. Assessment of alternative hand hygiene regimens to improve skin health among neonatal intensive care unit nurses. *Heart and Lung* 2000;**29**:136–142.
54. Kramer A, Rudolph P, Kampf G, Pittet D. Limited efficacy of alcohol-based hand gels. *Lancet* 2002;**359**:1489–1490.
55. Moadab A, Rupley KF, Wadhams P. Effectiveness of a non-rinse alcohol-free antiseptic hand wash. *Journal of the American Podiatric Medical Association* 2001;**91**:288–293.
56. Guilhermetti M, Hernandes SED, Fukushigue Y, Garcia LB, Cardoso CL. Effectiveness of hand-cleansing agents for removing Methicillin-Resistant *Staphylococcus aureus* from contaminated hands. *Infection Control and Hospital Epidemiolgy* 2001;**22**:105–108.
57. Paulson DS, Fendler EJ, Dolan MJ, Williams RA. A close look at alcohol gel as an antimicrobial sanitizing agent. *American Journal of Infection Control* 1999;**27**:332–338.
58. Cardoso CL, Pereira HH, Zequim JC, Guilhermetti M. Effectiveness of hand-cleansing agents for removing *Acinetobacter baumannii* strain from contaminated hands. *American Journal of Infection Control* 1999;**27**: 327–331.
59. Kampf G, Jarosch R, Ruden H. Limited effectiveness of chlorhexidine based hand disinfectants against Methicillin-Resistant *Staphylococcus aureus* (MRSA). *Journal of Hospital Infection* 1998;**38**:297–303.
60. Dyer DL, Gerenraich KB, Wadhams PS. Testing a new alcohol-free hand santitizer to combat infection. *AORN Journal* 1998;**68**:239–251.
61. Dharan S, Hugonnet S, Sax H, Pittet D. Comparison of waterless hand antisepsis agents at short application times: raising the flag of concern. *Infection Control and Hospital Epidemiology* 2003;**24**:160–164.
62. Sickbert-Bennett EE, Weber DJ, Gergen-Teague MF, Sobsey MD, Samsa GP, Rutala WA. Comparative efficacy of hand hygiene agents in the reduction of bacteria and viruses. *American Journal of Infection Control* 2005;**33**:67–77.
63. Faoagali JL, George N, Fong J, Davy J, Dowser M. Comparison of the antibacterial efficacy of 4% chlorhexidine gluconate and 1% triclosan handwash products in an acute clinical ward. *American Journal of Infection Control* 1999;**27**:320–326.
64. Storr J, Bowler I. Hand Hygiene Project. Unpublished document. Acknowledgement, Julie Storr, National Patient Safety Agency. July 2002.
65. Trick WE, Vernon MO, Hayes RA. Impact of ring wearing on hand contamination and comparison of hand hygiene agents in a hospital. *Clinical Infectious Diseases* 2003;**36**: 1383–1390.
66. Gustafson DR, Vetter EA, Larson DR, Ilstrup DM, Maker MD, Thompson RL, *et al*. Effects of 4 hand-drying methods for removing bacteria from washed hands: A randomised trial. *Mayo Clinic Proceedings* 2000;**75**:705–708.
67. Yamaoto Y, Kazuhiro U, Takahashi Y. Efficiency of hand drying for removing bacteria from washed hands: comparison of paper towel drying with warm air drying. *Infection Control and Hospital Epidemiology* 2005;**26**: 316–320.
68. Boyce JM, Kelliher S, Vallande N. Skin irritation and dryness associated with two hand-hygiene regimens: Soap-and-water hand washing versus hand antisepsis with an alcoholic hand gel. *Infection Control and Hospital Epidemiology* 2000;**21**:442–448.
69. Forrester BG, Roth VS. Hand dermatitis in intensive care units. *Journal of Environmental Medicine* 1998;**40**:881–885.
70. Kampf G, Muscatiello M. Dermal tolerance of sterillium, a propanol-based hand rub. *Journal of Hospital Infection* 2003;**55**:295–298.
71. Pietsch H. Hand antiseptics: rubs versus scrubs, alcohol solutions versus alcoholic gels. *Journal of Hospital Infection* 2001;**48**(Supplement A):S33–S36.
72. Naikoba S, Hayward A. The effectiveness of interventions aimed at increasing handwashing in healthcare workers – a systematic review. *Journal of Hospital Infection* 2001; **47**:173–180.
73. Hilburn J, Hammond BS, Fendler EJ, Groziak PA. Use of alcohol hand sanitizer as an infection control strategy in an acute care facility. *American Journal of Infection Control* 2003;**31**:109–116.
74. Rosenthal VD. Guzman S, Safdar N. Reduction in nosocomial infection with improved hand hygiene in intensive care units of a tertiary care hospital in Argentina. *American Journal of Infection Control* 2005; **33**:392–397.
75. Rosenthal VD, McCormick RD, Guzman S, Villamayor C, Orellano PW. Effect of education and performance feedback on handwashing: the benefit of administrative support in Argentinean hospitals. *American Journal of Infection Control* 2003;**31**:85–92.
76. Won SP, Chou HC, Hsieh WS, Chen CY Huang SM, Tsou KI, Tsao PN. Handwashing programme for the prevention of nosocomial infections in a neonatal intensive care unit. *Infection Control and Hospital Epidemiology* 2004;**25**: 742–746.
77. Macdonald A, Dinah F, Mackenzie D, Wilson A. Performance feedback of hand hygiene, using alcohol hand gel as the skin decontaminant, reduces the number of inpatients newly affected by MRSA and antibiotic costs. *Journal of Hospital Infection* 2004;**56**:56–63.
78. Wendt C, Knautz D, Baum H. Differences in hand hygiene behaviour related to the contamination risk of healthcare activities in different groups of healthcare workers. *Infection Control and Hospital Epidemiology* 2004;**25**: 203–206.
79. Cohen B, Saiman L, Cimmiotti J, Larson E. Factors associated with hand hygiene practices in two neonatal intensive care units. *The Paediatric Infectious Disease Journal* 2003;**22**:494–498.
80. Brown SM Lubimova AV, Khrustalyeva NM, Shulaeva SV, Tekhova I, Zueva LP, Goldmann D, O'Rourke EJ. Use of an alcohol-based hand rub and quality improvement interventions to improve hand hygiene in a Russian

neonatal intensive care unit. *Infection Control and Hospital Epidemiology* 2003;**24**:172–179.
81. Kuzu N, Ozer F, Aydemir S *et al* Compliance with hand hygiene and glove use in a university-affiliated hospital. *Infection Control and Hospital Epidemiology* 2005;**26**: 312–315.
82. Kim PW, Roghmann M, Perencevich EN *et al* Rates of hand disinfection associated with glove use, patient isolation, and changes between exposure to various body sites. *American Journal of Infection Control* 2003;**31**:97–103.
83. McGuckin M, Taylor A, Martin V, Porten L, Salcido R. Evaluation of a patient education model for increasing hand hygiene compliance in an inpatient rehabilitation unit. *American Journal of Infection Control* 2004;**32**:235–238.
84. McGuckin M. Waterman R. Storr J. Bowler ICJ. Ashby M. Topley K. Porten L. Evaluation of a patient-empowering hand hygiene programme in the UK. *Journal of Hospital Infection* 2001;**48**:222–227.
85. Clark L, Smith W, Young L. *Protective Clothing; Principles and Guidance*. London: Infection Control Nurses Association; 2002.
86. Health and Safety Executive. *Management of Health and Safety at Work Regulations*. London: HSE Books. 1999.
87. Health and Safety Executive. *Personal Protective Equipment at Work Regulations: Guidance on Regulations*. London: HSE Books. 1992.
88. Health and Safety Commission. *Control of Substances Hazardous to Health Regulations 2002. Approved Codes of Practice*. London: HSE Books. 2002.
89. Sax H, Perneger T, Hugonnet S, Herrault P, Chraiti M, Pittet D. Knowledge of standard and isolation precautions in a large teaching hospital. *Infection Control and Hospital Epidemiology* 2005;**26**:298–304.
90. Trim JC, Adams D, Elliot TSJ. Healthcare workers' knowledge of inoculation injuries and glove use. *British Journal of Nursing* 2003;**12**:215–221.
91. Ferguson KJ, Waitzkin H, Beekmann SE, Doebbeling BN. Critical incidents of nonadherence with standard precautions guidelines among community hospital-based health care workers. *Journal of General Internal Medicine* 2004;**19**:726–730.
92. British Standards Institution. *Medical Gloves for Single Use Part 1: Specification for freedom from holes*. BS-EN 455-1 London: BSI 2000.
93. British Standards Institution. *Medical Gloves for Single Use Part 2: Specification for physical properties*. BS-EN 455-2 London: BSI 2000.
94. British Standards Institution. *Medical Gloves for Single Use Part 3: Requirements and testing for biological evaluation*. BS-EN 455-3 London: BSI 2000.
95. Tenorio AR, Badri SM, Sahgal NB, Hota B, Matushek M, Hayden MK, Trenholme GM, Weinstein RA. Effectiveness of gloves in the prevention of hand carriage of vancomycin-resistant enterococcus species by health care workers after patient care. *Clinical Infectious Diseases* 2001;**32**:826–829.
96. Korniewicz DM, El-Masri M, Broyles JM. To determine the effects of gloves stress, type of material (vinyl, nitrile, copolymer, latex) and manufacturer on the barrier effectiveness of medical examination gloves. *American Journal of Infection Control* 2002;**30**:133–138.
97. Callaghan I. Bacterial contamination of nurses' uniforms: a study. *Nursing Standard* 1998;**13**:37–42.
98. Perry C, Marshall R, Jones E. Bacterial contamination of uniforms. *Journal of Hospital Infection* 2001;**48**:238–241.
99. Huntley DE, Campbell J. Bacterial contamination of scrub jackets during dental hygiene procedures. *Journal of Dental Hygiene* 1998;**72**:19–23.
100. Zachary KC, Bayne PS, Morrison VJ, Ford DS, Silver LC, Hooper DC. Contamination of gowns, gloves, and stethoscopes with vancomycin-resistant enterococci. *Infection Control and Hospital Epidemiology* 2001;**22**:560–564.
101. Webster J, Pritchard MA. Gowning by attendants and visitors in newborn nurseries for prevention of neonatal morbidity and mortality (Review). *The Cochrane Database of Systematic Reviews* 2003;**2**:1–23.
102. Puzniak LA, Leet T, Mayfield J, Kollef M, Mundy LM. To gown or not to gown: The effect on acquisition of vancomycin-resistant enterococci. *Clinical Infectious Diseases* 2002;**35**:18–25.
103. Srinivasan A, Song X, Ross T, Merz W, Brower R, Perl TM. A prospective study to determine whether cover gowns in addition to gloves decrease nosocomial transmission of vancomycin-resistant enterococci in an intensive care unit. *Infection Control and Hospital Epidemiology* 2002; **23**:424–428.
104. Garner JS, Hospital Infection Control Practices Advisory Committee. Guideline for isolation precautions in hospitals. *Infection Control and Hospital Epidemiology* 1996;**17**:53-80 and *American Journal of Infection Control* 1996;**24**:24–52.
105. National Collaborating Centre for Chronic Conditions for the National Institute for Health and Clinical Excellence. *Tuberculosis: Clinical diagnosis and management of tuberculosis, and measures for its prevention and control*. London: Royal College of Physicians 2006.
106. The Interdepartmental Working Group on Tuberculosis. *The Prevention and Control of Tuberculosis in the United Kingdom: UK Guidance on the prevention and control of transmission of 1. HIV-related tuberculosis 2. Drug-resistant, including multiple drug-resistant, tuberculosis*. London: Department of Health 1998.
107. Health and Safety Commission. *Control of Substances Hazardous to Health Regulations 1999. Approved Codes of Practice*. HSE Books; 1999.
108. Seto WH, Tsang D, Yung RWH, Ching TY, Ng TK, Ho M *et al*. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). *Lancet* 2003;**361**:1519–1520.
109. Chia SE, Koh, Fones C *et al*. Appropriate use of personal protective equipment among healthcare workers in public sector hospitals and primary healthcare polyclinics during the SARS outbreak in Singapore. *Occupational Environmental Medicine* 2004;**62**:473–477.
110. Health Services Advisory Committee. *Safe Disposal of Clinical Waste*. Sheffield: Health and Safety Executive; 1999.
111. National Audit Office. *A Safer Place to Work: improving the Management of Health and Safety Risks to Staff in NHS Trusts*. London: The Stationery Office; 2003.
112. Watterson L. Monitoring sharps injuries: EPINet™ surveillance results. *Nursing Standard* 2004:**19**;33–38.
113. Health Protection Agency. *Eye of the Needle: United Kingdom Surveillance of Significant Occupational Exposure to Bloodborne Viruses in Healthcare Workers*. Centre for Infections; London: Health Protection Agency; November 2006 [http://www.hpa.org.uk/infections/topics_az/bbv/s_report.htm].
114. Center for Disease Control and Prevention. *Workbook for Designing, Implementing and Evaluating a Sharps Injury Prevention Program*. 2006 [http://www.cdc.gov/sharpssafety/workbook.html]
115. Ward V, Wilson J, Taylor L, Cookson B, Glynn A. *Preventing Hospital-acquired Infection: Clinical Guidelines*. London: Public Health Laboratory Service; 1997.

116. Centers for Disease Control. Update. Universal Precautions for prevention of transmission of human immunodeficiency virus, hepatitis B virus and other blood borne pathogens in health care settings. *Morbidity and Mortality Weekly Report* 1988;**37**:24.
117. Occupational Safety and Health Administration. *Enforcement procedures for the occupational exposure to bloodborne pathogens*. Directive number CPL2-2.44D; 1999.
118. Expert Advisory Group on AIDS. *HIV Post-exposure Prophylaxis*. London: Department of Health; 2000 [http://www.infectioncontrol.nhs.uk].
119. Department of Health. *An organisation with a memory*. London: Stationery Office; 2000.
120. NHS Employees. *The Management of Health Safety and Welfare: Issues for NHS staff*. London: Stationery Office; 2005.
121. ECRI. *Sharps safety and needlestick prevention*. 2nd edition. Plymouth: 2003 [http://www.ecri.org].
122. Asai T, Hidaka I, Kawashima A, Miki T, Inada K, Kawachi S. Efficacy of catheter needles with safeguard mechanisms. *Anaesthesia* 2002;**57**:572–577.
123. Sohn S, Eagan J, Sepkowitz, K A., Zuccotti G. Effect of implementing safety- engineered devices on percutaneous injury epidemiology. *Infection Control and Hospital Epidemiology* 2004;**25**:536–542.
124. Alvarado-Ramy F, Beltrami EM, Short LJ, Srivastava PU, Henry K, Mendleson M, Gerberding JL, Delclos GL, Campbell S, Solomon R, Fahrner R, Culver DH, Bell D, Cardo DM, Chamberland ME. A comprehensive approach to percutaneous injury prevention during phlebotomy: Results of a multicenter study, 1993-1995. *Infection Control and Hospital Epidemiology* 2003; **24**:97–104.
125. Rogues A M, Verdun-Esquer C, Buisson-Valles I, Laville MF, Lasheras A, Sarrat A, Beaudelle H, Brochard P, Gachie JP. Impact of safety devices for preventing percutaneous injuries related to phlebotomy procedures in health care workers. *American Journal of Infection Control* 2004;**32**: 441–444.
126. Mendelson MH, Lin-Chen BY, Solomon R, Bailey E, Kogan G, Goldbold J. Evaluation of a safety resheathable winged steel needle for prevention of percutaneous injuries associated with intravascular-access procedures among healthcare workers. *Infection Control and Hospital Epidemiology* 2003;**24**:105–112.
127. Adams D, Elliott TSJ. A comparative user evaluation of three needle-protective devices. *British Journal of Nursing* 2003;**12**:470–474.
128. Cullen BL, Genasi F, Symington I, Bagg J, McCreadie M, Taylor A, Henry M, Hutchinson SJ, Goldberg D. Potential for reported needlestick injury prevention among healthcare workers through safety devices usage and improvement of guideline adherence: expert panel assessment. *Journal of Hospital Infection* 2006;**63**:445–451.
129. Centers for Disease Control. Evaluation of safety devices for preventing percutaneous injuries among health care workers during phlebotomy procedures – Minneapolis-St Paul, New York City, and San Francisco, 1993-1995. *Morbidity and Mortality Weekly Report* 1997;**46**:21–25.
130. National Institute for Occupational Safety and Health. *Preventing Needlestick Injuries in Health Care Settings*. Cincinnati: DHHS (NIOSH); 1999.
131. NHS Purchasing and Supply Agency. *Sharps and needlestick interactive website 2006*. [http://www.pasa.doh.gov.uk]
132. Department of Health. *Winning Ways: Working together to reduce Healthcare Associated Infection in England*. Report from the Chief Medical Officer. London: Department of Health; 2002.
133. Baird DR, Henry M, Liddell KG, Mitchell CM, Sneddon JG. Post-operative endophthalmitis: the application of hazard analysis critical control points (HACCP) to an infection control problem. *Journal of Hospital Infection* 2001;**49**: 14–22.
134. Wong ES, Hooton TM. Guideline for prevention of catheter-associated urinary tract infections. *American Journal of Infection Control* 1983;**11**:28–36.
135. Dieckhaus KD, Garibaldi RA. Prevention of Catheter-Associated Urinary Tract Infections. In: Abrutytn E, Goldmann DA, Scheckler WE (eds). *Saunders Infection Control Reference Service*. Philadelphia: W.B. Saunders Co.; 1998: 169–174.
136. Kunin CM. *Urinary Tract Infections: Detection, Prevention, and Management* 5th ed. Baltimore MD: Williams and Wilkins; 1997.
137. Stamm WE. Urinary Tract Infections. In: Bennett JV, Brachman PS (eds). *Hospital Infection* 4th ed. Philadelphia: Lippincott-Raven; 1998: 477–485.
138. Garibaldi RA, Burke JP, Britt MR, Miller WA, Smith CB. Meatal colonisation and catheter associated bacteriuria. *New England Journal of Medicine* 1980;**303**:316–18.
139. Garibaldi RA, Mooney BR, Epstein BJ, Britt MR. An evaluation of daily bacteriologic monitoring to identify preventable episodes of catheter-associated urinary tract infections. *Infection Control* 1982;**3**:466.
140. Saint S, Lipsky BA. Preventing Catheter-Related Bacteriuria: Should We? Can We? How? *Archive of Internal Medicine* 1999;**159**:800–808.
141. Dougherty L, Lister S (eds). *The Royal Marsden Manual of Clinical Nursing Procedures* 6th ed. Oxford: Blackwell Publishing; 2004: 339.
142. Cornia PB, Amory JK, Shelagh F, Saint S, and Lipsky BA. Computer-based order entry decreases duration of indwelling urinary catheterisation in hospitalised patients. *American Journal of Medicine* 2003;**114**:404–407.
143. Lopez-Lopez G, Pascual A, Martinez-Martinez L, Perea EJ. Effect of a siliconized latex urinary catheter on bacterial adherence and human neutrophil activity. *Diagnostic Microbiology and Infectious Disease* 1991;**14**:1–6.
144. Nickel JC, Feero P, Costerton JW, Wilson E. Incidence and importance of bacteriuria in postoperative short-term urinary catheterisation. *Canadian Journal of Surgery* 1989;**32**:131–132.
145. Talja M, Korpela A, Jarvi K. Comparison of urethral reaction to full silicone, hydrogen-coated and siliconised latex catheters. *British Journal of Urology* 1990;**66**: 652–657.
146. Riley DK, Classen DC, Stevens LE, Burke JP. A large randomised clinical trial of a silver-impregnated urinary catheter: lack of efficacy and staphylococcal super-infection. *American Journal of Medicine* 1995;**98**: 349–356.
147. Johnson JR, Roberts PL, Olsen RJ, Moyer KA, Stamm WE. Prevention of catheter-associated urinary tract infection with a silver oxide-coated urinary catheter: clinical and microbiologic correlates. *Journal of Infectious Diseases* 1990;**162**:1145–150.
148. Liedberg H, Lundeberg T, Ekman P. Refinements in the coating of urethral catheters reduces the incidence of catheter-associated bacteriuria. An experimental and clinical study. *European Urology* 1990;**17**:236–240.
149. Liedberg H, Lundeberg T. Silver alloy coated catheters reduce catheter-associated bacteriuria. *British Journal of Urology* 1990;**65**:379–381.
150. Saint S, Elmore JG, Sullivan SD, Emerson SS, Koepsell TD. The efficacy of sliver alloy-coated urinary catheters in

preventing urinary tract infection: A meta-analysis. *American Journal of Medicine* 1998;**105**:236–241.
151. Brosnahan J, Jull A, Tracy C. *Types of urethral catheters for management of short-term voiding problems in hospitalised adults. (Cochrane Review). The Cochrane Library* (Issue 1). Chichester: John Wiley and Sons; 2004.
152. Johnson JR, Kuskowski MA, Wilt TJ. Systematic Review: Antimicrobial Urinary Catheters To Prevent Catheter-Associated Urinary Tract Infection in Hospitalized Patients. A*nnals of Internal Medicine* 2006;**144**:116–126.
153. Dunn S, Pretty L, Reid H, Evans D. *Management of short term indwelling urethral catheters to prevent urinary tract infections. A Systematic Review.* Australia: The Joanna Briggs Institute for Evidence Based Nursing and Midwifery; 2000.
154. Niel-Weise BS, Arend SM, van den Broek PJ. Is there evidence for recommending silver-coated urinary catheters in guidelines? *Journal of Hospital Infection* 2002;**52**:81–87.
155. Verleyen P, De Ridder D, Van Poppel H, Baert L. Clinical application of the Bardex IC Foley Catheter. *European Urology* 1998;**36**:240–246.
156. Karchmer TB, Giannetta ET, Muto CA, Strain BA, Farr BM. A Randomized Crossover Study of Silver-Coated Urinary Catheters in Hospitalized Patients. *Archives Internal Medicine* 2000;**160**,3294–3298.
157. Saint S, Veenstra DL, Sullivan SD, Chenoweth C, Fendrick M. The potential clinical and economic benefits of silver alloy urinary catheters in preventing urinary tract infection. *Archives Internal Medicine* 2000;**160**:2670–2675.
158. Newton T, Still JM, Law E. A comparison of the effect of early insertion of standard latex and silver impregnated latex Foley catheters on urinary tract infections in burn patients. *Infection Control and Hospital Epidemiology* 2002;**23**:217–218.
159. Gentry H, Cope S. Using silver to reduce catheter-associated urinary tract infections, *Nursing Standard* 2005;**19**:51–54.
160. Madeo M, Davies D, Johnson G, Owen E, Wadsworth P, Martin CR. The impact of using silver alloy urinary catheters in reducing the incidence of urinary tract infections in the critical care setting. *British Journal of Infection Control* 2004;**5**:21–24.
161. Rupp ME, Fitzgerald T, Marion N, Helget V, Puumala S, Anderson JR, Fey PD. Effect of silver-coated urinary catheters: efficacy, cost-effectiveness, and antimicrobial resistance. *American Journal of Infection Control* 2004; **32**:445–50.
162. Chaiban G, Hanna H, Dvorak T, Raad I. A rapid method of impregnating endotracheal tubes and urinary catheters with gendine: a novel antiseptic agent. *Journal of Antimicrobial Chemotherapy* 2000;**55**:51–56.
163. Cho YW, Park JH, Kim SH, Cho Y H, Choi JM, Shin HJ, Bae YH, Chung H, Jeong SY, Kwon IC. Gentamicin-releasing urethral catheter for short-term catheterization. *Journal of Biomaterials Science*, Polymer Edition 2003;**14**:963–972.
164. Thibon P, Le Coutour X, Leroyer R, Fabry J. Randomized multi-centre trial of the effects of a catheter coated with hydrogel and silver salts on the incidence of hospital-acquired urinary tract infections. *Journal of Hospital Infection* 2000;**45**:117–124.
165. Lai KK. Use of silver-hydrogel urinary catheters on the incidence of catheter-associated urinary tract infections in hospitalized patients. *American Journal of Infection Control* 2002;**30**:221–225.
166. Gaonkar TA, Sampath LA, Modak SM. Evaluation of the antimicrobial efficacy of urinary catheters impregnated with antiseptics in an in vitro urinary tract model. *Infection Control and Hospital Epidemiology* 2003;**24**: 506–513.
167. Darouche RO, Smith JA, Hanna H, Dhabuwala CB, Steiner MS, Babaian RJ, Boone TB, Scardino PT, Thornby JI, Raad II. Efficacy of antimicrobial-impregnated bladder catheters in reducing catheter-associated bacteriuria: a prospective, randomized, multicenter clinical trial. *Urology* 1999;**54**:976–981.
168. Al-Habdan I, Sadat-Ali M, Corea JR, Al-Othman A, Kamal BA, Shriyan DS. Assessment of nosocomial urinary tract infections in orthopaedic patients: a prospective and comparative study using two different catheters. *International Surgery* 2003; 88(3):152–154.
169. Pomfret IJ. Continence clinic. Catheters: design, selection and management. *British Journal of Nursing* 1996;**5**: 245–251.
170. Roe BH, Brocklehurst JC. Study of patients with indwelling catheters, *Journal of Advanced Nursing* 1987;**12**:713–718.
171. Kass EH, Schneiderman LJ. Entry of bacteria into the urinary tract of patients with inlying catheters. *New England Journal of Medicine* 1957;**256**:556–557.
172. Desautels RF, Walter CW, Graves RC, Harrison JH. Technical advances in the prevention of urinary tract infection. *Journal of Urology* 1962;**87**:487–490.
173. Kunin CM, McCormack RC. Prevention of catheter-induced urinary tract infections by sterile closed drainage. *New England Journal of Medicine* 1966;**274**:1155–1162.
174. Garibaldi RA, Burke JP, Dickman ML, Smith CB. Factors predisposing to bacteriuria during indwelling urethral catheterisation. *New England Journal of Medicine* 1974; **291**:215–218.
175. Thornton GF, Andriole VT. Bacteriuria during indwelling catheter drainage: II. Effect of a closed sterile draining system. *Journal of the American Medical Association* 1970;**214**:339.
176. Gillespie WA, Simpson RA, Jones JE, Nashef L, Teasdale C, Speller DC. Does the addition of disinfectant to urine drainage bags prevent infection in catheterised patients? *Lancet* 1983;**1**:1037–1039.
177. Gillespie WA, Lennon GG, Linton KB, Slade N. Prevention of urinary infections in gynaecology. *British Medical Journal* 1964;**2**:423–425.
178. Platt R, Murdock B, Polk BF, Rosner B. Reduction of mortality associated with nosocomial urinary tract infection. *Lancet* 1983;**1**:893–897.
179. Keerasuntonpong A, Thearawiboon W, Panthawanan A., Judaeng T, Kachintorn K, Jintanotaitavorn D, Suddhisanont L, Waitayapiches S, Tiangrim S, and Thamlikitkul V. Incidence of urinary tract infections in patients with short-term indwelling urethral catheters: a comparison between a 3-day urinary drainage bag change and no change regimens. *American Journal of Infection Control* 2003;**31**:9–12.
180. Maizels M, Shaeffer AJ. Decreased incidence of bacteriuria associated with periodic instillations of hydrogen peroxide into the urethral catheter drainage bag. *Journal of Urology* 1980;**123**:841–845.
181. Sweet DE, Goodpasture HC, Holl K, Smart S, Alexander H, Hedari A. Evaluation of H2O2 prophylaxis of bacteriuria inpatients with long-term indwelling Foley catheters: a randomised controlled study. *Infection Control* 1985;**6**: 263–266.
182. Thompson RL, Haley CE, Searcy MA, Guenthner SM, Kaiser DL. Catheter-associated bacteriuria. Failure to reduce attack rates using periodic instillations of a disinfectant into urinary drainage systems. *Journal of the American Medical Association* 1984;**251**:747–751.

183. Cleland V, Cox F, Berggren H, MacInnis MR. Prevention of bacteriuria in female patients with indwelling catheters. *Nursing Research* 1971;**20**:309–318.
184. Burke JP, Garibaldi RA, Britt MR. Prevention of catheter-associated urinary tract infections. Efficacy of daily meatal care regimens. *The American Journal of Medicine* 1981;**70**:655–658.
185. Burke JP, Jacobson JA, Garibaldi RA, Conti MT, Alling DW. Evaluation of daily meatal care with poly-antibiotic ointment in the prevention of urinary catheter-associated bacteriuria. *Journal of Urology* 1983;**129**;331–334.
186. Classen DC, Larsen RA, Burke JP, Stevens LE. Prevention of catheter-associated bacteriuria: clinical trial of methods to block three known pathways of infection. *American Journal of Infection Control* 1991;**19**:136–142.
187. Classen DC, Larsen RA, Burke JP, Alling DW, Stevens LE. Daily meatal care for the prevention of catheter-associated bacteriuria: results using frequent applications of poly-antibiotic cream. *Infection Control and Hospital Epidemiology* 1991;**12**:157–162.
188. Huth TS, Burke JP, Larsen RA, Classen DC, Stevens LE. Randomized trial of meatal care with silver sulfadiazine cream for the prevention of catheter-associated bacteriuria. *Journal of Infectious Diseases* 1992;**165**:14–18.
189. Webster J, Hood RH, Burridge CA, Doidge ML, Phillips KM, George N. Water or antiseptic for periurethral cleaning before urinary catheterization: A randomized controlled trial. *American Journal of Infection Control* 2001;**29**: 389–394.
190. Davies AJ, Desai HN, Turton S, Dyas A. Does instillation of chlorhexidine into the bladder of catheterized geriatric patients help reduce bacteriuria? *Journal of Hospital Infection* 1987;**9**:72–75.
191. Ball AJ, Carr TW, Gillespie WA, Kelly M, Simpson RA, Smith PJ. Bladder irrigation with chlorhexidine for the prevention of urinary infection after transurethral operations: a prospective controlled study. *Journal of Urology* 1987; **138**:491–494.
192. Jones MA, Hasan A. Controlled trial of intravesical noxythiolin in the prevention of infection following outflow tract surgery. *British Journal of Urology* 1988; **62**:311–314.
193. Schneeberger PM, Vreede RW, Bogdanowicz JF, van Dijk WC. A randomised study on the effect of bladder irrigation with povidone-iodine before removal of an indwelling catheter. *Journal of Hospital Infection* 1992;**21**:223–229.
194. Warren JW, Platt R, Thomas RJ, Rosner B, Kass EH. Antibiotic irrigation and catheter-associated urinary-tract infections. *New England Journal of Medicine* 1978;**299**: 570–573.
195. Muncie HLJ, Hoopes JM, Damron DJ, Tenney JH, Warren JW. Once-daily irrigation of long-term urethral catheters with normal saline. Lack of benefit. *Archives of Internal Medicine* 1989;**149**:441–443.
196. Kennedy AP, Brocklehurst JC, Robinson JM, Faragher EB. Assessment of the use of bladder washouts/instillations in patients with long-term indwelling catheters. *British Journal of Urology* 1992;**70**:610–615.
197. Cox F, Smith RF, Elliott JP, Quinn EL. Neomycin-polymyxin prophylaxis of urinary-tract infection associated with indwelling catheters. *Antimicrobial Agents and Chemotherapy* 1966;**6**:165–168.
198. Getliffe KA. The Use of Bladder Wash-Outs to Reduce Urinary Catheter Encrustation. *British Journal of Urology* 1994;**73**:696–700.
199. Kennedy AP, Brocklehurst JC. Assessment of the Use of Bladder Washouts/Instillations in Patients with Long-term Indwelling Catheters. *British Journal of Urology* 1992;**70**: 610–615.
200. Getliffe KA, Hughes SC, Le Claire M. The dissolution of urinary catheter encrustation. *British Journal of Urology International* 2000;**85**:60–64.
201. Emmerson AM, Enstone JE, Griffin M, Kelsey MC, Smyth ETM. The second national prevalence survey of infection in hospital – overview of results. *Journal of Hospital Infection* 1996;**32**:175–190.
202. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients: excess length of stay, extra costs, and attributable mortality. *Journal of the American Medical Association* 1994;**271**:1598–1601.
203. Plowman R, Graves N, Griffin MAS, Roberts JA, Swan AV, Cookson B, Taylor L The rate and cost of hospital-acquired infections occurring in patients admitted to selected specialities of a district general hospital in England and the national burden imposed. *Journal of Hospital Infection* 2001;**47**:198–209.
204. Wenzel RP, Edmond MB The impact of hospital-acquired bloodstream infections. *Emerging Infectious Diseases* 2001;**7**:174–177.
205. Coello R, Charlett A, Ward V, Wilson J, Pearson A, Sedgwick J, Borriello P. Device-related sources of bacteraemia in English hospitals – opportunities for the prevention of hospital-acquired bacteraemia. *Journal of Hospital Infection* 2003;**53**:46–57,
206. Fletcher SJ, Bodenham AR. Catheter-related sepsis: an overview – Part 1. *British Journal of Intensive Care* 1999;**9**:46–53.
207. Farr B. Nosocomial Infections Related to Use of Intravascular Devices Inserted for Short-Term Vascular Access. In: Mayhall CG, editor. *Hospital Epidemiology and Infection Control* 2nd ed. Philadelphia: Lippincott Williams and Wilkins; 1999: p.157.
208. Pearson ML. Hospital Infection Control Practices Advisory Committee. Guideline for Prevention of Intravascular-device-related Infections. *Infection Control and Hospital Epidemiology* 1996;**17**:438–473.
209. Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular-catheter-related infections. *Morbidity and Mortality Weekly Report* 2002;51(No. RR-10):1-29 [http://www.cdc.gov/mmwr/PDF/rr/rr5110.pdf].
210. Eggimann P, Hugonnet S, Sax H, Harbarth S, Chevrolet JC, Pittet D. Long-term Reduction of Vascular Access-Associated Bloodstream Infection. *Annals of Internal Medicine* 2005;**42**:875–876.
211. Warren, DK, Zack JE, Mayfield JL, Chen A, Prentice D, Fraser VJ, Kollef MH. The effect of an education programme on the incidence of central venous catheter-associated bloodstream infection in a medical ICU. *CHEST* November 2004;**126**:1612–1618.
212. East D, Jacoby K. The Effect of a nursing staff education program on compliance with central line care policy in the cardiac intensive care unit. *Pediatric Nursing* 2005;**31**: 182–184.
213. Lobo RD, Levin AS, Brasileiro Gomes LM, Cursino R, Park M, Figueiredo VB, Taniguchi L, Polido CG, Costa SF. Impact of an educational program and policy changes on decreasing catheter-associated bloodstream infections in a medical intensive care unit in Brazil. *American Journal of Infection Control* 2005;**33**:83–87.
214. Rosenthal VD, Guzman S, Pezzotto SM, Crnich CJ. Effect of an infection control program using education and performance feedback on rates of intravascular device-associated bloodstream infections in intensive care units in Argentina. *American Journal of Infection Control* 2003; **31**:405–409.

215. Tebbs SE, Sawyer A, Elliot TSJ. Influence of surface morphology on in vitro bacterial adherence to central venous catheters. *British Journal of Anaesthesia* 1994;**72**: 587–591.
216. Pemberton LB, Lyman B, Lander V, Covinsky J. Sepsis from triple- vs single-lumen catheters during total parenteral nutrition in surgical or critically ill patients. *Archives of Surgery* 1986;**121**:591–594.
217. McCarthy MC, Shives JK, Robison RJ, Broadie TA. Prospective evaluation of single and triple lumen catheters in total parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* 1987;**11**:259–262.
218. Hilton E, Haslett TM, Borenstein MT, Tucci V, Isenberg HD, Singer C. Central catheter infections; single- versus triple-lumen catheters. Influence of guide wires on infection rates when used for replacement of catheters. *American Journal of Medicine* 1988;**84**:667–672.
219. Yeung C, May J, Hughes R. Infection rate for single-lumen vs triple-lumen subclavian catheters. *Infection Control and Hospital Epidemiology* 1988;**9**:154–159.
220. Clark-Christoff N, Watters VA, Sparks W, Snyder P, Grant JP. Use of triple-lumen subclavian catheters for administration of total parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* 1992;**16**:403–407.
221. Farkas JC, Liu N, Bleriot JP, Chevret S, Goldstein FW, Carlet J. Single-versus triple-lumen central catheter-related sepsis: a prospective randomised study in a critically ill population. *American Journal of Medicine* 1992;**93**:277–282.
222. Gil RT, Kruse JA, Thill-Baharozian MC, Carolson RW. Triple- vs single-lumen central venous catheters. A prospective study in a critically ill population. *Archives of Internal Medicine* 1989;**149**:1139–1143.
223. Dezfulian C, Lavelle J, Nallamothu BK, Kaufman SR, Saint, S. Rates of infection for single-lumen versus multilumen central venous catheters: A meta-analysis. *Critical Care Medicine* 2003:**31**:2385–2390.
224. Zürcher M, Tramèr M, Walder B. Colonization and Bloodstream Infection with Single- Versus Multi-Lumen Central Venous Catheters: A Quantitative Systematic Review. *Anesthesia and Analgesia* 2004;**99**:177–182.
225. Abraham JL, Mullen JL. A prospective study of prolonged central venous access in leukaemia. *Journal of the American Medical Association* 1982;**248**:2868–2873.
226. Shapiro ED, Wald ER, Nelson KA, Spiegelman KN. Broviac catheter-related bacteraemia in oncology patients. *American Journal of Diseases in Children* 1982;**136**:679–681.
227. Press OW, Ramsey PG, Larson EB, Fefer A, Hickman RO. Hickman catheter infections in patients with malignancies. *Medicine* 1984;**63**:189–200.
228. Darbyshire PJ, Weightman NC, Speller DC. Problems associated with indwelling central venous catheters. *Archives of Diseases in Childhood* 1985;**60**:129–134.
229. Pessa ME, Howard RJ. Complications of Hickman-Broviac catheters. *Surgical Gynecology Obstetrics* 1985;**161**: 257–260.
230. Schuman ES, Winters V, Gross GF, Hayes JF. Management of Hickman catheter sepsis. *American Journal of Surgery* 1985;**149**:627–628.
231. Rannem T, Ladefoged K, Tvede M, Lorentzen JE, Jarnum S. Catheter-related septicemia in patients receiving home parenteral nutrition. *Scandinavavian Journal of Gastroenterology* 1986;**21**:455–460.
232. Shulman RJ, Smith EO, Rahman S, Gardner P, Reed T, Mahoney D. Single- vs double-lumen central venous catheters in pediatric oncology patients. *American Journal of Diseases in Children* 1988;**142**:893–895.
233. Weightman NC, Simpson EM, Speller DC, Mott MG, Oakhill A. Bactermia related to indwelling central venous catheters: prevention, diagnosis, and treatment. *European Journal of Clinical Microbiology and Infectious Diseases* 1988;**7**:125–129.
234. Raad I, Davis S, Becker M, *et al*. Low infection rate and long durability of nontunneled silastic catheters. A safe cost-effective alternative for long-term venous access. *Archives of Internal Medicine* 1993;**153**:1791–1796.
235. Andrivet P, Bacquer A, Ngoc CV, *et al*. Lack of clinical benefit from subcutaneous tunnel insertion of central venous catheters in immunocompromised patients. *Clinical Infectious Diseases* 1994;**18**:199–206.
236. Gyves J, Ensminger W, Niederhuber J, *et al*. A totally-implanted injection port system for blood sampling and chemotherapy administration. *Journal of the American Medical Association* 1984;**251**:2538–2541.
237. Lokich JJ, Bothe AJ, Benotti P, Moore C. Complications and management of implanted venous access catheters. *Journal of Clinical Oncology* 1985;**3**:710–717.
238. Khoury MD, Lloyd LR, Burrows J, Berg R, Yap J. A totally implanted venous access system for the delivery of chemotherapy. *Cancer* 1985;**56**:1231–1234.
239. McDowell HP, Hart CA, Martin J. Implantable subcutaneous venous catheters. *Archives of Diseases in Childhood* 1986; **61**:1037–1038.
240. Brickner H, Saeter G. Fifty-five patient years' experience with a totally implanted system for intravenous chemotherapy. *Cancer* 1986;**57**:1124–1129.
241. Wurzel CL, Halom K, Feldman JG, Rubin LG. Infection rates of Broviac-Hickman catheters and implantable venous devices. *American Journal of Diseases in Children* 1988;**142**:536–540.
242. Kappers-Klunne MC, Degener JE, Stijnen T, Abels J. Complications from long-term indwelling central venous catheters in hematologic malignancy patients with special reference to infection. *Cancer* 1989;**64**:1747–1752.
243. Carde P, Cosset-Delaigue MF, Laplanche A, Chareau I. Classical external indwelling central venous catheter versus total implanted venous access systems for chemotherapy administration. A randomised trial in 100 patients with solid tumors. *European Journal of Cancer and Clinical Oncology* 1989;**25**:939–944.
244. Pegues D, Axelrod P, McClarren C, *et al*. Comparison of infections in Hickman and implanted port catheters in adult solid tumor patients. *Journal of Surgical Oncology* 1992;**49**:156–162.
245. van der Pijl H, Frissen PH. Experience with a totally implantable venous access device (Port-A-Cath) in patients with AIDS. *AIDS* 1992;**6**:709–713.
246. Groeger JS, Lucas AB, Thaler HT, *et al*. Infectious morbidity associated with long-term use of venous access devices in patients with cancer. *Annals of Internal Medicine* 1993;**119**:1168–1174
247. Timsit JF, Sebille V, Farkas JC, Misset B, Martin JB, Chevret S, *et al*. Effects of subcutaneous tunneling on internal jugular catheter-related sepsis in critically ill patient: a prospective randomised multicenter study. *Journal of the American Medical Association* 1996;**276**:1416–1420.
248. Timsit JF, Bruneel F, Cheval C, Mamzer MF, Garrouster-Orgeas M, Wolff M, *et al*. Use of tunneled femoral catheters to prevent catheter-related infection: a randomised controlled trial. *Annals of Internal Medicine* 1999;**130**:729–735.
249. Randolph A, Cook D, Gonzales C, Brun-Buisson C. Tunneling short-term central venous catheters to prevent catheter-related infection: A meta-analysis of randomized

controlled trials. *Critical Care Medicine* 1998;**26**: 1452–1457.
250. Maki DG, Stolz SM, Wheeler S, Mermel LA. Prevention of central venous catheter–related bloodstream infection by use of an antiseptic-impregnated catheter. A randomized controlled trial. *Annals of Internal Medicine* 1997; **127**:257–266.
251. Logghe C, Van Ossel Ch, D'Hoore W, Ezzedine H, Wauters G, Haxhe JJ. Evaluation of chlorhexidine and silver-sulfadiazine impregnated central venous catheters for the prevention of bloodstream infection in leukaemic patients: a randomized controlled trial. *Journal of Hospital Infection* 1997;**37**:145–156.
252. Heard SO, Wagle M, Vijayakumar E, McLean S, Brueggemann A, Napolitano LM, Edwards LP, O'Connell FM, Puyana JC, Doern G. Influence of triple-lumen central venous catheters coated with chlorhexidine and sliver sulfadiazine on the incidence of catheter-related bacteremia. *Archives of Internal Medicine* 1998;**158**: 81–87.
253. Haxhe JJ, D'Hoore W. A meta-analysis dealing with the effectiveness of chlorhexidine and silver-sulfadiazine impregnated central venous catheters. *Journal of Hospital Infection* 1998;40:166-168.
254. Oda T, Hamasaki J, Kanda N, Mikami K. Anaphylactic shock induced by an antiseptic-coated central venous catheter. *Anesthesiology* 1997;**87**:1242–1244.
255. Veenstra DL, Saint S, Sullivan S. Cost-effectiveness of antiseptic-impregnated central venous catheters for the prevention of catheter-related bloodstream infection. *Journal of the American Medical Association* 1999;**282**: 554–560.
256. Raad I, Darouiche R, Dupuis J, Abi-Said D, Gabrielli A, Hachem R, Harris R, Jones J, Buzaid A, Robertson C, Shenaq S, Curling P, Burke T, Ericsson C, the Texas Medical Center Catheter Study Group. Central venous catheters coated with minocycline and rifampin for the prevention of catheter-related colonization and bloodstream infections. A randomized, double-blind trial. *Annals of Internal Medicine* 1997;**127**:267–274.
257. Colin GR. Decreasing catheter colonization through the use of an antiseptic-impregnated catheter: a continuous quality improvement project. *Chest* 1999;**115**:1632–1640.
258. Darouiche RO, Raad I, Heard S, Thornby JL, Wenker OC, Gabrielli A, Berg J, Khardori N, Hanna H, Henchem R, Harris R, Mayhall G. A comparison of two antimicrobial-impregnated central venous catheters. *New England Journal of Medicine* 1999;**340**:1–8.
259. Veenstra DL, Saint S, Saha S, Lumley T, Sullivan S. Efficacy of antiseptic-impregnated central venous catheters in preventing catheter-related bloodstream infection: a meta-analysis. *Journal of the American Medical Association* 1999;**281**:261–267.
260. Mermel LA. Prevention of intravascular catheter-related infections. *Annals of Internal Medicine* 2000;**132**:391–402.
261. Walder B, Pittet D, Tramer M. Prevention of bloodstream infections with central venous catheters treated with anti-infective agents depends on catheter type and insertion time: evidence from a meta-analysis. *Infection Control and Hospital Epidemiology* 2002;**23**:748–756.
262. Bassetti S, Hu J, D'Agostino RB Jr, Sherertz RJ. Prolonged antimicrobial activity of a catheter containing chlorhexidine/silver sulfadiazine extends protection against catheter infections in vivo. *Antimicrobial Agents and Chemotherapy* 2001;**45**:1535–1538.
263. Hockenhull JC, Dwan K, Boland A, Smith G, Bagust A, Dickson R, Dundar Y, Gambol C, McCleod C, Walley T. *The clinical and cost effectiveness of central venous catheters treated with anti-microbial agents in preventing bloodstream infections: a systematic review and economic evaluation.* Health Technology Assessment 2006 [http://www.hta.nhsweb.nhs.uk/]
264. Mermel LA, McCormick RD, Springman SR, Maki DG. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. *American Journal of Medicine* 1991;**91**(suppl 3B):S197–S205.
265. Richet H, Hubert B, Nitemberg G, *et al*. Prospective multicenter study of vascular-catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. *Journal of Clinical Microbiology* 1990;**28**:2520–2525.
266. Goetz AM, Wagener MM, Miller JM, Muder RR. Risk of infection due to central venous catheters: effect of site of placement and catheter type. *Infection Control and Hospital Epidemiology* 1998;**19**:842–845.
267. Trottier SJ, Veremakis C, O'Brien J, Auer AI. Femoral deep vein thrombosis associated with central venous catheterization: results from a prospective, randomized trial. *Critical Care Medicine* 1995;**23**:52–59.
268. Merrer J, De Jonghe B, Golliot F, *et al*. Complications of femoral and subclavian venous catheterization in critically ill patients: a randomized controlled trial. *Journal of the American Medical Association* 2001;**286**: 700–707.
269. Joynt GM, Kew J, Gomersall CD, Leung VY, Liu EK. Deep venous thrombosis caused by femoral venous catheters in critically ill adult patients. *Chest* 2000;**117**:178–183.
270. Mian NZ, Bayly R, Schreck DM, Besserman EB, Richmand D. Incidence of deep venous thrombosis associated with femoral venous catheterization. A*cademic Emergency Medicine* 1997;**4**:1118–1121.
271. Durbec O, Viviand X, Potie F, Vialet R, Albanese J, Martin C. A prospective evaluation of the use of femoral venous catheters in critically ill adults. *Critical Care Medicine* 1997;**25**:1986–1989.
272. Randolph AG, Cook DJ, Gonzales CA, Pribble CG. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Critical Care Medicine* 1996;**24**:2053–2058.
273. National Institute for Clinical Excellence. *Guidance on the use of ultrasound locating devices for placing central venous catheters (No. 49)*. September 2002 [http://www.nice.org.uk]
274. Ryder MA. Peripheral access options. *Surgical Oncology Clinics of North America* 1995;**4**;395–427.
275. Noble WC. Skin microbiology: coming of age. *Journal of Medical Microbiology* 1984;**17**:1–12.
276. Safdar N, Maki DG. Risk of catheter-related bloodstream infection with peripherally inserted central venous catheters used in hospitalized patients. *Chest* 2005;**128**: 489–495.
277. Maki DG. Yes, Virginia, aseptic technique is very important: maximal barrier precautions during insertion reduce the risk of central venous catheter-related bacteremia. *Infection Control and Hospital Epidemiology* 1994;**15**:227–230.
278. Bull DA, Neumayer LA, Hunter GC, *et al*. Improved sterile technique diminishes the incidence of positive line cultures in cardiovascular patients. *Journal of Surgical Research* 1992;**52**:106–110.
279. Raad I, Hohn DC, Gilbreath BJ, *et al*. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infection Control and Hospital Epidemiology* 1994;**15**:231–238.

280. Maki DG, Mermel LA. Infections due to Infusion Therapy. In: Bennett JV, Brachman PS, editors. *Hospital Infections* 4th ed. Philadelphia: Lippincott-Raven Publishers;1998: 709–710.
281. Raad I, Umphrey J. Catheter-Related Bloodstream Infections: Evaluation of CDC Guidelines. In: Abrutyn EA, Goldman DA, Scheckler WE, editors. *Saunders Infection Control Reference Services*. Philadelphia: WB Saunders Co.; 1998: 191–194.
282. Fletcher SJ, Bodenham AR. Catheter-related sepsis: an overview – Part 2. *British Journal of Intensive Care* 1999; **9**:74–80.
283. Hu KK, Lipsky BA, Veenstra DL, Saint S. Using maximal sterile barriers to prevent central venous catheter-related infection: A systematic evidence-based review. *American Journal of Infection Control* 2004;**32**:142–146.
284. Mimoz O, Pieroni L, Lawrence C, Edouard A, Costa Y, Samii K, Brun-Buisson C. Prospective, randomized trial of two antiseptic solutions for prevention of central venous or arterial catheter colonization and infection in intensive care unit patients. *Critical Care Medicine* 1996;**24**: 1818–1823.
285. Maki DG, Ringer M, Alvarado CJ. Prospective randomized trial of povidone-iodine, alcohol, and chlorhexidine for prevention of infection associated with central venous and arterial catheters. *Lancet* 1991;**338**:339–343.
286. Mimoz O, Pieroni L, Lawrence C, Edouard A, Costa Y, Samii K, Brun-Buisson C. Prospective, randomized trial of two antiseptic solutions for prevention of central venous or arterial catheter colonization and infection in intensive care unit patients. *Critical Care Medicine* 1996;**24**: 1818–1823.
287. Larson E. Guideline for use of topical antimicrobial agents. *American Journal of Infection Control* 1988;**16**: 253–266.
288. Rannem T, Ladefoged K, Hegnhoj F, Hylander Moller E, Bruun B, Farnum S. Catheter-related sepsis in long-term parenteral nutrition with Broviac catheters. An evaluation of different disinfectants. *Clinical Nutrition* 1990;**9**: 131–136.
289. Prager RL, Silva J. Colonization of central venous catheters. *Southern Medical Journal* 1984;**77**:458–461.
290. Moran JM, Atwood RP, Rowe MI. A clinical and bacteriologic study of infections associated with venous cutdowns. *New England Journal of Medicine* 1965;**272**:554–560.
291. Norden CW. Application of antibiotic ointment to the site of venous catheterization: a controlled trial. *Journal of Infectious Diseases* 1969;**120**:611–615.
292. Zinner SH, Denny-Brown BC, Braun P, Burke JP, Toala P, Kass EH. Risk of infection with indwelling intravenous catheters: effect of application of antibiotic ointment. *Journal of Infectious Diseases* 1969;**120**:616–619.
293. Jarrad MM, Freeman JB. The effects of antibiotic ointments and antiseptics on the skin flora beneath subclavian catheter dressings during intravenous hyperalimentation. *Journal of Surgical Research* 1977;**22**:520–526.
294. Maki DG, Band JD. A comparative study of polyantibiotic and iodophor ointment in prevention of vascular catheter-related infection. *American Journal of Medicine* 1981; **70**:739–744.
295. Chaiyakunapruk N, Veenstra DL, Lipsky BA, Saint S. Chlorhexidine compared with povidone-iodine solution for vascular catheter-site care: A meta-analysis. *Annals of Internal Medicine* 4 June 2002;**136**:792–801.
296. Langgartner J, Linde, HJ, Lehn N, Reng M, Schölmerich J, Gluck. Combined skin disinfection with chlorhexidine/ propanol and aqueous povidone-iodine reduces bacterial colonisation of central venous catheters. *Intensive Care Medicine* 2004;**30**:1081–1088.
297 Parienti JJ, du Cheyron D, Ramakers M, Malbruny B, Leclercq R, Le Coutour X, Charbonneau P, (for) Members of the NACRE Study Group. Alcoholic povidone-iodine to prevent central venous catheter colonization: a randomized unit-crossover study. *Critical Care Medicine* 2004;**32**:708–13.
298. Gillies D, O'Riordan L, Carr D, Frost J, Gunning R, O'Brien I. Gauze and tape and transparent polyurethane dressings for central venous catheters (Review). *The Cochrane Database of Systematic Reviews* 2003;**3**:1–18.
299. Miller JJ, Venus B, Mathru M. Comparison of the sterility of long-term central venous catheterisation using single-lumen, triple-lumen, and pulmonary artery catheters. *Critical Care Medicine* 1984;**12**:634–637.
300. Ullman RF, Gurevich I, Schoch PE, Cunha BA. Colonization and bacteremia related to duration of triple-lumen intravascular catheter placement. *American Journal of Infection Control* 1990;**18**:201–207.
301. Cobb DK, High KP, Sawyer RG, *et al*. A controlled trial of scheduled replacement of central venous and pulmonary artery catheters. *New England Journal of Medicine* 1992; **237**:1062–1068.
302. Michel LA, Bradpiece HA, Randour P, Pouthier F. Safety of central venous catheter change over a guide wire for suspected catheter-related sepsis: a prospective randomised trial. *International Surgery* 1988;**73**:180–186.
303. Cook D, Randolph A, Kemerman P, Cupido C, King D, Soukup C, Brun-Buisson C. Central venous catheter replacement strategies: A systematic review of the literature. *Critical Care Medicine* 1997;**25**:1417–1424.
304. Armstrong CW, Mayhall CG, Miller KB, *et al*. Prospective study of catheter replacement and other risk factors for infection of hyperalimentation catheters. *Journal of Infectious Diseases* 1986;**154**:808–816.
305. Synder RH, Archer FJ, Endy T, *et al*. Catheter infection. A comparison of two catheter maintenance techniques. *Annals of Surgery* 1988;**208**:651–653.
306. Pettigrew RA, Lang SDR, Haydock DA, Parry BR, Bremner DA, Hill GL. Catheter-related sepsis in patients on intravenous nutrition: a prospective study of quantitative catheter cultures and guide wire changes for suspected sepsis. *British Journal of Surgery* 1985;**72**:52–55.
307. Newsome HH Jr, Armstrong CW, Mayhall CG, *et al*. Mechanical complications from insertion of subclavian venous feeding catheters: comparison of de novo percutaneous venipuncture to change of catheter over guide wire. *Journal of Parenteral and Enteral Nutrition* 1984;**8**:560–562.
308. Farr BM. Accuracy and cost-effectiveness of new tests for diagnosis of catheter-related bloodstream infections. *Lancet* 1999;**354**:1487–1488.
309. Siegman-Igra Y, Anglim AM, Shapiro D, Adal KA, Strain B, Farr MB. Diagnosis of vascular catheter-related bloodstream infection: a meta-analysis. *Journal of Clinical Microbiology* 1997;**35**:928–936.
310. deCicco M, Chiaradia V, Veronesi A, *et al*. Source and route of microbial colonization of parenteral nutrition catheters. *Lancet* 1982;**2**:1258–1261.
311. Capell S, Linares J, Sitges-Serra A. Catheter sepsis due to coagulase-negative staphylococci in patients on total parenteral nutrition. *European Journal of Clinical Microbiology and Infectious Diseases*1986:**5**:40–42.
312. Salzman MB, Isenberg HD, Shapiro JF, Lipsitz PJ, Rubin LG. A prospective study of the catheter hub as the portal of entry for microorganisms causing catheter-related sepsis in neonates. *Journal of Infectious Diseases* 1993;**167**:487–490.

313. Peters G, Locci R, Pulverer G. Adherence and growth of coagulase-negative staphylococci on surfaces of intravenous catheters. *Journal of Infectious Diseases* 1982;**146**:479–482.
314. Linares J, Sitges-Serra A, Garau J, Perez JL, Martin R. Pathogenesis of catheter sepsis: a prospective study with quantitative and semiquantitative cultures of catheter hub and segments. *Journal of Clinical Microbiology* 1985; **21**:357–360.
315. Sitges-Serra A, Linares J, Perez JL, Jaurrieta E, Lorente L. A randomized trial on the effect of tubing changes on hub contamination and catheter sepsis during parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* 1985;**9**:322–325.
316. Raad I, Costerton W, Sabharwal U, Sacilowski M, Anaissie E, Bodey GP. Ultrastructural analysis of indwelling vascular catheters: a quantitative relationship between luminal colonization and duration of placement. *Journal of Infectious Diseases* 1993;**168**:400–407.
317. Weist K, Sperber A, Dietz E, Ruden H. Contamination of stopcocks mounted in administration sets for central venous catheters with replacement at 24 hrs versus 72 hrs: a prospective cohort study. *Infection Control and Hospital Epidemiology* 1997;**18**:24.
318. Salzman MB, Isenberg HD, Rubin LG. Use of disinfectants to reduce microbial contamination of hubs of vascular catheters. *Journal of Clinical Microbiology* 1993;**31**:475–479.
319. Rushman KL, Fulton JS. Effectiveness of disinfectant techniques on intravenous tubing latex injection ports. *Journal of Intravenous Nursing* 1993;**16**:304–308.
320. Casey AL, Worthington T, Lambert PA, Quinn D, Faroqui MH, Elliott TSJ. A randomized, prospective clinical trial to assess the potential infection risk associated with the PosiFlow® needleless connector. *Journal of Hospital Infection* 2003;**54**:288–293.
321. Van de Wetering MD, van Woensel JBM. Prophylactic antibiotics for preventing early central venous catheter Gram positive infections in oncology patients (Review). *The Cochrane Database of Systematic Reviews* 2003;**1**: 1–16.
322. Hoar PF, Wilson RM, Managano DT, *et al*. Heparin bonding reduces thrombogenicity of pulmonary-artery catheters. *New England Journal of Medicine* 1981;**305**:993–995.
323. Raad II,Luna M, Kahlil SA, Costerton JW, Lam C, Bradley GP. The relationship between the thrombotic and infectious complications of central venous catheters. *Journal of the American Medical Association* 1994;**271**:1014–1016.
324. Chastre J., Comud F, Bouchama A, *et al*. Thrombosis as a complication of pulmonary-artery catheterisation within the internal jugular vein. *New England Journal of Medicine* 1982;**306**:278–281.
325. Valerio D, Hussey JK, Smith FW. Central venous thrombosis associated with intravenous feeding: a prospective study. *Journal of Parenteral and Enteral Nutrition* 1981;**5**: 240–242.
326. Andrew M, Marzinotto V, Pencharz P, *et al*. A cross-sectional study of catheter-related thrombosis in children receiving total parenteral nutrition at home. *Journal of Pediatrics* 1995;**126**:358–363.
327. Krafte-Jacobs B, Sivit CJ, Mejia R, *et al*. Catheter-related thrombosis in critically ill children: comparison of catheters with and without heparin bonding. *Journal of Pediatrics* 1995;**126**:50–54.
328. Talbott GA, Winters WD, Bratton SL, *et al*. A prospective study of femoral catheter-related thrombosis in children. Archives of Pediatric and Adolescent Medicine 1995; **149**:288–289.
329. Randolph AG, Cook DJ, Gonzales CA, Andrew M. Benefit of Heparin in Central Venous and Pulmonary Artery Catheters: A Meta-analysis of Randomized Controlled Trials. *Chest* January 1998;**113**:165–171.
330. Mehta DK, executive editor. *British National Formulary No. 51*. London: British Medical Association and the Royal Pharmaceutical Society of Great Britain; 2006:119–126.
331. Bern MM, Lokich JJ, Wallach SR, Bothe A Jr, Benotti PN, Arkin CF, *et al*. Very low doses of warfarin can prevent thrombosis in central venous catheters. A randomized prospective trial. *Annals of Internal Medicine* 1990;**112**: 423–428.
332. Passannante A, Macik BG. Case report: the heparin flush syndrome: a cause of iatrogenic hemorrhage. *American Journal of Medical Science* July 1998;**296**:71–73.
333. Randolph AG, Cook DJ, Gonzales CA, Andrew M. Benefit of heparin in peripheral venous and arterial catheters: systematic review and meta-analysis of randomised controlled trials. *British Medical Journal* 1998;**316**: 969–975.
334. Goode CJ, Titler M, Rakel B, Ones DS, Kleiber C, Small S, *et al*. A meta-analysis of effects of heparin flush and saline flush: quality and cost implications. *Nursing Research* 1991;**40**:324-330.
335. Peterson FY, Kirchoff KT. Analysis of the research about heparinized versus nonheparinized intravascular lines. *Heart and Lung* 1991;**20**:631–640.