



ELSEVIER

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

Journal of Hospital Infection

journal homepage: [www.elsevierhealth.com/journals/jhin](http://www.elsevierhealth.com/journals/jhin)



# epic3: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England

H.P. Loveday<sup>a\*</sup>, J.A. Wilson<sup>a</sup>, R.J. Pratt<sup>a</sup>, M. Golsorkhi<sup>a</sup>, A. Tingle<sup>a</sup>, A. Bak<sup>a</sup>, J. Browne<sup>a</sup>, J. Prieto<sup>b</sup>, M. Wilcox<sup>c</sup>

<sup>a</sup> Richard Wells Research Centre, College of Nursing, Midwifery and Healthcare, University of West London (London).

<sup>b</sup> Faculty of Health Sciences, University of Southampton (Southampton).

<sup>c</sup> Microbiology and Infection Control, Leeds Teaching Hospitals and University of Leeds (Leeds).

## Executive Summary

National evidence-based guidelines for preventing healthcare-associated infections (HCAI) in National Health Service (NHS) hospitals in England were originally commissioned by the Department of Health and developed during 1998-2000 by a nurse-led multi-professional team of researchers and specialist clinicians. Following extensive consultation, they were first published in January 2001<sup>1</sup> and updated in 2007.<sup>2</sup> 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 for the prevention of HCAI, incorporated into amended guidelines. Periodically updating the evidence base and guideline recommendations is essential in order to maintain their validity and authority.

The Department of Health commissioned a review of new evidence and we have updated the evidence base for making infection prevention and control recommendations. A critical assessment of the updated evidence indicated that the epic2 guidelines published in 2007 remain robust, relevant and appropriate, but some guideline recommendations required adjustments to enhance clarity and a number of new recommendations were required. These have been clearly identified in the text. In addition, the synopses of evidence underpinning the guideline recommendations have been updated.

These guidelines (epic3) provide comprehensive recommendations for preventing HCAI in hospital and other acute care settings based on the best currently available evidence. National evidence-based guidelines are broad principles of best practice that need to be integrated into local practice guidelines and audited to reduce variation in practice and maintain patient safety.

Clinically effective infection prevention and control practice is an essential feature of patient protection. 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 health care in NHS hospitals in England can be minimised.



NICE has accredited the process used by the University of West London to produce its epic3 guidance. Accreditation is valid for 5 years from December 2013. More information on accreditation can be viewed at: [www.nice.org.uk/accreditation](http://www.nice.org.uk/accreditation)

For full details on our accreditation visit: [www.nice.org.uk/accreditation](http://www.nice.org.uk/accreditation)

\* Corresponding author. Address: Richard Wells Research Centre, College of Nursing, Midwifery and Healthcare, University of West London, Paragon House, Boston Manor Road, Brentford TW8 9GB, UK. Tel.: +44 (0) 20 8209 4110  
E-mail address: [heather.loveday@uwl.ac.uk](mailto:heather.loveday@uwl.ac.uk) (Heather Loveday)

## 1 Introductory Section

### 1.1 Guideline Development Team

- Professor Heather P. Loveday (Project Lead), Professor of Evidence-based Healthcare, College of Nursing, Midwifery and Healthcare, University of West London (London) (HL).
- Ms Jennie A. Wilson, Reader, Healthcare Epidemiology, University of West London (London) (JW).
- Dr Jacqui Prieto, Senior Clinical Academic Research Fellow, University of Southampton (Southampton).
- Professor Mark Wilcox, Professor of Medical Microbiology, University of Leeds (Leeds) (MW).
- Professor Robert J. Pratt CBE, Professor of Nursing, University of West London (London).
- Ms Aggie Bak, Research Assistant, University of West London (London).
- Ms Jessica Browne, Research Assistant, University of West London (London).
- Ms Sharon Elliott, Senior Lecturer (Director Clinical Simulation), University of West London (London).
- Ms Mana Golsorkhi, Research Assistant, University of West London (London).
- Mr Roger King, Lecturer (Operating Department Practice), University of West London (London).
- Ms Caroline Smales, Senior Lecturer (Infectious Diseases), University of West London (London).
- Ms Alison Tingle, Principal Research Programme Officer, University of West London (London).

### 1.2 Guideline Advisory Group

- Dr Debra Adams, NHS Trust Development Authority (DA)
- Ms Susan Bennett, Lay Member (SB)
- Dr Tim Boswell, Nottingham University Hospitals NHS Trust (TB)
- Ms Maria Cann, Lay Member (MC)
- Ms Tracey Cooper, South London NHS Trust (TC)
- Dr Peter Cowling, Northern Lincolnshire & Goole Hospitals NHS Trust
- Ms Judith Hudson, Association of Healthcare Cleaning Professionals
- Ms Theresa Neale, Urology Nurse Specialist, British Association of Urological Nurses (Consultant)
- Dr Jeff Phillips, Consultant Intensivist and Clinical Lead for Anaesthetics (Consultant) (JPh), Princess Alexandra Hospital Harlow
- Dr Jacqui Prieto, University of Southampton (Infection Prevention Adviser)
- Mr Julian Shah, Consultant Urologist (Consultant), King Edward VII Hospital, London
- Professor Mark Wilcox, Leeds Teaching Hospitals and University of Leeds
- Ms Carole Fry, Department of Health (Observer)
- Professor Brian I. Duerden CBE, Duerden Microbiology Consulting Ltd (Chair of Face-to-Face Meeting)
- Ms Meg Morse, Administrative Officer, University of West London

### 1.3 Acknowledgements

We would like to acknowledge the assistance of the Infection Prevention Society, British Infection Association and the Healthcare Infection Society for their input into the development of these guidelines; and other associations, learned societies, professional organisations, Royal Colleges and patient groups who took an active role in the external review of the guidelines. We would also like to acknowledge the support received from Professor Brian Duerden CBE in chairing the Guideline Development Advisory Group, and Carole Fry in the Chief Medical Officer's Team at the Department of Health (England).

### 1.4 Source of Funding

The Department of Health (England).

### 1.5 Disclosure of Potential Conflict of Interest

HL: Trustee and Director of the International Clinical Virology Centre and the Infection Prevention Society; educational grant from Care Fusion to attend SHEA conference in April 2010 and consultancy for GAMA Healthcare Ltd in January 2012.

JW: Trustee of the Infection Prevention Society; consultancy for Care Fusion and ICNet.

MW: Research on the use of hydrogen peroxide decontamination supported by Hygiene Solutions (Deprox).

JPh: Sponsored speaker/session chair for Cook Medical.

TC: Consultancy NIHR HTA Programme.

DA: Consultancy and commissioned publications from Sanofi, BD, Smiths-Industry; consultancy from NHS Midlands and East; PhD supported by an education grant from BD and Enturia.

TB: Advisor to Fresenius Medical Care Renal Services and Nottingham Woodthorpe Hospital (Ramsay Healthcare); sponsored speaker for Advanced Sterilisation Products.

SB: Member of NICE Medical Technology Advisory Committee; former trustee of Bladder and Bowel Foundation; sponsorship from a number of urinary catheter manufacturers; Urology Trade Association; Bladder and Bowel Foundation representative on the Urology User Group Coalition.

MC: Trustee of MRSA Action UK; conference attendances sponsored by Mölnlycke Healthcare.

All other authors: no conflicts declared.

### 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 epic2 guidelines in the *Journal of Hospital Infection* in 2007.

### 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. Some recommendations from the previous guidelines have been revised to improve clarity; where a new recommendation has been made, this is indicated in the text. These recommendations are not detailed procedural protocols, and need to be incorporated into local guidelines. None are regarded as optional.

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 five distinct interventions:

- hospital environmental hygiene;
- hand hygiene;
- use of personal protective equipment (PPE);
- safe use and disposal of sharps; and
- principles of asepsis.

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

#### **Hospital environmental hygiene**

SP1 The hospital environment must be visibly clean; free from non-essential items and equipment, dust and dirt; and acceptable to patients, visitors and staff.

*Class D/GPP*

SP2 Levels of cleaning should be increased in cases of infection and/or colonisation when a suspected or known pathogen can survive in the environment, and environmental contamination may contribute to the spread of infection.

*Class D/GPP*

SP3 The use of disinfectants should be considered for cases of infection and/or colonisation when a suspected or known pathogen can survive in the environment, and environmental contamination may contribute to the spread of infection.

*Class D/GPP*

SP4 Shared pieces of equipment used in the delivery of patient care must be cleaned and decontaminated after each use with products recommended by the manufacturer.

*Class D/GPP*

SP5 All healthcare workers need to be educated about the importance of maintaining a clean and safe care environment for patients. Every healthcare worker needs to know their specific responsibilities for cleaning and decontaminating the clinical environment and the equipment used in patient care.

*Class D/GPP*

#### **Hand hygiene**

SP6 Hands must be decontaminated:

- immediately before each episode of direct patient contact or care, including clean/aseptic procedures;
- immediately after each episode of direct patient contact or care;
- immediately after contact with body fluids, mucous membranes and non-intact skin;
- immediately after other activities or contact with objects and equipment in the immediate patient environment that may result in the hands becoming contaminated; and
- immediately after the removal of gloves.

*Class C*

SP7 Use an alcohol-based hand rub for decontamination of hands before and after direct patient contact and clinical care, except in the following situations when soap and water must be used:

- when hands are visibly soiled or potentially contaminated with body fluids; and
- when caring for patients with vomiting or diarrhoeal illness, regardless of whether or not gloves have been worn.

*Class A*

SP8 Healthcare workers should ensure that their hands can be decontaminated effectively by:

- removing all wrist and hand jewellery;
- wearing short-sleeved clothing when delivering patient care;
- making sure that fingernails are short, clean, and free from false nails and nail polish; and
- covering cuts and abrasions with waterproof dressings.

*Class D/GPP*

- SP9 Effective handwashing technique involves three stages: preparation, washing and rinsing, and drying.
- Preparation: wet hands under tepid running water before applying the recommended amount of liquid soap or an antimicrobial preparation.
  - Washing: the handwash solution must come into contact with all of the surfaces of the hand. The hands should be rubbed together vigorously for a minimum of 10-15 s, paying particular attention to the tips of the fingers, the thumbs and the areas between the fingers. Hands should be rinsed thoroughly.
  - Drying: use good-quality paper towels to dry the hands thoroughly.
- Class D/GPP*
- SP10 When decontaminating hands using an alcohol-based hand rub, hands should be free of dirt and organic material, and:
- hand rub solution must come into contact with all surfaces of the hand; and
  - hands should 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/GPP*
- SP11 Clinical staff should be made aware of the potentially damaging effects of hand decontamination products, and encouraged to use an emollient hand cream regularly to maintain the integrity of the skin. Consult the occupational health team or a general practitioner if a particular liquid soap, antiseptic handwash or alcohol-based hand rub causes skin irritation.
- Class D/GPP*
- SP12 Alcohol-based hand rub should be made available at the point of care in all healthcare facilities.
- Class C*
- SP13 Hand hygiene resources and healthcare worker adherence to hand hygiene guidelines should be audited at regular intervals, and the results should be fed back to healthcare workers to improve and sustain high levels of compliance.
- Class C*
- SP14 Healthcare organisations must provide regular training in risk assessment, effective hand hygiene and glove use for all healthcare workers.
- Class D/GPP*
- SP15 Local programmes of education, social marketing, and audit and feedback should be refreshed regularly and promoted by senior managers and clinicians to maintain focus, engage staff and produce sustainable levels of compliance.
- New recommendation Class C**
- SP16 Patients and relatives should be provided with information about the need for hand hygiene and how to keep their own hands clean.
- New recommendation Class D/GPP**
- SP17 Patients should be offered the opportunity to clean their hands before meals; after using the toilet, commode or bedpan/urinal; and at other times as appropriate. Products available should be tailored to patient needs and may include alcohol-based hand rub, hand wipes and access to handwash basins.
- New recommendation Class D/GPP**
- Use of personal protective equipment**
- SP18 Selection of personal protective equipment must be based on an assessment of the:
- risk of transmission of microorganisms to the patient or carer;
  - risk of contamination of healthcare practitioners' clothing and skin by patients' blood or body fluids; and
  - suitability of the equipment for proposed use.
- Class D/GPP/H&S*
- SP19 Healthcare workers should be educated and their competence assessed in the:
- assessment of risk;
  - selection and use of personal protective equipment; and
  - use of standard precautions.
- Class D/GPP/H&S*
- SP20 Supplies of personal protective equipment should be made available wherever care is delivered and risk assessment indicates a requirement.
- Class D/GPP/H&S*

- SP21 Gloves must be worn for:
- invasive procedures;
  - contact with sterile sites and non-intact skin or mucous membranes;
  - all activities that have been assessed as carrying a risk of exposure to blood or body fluids; and
  - when handling sharps or contaminated devices.
- Class D/GPP/H&S*
- SP22 Gloves must be:
- worn as single-use items;
  - put on immediately before an episode of patient contact or treatment;
  - removed as soon as the episode is completed;
  - changed between caring for different patients; and
  - disposed of into the appropriate waste stream in accordance with local policies for waste management.
- Class D/GPP/H&S*
- SP23 Hands must be decontaminated immediately after gloves have been removed.
- Class D/GPP/H&S*
- SP24 A range of CE-marked medical and protective gloves that are acceptable to healthcare personnel and suitable for the task must be available in all clinical areas.
- Class D/GPP/H&S*
- SP25 Sensitivity to natural rubber latex in patients, carers and healthcare workers must be documented, and alternatives to natural rubber latex gloves must be available.
- Class D/GPP/H&S*
- SP26 Disposable plastic aprons must be worn when close contact with the patient, materials or equipment pose a risk that clothing may become contaminated with pathogenic microorganisms, blood or body fluids.
- Class D/GPP/H&S*
- SP27 Full-body fluid-repellent gowns must be worn where there is a risk of extensive splashing of blood or body fluids on to the skin or clothing of healthcare workers.
- Class D/GPP/H&S*
- SP28 Plastic aprons/fluid-repellent gowns should be worn as single-use items for one procedure or episode of patient care, and disposed of into the appropriate waste stream in accordance with local policies for waste management. When used, non-disposable protective clothing should be sent for laundering.
- Class D/GPP/H&S*
- SP29 Fluid-repellent surgical face masks and eye protection must be worn where there is a risk of blood or body fluids splashing into the face and eyes.
- Class D/GPP/H&S*
- SP30 Appropriate respiratory protective equipment should be selected according to a risk assessment that takes account of the infective microorganism, the anticipated activity and the duration of exposure.
- Class D/GPP/H&S*
- SP31 Respiratory protective equipment must fit the user correctly and they must be trained in how to use and adjust it in accordance with health and safety regulations.
- Class D/GPP/H&S*
- SP32 Personal protective equipment should be removed in the following sequence to minimise the risk of cross/self-contamination:
- gloves;
  - apron;
  - eye protection (when worn); and
  - mask/respirator (when worn).
- Hands must be decontaminated following the removal of personal protective equipment.
- New recommendation** *Class D/GPP/H&S*
- Safe use and disposal of sharps**
- SP33 Sharps must not be passed directly from hand to hand, and handling should be kept to a minimum.
- Class D/GPP/H&S*
- SP34 Needles must not be recapped, bent or disassembled after use.
- Class D/GPP/H&S*
- SP35 Used sharps must be discarded at the point of use by the person generating the waste.
- Class D/GPP/H&S*
- SP36 All sharps containers must:
- conform to current national and international standards;
  - be positioned safely, away from public areas and out of the reach of children, and at a height that enables safe disposal by all members of staff;
  - be secured to avoid spillage;
  - be temporarily closed when not in use;
  - not be filled above the fill line; and
  - be disposed of when the fill line is reached.
- Class D/GPP/H&S*



SP37 All clinical and non-clinical staff must be educated about the safe use and disposal of sharps and the action to be taken in the event of an injury.

*Class D/GPP/H&S*

SP38 Use safer sharps devices where assessment indicates that they will provide safe systems of working for healthcare workers.

*Class C/H&S*

SP39 Organisations should involve end-users in evaluating safer sharps devices to determine their effectiveness, acceptability to practitioners, impact on patient care and cost benefit prior to widespread introduction.

*Class D/GPP/H&S*

### **Asepsis**

SP40 Organisations should provide education to ensure that healthcare workers are trained and competent in performing the aseptic technique.

**New recommendation** *Class D/GPP*

SP41 The aseptic technique should be used for any procedure that breaches the body's natural defences, including:

- insertion and maintenance of invasive devices;
- infusion of sterile fluids and medication; and
- care of wounds and surgical incisions.

**New recommendation** *Class D/GPP*

### **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. Some recommendations from the previous guidelines have been revised to improve clarity; where a new recommendation has been made, this is indicated in the text. These recommendations are not detailed procedural protocols, and need to be incorporated into local guidelines. None are regarded as optional.

These guidelines apply to adults and children aged  $\geq 1$  year who require a short-term indwelling urethral catheter ( $\leq 28$  days), and should be read in conjunction with the guidance on Standard Principles. The recommendations are divided into six distinct interventions:

- assessing the need for catheterisation;
- selection of catheter type and system;
- catheter insertion;
- catheter maintenance;
- education of patients, relatives and healthcare workers; and
- system interventions for reducing the risk of infection.

### **Assessing the need for catheterisation**

UC1 Only use a short-term indwelling urethral catheter in patients for whom it is clinically indicated, following assessment of alternative methods and discussion with the patient.

*Class D/GPP*

UC2 Document the clinical indication(s) for catheterisation, date of insertion, expected duration, type of catheter and drainage system, and planned date of removal.

*Class D/GPP*

UC3 Assess and record the reasons for catheterisation every day. Remove the catheter when no longer clinically indicated.

*Class D/GPP*

### **Selection of catheter type**

UC4 Assess patient's needs prior to catheterisation in terms of:

- latex allergy;
- length of catheter (standard, female, paediatric);
- type of sterile drainage bag and sampling port (urometer, 2-L bag, leg bag) or catheter valve; and
- comfort and dignity.

**New recommendation** *Class D/GPP*

UC5 Select a catheter that minimises urethral trauma, irritation and patient discomfort, and is appropriate for the anticipated duration of catheterisation.

*Class D/GPP*

UC6 Select the smallest gauge catheter that will allow urinary outflow and use a 10-mL retention balloon in adults (follow manufacturer's instructions for paediatric catheters). Urological patients may require larger gauge sizes and balloons.

*Class D/GPP*

### **Catheter insertion**

UC7 Catheterisation is an aseptic procedure and should only be undertaken by healthcare workers trained and competent in this procedure.

*Class D/GPP*

UC8 Clean the urethral meatus with sterile, normal saline prior to the insertion of the catheter.

*Class D/GPP*

UC9 Use lubricant from a sterile single-use container to minimise urethral discomfort, trauma and the risk of infection. Ensure the catheter is secured comfortably.

*Class D/GPP*

### **Catheter maintenance**

UC10 Connect a short-term indwelling urethral catheter to a sterile closed urinary drainage system with a sampling port.

*Class A*

UC11 Do not break the connection between the catheter and the urinary drainage system unless clinically indicated.

*Class A*

UC12 Change short-term indwelling urethral catheters and/or drainage bags when clinically indicated and in line with the manufacturer's recommendations.

**New recommendation** *Class D/GPP*

UC13 Decontaminate hands and wear a new pair of clean non-sterile gloves before manipulating each patient's catheter. Decontaminate hands immediately following the removal of gloves.

*Class D/GPP*

UC14 Use the sampling port and the aseptic technique to obtain a catheter sample of urine.

*Class D/GPP*

UC15 Position the urinary drainage bag below the level of the bladder on a stand that prevents contact with the floor.

*Class D/GPP*

UC16 Do not allow the urinary drainage bag to fill beyond three-quarters full.

*Class D/GPP*

UC17 Use a separate, clean container for each patient and avoid contact between the urinary drainage tap and the container when emptying the drainage bag.

*Class D/GPP*

UC18 Do not add antiseptic or antimicrobial solutions to urinary drainage bags.

*Class A*

UC19 Routine daily personal hygiene is all that is required for meatal cleansing.

*Class A*

### **Education of patients, relatives and healthcare workers**

UC20 Do not use bladder maintenance solutions to prevent catheter-associated infection.

*Class A*

UC21 Healthcare workers should be trained and competent in the appropriate use, selection, insertion, maintenance and removal of short-term indwelling urethral catheters.

*Class D/GPP*

UC22 Ensure patients, relatives and carers are given information regarding the reason for the catheter and the plan for review and removal. If discharged with a catheter, the patient should be given written information and shown how to:

- manage the catheter and drainage system;
- minimise the risk of urinary tract infection; and
- obtain additional supplies suitable for individual needs.

*Class D/GPP*

### **System interventions for reducing the risk of infection**

UC23 Use quality improvement systems to support the appropriate use and management of short-term urethral catheters and ensure their timely removal. These may include:

- protocols for catheter insertion;
- use of bladder ultrasound scanners to assess and manage urinary retention;
- reminders to review the continuing use or prompt the removal of catheters;
- audit and feedback of compliance with practice guidelines; and
- continuing professional education

**New recommendation** *Class D/GPP*

UC24 No patient should be discharged or transferred with a short-term indwelling urethral catheter without a plan documenting the:

- reason for the catheter;
- clinical indications for continuing catheterisation; and
- date for removal or review by an appropriate clinician overseeing their care.

**New recommendation** *Class D/GPP*

### **Guidelines for preventing infections associated with the use of intravascular access devices**

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. Some recommendations from the previous guidelines have been revised to improve clarity; where a new recommendation has been made, this is indicated in the text. These recommendations are not detailed procedural protocols, and need to be incorporated into local guidelines. None are regarded as optional.

#### **Education of healthcare workers and patients**

- IVAD1 Healthcare workers caring for patients with intravascular catheters should be trained and assessed as competent in using and consistently adhering to practices for the prevention of catheter-related bloodstream infection.  
*Class D/GPP*
- IVAD2 Healthcare workers should be aware of the manufacturer's advice relating to individual catheters, connection and administration set dwell time, and compatibility with antiseptics and other fluids to ensure the safe use of devices.  
**New recommendation** *Class D/GPP*
- IVAD3 Before discharge from hospital, patients with intravascular catheters and their carers should be taught any techniques they may need to use to prevent infection and manage their device.  
*Class D/GPP*

#### **General asepsis**

- IVAD4 Hands must be decontaminated, with an alcohol-based hand rub or by washing with liquid soap and water if soiled or potentially contaminated with blood or body fluids, before and after any contact with the intravascular catheter or insertion site.  
*Class A*
- IVAD5 Use the aseptic technique for the insertion and care of an intravascular access device and when administering intravenous medication.  
*Class B*

#### **Selection of catheter type**

- IVAD6 Use a catheter with the minimum number of ports or lumens essential for management of the patient.  
*Class A*
- IVAD7 Preferably use a designated single-lumen catheter to administer lipid-containing parenteral nutrition or other lipid-based solutions.  
*Class D/GPP*
- IVAD8 Use a tunnelled or implanted central venous access device with a subcutaneous port for patients in whom long-term vascular access is required.  
*Class A*
- IVAD9 Use a peripherally inserted central catheter for patients in whom medium-term intermittent access is required.  
**New recommendation** *Class D/GPP*
- IVAD10 Use an antimicrobial-impregnated central venous access device for adult patients whose central venous catheter is expected to remain in place for >5 days if catheter-related bloodstream infection rates remain above the locally agreed benchmark, despite the implementation of a comprehensive strategy to reduce catheter-related bloodstream infection.  
*Class A*

#### **Selection of catheter insertion site**

- IVAD11 In selecting an appropriate intravascular insertion site, assess the risks for infection against the risks of mechanical complications and patient comfort.  
*Class D/GPP*
- IVAD12 Use the upper extremity for non-tunnelled catheter placement unless medically contraindicated.  
*Class C*

#### **Maximal sterile barrier precautions during catheter insertion**

- IVAD13 Use maximal sterile barrier precautions for the insertion of central venous access devices.  
*Class C*



**Cutaneous antisepsis**

IVAD14 Decontaminate the skin at the insertion site with a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) and allow to dry prior to the insertion of a central venous access device.  
*Class A*

IVAD15 Decontaminate the skin at the insertion site with a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) and allow to dry before inserting a peripheral vascular access device.  
**New recommendation** *Class D/GPP*

IVAD16 Do not apply antimicrobial ointment routinely to the catheter placement site prior to insertion to prevent catheter-related bloodstream infection.  
*Class D/GPP*

**Catheter and catheter site care**

IVAD17 Use a sterile, transparent, semi-permeable polyurethane dressing to cover the intravascular insertion site.  
*Class D/GPP*

IVAD18 Transparent, semi-permeable polyurethane dressings should be changed every 7 days, or sooner, if they are no longer intact or if moisture collects under the dressing.  
*Class D/GPP*

IVAD19 Use a sterile gauze dressing if a patient has profuse perspiration or if the insertion site is bleeding or leaking, and change when inspection of the insertion site is necessary or when the dressing becomes damp, loosened or soiled. Replace with a transparent semi-permeable dressing as soon as possible.  
*Class D/GPP*

IVAD20 Consider the use of a chlorhexidine-impregnated sponge dressing in adult patients with a central venous catheter as a strategy to reduce catheter-related bloodstream infection.  
**New recommendation** *Class B*

IVAD21 Consider the use of daily cleansing with chlorhexidine in adult patients with a central venous catheter as a strategy to reduce catheter-related bloodstream infection.  
**New recommendation** *Class B*

IVAD22 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. A dressing may no longer be required once the insertion site has healed.  
*Class D/GPP*

IVAD23 Use a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) to clean the central catheter insertion site during dressing changes, and allow to air dry.  
*Class A*

IVAD24 Use a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) to clean the peripheral venous catheter insertion site during dressing changes, and allow to air dry.  
**New recommendation** *Class D/GPP*

IVAD25 Do not apply antimicrobial ointment to catheter insertion sites as part of routine catheter site care.  
*Class D/GPP*

**Catheter replacement strategies**

IVAD26 Do not routinely replace central venous access devices to prevent catheter-related infection.  
*Class A*

IVAD27 Do not use guidewire-assisted catheter exchange for patients with catheter-related bloodstream infection.  
*Class A*

IVAD28 Peripheral vascular catheter insertion sites should be inspected at a minimum during each shift, and a Visual Infusion Phlebitis score should be recorded. The catheter should be removed when complications occur or as soon as it is no longer required.  
**New recommendation** *Class D/GPP*

IVAD29 Peripheral vascular catheters should be re-sited when clinically indicated and not routinely, unless device-specific recommendations from the manufacturer indicate otherwise.

**New recommendation Class B**

### **General principles for catheter management**

IVAD30 A single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) should be used to decontaminate the access port or catheter hub. The hub should be cleaned for a minimum of 15 s and allowed to dry before accessing the system.

*Class D/GPP*

IVAD31 Antimicrobial lock solutions should not be used routinely to prevent catheter-related bloodstream infections.

*Class D/GPP*

IVAD32 Do not routinely administer intranasal or systemic antimicrobials before insertion or during the use of an intravascular device to prevent catheter colonisation or bloodstream infection.

*Class A*

IVAD33 Do not use systemic anticoagulants routinely to prevent catheter-related bloodstream infection.

*Class D/GPP*

IVAD34 Use sterile normal saline for injection to flush and lock catheter lumens that are accessed frequently.

*Class A*

IVAD35 The introduction of new intravascular devices or components 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 in the UK.

*Class D/GPP*

IVAD36 When safer sharps 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*

IVAD37 Administration sets in continuous use do not need to be replaced more frequently than every 96 h, unless device-specific recommendations from the manufacturer indicate otherwise, they become disconnected or the intravascular access device is replaced.

*Class A*

IVAD38 Administration sets for blood and blood components should be changed when the transfusion episode is complete or every 12 h (whichever is sooner).

*Class D/GPP*

IVAD39 Administration sets used for lipid-containing parenteral nutrition should be changed every 24 h.

*Class D/GPP*

IVAD40 Use quality improvement interventions to support the appropriate use and management of intravascular access devices (central and peripheral venous catheters) and ensure their timely removal. These may include:

- protocols for device insertion and maintenance;
- reminders to review the continuing use or prompt the removal of intravascular devices;
- audit and feedback of compliance with practice guidelines; and
- continuing professional education.

**New recommendation Class C/GPP**

## 1.9 Introduction - the epic3 Guidelines

National evidence-based guidelines for preventing HCAI in NHS hospitals were first published in January 2001<sup>1</sup> and updated in 2007.<sup>2</sup> This second update was commissioned by the Department of Health in 2012 for publication in 2013.

### **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 the NHS and other acute healthcare settings.

### **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 antimicrobial-resistant strains of disease-causing microorganisms that are now endemic in many healthcare environments. The financial and personal costs 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 the risk of acquiring a new infection.

Many, although not all, HCAI can be prevented. 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, and when combined with quality improvement methods can account for significant reductions in HCAI such as methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile*.

### **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 healthcare settings.

### **What is the scope of the guidelines?**

Three sets of guidelines were developed originally and have now been updated. They include:

- standard infection control principles: including best practice recommendations for hospital environmental hygiene, effective hand hygiene, the appropriate use of PPE, the safe use and disposal of sharps, and the principles of asepsis;
- guidelines for preventing infections associated with the use of short-term indwelling urethral catheters; and
- guidelines for preventing infections associated with the use of intravascular access devices.

### **What is the evidence for these guidelines?**

The evidence for these guidelines was identified by multiple systematic reviews of peer-reviewed 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 tool.<sup>3</sup> 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?**

A team of specialist infection prevention and control researchers and clinical specialists and a Guideline Development Advisory Group, comprising lay members and specialist clinical practitioners, developed the epic3 guidelines (see Sections 1.1 and 1.2).

### **Who are these guidelines for?**

These guidelines can be appropriately adapted and used by all hospital practitioners. This 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 prevention and control teams, and individual healthcare 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 will also help patients and carers/relatives to understand the standard infection prevention precautions they can expect all healthcare workers to implement to protect them from HCAI.

### **How are these guidelines structured?**

Each set of guidelines follows an identical format, which consists of:

- a brief introduction;
- the intervention heading;
- a headline statement describing the key issues being addressed;
- a synthesis of the related evidence; and
- guideline recommendation(s) classified according to the strength of the underpinning evidence.

### **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 for the prevention of HCAI, incorporated into amended guidelines. The evidence base for these guidelines will be reviewed in 2 years (2015) and the guidelines will be considered for updating approximately 4 years after publication (2017). Following publication the DH will ask the Advisory Group on Antimicrobial Resistance and Healthcare Associated Infection to advise whether the

evidence base has progressed significantly to alter the guideline recommendations and warrant an update.

### ***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 on-going quality improvements. There are a number of audit tools available locally, nationally and internationally that can be used to audit compliance with guidance including high-impact intervention tools for auditing care bundles.

### ***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 healthcare professionals.

## **1.10 Guideline Development Methodology**

The guidelines were developed using a systematic review process (Appendix A.1). In each set of guidelines, a summary 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 periods identified for each search question. 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 (RCTs) and current national and international guidelines. International and national guidelines were retrieved and subjected to critical appraisal using the AGREE II Instrument,<sup>3</sup> an evaluation method used internationally for assessing the methodological quality of clinical guidelines.

Following appraisal, accepted guidelines were included as part of the evidence base supporting guideline development and, where appropriate, for delineating search limits. 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 developed for each set of epic guideline topics following recommendations from scientific advisors and the Guideline Development Advisory Group.

Searches were constructed using relevant MeSH (medical subject headings) and free-text terms. The following databases were searched:

- Medline;
- Cumulated Index of Nursing and Allied Health Literature;
- Embase;
- the Cochrane Library; and
- PsycINFO (only searched for hand hygiene).

### ***Abstract review - identifying studies for appraisal***

Search results were downloaded into a Refworks™ database, and titles and abstracts were printed for review. Titles and abstracts were assessed independently by two reviewers, and studies were retrieved where the title or abstract: addressed one or more of the review questions; identified primary research or systematically conducted secondary research; or indicated a theoretical/clinical/in-use study. 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 identified for retrieval.

Full-text studies were retrieved and read in detail by two experienced reviewers; those meeting the study inclusion criteria were independently quality assessed for inclusion in the systematic review.

### ***Quality assessment and data extraction***

Included studies were appraised using tools based on systems developed by the Scottish Intercollegiate Guideline Network (SIGN) for study quality assessment.<sup>4</sup> Studies were appraised independently by two reviewers and data were extracted by one experienced reviewer. Any disagreement between reviewers was resolved through discussion. Evidence tables were constructed from the quality assessments, and the studies were summarised in adapted considered judgement forms. The evidence was classified using methods from SIGN, and adapted to include interrupted time series design and controlled before-after studies using criteria developed by the Cochrane Effective Practice and Organisation of Care (EPOC) Group (Table 1).<sup>4,5</sup> This system is similar that used in the previous epic guidelines.<sup>2</sup>

The evidence tables and considered judgement reports were presented to the Guideline Development Advisory Group for discussion. The guidelines were drafted after extensive discussion.

- Factors influencing the guideline recommendations included:
- the nature of the evidence;
  - the applicability of the evidence to practice;
  - patient preference and acceptability; and
  - costs and knowledge of healthcare systems.

The classification scheme adopted by SIGN was used to define the strength of recommendation (Table 2).<sup>4</sup>

**Table 1**  
Levels of evidence for intervention studies<sup>5</sup>

1++	High-quality meta-analyses, systematic reviews of RCTs or RCTs with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews or RCTs with a low risk of bias
1-	Meta-analyses, systematic reviews or RCTs 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 or bias and a high probability that the relationship is causal. Interrupted time series with a control group: (i) there is a clearly defined point in time when the intervention occurred; and (ii) at least three data points before and three data points after the intervention
2+	Well-conducted case-control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal. Controlled before-after studies with two or more intervention and control sites
2-	Case-control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal. Interrupted time series without a parallel control group: (i) there is a clearly defined point in time when the intervention occurred; and (ii) at least three data points before and three data points after the intervention. Controlled before-after studies with one intervention and one control site
3	Non-analytic studies (e.g. uncontrolled before-after studies, case reports, case series)
4	Expert opinion. Legislation

\*Studies with an evidence level of '1-' and '2-' should not be used as a basis for making a recommendation.  
RCT, randomised controlled trial.

**Table 2**  
Classification of recommendations<sup>4</sup>

A	At least one meta-analysis, systematic review or RCT rated as 1++, and directly applicable to the target population; or A body of evidence consisting principally of studies rated as 1+, directly applicable to the target population, and demonstrating overall consistency of results
B	A body of evidence including studies rated as 2++, directly applicable to the target population, and demonstrating overall consistency of results; or Extrapolated evidence from studies rated as 1++ or 1+
C	A body of evidence including studies rated as 2+, directly applicable to the target population and demonstrating 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+
Good Practice Points	Recommended best practice based on the clinical experience of the Guideline Development Advisory Group and patient preference and experience
IP	Recommendation from NICE Interventional Procedures guidance

RCT, randomised controlled trial; NICE, National Institute for Health and Clinical Excellence.

## 1.11 Consultation Process

These guidelines have been subject to extensive external consultation with key stakeholders, including Royal Colleges, professional societies and organisations, patients and trade unions (Appendix A.2). Comments were requested on:

- format;
- content;
- practice applicability of the guidelines;
- patient preference and acceptability; and
- specific sections or recommendations.

All the comments were collated and sent to the scientific advisors and the Guideline Development Advisory Group for consideration prior to virtual meetings for discussion and agreement on any changes in the light of comments. Final agreement was sought from the scientific advisors and the Guideline Development Advisory Group following revision.



## 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. Some recommendations from the previous guidelines have been revised to improve clarity; where a new recommendation has been made, this is indicated in the text. These recommendations are not detailed procedural protocols, and need to be incorporated into local guidelines. None are regarded as optional.

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 five distinct interventions:

- hospital environmental hygiene;
- hand hygiene;
- use of PPE;
- safe use and disposal of sharps; and
- principles of asepsis.

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

### 2.2 Hospital Environmental Hygiene

#### ***Hospital hygiene is important for the prevention of healthcare-associated infections in hospitals***

This section discusses the evidence upon which recommendations for hospital environmental hygiene are based. The evidence identified in the previous systematic review was used as the basis for updating the searches, and searches were conducted for new evidence published since 2006.<sup>2</sup> Hospital environmental hygiene encompasses a wide range of routine activities. 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***

Current legislation, regulatory frameworks and quality standards emphasise the importance of the healthcare environment and shared clinical equipment being clean and properly decontaminated to minimise the risk of transmission of HCAI and to maintain public confidence.<sup>6-10</sup> Patients and their relatives expect the healthcare environment to be clean and infection hazards to be controlled adequately.<sup>9</sup>

The term 'cleaning' is used to describe the physical removal of soil, dirt or dust from surfaces. Conventionally, this is achieved in healthcare settings using cloths and mops. Dust may be removed using dry dust-control mops/cloths. Detergent and water is used for cleaning of soiled or contaminated surfaces, although microfibre cloths and water can also be used for surface cleaning.<sup>9</sup>

Enhanced cleaning describes the use of methods in addition to standard cleaning specifications. These may include increased cleaning frequency for all or some surfaces, or the use of additional cleaning equipment. Enhanced cleaning may be applied to all areas of the healthcare environment or in specific circumstances, such as cleaning of rooms or bed spaces following the transfer or discharge of patients who are colonised or infected with a pathogenic microorganism. This is sometimes referred to as 'terminal cleaning'.

Disinfection is the use of chemical or physical methods to reduce the number of pathogenic microorganisms on surfaces. These methods need to be used in combination with cleaning as they have limited ability to penetrate organic material. The term 'decontamination' is used for the process that results in the removal of hazardous substances (e.g. microorganisms, chemicals) and therefore may apply to cleaning or disinfection.

Research evidence in this field remains largely limited to ecological studies and weak quasi-experimental and observational study designs. There is evidence from outbreak reports and observational research which demonstrates that the hospital environment becomes contaminated with microorganisms responsible for HCAI. Pathogens may be recovered from a variety of surfaces in clinical environments, including those near to the patient that are touched frequently by healthcare workers.<sup>11-20</sup> However, no studies have provided high-quality evidence of direct transmission of the same strain of microorganisms found in the environment to those found in colonised or infected patients.

We identified one prospective cohort study that found a significant independent association between acquisition of two multi-drug-resistant pathogens and a prior room occupant with the same organism [multi-drug-resistant *Pseudomonas aeruginosa* odds ratio (OR) 2.3, 95% confidence interval (CI) 1.2-4.3,  $p=0.012$ ; multi-drug-resistant *Acinetobacter baumannii* OR 4.2, 95% CI 1.1-1.3,  $p=0.04$ ] after adjustment for severity of underlying illness, comorbidities, antimicrobial exposure and some other risk factors.<sup>21</sup> A further study reported an association between MRSA and vancomycin-resistant enterococcus (VRE),<sup>22</sup> but conclusions that can be drawn from the findings are limited by the retrospective study design and lack of adjustment for severity of underlying illness, colonisation pressure and antibiotic exposure. Similarly, another retrospective cohort study found an association between acquisition of *C. difficile* and prior room occupant with the same infection; however, this was based solely on clinical diagnosis rather than active surveillance.<sup>23</sup>

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.<sup>15</sup> There is some evidence that enhanced cleaning regimens are associated with the control of outbreaks of HCAI;<sup>24</sup> however, these study designs do not provide robust evidence of cause and effect.

Enhanced cleaning has been recommended, particularly 'terminal cleaning', after a bed area has been used by a patient colonised or infected with an HCAI. We searched for robust evidence from studies conducted in the healthcare environment which demonstrated cleaning interventions that were associated with reductions in both environmental contamination and HCAI. A randomised crossover study of daily enhanced cleaning of high-touch surfaces in an intensive care unit (ICU) demonstrated a reduction in the daily number of



sites in a bed area contaminated with MRSA (OR 0.59, 95% CI 0.4-0.86,  $p=0.006$ ), and the aerobic colony count in communal areas (OR 0.65, 95% CI 0.47-0.92,  $p=0.013$ ). Although the reduction in MRSA in the environment was associated with a large reduction in MRSA contaminating doctors' hands (OR 0.26, 95% CI 0.07-0.95,  $p=0.025$ ), there was no effect on the incidence of MRSA acquisition by patients (OR 0.98, 95% CI 0.58-1.65,  $p=0.93$ ).<sup>25</sup>

Disinfectants have been recommended for cleaning the hospital environment;<sup>1,2</sup> however, a systematic review failed to confirm a link between disinfection and the prevention of HCAI, although contamination of detergent and inadequate disinfection strength could have been an important confounder.<sup>26</sup> Whilst subsequent studies may have demonstrated a link between disinfection and reduced environmental contamination, and sometimes the acquisition of HCAI, the study designs are weak with no control groups or randomisation of intervention, and/or the introduction of multiple interventions at the same time. This makes it difficult to draw definitive conclusions about the specific effect of disinfection or cleaning.

### Emerging technology

New technologies for cleaning and decontaminating the healthcare environment have become available over the past 10 years, including hydrogen peroxide, and others are in the early stages of development. Whilst hydrogen peroxide has been used for decontamination of selected rooms in a US hospital following use by patients with a multi-drug-resistant organism or *C. difficile*, this study found that it was not possible to use hydrogen peroxide routinely for this purpose.<sup>27</sup> The effectiveness, cost-effectiveness and practicality of this and other new technologies in terms of reducing HCAI and routine use in the variety of facilities in UK hospitals has yet to be demonstrated.

We identified three studies conducted in patient care environments that provided evidence for the effectiveness of different products, containing chemical or other disinfection agents, on environmental contamination but not reductions in HCAI. A prospective randomised crossover study provided evidence for the effectiveness of daily cleaning of high-touch surfaces with microfibre/copper-impregnated cloths on the reduction of MRSA, as discussed above.<sup>25</sup> An RCT demonstrated the efficacy of daily high-touch surface cleaning with peracetic acid on MRSA and *C. difficile* contamination of the environment, with a significant reduction in MRSA and *C. difficile* isolated from samples taken from surfaces with gloved hands ( $p<0.001$ ) and the hands of healthcare workers (3/27 in peracetic acid group vs 15/38 in standard cleaning group,  $p=0.13$ ).<sup>28</sup> A non-randomised controlled trial (NRCT) in two wards at a single hospital provided evidence that an additional cleaner was associated with a 32.5% reduction in environmental microbial contamination of hand-touch sites (95% CI 20.2-42.9,  $p<0.0001$ ) and 26.6% reduction in acquisition of MRSA infection (95% CI 7.7-92.3,  $p=0.032$ ), although the infection types were not specified.<sup>29</sup>

Hydrogen peroxide has been used as a method of decontamination of the environment in situations where wards/beds can be closed or left unused for the required period of time.<sup>30-32</sup> We identified a prospective, randomised before-after study that compared the efficacy of hypochlorite and

a hydrogen peroxide decontamination system for terminal cleaning of rooms used by a patient with *C. difficile* infection in reducing environmental contamination with *C. difficile*. Although both methods reduced environmental contamination significantly compared with cleaning alone, hydrogen peroxide achieved a significantly greater reduction (91% vs 30% decrease in proportion of samples with *C. difficile*,  $p<0.005$ ).<sup>33</sup> A prospective cohort study provided evidence for the efficacy of hydrogen peroxide when used for terminal decontamination after standard cleaning in significantly reducing the acquisition of multi-drug-resistant organisms in patients subsequently admitted to the rooms (adjusted incidence rate ratio 0.36, 95% CI 0.19-0.7). However, the effect was mainly driven by reduction in acquisition of VRE, and the results could have been confounded by the concurrent implementation of chlorhexidine baths, incomplete surveillance data and non-random assignment of rooms to the intervention.<sup>34</sup>

The efficacy of antimicrobial surfaces in the clinical environment in reducing surface contamination and HCAI is an area of emerging research. Four non-randomised, experimental studies, conducted in clinical environments, demonstrated significant reductions in microbial burden of between 80% and 90% on high-touch surfaces coated with metallic copper and/or its alloys compared with similar non-copper surfaces.<sup>35-38</sup> One RCT conducted in three ICUs reported a significantly lower acquisition of HCAI in patients allocated to rooms with six high-touch copper-coated surfaces (3.4% vs 8.1%,  $p=0.013$ ). A multi-variate analysis suggested that both severity of underlying illness and room assignment were independently associated with the acquisition of HCAI or colonisation. However, these findings may have been biased by poor discrimination of patients colonised on admission because of limited surveillance cultures, poor agreement in defining cases of HCAI, and incomplete adjustment for confounders in the multi-variate analysis.<sup>39</sup> Evidence of the effectiveness and cost-effectiveness of these technologies and their contribution to reductions in HCAI is therefore not currently available.

### Assessing environmental cleanliness

Indicators of cleanliness based on levels of microbial or adenosine triphosphate (ATP) contamination have been recommended; however, relationships between ATP and aerobic colony counts are not consistent, and neither method distinguishes normal environmental flora and pathogens responsible for HCAI.<sup>40,41</sup> Benchmark values of between 250 and 500 relative light units have been proposed as a more objective measure of assessing the efficacy of cleaning than visual assessment, although these are based on arbitrary standards of acceptable contamination that have not been shown to be associated with reductions in HCAI.<sup>42-44</sup> We identified a number of uncontrolled before-after studies that used ATP in various forms to highlight the extent of contamination of the healthcare environment. In addition, some studies described the use of ATP monitoring as an intervention to improve cleaning, but the lack of a control group in the study design precluded their inclusion in this review. As cleaning will only have a transient effect on the numbers of microorganisms, regular cleaning or disinfection of hospital surfaces will not guarantee a pathogen-free environment. Preventing the transfer of pathogens from the environment to patients therefore still depends on ensuring that hands are decontaminated prior to patient contact.

- SP1 The hospital environment must be visibly clean; free from non-essential items and equipment, dust and dirt; and acceptable to patients, visitors and staff.

*Class D/GPP*

- SP2 Levels of cleaning should be increased in cases of infection and/or colonisation when a suspected or known pathogen can survive in the environment, and environmental contamination may contribute to the spread of infection.

*Class D/GPP*

- SP3 The use of disinfectants should be considered for cases of infection and/or colonisation when a suspected or known pathogen can survive in the environment, and environmental contamination may contribute to the spread of infection.

*Class D/GPP*

### **Decontamination of equipment**

Shared clinical equipment used to deliver care in the clinical environment comes into contact with intact skin and is therefore unlikely to introduce infection directly. However, it can act as a vehicle by which microorganisms are transferred between patients, which may subsequently result in infection. Equipment should therefore be cleaned and decontaminated after each use with cleaning agents compatible with the piece of equipment being cleaned. In some outbreak situations, the use of chlorine-releasing agents and detergent should be considered.<sup>6-9</sup>

- SP4 Shared pieces of equipment used in the delivery of patient care must be cleaned and decontaminated after each use with products recommended by the manufacturer.

*Class D/GPP*

### **Healthcare workers' role in maintaining a clean environment**

In a systematic review of healthcare workers' knowledge about MRSA and/or frequency of cleaning practices, three studies indicated that staff were not using appropriate cleaning practices with sufficient frequency to ensure minimisation of MRSA contamination of personal equipment.<sup>13</sup> Staff education was lacking on optimal cleaning practices in the clinical areas. The finding of the review is reinforced by a later observational study, which noted that lapses in adherence to the cleaning protocol were linked with an increase in environmental contamination with isolates of *A. baumannii*.<sup>15</sup> A second systematic review of four cohort studies that compared the use of detergents and disinfectants on microbial-contaminated hospital environmental surfaces suggested that a lack of effectiveness was, in many instances, due to inadequate strengths of disinfectants, probably resulting from a lack of knowledge.<sup>26</sup>

We identified no new, robust research studies of education or system interventions for this review. However, creating a culture of responsibility for maintaining a clean environment and increasing knowledge about how to decontaminate equipment and high-touch surfaces effectively requires education and training of both healthcare cleaning professionals and clinical staff.

- SP5 All healthcare workers need to be educated about the importance of maintaining a clean and safe care environment for patients. Every healthcare worker needs to know their specific responsibilities for cleaning and decontaminating the clinical environment and the equipment used in patient care.

*Class D/GPP*

## Hospital Hygiene - Systematic Review Process

### Systematic Review Questions

1. What is the evidence that the patient environment (including clinical equipment) is a significant factor in the transmission of HCAI?
2. What is the effectiveness and cost-effectiveness of conventional cleaning vs enhanced cleaning of the patient bed space in reducing environmental contamination and HCAI?
3. What is the effectiveness and cost-effectiveness of antimicrobial surfaces (e.g. silver, copper) in the patient environment in reducing environmental contamination and HCAI?
4. What is the effectiveness of education interventions in improving healthcare workers' knowledge and behaviour in maintaining a clean patient environment (including clinical equipment) and in reducing environmental contamination and HCAI?
5. What is the effectiveness of system interventions in driving improvements in hospital environmental hygiene and in reducing environmental contamination and HCAI?

### Databases and Search Terms Used

#### DATABASES

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDR, CCRCT, CMR), US Guideline Clearing House, DARE (NHS Evidence, HTA), Prospero

#### MeSH TERMS

Infection control; cross infection; equipment contamination; disease transmission; disinfection; disinfectants; soaps; anti-infective agents; surface-active agents; hospital housekeeping; hydrogen peroxide; silver

#### THESAURUS AND FREE-TEXT TERMS

Hospital hygiene; hospital housekeeper; blood spill; blood exposure; blood splash

#### SEARCH DATE

Jan 2005-Nov 2012

### Search Results

Total number of articles located = 5944

### Sift 1 Criteria

Abstract indicates that the article: relates to infections associated with hospital hygiene; is written in English; is primary research, 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 = 164

### Sift 2 Criteria

Full text confirms that the article: relates to infections associated with hospital hygiene; is written in English; is primary research (randomised controlled trials, prospective cohort, interrupted time series, controlled before-after, quasi-experimental, experimental studies answering specific questions), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

### Articles Selected for Appraisal

Total number of studies selected for appraisal during Sift 2 = 26

### Critical Appraisal

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

### Accepted and Rejected Evidence

Total number of studies accepted after critical appraisal = 12  
Total number of studies rejected after critical appraisal = 14

## 2.3 Hand Hygiene

This section discusses the evidence for recommendations concerning hand hygiene practice. Designing and conducting robust, ethical RCTs in the field of hand hygiene is challenging, meaning that recommendations are based on evidence from NRCTs, quasi-experimental studies, observational studies and laboratory studies with volunteers. In addition, expert opinion derived from systematically retrieved and appraised professional, national and international guidelines is used. The areas discussed in this section include:

- assessment of the need to decontaminate hands;
- efficacy of hand decontamination agents and preparations;
- 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; and
- involving patients and carers in hand hygiene.

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

The transfer of organisms between humans can occur directly via hands, or indirectly via an environmental source (e.g. commode or wash basin). Epidemiological evidence indicates that hand-mediated transmission is a major contributing factor in the acquisition and spread of infection in hospitals.<sup>1,2,45</sup>

The hands are colonised by two categories of microbial flora. The resident flora are found on the surface, just below the uppermost layer of skin, are adapted to survive in the local conditions and are generally of low pathogenicity, although some, such as *Staphylococcus epidermidis*, may cause infection if transferred on to a susceptible site such as an invasive device. The transient flora are made up of microorganisms acquired by touching contaminated surfaces such as the environment, patients or other people, and are readily transferred to the next person or object touched. They may include a range of antimicrobial-resistant pathogens such as MRSA, *Acinetobacter* or other multi-resistant Gram-negative bacteria.<sup>1</sup> If transferred into susceptible sites such as invasive devices or wounds, these microorganisms can cause life-threatening infections. Transmission to non-vulnerable sites may leave a patient colonised with pathogenic and antibiotic-resistant organisms, which may result in an HCAI at some point in the future.

Outbreak reports and observational studies of the dynamics of bacterial hand contamination have demonstrated an association between patient care activities that involve direct patient contact and hand contamination.<sup>2,45-48</sup> The association between hand decontamination, using liquid soap and water and waterless alcohol-base hand rub (ABHR), and reductions in infection have been confirmed by clinically-based non-randomised trials<sup>49,50</sup> and observational studies.<sup>51,52</sup>

Current national and international guidance has consistently identified that effective hand decontamination results in significant reductions in the carriage of potential pathogens on the hands, and therefore it is logical that the incidence of preventable HCAI is decreased, leading to a reduction in patient morbidity and mortality.<sup>2,45,53</sup>

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

Patients are put at risk of developing an HCAI when informal carers or healthcare workers caring for them have contaminated hands. Decontamination refers to a process for the physical removal of dirt, blood and body fluids, and the removal or destruction of microorganisms from the hands.<sup>45</sup> The World Health Organization's (WHO) 'Five Moments for Hand Hygiene'<sup>53</sup> provides a framework for training healthcare workers, audit and feedback of hand hygiene practice, and has been adopted without modification in many countries and adapted in others (e.g. Canada).<sup>54</sup>

Hands must be decontaminated at critical points before, during and after patient care activity to prevent cross-transmission of microorganisms.<sup>1,2,45,55</sup> Evidence considered by the National Institute for Health and Clinical Excellence (NICE)<sup>56</sup> indicated increases in hand decontamination compliance before and after patient contact associated with implementation of the WHO 'Five Moments' and US Centers for Disease Control and Prevention 2002 guidelines, but no difference in compliance after contact with patient surroundings. The following recommendations are derived from the WHO framework and NICE guidelines,<sup>56</sup> and include additional points of emphasis.

- SP6 Hands must be decontaminated:
- immediately before each episode of direct patient contact or care, including clean/aseptic procedures;
  - immediately after each episode of direct patient contact or care;
  - immediately after contact with body fluids, mucous membranes and non-intact skin;
  - immediately after other activities or contact with objects and equipment in the immediate patient environment that may result in the hands becoming contaminated; and
  - immediately after the removal of gloves.

*Class C*

### **Is any one hand-cleaning preparation better than another?**

Current national and international guidelines<sup>2,45,53</sup> consider the efficacy of various preparations for the decontamination of hands using liquid soap and water, antiseptic handwash agents and ABHR in laboratory studies and their effectiveness in clinical use. Overall, there is no compelling evidence to favour the general use of antiseptic handwashing agents over liquid soap or one antiseptic agent over another.<sup>2,45,53,57</sup> All hand hygiene products for use in clinical care must comply with current British Standards.<sup>58</sup>

Many studies have been conducted during the past 15 years to compare hand hygiene preparations, including ABHR and gels, antiseptic handwash and liquid soap.<sup>45</sup> RCTs and other quasi-experimental studies have generally demonstrated alcohol-based preparations to be more effective hand hygiene agents than non-medicated soap and antiseptic handwashing agents,

although a small number of studies reported no statistically significant difference.<sup>59-76</sup> Many of these studies involved the use of ABHR as part of a number of interventions, or multi-modal campaigns, to improve hand hygiene practice, and had methodological flaws that weaken the causal relationship between the introduction of ABHR and reductions in HCAI.<sup>77</sup>

We identified one multi-variate, interrupted time series which suggested that the amount of ABHR used per patient-day was the only factor associated with a reduction in MRSA incidence density ( $p=0.011$ ) in a neonatal ICU in Japan.<sup>78</sup> Incidence density fell over a 4-year period from an average of 15 per 1000 patient-days, with a peak of 20 per 1000 patient-days in August 2006, to 0 per 1000 patient-days in October 2008 and was sustained to July 2009 (average incidence density 7.5 per 1000 patient-days). The supporting evidence from laboratory studies of the efficacy of ABHR indicates that these products are highly effective at reducing hand carriage, whilst overcoming some of the recognised barriers to handwashing; most importantly, the ease of use at the point of patient care.

These studies underpin a continuing trend to adopt ABHR for routine use in clinical practice. However, some studies highlight the need for continued evaluation of the use of ABHR within the clinical environment to ensure staff adherence to guidelines and effective hand decontamination technique.<sup>75,76</sup>

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

Choosing the method of hand decontamination will depend upon the assessment of what is appropriate for the episode of care, the availability of resources at or near the point of care, what is practically possible and, to some degree, personal preferences based on the acceptability of preparations or materials.

In general, effective handwashing with liquid soap and water or the effective use of ABHR will remove transient microorganisms and render the hands socially clean. The effective use of ABHR will also substantially reduce resident microorganisms. This level of decontamination is sufficient for general social contact and most clinical care activities.<sup>2,45,53</sup> Liquid soap preparations that contain an antiseptic affect both transient microorganisms and resident flora, and some exert a residual effect. The use of preparations containing an antiseptic is required in situations where prolonged reduction in microbial flora on the skin is necessary (e.g. surgery, some invasive procedures or in outbreak situations).<sup>2,45,53</sup>

ABHR is not effective against all microorganisms (e.g. some viruses such as Norovirus and spore-forming microorganisms such as *C. difficile*). It will not remove dirt and organic material, and may not be effective in some outbreak situations.<sup>52,79</sup>

We identified two laboratory studies which demonstrated that ABHR was not effective in removing *C. difficile* spores from hands.<sup>80,81</sup> In the first study, a comparison of liquid soap and water, chlorhexidine gluconate (CHG) soap and water, antiseptic hand wipes and ABHR resulted in all the soap and water protocols yielding greater mean colony-forming unit (cfu) reductions, followed by the antiseptic hand wipes, than ABHR. ABHR was equivalent to no intervention (0.06 log<sub>10</sub> cfu/mL, 95% CI -0.34 to 0.45 log<sub>10</sub> cfu/mL).<sup>80</sup> In the second study, three ABHR preparations with a minimum 60% alcohol



concentration were compared with antiseptic (CHG) soap and water. Antiseptic soap and water reduced spore counts significantly compared with each of the ABHRs (CHG vs Isagel,  $p=0.005$ ; CHG vs Endure,  $p=0.010$ ; CHG vs Purell,  $p=0.005$ ). In addition, 30% of the residual spores were readily transferred by handshake following the use of ABHR.<sup>81</sup> Recent evidence from a laboratory study that compared the efficacy of liquid soap and water and ABHR with and without CHG against H1N1 influenza virus demonstrated that all the hand hygiene protocols were effective in reducing virus copies.<sup>82</sup> A further study that compared the use of liquid soap and water and 65% ethanol hand sanitisers for the removal of Rhinovirus indicated that the hand sanitisers were more effective than soap and water.<sup>83</sup>

Two economic evaluations from the USA, included in recent NICE primary care guidelines, suggest that non-compliance with hand hygiene guidelines results in increased infection-related costs.<sup>56</sup> Although compliance increases procurement costs of hand hygiene products, even a small increase in compliance is likely to result in reduced infection costs. We identified a further economic analysis of a hand hygiene programme based on the introduction of point-of-use ABHR and associated implementation materials. This demonstrated a reduction in episodes of HCAI and a saving of \$23.7 for every \$1 spent on the programme when future costs were considered. Sensitivity analyses showed that the programme remained cost saving in all alternative scenarios.<sup>84</sup> ABHR is likely to be less costly and result in greater compliance.

National and international guidelines suggest that the acceptability of agents and techniques is an essential criterion for the selection of preparations for hand hygiene.<sup>2,45,53</sup> 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.<sup>58</sup> ABHR is preferable for routine use due to its efficacy, availability at the point of care and acceptability to healthcare workers.<sup>45</sup> However, ABHR does not remove organic matter and is ineffective against some microorganisms; therefore, handwashing is required.

- SP7 Use an alcohol-based hand rub for decontamination of hands before and after direct patient contact and clinical care, except in the following situations when soap and water must be used:
- when hands are visibly soiled or potentially contaminated with body fluids; and
  - when caring for patients with vomiting or diarrhoeal illness, regardless of whether or not gloves have been worn.

Class A

### *Is hand decontamination technique important?*

Investigations of technique for hand decontamination are limited and generally laboratory-based or small-scale observational designs. Hand hygiene technique involves both the preparation and the physical process of decontamination.<sup>2,45,53</sup>

Hands and wrists need to be fully exposed to the hand hygiene product and therefore should be free from jewellery and long-sleeved clothing. A number of small-scale observational studies have demonstrated that wearing rings and false nails is associated with increased carriage of microorganisms and, in some cases, linked to the carriage of outbreak strains. Department of Health guidance on uniforms and work wear and NICE guidelines indicate that healthcare workers should remove rings and wrist jewellery, and wear short-sleeved clothing whilst delivering patient care.<sup>56,85</sup>

Evidence for the duration of hand decontamination has been considered in previous systematic reviews underpinning guidelines, and suggests that different durations of handwashing and hand rubbing do not significantly affect the reduction of bacteria.<sup>59,76</sup> The WHO guidelines indicate that decontamination using ABHR should take 20-30 s for a seven-step process, and that handwashing should take 40-60 s for a nine-step process.<sup>45</sup>

We identified one recent RCT in a single hospital which demonstrated that allowing staff to decontaminate their hands 'in no particular order' took less time and was as effective as using the WHO seven-step technique using ABHR or liquid antimicrobial soap and water ( $p=0.04$  and  $p<0.001$ , respectively). All three of the protocols tested in this study were effective in reducing hand bacterial load ( $p<0.01$ ).<sup>86</sup> A similar result was reported by authors of a laboratory study that tested the EN1500 six-step technique against a range of other protocols. They reported that allowing volunteers to use their own 'responsible application' or a new five-step technique resulted in better coverage of the hands during hand decontamination.<sup>87</sup>

A number of laboratory-based studies that investigated methods of hand drying suggested that there is no significant difference in the efficacy of different methods of drying hands, but that good-quality paper towels dry hands efficiently and remove bacteria effectively.<sup>88,89</sup> Current guidance on infection control in the built environment suggests that air and jet driers are not appropriate for use in clinical areas.<sup>90</sup> We identified one systematic review of studies on hand drying that failed to meet the quality criteria for inclusion.<sup>91</sup>

Due to the methodological limitations of studies, evidence recommendations are based on national and international guidelines which state 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.<sup>2,45,53</sup>

- SP8 Healthcare workers should ensure that their hands can be decontaminated effectively by:
- removing all wrist and hand jewellery;
  - wearing short-sleeved clothing when delivering patient care;
  - making sure that fingernails are short, clean, and free from false nails and nail polish; and
  - covering cuts and abrasions with waterproof dressings.

*Class D/GPP*

- SP9 Effective handwashing technique involves three stages: preparation, washing and rinsing, and drying.
- Preparation: wet hands under tepid running water before applying the recommended amount of liquid soap or an antimicrobial preparation.
  - Washing: the handwash solution must come into contact with all of the surfaces of the hand. The hands should be rubbed together vigorously for a minimum of 10-15 s, paying particular attention to the tips of the fingers, the thumbs and the areas between the fingers. Hands should be rinsed thoroughly.
  - Drying: use good-quality paper towels to dry the hands thoroughly.

*Class D/GPP*

- SP10 When decontaminating hands using an alcohol-based hand rub, hands should be free of dirt and organic material and:
- hand rub solution must come into contact with all surfaces of the hand; and
  - hands should 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/GPP*

### **Does hand decontamination damage skin?**

Expert opinion suggests that skin damage is generally associated with the detergent base of the preparation and/or poor handwashing technique.<sup>1,2,45,53</sup> In addition, the frequent use of some hand hygiene agents may cause damage to the skin and alter normal hand flora. Sore hands are associated with increased colonisation by potentially pathogenic microorganisms and increase the risk of transmission.<sup>1,2,45,53</sup> The irritant and drying effects of liquid soap and antiseptic soap preparations have been identified as one of the reasons why healthcare practitioners fail to adhere to hand hygiene guidelines.<sup>1,2,45,53,92</sup> In addition, washing hands regularly with liquid soap and water before or after the use of ABHR is associated with dermatitis and is not necessary.<sup>45</sup>

Systematic reviews conducted to underpin national guidelines<sup>1,2,45,53,57</sup> have identified a range of studies that compared the use of alcohol-based preparations with liquid soap and water using self-assessment of skin condition by nurses. These studies found that ABHR was associated with less skin irritation than liquid soap and water.<sup>60,61,64,67,93-95</sup> In addition, a longitudinal study of the introduction and subsequent use of ABHR over a 7-year period observed no reports of irritant and contact dermatitis associated with the use of ABHR.<sup>51</sup>

We identified a recent study which suggested that two ABHR preparations containing a glycerol emollient were more acceptable to staff ( $p < 0.001$ ).<sup>96</sup> Hand moisturisers/emollients that are for shared use are more likely to become contaminated, and have been associated with an outbreak of infection in a neonatal unit.<sup>97</sup>

Current national and international guidance suggests that skin care, through the appropriate use of hand lotion or moisturisers 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.<sup>2,45,53</sup>

- SP11 Clinical staff should be made aware of the potentially damaging effects of hand decontamination products, and encouraged to use an emollient hand cream regularly to maintain the integrity of the skin. Consult the occupational health team or a general practitioner if a particular liquid soap, antiseptic handwash or alcohol-based hand rub causes skin irritation.

*Class D/GPP*

### **How can adherence to hand hygiene guidance be promoted?**

National and international guidelines emphasise the importance of adherence to hand hygiene guidance, and provide an overview of the barriers and factors that influence hand hygiene compliance.<sup>1,2,45,53</sup>

The use of multi-modal approaches to improving hand hygiene practice and behaviour has been advocated for over 10 years. Observational studies have consistently reported an association between multi-modal interventions involving the introduction of near-patient ABHR, audit and feedback, reminders and education, and greater compliance by healthcare staff.<sup>51,98-109</sup>

An early systematic review of 21 studies involving interventions to improve hand hygiene compliance concludes 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; and
- multi-faceted approaches have a more marked effect on hand hygiene and rates of HCAI.<sup>110</sup>



National hand hygiene campaigns have been modelled on the multi-modal approach and implemented across the world.<sup>45,51,111,112</sup> In England and Wales, the National Patient Safety Agency's 'Cleanyourhands Campaign' was piloted and implemented between 2004 and 2008 with the aim of creating sustainable change in hand hygiene compliance. The campaign comprised the use of near-patient ABHR, national poster materials, audit and feedback, and materials for patient engagement.

Recent Cochrane reviews of randomised and controlled clinical trials, interrupted time series and controlled before-after studies have suggested that the majority of studies conducted in this field have methodological biases that exclude them from this review.<sup>77,113</sup> We identified four systematic reviews of interventions to improve hand hygiene compliance.<sup>77,114-116</sup>

The most recent Cochrane review identified 84 studies published after 2006 for potential inclusion, but only four studies (one RCT, two interrupted time series and one controlled before-after study) were included following detailed quality assessment.<sup>77</sup> The heterogeneity of interventions and methods precluded the pooling and meta-analysis of results, and it was concluded that multi-faceted campaigns that include social marketing or staff engagement may be more effective than campaigns without these components, and that education or product substitution alone were less effective.

An integrative systematic review of 35 studies that reported a wide range of interventions, including multi-modal interventions and hand hygiene product changes, only scored nine of the included studies as having limited or no fatal flaws.<sup>114</sup> The authors concluded that design limitations made it difficult to generalise the study results or isolate the specific effects of hand hygiene (or other interventions) on reductions in HCAI.

An earlier systematic review of 'bundled' behavioural intervention studies that reported HCAI or rates of colonisation as the primary outcome identified 33 potential studies for inclusion; of these, only four had quality scores >80%. Again, due to the heterogeneity of study interventions and outcomes, the results were narratively synthesised.<sup>115</sup> The authors concluded that the formation of multi-disciplinary quality improvement teams and educational interventions might be effective strategies to improve hand hygiene and reduce rates of HCAI.

The final systematic review focused specifically on educational interventions to improve hand hygiene compliance and competence in hospital settings, and included all study designs that reported at least one outcome measure of hand hygiene competence and had a follow-up of at least 6 months.<sup>116</sup> Thirty studies met the inclusion criteria for the review, but it was not possible to separate competence from compliance. Educational interventions taught or re-taught the correct methods for hand hygiene and then assessed compliance. The authors concluded that educational interventions had a greater impact if compliance with hand hygiene was low. Multiple interventions were better than single interventions in sustaining behaviour change, as were continuous, rather than one-off, interventions. However, it was not possible to determine the duration or sustainability of behaviour change in these studies.

We identified six new studies in our systematic review: one cluster RCT and process evaluation,<sup>117,118</sup> one step-wedge

cluster RCT,<sup>119</sup> two interrupted time series studies<sup>84,120</sup> and one controlled before-after study<sup>121</sup> that evaluated multi-modal interventions with varying components. In a cluster RCT that also included a process evaluation, the authors tested a set of core elements in a 'state-of-the-art strategy' (SAS) against a team-leader-directed strategy (TDS) at baseline (T1), immediately following the intervention (T2) and 6 months later (T3) to ascertain the additional benefits of leadership and staff engagement components.<sup>117,118</sup> In the intention-to-treat analysis (ITT), an OR of 1.64 (95% CI 1.33-2.02,  $p<0.001$ ) in favour of the TDS between T2 and T3 suggested that engaging ward leadership and the involvement of teams in setting norms and targets resulted in greater compliance with hand hygiene. However, there was no significant difference between the groups' compliance at T3 in the ITT ( $p=0.187$ ), with the SAS also having a sustained effect.<sup>117</sup> The process evaluation examined the extent to which the content, dosage and coverage of the intervention had been delivered.<sup>118</sup> An as-treated analysis demonstrated a greater effect size for the TDS at T3 with a significant difference in hand hygiene compliance ( $p<0.01$ ). The process evaluation also suggested that feedback about individual hand hygiene performance at T2 and T3 ( $p<0.05$  and  $p<0.01$ , respectively), challenging colleagues on undesirable hand hygiene practice ( $p<0.01$ ), and support from colleagues in performing hand hygiene ( $p<0.01$ ) were positively correlated with changes in nurses' hand hygiene compliance.<sup>118</sup>

The second cluster RCT used a step-wedge design to assess a behavioural feedback intervention in intensive therapy units (ITUs) and acute care of the elderly (ACE) wards at sites participating in the 'Cleanyourhands Campaign'.<sup>119</sup> The primary and secondary outcome measures were hand hygiene compliance measured by covert direct observation for 1 h every 6 weeks, and soap and ABHR procurement, respectively. Sixty wards were recruited, of which 33 implemented the intervention. The ITT analysis (60 wards) showed a significant effect of the intervention in the ITUs but not the ACE wards, equating to a 7-9% increase in compliance, with estimated OR of 1.44 (95% CI 1.018-1.76,  $p<0.001$ ) in ITUs and estimated OR of 1.06 (95% CI 0.87-1.25,  $p=0.5$ ) in ACE wards. The per-protocol analysis (33 wards) showed a significant increase in compliance in both ACE wards and ITUs of 10-13% and 13-18%, respectively, with estimated OR of 1.67 (95% CI 1.26-2.22,  $p<0.001$ ) in ACE wards and estimated OR of 2.09 (95% CI 1.55-2.81,  $p<0.001$ ) in ITUs. The authors concluded that individual feedback and team action planning resulted in moderate but sustained improvements in hand hygiene adherence. The difficulties in implementing this intervention point to the problems that might be faced in a non-trial context.

Two interrupted time series studies of the 4-year national 'Cleanyourhands Campaign' in England and a 4-year hospital-wide programme in Taiwan demonstrated increased hand hygiene compliance (measured by procurement of ABHR and liquid soap) and reductions in HCAI [MRSA and *C. difficile*, and MRSA and extensively-drug-resistant *Acinetobacter* (XDRAB)].<sup>84,120</sup> In the national study, increased procurement of soap was independently associated with reductions in *C. difficile* infection (adjusted incidence rate ratio for 1-mL increase per patient-bed-day 0.993, 95% CI 0.990-0.996,  $p<0.0001$ ) and MRSA in the last four quarters of the study (adjusted incidence rate ratio for 1-mL increase per patient-bed-day 0.990, 95% CI 0.985-0.995,  $p<0.0001$ ).<sup>120</sup> The 'Cleanyourhands Campaign' was not independent of other national programmes to reduce

MRSA bloodstream infections and *C. difficile* infection. Analysis also identified that the publication of the Health Act and the Department of Health improvement team visits were associated with reductions in MRSA and *C. difficile*. In the hospital-wide study,<sup>84</sup> the authors demonstrated a decrease in the cumulative incidence of HCAI caused by MRSA (change in level,  $p=0.03$ ; change in trend,  $p=0.04$ ) and XDRAB (change in level,  $p=0.78$ ; change in trend,  $p<0.001$ ) during the intervention period. Hand hygiene compliance was significantly correlated with increased consumption of ABHR, and improved overall from 43.3% in 2004 to 95.6% in 2007 ( $p<0.001$ ). Hand hygiene compliance was also significantly correlated with professional categories of healthcare workers ( $p<0.001$ ) in both general wards and ICUs ( $p<0.001$ ).

The controlled before-after study<sup>121</sup> of a range of patient safety interventions in England, including hand hygiene, as measured by ABHR and soap consumption in non-specialist acute hospitals, reported no significant differences in the rate of increase in consumption of ABHR ( $p=0.760$  favouring controls and  $p=0.889$  favouring intervention) and non-significant decreases in *C. difficile* ( $p=0.652$ ) and MRSA ( $p=0.693$ ).

- SP12 Alcohol-based hand rub should be made available at the point of care in all healthcare facilities.  
*Class C*
- SP13 Hand hygiene resources and healthcare worker adherence to hand hygiene guidelines should be audited at regular intervals, and the results should be fed back to healthcare workers to improve and sustain high levels of compliance.  
*Class C*
- SP14 Healthcare organisations must provide regular training in risk assessment, effective hand hygiene and glove use for all healthcare workers.  
*Class D/GPP*
- SP15 Local programmes of education, social marketing, and audit and feedback should be refreshed regularly and promoted by senior managers and clinicians to maintain focus, engage staff and produce sustainable levels of compliance.  
**New recommendation Class C**

### **Patient involvement in hand hygiene**

Patient involvement in multi-modal strategies to improve hand hygiene among healthcare workers is established, and includes making it acceptable for patients and carers to request that healthcare workers clean their hands.<sup>45</sup> However, research suggests that many patients and carers do not feel empowered to challenge staff, particularly doctors.<sup>108,109,122,123</sup> Many NHS trusts have promoted hand hygiene among visitors by placing ABHR at the entrances to wards and patient rooms, but there is no evidence that this reduces HCAI. Despite being highlighted as an important gap in research, the role of patients' hands in the cross-transmission of microorganisms has not been investigated systematically, other than in ecologic studies that describe hand or skin contamination<sup>124-126</sup> or observations of non-use of hand hygiene products.<sup>127</sup> Studies of effective interventions to enable patients to clean their hands remain small scale and descriptive in nature.<sup>128-131</sup>

We identified three studies that described interventions to improve patient hand hygiene: one in an outbreak situation, one uncontrolled before-after study of parent education in a single paediatric ICU, and one as part of a prospective observational study in a community hospital. None of these studies met the quality criteria for inclusion in this systematic review.<sup>132-134</sup> However, all of these studies suggested that improving patient/carer hand hygiene had some effect on cross-transmission of microorganisms and hand hygiene technique. National guidelines indicate that it is important to educate patients and carers about the importance of hand hygiene, and inform them about the availability of hand hygiene facilities and their role in maintaining standards of healthcare workers' hand hygiene.<sup>56</sup>

- SP16 Patients and relatives should be provided with information about the need for hand hygiene and how to keep their own hands clean.  
**New recommendation Class D/GPP**
- SP17 Patients should be offered the opportunity to clean their hands before meals; after using the toilet, commode or bedpan/urinal; and at other times as appropriate. Products available should be tailored to patient needs and may include alcohol-based hand rub, hand wipes and access to handwash basins.  
**New recommendation Class D/GPP**

**Hand Hygiene - Systematic Review Process****Systematic Review Questions**

1. What is the effectiveness and cost-effectiveness of hand decontamination preparations on hand hygiene compliance among healthcare workers, reductions in HCAI, reductions in transient and/or resident skin microorganisms, and the removal of organic soil?
2. What is the most effective hand decontamination technique, including duration, for achieving reductions in transient and/or resident skin microorganisms and the removal of organic soil?
3. What is the effectiveness of hand decontamination preparations on user preference and minimising contact dermatitis/allergy in healthcare workers?
4. What is the effectiveness of system interventions, electronic monitoring and education programmes in increasing hand hygiene compliance among healthcare workers and reducing infection?
5. What is the effectiveness of interventions that provide patients with opportunities to decontaminate their hands while in hospital?

**Databases and Search Terms Used****DATABASES**

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDJR, CCRCT, CMR), US Guideline

Clearing House, DARE (NHS Evidence, HTA), Prospero, PsycINFO  
**MeSH TERMS**

Infection control; cross infection; equipment contamination; disease transmission; disinfectants; soaps; anti-infective agents; surface active agents; guideline adherence; consumer satisfaction

**THESAURUS AND FREE-TEXT TERMS**

Handwashing; skin; nails; antisepsis; decontamination; WHO Five Moments; multi-modal campaign; patient education; hand hygiene audit; hand hygiene compliance

**SEARCH DATE**

Jan 2006-Jan 2013

**Search Results**

Total number of articles located = 8223

**Sift 1 Criteria**

Abstract indicates that the article: relates to infections associated with hand hygiene; is written in English; is primary research, 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 = 255

**Sift 2 Criteria**

Full text confirms that the article: relates to infections associated with hand hygiene; is written in English; is primary research (randomised controlled trials, prospective cohort, interrupted time series, controlled before-after, quasi-experimental, experimental studies answering specific questions), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

**Articles Selected for Appraisal**

Total number of studies selected for appraisal during Sift 2 = 78

**Critical Appraisal**

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

**Accepted and Rejected Evidence**

Total number of studies accepted after critical appraisal = 17  
Total number of studies rejected after critical appraisal = 61

**2.4 Use of Personal Protective Equipment**

This section discusses the evidence and associated recommendations for the use of PPE by healthcare workers in acute care settings and includes the use of aprons, gowns, gloves, eye protection and face masks/respirators to prevent potential transmission of pathogenic microorganisms to staff, patients and the healthcare environment. The use of gloves for other purposes does not form part of these guidelines. Where health and safety legislation underpins a recommendation, this is indicated by 'Health & Safety (H&S)' in addition to the classification of any clinical evidence underpinning the recommendations.

**Infection prevention and control dress code - protect your patients and yourself**

The primary roles of PPE are to protect staff and reduce opportunities for cross-transmission of microorganisms in hospitals.<sup>1,2,135</sup> There is no evidence that uniforms or work clothing are associated with HCAI. However, there is a public expectation that healthcare workers will wear work and protective clothing to minimise any potential risk to patients and themselves.<sup>85,136</sup> The decision to use or wear PPE 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.<sup>137-140</sup> There is evidence that both a lack of knowledge of guidelines and non-adherence to guideline recommendations are common, and that regular in-service education and training is required.<sup>106,141-144</sup>

SP18 Selection of personal protective equipment must be based on an assessment of the:

- risk of transmission of microorganisms to the patient or carer;
- risk of contamination of healthcare practitioners' clothing and skin by patients' blood or body fluids; and
- suitability of the equipment for proposed use.

*Class D/GPP/H&S*

SP19 Healthcare workers should be educated and their competence assessed in the:

- assessment of risk;
- selection and use of personal protective equipment; and
- use of standard precautions.

*Class D/GPP/H&S*

SP20 Supplies of personal protective equipment should be made available wherever care is delivered and risk assessment indicates a requirement.

*Class D/GPP/H&S*

### **Gloves: use them appropriately**

The use of gloves as an element of PPE and contact precautions is an everyday part of clinical practice for healthcare workers.<sup>1,2,135</sup> There are other indications unrelated to preventing the cross-transmission of infection that require gloves to be worn (e.g. the use of some chemicals or medications). The two main indications for the use of gloves in the prevention of HCAI<sup>1</sup> are:

- to protect hands from contamination with organic matter and microorganisms; and
- to reduce the risk of cross-transmission of microorganisms to staff and patients.

Gloves should be selected on the basis of a risk assessment, and should be suitable for the proposed task and the materials being handled.<sup>138-140</sup> Gloves are categorised as medical gloves (examination and surgical) and protective gloves.<sup>145</sup> Examination gloves are available as sterile or non-sterile for use by healthcare workers during clinical care to prevent contamination with microorganisms, blood and body fluids. Surgical gloves are available as sterile for use by healthcare workers during surgical and other invasive procedures. Protective gloves are used to protect healthcare workers from chemical hazards.<sup>145</sup>

Gloves should not be worn as a substitute for hand hygiene. Their prolonged and unnecessary use may cause adverse reactions and skin sensitivity, and may lead to cross-contamination of the patient environment.<sup>1,2</sup> The need to wear gloves and the selection of appropriate glove materials requires careful assessment of the task to be performed and its related risks to patients and healthcare workers.<sup>1,2,135,146,147</sup> Risk assessment should include consideration of:

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

We identified four observational studies which suggested that clinical gloves are not used in line with current guidance, and that glove use impacts negatively on hand hygiene.<sup>148-151</sup> In addition, a cluster RCT of screening and enhanced contact precautions for patients colonised with MRSA or VRE found no reduction in transmission, but also found that adherence to contact precautions was less than ideal.<sup>152</sup> Gloves must be removed immediately following each care activity for which they have been worn, and hands must be decontaminated in order to prevent the cross-transmission of microorganisms to other susceptible sites in that individual or to other patients. Gloves should not be washed or decontaminated with ABHR as a substitute for changing gloves between care activities.<sup>45</sup>

### **Gloves are not infallible**

There is evidence that hands become contaminated when clinical gloves are worn, even when the integrity of the glove appears undamaged.<sup>1,2,135</sup> In terms of leakage, gloves made from natural rubber latex (NRL) perform better than vinyl gloves in laboratory test conditions.<sup>1,2</sup> Standards for the manufacture of medical gloves for single use require gloves to perform to European standards.<sup>153-157</sup> However, the integrity of gloves cannot be guaranteed, and hands may become contaminated during the removal of gloves.<sup>1,2,149,156</sup>

The appropriate use of medical gloves provides barrier protection and reduces the risk of hand contamination from blood, body fluids, secretions and excretions, but does not eliminate the risk. Hands cannot be considered to be clean because gloves have been worn, and should be decontaminated following the removal of gloves. Used gloves must be disposed of in accordance with the requirements of current legislation and local policy for waste management.<sup>157</sup>

SP21 Gloves must be worn for:

- invasive procedures;
- contact with sterile sites and non-intact skin or mucous membranes;
- all activities that have been assessed as carrying a risk of exposure to blood or body fluids; and
- when handling sharps or contaminated devices.

*Class D/GPP/H&S*

SP22 Gloves must be:

- worn as single-use items;
- put on immediately before an episode of patient contact or treatment;
- removed as soon as the episode is completed;
- changed between caring for different patients; and
- disposed of into the appropriate waste stream in accordance with local policies for waste management.

*Class D/GPP/H&S*

SP23 Hands must be decontaminated immediately after gloves have been removed.

*Class D/GPP/H&S*



## Making choices

Clinical gloves should be used by healthcare workers to prevent the risk of hand contamination with blood, body fluids, secretions and excretions, and to protect patients from potential cross-contamination of susceptible body sites or invasive devices.<sup>1</sup> 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; and
- surgical or examination gloves, based on the aspect of care or treatment to be undertaken.

Healthcare organisations must provide gloves that conform to European standards (EN455-1, 455-2, 455-3), and which are acceptable to healthcare practitioners.<sup>153-155</sup> Medical gloves are available in a range of materials, the most common being NRL, which remains the material of choice due to its efficacy in protecting against bloodborne viruses and properties that enable the wearer to maintain dexterity.<sup>1,158</sup> Patient or healthcare practitioner sensitivity to NRL proteins must also be taken into account when deciding on glove materials.<sup>146</sup>

Synthetic gloves are generally more expensive than NRL gloves and may not be suitable for all purposes.<sup>1</sup> Nitrile gloves have the same chemical range as NRL gloves and may also lead to sensitivity problems in healthcare workers and patients. Polythene gloves are not suitable for clinical use due to their permeability and tendency to damage easily.<sup>1</sup> A study that compared the performance of nitrile, latex, copolymer and vinyl gloves under stressed and unstressed conditions found that nitrile gloves had the lowest failure rate, suggesting that nitrile gloves are a suitable alternative to NRL gloves, provided that there are no sensitivity issues. Importantly, the study noted variation in performance of the same type of glove produced by different manufacturers.<sup>158</sup> The Health and Safety Executive (HSE) also provide a guide-to-glove selection for employers.<sup>147</sup>

SP24 A range of CE-marked medical and protective gloves that are acceptable to healthcare personnel and suitable for the task must be available in all clinical areas.

*Class D/GPP/H&S*

SP25 Sensitivity to natural rubber latex in patients, carers and healthcare workers must be documented, and alternatives to natural rubber latex gloves must be available.

*Class D/GPP/H&S*

## Aprons or gowns?

National and international guidelines recommend that PPE 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 or body fluids.<sup>2,138,159</sup> Disposable plastic aprons are recommended for general clinical use.<sup>2</sup> Full-body gowns need only be used where there is the possibility of extensive splashing of blood or body fluids, and should be fluid repellent.<sup>2,159</sup>

We identified a systematic review of the evidence that microbial contaminants found on the work clothing of healthcare practitioners are a significant factor in cases of HCAI.<sup>136</sup> The reviewers identified seven small-scale studies that described the progressive contamination of work clothing during clinical care, and a further three studies that suggested a link with microbial contamination and infection.<sup>17,160-169</sup> One of the three studies was conducted in a simulated scenario and demonstrated that it was possible to transfer *S. aureus* from nurses' gowns to patients' bed sheets, but this was not associated with clinical infection.<sup>167</sup> A further pair of linked studies, associated with an outbreak of *Bacillus cereus*, showed an epidemiological link between contaminated clothing and HCAI, but this occurred when surgical scrub suits became highly contaminated in an industrial laundry, rather than as a result of clinical care.<sup>168,169</sup> A further study demonstrated high levels of contamination of gowns, gloves and stethoscopes with VRE following examination of patients known to be infected.<sup>170</sup>

A systematic review of eight studies that assessed the effects of gowning by attendants and visitors found no evidence to suggest that over-gowns are effective in reducing mortality, clinical infection or bacterial colonisation in infants admitted to newborn nurseries.<sup>171</sup> One quasi-experimental study investigated the use of gowns and gloves as opposed to gloves alone for prevention of acquisition of VRE in a medical ICU setting.<sup>172</sup> A further prospective observational study investigated the use of a similar intervention in a medical ICU.<sup>173</sup> These studies suggested that the use of gloves and gowns may minimise the transmission of VRE when colonisation pressure is high.

SP26 Disposable plastic aprons must be worn when close contact with the patient, materials or equipment pose a risk that clothing may become contaminated with pathogenic microorganisms, blood or body fluids.

*Class D/GPP/H&S*

SP27 Full-body fluid-repellent gowns must be worn where there is a risk of extensive splashing of blood or body fluids on to the skin or clothing of healthcare workers.

*Class D/GPP/H&S*

SP28 Plastic aprons/fluid-repellent gowns should be worn as single-use items for one procedure or episode of patient care, and disposed of into the appropriate waste stream in accordance with local policies for waste management. When used, non-disposable protective clothing should be sent for laundering.  
*Class D/GPP/H&S*

### **When are a face mask, respiratory protection and eye protection necessary?**

Healthcare workers (and sometimes patients) may use standard, fluid-repellent surgical face masks to prevent respiratory droplets from the mouth and nose being expelled into the environment. Face masks 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 reviews failed to reveal any robust experimental studies that demonstrated that healthcare workers wearing surgical face masks protected patients from HCAI during routine ward procedures, such as wound dressing or invasive medical procedures.<sup>1,2</sup>

Face masks are also used to protect the wearer from inhaling aerosolised droplet nuclei expelled from the respiratory tract. As surgical face masks are not effective at filtering out such particles, specialised respiratory protective equipment (respirators) may be recommended for the care of patients with certain respiratory diseases [e.g. active multiple drug-resistant pulmonary tuberculosis,<sup>174</sup> severe acute respiratory syndrome (SARS) and pandemic influenza].<sup>175</sup> The filtration efficiency of these 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.<sup>1,2,176</sup>

The selection of the most appropriate respiratory protective equipment (RPE) should be based on a suitable risk assessment that includes the task being undertaken, the characteristics of the biological agent to which there is a risk of exposure, as well as the duration of the task and the local environment. Where the activity involves procedures likely to generate aerosols of biological agents transmitted by an airborne route (e.g. intubation), RPE with an assigned protection factor (APF) of 20 (equivalent to FFP3) should be used. In other circumstances, such as where the agent is transmitted via droplet rather than aerosol or where the level of aerosol exposure is low, the risk assessment may conclude that other forms of RPE (e.g. APF10/FFP2) or a physical barrier (e.g. surgical face mask) may be appropriate, such as when caring for patients with influenza. Where RPE is required, it must fit the user properly and the user must be fully trained in how to wear and adjust it.<sup>177</sup>

We identified four systematic reviews of the use of facial protection, all of which had been undertaken in the aftermath of the SARS outbreak and in response to the H1N1 influenza pandemic. A range of study designs were considered in each of the reviews, including cluster RCTs, RCTs, cohort studies and descriptive before-after studies. Overall, many studies were poorly controlled, with no accounting for confounders,

such as poor compliance in the weaker studies. The authors of each of the reviews concluded that there was no strong evidence that masks/respirators alone are effective for the prevention of respiratory viral infections. Masks/respirators should be used together with other protective measures to reduce transmission.<sup>178-181</sup>

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.<sup>1</sup> Expert opinion recommends that face and eye protection reduce the risk of occupational exposure of healthcare workers to splashes of blood or body fluids.<sup>1,2,159,182</sup>

SP29 Fluid-repellent surgical face masks and eye protection must be worn where there is a risk of blood or body fluids splashing into the face and eyes.  
*Class D/GPP H&S*

SP30 Appropriate respiratory protective equipment should be selected according to a risk assessment that takes account of the infective microorganism, the anticipated activity and the duration of exposure.  
*Class D/GPP/H&S*

SP31 Respiratory protective equipment must fit the user correctly and they must be trained in how to use and adjust it in accordance with health and safety regulations.  
*Class D/GPP/H&S*

SP32 Personal protective equipment should be removed in the following sequence to minimise the risk of cross/self-contamination:

- gloves;
- apron;
- eye protection (when worn); and
- mask/respirator (when worn).

Hands must be decontaminated following the removal of personal protective equipment.

**New recommendation** *Class D/GPP/H&S*



## Personal Protective Equipment - Systematic Review Process

### Systematic Review Questions

1. What is the evidence that healthcare workers' use of clinical gloves is clinically appropriate and cost-effective?
2. What is the effect of glove use on hand hygiene compliance?
3. What is the effect of glove material (vinyl, latex or nitrile) on user preference and hypersensitivity, protection against bloodborne infections, glove porosity and tears? (adapted from NICE 139)
4. What is the evidence that the uniforms/clothes of healthcare workers contribute to the transmission of HCAI?
5. What is the evidence that the use of protective clothing reduces the risk of transmission of HCAI?
6. What is the effectiveness of PPE (aprons, gloves and mouth/facial protection) in preventing the transmission of bloodborne viruses?
7. What is the effectiveness of facial protection (face masks, respirators) in preventing the transmission of respiratory pathogens?
8. What is the effectiveness of education interventions in improving healthcare workers' knowledge and behaviour in the appropriate use of PPE and reducing infection?

### Databases and Search Terms Used

#### DATABASES

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDSR, CCRCT, CMR), US Guideline Clearing House, DARE (NHS Evidence, HTA), Prospero

#### MESH TERMS

Infection control; cross infection; equipment contamination; universal precaution; disease transmission; protective clothing; disposable equipment; masks; gloves, protective; eye protective devices; education; health education, medical education; in-service training; health knowledge

#### THESAURUS AND FREE-TEXT TERMS

Infection; contamination; antisepsis; universal precaution; disease transmission; disinfection; sterilisation; decontamination; disposable equipment; masks; gloves; face shield; goggles; apron; gown; protective clothes; visor; hood; eye protection devices

#### SEARCH DATE

Apron, gloves (AG): Apr 2011-Feb 2013, facial protection (FP): Jan 2006-Jan 2013

### Search Results

Total number of articles located = AG (867), FP (8160)

### Sift 1 Criteria

Abstract indicates that the article: relates to infections associated with protective clothing; is written in English; is primary research, 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 = AG (32), FP (25)

### Sift 2 Criteria

Full text confirms that the article: relates to infections associated with protective clothing; is written in English; is primary research (randomised controlled trials, prospective cohort, interrupted time series, controlled before-after, quasi-experimental), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

### Articles Selected for Appraisal

Total number of studies selected for appraisal during Sift 2 = AG (6), FP (6)

### Critical Appraisal

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

### Accepted and Rejected Evidence

Total number of studies accepted after critical appraisal = AG (6), FP (4)  
Total number of studies rejected after critical appraisal = AG (0), FP (2)

## 2.5 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. This includes minimising the potential infection risks associated with sharps use and disposal, and the use of needle protection devices. The use and disposal of sharps is subject to the Health and Safety at Work Act 1974<sup>183</sup> and several elements of health and safety legislation including:

- The Health and Safety (Sharp Instruments in Healthcare) Regulations 2013;<sup>184</sup>
- Control of Substances Hazardous to Health Regulations 2002;<sup>139</sup>
- Management of Health and Safety at Work Regulations 1999;<sup>137</sup>
- The Provision and Use of Work Equipment Regulations 1998;<sup>185</sup>
- Reporting of Diseases, Injuries and Dangerous Occurrences Regulations 1995;<sup>186</sup>
- The Personal Protective Equipment Regulations 1992;<sup>187</sup> and
- Health and Safety (First Aid) Regulations 1981.<sup>188</sup>

Where health and safety legislation underpins a recommendation, this is indicated by 'H&S' in addition to the classification of any clinical evidence underpinning the recommendations.

### Sharps injuries - what's the problem?

The HSE define a sharp as a needle, blade or other medical instrument capable of cutting or piercing the skin.<sup>184</sup> Similarly, a sharps injury is an incident that causes a needle, blade or other medical instrument to penetrate the skin (percutaneous injury). 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.<sup>159</sup>

The National Audit Office identified that needlestick and sharps injuries ranked alongside moving and handling, falls, trips and exposure to hazardous substances as the main types of accidents experienced by NHS staff.<sup>189</sup> A later Royal College of Nursing survey of 4407 nurses found that almost half (48%) had, at some point in their career, sustained a sharps injury from a device that had previously been used on a patient. A similar number (52%) reported fearing sharps injuries, and nearly half (45%) reported that they had not received training from their employer on safe needle use.<sup>190</sup> The 2012 'Eye of the Needle' report from the Health Protection Agency confirms that healthcare workers continue to be exposed to bloodborne virus infections, even though such exposures are largely preventable.<sup>191</sup> The number of reported occupational exposures almost doubled from 276 in 2002 to 541 in 2011, with almost half of all exposures occurring in nurses. However, in 2011, medical and dental professions reported a similar number of occupational exposures as nursing professions, with exposures in these groups increasing by 131% between 2002 and 2011. The report draws attention to the need for healthcare providers to comply with the European Council Directive 2010/32/EU and adopt safety devices in order to prevent sharps 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:<sup>135,191,192</sup>

- hepatitis B virus, one in three;
- hepatitis C virus, one in 30; and
- human immunodeficiency virus, one in 300.

### **Avoiding sharps injuries is everybody's responsibility**

National and international guidelines are consistent in their recommendations for the safe use and disposal of sharp instruments and needles, and the management of healthcare workers who are exposed to potential infection from bloodborne viruses.<sup>135,193-195</sup> 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.<sup>139</sup>

National<sup>184</sup> and European Union<sup>196</sup> legislation requires the UK and all EU member states to provide protection for all healthcare workers exposed to the risk of sharps injuries. In summary, the Health and Safety (Sharp Instruments in Healthcare) Regulations 2013 require all employers, under existing health and safety law, to:

- conduct risk assessments;
- avoid unnecessary use of sharps and, where this is not possible, use safer sharps that incorporate protection mechanisms;
- prevent the recapping of needles;
- ensure safe disposal by placing secure sharps containers close to the point of use;
- provide employees with adequate information and training on the safe use and disposal of sharps, what to do in the event of a sharps injury and the arrangements for testing, immunisation and post-exposure prophylaxis, where appropriate;
- record and investigate sharps incidents; and
- provide employees who have been injured with access to medical advice, and offer testing, immunisation, post-exposure prophylaxis and counselling, where appropriate.<sup>184,193</sup>

Legislation also includes a duty for employees who receive a sharps injury whilst undertaking their work to inform their employer as soon as is practicable.<sup>184,193</sup> All healthcare workers must be aware of their responsibility in avoiding sharps injuries.

We identified a systematic review which included studies that focused on education and training interventions to minimise the incidence of occupational injuries involving sharps devices.<sup>197</sup> The authors identified five primary before-after studies that demonstrated a consistent reduction in the incidence of percutaneous injuries when other safety initiatives (e.g. training) were implemented before and during the introduction of safer sharps devices.<sup>198-202</sup> These studies used a range of interventions in one setting and are not generalisable. However, education is essential in ensuring that staff understand safe ways of working and how to use safer sharps devices. This should form a part of induction programmes for new staff and on-going in-service education. The introduction of new devices should include an appropriate training programme as part of staff introduction.

SP33 Sharps must not be passed directly from hand to hand, and handling should be kept to a minimum.

*Class D/GPP/H&S*

SP34 Needles must not be recapped, bent or disassembled after use.

*Class D/GPP/H&S*

SP35 Used sharps must be discarded at the point of use by the person generating the waste.

*Class D/GPP/H&S*

SP36 All sharps containers must:

- conform to current national and international standards;
- be positioned safely, away from public areas and out of the reach of children, and at a height that enables safe disposal by all members of staff;
- be secured to avoid spillage;
- be temporarily closed when not in use;
- not be filled above the fill line; and
- be disposed of when the fill line is reached.

*Class D/GPP/H&S*

SP37 All clinical and non-clinical staff must be educated about the safe use and disposal of sharps and the action to be taken in the event of an injury.

*Class D/GPP/H&S*

### **Needle protection devices reduce avoidable injuries**

To improve patient and staff safety, legislation and the Department of Health require healthcare providers and their employees to pursue safer methods of working through risk assessment to eliminate the use of sharps and, where this is not possible, the use of safer sharps.<sup>184,203,204</sup> The incidence of sharps injuries has led to the development of safety devices in many different product groups.<sup>205</sup> They are designed to minimise the risk of operator injury during sharps use, as well as 'downstream' injuries that occur after disposal, often involving the housekeeping or portering staff responsible for the collection of sharps disposal units.

The lack of well-designed, controlled intervention studies means that evidence to show whether or not safety devices are effective in reducing rates of infection is limited. However, a small number of studies have shown significant reductions in injuries associated with the use of safety devices<sup>2</sup> in cannulation,<sup>206,207</sup> phlebotomy<sup>208-210</sup> and injections.<sup>211</sup>

It is logical that where needle-free or other safety devices are used, there is 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.<sup>212</sup> However, some studies have identified 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.<sup>2</sup> A comprehensive report and product review

conducted in the 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 programme.<sup>205</sup> It reported 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 if used incorrectly.<sup>213</sup>

NICE identified three RCTs that compared safety cannulae with standard cannulae. The studies were all in hospital settings and of low/very-low quality. The quality of evidence for safety needle devices was low, with no RCTs identified and the five before-after implementation studies being of very-low quality. The quality of evidence for training was similarly low, with the type of training varying across the five observational studies identified.<sup>56</sup>

We identified a systematic review undertaken by the HSE which reviewed 41 studies that provided evidence for reductions in the incidence of occupational sharps injuries associated with use of sharps safety devices, education and training, and the acceptability of sharps safety devices.<sup>197</sup> Thirteen studies, predominantly with observational designs, demonstrated that safer sharps devices were associated with a significant reduction in the incidence of healthcare worker needlestick injury.<sup>199,201,208-210,214-221</sup> However, safety devices were not the total solution to reducing occupational injury. The beneficial outcome of consulting with end-users of safer sharps devices before they are introduced was demonstrated in five studies identified in this review.<sup>208,211,222-225</sup>

In the USA, the Occupational Safety Health Administration and the National Institute for Occupational Safety and Health suggest that a thorough evaluation of any device is essential before purchasing decisions are made.<sup>195,226</sup> Similarly, the HSE suggests that the end-users of any safer sharps device should be involved in the assessment of user acceptability and clinical applicability of any needle safety devices.<sup>184</sup> The evaluation should ensure that the safety feature works effectively and reliably, that the device is acceptable to healthcare practitioners and that it does not have an adverse effect on patient care.

SP38 Use safer sharps devices where assessment indicates that they will provide safe systems of working for healthcare workers.

*Class C/H&S*

SP39 Organisations should involve end-users in evaluating safer sharps devices to determine their effectiveness, acceptability to practitioners, impact on patient care and cost benefit prior to widespread introduction.

*Class D/GPP/H&S*

## Sharps - Systematic Review Process

### Systematic Review Questions

1. What are the risk factors associated with sharps injuries in secondary health care? (\*B)
  2. What are the changes in legislation in relation to the use and disposal of sharps and the prevention of injuries in healthcare settings? (B)
  3. What is the effectiveness and cost-effectiveness of using safety needle cannulae vs standard cannulae on healthcare workers' compliance with recommended use and disposal, risk of infection and injury to patients or healthcare workers? (adapted from NICE 139) *Note: This question may refer to PVC review questions too.*
  4. What is the effectiveness and cost-effectiveness of healthcare workers using safety needle devices (needle-free, retractable needle, safety re-sheathing devices) vs standard needles on healthcare workers' compliance with recommended use and disposal, risk of infection and injury to patients or healthcare workers? (adapted from NICE 139)
  5. What is the effectiveness of education interventions in improving healthcare workers' knowledge and behaviour in the use and disposal of sharps?
- \*B: Background question

### Databases and Search Terms Used

#### DATABASES

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDSR, CCRC, CMR), US Guideline Clearing House, DARE (NHS Evidence, HTA), Prospero

#### MeSH TERMS

Infection control; cross infection; universal precautions, equipment contamination; disease transmission; needlestick injuries; education; health education; medical education; inservice training; health knowledge

#### THESAURUS AND FREE-TEXT TERMS

Needles; syringes; sharps; resheathing; safe needle; safe lancet; safe cannula, needle retract; needle covered; needle capped; needle fixed; needle uncapped; needleless; needle free

#### SEARCH DATE

Jan 2005-Feb 2013

### Search Results

Total number of articles located = 3989

### Sift 1 Criteria

Abstract indicates that the article: relates to infections associated with sharps; is written in English, is primary research, 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 = 18

### Sift 2 Criteria

Full text confirms that the article: relates to infections associated with sharps; is written in English; is primary research (randomised controlled trials, prospective cohort, interrupted time series, controlled before-after, quasi-experimental), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

### Articles Selected for Appraisal

Total number of studies selected for appraisal during Sift 2 = 2

### Critical Appraisal

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

### Accepted and Rejected Evidence

Total number of studies accepted after critical appraisal = 1  
Total number of studies rejected after critical appraisal = 1

## 2.6 Asepsis

The term 'asepsis' means the absence of potentially pathogenic microorganisms.<sup>227</sup> Asepsis applies to both medical and surgical procedures. Medical asepsis aims to minimise the risk of contamination by microorganisms, and prevent their transmission by applying standard principles of infection prevention, including decontaminating hands, use of PPE, maintaining an aseptic area, and not touching susceptible sites or the surface of invasive devices.<sup>56</sup> Surgical asepsis is a more complex process, including procedures to eliminate microorganisms from an area (thus creating an aseptic environment), and is practised in operating theatres and for invasive procedures, such as the insertion of a central venous catheter (CVC).<sup>56</sup> 'Aseptic technique' is a term applied to a set of specific practices and procedures used to assure asepsis and prevent the transfer of potentially pathogenic microorganisms to a susceptible site on the body (e.g. an open wound or insertion site for an invasive medical device) or to sterile equipment/devices. It involves ensuring that susceptible body sites and the sterile parts of devices in contact with a susceptible site are not contaminated during the procedure.

The aseptic technique is an essential element of the prevention of HCAI, particularly when the body's natural defence mechanisms are compromised. However, similar to NICE,<sup>56</sup> we identified no clinical or economic evidence that any one approach to the aseptic technique is more clinically or cost-effective than another. Thus, all recommendations here are Class D/GPP.

## Improving the practice of the aseptic technique

No studies that met the inclusion criteria and compared education interventions for improving the aseptic technique generally were identified. We identified one systematic review that assessed education interventions to improve competence in the aseptic insertion and maintenance of CVCs.<sup>228</sup> The review included 47 studies of educational interventions that were designed to change staff behaviour related to: general asepsis, maximal sterile barrier (MSB) precautions during insertion, cutaneous antisepsis, and other aspects of insertion and maintenance practice. The studies all described multi-modal education approaches alone or combined with demonstration, simulation, video and self-study. Only one of these studies reported improvements in competence with performing the aseptic technique as a discrete outcome, and nine studies measured overall compliance with the total insertion bundle.

Variations in terminology are used in the literature to describe the aseptic technique. Inconsistencies in the use of terms and application of the principles of asepsis in clinical practice have been addressed in a framework referred to as 'aseptic non-touch technique'.<sup>229</sup> This provides a practice structure and educational materials aimed at minimising variation and developing competence in practice.<sup>229</sup> However, no comparative evidence indicating the efficacy of this approach was identified.

SP40 Organisations should provide education to ensure that healthcare workers are trained and competent in performing the aseptic technique.

**New recommendation Class D/GPP**

SP41 The aseptic technique should be used for any procedure that breaches the body's natural defences, including the:

- insertion and maintenance of invasive devices;
- infusion of sterile fluids and medication; and
- care of wounds and surgical incisions.

**New recommendation Class D/GPP**



**Asepsis - Systematic Review Process****Systematic Review Questions**

1. What are the principles of asepsis? (\*B)
2. When should the principles of asepsis be used in clinical care? (B)
3. What is the effectiveness of system interventions and education programmes in increasing healthcare workers' adherence to the principles of the aseptic technique and reducing HCAI?  
\*B: Background question

**Databases and Search Terms Used****DATABASES**

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDR, CCRCT, CMR), US Guideline Clearing House, DARE (NHS Evidence, HTA), Prospero

**MeSH TERMS**

Healthcare-associated infection, catheter-associated bloodstream infection, catheter-associated urinary tract infection, catheterisation, indwelling catheter, intravascular access device, ANTT, asepsis

**THESAURUS AND FREE-TEXT TERMS**

Non-touch, no touch, aseptic technique, sterile procedure, healthcare workers, education and training

**SEARCH DATE**

Jan 2011-Apr 2013

**Search Results**

Total number of articles located = Asepsis-UC (55), Asepsis-IVAD (205)

**Sift 1 Criteria**

**Abstract indicates** that the article: relates to infections associated with asepsis; is written in English; is primary research, 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 = Asepsis-UC (10), Asepsis-IVAD (25)

**Sift 2 Criteria**

**Full text confirms** that the article: relates to infections associated with asepsis; is written in English; is primary research (randomised controlled trials/RCT), prospective cohort, interrupted time series, controlled before-after, quasi-experimental), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

**Articles Selected for Appraisal**

Total number of studies selected for appraisal during Sift 2 = 1

**Critical Appraisal**

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

**Accepted and Rejected Evidence**

Total number of studies accepted after critical appraisal = 0  
Total number of studies rejected after critical appraisal = 1

**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. Evidence identified in the Healthcare Infection Control Practices Advisory Committee (HICPAC) systematic review was used to support the recommendations in these guidelines.<sup>230</sup> Some recommendations from the previous guidelines have been revised to improve clarity; where a new recommendation has been made, this is indicated in the text. These recommendations are not detailed procedural protocols, and need to be incorporated into local guidelines. None are regarded as optional.

These guidelines apply to adults and children aged  $\geq 1$  year who require a short-term indwelling urethral catheter ( $\leq 28$  days), and should be read in conjunction with the guidance on Standard Principles. The recommendations are divided into six distinct interventions:

- assessing the need for catheterisation;
- selection of catheter type and system;
- catheter insertion;
- catheter maintenance;
- education of patients, relatives and healthcare workers; and
- system interventions for reducing the risk of infection.

**3.2 Background and Context of the Guidelines**

Urinary tract infection (UTI) is the most common infection acquired as a result of health care, accounting for 19% of HCAI, with between 43% and 56% of UTIs associated with a urethral catheter.<sup>231,232</sup> Catheters predispose to infection because microorganisms are able to bypass natural host mechanisms, such as the urethra and micturition, and gain entry to the bladder.<sup>233</sup> Most microorganisms causing catheter-associated UTI (CAUTI) 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 healthcare workers' hands or from the patient's own perineal flora. Extraluminal contamination is also thought to occur from microorganisms ascending from the perineum. Intraluminal contamination occurs by reflux of microorganisms from a contaminated urine drainage bag.<sup>234</sup>

The bladder is normally sterile; in the non-catheterised patient, a UTI is usually identified from the symptoms of dysuria and frequency of urination. Patients who develop a UTI with a short-term indwelling urethral catheter in place may not experience these symptoms, and diagnosis may be based on other signs, such as fever or suprapubic or loin tenderness.<sup>235</sup> After a few days of catheterisation, microorganisms may be isolated from urine and, in the absence of any symptoms of UTI, this is called 'bacteriuria'.<sup>236</sup> The duration of catheterisation is the dominant risk factor for CAUTI, and virtually all catheterised patients develop bacteriuria within 1 month.<sup>230</sup> For the purpose of these guidelines, a duration of catheterisation of  $\leq 28$  days is considered to be a short-term catheterisation.<sup>234</sup>

Several factors contribute to the potential development of CAUTI, including the formation of biofilms and encrustation of the catheter. Bacteria on the catheter surface and drainage bag multiply rapidly, adhering to the surface by excreting extracellular polysaccharides and forming a layer known as a 'biofilm'. Bacteria within the biofilm are morphologically and physiologically different from free-living planktonic bacteria in the urine, and have considerable survival advantages as they are protected from the action of antibiotic therapy.<sup>234</sup>

Whilst biofilms commonly form on devices inserted into the body, they can cause additional problems on urethral catheters if the bacteria produce the enzyme urease, such as *Proteus mirabilis*.<sup>234</sup> This enzyme causes the urine to become alkaline, inducing crystallisation of calcium and magnesium phosphate within the urine. These crystals are incorporated into the biofilm and, over time, result in encrustation of the catheter. Encrustation is generally associated with long-term catheterisation, as it has a direct relationship with the length of catheterisation.<sup>234</sup>

Urinary catheterisation is a frequent intervention during clinical care in hospital, affecting a significant number of patients. It has been estimated that 15-25% of hospitalised patients have a urinary catheter inserted during their stay.<sup>237-240</sup> This number is much higher in ICUs.<sup>241</sup> The risk of infection is associated with the method and duration of catheterisation, the quality of catheter care and patient susceptibility.<sup>242</sup> Bacteriuria develops in approximately 30% of catheterised patients after 2-10 days, and 24% (95% CI 23-29%) of these will develop symptoms of CAUTI.<sup>242</sup> Approximately 3.6% (95% CI 3.4-3.8%) of those with CAUTI develop life-threatening secondary infections, such as bacteraemia or sepsis, where mortality rates range from 10% to 33%.<sup>243,244</sup> CAUTI is associated with prolonged hospitalisation, re-admission and increased mortality.<sup>245</sup> Patients at particular risk are those who are immunocompromised, the elderly and patients with diabetes.<sup>246</sup>

Physical and psychological discomfort associated with insertion, removal and the catheter *in situ* are common.<sup>247</sup> Complications such as inflammation, urethral strictures, mechanical trauma, bladder calculi and other infections of the renal system also occur.<sup>237,248-250</sup> Urine retention after catheter removal is also a frequent occurrence.<sup>251</sup> In some instances, especially in older people, CAUTI may contribute to falls and delirium.<sup>252</sup> The treatment of both CAUTI and other infection sequelae contribute to the emerging problem of antibiotic resistance in hospitals, and uropathogens are a major source of infections caused by antimicrobial-resistant organisms.<sup>253</sup>

CAUTI also increases the cost of health care due to delayed discharge from hospital, antimicrobial treatment and staff resources. The financial burden of CAUTI on the NHS has been estimated as £99 million per year, with an estimated cost per episode of £1968.<sup>254,255</sup> However, there are no robust economic assessments of the cost of CAUTI.

### 3.3 Assessing the Need for Catheterisation

#### ***Catheters place patients at significant risk of acquiring a urinary tract infection. The longer a catheter is in place, the greater the danger***

There is a strong association between the duration of catheterisation and the risk of infection (i.e. the longer the catheter is in place, the higher the incidence of UTI).<sup>242,256,257</sup> In acute care facilities, the risk of developing bacteriuria increases 5% for each day of catheterisation. Approximately 24% of bacteriuric patients will develop CAUTI, and of these, up to 4% develop a severe secondary infection such as bloodstream infection.<sup>242</sup>

Current best practice emphasises the importance of documenting all procedures involving the catheter or drainage system in the patient's records,<sup>255</sup> and providing patients with adequate information in relation to the need for catheterisation, details of the insertion, catheter and drainage system, maintenance procedures and plan for removal of the catheter.<sup>255,258</sup> There is some evidence to suggest that computer management systems improve documentation and are associated with reduced duration of catheterisation.<sup>259</sup>

#### ***What are the indications for using a short-term indwelling urethral catheter?***

Using a short-term indwelling urethral catheter only when necessary after considering alternatives and ensuring the catheter is removed as soon as possible are simple and effective methods to prevent CAUTI. The use of a short-term indwelling urethral catheter may be appropriate in patients with acute urinary retention or obstruction, those who require precise urine output measures to monitor an underlying condition, and patients undergoing certain surgical procedures (especially urological procedures and those of prolonged duration). A short-term indwelling urethral catheter may also be appropriate to minimise discomfort or distress (e.g. during end-of-life care or in the management of open sacral or perineal wounds when the patient is incontinent).<sup>230</sup> However, short-term indwelling urethral catheterisation should not be used as a method of managing urinary incontinence.

While the use of a short-term indwelling urethral catheter is sometimes unavoidable, there is evidence that catheters are inserted without a clear clinical indication, clinicians are not always aware they are *in situ*, and they are not removed promptly when no longer required.<sup>238,260</sup> Interventions that prompt or facilitate the removal of unnecessary catheters may, therefore, reduce the risk of CAUTI. These interventions have been categorised as reminder systems which prompt clinicians that the catheter is in place and removal should be considered, or stop orders, which indicate that catheters should be removed after a set period of time or when defined clinical criteria have been met.<sup>259,261-263</sup>

A systematic review of 14 studies (one RCT, one NRCT, three controlled before-after studies and nine uncontrolled before-after studies) on reminder and stop order systems found that these interventions significantly decreased the rate of CAUTI and did not increase the need for re-catheterisation, although, as some of the studies were not controlled, they were susceptible to bias in favour of the intervention.<sup>261</sup>



A second systematic review identified a number of uncontrolled before-after studies that used ultrasound bladder scanners to assess for urinary retention and support appropriate catheterisation.<sup>264</sup> When used in combination with guidelines,<sup>265</sup> insertion checklist/kit, education, audit and feedback,<sup>266</sup> and reminder/stop orders,<sup>267</sup> ultrasound bladder scanners were found to decrease the use of urethral catheters by 5-15%.<sup>264</sup>

- UC1 Only use a short-term indwelling urethral catheter in patients for whom it is clinically indicated, following assessment of alternative methods and discussion with the patient.  
*Class D/GPP*
- UC2 Document the clinical indication(s) for catheterisation, date of insertion, expected duration, type of catheter and drainage system, and planned date of removal.  
*Class D/GPP*
- UC3 Assess and record the reasons for catheterisation every day. Remove the catheter when no longer clinically indicated.  
*Class D/GPP*

### 3.4 Selection of Catheter Type

#### *Is one catheter better than another?*

Evidence from best practice indicates that the incidence of CAUTI in patients catheterised for a short time (up to 1 week) is not influenced by any particular type of catheter material.<sup>268,269</sup> However, many practitioners have strong preferences for one type of catheter over another. This preference is often based on clinical experience, patient assessment and materials that 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.<sup>270,271</sup> There is also a risk of urethral trauma associated with using a female length catheter in a male patient, and systems should be in place to ensure that this does not occur.<sup>272</sup> However, in adults that have recently undergone urological surgery, larger gauge catheters may be indicated to allow for the passage of blood clots. Our previous evidence-based guidelines<sup>1</sup> identified three experimental studies that compared the use of latex with silicone catheters, which found no significant difference in the incidence of bacteriuria.<sup>249,273,274</sup>

We identified one new systematic review which included three trials that compared different types of standard (non-antiseptic-/non-antimicrobial-impregnated) catheters. These studies did not provide sufficient evidence to suggest that one type of catheter may be more effective than another for the prevention of bacteriuria.<sup>274-277</sup>

In our previous systematic review,<sup>278</sup> we found evidence related to the efficacy of using short-term indwelling urethral catheters coated or impregnated with antiseptic or

antimicrobial agents from four systematic reviews and one meta-analysis. In general, all of these five studies suggested that antiseptic-impregnated or antimicrobial-coated short-term indwelling urethral catheters can significantly prevent or delay the onset of CAUTI compared with standard untreated urinary catheters.<sup>235,279-282</sup> 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 eight studies out of 117 met the inclusion criteria,<sup>280</sup> and in another, of the six reports describing seven trials included, only one scored five in the quality assessment. The other five reports only scored one.<sup>282</sup> The studies included in these reviews investigated a wide range of coated or impregnated catheters, including catheters coated or impregnated with: silver alloy,<sup>279,280,282-289</sup> silver oxide,<sup>280</sup> gentine,<sup>290</sup> gentamicin,<sup>291</sup> silver-hydrogel,<sup>292-294</sup> minocycline,<sup>294</sup> rifampicin,<sup>295</sup> chlorhexidine-silver-sulfadiazine,<sup>294</sup> chlorhexidine-sulfadiazine-triclosan,<sup>294</sup> nitrofurazone<sup>294</sup> and nitrofuraxone.<sup>296</sup> Four studies compared the use of silver-coated (silver alloy or silver oxide) catheters with silicone, hydrogel or Teflon® latex.<sup>297-300</sup> A systematic review and meta-analysis of these and other studies found that silver-alloy-coated (but not silver-oxide-coated) catheters were associated with a lower incidence of bacteriuria.<sup>256,280</sup> Despite their unit cost, these devices may provide a cost-effective option if overall numbers of infections are reduced significantly through their use. However, the few studies that have explored the cost-benefit/cost-effectiveness of using these devices have been inconclusive.<sup>285,287,289,291</sup>

We identified two new systematic reviews of the efficacy of silver-coated or antimicrobial-impregnated catheters for the prevention of CAUTI.<sup>235,275</sup> The first systematic review included 22 RCTs, as well as one NRCT, and concluded that silver-coated (alloy or oxide) short-term indwelling urethral catheters reduced the risk of bacteriuria but did not demonstrate an effect on CAUTI.<sup>275</sup> Catheters impregnated with antimicrobial agents (minocycline, rifampicin or nitrofurazone) were found to reduce the rate of bacteriuria during the first week of catheterisation, but not for catheter durations exceeding 1 week. Although antimicrobial-impregnated catheters reduced the risk of CAUTI, the number of cases was too small to demonstrate a significant effect. The second systematic review, which included nine RCTs and three quasi-experimental studies, concluded that, compared with standard catheters, both nitrofurazone-impregnated and silver-alloy-coated catheters can prevent and delay the onset of bacteriuria during short-term use. However, there were no data on the risk of CAUTI.<sup>235</sup>

We identified one multi-centre RCT that compared silver-alloy-coated and nitrofurazone-impregnated catheters with standard Teflon-coated latex for short-term catheterisation.<sup>301</sup> Although the nitrofurazone-impregnated and silver-alloy-coated catheters were associated with a reduced risk of CAUTI compared with the Teflon-coated latex, the effect was not considered to be clinically effective (adjusted OR 0.81, 95% CI 0.66-1.01 and adjusted OR 0.96, 95% CI 0.78-1.19, respectively). The nitrofurazone-impregnated catheter, but not the silver-alloy-coated catheter, was associated with a significantly lower incidence of bacteriuria (OR 0.68, 95% CI 0.48-0.99,  $p=0.017$ ). However, the nitrofurazone-impregnated catheter was associated with increased discomfort during the period the catheter was in place. A major limitation of this study was that the median duration of catheterisation was 2

days (range 1-3 days) and the risk of CAUTI associated with this short period is correspondingly low. Also, UTIs developing up to 6 weeks post randomisation were included in the outcome measurement, even though they may not have been directly associated with catheterisation. The economic analysis suggested that nitrofurazone-impregnated catheters, but not silver-alloy-coated catheters, may be cost-effective, but the measures of cost were associated with a large amount of uncertainty.

Overall, the evidence suggests that silver-coated urethral catheters reduce the risk of bacteriuria, but there is insufficient evidence to indicate whether they reduce the risk of CAUTI in short-term catheterised patients.

- UC4 Assess patient's needs prior to catheterisation in terms of:
- latex allergy;
  - length of catheter (standard, female, paediatric);
  - type of sterile drainage bag and sampling port (urometer, 2-L bag, leg bag) or catheter valve; and
  - comfort and dignity.

**New recommendation Class D/GPP**

- UC5 Select a catheter that minimises urethral trauma, irritation and patient discomfort, and is appropriate for the anticipated duration of catheterisation.  
*Class D/GPP*
- UC6 Select the smallest gauge catheter that will allow urinary outflow and use a 10-mL retention balloon in adults (follow manufacturer's instructions for paediatric catheters). Urological patients may require larger gauge sizes and balloons.  
*Class D/GPP*

### 3.5 Catheter Insertion

#### ***What technique should be used to insert a catheter?***

In our previous review,<sup>2</sup> we found evidence from one systematic review which suggested that the use of the aseptic technique has not demonstrated a reduction in the rate of CAUTI.<sup>281</sup> However, principles of good practice, clinical guidance<sup>258,302</sup> and expert opinion,<sup>269,270,303-307</sup> together with findings from another systematic review,<sup>256</sup> agree that short-term indwelling urethral catheters must be inserted using sterile equipment and the aseptic technique.

Expert opinion indicates that there is no advantage in using antiseptic preparations for cleansing the urethral meatus prior to catheter insertion.<sup>230,258,269,270</sup> Whilst there is low-quality evidence to suggest that pre-lubrication of the catheter decreases the risk of bacteriuria, it is also important to use lubricant or anaesthetic gel in order to minimise urethral trauma and discomfort.<sup>230</sup> There is no evidence suggesting a general benefit of securing the catheter in terms of preventing the risk of CAUTI, but it is important in order to minimise patient discomfort.<sup>230</sup> Ensuring healthcare practitioners are trained and competent in the insertion of short-term indwelling

urethral catheters will minimise trauma, discomfort and the potential for CAUTI.<sup>270,302,306,307</sup>

Neither we nor HICPAC identified any additional evidence of acceptable quality whilst updating our systematic review.<sup>230</sup>

- UC7 Catheterisation is an aseptic procedure and should only be undertaken by healthcare workers trained and competent in this procedure.  
*Class D/GPP*
- UC8 Clean the urethral meatus with sterile, normal saline prior to the insertion of the catheter.  
*Class D/GPP*
- UC9 Use lubricant from a sterile single-use container to minimise urethral discomfort, trauma and the risk of infection. Ensure the catheter is secured comfortably.  
*Class D/GPP*

### 3.6 Catheter Maintenance

#### ***How should the drainage system be managed?***

Maintaining a sterile, continuously closed urinary drainage system is central to the prevention of CAUTI.<sup>258,270,302,306,308,309</sup> The risk of infection reduces from 97% with an open system to 8-15% when a sterile closed system is employed.<sup>269,307,310</sup> Breaches in the closed system, such as unnecessary emptying, changing of the urinary drainage bag or taking a urine sample, will increase the risk of CAUTI and therefore should be avoided.<sup>269,302,311</sup> Hands must be decontaminated, and clean and non-sterile gloves should be worn before manipulation of the catheter or the closed system, including drainage taps. A systematic review has suggested that sealed (e.g. taped, pre-sealed) drainage systems contribute to preventing bacteriuria.<sup>281</sup> However, there is limited evidence regarding how often catheter bags should be changed. One study showed that higher rates of symptomatic and asymptomatic CAUTI were associated with a 3-day urinary drainage bag change regimen compared with no routine change regimen.<sup>312</sup> Best practice suggests that drainage bags should only be changed when necessary (i.e. according either to the manufacturer's recommendations or the patient's clinical need).<sup>258,302</sup> Reflux of urine is associated with infection and, consequently, drainage bags should be positioned in a way that ensures the free flow of urine and prevents back-flow.<sup>270,302</sup> It is also recommended that urinary drainage bags should be hung on an appropriate stand that prevents contact with the floor.<sup>269</sup>

A number of studies have investigated the addition of disinfectants and antimicrobials to drainage bags as a way of preventing CAUTI.<sup>256</sup> Three acceptable studies<sup>313-315</sup> from our original systematic review<sup>1</sup> demonstrated no reduction in the incidence of bacteriuria following the addition of hydrogen peroxide or chlorhexidine to urinary drainage bags. These findings are supported by a further systematic review, which suggested that adding bacterial solutions to drainage bags had no effect on catheter-associated infection.<sup>281</sup>

Neither we nor HICPAC identified any additional evidence of acceptable quality whilst updating our systematic review.<sup>230</sup>

- UC10 Connect a short-term indwelling urethral catheter to a sterile closed urinary drainage system with a sampling port.  
*Class A*
- UC11 Do not break the connection between the catheter and the urinary drainage system unless clinically indicated.  
*Class A*
- UC12 Change short-term indwelling urethral catheters and/or drainage bags when clinically indicated and in line with the manufacturer's recommendations.  
**New recommendation Class D/GPP**
- UC13 Decontaminate hands and wear a new pair of clean non-sterile gloves before manipulating each patient's catheter. Decontaminate hands immediately following the removal of gloves.  
*Class D/GPP*
- UC14 Use the sampling port and the aseptic technique to obtain a catheter sample of urine.  
*Class D/GPP*
- UC15 Position the urinary drainage bag below the level of the bladder on a stand that prevents contact with the floor.  
*Class D/GPP*
- UC16 Do not allow the urinary drainage bag to fill beyond three-quarters full.  
*Class D/GPP*
- UC17 Use a separate, clean container for each patient and avoid contact between the urinary drainage tap and the container when emptying the drainage bag.  
*Class D/GPP*
- UC18 Do not add antiseptic or antimicrobial solutions to urinary drainage bags.  
*Class A*

### ***Routine meatal cleansing with antiseptic solutions is unnecessary***

Our previous systematic reviews<sup>1,2</sup> found eight acceptable studies that compared meatal cleansing with a variety of antiseptic/antimicrobial agents or soap and water. No reduction in bacteriuria was demonstrated when using any of these preparations for meatal/peri-urethral hygiene compared with routine bathing or showering.<sup>281,316-322</sup>

Expert opinion and other systematic reviews support the view that active meatal cleansing is not necessary and may increase the risk of infection.<sup>56,230,256,258,269,270</sup> Daily routine bathing or showering is all that is needed in order to maintain patient comfort.

Neither we nor HICPAC identified any additional evidence of acceptable quality whilst updating our systematic review.<sup>230</sup>

- UC19 Routine daily personal hygiene is all that is required for meatal cleansing.  
*Class A*

### ***Irrigation, instillation and washout do not prevent infection***

Evidence from our previous systematic review did not demonstrate any beneficial effect of bladder irrigation, instillation or washout with a variety of antiseptic or antimicrobial agents for the prevention of CAUTI.<sup>1,2,323-331</sup>

Evidence from best practice supports these findings of no beneficial effect, and indicates that the introduction of such bladder maintenance solutions may have local toxic effects and contribute to the development of resistant microorganisms. However, continuous or intermittent bladder irrigation may be required for other urological or catheter management indications.<sup>256,258,269,270,302</sup>

- UC20 Do not use bladder maintenance solutions to prevent catheter-associated urinary tract 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 UTI, 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 UTI and how to access expert help when difficulties arise. Healthcare professionals must be confident and proficient in associated procedures.

We identified two systematic reviews that reported evidence of the efficacy of healthcare workers' education in reducing the risk of CAUTI within other system interventions.<sup>264,332</sup> Most of the studies included in these reviews provided low-grade evidence from uncontrolled before-after studies where a combination of different system interventions focusing on reducing the use of urethral catheters and risk of CAUTI were introduced. The first systematic review<sup>264</sup> identified one small controlled before-after study<sup>263</sup> of an educational intervention with guideline change and posters that was associated with a reduction in use of urethral catheters [relative risk (RR) 0.86, 95% CI 0.68-1.10]. Another systematic review included one controlled before-after study that demonstrated a significant ( $p < 0.01$ ) increase in adherence to a clinical guideline on the insertion and maintenance of urethral catheters in association with an education programme.<sup>332,333</sup> A further study reported a reduction in CAUTI and an increase in adherence to protocols for hand hygiene and catheter care in association with an education programme. However, this study did not include a control group.<sup>100</sup>

UC21 Healthcare workers should be trained and competent in the appropriate use, selection, insertion, maintenance and removal of short-term indwelling urethral catheters.

*Class D/GPP*

UC22 Ensure patients, relatives and carers are given information regarding the reason for the catheter and the plan for review and removal. If discharged with a catheter, the patient should be given written information and shown how to:

- manage the catheter and drainage system;
- minimise the risk of urinary tract infection; and
- obtain additional supplies suitable for individual needs.

*Class D/GPP*

### 3.8 System Interventions for Reducing the Risk of Infection

A number of studies have reported the effect of quality improvement programmes on the risk of CAUTI.<sup>230</sup> The components of these programmes include various combinations of clinical guidelines for catheter insertion and maintenance, education, audit and feedback of compliance with policy, physician/nurse reminder systems (to prompt removal if no longer necessary), automated or nurse-driven removal protocols [where the catheter is removed after a specified period (e.g. 48-72 h) unless countermanded by the physician] and the use of bladder scanners to assess urinary retention and support appropriate catheterisation.<sup>230</sup>

We identified three systematic reviews relevant to this question.<sup>261,264,332</sup> The first was a review of interventions to remind physicians/nurses to remove unnecessary catheters and the outcome on CAUTI, short-term indwelling urethral catheter use and catheter replacement. It included 14 studies (one RCT, one NRCT, three controlled before-after studies and nine uncontrolled before-after studies).<sup>261</sup> Interventions included prewritten or computer-generated stop orders, nurse-generated daily bedside reminders to remove catheters, and daily use of a checklist or protocol to review need for the catheter. Some studies also implemented catheter placement restrictions and education. The meta-analysis suggested that the use of reminder or stop order systems reduced the rate of CAUTI by 52% ( $p < 0.001$ ) and the mean duration of catheterisation by 37%, with 2.61 fewer days of catheterisation in the intervention group compared with the control group, and no difference in re-catheterisation rates.

The second systematic review was a review of interventions to minimise the placement of urethral catheters in acute care patients.<sup>264</sup> It included one RCT, one NRCT and six uncontrolled before-after studies. Interventions included various combinations of clinician reminders, stop orders and indication checklists, use of bladder scanners and education. The authors concluded that the studies were too small and heterogeneous to draw a definitive conclusion about efficacy in terms of reducing inappropriate catheter placement.

The third systematic review included three controlled before-after studies and seven uncontrolled before-after studies measuring interventions that increased adherence to catheter care protocols or reduced unnecessary catheter use.<sup>332</sup> Interventions included reminders, stop orders, use of bladder scanners, education and catheterisation protocols with audit and feedback on performance. Physician/nurse reminders, particularly automatic stop orders, were found to reduce the duration of catheterisation, although there were insufficient data to determine their effect on CAUTI.

Many studies in this area are uncontrolled before-after designs and therefore susceptible to bias in favour of the intervention. However, these interventions constitute best practice, and this evidence supports the use of systems to minimise the insertion of catheters and promote timely removal to reduce both the duration of catheterisation and the risk of CAUTI.

- UC23 Use quality improvement systems to support the appropriate use and management of short-term urethral catheters and ensure their timely removal. These may include:
- protocols for catheter insertion;
  - use of bladder ultrasound scanners to assess and manage urinary retention;
  - reminders to review the continuing use or prompt the removal of catheters;
  - audit and feedback of compliance with practice guidelines; and
  - continuing professional education.

**New recommendation Class D/GPP**

- UC24 No patient should be discharged or transferred with a short-term indwelling urethral catheter without a plan documenting the:
- reason for the catheter;
  - clinical indications for continuing catheterisation; and
  - date for removal or review by an appropriate clinician overseeing their care.

**New recommendation Class D/GPP**

## Short-term Indwelling Urethral Catheters - Systematic Review Process

### Systematic Review Questions

1. What are the clinical indications for the use of short-term urinary catheters?(\*B)
  2. What is the risk associated with short-term catheterisation in terms of bacteriuria, CAUTI, other morbidities and mortality? (B)
  3. What is the effectiveness (in terms of patient acceptability and reduced risk of bacteriuria, CAUTI, other morbidities and mortality) and the cost-effectiveness of different types of short-term indwelling urinary catheters (material, coatings and design)?
  4. What is the most effective catheter insertion technique in terms of patient acceptability and minimisation of urethral trauma, bacteriuria, CAUTI and other morbidities?
  5. What is the most effective and cost-effective means of maintaining meatal hygiene and a closed drainage system?
  6. What is the effectiveness of system interventions in reducing the use and duration of short-term urinary catheterisation to minimise the risk of bacteriuria, CAUTI, other morbidities and mortality?
  7. What is the effectiveness of system interventions in improving healthcare workers' knowledge and behaviour relating to the insertion, maintenance and timely removal of indwelling urinary catheters to minimise the risk of bacteriuria, CAUTI, other morbidities and mortality?
- \*B: Background question

### Databases and Search Terms Used

#### DATABASES

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDSR, CCRCT, CMR), US Guideline Clearing House, DARE (NHS Evidence, HTA), Prospero

#### MeSH TERMS

Infection control; cross infection; disease transmission; urinary tract infections; urinary catheterisation; indwelling catheters; irrigation; biofilms; hydrogen ion concentration; nursing education; nursing care; inservice training

#### THESAURUS AND FREE-TEXT TERMS

Urinary catheterisation; urinary tract infection; cross infection; disease transmission; bacteriuria; funguria; encrustation; bladder irrigation; washout; lubrication; urinary dipstick; patient education; quality improvement

#### SEARCH DATE

Jan 2007-Apr 2013

### Search Results

Total number of articles located = 7073

### Sift 1 Criteria

Abstract indicates that the article: relates to infections associated with short-term indwelling urethral catheters; is written in English; is primary research, 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 = 54

### Sift 2 Criteria

Full text confirms that the article: relates to infections associated with short-term indwelling urethral catheters; is written in English; is primary research (randomised controlled trials, prospective cohort, interrupted time series, controlled before-after, quasi-experimental), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

### Articles Selected for Appraisal

Total number of studies selected for appraisal during Sift 2 = 16

### Critical Appraisal

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

### Accepted and Rejected Evidence

Total number of studies accepted after critical appraisal = 6  
Total number of studies rejected after critical appraisal = 10



## 4 Guidelines for Preventing Infections Associated with the Use of Intravascular Access Devices

### 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. Evidence identified in the HICPAC systematic review was used to support the recommendations in these guidelines.<sup>334</sup> Some recommendations from the previous guidelines have been revised to improve clarity; where a new recommendation has been made, this is indicated in the text. These recommendations are not detailed procedural protocols, and need to be incorporated into local guidelines. None are regarded as optional.

#### Background and context to the guidelines

Intravascular access devices, including peripheral, central venous and arterial catheters, are commonly used in the management of patients in acute and chronic care settings. CVCs are frequently used during clinical care and include peripherally inserted, non-tunnelled and tunnelled, and totally implantable CVCs (Table 3).<sup>334</sup> The use of any of these catheters can result in bloodstream infection.

Catheter-related bloodstream infections (CR-BSI) associated with the insertion and maintenance of CVCs are potentially among the most dangerous complications associated with health care.<sup>231,232,335</sup> In the most recent national prevalence survey, the Health Protection Agency reported that the prevalence of BSI was 0.5%, accounting for 7.3% of the HCAI detected; 64% of BSI occurred in patients with a vascular access device.<sup>231</sup> A previous point prevalence survey reported that the prevalence of BSI was 0.85%, accounting for 7% of the HCAI detected; of these, 70% were primary CR-BSI.<sup>232</sup> Peripheral venous catheters (PVCs) cause phlebitis in some patients, with studies indicating mean rates of 7-27%,<sup>336-339</sup> but evidence suggests that these devices are less frequently associated with CR-BSI.<sup>334,336-340</sup>

CR-BSI involves the presence of systemic infection and evidence implicating the intravascular catheter as its source (i.e. the isolation of the same microorganism from blood cultures as that shown to be significantly colonising the intravascular catheter).<sup>334,335</sup> Catheter colonisation refers to the growth of microorganisms on either the endoluminal or the external catheter surface beneath the skin in the absence of systemic infection.<sup>334,335</sup>

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 microorganisms most frequently implicated in CR-BSI. Other microorganisms commonly involved include *S. aureus*, *Candida* species and enterococci.<sup>341-343</sup>

CR-BSI is generally caused either by skin microorganisms at the insertion site, which contaminate the catheter during insertion and migrate along the cutaneous catheter track after insertion,<sup>344-346</sup> or microorganisms from the hands of healthcare workers that contaminate and colonise the catheter hub during care interventions.<sup>347</sup> Less commonly, infusate contamination or seeding from a different site of infection in the body via the bloodstream is identified as a cause of CR-BSI.<sup>348,349</sup>

### 4.2 What is the Evidence for these Guidelines?

These guidelines are based upon evidence-based guidelines for preventing intravascular device (IVD)-related infections, developed at the US Centers for Disease Control and Prevention by HICPAC and published in 2011.<sup>334</sup> The AGREE II collaboration appraisal instrument was used by four appraisers to review the guidelines independently.<sup>3</sup>

The appraisal process resulted in the decision that the guideline 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. The Guideline Development Advisory Group considered that they were the most authoritative reference guidelines currently available. Following the AGREE process, we systematically searched, retrieved and appraised additional evidence published since the search period identified in the HICPAC technical report.<sup>334</sup> Our search period for additional evidence spanned from 2009 to 2012.

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

These recommendations describe general principles of best practice that apply to all patients in hospital in whom an intravascular catheter is being used during an acute episode of treatment/care. They do not specifically address the more detailed, technical aspects of the care of infants under 1 year of age, or those children or adults receiving haemodialysis or chemotherapy who will generally have long-term intravascular catheters managed in renal dialysis or outpatient settings.

The recommendations are divided into nine distinct interventions:

- education of healthcare workers and patients;
- general asepsis;
- selection of type of intravascular catheter;
- selection of intravascular catheter insertion site;
- MSB precautions during insertion;
- cutaneous antisepsis;
- catheter and catheter site care;
- replacement strategies; and
- general principles for catheter management.

### 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 intravascular catheters 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. Structured educational programmes that enable healthcare workers to provide, monitor and evaluate care and continually increase their competence are critical to the success of any strategy designed to reduce the risk of infection. Evidence reviewed by HICPAC demonstrates that the risk of infection declines following standardisation of the aseptic technique,<sup>350-356</sup> and increases when the maintenance of intravascular catheters is undertaken by inexperienced healthcare workers.<sup>353,357</sup>

**Table 3**  
Catheters used for venous and arterial access

Catheter type	Features	Common use	Duration
<b>Peripheral</b>			
Peripheral venous catheters	Peripheral single lumen Inserted in veins of forearm or hand in adults	Administration of fluid/blood and medication	Short, up to 7-10 days
Peripheral arterial catheters	Single lumen, large calibre Most commonly placed in radial artery; alternatives are femoral, axillary, brachial and posterior tibial arteries	Haemodynamic monitoring Access/blood draw Administration of fluid and medication	Short, up to 7-10 days
Midline catheters	Commonly placed in proximal basilic or cephalic veins via the antecubital fossa. Does not enter central veins	Administration of fluid, blood and medication	Short, 1-4 weeks
<b>Central</b>			
Non-tunnelled central venous catheters	Single and multiple (up to five) lumens Percutaneously inserted into subclavian, internal jugular or femoral veins	Administration of fluid, blood and medication Access/blood draw Multi-lumen catheters used for administration of parenteral nutrition	Short, up to 7-10 days
Tunnelled central venous catheters	Image guided or surgical placement Implanted into subclavian, internal jugular or femoral veins	Frequent long-term access Parenteral nutrition Transfusion Haemodialysis Blood sampling	Long, months/years
Totally implantable catheters	Image guided or surgical placement Tunnelled beneath skin and have a subcutaneous port accessed with a needle  Implanted into subclavian or internal jugular vein	Single or double lumen Infrequent access on a long-term basis	Long, months/years
Peripherally inserted central venous catheters	Inserted into basilic, cephalic or brachial veins and enter the superior vena cava	Administration of fluid and medication including chemotherapy Parenteral nutrition Blood sampling	Medium, 4 weeks to 6 months

Adapted from O'Grady et al. 2011.<sup>334</sup>

We identified two recent systematic reviews that assessed the effectiveness of education interventions in reducing CR-BSI.<sup>228,358</sup> The first concluded that current evidence comes predominantly from uncontrolled before-after studies that do not convincingly distinguish intervention effectiveness from secular trends. Clinical practices are addressed by a wide variety of educational strategies that do not draw upon pedagogic, theoretical or conceptual frameworks and consequently do not provide generalisable conclusions about the most effective approaches to education to improve practice.<sup>358</sup> The second systematic review concluded first that educational interventions appear to have the most prolonged and profound effect when used in conjunction with audit and feedback, and when availability of clinical equipment is consistent with the content of the education provided. Second, that educational interventions will have a greater impact if baseline compliance with best practice is low. Third, that repeated educational sessions, fed into daily practice, using practical participation, appear to have a small, additional effect on practice change compared with education alone.<sup>228</sup>

Healthcare workers should be aware of the manufacturers' advice relating to the compatibility of individual devices with antiseptic solutions, dwell time and connections to ensure safe use.

IVAD1 Healthcare workers caring for patients with intravascular catheters should be trained and assessed as competent in using and consistently adhering to practices for the prevention of catheter-related bloodstream infection.  
*Class D/GPP*

IVAD2 Healthcare workers should be aware of the manufacturer's advice relating to individual catheters, connection and administration set dwell time and compatibility with antiseptics and other fluids to ensure the safe use of devices.  
**New recommendation** *Class D/GPP*

IVAD3 Before discharge from hospital, patients with intravascular catheters and their carers should be taught any techniques they may need to use to prevent infection and manage their device.  
*Class D/GPP*

#### 4.4 General Asepsis

Hand decontamination and meticulous attention to the aseptic technique are essential during catheter insertion, manipulation, changing catheter site dressings and for accessing the system. Hands should be decontaminated using ABHR or liquid soap and water when hands are visibly soiled or potentially contaminated with organic material, such as blood and other body fluids.<sup>45,53</sup>

The aseptic technique should be used for the insertion and management of IVDs. Structured education should be provided to ensure that healthcare workers are trained and assessed as competent in performing the aseptic technique. Gloves should be worn for procedures involving contact with blood or body fluids. Sterile gloves must be worn for the insertion and dressing of CVCs.<sup>334</sup>

**IVAD4** Hands must be decontaminated, with an alcohol-based hand rub or by washing with liquid soap and water if soiled or potentially contaminated with blood or body fluids, before and after any contact with the intravascular catheter or insertion site.

*Class A*

**IVAD5** Use the aseptic technique for the insertion and care of an intravascular access device and when administering intravenous medication.

*Class B*

#### 4.5 Selection of Catheter Type

The selection of the most appropriate intravascular catheter for each individual patient can reduce the risk of subsequent catheter-related infection.

##### *Catheter material*

Intravascular catheter material may be an important determinant in the development of catheter-related infection. Polytetrafluoroethylene (Teflon) and polyurethane catheters have been associated with fewer infections than catheters made of polyvinyl chloride or polyethylene.<sup>359-361</sup>

##### *Number of catheter lumens*

Multi-lumen intravascular access devices may be used because they permit the concurrent administration of fluids and medications, parenteral nutrition and haemodynamic monitoring among critically ill patients.

Several RCTs and other studies suggest that multi-lumen catheters are associated with a higher risk of infection than single-lumen catheters.<sup>334,362-367</sup> However, other studies examined by HICPAC failed to demonstrate a difference in the rates of CR-BSI.<sup>368,369</sup>

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 CVC manipulation.<sup>364,365</sup> Patients with multi-lumen catheters tend to be more severely ill, although the increased risk of CR-BSI appears to be independent of underlying illness.<sup>366</sup>

##### *A dedicated catheter lumen is needed for parenteral nutrition*

A prospective epidemiological study in patients receiving parenteral nutrition concluded that either using a single-lumen catheter or a dedicated port in a multi-lumen catheter for parenteral nutrition would reduce the risk of CR-BSI.<sup>359</sup> Neither we nor HICPAC identified any additional evidence for this recommendation whilst updating our systematic review, and HICPAC considered this to be a unresolved issue.<sup>334</sup>

In a systematic review and quantitative meta-analysis focused on determining the risk of CR-BSI and catheter colonisation in multi-lumen catheters compared with single-lumen catheters, the reviewers reported that, although CR-BSI was more common in patients with multi-lumen catheters, when confined to high-quality studies that control for patient differences, there is no significant difference in rates of CR-BSI for the two types of catheter. This analysis suggests that multi-lumen catheters are not a significant risk factor for increased CR-BSI or local catheter colonisation compared with single-lumen CVCs.<sup>370</sup>

A later systematic review and quantitative meta-analysis tested whether single- vs multi-lumen CVCs had an impact on catheter colonisation and CR-BSI. The study authors concluded that there is some evidence from five RCTs with data on 530 CVCs that for every 20 single-lumen catheters inserted, one CR-BSI (which would have occurred had multi-lumen catheters been used) would be avoided.<sup>371</sup>

Neither we nor HICPAC identified any additional evidence of acceptable quality whilst updating our systematic reviews.<sup>334</sup>

**IVAD6** Use a catheter with the minimum number of ports or lumens essential for management of the patient.

*Class A*

**IVAD7** Preferably use a designated single-lumen catheter to administer lipid-containing parenteral nutrition or other lipid-based solutions.

*Class D/GPP*

##### *Tunnelled and totally implantable ports*

Surgically implanted (tunnelled) devices (e.g. Hickman® catheters) are commonly used to provide vascular access to patients requiring long-term intravenous therapy. Alternatively, totally implantable intravascular access 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.

Multiple studies comparing the incidence of infection associated with long-term tunneled CVCs and/or totally implantable IVDs with that from percutaneously (non-tunneled) inserted catheters have been assessed by HICPAC.<sup>372</sup> Although most studies reported a lower rate of infection in patients with tunneled CVCs,<sup>373-381</sup> some studies found no significant difference in the rate of infection between tunneled and non-tunneled catheters.<sup>382,383</sup> Additionally, most studies concluded that totally implantable devices had the lowest reported rates of CR-BSI compared with either tunneled or non-tunneled CVCs.<sup>384-394</sup> However, although these devices are less disruptive for patients in terms of daily living, they have a number of disadvantages including the need for needle insertion resulting in increased discomfort.<sup>395</sup>

Additional evidence was obtained from studies of efficacy of tunnelling to reduce catheter-related infections in patients with short-term CVCs. One RCT demonstrated that subcutaneous tunnelling of short-term CVCs inserted into the internal jugular vein reduced the risk for CR-BSI.<sup>396</sup> In a later RCT, the same investigators failed to show a statistically significant difference in the risk for CR-BSI for subcutaneously tunneled femoral vein catheters.<sup>397</sup>

An additional meta-analysis of RCTs was focused on the efficacy of tunnelling short-term CVCs to prevent catheter-related infections.<sup>398</sup> Data synthesis demonstrated that tunnelling decreased catheter colonisation by 39% and decreased CR-BSI by 44% in comparison with non-tunneled placement. The majority of the benefit in the decreased rate of catheter sepsis came from one trial of CVCs 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. This meta-analysis concluded that tunnelling decreased catheter-related 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.

Peripherally inserted central catheters (PICCs) are increasingly used for medium term (6 weeks to 6 months)<sup>395</sup> intravascular access, particularly in adults and children requiring antimicrobial treatment, chemotherapy and parenteral nutrition. Evidence examined by HICPAC suggested that PICCs are associated with a lower rate of infection than that associated with other non-tunneled CVCs.<sup>382,398</sup> Retrospective studies in outpatient settings indicate that rates of PICC-related bloodstream infection range from 0.4 to 0.8 per 1000 catheter-days.<sup>399-404</sup> However, there is little recent robust evidence regarding comparison of rates of CR-BSI in PICCs vs other long-term central venous access devices. A prospective study<sup>405</sup> that compared the use of inpatient PICCs indicated a similar rate of CR-BSI to non-tunneled catheters placed in the internal jugular or subclavian veins and a higher rate than cuffed and tunneled (CT) catheters (PICC 3.5 CR-BSI per 1000 catheter-days vs non-tunneled 2.7 CR-BSI per 1000 catheter-days vs cuffed and tunneled 1.6 CR-BSI per 1000 catheter-days). A systematic review of 200 studies indicated that when used in inpatients, PICCs pose a slightly lower risk of CR-BSI than standard non-cuffed and non-medicated CVCs placed in the subclavian or internal jugular vein (2.1 CR-BSI per 1000 catheter-days vs 2.7 CR-BSI per 1000 catheter-days).<sup>340</sup>

Neither we nor HICPAC identified any additional evidence of acceptable quality whilst updating our systematic review.<sup>334</sup>

**IVAD8** Use a tunneled or implanted central venous access device with a subcutaneous port for patients in whom long-term vascular access is required.

*Class A*

**IVAD9** Use a peripherally inserted central catheter for patients in whom medium-term intermittent access is required.

**New recommendation Class D/GPP**

### **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/rifampicin, platinum/silver, and ionic silver in subcutaneous collagen cuffs attached to CVC. Evidence reviewed by HICPAC<sup>406-416</sup> indicated that the use of antimicrobial or antiseptic-impregnated CVC in adults whose catheter is expected to remain in place for more than five days could decrease the risk for CR-BSI. This may be cost-effective in high-risk patients (intensive care, burn and neutropenic patients) and in other patient populations in whom the rate of CR-BSI exceeds 3.3 per 1,000 catheter days even when there is a comprehensive strategy to reduce rates of CR-BSI.<sup>406</sup>

A meta-analysis of 23 RCTs published between 1988-1999 included data on 4,660 catheters (2,319 anti-infective and 2,341 control).<sup>417</sup> Eleven of the trials in this meta-analysis were conducted in intensive care unit (ICU) settings; four among oncology patients, two among surgical patients; two among patients receiving total parenteral nutrition (TPN) and four among other patient populations. Study authors concluded that antibiotic and chlorhexidine-silver sulfadiazine coatings are anti-infective for short (approximately one week) insertion time. For longer insertion times, there was 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 on both the internal and external luminal surfaces are now available. The external surface of these catheters have 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.<sup>418</sup>

A systematic review and economic evaluation in 2006 concluded that rates of CR-BSI were statistically significantly reduced when an antimicrobial CVC was used. Studies in this review 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.<sup>419</sup>

We identified two additional systematic reviews and one RCT in our updated search. A recent Cochrane review of studies using impregnation, coating or bonding for reducing central venous catheter-related infections in adults included 56, predominantly unblinded studies, with low or unclear risk of bias. Patients with impregnated catheters had lower rates of CR-BSI (actual risk reduction of 2% (95% CI, 3% to 1%)), and catheter colonisation (actual risk reduction 10% (95% CI, 13% to 7%)). In terms of catheter colonisation sub-group analysis showed that impregnated catheters were more beneficial in studies conducted in intensive care units (RR 0.68 (95% CI, 0.59 to 0.78)) than in studies conducted in haemo-oncology (RR 0.75 (95% CI, 0.51 to 1.11)) or in patients requiring long-term parenteral nutrition RR 0.99 (95% CI, 0.74 to 1.34)). However, sub-group analysis did not identify the same benefit in terms of CR-BSI. There were no statistically significant differences in the overall rates of bloodstream infections or mortality, although these outcomes were less often assessed than CR-BSI and catheter colonisation.<sup>420</sup> A collaborative network meta-analysis of CVC use in adults indicated that rifampicin-based impregnated CVC was the only type of impregnated/coated CVC that reduced catheter colonisation and CR-BSI compared with standard CVC.<sup>421</sup> In a single blind non-inferiority trial, authors concluded that CVC coated with 5-fluorouracil were non-inferior to chlorhexidine and silver sulfadiazine coated CVCs with respect to the incidence of catheter colonisation (2.9% vs. 5.3%, respectively).<sup>422</sup>

### **Be aware of patient sensitivity to chlorhexidine gluconate**

Chlorhexidine is a potential allergenic antiseptic that is present in many products and is widely used in health care for skin antiseptics, insertion of urinary catheters or coating CVCs.<sup>406</sup> In susceptible individuals, initial contact will cause a minor hypersensitivity reaction that, although not severe, should not go undocumented as subsequent exposures to chlorhexidine may lead to anaphylaxis.<sup>423,424</sup> The Medicines and Healthcare Products Regulatory Agency has alerted all healthcare providers in the UK to the risk of chlorhexidine allergy<sup>425</sup> and requires them to have systems in place that ensure:

- awareness of the potential for an anaphylactic reaction to chlorhexidine;
- known allergies are recorded in patient notes;
- labels and instructions for use are checked to establish if products contain chlorhexidine prior to use on patients with a known allergy;
- if a patient experiences an unexplained reaction, checks are carried out to identify whether chlorhexidine was used or was impregnated in a medical device that was used; and
- reporting of allergic reactions to products containing chlorhexidine to the Medicines and Healthcare Products Regulatory Agency.

IVAD10 Use an antimicrobial-impregnated central venous access device for adult patients whose central venous catheter is expected to remain in place for >5 days if catheter-related bloodstream infection rates remain above the locally agreed benchmark, despite the implementation of a comprehensive strategy to reduce catheter-related bloodstream infection.

*Class A*

## **4.6 Selection of Catheter Insertion Site**

The site at which a vascular access catheter is placed can influence the subsequent risk of CR-BSI because of variation in both the density of local skin flora and the risk of thrombophlebitis. CVCs 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 basilic veins of the antecubital space). PVCs are normally inserted in the upper extremity, although alternatives, such as the foot and scalp, may be used in children and babies.

### **Subclavian, jugular and femoral placements**

HICPAC examined a number of studies that compared insertion sites and concluded that CVCs inserted into subclavian veins had a lower risk for catheter-related infection than those inserted into either jugular or femoral veins.<sup>345,408,426-434</sup> Guideline developers suggested that internal jugular insertion sites may pose a greater risk for infection because of their proximity to oropharyngeal secretions and because CVCs at this site are difficult to immobilise.<sup>334</sup> However, mechanical complications associated with catheterisation might be less common with internal jugular than with subclavian vein insertion.

Femoral catheters have been demonstrated to have relatively high colonisation rates compared with subclavian and internal jugular sites when used in adults, and current guidelines suggest that the femoral site should be avoided because it is associated with both a higher risk of deep vein thrombosis and catheter-related infection than internal jugular or subclavian catheters.<sup>428,432-437</sup> One study also found that the risk of infection associated with catheters placed in the femoral vein is accentuated in obese patients.<sup>409</sup> Thus, in adult patients, a subclavian site is preferred for preventing infection, 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.

We identified a systematic review and meta-analysis<sup>438</sup> in which investigators reviewed two RCTs, eight cohort studies and data from a national HCAI programme. These provided evidence that the selection of device insertion site is not a significant factor for the prevention of CR-BSI. The meta-analysis demonstrated no difference in the risk of CR-BSI between the femoral, subclavian and internal jugular sites,



having removed two studies that were statistical outliers. The authors concluded that a pragmatic approach to site selection for central venous access, taking into account underlying disease (e.g. renal disease), the expertise and skill of the operator and the risks associated with placement, should be used.<sup>438</sup> Two meta-analyses<sup>439,440</sup> indicate that the use of real-time two-dimensional ultrasound for the placement of CVCs substantially reduced mechanical complications compared with the standard landmark placement technique. Consequently, the use of ultrasound may indirectly reduce the risk of infection by facilitating mechanically uncomplicated subclavian placement. In the UK, NICE guidelines provide recommendations for two-dimensional ultrasound placement of CVCs.<sup>441</sup>

### Upper arm placement

PICCs may be used as an alternative to subclavian or jugular vein catheterisation. These are inserted into the superior vena cava via the major veins of the upper arm above the antecubital fossa. HICPAC indicated that they are less expensive, associated with fewer mechanical complications (e.g. haemothorax, infiltration and phlebitis) and easier to maintain than short peripheral venous catheters.<sup>334</sup> In a prospective cohort study using data from two randomised trials and a systematic review to estimate rates of PICC-related bloodstream infection in hospitalised patients, the author concluded that PICCs used in high-risk hospitalised patients are associated with a rate of CR-BSI similar to conventional CVCs placed in the internal jugular or subclavian veins (two to five per 1000 catheter-days).<sup>441</sup>

### Peripheral venous catheters

To reduce the risk of CR-BSI and phlebitis, it is preferable to use an upper extremity site for inserting a PVC in adults and to replace a device inserted in a lower extremity to a site in the upper extremity as soon as possible.<sup>334</sup> In paediatric patients, the upper or lower extremity and the scalp (in young infants) can be used for siting a PVC.<sup>405,442</sup>

IVAD11 In selecting an appropriate intravascular insertion site, assess the risks for infection against the risks of mechanical complications and patient comfort.  
*Class D/GPP*

IVAD12 Use the upper extremity for non-tunnelled catheter placement unless medically contraindicated.  
*Class C*

### 4.7 Maximal Sterile Barrier Precautions during Catheter Insertion

#### ***Maximal sterile barrier precautions for the insertion of central venous catheters reduces the risk of infection***

The importance of strict adherence to hand decontamination and the aseptic technique as the cornerstone for preventing catheter-related 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.

Studies examined by HICPAC concluded that if MSB precautions were used consistently during CVC insertion, catheter contamination and subsequent catheter-related infections could be reduced significantly.<sup>345,352,443,444</sup> A prospective randomised trial that tested the efficacy of MSB precautions to reduce infections associated with long-term, non-tunnelled subclavian silicone catheters, compared with routine procedures, found that they decreased the risk of CR-BSI significantly.<sup>443</sup>

MSB precautions involve wearing sterile gloves and gown, cap and mask, and using a full-body sterile drape during insertion of the catheter.<sup>334</sup> It has been generally assumed that CVCs inserted in the operating theatre pose a lower risk of infection than those inserted on inpatient wards or other patient care areas.<sup>372</sup> However, data examined by HICPAC from two prospective studies suggest 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 vs operating theatre).<sup>345,443</sup>

A systematic review of the value of MSB precautions to prevent CR-BSI defined the components as: the person inserting the catheter should wear a head cap, face mask, sterile body gown and sterile gloves, and use a full-size sterile drape. Their search identified 95 papers discussing the prevention of CR-BSI. The majority of these were narrative reviews or consensus statements. Three primary research studies, differing in design, patient population and clinical settings, that compared infection outcomes using MSB precautions with less stringent barrier techniques, concluded that the use of MSB precautions resulted in a reduction in catheter-related infections. The authors concluded that using MSB precautions appears to decrease transmission of microorganisms, delay colonisation and reduce the rate of HCAI. They also suggested that biological plausibility and the available evidence support using MSB precautions during routine insertion of a CVC to minimise the risk of infection. They recommended that, given the lack of adverse patient reactions, the relatively low cost of MSB precautions and the high cost of CR-BSI, it is probable that MSB precautions will prove to be a cost-effective, or even a cost-saving, intervention.<sup>445</sup>

Neither we nor HICPAC identified any additional evidence of acceptable quality whilst updating our systematic review.<sup>334</sup>

IVAD13 Use maximal sterile barrier precautions 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 vascular catheter insertion site are the cause of most CR-BSI.<sup>416,446</sup> As the risk of infection increases with the density of microorganisms around the insertion site, skin cleansing/antisepsis of the insertion site is one of the most important measures for preventing catheter-related infections.<sup>334</sup> Since the early 1990s, research has focused on identifying the most effective antiseptic agent for skin preparation prior to the insertion of IVDs in order to prevent catheter-related infections, especially CR-BSI. In the UK, clinicians principally use alcohol, or either povidone iodine (PVI) or CHG, in various strengths, and the latter two as either aqueous or alcohol-based solutions.

A prospective randomised trial of agents used for cutaneous antisepsis demonstrated that 2% aqueous CHG was superior to either 10% PVI or 70% alcohol for the prevention of central venous and arterial catheter-related infections.<sup>447</sup> A further prospective, randomised trial demonstrated that a 4% alcohol-based solution of 0.25% CHG and 0.025% benzalkonium chloride was more effective for the prevention of central venous or arterial catheter colonisation and infection than 10% PVI.<sup>448</sup>

The use of 5% PVI solution in 70% ethanol has been shown to be associated with a substantial reduction in catheter-related colonisation and infection compared with 10% aqueous PVI.<sup>449</sup> Clinicians may find this useful for those patients for whom alcoholic CHG is contraindicated.

A meta-analysis<sup>450</sup> of studies that compared the risk for CR-BSI following insertion-site skin care with any type of CHG solution vs PVI solution indicated that the use of CHG rather than PVI can reduce the risk for CR-BSI by approximately 49% (RR 0.51, 95% CI 0.27-0.97) in hospitalised patients who require short-term catheterisation (i.e. for every 1000 catheter sites disinfected with CHG rather than PVI, 71 episodes of catheter colonisation and 11 episodes of CR-BSI would be prevented). In this analysis, several types of CHG solution were used in the individual trials, including 0.5% or 1% CHG alcohol solution and 0.5% or 2% 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 significant reduction in CR-BSI. As few studies used CHG aqueous solution, the lack of a significant difference seen for this solution compared with PVI solution may be a result of inadequate statistical power. Additionally, an economic decision analysis based on available evidence from the same authors suggested that the use of CHG, rather than PVI, for skin care would result in a 1.6% decrease in the incidence of CR-BSI, a 0.23% decrease in mortality, and financial savings per catheter used.<sup>451</sup>

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.<sup>448</sup> Reported efficacy of this practice for the prevention of catheter-related infections yielded contradictory findings.<sup>449-457</sup> 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.<sup>458,459</sup>

NICE<sup>56</sup> identified three RCTs that compared the effectiveness of different antiseptic solutions for the insertion of PVCs in hospitalised patients. The evidence from these studies was considered to be of very low quality, and no conclusion could be drawn about the benefits of one particular antiseptic solution over another. However, while there is no evidence comparing different concentrations of CHG, the reviewers indicated that the trend in the evidence suggests that CHG in alcohol may be more effective than PVI in alcohol.

We identified one recent systematic review of the clinical efficacy and perceived role of CHG in skin antisepsis that included studies about intravascular access.<sup>460</sup> The authors suggested a potential source of bias, as many studies have overlooked the importance of alcohol when assessing the efficacy of CHG. The authors assessed the attribution of CHG in each study as correct, incorrect or intermediate. Studies were scored and analysis was performed separately to assess CHG efficiency. The authors concluded that CHG is more efficient than PVI or any other technique alone, but that the presence of alcohol provides additional benefit. The authors suggested that vascular catheters require the immediate antiseptic activity provided by alcohol prior to insertion. They also require a long-lasting antiseptic, as they stay in place for prolonged periods of time.

IVAD14 Decontaminate the skin at the insertion site with a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) and allow to dry prior to the insertion of a central venous access device.

*Class A*

IVAD15 Decontaminate the skin at the insertion site with a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) and allow to dry before inserting a peripheral vascular access device.

**New recommendation** *Class D/GPP*

IVAD16 Do not apply antimicrobial ointment routinely to the catheter placement site prior to insertion to prevent catheter-related bloodstream infection.

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

### *Choose the right dressing for insertion sites to minimise infection*

Following placement of a PVC or CVC, a dressing is used to protect the insertion site. As 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.<sup>446</sup> 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 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, including the largest controlled trial of dressing regimens on PVCs,<sup>361</sup> a meta-analysis comparing the risk of CR-BSI using transparent vs gauze dressings<sup>461</sup> and a Cochrane review.<sup>462</sup> All concluded that the choice of dressing can be a matter of preference, but if blood is leaking from the catheter insertion site, a gauze dressing might be preferred to absorb the fluid. We identified an updated Cochrane review which concluded that bloodstream infection was higher in the transparent polyurethane group compared with the gauze and tape group.<sup>463</sup> The included trials were graded low quality due to the small sample size and risk of bias. There was additional low-quality evidence that demonstrated no difference between highly permeable polyurethane dressings and other polyurethane dressings in the prevention of CR-BSI.

HICPAC reviewed the evidence related to impregnated sponge dressings compared with standard dressings and found two RCTs in adults which demonstrated that chlorhexidine-impregnated sponge dressings were associated with a significant reduction in CR-BSI. However, a meta-analysis that included eight RCTs found a reduction in exit site colonisation but no significant reduction in CR-BSI. In paediatric patients, two small RCTs found a reduction in catheter colonisation but not CR-BSI, and evidence of localised contact dermatitis when used for infants of very low birth weight.<sup>334</sup>

We identified one systematic review and meta-analysis, undertaken as part of a quality improvement collaborative, that synthesised the effects of the routine use of CHG-impregnated sponge dressings in reducing centrally inserted CR-BSI.<sup>464</sup> Five studies were included in the analysis; two of the

five studies were in patients in haemo/oncological ICUs, and the remaining three studies were in surgical and medical ICUs. Four of the five studies were sponsored by the manufacturer of the product. The reviewers concluded that CHG-impregnated sponge dressings are effective for the prevention of CR-BSI (OR 0.43, 95% CI 0.29-0.64) and catheter colonisation (OR 0.43, 95% CI 0.36-0.51).

We identified an economic evaluation of the use of CHG sponge dressings and the non-inferiority of dressing changes at 3 and 7 days.<sup>465</sup> The authors concluded that the major cost avoided by the use of CHG sponge dressings and 7-day dressing changes rather than 3-day dressing changes was the increased length of stay of 11 days associated with CR-BSI. Chlorhexidine-impregnated sponge dressings remained cost saving for any value where the cost per CR-BSI was >\$4400 and the baseline rate of CR-BSI was >0.35%.<sup>465</sup>

We identified a further RCT of CHG dressings compared with highly adhesive semi-permeable dressings or standard semi-permeable dressings for the prevention of CR-BSI in 1879 patients.<sup>466</sup> In the CHG group, the major catheter-related infection rate was 67% lower (0.7 vs 2.1 per 1000 catheter-days, HR 0.328, 95% CI 0.174-0.619,  $p=0.0006$ ) and the CR-BSI rate was 60% lower (0.5 vs 1.3 per 1000 catheter-days, HR 0.402, 95% CI 0.186-0.868,  $p=0.02$ ) than with non-chlorhexidine dressings. Decreases were also noted in catheter colonisation and skin colonisation rates at catheter removal. Highly adhesive dressings decreased the detachment rate to 64.3% vs 71.9% ( $p<0.0001$ ) and the number of dressings per catheter to two (one to four) vs three (one to five) ( $p<0.0001$ ), but increased skin colonisation ( $p<0.0001$ ) and catheter colonisation (HR 1.650, 95% CI 1.21-2.26,  $p=0.0016$ ) without influencing CR-BSI rates.

HICPAC identified three studies that investigated the efficacy of a 2% CHG-impregnated washcloth in reducing the risk of CR-BSI.<sup>334</sup> These studies were included in a subsequent systematic review and meta-analysis on the efficacy of either 2% CHG-impregnated cloths or 4% CHG solution for daily skin cleansing in adult acute care settings, mostly ICUs.<sup>467</sup> Twelve studies were included: one RCT, one cluster NRCT and 10 controlled interrupted time series. Five studies that reported the insertion technique included the use of CHG. There was a high level of clinical heterogeneity and moderate statistical heterogeneity, which remained following a subgroup analysis by type of CHG formulation. The authors concluded that among ICU patients, daily CHG bathing with CHG liquid (OR 0.47, 95% CI 0.31-0.71) or cloths (OR 0.41, 95% CI 0.25-0.65) reduces the risk of CR-BSI. Similar benefit is obtained regardless of whether CHG cloths or liquid preparation is used (OR 0.44, 95% CI 0.44-0.59). This review was not generalisable to paediatric care.

Whenever CHG is used for insertion site dressings or skin cleansing, systems should be in place to ensure that it is not used for patients with a history of chlorhexidine sensitivity.<sup>408</sup>

A single RCT compared the efficacy of two commercially available alcohol-based antiseptic solutions for preparation and care of CVC insertion sites, with and without octenidine dihydrochloride.<sup>468</sup> Data were collected from 2002 to 2005 and published in 2010. The authors concluded that octenidine in alcoholic solution is a better option than alcohol alone for the prevention of CVC-associated infections, and may be as effective as CHG in practice but a comparative trial is needed.

- IVAD17 Use a sterile, transparent, semi-permeable polyurethane dressing to cover the intravascular insertion site.  
*Class D/GPP*
- IVAD18 Transparent, semi-permeable polyurethane dressings should be changed every 7 days, or sooner, if they are no longer intact or if moisture collects under the dressing.  
*Class D/GPP*
- IVAD19 Use a sterile gauze dressing if a patient has profuse perspiration or if the insertion site is bleeding or leaking, and change when inspection of the insertion site is necessary or when the dressing becomes damp, loosened or soiled. Replace with a transparent semi-permeable dressing as soon as possible.  
*Class D/GPP*
- IVAD20 Consider the use of a chlorhexidine-impregnated sponge dressing in adult patients with a central venous catheter as a strategy to reduce catheter-related bloodstream infection.  
**New recommendation Class B**
- IVAD21 Consider the use of daily cleansing with chlorhexidine daily in adult patients with a central venous catheter as a strategy to reduce catheter-related bloodstream infection.  
**New recommendation Class B**
- IVAD22 Dressings used on tunneled 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. A dressing may no longer be required once the insertion site is healed.  
*Class D/GPP*

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

Research previously described in these guidelines has described the superior effectiveness of CHG to minimise the density of microorganisms around vascular catheter insertion sites.<sup>447,448,450</sup> Consequently, alcoholic CHG is now widely used in the UK for disinfecting 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 catheter-related infection do not clearly demonstrate efficacy.<sup>454,459</sup>

Most modern intravascular catheters and other catheter materials 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 catheter tubing (e.g. some catheters used in haemodialysis). The manufacturer's recommendations to only use disinfectants that are compatible with specific catheter materials must therefore be followed.

- IVAD23 Use a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) to clean the central catheter insertion site during dressing changes, and allow to air dry.  
*Class A*
- IVAD24 Use a single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) to clean the peripheral venous catheter insertion site during dressing changes, and allow to air dry.  
**New recommendation Class D/GPP**
- IVAD25 Do not apply antimicrobial ointment to catheter insertion sites as part of routine catheter site care.  
*Class D/GPP*



## 4.10 Catheter Replacement Strategies

### **Replacing intravascular devices routinely does not prevent infection**

Evidence indicates that the routine replacement of CVCs at scheduled time intervals does not reduce rates of CR-BSI. Three randomised trials investigated strategies for replacing CVCs routinely at either 7 days<sup>469,470</sup> or 3 days<sup>471</sup> compared with changing catheters when clinically indicated. Two studies were conducted in adult ICUs<sup>469,471</sup> and a third study was undertaken in a renal dialysis unit.<sup>470</sup> No difference in CR-BSI was observed in patients in the scheduled replacement groups compared with those replaced when clinically indicated.

Another suggested strategy for the prevention of CR-BSI is the routine scheduling of guidewire exchange of CVCs. A systematic review and meta-analysis<sup>472</sup> of 12 RCTs concluded that when compared with insertion at a new site, guidewire exchange was associated with a trend towards increased rates of catheter colonisation (RR 1.26, 95% CI 0.87-1.84), regardless of suspected CR-BSI at the time of replacement. Guidewire exchange was also associated with a trend towards increased rates of catheter exit-site infection (RR 1.52, 95% CI 0.34-6.73) and CR-BSI (RR 1.72, 95% CI 0.89-3.33), but also associated with fewer mechanical complications relative to insertion at a new site.<sup>472</sup>

Neither we nor HICPAC identified any additional evidence for these recommendations whilst updating our systematic review.<sup>334</sup>

### **Peripheral vascular devices**

We identified one RCT that compared a routine 3-day re-siting of PVCs compared with a clinically indicated re-siting. IVD-related complication rates were 68 per 1000 IVD-days (clinically indicated) and 66 per 1000 IVD-days (routine replacement) ( $p=0.86$ , hazard ratio 1.03, 95% CI 0.74-1.43). Re-siting a device on clinical indication would allow one in two patients to have a single cannula per course of intravenous treatment, as opposed to one in five patients managed with routine re-siting; overall complication rates appear similar. Clinically indicated re-siting would achieve savings in equipment, staff time and patient discomfort.<sup>473</sup>

A recent update of a Cochrane review found no evidence to support changing catheters every 72-96 h.<sup>474</sup> Consequently, healthcare organisations may consider moving to a policy whereby catheters are changed only if clinically indicated. This would provide cost savings and spare patients the unnecessary pain of routine re-siting of devices in the absence of clinical indications. To minimise peripheral catheter-related complications, the insertion site should be inspected at each shift change and the catheter removed if signs of inflammation, infiltration or blockage are present.<sup>474</sup>

IVAD26 Do not routinely replace central venous access devices to prevent catheter-related infection.  
*Class A*

IVAD27 Do not use guidewire-assisted catheter exchange for patients with catheter-related bloodstream infection.  
*Class A*

IVAD28 Peripheral vascular catheter insertion sites should be inspected at a minimum during each shift, and a Visual Infusion Phlebitis score should be recorded. The catheter should be removed when complications occur or as soon as it is no longer required.

**New recommendation Class D/GPP**

IVAD29 Peripheral vascular catheters should be re-sited when clinically indicated and not routinely, unless device-specific recommendations from the manufacturer indicate otherwise.

**New recommendation Class B**

## 4.11 General Principles for Catheter Management

### **Aseptic technique is important when accessing the system**

Evidence demonstrating that contamination of the catheter hub contributes to intraluminal microbial colonisation of catheters, particularly long-term catheters, was considered by HICPAC.<sup>346,475-480</sup> Catheter hubs are accessed more frequently when catheterisation is prolonged, and this increases the risk of CR-BSI originating from a colonised catheter hub rather than the insertion site.<sup>346</sup> Evidence from a prospective cohort study suggested that frequent catheter hub manipulation increases the risk for microbial contamination.<sup>481</sup> Additional studies concurred and recommended that hubs and sampling ports should be disinfected using either povidone iodine or chlorhexidine before they are accessed.<sup>406,482,483</sup>

A randomised prospective clinical trial investigated the use of needleless connectors or standard caps attached to CVC luer connections. Results suggested that the use of needleless connectors may reduce the microbial contamination rate of CVC luers compared with standard caps. Furthermore, disinfection of needleless connectors with either chlorhexidine/alcohol or PVI significantly reduced external microbial contamination. Both these strategies may reduce the risk of catheter-related infections acquired via the intraluminal route.<sup>484</sup>

We found no RCT evidence comparing the efficacy of different methods for the decontamination of ports and hubs prior to access. Expert opinion, based on consensus and evidence extrapolated from experimental studies of hub decontamination,<sup>56,485,486</sup> and studies of skin decontamination prior to insertion and during dressing changes, suggests that injection ports or catheter hubs should be decontaminated for a minimum of 15 s using CHG in 70% alcohol before and after accessing the system. Although most intravascular catheters and catheter hub materials are now chemically compatible with alcohol or iodine, some may be incompatible and therefore the manufacturer's recommendations should be followed.



IVAD30 A single-use application of 2% chlorhexidine gluconate in 70% isopropyl alcohol (or povidone iodine in alcohol for patients with sensitivity to chlorhexidine) should be used to decontaminate the access port or catheter hub. The hub should be cleaned for a minimum of 15 s and allowed to dry before accessing the system.  
*Class D/GPP*

### **Using lock solutions to prevent infection**

The procedure of flushing and then leaving the lumen of a CVC filled with an antibiotic solution is termed 'antibiotic lock prophylaxis' and has been described as a measure to prevent CR-BSI in haemodialysis or a patient who has a history of multiple CR-BSI despite optimal maximal adherence to the aseptic technique. Evidence reviewed by HICPAC<sup>334</sup> demonstrated the effectiveness of this type of prophylaxis. However, the majority of the studies were conducted in haemodialysis patients and therefore may not be generalisable.

We identified a systematic review of RCTs which concluded that the scientific evidence for the effectiveness of the routine use of antibiotic-based lock solutions is weak,<sup>487</sup> thus supporting the HICPAC evidence. In addition, there is concern that the use of such solutions could lead to an increase in antimicrobial-resistant microorganisms.<sup>334</sup>

An additional placebo-RCT of daily ethanol locks to prevent CR-BSI in patients with tunneled catheters<sup>488</sup> found that the reduction in the incidence of endoluminal CR-BSI using preventive ethanol locks was non-significant, although the low incidence of endoluminal CR-BSI precludes definite conclusions, and the low incidence of CR-BSI in the placebo arm meant the study was underpowered in retrospect. Significantly more patients treated with ethanol locks discontinued their prophylactic treatment due to non-severe, ethanol-related adverse effects.

IVAD31 Antimicrobial lock solutions should not be used routinely to prevent catheter-related bloodstream infections.  
*Class D/GPP*

### **Antibiotic prophylaxis does not prevent catheter-related bloodstream infection**

HICPAC identified no studies which demonstrated that oral or parenteral antibacterial or antifungal drugs reduced the incidence of CR-BSI among adults. However, among low-birthweight infants, two studies on vancomycin prophylaxis demonstrated a reduction in CR-BSI but no reduction in mortality. As the prophylactic use of vancomycin is an independent risk factor for the acquisition of VRE, it is likely that the risk of acquiring VRE outweighs the benefit of using prophylactic vancomycin.<sup>334,489</sup>

Topical mupirocin is used to suppress *S. aureus* in nasal carriers. Some studies have shown that mupirocin applied nasally (or locally to the insertion site) results in reduced risk of CR-BSI.<sup>334</sup> However, rates of mupirocin resistance of 12% have been reported in the UK,<sup>490</sup> and its incompatibility with polyurethane catheters means that it should not be used routinely.<sup>334</sup>

Long-term tunneled CVCs are frequently used for patients with cancer who require intravenous treatments. A Cochrane review published in 2003 concluded that prophylactic antibiotics or catheter flushing with vancomycin and heparin may be of benefit in reducing the risk of catheter-related infections in these high-risk cancer patients.<sup>491</sup> However, this practice should not be used routinely in order to minimise the development of antimicrobial resistance.<sup>491</sup>

IVAD32 Do not routinely administer intranasal or systemic antimicrobials before insertion or during the use of an intravascular device to prevent catheter colonisation or bloodstream infection.  
*Class A*

### **Maintaining device patency and preventing catheter thrombosis may help prevent infections**

The placement of any CVC or pulmonary artery catheter leads to thrombus formation shortly after insertion, providing a focus for bacterial growth.<sup>492</sup> Catheters manufactured from silicone or polyethylene and placed in the subclavian vein are less frequently associated with thrombus formation.<sup>493</sup> Between 35% and 65% of patients with long-term CVCs and PICCs develop a thrombosis of the large vessels, and patients are treated with prophylactic heparin to prevent the formation of both deep vein thrombosis and catheter thrombus.<sup>334,494-499</sup>

### **The use of anticoagulants**

Heparin may be administered through several different routes. An early meta-analysis of RCTs compared the effectiveness of heparin administration via an infusion, subcutaneously or intermittent flush for the prevention of thrombus formation and CR-BSI in patients with short-term CVCs.<sup>500</sup> Prophylactic heparin infusion was associated with a decrease in catheter thrombus formation, deep vein thrombosis, catheter colonisation and a trend towards reductions in CR-BSI, but this was not statistically

significant. HICPAC identified an additional prospective randomised trial that demonstrated a significant decrease in the rate of CR-BSI in patients with non-tunnelled CVCs who received continuous heparin infusion.<sup>501</sup> Heparin-bonded (HB) catheters have also been shown to reduce the risk of both thrombus formation and CR-BSI.<sup>502-505</sup>

We identified one systematic review of HB CVCs in children.<sup>506</sup> The reviewers identified two RCTs of 287 children aged 1 day to 16 years who received either an HB catheter or a standard catheter. There was no significant difference in the median duration of catheter patency in the two groups: 7 days in the HB catheter group and 6 days in the standard catheter group. The authors also reported a trend towards a reduction in the risk of catheter-related thrombosis and catheter occlusion in the HB group. The risks of catheter colonisation and catheter-related infection were significantly reduced in the treatment group, with a delay to infection in the HB catheter group. However, the reviewers considered the need for further studies to confirm the efficacy of HB catheters.

The use of warfarin has also been shown to reduce the risk of catheter-related thrombosis in some patient groups but not in others, and is generally not associated with a reduction in infection-related complications.<sup>501,507-509</sup>

### **Heparin vs normal saline intermittent flushes**

Systemic heparin, as either an infusion or flush, has a number of side effects that contraindicate its routine use for maintaining the patency of CVCs and preventing thrombus formation; these include thrombocytopenia, allergic reactions and bleeding.<sup>510</sup> Normal saline is an alternative to the use of heparin flush.

HICPAC refer to three systematic reviews, and meta-analysis of RCTs evaluating the effect of heparin on the duration of catheter patency and on the 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.<sup>511-514</sup> However, manufacturers of implanted ports or opened-ended catheter lumens may recommend heparin flushes for maintaining CVCs that are accessed infrequently.

We identified one systematic review and two RCTs that compared heparin with normal saline to maintain the patency of CVCs and PVCs, respectively.<sup>515-517</sup> A systematic review<sup>515</sup> of heparin flushing and other interventions to maintain the patency of CVCs concluded that the evidence base for heparin flushing and other interventions to prevent catheter occlusion is limited and published studies are of low quality. The reviewers concluded that there is no direct evidence of the effectiveness of heparin flushes to prevent CR-BSI or other central line complications.

In a single-centre RCT<sup>516</sup> of newly placed multi-lumen CVCs in patients in medical ICUs and surgical/burn/trauma ICUs, normal saline and heparin flush solutions were found to have similar rates of lumen non-patency. Given potential safety concerns with the use of heparin, normal saline may be the preferred flushing solution for short-term use for CVC maintenance. Secondary outcomes for CR-BSI were non-significant between groups.

A single-centre cluster RCT<sup>517</sup> of 214 medical patients found that twice-daily heparin (100 U/mL) flushes for maintenance of PVCs was more effective than normal saline solution. The number of catheter-related phlebitis/occlusions and the number of catheters per patient was reduced; however, infection outcomes were not measured.

IVAD33 Do not use systemic anticoagulants routinely to prevent catheter-related bloodstream infection.

*Class D/GPP*

IVAD34 Use sterile normal saline for injection to flush and lock catheter lumens that are accessed frequently.

*Class A*

### **Safer sharps devices require vigilance**

Needle-free infusion systems and connection devices have been widely introduced to reduce the incidence of sharps injuries and minimise the risk of transmission of bloodborne pathogens to healthcare workers.<sup>334</sup> There is limited evidence that needleless devices or valves reduce the risk of catheter colonisation compared with standard devices.<sup>334</sup> In addition, the design features of some of these devices pose a potential risk for contamination, and have been associated with reports of an increase in bloodstream infection rates.<sup>518-521</sup>

IVAD35 The introduction of new intravascular devices or components 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 in the UK.

*Class D/GPP*

IVAD36 When safer sharps 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*

### **Change intravenous administration sets appropriately**

HICPAC reviewed three well-controlled studies on the optimal interval for the routine replacement of intravenous solution administration sets.<sup>334</sup> A Cochrane review<sup>522</sup> of 13 RCTs with 4783 patients concluded that there is no evidence that changing intravenous administration sets more often than every 96 h reduces the incidence of bloodstream infection. The reviewers were unable to conclude if changing administration sets less often than every 96 h affects the incidence of infection from the studies. There were no differences between participants with central vs peripheral catheters, nor between participants who did and did not receive parenteral nutrition, or between children and adults. Administration sets that do

not contain lipids, blood or blood products may be left in place for intervals of up to 96 h without increasing the incidence of infection. There is no evidence to suggest that administration sets which contain lipids should not be changed every 24 h as currently recommended.

IVAD37 Administration sets in continuous use do not need to be replaced more frequently than every 96 h, unless device-specific recommendations from the manufacturer indicate otherwise, they become disconnected or the intravascular access device is replaced.

*Class A*

IVAD38 Administration sets for blood and blood components should be changed when the transfusion episode is complete or every 12 h (whichever is sooner).

*Class D/GPP*

IVAD39 Administration sets used for lipid-containing parenteral nutrition should be changed every 24 h.

*Class D/GPP*

### **System interventions to reduce catheter-related infection**

Ensuring that patients receive care that is evidence based is an essential element of delivering high-quality health care. In 2005, the Department of Health issued a series of high-impact interventions that were derived from national and international evidence-based guidelines for the prevention of healthcare-associated infection and based on experience from the Institute of Healthcare Improvement 100,000 Lives Campaign focused on reducing patient harm.<sup>523</sup> The high-impact interventions focused on increasing the reliability of care and ensuring that recommendations were implemented every time for every patient. The intervention for the prevention of infection associated with the use of IVDs included six key interventions often referred to as a 'care bundle', together with audit tools to measure adherence. These six practices included:

- aseptic insertion of an appropriate device;
  - correct siting of the device;
  - effective cutaneous antisepsis;
- and for continuing care of the device:
- hand decontamination and asepsis for any contact with the device;
  - daily observation of the insertion site; and
  - clean, intact dressing.

A small number of well-designed studies<sup>523,524</sup> have described the use of 'bundled' approaches to reducing CR-BSI, and have stimulated individual observational and quality improvement reports of the results of using key evidence-based practices for the prevention of CR-BSI. The most prominent of these was a study conducted in the ICU setting of 108 hospitals in the USA, which was then adopted by other countries including the UK.<sup>525,526</sup> The authors reported the success of five evidence-based practices combined with system and organisational support, which resulted in a 66% decrease in CR-BSI 18 months after the

inception of the programme (incidence rate ratio 0.62, 95% CI 0.47-0.81 to incidence rate ratio 0.34, 95% CI 0.23-0.50) and sustained reductions thereafter.<sup>525</sup> The intervention comprised: hand hygiene using ABHR; MSB precautions for insertion; cutaneous antisepsis of the insertion site with 2% CHG; avoiding the femoral site; and removing CVCs as soon as they are no longer clinically indicated. In addition, system changes that prompted the clinician to 'do the right thing' included placing all the equipment needed in a cart for ease of access; the use of a checklist; authorising staff to halt procedures if best practice was not being followed; daily rounds to ensure the timely removal of CVCs; feedback of CR-BSI cases to clinical staff; and organisational support to purchase essential equipment and solutions prior to the start of the study.

Audit and feedback are an essential component of any quality improvement intervention as this promotes a continuous 'Hawthorne effect' and enables staff to maintain vigilance and sustain improvement. The use of dashboards and statistical process control charts alerts clinicians to variability outside control limits, and prompts scrutiny of practice and organisational systems, and remedial action to be taken.<sup>527</sup>

We identified three additional studies that reported 'bundled interventions' to reduce CR-BSI.<sup>528-530</sup> None were included in the systematic review as they failed to meet study quality criteria. The features of any quality improvement initiative need to be tailored to the local conditions and may include some or all of the following:

- hand hygiene, aseptic insertion using MSB precautions (CVC), aseptic technique (PVC), cutaneous antisepsis using 2% CHG in alcohol unless contraindicated, appropriate siting of the CVC or PVC, and prompt removal when no longer indicated;
- audit and feedback;
- education and training; and
- accessibility of equipment and appropriate system changes developed with clinical staff to make best practice the norm.

In one cost-effectiveness study, a Markov decision model was used to evaluate the cost-effectiveness of a care bundle to prevent CR-BSI.<sup>531</sup> The care bundle included in the model was based on the bundle advocated by the Institute for Health Improvement 100,000 Lives Campaign,<sup>532</sup> comprising optimal hand hygiene, chlorhexidine skin antisepsis, MSB precautions for catheter insertion and insertion equipment kit, optimal insertion site and prompt catheter removal. Costs included monitoring, education and clinical leadership activities. The authors estimated that the bundle would be cost-effective if the costs of implementation were less than AU\$94,559 (£55,817) per ICU.

IVAD40 Use quality improvement interventions to support the appropriate use and management of intravascular access devices (central and peripheral venous catheters) and ensure their timely removal. These may include:

- protocols for device insertion and maintenance;
- reminders to review the continuing use or prompt the removal of intravascular devices;
- audit and feedback of compliance with practice guidelines; and
- continuing professional education.

**New recommendation** *Class C/GPP*

**Intravascular Access Devices - Systematic Review Process****Systematic Review Questions**

1. What types of CVCs (material, coating, antibiotic impregnation, cuffed, tunnelled, midline, PICC) and PVCs (material, coating, antibiotic impregnation) are most effective in reducing the risk of CR-BSI and related complications/adverse events including phlebitis, related mortality, catheter tip colonisation and premature line removal?
2. Which CVC/PVC insertion site is associated with the lowest risk of CR-BSI and related complications including phlebitis, related mortality, catheter tip colonisation and premature line removal?
3. What is the evidence that additional ports or lumens increase the risk of CR-BSI and related complications/adverse events including phlebitis, mortality, catheter tip colonisation and premature line removal?
4. Which infection prevention precautions used for inserting intravascular catheters are most effective in reducing the risk of CR-BSI and related complications/adverse events including phlebitis, catheter tip colonisation, premature line removal and mortality?
5. What levels of barrier precautions are most effective in reducing the risk of CR-BSI and related complications/adverse events including phlebitis, catheter tip colonisation, premature line removal and mortality?
6. What is the most effective skin antiseptic solution/antiseptic-impregnated product for decontamination of the skin prior to insertion of CVCs and PVCs to reduce the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
7. What is the effectiveness of antiseptics vs antiseptic-impregnated products (sponges or cloths) for decontaminating skin at the insertion site or surrounding area whilst a CVC or PVC is *in situ* in reducing the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
8. What is the evidence for the effectiveness of using antibiotics or antiseptics to lock, flush or clean the catheter hub or entry ports of CVCs and PVCs in reducing the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
9. What is the effectiveness of low-dose systemic anticoagulation to reduce the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
10. Which dressing type is the most clinically effective in reducing the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality, and how frequently should dressings be changed?
11. What is the optimal frequency to change or re-site PVCs or midline catheters to reduce the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
12. What is the evidence for the effectiveness of replacing administration sets to reduce the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
13. What is the effectiveness of the prophylactic administration of systemic antimicrobials in reducing the incidence of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
14. What is the evidence that the needle-safe devices are associated with increased risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality?
15. What is the effectiveness of system interventions in reducing the risk of CR-BSI and related complications including phlebitis, catheter tip colonisation, premature line removal and mortality, and improving healthcare workers' knowledge and behaviour relating to the use of central venous access device (CVAD) and peripheral vascular device (PVD)?

**Databases and Search Terms Used****DATABASES**

Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, NEHL Guideline Finder, National Institute for Health and Clinical Excellence, the Cochrane Library (CDSR, CCRCT, CMR), US Guideline Clearing House, DARE (NHS Evidence, HTA), Prospero

**MeSH TERMS**

Infection control; cross infection; disease transmission; universal precautions; central venous catheter; bacteremia; chlorhexidine; povidone-iodine; anticoagulants; sepsis; sterilisation; antiseptics; catheterisation; peripheral catheterisation; peripheral catheter

**THESAURUS AND FREE-TEXT TERMS**

PICC; TPN; catheter hub; implantable catheter; catheter port; needle-free devices; needleless connector; intravenous-access; skin preparation; care bundle; Matching Michigan; catheter team, IV team; specialist nurses

**SEARCH DATE**

Jan 2010-Feb 2013

**Search Results**

Total number of articles located = 8053

**Sift 1 Criteria**

**Abstract indicates** that the article: relates to infections associated with intravascular access devices; is written in English; is primary research, 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 = 96

**Sift 2 Criteria**

**Full text confirms** that the article: relates to infections associated with intravascular access devices; is written in English; is primary research (randomised controlled trials, prospective cohort, interrupted time series, controlled before-after, quasi-experimental), a systematic review or a meta-analysis including the above designs; and informs one or more of the review questions.

**Articles Selected for Appraisal**

Total number of studies selected for appraisal during Sift 2 = 30

**Critical Appraisal**

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

**Accepted and Rejected Evidence**

Total number of studies accepted after critical appraisal = 22

Total number of studies rejected after critical appraisal = 8



## References

- Pratt RJ, Pellowe C, Loveday HP, et al.; Department of Health (England). The epic project: developing national evidence-based guidelines for preventing healthcare associated infections. Phase I: Guidelines for preventing hospital-acquired infections. *J Hosp Infect* 2001;**47**(Suppl. 1):S3-S82.
- Pratt RJ, Pellowe CM, Wilson JA, et al. epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *J Hosp Infect* 2007;**65**(Suppl. 1):S1-S59.
- AGREE II Instrument. *Appraisal of guidelines for research and evaluation II*. 2009. Available at: <http://www.agreetrust.org/resource-centre/agree-ii/>. Accessed October 5, 2012.
- Scottish Intercollegiate Guidelines Network. *SIGN 50: a guideline developer's handbook*. Edinburgh: Healthcare Improvement Scotland. Revised edition. 2011. Available at: <http://www.sign.ac.uk/guidelines/fulltext/50/index.html>. Accessed July 25, 2013.
- Cochrane Effective Practice and Organisation of Care Review Group. *EPOC resources*. The Cochrane Collaboration; 2013. Available at: <http://epoc.cochrane.org/epoc-resources>. Accessed 6 August, 2013.
- Department of Health. *The Health and Social Care Act 2008: code of practice for the NHS on the prevention and control of healthcare associated infections and related guidance*. London: Department of Health; 2009.
- Department of Health. *Decontamination of re-usable medical devices in the primary, secondary and tertiary care sectors (NHS and independent providers)*. London: Department of Health; 2007.
- Care Quality Commission. *Guidance about compliance. Essential standards of quality and safety*. London: Care Quality Commission; 2010. Available at: [http://www.cqc.org.uk/sites/default/files/media/documents/essential\\_standards\\_of\\_quality\\_and\\_safety\\_march\\_2010\\_final\\_0.pdf](http://www.cqc.org.uk/sites/default/files/media/documents/essential_standards_of_quality_and_safety_march_2010_final_0.pdf). Accessed August 1, 2013.
- National Patient Safety Agency. *The revised healthcare cleaning manual*. London: NPSA; 2009. Available at: <http://www.nrls.npsa.nhs.uk/EasySiteWeb/getresource.axd?AssetID=61814&>. Accessed July 19, 2013.
- National Institute for Health and Care Excellence. *Guidance 36. Prevention and control of healthcare-associated infections. Quality improvement guide*. London: National Institute for Health and Care Excellence; 2011. Available at: [www.nice.org.uk/guidance/PH36](http://www.nice.org.uk/guidance/PH36). Accessed July 25, 2013.
- Boyce JM, Havill NL, Otter JA, Adams NMT. Widespread environmental contamination associated with patients with diarrhoea and methicillin-resistant *Staphylococcus aureus* colonization of the gastrointestinal tract. *Infect Control Hosp Epidemiol* 2007;**28**:1142-1147.
- Dancer SJ. Importance of the environment in methicillin-resistant *Staphylococcus aureus* acquisition: the case for hospital cleaning. *Lancet Infect Dis* 2008;**8**:101-113.
- Griffiths R, Fernandez R, Halcomb E. Reservoirs of MRSA in the acute hospital setting: a systematic review. *Contemp Nurse* 2002;**13**:38-49.
- Barker J, Vipond IB, Bloomfield SF. Effects of cleaning and disinfection in reducing the spread of Norovirus contamination via environmental surfaces. *J Hosp Infect* 2004;**58**:42-49.
- Denton M, Wilcox MH, Parnell P, et al. Role of environmental cleaning in controlling an outbreak of *Acinetobacter baumannii* on a neurosurgical intensive care unit. *J Hosp Infect* 2004;**56**:106-110.
- Wilcox MH, Fawley WN, Wigglesworth N, Parnell P, Verity P, Freeman J. Comparison of the effect of detergent versus hypochlorite cleaning on environmental contamination and incidence of *Clostridium difficile* infection. *J Hosp Infect* 2003;**54**:109-114.
- Boyce JM, Potter-Bynoe G, Chenevert C, King T. Environmental contamination due to methicillin-resistant *Staphylococcus aureus*: possible infection control implications. *Infect Control Hosp Epidemiol* 1997;**18**:622-627.
- Oie S, Hosokawa I, Kamiya A. Contamination of room door handles by methicillin-sensitive/methicillin-resistant *Staphylococcus aureus*. *J Hosp Infect* 2002;**51**:140-143.
- Schultz M, Gill J, Zubairi S, Huber R, Gordin F. Bacterial contamination of computer keyboards in a teaching hospital. *Infect Control Hosp Epidemiol* 2003;**24**:302-303.
- Brooks SE, Walczak MA, Hameed R, Coonan P. Chlorhexidine resistance in antibiotic-resistant bacteria isolated from the surfaces of dispensers of soap containing chlorhexidine. *Infect Control Hosp Epidemiol* 2002;**23**:692-695.
- Nseir S, Blazejewski C, Lubret R, Wallet F, Courcol R, Durocher A. Risk of acquiring multidrug-resistant Gram-negative bacilli from prior room occupants in the intensive care unit. *Clin Microbiol Infect* 2011;**17**:1201-1208.
- Huang SS, Datta R, Platt R. Risk of acquiring antibiotic-resistant bacteria from prior room occupants. *Arch Intern Med* 2006;**166**:1945-1951.
- Shaughnessy MK, Micielli RL, DePestel DD, et al. Evaluation of hospital room assignment and acquisition of *Clostridium difficile* infection. *Infect Control Hosp Epidemiol* 2011;**32**:201-206.
- Ramplung A, Wiseman S, Davis L, et al. Evidence that hospital hygiene is important in the control of methicillin-resistant *Staphylococcus aureus*. *J Hosp Infect* 2001;**49**:109-116.
- Wilson AP, Smyth D, Moore G, et al. The impact of enhanced cleaning within the intensive care unit on contamination of the near-patient environment with hospital pathogens: a randomized crossover study in critical care units in two hospitals. *Crit Care Med* 2011;**39**:651-658.
- Dettenkofer M, Wenzler S, Amthor S, Antes G, Motschall E, Daschner FD. Does disinfection of environmental surfaces influence nosocomial infection rates? A systematic review. *Am J Infect Control* 2004;**32**:84-89.
- Otter JA, Puchowicz M, Ryan D, et al. Feasibility of routinely using hydrogen peroxide vapor to decontaminate rooms in a busy United States hospital. *Infect Control Hosp Epidemiol* 2009;**30**:574-577.
- Kundrapu S, Sunkesula V, Jury LA, Sitzlar BM, Donskey CJ. Daily disinfection of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers' hands. *Infect Control Hosp Epidemiol* 2012;**33**:1039-1042.
- Dancer S, White L, Lamb J, Girvan EK, Robertson C. Measuring the effect of enhanced cleaning in a UK hospital: a prospective cross-over study. *BMC Med* 2009;**7**:28.
- 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. *J Hosp Infect* 2004;**57**:31-37.
- Otter JA, Yezli S, Perl TM, Barbut F, French GL. The role of 'no-touch' automated room disinfection systems in infection prevention and control. *J Hosp Infect* 2013;**83**:1-13.
- Fu TY, Gent P, Kumar V. Efficacy, efficiency and safety aspects of hydrogen peroxide vapour and aerosolized hydrogen peroxide room disinfection systems. *J Hosp Infect* 2012;**80**:199-205.
- Barbut F, Menuet D, Verachten M, Girou E. Comparison of the efficacy of a hydrogen peroxide dry-mist disinfection system and sodium hypochlorite solution for eradication of *Clostridium difficile* spores. *Infect Control Hosp Epidemiol* 2009;**30**:507-514.
- Passaretti CL, Otter JA, Reich NG, et al. An evaluation of environmental decontamination with hydrogen peroxide vapor for reducing the risk of patient acquisition of multidrug-resistant organisms. *Clin Infect Dis* 2013;**56**:27-35.
- Schmidt MG, Cantey JR, Freeman KD, et al. Sustained reduction of microbial burden on common hospital surfaces through introduction of copper. *J Clin Microbiol* 2012;**50**:2217-2223.
- Schmidt MG, Attaway III HH, Fairey SE, Steed LL, Michels HT, Salgado CD. Copper continuously limits the concentration of bacteria resident on bed rails within the intensive care unit. *Infect Control Hosp Epidemiol* 2013;**34**:530-533.
- Casey AL, Elliott TSJ, Adams D, et al. Role of copper in reducing hospital environment contamination. *J Hosp Infect* 2010;**74**:72-77.
- Karpanen TJ, Casey AL, Lambert PA, et al. The antimicrobial efficacy of copper alloy furnishing in the clinical environment: a crossover study. *Infect Control Hosp Epidemiol* 2012;**33**:3-9.
- Salgado CD, Sepkowitz KA, John JF, et al. Copper surfaces reduce the rate of healthcare-acquired infections in the intensive care unit. *Infect Control Hosp Epidemiol* 2013;**34**:479-486.
- Mulvey D, Redding P, Robertson C, et al. Finding a benchmark for monitoring hospital cleanliness. *J Hosp Infect* 2011;**77**:25-30.



41. Boyce JM, Havill NL, Dumigan DG, Golebiewski M, Balogun O, Rizvani R. Monitoring the effectiveness of hospital cleaning practices by use of an adenosine triphosphate bioluminescence assay. *Infect Control Hosp Epidemiol* 2009;**30**:678-684.
42. Lewis T, Griffith C, Gallo M, Weinbren M. A modified ATP benchmark for evaluating the cleaning of some hospital environmental surfaces. *J Hosp Infect* 2008;**69**:156-163.
43. Griffith CJ, Obee P, Cooper RA, Burton NF, Lewis M. The effectiveness of existing and modified cleaning regimens in a Welsh hospital. *J Hosp Infect* 2007;**66**:352-359.
44. Malik RE, Cooper RA, Griffith CJ. Use of audit tools to evaluate the efficacy of cleaning systems in hospitals. *Am J Infect Control* 2003;**31**:181-187.
45. World Health Organization. *WHO Patient Safety. WHO guidelines on hand hygiene in health care*. Geneva: World Health Organization; 2009.
46. Gupta A, Della-Latta P, Todd B, et al. Outbreak of extended-spectrum beta-lactamase-producing *Klebsiella pneumoniae* in a neonatal intensive care unit linked to artificial nails. *Infect Control Hosp Epidemiol* 2004;**25**:210-215.
47. Pittet D, Dharan S, Touveneau S, Sauvan V, Perneger TV. Bacterial contamination of the hands of hospital staff during routine patient care. *Arch Intern Med* 1999;**159**:821-826.
48. Pessoa-Silva CL, Dharan S, Hugonnet S, et al. Dynamics of bacterial hand contamination during routine neonatal care. *Infect Control Hosp Epidemiol* 2004;**25**:192-197.
49. 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. *Am J Infect Control* 2002;**30**:226-233.
50. Ryan MA, Christian RS, Wohlrahe J. Handwashing and respiratory illness among young adults in military training. *Am J Prev Med* 2001;**21**:79-83.
51. Pittet D, Hugonnet S, Harbarth S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *Lancet* 2000;**356**:1307-1312.
52. Gordin FM, Schultz ME, Huber RA, Gill JA. Reduction in nosocomial transmission of drug-resistant bacteria after introduction of an alcohol-based handrub. *Infect Control Hosp Epidemiol* 2005;**26**:650-653.
53. Boyce JM, Pittet D; Healthcare Infection Control Practices Advisory Committee; Society for Healthcare Epidemiology of America/Association for Professionals in Infection Control/ Infectious Diseases Society of America Hand Hygiene Task Force. Guideline 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. *Infect Control Hosp Epidemiol* 2002;**23**(Suppl. 12):S3-S40.
54. Provincial Infectious Diseases Advisory Committee. *Best practices for hand hygiene in all health care settings*. Toronto: Ontario Ministry of Health and Long-Term Care/Public Health Division; 2010. Available at: <http://www.oahpp.ca/resources/documents/pidac/2010-12%20BP%20Hand%20Hygiene.pdf>. Accessed July 20, 2013.
55. Sax H, Allegranzi B, Uçkay I, Larson E, Boyce J, Pittet D. 'My five moments for hand hygiene': a user-centred design approach to understand, train, monitor and report hand hygiene. *J Hosp Infect* 2007;**67**:9-21.
56. National Clinical Guideline Centre. *Infection: prevention and control of healthcare-associated infections in primary and community care: partial update of NICE Clinical Guideline 2. NICE Clinical Guidelines, No. 139*. London: Royal College of Physicians; 2012.
57. Pellowe C, Pratt R, Harper P, et al. Infection control: prevention of healthcare-associated infection in primary and community care. *J Hosp Infect* 2003;**55**(Suppl. 2):1-127.
58. British Standards Institution. *Chemical disinfectants and antiseptics. Hygienic handrub. Test method and requirements (phase 2/step 2)*. 1997. Available at: <http://www.fda.gov/ohrms/dockets/dailys/03/Sept03/090303/75n-0183h-c000081-09-Tab-04-A-vol161.pdf>. Accessed August 15, 2013.
59. Lucet JC, Rigaud MP, Mentre F, et al. Hand contamination before and after different hand hygiene techniques: a randomized clinical trial. *J Hosp Infect* 2002;**50**:276-280.
60. Winnefeld M, Richard MA, Drancourt M, Grob JJ. Skin tolerance and effectiveness of two hand decontamination procedures in everyday hospital use. *Br J Dermatol* 2000;**143**:546-550.
61. Larson EL, Aiello AE, Bastyr J, et al. Assessment of two hand hygiene regimens for intensive care unit personnel. *Crit Care Med* 2001;**29**:944-951.
62. 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. *BMJ* 2002;**325**:362-365.
63. Zaragoza M, Sallés M, Gomez J, Bayas JM, Trilla A. Handwashing with soap or alcoholic solutions? A randomized clinical trial of its effectiveness. *Am J Infect Control* 1999;**27**:258-261.
64. Larson EL, Cimiotti J, Haas J, et al. Effect of antiseptic handwashing vs alcohol sanitizer on health care-associated infections in neonatal intensive care units. *Arch Pediatr Adolesc Med* 2005;**159**:377-383.
65. 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. *Am J Infect Control* 2001;**29**:162-167.
66. 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.
67. Larson E, Silberger M, Jakob K, et al. Assessment of alternative hand hygiene regimens to improve skin health among neonatal intensive care unit nurses. *Heart Lung* 2000;**29**:136-142.
68. Kramer A, Rudolph P, Kampf G, Pittet D. Limited efficacy of alcohol-based hand gels. *Lancet* 2002;**359**:1489-1490.
69. Moadab A, Rupley KF, Wadhams P. Effectiveness of a nonrinse, alcohol-free antiseptic hand wash. *J Am Podiatr Med Assoc* 2001;**91**:288-293.
70. Guilhermetti M, Hernandes SED, Fukushigue Y, Garcia LB, Cardoso CL. Effectiveness of hand-cleansing agents for removing methicillin-resistant *Staphylococcus aureus* from contaminated hands. *Infect Control Hosp Epidemiol* 2001;**22**:105-108.
71. Paulson DS, Fendler EJ, Dolan MJ, Williams RA. A close look at alcohol gel as an antimicrobial sanitizing agent. *Am J Infect Control* 1999;**27**:332-338.
72. Cardoso CL. Effectiveness of hand-cleansing agents for removing *Acinetobacter baumannii* strain from contaminated hands. *Am J Infect Control* 1999;**27**:327-331.
73. Kampf G, Jarosch R, Rüdén H. Limited effectiveness of chlorhexidine based hand disinfectants against methicillin-resistant *Staphylococcus aureus* (MRSA). *J Hosp Infect* 1998;**38**:297-303.
74. Dyer DL, Gerenratch KB, Wadhams PS. Testing a new alcohol-free hand sanitizer to combat infection. *AORN J* 1998;**68**:239-241, 243-244, 247-251.
75. Dharan S, Hugonnet S, Sax H, Pittet D. Comparison of waterless hand antiseptics agents at short application times: raising the flag of concern. *Infect Control Hosp Epidemiol* 2003;**24**:160-164.
76. 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. *Am J Infect Control* 2005;**33**:67-77.
77. Gould DJ, Moralejo D, Drey N, Chudleigh JH. Interventions to improve hand hygiene compliance in patient care. *Cochrane Database Syst Rev* 2011;**8**:CD005186.
78. Sakamoto F, Yamada H, Suzuki C, Sugiura H, Tokuda Y. Increased use of alcohol-based hand sanitizers and successful eradication of methicillin-resistant *Staphylococcus aureus* from a neonatal intensive care unit: a multivariate time series analysis. *Am J Infect Control* 2010;**38**:529-534.
79. 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. *Am J Infect Control* 1999;**27**:320-326.
80. Oughton MT, Loo VG, Dendukuri N, Fenn S, Libman MD. Hand hygiene with soap and water is superior to alcohol rub and antiseptic wipes for removal of *Clostridium difficile*. *Infect Control Hosp Epidemiol* 2009;**30**:939-944.
81. Jabbar U, Leischner J, Kasper D, et al. Effectiveness of alcohol-based hand rubs for removal of *Clostridium difficile* spores from

- hands. *Infect Control Hosp Epidemiol* 2010;31:565-570.
82. Grayson ML, Melvani S, Druce J, et al. Efficacy of soap and water and alcohol-based hand-rub preparations against live H1N1 influenza virus on the hands of human volunteers. *Clin Infect Dis* 2009;48:285-291.
  83. Turner RB, Fuls JL, Rodgers ND. Effectiveness of hand sanitizers with and without organic acids for removal of rhinovirus from hands. *Antimicrob Agents Chemother* 2010;54:1363-1364.
  84. Chen Y, Sheng W, Wang J, et al. Effectiveness and limitations of hand hygiene promotion on decreasing healthcare-associated infections. *PLoS One* 2011;6:e27163.
  85. Department of Health. *Uniforms and workwear: guidance on uniform and workwear policies for NHS employers*. London: Department of Health; 2010.
  86. Chow A, Arah OA, Chan S, et al. Alcohol handrubbing and chlorhexidine handwashing protocols for routine hospital practice: a randomized clinical trial of protocol efficacy and time effectiveness. *Am J Infect Control* 2012;40:800-805.
  87. Kampf G, Reichel M, Feil Y, Eggerstedt S, Kaulfers P. Influence of rub-in technique on required application time and hand coverage in hygienic hand disinfection. *BMC Infect Dis* 2008;8:149.
  88. Gustafson DR, Vetter EA, Larson DR, et al. Effects of 4 hand-drying methods for removing bacteria from washed hands: a randomized trial. *Mayo Clin Proc* 2000;75:705-708.
  89. Yamamoto Y, Ugai K, Takahashi Y. Efficiency of hand drying for removing bacteria from washed hands: comparison of paper towel drying with warm air drying. *Infect Control Hosp Epidemiol* 2005;26:316-320.
  90. Department of Health. *Infection control in the built environment. Health Building Note 00-09*. London: Department of Health; 2013.
  91. Huang C, Ma W, Stack S. The hygienic efficacy of different hand-drying methods: a review of the evidence. *Mayo Clin Proc* 2012;87:791-798.
  92. Pietsch H. Hand antiseptics: rubs versus scrubs, alcoholic solutions versus alcoholic gels. *J Hosp Infect* 2001;48(Suppl. A):S33-S36.
  93. Boyce JM, Kelliher S, Vallande N. Skin irritation and dryness associated with two hand-hygiene regimens: soap-and-water hand washing versus hand antiseptics with an alcoholic hand gel. *Infect Control Hosp Epidemiol* 2000;21:442-448.
  94. Forrester BG, Roth VS. Hand dermatitis in intensive care units. *J Occup Environ Med* 1998;40:881-885.
  95. Kampf G, Muscatiello M. Dermal tolerance of Sterillium, a propanol-based hand rub. *J Hosp Infect* 2003;55:295-298.
  96. Pittet D, Allegranzi B, Sax H, et al. Double-blind, randomized, crossover trial of 3 hand rub formulations: fast-track evaluation of tolerability and acceptability. *Infect Control Hosp Epidemiol* 2007;28:1344-1351.
  97. Becks VE, Lorenzoni NM. Pseudomonas aeruginosa outbreak in a neonatal intensive care unit: a possible link to contaminated hand lotion. *Am J Infect Control* 1995;23:396-398.
  98. Hilburn J, Hammond BS, Fendler EJ, Groziak PA. Use of alcohol hand sanitizer as an infection control strategy in an acute care facility. *Am J Infect Control* 2003;31:109-116.
  99. 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. *Am J Infect Control* 2005;33:392-397.
  100. Rosenthal VD, Guzman S, Safdar N. Effect of education and performance feedback on rates of catheter-associated urinary tract infection in intensive care units in Argentina. *Infect Control Hosp Epidemiol* 2004;25:47-50.
  101. Won S, Chou H, Hsieh W, et al. Handwashing program for the prevention of nosocomial infections in a neonatal intensive care unit. *Infect Control Hosp Epidemiol* 2004;25:742-746.
  102. MacDonald A, Dinah F, MacKenzie D, Wilson A. Performance feedback of hand hygiene, using alcohol gel as the skin decontaminant, reduces the number of inpatients newly affected by MRSA and antibiotic costs. *J Hosp Infect* 2004;56:56-63.
  103. Wendt C, Knautz D, von Baum H. Differences in hand hygiene behavior related to the contamination risk of healthcare activities in different groups of healthcare workers. *Infect Control Hosp Epidemiol* 2004;25:203-206.
  104. Cohen B, Saiman L, Cimiotti J, Larson E. Factors associated with hand hygiene practices in two neonatal intensive care units. *Pediatr Infect Dis J* 2003;22:494-499.
  105. Brown SM, Lubimova AV, Khrustalyeva NM, et al. Use of an alcohol-based hand rub and quality improvement interventions to improve hand hygiene in a Russian neonatal intensive care unit. *Infect Control Hosp Epidemiol* 2003;24:172-179.
  106. Kuzu N, Özer F, Aydemir S, Yalcin AN, Zencir M. Compliance with hand hygiene and glove use in a university-affiliated hospital. *Infect Control Hosp Epidemiol* 2005;26:312-315.
  107. Kim PW, Roghmann M, Perencevich EN, Harris AD. Rates of hand disinfection associated with glove use, patient isolation, and changes between exposure to various body sites. *Am J Infect Control* 2003;31:97-103.
  108. 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. *Am J Infect Control* 2004;32:235-238.
  109. McGuckin M, Waterman R, Storr IJ, et al. Evaluation of a patient-empowering hand hygiene programme in the UK. *J Hosp Infect* 2001;48:222-227.
  110. Naikoba S, Hayward A. The effectiveness of interventions aimed at increasing handwashing in healthcare workers - a systematic review. *J Hosp Infect* 2001;47:173-180.
  111. Magiorakos AP, Leens E, Michael S, et al. National hand hygiene campaigns in Europe, 2000-2009. Euro surveillance: bulletin Européen sur les maladies transmissibles. *Eur Commun Dis Bull* 2009;14:17.
  112. Grayson ML, Russo PL, Cruickshank M, et al. Outcomes from the first 2 years of the Australian national hand hygiene initiative. *Med J Aust* 2011;195:615-619.
  113. Gould DJ, Chudleigh JH, Moralejo D, Drey N. Interventions to improve hand hygiene compliance in patient care. *Cochrane Database Syst Rev* 2007;18:CD005186.
  114. Backman C, Zoutman DE, Marck PB. An integrative review of the current evidence on the relationship between hand hygiene interventions and the incidence of health care-associated infections. *Am J Infect Control* 2008;36:333-348.
  115. Aboelela SW, Stone PW, Larson EL. Effectiveness of bundled behavioural interventions to control healthcare-associated infections: a systematic review of the literature. *J Hosp Infect* 2007;66:101-108.
  116. Cherry MG, Brown JM, Bethell GS, Neal T, Shaw NJ. Features of educational interventions that lead to compliance with hand hygiene in healthcare professionals within a hospital care setting. A BEME systematic review: BEME Guide No. 22. *Med Teach* 2012;34:e406-e420.
  117. Huis A, Schoonhoven L, Grol R, Donders R, Hulscher M, van Achterberg T. Impact of a team and leaders-directed strategy to improve nurses' adherence to hand hygiene guidelines: a cluster randomised trial. *Int J Nurs Stud* 2013;50:464-474.
  118. Huis A, Holleman G, van Achterberg T, Grol R, Schoonhoven L, Hulscher M. Explaining the effects of two different strategies for promoting hand hygiene in hospital nurses: a process evaluation alongside a cluster randomised controlled trial. *Implement Sci* 2013;8:41.
  119. Fuller C, Duckworth G, Jeanes A, et al. The Feedback Intervention Trial (FIT) - improving hand-hygiene compliance in UK healthcare workers: a stepped wedge cluster randomised controlled trial. *PLoS One* 2012;7:e41617.
  120. Stone SP, Jeanes A, Roberts J, et al. Evaluation of the national Cleanyourhands campaign to reduce Staphylococcus aureus bacteraemia and Clostridium difficile infection in hospitals in England and Wales by improved hand hygiene: four year, prospective, ecological, interrupted time series study. *BMJ* 2012;3:e3005.
  121. Benning A, Carmalt M, Rudge G, et al. Multiple component patient safety intervention in English hospitals: controlled evaluation of second phase. *BMJ* 2011;342:d199.
  122. Longtin Y, Sax H, Allegranzi B, Hugonnet S, Pittet D. Patients' beliefs and perceptions of their participation to increase healthcare worker compliance with hand hygiene. *Infect Control Hosp Epidemiol* 2009;30:830-839.
  123. Lent V, Eckstein BC, Eckstein EC, Cameron AS, Budavich R, Donskey CJ. Evaluation of patient participation in a patient empowerment initiative to improve hand hygiene practices in a veterans affairs medical center. *Am J Infect Control* 2009;37:117-120.

124. Sanderson PJ, Weissler S. Recovery of coliforms from the hands of nurses and patients: activities leading to contamination. *J Hosp Infect* 1992;21:85-93.
125. Larson EL, Cronquist AB, Whittier S, Lai L, Lyle CT, Latta PD. Differences in skin flora between inpatients and chronically ill outpatients. *Heart Lung* 2000;29:298-305.
126. Banfield KR, Kerr KG. Could hospital patients' hands constitute a missing link? *J Hosp Infect* 2005;61:183-188.
127. Savage J, Fuller C, Besser S, Stone S. Use of alcohol hand rub (AHR) at ward entrances and use of soap and AHR by patients and visitors: a study in 27 wards in nine acute NHS trusts. *J Infect Prev* 2011;12:54-58.
128. Lawrence M. Patient hand hygiene: a clinical inquiry. *Nurs Times* 1983;79:24-25.
129. Duncan C. An exploratory study of patient's feelings about asking healthcare professionals to wash their hands. *J Ren Care* 2007;33:30-34.
130. Burnett E, Lee K, Kydd P. Hand hygiene: what about our patients? *Br J Infect Contr* 2008;9:19-24.
131. Burnett E. Perceptions, attitudes, and behavior towards patient hand hygiene. *Am J Infect Control* 2009;37:638-642.
132. Cheng VCC, Wu AKL, Cheung CHY, et al. Outbreak of human metapneumovirus infection in psychiatric inpatients: implications for directly observed use of alcohol hand rub in prevention of nosocomial outbreaks. *J Hosp Infect* 2007;67:336-343.
133. Chen YC, Chiang LC. Effectiveness of hand-washing teaching programs for families of children in paediatric intensive care units. *J Clin Nurs* 2007;16:1173-1179.
134. Gagné D, Bédard G, Maziade PJ. Systematic patients' hand disinfection: impact on methicillin-resistant *Staphylococcus aureus* infection rates in a community hospital. *J Hosp Infect* 2010;75:269-272.
135. Expert Advisory Group on AIDS and the Advisory Group on Hepatitis. *Guidance for clinical healthcare workers: protection against infection with bloodborne viruses*. London: Department of Health; 1998.
136. Wilson JA, Loveday HP, Hoffman PN, Pratt RJ. Uniform: an evidence review of the microbiological significance of uniforms and uniform policy in the prevention and control of healthcare-associated infections. Report to the Department of Health (England). *J Hosp Infect* 2007;66:301-307.
137. Health and Safety Executive. *Management of Health and Safety at Work Regulations*. London: HSE Books; 1999.
138. Health and Safety Executive. *Personal protective equipment at work. Personal Protective Equipment at Work Regulations 1992 (as amended): guidance on regulations*. 2nd ed. London: HSE Books; 2005.
139. Health and Safety Commission. *Control of substances hazardous to health. Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved code of practice and guidance*. 5th ed. London: HSE Books; 2002.
140. Health and Safety Executive. *Personal protective equipment (PPE) at work: a brief guide*. INDG174 (rev2). London: HSE Books; 2013. Available at: <http://www.hse.gov.uk/pubns/indg174.pdf>. Accessed June 5, 2013.
141. Sax H, Perneger T, Hugonnet S, Herrault P, Chraïti M, Pittet D. Knowledge of standard and isolation precautions in a large teaching hospital. *Infect Control Hosp Epidemiol* 2005;26:298-304.
142. Trim JC, Adams D, Elliott TSJ. Healthcare workers' knowledge of inoculation injuries and glove use. *Br J Nurs* 2003;12:215-221.
143. Ferguson KJ, Waitzkin H, Beekmann SE, Doebbeling BN. Critical incidents of nonadherence with standard precautions guidelines among community hospital-based health care workers. *J Gen Intern Med* 2004;19:726-731.
144. Prieto J. Contact precautions for *Clostridium difficile* and methicillin-resistant *Staphylococcus aureus* (MRSA): assessing the impact of a supportive intervention to improve practice. *J Res Nurs* 2005;10:511-526.
145. Royal College of Nursing. *Tools of the trade; RCN guidance for healthcare staff on glove use and prevention of contact dermatitis*. London: Royal College of Nursing 2012. Available at: [http://www.rcn.org.uk/\\_\\_data/assets/pdf\\_file/0003/450507/RCNguidance\\_glovesdermatitis\\_WEB2.pdf](http://www.rcn.org.uk/__data/assets/pdf_file/0003/450507/RCNguidance_glovesdermatitis_WEB2.pdf). Accessed July 22, 2013.
146. Health and Safety Executive. *Selecting latex gloves*. London: HSE Books; 2013. Available at: <http://www.hse.gov.uk/skin/employ/latex-gloves.htm>. Accessed July 25, 2013.
147. Health and Safety Executive. *Choosing the right gloves to protect skin: a guide for employers*. London: HSE Books; 2013. Available at: <http://www.hse.gov.uk/skin/employ/gloves.htm>. Accessed July 25, 2013.
148. Fuller C, Savage J, Besser S, et al. "The dirty hand in the latex glove": a study of hand hygiene compliance when gloves are worn. *Infect Control Hosp Epidemiol* 2011;32:1194-1199.
149. Eveillard M, Guilloteau V, Kempf M, et al. Impact of improving glove usage on the hand hygiene compliance. *Am J Infect Control* 2011;39:608-610.
150. Eveillard M, Raymond F, Joly-Guillou M, et al. Measurement of hand hygiene compliance and gloving practices in different settings for the elderly considering the location of hand hygiene opportunities during patient care. *Am J Infect Control* 2011;39:339-341.
151. Katherason SG, Naing L, Jaalam K, et al. Hand decontamination practices and the appropriate use of gloves in two adult intensive care units in Malaysia. *J Infect Dev Ctries* 2010;4:118-123.
152. Huskins WC, Samore M, Wallace D, et al. Intervention to reduce transmission of resistant bacteria in intensive care. *N Engl J Med* 2011;364:1407-1418.
153. British Standards Institution. *Medical gloves for single use. Part 1: Specification for freedom from holes*. BS-EN 455-1. London: British Standards Institution; 2000.
154. British Standards Institution. *Medical gloves for single use. Part 2: Specification for physical properties*. BS-EN 455-2. London: British Standards Institution; 2000.
155. British Standards Institution. *Medical gloves for single use. Part 3: Requirements and testing for biological evaluation*. BS-EN 455-3. London: British Standards Institution; 2000.
156. Tenorio AR, Badri SM, Sahgal NB, et al. Effectiveness of gloves in the prevention of hand carriage of vancomycin-resistant enterococcus species by health care workers after patient care. *Clin Infect Dis* 2001;32:826-829.
157. Department of Health. *Health Technical Memorandum 07-01: safe management of healthcare waste*. London: Department of Health; 2013.
158. Korniewicz D, El-Masri M, Broyles J. To determine the effects of gloves stress, type of material (vinyl, nitrile, copolymer, latex) and manufacturer on the barrier effectiveness of medical examination gloves. *Am J Infect Control* 2002;30:133-138.
159. Siegel JD, Rhinehart E, Jackson M, Chiarello L, and the Healthcare Infection Control Practices Advisory Committee. *2007 Guideline for isolation precautions: preventing transmission of infectious agents in health care settings*. United States: Mosby, Inc; 2007.
160. Nye KJ, Leggett VA, Watterson L. Provision and decontamination of uniforms in the NHS. *Nurs Stand* 2005;19:41-45.
161. Speers R, Jr, Shooter RA, Gaya H, Patel N. Contamination of nurses' uniforms with *Staphylococcus aureus*. *Lancet* 1969;2:233-235.
162. Babb JR, Davies JG, Ayliffe GA. Contamination of protective clothing and nurses' uniforms in an isolation ward. *J Hosp Infect* 1983;4:149-157.
163. Callaghan I. Bacterial contamination of nurses' uniforms: a study. *Nurs Stand* 1998;13:37-42.
164. Perry C, Marshall R, Jones E. Bacterial contamination of uniforms. *J Hosp Infect* 2001;48:238-241.
165. Wong D, Nye K, Hollis P. Microbial flora on doctors' white coats. *BMJ* 1991;303:1602-1604.
166. Loh W, Ng VV, Holton J. Bacterial flora on the white coats of medical students. *J Hosp Infect* 2000;45:65-68.
167. Hambraeus A. Transfer of *Staphylococcus aureus* via nurses' uniforms. *J Hyg* 1973;71:799-814.
168. Barrie D, Wilson JA, Hoffman PN, Kramer JM. *Bacillus cereus* meningitis in two neurosurgical patients: an investigation into the source of the organism. *J Infect* 1992;25:291-297.
169. Barrie D, Hoffman PN, Wilson JA, Kramer JM. Contamination of hospital linen by *Bacillus cereus*. *Epidemiol Infect* 1994;113:297-306.
170. Zachary KC, Bayne PS, Morrison VJ, Ford DS, Silver LC, Hooper DC. Contamination of gowns, gloves, and stethoscopes with



- vancomycin-resistant enterococci. *Infect Control Hosp Epidemiol* 2001;22:560-564.
171. Webster J, Pritchard MA. Gowning by attendants and visitors in newborn nurseries for prevention of neonatal morbidity and mortality. *Cochrane Database Syst Rev* 2003;3:CD003670.
  172. Puzniak LA, Leet T, Mayfield J, Kollef M, Mundy LM. To gown or not to gown: the effect on acquisition of vancomycin-resistant enterococci. *Clin Infect Dis* 2002;35:18-25.
  173. 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. *Infect Control Hosp Epidemiol* 2002;23:424-428.
  174. National Collaborating Centre for Chronic Conditions. *Tuberculosis: clinical diagnosis and management of tuberculosis, and measures for its prevention and control*. London: Royal College of Physicians; 2006.
  175. Department of Health. *Pandemic (H1N1) 2009 influenza. A summary of guidance for infection control in healthcare settings*. London: Department of Health; 2009.
  176. Department of Health. *The Interdepartmental Working Group on Tuberculosis: the prevention and control of tuberculosis in the United Kingdom*. London: Department of Health; 1998.
  177. Health and Safety Executive. *Respiratory protective equipment at work: a practical guide*. HSG 53. 4th ed. London: HSE Books; 2013.
  178. Jefferson T, Del Mar C, Dooley L, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses. *Cochrane Database Syst Rev* 2010;1:CD006207.
  179. Cowling BJ, Zhou Y, Ip DK, Leung GM, Aiello AE. Face masks to prevent transmission of influenza virus: a systematic review. *Epidemiol Infect* 2010;138:449-456.
  180. Gralton J, McLaws ML. Protecting healthcare workers from pandemic influenza: N95 or surgical masks? *Crit Care Med* 2010;38:657-667.
  181. Bin-Reza F, Lopez Chavarrias V, Nicoll A, Chamberland ME. The use of masks and respirators to prevent transmission of influenza: a systematic review of the scientific evidence. *Influenza Other Respir Viruses* 2012;6:257-267.
  182. Health and Safety Commission. *Control of Substances Hazardous to Health Regulations. Approved codes of practice*. London: HSE Books; 1999. p. 75.
  183. Health and Safety Executive. *Health and Safety at Work Act 1974*. London: HMSO; 1994 Available at: [http://www.legislation.gov.uk/ukpga/1974/37/pdfs/ukpga\\_19740037\\_en.pdf](http://www.legislation.gov.uk/ukpga/1974/37/pdfs/ukpga_19740037_en.pdf). Accessed August 1, 2013.
  184. Health and Safety Executive. *Health and Safety (Sharp Instruments in Healthcare) Regulations 2013. Guidance for employers and employees. Health Services Information Sheet 7*. 2013. Available at: [www.hse.gov.uk/pubns/hsis7.htm](http://www.hse.gov.uk/pubns/hsis7.htm). Accessed July 25, 2013.
  185. Health and Safety Executive. *The Provision and Use of Work Equipment Regulations 1998*. Available at: <http://www.hse.gov.uk/work-equipment-machinery/puwer.htm>. Accessed August 1, 2013.
  186. Health and Safety Executive. *The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995*. London: HSE Books; 1995.
  187. Health and Safety Executive. *Personal protective equipment at work: Personal Protective Equipment at Work Regulations*. London: HMSO; 1992.
  188. Health and Safety Executive. *The Health and Safety (First-Aid) Regulations 1981. Approved code of practice and guidance*. London: HSE Books; 1981.
  189. 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.
  190. Ball J, Pike G; Royal College of Nursing. *Needlestick injury in 2008: results from a survey of RCN members*. London: Royal College of Nursing; 2008.
  191. Health Protection Agency, Centre for Infections. *Eye of the needle: United Kingdom surveillance of significant occupational exposures to bloodborne viruses in healthcare workers*. London: Health Protection Agency; 2008.
  192. Yazdanpanah Y, Domart M, Tarantola A, et al. Risk factors for hepatitis C virus transmission to health care workers after occupational exposure: a European case-control study. *Clin Infect Dis* 2005;41:1423-1430.
  193. Department of Health. *HIV Post-exposure prophylaxis: guidance from the UK Chief Medical Officers' Expert Advisory Group on AIDS*. London: Department of Health; 2008.
  194. Centers for Disease Control. Update. Universal precautions for prevention of transmission of human immunodeficiency virus, hepatitis B virus and other bloodborne pathogens in health care settings. *MMWR* 1988;37:377-382, 387-388.
  195. Occupational Safety and Health Administration. *Enforcement procedures for the occupational exposure to bloodborne pathogens*. Directive number CPL2-2.44D. Washington DC: OSHA; 1999. Available at: [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=DIRECTIVES&p\\_id=1556](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=1556). Accessed August 6, 2013.
  196. Council Directive 2010/32/EU. Implementing the framework agreement on prevention from sharps injuries in the hospital and health care sector. Concluded by HOSPEEM and EPSU. *OJEU* 2010;L:66-72.
  197. Health and Safety Executive. *An evaluation of the efficacy of safer sharps devices. Systematic review*. 2012. Available at: <http://www.hse.gov.uk/research/rrpdf/rr914.pdf>. Accessed July 25, 2013.
  198. Brusaferrro S, Calligaris L, Farneti F, Gubian F, Londero C, Baldo V. Educational programmes and sharps injuries in health care workers. *Occup Med (Lond)* 2009;59:512-514.
  199. Valls V, Lozano MS, Yáñez R, et al. Use of safety devices and the prevention of percutaneous injuries among healthcare workers. *Infect Control Hosp Epidemiol* 2007;28:1352-1360.
  200. Adams D, Elliott TSJ. Impact of safety needle devices on occupationally acquired needlestick injuries: a four-year prospective study. *J Hosp Infect* 2006;64:50-55.
  201. Zakrzewska JM, Greenwood I, Jackson J. Introducing safety syringes into a UK dental school - a controlled study. *Br Dent J* 2001;190:88-92.
  202. Yang Y, Liou S, Chen C, et al. The effectiveness of a training program on reducing needlestick injuries/sharp object injuries among soon graduate vocational nursing school students in Southern Taiwan. *J Occup Health* 2007;49:424-429.
  203. Department of Health. *An organisation with a memory*. London: Stationery Office; 2000.
  204. National Health Service Employees. *The management of health safety and welfare: issues for NHS staff*. London: Stationery Office; 2005.
  205. ECRI Institute. *Sharps safety and needlestick prevention*. 2nd ed. Plymouth: ECRI; 2003.
  206. Asai T, Hidaka I, Kawashima A, Miki T, Inada K, Kawachi S. Efficacy of catheter needles with safeguard mechanisms. *Anaesthesia* 2002;57:572-7.
  207. Sohn S, Eagan J, Sepkowitz KA, Zuccotti G. Effect of implementing safety-engineered devices on percutaneous injury epidemiology. *Infect Control Hosp Epidemiol* 2004;25:536-542.
  208. Alvarado-Ramy F, Solomon R, Fahrner R, et al. A comprehensive approach to percutaneous injury prevention during phlebotomy: results of a multicenter study, 1993-1995. *Infect Control Hosp Epidemiol* 2003;24:97-104.
  209. Rogues A, Verdun-Esquer C, Buisson-Valles I, et al. Impact of safety devices for preventing percutaneous injuries related to phlebotomy procedures in health care workers. *Am J Infect Control* 2004;32:441-444.
  210. 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. *Infect Control Hosp Epidemiol* 2003;24:105-112.
  211. Adams D, Elliott TSJ. A comparative user evaluation of three needle-protective devices. *Br J Nurs* 2003;12:470-474.
  212. Cullen BL, Genasi F, Symington I, et al. Potential for reported needlestick injury prevention among healthcare workers through safety device usage and improvement of guideline adherence: expert panel assessment. *J Hosp Infect* 2006;63:445-451.
  213. 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. *MMWR* 1997;46:21-25.
  214. Sullivan S, Williamson B, Wilson LK, Korte JE, Soper D. Blunt

- needles for the reduction of needlestick injuries during cesarean delivery: a randomized controlled trial. *Obstet Gynecol* 2009;114:211.
215. Hotaling M. A retractable winged steel (butterfly) needle performance improvement project. *Jt Comm J Qual Patient Saf* 2009;35:100-105.
  216. Lamontagne F, Abiteboul D, Lolom I, et al. Role of safety-engineered devices in preventing needlestick injuries in 32 French hospitals. *Infect Control Hosp Epidemiol* 2007;28:18-23.
  217. Azar-Cavanagh M, Burdt P, Green-McKenzie J. Effect of the introduction of an engineered sharps injury prevention device on the percutaneous injury rate in healthcare workers. *Infect Control Hosp Epidemiol* 2007;28:165-170.
  218. Sohn S, Eagan J, Sepkowitz KA. Safety-engineered device implementation: does it introduce bias in percutaneous injury reporting? *Infect Control Hosp Epidemiol* 2004;25:543-547.
  219. McCleary J, Caldero K, Adams T. Guarded fistula needle reduces needlestick injuries in hemodialysis. *Nephrol News Issues* 2002;16:66-70.
  220. Rogers B, Goodno L. Evaluation of interventions to prevent needlestick injuries in health care occupations. *Am J Prev Med* 2000;18:90-98.
  221. Reddy SG, Emery RJ. Assessing the effect of long-term availability of engineering controls on needlestick injuries among health care workers: a 3-year preimplementation and postimplementation comparison. *Am J Infect Control* 2001;29:425-427.
  222. Prunet B, Meaudre E, Montcriol A, et al. A prospective randomized trial of two safety peripheral intravenous catheters. *Anesth Analg* 2008;107:155-158.
  223. Bamberg R, Rivers C, Moore C. Use of needle safety devices by clinical laboratories in North Carolina hospitals. *Clin Leadersh Manag Rev* 2003;17:21-25.
  224. Casey AL, Elliott TS. The usability and acceptability of a needleless connector system. *Br J Nurs* 2007;16:267-271.
  225. Clarke SP, Rockett JL, Sloane DM, Aiken LH. Organizational climate, staffing, and safety equipment as predictors of needlestick injuries and near-misses in hospital nurses. *Am J Infect Control* 2002;30:207-216.
  226. National Institute for Occupational Safety and Health. *Preventing needlestick injuries in health care settings*. Cincinnati: Department of Health and Human Services; 1999.
  227. Wilson J. *Infection control in clinical practices*. London: Bailliere Tindall; 2006.
  228. Cherry MG, Brown JM, Neal T, Ben Shaw N. What features of educational interventions lead to competence in aseptic insertion and maintenance of CV catheters in acute care? BEME Guide No. 15. *Med Teach* 2010;32:198-198.
  229. Rowley S, Clare S, Macqueen S, Molyneux R. ANTT v2: an updated practice framework for aseptic technique. *Br J Nurs* 2010;19(Suppl.):S5-S11.
  230. Gould CV, Umscheid CA, Agarwal RK, Kuntz G, Pegues DA; Healthcare Infection Control Practices Advisory Committee. Guideline for prevention of catheter-associated urinary tract infections. *Infect Control Hosp Epidemiol* 2010;31:319-326.
  231. Health Protection Agency. *English national point prevalence survey on healthcare associated infections and antimicrobial use, 2011: preliminary data*. 2012. Available at: [http://www.hpa.org.uk/webc/HPAwebFile/HPAweb\\_C/1317134305239](http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317134305239). Accessed July 25, 2013.
  232. Smyth ETM, McIlvenny G, Enstone JE, et al. Four country healthcare associated infection prevalence survey 2006: overview of the results. *J Hosp Infect* 2008;69:230-248.
  233. Department of Health. *Urinary catheter care. Essential steps to safe, clean care: reducing healthcare associated infections*. London: Department of Health; 2006.
  234. Chenoweth C, Saint S. Preventing catheter-associated urinary tract infections in the intensive care unit. *Crit Care Clin* 2013;29:19-32.
  235. Johnson JR, Kuskowski MA, Wilt TJ. Systematic review: antimicrobial urinary catheters to prevent catheter-associated urinary tract infection in hospitalized patients. *Ann Intern Med* 2006;144:116-126.
  236. Warren JW, Tenney JH, Hoopes JM, Muncie HL, Anthony WC. A prospective microbiologic study of bacteriuria in patients with chronic indwelling urethral catheters. *J Infect Dis* 1982;146:719-723.
  237. Warren JW. Catheter-associated urinary tract infections. *Int J Antimicrob Agents* 2001;17:299-303.
  238. Saint S, Wiese J, Amory JK, et al. Are physicians aware of which of their patients have indwelling urinary catheters? *Am J Med* 2000;109:476-480.
  239. Munasinghe RL, Yazdani H, Siddique M, Hafeez W. Appropriateness of use of indwelling urinary catheters in patients admitted to the medical service. *Infect Control Hosp Epidemiol* 2001;22:647-649.
  240. Jain P, Parada JP, David A, Smith LG. Overuse of the indwelling urinary tract catheter in hospitalized medical patients. *Arch Intern Med* 1995;155:1425-1429.
  241. Burton DC, Edwards JR, Srinivasan A, Fridkin SK, Gould CV. Trends in catheter-associated urinary tract infections in adult intensive care units - United States, 1990-2007. *Infect Control Hosp Epidemiol* 2011;32:748-756.
  242. Saint S. Clinical and economic consequences of nosocomial catheter-related bacteriuria. *Am J Infect Control* 2000;28:68-75.
  243. Shuman EK, Chenoweth CE. Recognition and prevention of healthcare-associated urinary tract infections in the intensive care unit. *Crit Care Med* 2010;38(Suppl.):S373-S379.
  244. Chang R, Todd Greene M, Chenoweth CE, et al. Epidemiology of hospital-acquired urinary tract-related bloodstream infection at a university hospital. *Infect Control Hosp Epidemiol* 2011;32:1127-1129.
  245. Beattie M, Taylor J. Silver alloy vs. uncoated urinary catheters: a systematic review of the literature. *J Clin Nurs* 2011;20:2098-2108.
  246. Ha U, Cho Y. Catheter-associated urinary tract infections: new aspects of novel urinary catheters. *Int J Antimicrob Agents* 2006;28:485-490.
  247. Bernard MS, Hunter KF, Moore KN. A review of strategies to decrease the duration of indwelling urethral catheters and potentially reduce the incidence of catheter-associated urinary tract infections. *Urol Nurs* 2012;32:29-37.
  248. Saint S, Savel RH, Matthay MA. Enhancing the safety of critically ill patients by reducing urinary and central venous catheter-related infections. *Am J Respir Crit Care Med* 2002;165:1475-1479.
  249. Talja M, Korpela A, Jarvi K. Comparison of urethral reaction to full silicone, hydrogen-coated and siliconised latex catheters. *Br J Urol* 1990;66:652-657.
  250. Robertson GS, Everitt N, Burton PR, Flynn JT. Effect of catheter material on the incidence of urethral strictures. *Br J Urol* 1991;68:612-617.
  251. Crowe H, Clift R, Duggan G, Bolton DM, Costello AJ. Randomised study of the effect of midnight versus 0600 removal of urinary catheters. *Br J Urol* 1993;71:306-308.
  252. Hazelett S, Tsai M, Gareri M, Allen K. The association between indwelling urinary catheter use in the elderly and urinary tract infection in acute care. *BMC Geriatr* 2006;6:15.
  253. Curran E, Murdoch H. Aiming to reduce catheter associated urinary tract infections (CAUTI) by adopting a checklist and bundle to achieve sustained system improvements. *J Infect Prev* 2009;10:57-61.
  254. Davenport K, Keeley FX. Evidence for the use of silver-alloy-coated urethral catheters. *J Hosp Infect* 2005;60:298-303.
  255. Ward L, Fenton K, Maher L. The high impact actions for nursing and midwifery 5: protection from infection. *Nurs Times* 2010;106:20-21.
  256. Saint S, Lipsky BA. Preventing catheter-related bacteriuria: should we? Can we? How? *Arch Intern Med* 1999;159:800-808.
  257. Foxman B. Epidemiology of urinary tract infections: incidence, morbidity, and economic costs. *Dis Mon* 2003;49:53-70.
  258. Wong ES. Guideline for prevention of catheter-associated urinary tract infections. *Am J Infect Control* 1983;11:28-36.
  259. Cornia PB, Amory JK, Fraser S, Saint S, Lipsky BA. Computer-based order entry decreases duration of indwelling urinary catheterization in hospitalized patients. *Am J Med* 2003;114:404-407.
  260. Fakhri MG, Dueweke C, Meisner S, et al. Effect of nurse-led multidisciplinary rounds on reducing the unnecessary use of urinary catheterization in hospitalized patients. *Infect Control Hosp Epidemiol* 2008;29:815-819.
  261. Meddings J, Rogers MAM, Macy M, Saint S. Systematic review and



- meta-analysis: reminder systems to reduce catheter-associated urinary tract infections and urinary catheter use in hospitalized patients. *Clin Infect Dis* 2010;51:550-560.
262. Loeb M, Hunt D, O'Halloran K, Carusone SC, Dafoe N, Walter SD. Stop orders to reduce inappropriate urinary catheterization in hospitalized patients: a randomized controlled trial. *J Gen Intern Med* 2008;23:816-820.
  263. Stéphan F, Sax H, Wachsmuth M, Hoffmeyer P, Clergue F, Pittet D. Reduction of urinary tract infection and antibiotic use after surgery: a controlled, prospective, before-after intervention study. *Clin Infect Dis* 2006;42:1544-1551.
  264. Murphy C, Fader M, Prieto J. Interventions to minimise the initial use of indwelling urinary catheters in acute care: a systematic review. *Int J Nurs Stud* 2013;in press.
  265. Slappendel R, Weber EW. Non-invasive measurement of bladder volume as an indication for bladder catheterization after orthopaedic surgery and its effect on urinary tract infections. *Eur J Anaesthesiol* 1999;16:503-506.
  266. Patrizzi K, Fasnacht A, Manno M. A collaborative, nurse-driven initiative to reduce hospital-acquired urinary tract infections. *J Emerg Nurs* 2009;35:536-539.
  267. Topal J, Conklin S, Camp K, Morris V, Balcezak T, Herbert P. Prevention of nosocomial catheter-associated urinary tract infections through computerized feedback to physicians and a nurse-directed protocol. *Am J Med Qual* 2005;20:121-126.
  268. Pomfret I. Continence clinic. Catheters: design, selection and management. *Br J Nurs* 1996;5:245-251.
  269. Kunin C. *Urinary tract infections: detection, prevention and management*. 5th ed. Baltimore: Williams and Wilkins; 1997.
  270. Dieckhaus K, Garibaldi R. Prevention of catheter-associated urinary tract infections. In: Abrutyn E, Goldmann D, Scheckler W, editors. *Saunders infection control reference service*. Philadelphia: W.B. Saunders Co; 1998. p. 169-174.
  271. Roe B, Brocklehurst J. Study of patients with indwelling catheters. *J Adv Nurs* 1987;12:713-718.
  272. National Patient Safety Agency. *Rapid response report: female urinary catheters causing trauma to adult males*. NSPCA/2009/RRR02. 2009.
  273. Lopez-Lopez G, Pascual A, Martinez-Martinez L, Perea EJ. Effect of a siliconized latex urinary catheter on bacterial adherence and human neutrophil activity. *Diagn Microbiol Infect Dis* 1991;14:1-6.
  274. Nickel JC, Feero P, Costerton JW, Wilson E. Incidence and importance of bacteriuria in postoperative, short-term urinary catheterization. *Can J Surg* 1989;32:131-132.
  275. Schumm K, Lam T. Types of urethral catheters for management of short-term voiding problems in hospitalized adults: a short version Cochrane Review. *Sri Lanka J Obstet Gynaecol* 2010;31:110-121.
  276. Chene G, Boulard G, Gachie JP. A controlled trial of a new material for coating urinary catheters. *Agressologie* 1990;31:499-501.
  277. Tidd MJ, Gow JG, Pennington JH, Shelton J, Scott MR. Comparison of hydrophilic polymer-coated latex, uncoated latex and PVC indwelling balloon catheters in the prevention of urinary infection. *Br J Urol* 1976;48:285-291.
  278. Pellowe C, Pratt R, Loveday H, 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. *J Hosp Infect* 2005;59:373-374.
  279. Brosnahan J, Jull A, Tracy C. Types of urethral catheters for management of short-term voiding problems in hospitalised adults. *Cochrane Database Syst Rev* 2004;1:CD004013.
  280. Saint S, Elmore JG, Sullivan SD, Emerson SS, Koepsell TD. The efficacy of silver alloy-coated urinary catheters in preventing urinary tract infection: a meta-analysis. *Am J Med* 1998;105:236-241.
  281. Dunn S, Pretty L, Reid H, Evans D. Management of short term indwelling urethral catheters to prevent urinary tract infections. A systematic review. Adelaide, S. Australia: Joanna Briggs Institute for Evidence Based Nursing and Midwifery. Systematic Review; 6. 2000
  282. Niël-Weise BS, Arend SM, van den Broek PJ. Is there evidence for recommending silver-coated urinary catheters in guidelines? *J Hosp Infect* 2002;52:81-87.
  283. Verleyen P, De Ridder D, Van Poppel H, Baert L. Clinical application of the Bardex IC Foley catheter. *Eur Urol* 1999;36:240-246.
  284. Karchmer TB, Giannetta ET, Muto CA, Strain BA, Farr BM. A randomized crossover study of silver-coated urinary catheters in hospitalized patients. *Arch Intern Med* 2000;160:3294-3298.
  285. Saint S, Veenstra DL, Sullivan SD, Chenoweth C, Fendrick AM. The potential clinical and economic benefits of silver alloy urinary catheters in preventing urinary tract infection. *Arch Intern Med* 2000;160:2670-2675.
  286. 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. *Infect Control Hosp Epidemiol* 2002;23:217-218.
  287. Gentry H, Cope S. Using silver to reduce catheter-associated urinary tract infections. *Nurs Stand* 2005;19:51-54.
  288. Madeo M, Davies D, Johnson G, Owen E, Wadsworth P, Martin C. The impact of using silver alloy urinary catheters in reducing the incidence of urinary tract infections in the critical care setting. *Br J Infect Contr* 2004;5:21-24.
  289. Rupp ME, Fitzgerald T, Marion N, et al. Effect of silver-coated urinary catheters: efficacy, cost-effectiveness, and antimicrobial resistance. *Am J Infect Control* 2004;32:445-450.
  290. Chaiban G, Hanna H, Dvorak T, Raad I. A rapid method of impregnating endotracheal tubes and urinary catheters with gentidine: a novel antiseptic agent. *J Antimicrob Chemother* 2005;55:51-56.
  291. Cho YW, Park JH, Kim SH, et al. Gentamicin-releasing urethral catheter for short-term catheterization. *J Biomater Sci Polym Ed* 2003;14:963-972.
  292. 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. *J Hosp Infect* 2000;45:117-124.
  293. Lai KK, Fontecchio SA. Use of silver-hydrogel urinary catheters on the incidence of catheter-associated urinary tract infections in hospitalized patients. *Am J Infect Control* 2002;30:221-225.
  294. Gaonkar TA, Sampath LA, Modak SM. Evaluation of the antimicrobial efficacy of urinary catheters impregnated with antiseptics in an in vitro urinary tract model. *Infect Control Hosp Epidemiol* 2003;24:506-513.
  295. Darouiche RO, Raad II, Smith JA, et al. Efficacy of antimicrobial-impregnated bladder catheters in reducing catheter-associated bacteriuria: a prospective, randomized, multicenter clinical trial. *Urology* 1999;54:976-981.
  296. 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. *Int Surg* 2003;88:152-154.
  297. Riley DK, Classen DC, Stevens LE, Burke JP. A large randomized clinical trial of a silver-impregnated urinary catheter: lack of efficacy and staphylococcal superinfection. *Am J Med* 1995;98:349-356.
  298. 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. *J Infect Dis* 1990;162:1145-1150.
  299. 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. *Eur Urol* 1990;17:236-240.
  300. Liedberg H, Lundeberg T. Silver alloy coated catheters reduce catheter-associated bacteriuria. *Br J Urol* 1990;65:379-381.
  301. Pickard R, Buckley B, Glazener C, et al. Antimicrobial catheters for reduction of symptomatic urinary tract infection in adults requiring short-term catheterisation in hospital: a multicentre randomised controlled trial. *Lancet* 2012;380:1927-1935.
  302. Ward V, Wilson J, Taylor L, Cookson B, Glynn A. *Preventing hospital-acquired infection: clinical guidelines*. London: Public Health Laboratory Service; 1997.
  303. Stamm W. Urinary tract infections. In: Bennett JBP, editor. *Hospital infection*. 4th ed. Philadelphia: Lippincott-Raven; 1998. p. 477-485.
  304. Kass EH, Schneiderman LJ. Entry of bacteria into the urinary tracts of patients with indwelling catheters. *N Engl J Med* 1957;256:556-557.

305. Desautels RE, Walter CW, Graves RC, Harrison JH. Technical advances in the prevention of urinary tract infection. *J Urol* 1962;**87**:487-490.
306. Kunin CM, McCormack RC. Prevention of catheter-induced urinary-tract infections by sterile closed drainage. *N Engl J Med* 1966;**274**:1155-1161.
307. Garibaldi RA, Burke JP, Dickman ML, Smith CB. Factors predisposing to bacteriuria during indwelling urethral catheterization. *N Engl J Med* 1974;**291**:215-219.
308. Thornton GF, Andriole VT. Bacteriuria during indwelling catheter drainage: II. Effect of a closed sterile draining system. *JAMA* 1970;**214**:339-342.
309. 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.
310. Gillespie WA, Lennon GG, Linton KB, Slade N. Prevention of urinary tract infection in gynaecology. *BMJ* 1964;**2**:423-425.
311. Platt R, Polk BF, Murdock B, Rosner B. Reduction of mortality associated with nosocomial urinary tract infection. *Lancet* 1983;**1**:893-897.
312. Keerasuntonpong A, Thamlikitkul V, Thearawiboon W, et al. 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. *Am J Infect Control* 2003;**31**:9-12.
313. Maizels M, Schaeffer AJ. Decreased incidence of bacteriuria associated with periodic instillations of hydrogen peroxide into the urethral catheter drainage bag. *J Urol* 1980;**123**:841-845.
314. Sweet DE, Goodpasture HC, Holl K, Smart S, Alexander H, Hedari A. Evaluation of H<sub>2</sub>O<sub>2</sub> prophylaxis of bacteriuria in patients with long-term indwelling Foley catheters: a randomized controlled study. *Infect Control* 1985;**6**:263-266.
315. Thompson RL, Haley CE, Searcy MA, et al. Catheter-associated bacteriuria. Failure to reduce attack rates using periodic instillations of a disinfectant into urinary drainage systems. *JAMA* 1984;**251**:747-751.
316. Cleland V, Cox F, Berggren H, Macinnis MR. Prevention of bacteriuria in female patients with indwelling catheters. *Nurs Res* 1971;**20**:309-318.
317. Burke JP, Garibaldi RA, Britt MR, Jacobson JA, Conti M, Alling DW. Prevention of catheter-associated urinary tract infections. Efficacy of daily meatal care regimens. *Am J Med* 1981;**70**:655-658.
318. Burke JP, Jacobson JA, Garibaldi RA, Conti MT, Alling DW. Evaluation of daily meatal care with poly-antibiotic ointment in prevention of urinary catheter-associated bacteriuria. *J Urol* 1983;**129**:331-334.
319. Classen DC, Larsen RA, Burke JP, Stevens LE. Prevention of catheter-associated bacteriuria: clinical trial of methods to block three known pathways of infection. *Am J Infect Control* 1991;**19**:136-142.
320. Classen DC, Larsen RA, Burke JP, Alling DW, Stevens LE. Daily meatal care for prevention of catheter-associated bacteriuria: results using frequent applications of polyantibiotic cream. *Infect Control Hosp Epidemiol* 1991;**12**:157-162.
321. 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. *J Infect Dis* 1992;**165**:14-18.
322. Webster J, Hood RH, Burrigge CA, Doidge ML, Phillips KM, George N. Water or antiseptic for periurethral cleaning before urinary catheterization: a randomized controlled trial. *Am J Infect Control* 2001;**29**:389-394.
323. Davies AJ, Desai HN, Turton S, Dyas A. Does instillation of chlorhexidine into the bladder of catheterized geriatric patients help reduce bacteriuria? *J Hosp Infect* 1987;**9**:72-75.
324. 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. *J Urol* 1987;**138**:491-494.
325. Jones MA, Hasan A. Controlled trial of intravesical noxythiolin in the prevention of infection following outflow tract surgery. *Br J Urol* 1988;**62**:311-314.
326. Schneeberger PM, Vreede RW, Bogdanowicz JF, van Dijk WC. A randomized study on the effect of bladder irrigation with povidone-iodine before removal of an indwelling catheter. *J Hosp Infect* 1992;**21**:223-229.
327. Warren JW, Platt R, Thomas RJ, Rosner B, Kass EH. Antibiotic irrigation and catheter-associated urinary-tract infections. *N Engl J Med* 1978;**299**:570-573.
328. Muncie HL, Jr, Hoopes JM, Damron DJ, Tenney JH, Warren JW. Once-daily irrigation of long-term urethral catheters with normal saline. Lack of benefit. *Arch Intern Med* 1989;**149**:441-443.
329. Kennedy AP, Brocklehurst JC, Robinson JM, Faragher EB. Assessment of the use of bladder washouts/instillations in patients with long-term indwelling catheters. *Br J Urol* 1992;**70**:610-615.
330. Cox F, Smith RF, Elliott JP, Quinn EL. Neomycin-polymyxin prophylaxis of urinary-tract infection associated with indwelling catheters. *Antimicrob Agents Chemother* 1966;**6**:165-168.
331. Getliffe KA. The use of bladder wash-outs to reduce urinary catheter encrustation. *Br J Urol* 1994;**73**:696-700.
332. Ranji SR, Shetty K, Posley KA, et al. Closing the quality gap: a critical analysis of quality improvement strategies (Vol. 6: Prevention of healthcare-associated infections). Rockville (MD) Agency for Healthcare Research and Quality (US); 2007 Jan. Report No.: 04(07)-0051-6.
333. Ching TY, Seto WH. Evaluating the efficacy of the infection control liaison nurse in the hospital. *J Adv Nurs* 1990;**15**:1128-1131.
334. O'Grady NP, Pearson ML, Raad II, et al. Guidelines for the prevention of intravascular catheter-related infections. *Clin Infect Dis* 2011;**52**:e162-e193.
335. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. *JAMA* 1994;**271**:1598-1601.
336. Bregenzler TC, Sakmann D, Widmer P, Andreas F. Is routine replacement of peripheral intravenous catheters necessary? *Arch Intern Med* 1998;**158**:151-156.
337. Cornely OA, Bethe U, Pauls R, Waldschmidt D. Peripheral Teflon catheters: factors determining incidence of phlebitis and duration of cannulation. *Infect Control Hosp Epidemiol* 2002;**23**:249-253.
338. Grune F, Schrappe M, Basten J, Wenchel H, Tual E, Stutzer H. Phlebitis rate and time kinetics of short peripheral IV catheters. *Infection* 2004;**32**:30-32.
339. Rickard CM, Zhang L, McClymont A, et al. Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. *Lancet* 2012;**380**:1066-1074.
340. Maki DG, Kluger DM, Crnich CJ. The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. *Mayo Clin Proc* 2006;**81**:1159-1171.
341. Wisplinghoff H, Bischoff T, Tallent SM, Seifert H, Wenzel RP, Edmond MB. Nosocomial bloodstream infections in US hospitals: analysis of 24,179 cases from a prospective nationwide surveillance study. *Clin Infect Dis* 2004;**39**:309-317.
342. Gaynes R, Edwards JR; National Nosocomial Infections Surveillance System. Overview of nosocomial infections caused by Gram-negative bacilli. *Clin Infect Dis* 2005;**41**:848-854.
343. Safdar N, Maki DG. The pathogenesis of catheter-related bloodstream infection with noncuffed short-term central venous catheters. *Intensive Care Med* 2004;**30**:62-67.
344. Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous-catheter-related infection. *N Engl J Med* 1977;**296**:1305-1309.
345. 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. *Am J Med* 1991;**91**:1975-2055.
346. 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. *J Infect Dis* 1993;**168**:400-407.
347. Dobbins BM, Kite P, Kindon A, McMahon MJ, Wilcox MH. DNA fingerprinting analysis of coagulase negative staphylococci implicated in catheter related bloodstream infections. *J Clin Pathol* 2002;**55**:824-828.
348. Anaissie E, Samonis G, Kontoyiannis D, et al. Role of catheter

- colonization and infrequent hematogenous seeding in catheter-related infections. *Eur J Clin Microbiol Infect Dis* 1995;14:134-137.
349. Raad I, Mansour G, Hanna HA, Awad A, Alrahan A, Bivins C, et al. Optimal frequency of changing intravenous administration sets: is it safe to prolong use beyond 72 hours? *Infect Control Hosp Epidemiol* 2001;22:136-139.
  350. Yoo S, Ha M, Choi D, Pai H. Effectiveness of surveillance of central catheter-related bloodstream infection in an ICU in Korea. *Infect Control Hosp Epidemiol* 2001;22:433-436.
  351. Coopersmith CM, Rebmann TL, Zack JE, et al. Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit. *Crit Care Med* 2002;30:59-64.
  352. Sherertz RJ, Cruz J, Bowton DL, et al. Education of physicians-in-training can decrease the risk for vascular catheter infection. *Ann Intern Med* 2000;132:641-648.
  353. Eggimann P, Harbarth S, Constantin M, Touveneau S, Chevrolet J, Pittet D. Impact of a prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care. *Lancet* 2000;355:1864-1868.
  354. Sanders RA, Sheldon GF. Septic complications of total parenteral nutrition. A five year experience. *Am J Surg* 1976;132:214-220.
  355. Ryan JA, Jr, Abel RM, Abbott WM, et al. Catheter complications in total parenteral nutrition. A prospective study of 200 consecutive patients. *N Engl J Med* 1974;290:757-761.
  356. Murphy LM, Lipman TO. Central venous catheter care in parenteral nutrition: a review. *J Parenter Enteral Nutr* 1987;11:190-201.
  357. Armstrong CW, Mayhall CG, Miller KB, et al. Prospective study of catheter replacement and other risk factors for infection of hyperalimentation catheters. *J Infect Dis* 1986;154:808-816.
  358. Frampton GK, Harris P, Cooper K, et al. Educational interventions for preventing vascular catheter bloodstream infections in critical care: evidence map, systematic review and economic evaluation. Health Technology Assessment. Project No. 09/01/25. *Health Technol Assess* in press.
  359. Snyderman DR, Murray SA, Kornfeldt SJ, Majka JA, Ellis CA. Total parenteral nutrition-related infections: prospective epidemiologic study using semiquantitative methods. *Am J Med* 1982;73:695-699.
  360. Sheth NK, Franson TR, Rose HD, Buckmire FL, Cooper JA, Sohnle PG. Colonization of bacteria on polyvinyl chloride and Teflon intravascular catheters in hospitalized patients. *J Clin Microbiol* 1983;18:1061-1063.
  361. Maki DG, Ringer M. Evaluation of dressing regimens for prevention of infection with peripheral intravenous catheters. Gauze, a transparent polyurethane dressing, and an iodophor-transparent dressing. *JAMA* 1987;258:2396-2403.
  362. 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. *Arch Surg* 1986;121:591-594.
  363. McCarthy MC, Shives JK, Robison RJ, Broadie TA. Prospective evaluation of single and triple lumen catheters in total parenteral nutrition. *J Parenter Enteral Nutr* 1987;11:259-262.
  364. 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. *Am J Med* 1988;84:667-672.
  365. Yeung C, May J, Hughes R. Infection rate for single lumen v triple lumen subclavian catheters. *Infect Control Hosp Epidemiol* 1988;9:154-158.
  366. Clark-Christoff N, Watters VA, Sparks W, Snyder P, Grant JP. Use of triple-lumen subclavian catheters for administration of total parenteral nutrition. *J Parenter Enteral Nutr* 1992;16:403-407.
  367. Early TF, Gregory RT, Wheeler JR, Snyder SO, Jr, Gayle RG. Increased infection rate in double-lumen versus single-lumen Hickman catheters in cancer patients. *South Med J* 1990;83:34-36.
  368. Farkas JC, Liu N, Bleriot JP, Chevret S, Goldstein FW, Carlet J. Single- versus triple-lumen central catheter-related sepsis: a prospective randomized study in a critically ill population. *Am J Med* 1992;93:277-282.
  369. Gil RT, Kruse JA, Thill-Baharozian MC, Carlson RW. Triple- vs single-lumen central venous catheters. A prospective study in a critically ill population. *Arch Intern Med* 1989;149:1139-1143.
  370. Dezfulian C, Lavelle J, Nallamothu BK, Kaufman SR, Saint S. Rates of infection for single-lumen versus multilumen central venous catheters: a meta-analysis. *Crit Care Med* 2003;31:2385-2390.
  371. Zürcher M, Tramèr MR, Walder B. Colonization and bloodstream infection with single- versus multi-lumen central venous catheters: a quantitative systematic review. *Anesth Analg* 2004;99:177-182.
  372. Pearson ML. Guideline for prevention of intravascular device-related infections. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol* 1996;17:438-473.
  373. Abrahm JL, Mullen JL. A prospective study of prolonged central venous access in leukemia. *JAMA* 1982;248:2868-2873.
  374. Shapiro ED, Wald ER, Nelson KA, Spiegelman KN. Broviac catheter-related bacteremia in oncology patients. *Am J Dis Child* 1982;136:679-681.
  375. Press OW, Ramsey PG, Larson EB, Fefer A, Hickman RO. Hickman catheter infections in patients with malignancies. *Medicine* 1984;63:189-200.
  376. Darbyshire PJ, Weightman NC, Speller DC. Problems associated with indwelling central venous catheters. *Arch Dis Child* 1985;60:129-134.
  377. Pessa ME, Howard RJ. Complications of Hickman-Broviac catheters. *Surg Gynecol Obstet* 1985;161:257-260.
  378. Schuman ES, Winters V, Gross GF, Hayes JF. Management of Hickman catheter sepsis. *Am J Surg* 1985;149:627-628.
  379. Rannem T, Ladefoged K, Tvede M, Lorentzen J, Jarnum S. Catheter-related septicemia in patients receiving home parenteral nutrition. *Scand J Gastroenterol* 1986;21:455-460.
  380. Shulman RJ, Smith EO, Rahman S, Gardner P, Reed T, Mahoney D. Single- vs double-lumen central venous catheters in pediatric oncology patients. *Am J Dis Child* 1988;142:893-895.
  381. Weightman NC, Simpson EM, Speller DC, Mott MG, Oakhill A. Bacteraemia related to indwelling central venous catheters: prevention, diagnosis and treatment. *Eur J Clin Microbiol Infect Dis* 1988;7:125-129.
  382. Raad I, Davis S, Becker M, et al. Low infection rate and long durability of nontunneled silastic catheters. A safe and cost-effective alternative for long-term venous access. *Arch Intern Med* 1993;153:1791-1796.
  383. Andrivet P, Bacquer A, Ngoc CV, et al. Lack of clinical benefit from subcutaneous tunnel insertion of central venous catheters in immunocompromised patients. *Clin Infect Dis* 1994;18:199-206.
  384. Gyves JW, Ensminger WD, Niederhuber JE, et al. A totally implanted injection port system for blood sampling and chemotherapy administration. *JAMA* 1984;251:2538-2541.
  385. Lokich JJ, Bothe A, Jr, Benotti P, Moore C. Complications and management of implanted venous access catheters. *J Clin Oncol* 1985;3:710-717.
  386. 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.
  387. McDowell HP, Hart CA, Martin J. Implantable subcutaneous venous catheters. *Arch Dis Child* 1986;61:1037-1038.
  388. Brincker H, Saeter G. Fifty-five patient years' experience with a totally implanted system for intravenous chemotherapy. *Cancer* 1986;57:1124-1129.
  389. Wurzel CL, Halom K, Feldman JG, Rubin LG. Infection rates of Broviac-Hickman catheters and implantable venous devices. *Am J Dis Child* 1988;142:536-540.
  390. Kappers-Klunne MC, Degener JE, Stijnen T, Abels J. Complications from long-term indwelling central venous catheters in hematologic patients with special reference to infection. *Cancer* 1989;64:1747-1752.
  391. Carde P, Cosset-Delaigue MF, Laplanche A, Chareau I. Classical external indwelling central venous catheter versus totally implanted venous access systems for chemotherapy administration: a randomized trial in 100 patients with solid tumors. *Eur J Cancer Clin Oncol* 1989;25:939-944.
  392. Pegues D, Axelrod P, McClarren C, et al. Comparison of infections in Hickman and implanted port catheters in adult solid tumor patients. *J Surg Oncol* 1992;49:156-162.
  393. 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.



394. Groeger JS, Lucas AB, Thaler HT, et al. Infectious morbidity associated with long-term use of venous access devices in patients with cancer. *Ann Intern Med* 1993;119:1168-1174.
395. Galloway S, Bodenham A. Long-term central venous access. *Br J Anaesth* 2004;92:722-734.
396. Timsit JF, Sebillé V, Farkas JC, et al. Effect of subcutaneous tunneling on internal jugular catheter-related sepsis in critically ill patients: a prospective randomized multicenter study. *JAMA* 1996;276:1416-1420.
397. Timsit JF, Carlet J, Bruneel F, et al. Use of tunneled femoral catheters to prevent catheter-related infection. A randomized, controlled trial. *Ann Intern Med* 1999;130:729-735.
398. Randolph AG, Cook DJ, Gonzales CA, Brun-Buisson C. Tunneling short-term central venous catheters to prevent catheter-related infection: a meta-analysis of randomized, controlled trials. *Crit Care Med* 1998;26:1452-1457.
399. Ryder MA. Peripheral access options. *Surg Oncol Clin N Am* 1995;4:395-427.
400. Bottino J, McCredie KB, Groschel DH, Lawson M. Long-term intravenous therapy with peripherally inserted silicone elastomer central venous catheters in patients with malignant diseases. *Cancer* 1979;43:1937-1943.
401. Graham DR, Keldermans MM, Klemm LW, Semenza NJ, Shafer ML. Infectious complications among patients receiving home intravenous therapy with peripheral, central, or peripherally placed central venous catheters. *Am J Med* 1991;91(Suppl. 2):S95-S100.
402. Merrell SW, Peatross BG, Grossman MD, Sullivan JJ, Harker WG. Peripherally inserted central venous catheters. Low-risk alternatives for ongoing venous access. *West J Med* 1994;160:25-30.
403. Thiagarajan RR, Ramamoorthy C, Gettmann T, Bratton SL. Survey of the use of peripherally inserted central venous catheters in children. *Pediatrics* 1997;99:e4.
404. Skiest DJ, Abbott M, Keiser P. Peripherally inserted central catheters in patients with AIDS are associated with a low infection rate. *Clin Infect Dis* 2000;30:949-952.
405. 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.
406. 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. *Ann Intern Med* 1997;127:257-266.
407. Logghe C, Van Ossel C, 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. *J Hosp Infect* 1997;37:145-156.
408. Heard SO, Wagle M, Vijayakumar E, McLean S, Brueggemann A, Napolitano LM, et al. Influence of triple-lumen central venous catheters coated with chlorhexidine and silver sulfadiazine on the incidence of catheter-related bacteremia. *Arch Intern Med* 1998;158:81-87.
409. Haxhe JJ, D'Hoore W. A meta-analysis dealing with the effectiveness of chlorhexidine and silver-sulfadiazine impregnated central venous catheters. *J Hosp Infect* 1998;40:166-168.
410. Oda T, Hamasaki J, Kanda N, Mikami K. Anaphylactic shock induced by an antiseptic-coated central venous [correction of nervous] catheter. *Anesthesiology* 1997;87:1242-1244.
411. Veenstra DL, Saint S, Sullivan SD. Cost-effectiveness of antiseptic-impregnated central venous catheters for the prevention of catheter-related bloodstream infection. *JAMA* 1999;282:554-560.
412. Raad I, Buzaid A, Robertson C, et al. Central venous catheters coated with minocycline and rifampin for the prevention of catheter-related colonization and bloodstream infections. A randomized, double-blind trial. The Texas Medical Center Catheter Study Group. *Ann Intern Med* 1997;127:267-274.
413. Collin GR. Decreasing catheter colonization through the use of an antiseptic-impregnated catheter: a continuous quality improvement project. *Chest* 1999;115:1632-1640.
414. Darouiche RO, Hachem R, Harris RL, Mayhall G, Raad II, Heard SO, et al. A Comparison of Two Antimicrobial-Impregnated Central Venous Catheters. *N Engl J Med* 1999;340:1-8.
415. Veenstra DL, Saint S, Saha S, Lumley T, Sullivan SD. Efficacy of antiseptic-impregnated central venous catheters in preventing catheter-related bloodstream infection: a meta-analysis. *JAMA* 1999;281:261-267.
416. Mermel LA. Prevention of intravascular catheter-related infections. *Ann Intern Med* 2000;132:391-402.
417. Walder B, Pittet D, Tramèr MR. 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. *Infect Control Hosp Epidemiol* 2002;23:748-756.
418. 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. *Antimicrob Agents Chemother* 2001;45:1535-1538.
419. Hockenhull J, Dwan K, Boland A, Smith G, Bagust A, Dickson R, et al. The clinical effectiveness and cost-effectiveness of central venous catheters treated with anti-infective agents in preventing bloodstream infections: a systematic review and economic evaluation. *Health Technol Assess* 2008;12:1-154.
420. Lai NM, Chaiyakunapruk N, Lai NA, O'Riordan E, Pau WS, Saint S. Catheter impregnation, coating or bonding for reducing central venous catheter-related infections in adults. *Cochrane Database Syst Rev* 2013(6).
421. Wang H, Huang T, Jing J, Jin J, Wang P, Yang M, et al. Effectiveness of different central venous catheters for catheter-related infections: a network meta-analysis. *J Hosp Infect* 2010;76:1-11.
422. Walz JM, Avelar RL, Longtine KJ, Carter KL, Mermel LA, Heard SO, et al. Anti-infective external coating of central venous catheters: a randomized, noninferiority trial comparing 5-fluorouracil with chlorhexidine/silver sulfadiazine in preventing catheter colonization. *Crit Care Med* 2010;38:2095-2102.
423. Nakonechna A, Dorea P, Dixon T, et al. Immediate hypersensitivity to chlorhexidine is increasingly recognised in the United Kingdom. *Allergol Immunopathol* 2012; Dec19. pii: S0301-0546(12)00262-5. doi: 10.1016/j.aller.2012.08.001. [Epub ahead of print]
424. Guleri A, Kumar A, Morgan RJ, Hartley M, Roberts DH. Anaphylaxis to chlorhexidine-coated central venous catheters: a case series and review of the literature. *Surg Infect* 2012;13:171-174.
425. Medicines and Healthcare Products Regulatory Agency. *Medical Device Alert: All medical devices and medicinal products containing chlorhexidine*. MDA/2012/075. London: Medicines and Healthcare Products Regulatory Agency; 2012.
426. Parienti JJ, Thirion M, Megarbane B, et al. Femoral vs jugular venous catheterization and risk of nosocomial events in adults requiring acute renal replacement therapy: a randomized controlled trial. *JAMA* 2008;299:2413-2422.
427. Moretti EW, Ofstead CL, Kristy RM, Wetzler HP. Impact of central venous catheter type and methods on catheter-related colonization and bacteraemia. *J Hosp Infect* 2005;61:139-145.
428. Nagashima G, Kikuchi T, Tsuyuzaki H, et al. To reduce catheter-related bloodstream infections: is the subclavian route better than the jugular route for central venous catheterization? *J Infect Chemother* 2006;12:363-365.
429. Ruesch S, Walder B, Tramer MR. Complications of central venous catheters: internal jugular versus subclavian access - a systematic review. *Crit Care Med* 2002;30:454-460.
430. Sadoyama G, Gontijo Filho PP. Comparison between the jugular and subclavian vein as insertion site for central venous catheters: microbiological aspects and risk factors for colonization and infection. *Braz J Infect Dis* 2003;7:142-148.
431. Richet H, Bouvier AM, Hubert B, et al. Prospective multicenter study of vascular-catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. *J Clin Microbiol* 1990;28:2520-2525.
432. Safdar N, Kluger DM, Maki DG. A review of risk factors for catheter-related bloodstream infection caused by percutaneously inserted, noncuffed central venous catheters: implications for preventive strategies. *Medicine* 2002;81:466-479.
433. Lorente L, Jimenez A, Iribarren JL, Jimenez JJ, Martin MM, Mora ML. The micro-organism responsible for central venous catheter

- related bloodstream infection depends on catheter site. *Intensive Care Med* 2006;**32**:1449-1450.
434. Traore O, Liotier J, Souweine B. Prospective study of arterial and central venous catheter colonization and of arterial- and central venous catheter-related bacteremia in intensive care units. *Crit Care Med* 2005;**33**:1276-1280.
435. Merrer J, De Jonghe B, Golliot F, et al. Complications of femoral and subclavian venous catheterization in critically ill patients: a randomized controlled trial. *JAMA* 2001;**286**:700-707.
436. Goetz AM, Wagener MM, Miller JM, Muder RR. Risk of infection due to central venous catheters: effect of site of placement and catheter type. *Infect Control Hosp Epidemiol* 1998;**19**:842-845.
437. Deshpande KS, Hatem C, Ulrich HL, et al. The incidence of infectious complications of central venous catheters at the subclavian, internal jugular, and femoral sites in an intensive care unit population. *Crit Care Med* 2005;**33**:13-20.
438. Marik PE, Flemmer M, Harrison W. The risk of catheter-related bloodstream infection with femoral venous catheters as compared to subclavian and internal jugular venous catheters: a systematic review of the literature and meta-analysis. *Crit Care Med* 2012;**40**:2479-2485.
439. Randolph AG, Cook DJ, Gonzales CA, Pribble CG. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Crit Care Med* 1996;**24**:2053-2058.
440. Hind D, Calvert N, McWilliams R, et al. Ultrasonic locating devices for central venous cannulation: meta-analysis. *BMJ* 2003;**327**:361-364.
441. National Institute for Health and Care Excellence. *Guidance on the use of ultrasound locating devices for placing central venous catheters (No.49)*. London: National Institute for Clinical Excellence; 2002. Available at: <http://www.nice.org.uk/nicemedia/live/11474/32461/32461.pdf>. Accessed July 25, 2013.
442. Maki DG, Goldman DA, Rhame FS. Infection control in intravenous therapy. *Ann Intern Med* 1973;**79**:867-887.
443. Raad II, Hohn DC, Gilbreath BJ, et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infect Control Hosp Epidemiol* 1994;**15**:231-238.
444. Carrer S, Bocchi A, Bortolotti M, et al. Effect of different sterile barrier precautions and central venous catheter dressing on the skin colonization around the insertion site. *Minerva Anestesiol* 2005;**71**:197-206.
445. Hu KK, Lipsky BA, Veenstra DL, Saint S. Using maximal sterile barriers to prevent central venous catheter-related infection: a systematic evidence-based review. *Am J Infect Control* 2004;**32**:142-146.
446. Fletcher S, Bodenham A. Catheter-related sepsis: an overview - Part 1. *Br J Int Care* 1999;**9**:46-53.
447. Maki DG, Ringer M, Alvarado CJ. Prospective randomised trial of povidone-iodine, alcohol, and chlorhexidine for prevention of infection associated with central venous and arterial catheters. *Lancet* 1991;**338**:339-343.
448. Mimos O, Pieroni L, Lawrence C, et al. Prospective, randomized trial of two antiseptic solutions for prevention of central venous or arterial catheter colonization and infection in intensive care unit patients. *Crit Care Med* 1996;**24**:1818-1823.
449. Parienti JJ, du Cheyron D, Ramakers M, et al. Alcoholic povidone-iodine to prevent central venous catheter colonization: a randomized unit-crossover study. *Crit Care Med* 2004;**32**:708-713.
450. Chaiyakunapruk N, Veenstra DL, Lipsky BA, Saint S. Chlorhexidine compared with povidone-iodine solution for vascular catheter-site care: a meta-analysis. *Ann Intern Med* 2002;**136**:792-801.
451. Chaiyakunapruk N, Veenstra DL, Lipsky BA, Sullivan SD, Saint S. Vascular catheter site care: the clinical and economic benefits of chlorhexidine gluconate compared with povidone iodine. *Clin Infect Dis* 2003;**37**:764-771.
452. Larson E. Guideline for use of topical antimicrobial agents. *Am J Infect Control* 1988;**16**:253-266.
453. Rannem T, Ladefoged K, Hegnhøj J, Møller EH, Bruun B, Jarnum S. Catheter-related sepsis in long-term parenteral nutrition with Breviac catheters. An evaluation of different disinfectants. *Clin Nutr* 1990;**9**:131-136.
454. Prager RL, Silva J, Jr. Colonization of central venous catheters. *South Med J* 1984;**77**:458-461.
455. Moran JM, Atwood RP, Rowe MI. A clinical and bacteriologic study of infections associated with venous cutdowns. *N Engl J Med* 1965;**272**:554-560.
456. Norden CW. Application of antibiotic ointment to the site of venous catheterization - a controlled trial. *J Infect Dis* 1969;**120**:611-615.
457. Zinner SH, Denny-Brown BC, Braun P, Burke JP, Toala P, Kass EH. Risk of infection with intravenous indwelling catheters: effect of application of antibiotic ointment. *J Infect Dis* 1969;**120**:616-619.
458. Jarrard MM, Freeman JB. The effects of antibiotic ointments and antiseptics on the skin flora beneath subclavian catheter dressings during intravenous hyperalimentation. *J Surg Res* 1977;**22**:520-526.
459. Maki DG, Band JD. A comparative study of polyantibiotic and iodophor ointments in prevention of vascular catheter-related infection. *Am J Med* 1981;**70**:739-744.
460. Maiwald M, Chan ESY. The forgotten role of alcohol: a systematic review and meta-analysis of the clinical efficacy and perceived role of chlorhexidine in skin antiseptics. *PLoS One* 2012;**7**:e44277.
461. Hoffmann KK, Weber DJ, Samsa GP, Rutala WA. Transparent polyurethane film as an intravenous catheter dressing. A meta-analysis of the infection risks. *JAMA* 1992;**267**:2072-2076.
462. 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. *Cochrane Database Syst Rev* 2003;**4**:CD003827.
463. Webster J, Gillies D, O'Riordan E, Sherriff KL, Rickard CM. Gauze and tape and transparent polyurethane dressings for central venous catheters. *Cochrane Database Syst Rev* 2011;**9**:CD003827.
464. Chan R, Northfield S, Alexander A, Rickard C. Using the collaborative evidence based practice model: a systematic review and uptake of chlorhexidine-impregnated sponge dressings on central venous access devices in a tertiary cancer centre. *Aust J Cancer Nurs* 2012;**13**:10-15.
465. Schwebel C, Lucet JC, Vesin A, et al. Economic evaluation of chlorhexidine-impregnated sponges for preventing catheter-related infections in critically ill adults in the Dressing Study. *Crit Care Med* 2012;**40**:11-17.
466. Timsit JF, Mimos O, Mourvillier B, et al. Randomized controlled trial of chlorhexidine dressing and highly adhesive dressing for preventing catheter-related infections in critically ill adults. *Am J Respir Crit Care Med* 2012;**186**:1272-1278.
467. O'Horo JC, Silva GL, Munoz-Price LS, Safdar N. The efficacy of daily bathing with chlorhexidine for reducing healthcare-associated bloodstream infections: a meta-analysis. *Infect Control Hosp Epidemiol* 2012;**33**:257-267.
468. Dettenkofer M, Wilson C, Gratwohl A, et al. Skin disinfection with octenidine dihydrochloride for central venous catheter site care: a double-blind, randomized, controlled trial. *Clin Microbiol Infect* 2010;**16**:600-606.
469. Eyer S, Brummitt C, Crossley K, Siegel R, Cerra F. Catheter-related sepsis: prospective, randomized study of three methods of long-term catheter maintenance. *Crit Care Med* 1990;**18**:1073-1079.
470. Uldall PR, Merchant N, Woods F, Yarworski U, Vas S. Changing subclavian haemodialysis cannulas to reduce infection. *Lancet* 1981;**317**:1373.
471. Cobb DK, High KP, Sawyer RG, et al. A controlled trial of scheduled replacement of central venous and pulmonary-artery catheters. *N Engl J Med* 1992;**327**:1062-1068.
472. Cook D, Randolph A, Kernerman P, et al. Central venous catheter replacement strategies: a systematic review of the literature. *Crit Care Med* 1997;**25**:1417-1424.
473. Rickard CM, McCann D, Munnings J, McGrail MR. Routine resite of peripheral intravenous devices every 3 days did not reduce complications compared with clinically indicated resite: a randomised controlled trial. *BMC Med* 2010;**8**:53.
474. Webster J, Osborne S, Rickard C, New K. Clinically-indicated replacement versus routine replacement of peripheral venous catheters. *Cochrane Database Syst Rev* 2013;**4**(CD007798).
475. De Cicco M, Chiaradia V, Veronesi A, et al. Source and route of microbial colonisation of parenteral nutrition catheters. *Lancet* 1989;**334**:1258-1261.
476. Capell S, Linares J, Sitges-Serra A. Catheter sepsis due to coagulase-negative staphylococci in patients on total parenteral nutrition. *Eur J Clin Microbiol* 1986;**5**:40-42.

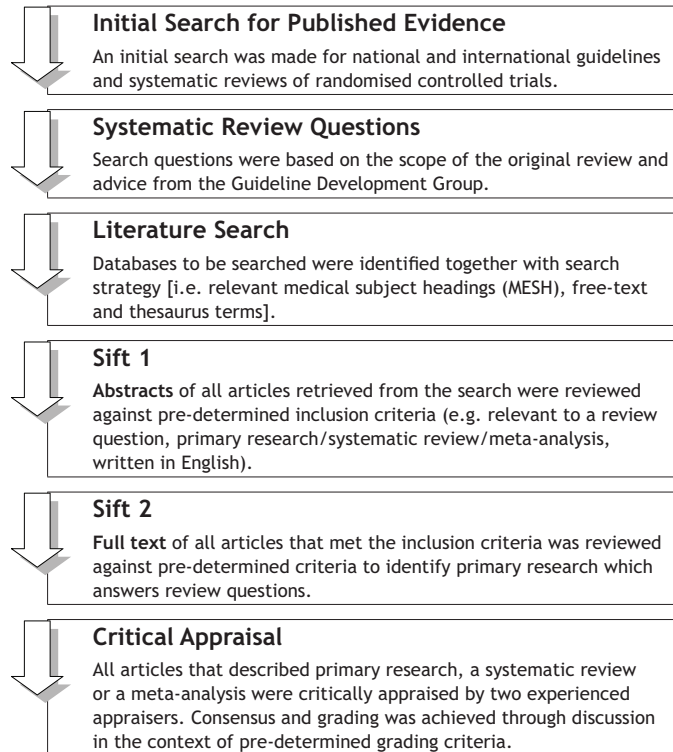


477. Salzman MB, Isenberg HD, Shapiro JF, Lipsitz PJ, Rubin LG. A prospective study of the catheter hub as the portal of entry for microorganisms causing catheter-related sepsis in neonates. *J Infect Dis* 1993;167:487-490.
478. Peters G, Locci R, Pulverer G. Adherence and growth of coagulase-negative staphylococci on surfaces of intravenous catheters. *J Infect Dis* 1982;146:479-482.
479. Liñares J, Sitges-Serra A, Garau J, Pérez JL, Martín R. Pathogenesis of catheter sepsis: a prospective study with quantitative and semiquantitative cultures of catheter hub and segments. *J Clin Microbiol* 1985;21:357-360.
480. 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. *J Parenter Enteral Nutr* 1985;9:322-325.
481. 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. *Infect Control Hosp Epidemiol* 1997;18:24.
482. Salzman MB, Isenberg HD, Rubin LG. Use of disinfectants to reduce microbial contamination of hubs of vascular catheters. *J Clin Microbiol* 1993;31:475-479.
483. Ruschman KL, Fulton JS. Effectiveness of disinfectant techniques on intravenous tubing latex injection ports. *J Intraven Nurs* 1993;16:304-308.
484. Casey AL, Worthington T, Lambert PA, Quinn D, Farouqi MH, Elliott TSJ. A randomized, prospective clinical trial to assess the potential infection risk associated with the PosiFlow® needleless connector. *J Hosp Infect* 2003;54:288-293.
485. Simmons S, Bryson C, Porter S. 'Scrub the hub': cleaning duration and reduction in bacterial load on central venous catheters. *Crit Care Nurs Q* 2011;34:31.
486. Kaler W, Chinn R. Successful disinfection of needleless access ports: a matter of time and friction. *JAMA* 2007;12:140-142.
487. Snaterse M, Rüger W, Scholte op Reimer WJM, Lucas C. Antibiotic-based catheter lock solutions for prevention of catheter-related bloodstream infection: a systematic review of randomised controlled trials. *J Hosp Infect* 2010;75:1-11.
488. Slobbe L, Doorduijn JK, Lugtenburg PJ, et al. Prevention of catheter-related bacteremia with a daily ethanol lock in patients with tunnelled catheters: a randomized, placebo-controlled trial. *PLoS One* 2010;5:e10840.
489. Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular-catheter-related infections. *MMWR* 2002;51:1-29.
490. Morris K, Howard P. Can high-level mupirocin resistance reporting be relied upon to ensure patients are prescribed appropriate treatment? *ECCMID* 2012:2378.
491. van de Wetering MD, van Woensel JB. Prophylactic antibiotics for preventing early central venous catheter Gram positive infections in oncology patients. *Cochrane Database Syst Rev* 2003;2:CD003295.
492. Hoar PF, Wilson RM, Mangano DT, Avery GJ, Szarnicki RJ, Hill JD. Heparin bonding reduces thrombogenicity of pulmonary-artery catheters. *N Engl J Med* 1981;305:993-995.
493. Ge X, Cavallazzi R, Li C, Pan SM, Wang YW, Wang FL. Central venous access sites for the prevention of venous thrombosis, stenosis and infection. *Cochrane Database Syst Rev* 2012;3:CD004084.
494. Raad II, Luna M, Khalil SA, Costerton JW, Lam C, Bodey GP. The relationship between the thrombotic and infectious complications of central venous catheters. *JAMA* 1994;271:1014-1016.
495. Chastre J, Cornud F, Bouchama A, Viau F, Benacerraf R, Gibert C. Thrombosis as a complication of pulmonary-artery catheterization via the internal jugular vein: prospective evaluation by phlebography. *N Engl J Med* 1982;306:278-281.
496. Valerio D, Hussey J, Smith F. Central vein thrombosis associated with intravenous feeding - a prospective study. *J Parenter Enteral Nutr* 1981;5:240-242.
497. Andrew M, Marzinotto V, Pencharz P, et al. A cross-sectional study of catheter-related thrombosis in children receiving total parenteral nutrition at home. *J Pediatr* 1995;126:358-363.
498. Krafte-Jacobs B, Sivitt CJ, Mejia R, Pollack MM. Catheter-related thrombosis in critically ill children: comparison of catheters with and without heparin bonding. *J Pediatr* 1995;126:50-54.
499. Talbott G, Winters W, Bratton S, O'Rourke P. A prospective study of femoral catheter-related thrombosis in children. *Arch Pediatr Adolesc Med* 1995;149:288-291.
500. 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* 1998;113:165-171.
501. Bern MM, Lokich JJ, Wallach SR, et al. Very low doses of warfarin can prevent thrombosis in central venous catheters. A randomized prospective trial. *Ann Intern Med* 1990;112:423-428.
502. Abdelkefi A, Abdeladhim AB, Torjman L, et al. Randomized trial of prevention of catheter-related bloodstream infection by continuous infusion of low-dose unfractionated heparin in patients with hematologic and oncologic disease. *J Clin Oncol* 2005;23:7864-7870.
503. Pierce CM, Wade A, Mok Q. Heparin-bonded central venous lines reduce thrombotic and infective complications in critically ill children. *Intensive Care Med* 2000;26:967-972.
504. Appelgren P, Ransjö U, Bindlev L, Espersen F, Larm O. Surface heparinization of central venous catheters reduces microbial colonization in vitro and in vivo: results from a prospective, randomized trial. *Crit Care Med* 1996;24:1482-1489.
505. Abdelkefi A, Achour W, Ben Othman T, et al. Use of heparin-coated central venous lines to prevent catheter-related bloodstream infection. *J Support Oncol* 2007;5:273-278.
506. Shah PS, Shah N. Heparin-bonded catheters for prolonging the patency of central venous catheters in children. *Cochrane Database Syst Rev* 2007;4:CD005983.
507. Boraks P, Seale J, Price J, et al. Prevention of central venous catheter associated thrombosis using minidose warfarin in patients with haematological malignancies. *Br J Haematol* 1998;101:483-486.
508. Akl E, Karmath G, Yosucio V, et al. Anticoagulation for thrombosis prophylaxis in cancer patients with central venous catheters. *Cochrane Database Syst Rev* 2007;18:CD00646.
509. Akl EA, Muti P, Schunemann HJ. Anticoagulation in patients with cancer: an overview of reviews. *Pol Arch Med Wewn* 2008;118:183-193.
510. Klerk CP, Smorenburg SM, Buller HR. Thrombosis prophylaxis in patient populations with a central venous catheter: a systematic review. *Arch Intern Med* 2003 ;163:1913-1921.
511. Passanante A, Macik BG. The heparin flush syndrome: a cause of iatrogenic hemorrhage. *Am J Med Sci* 1988;296:71-73.
512. 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. *BMJ* 1998;316:969-975.
513. Goode CJ, Titler M, Rakel B, et al. A meta-analysis of effects of heparin flush and saline flush: quality and cost implications. *Nurs Res* 1991;40:324-330.
514. Peterson FY, Kirchoff KT. Analysis of the research about heparinized versus nonheparinized intravascular lines. *Heart Lung* 1991;20:631-640.
515. Mitchell MD, Anderson BJ, Williams K, Umscheid CA. Heparin flushing and other interventions to maintain patency of central venous catheters: a systematic review. *J Adv Nurs* 2009;65:2007-2021.
516. Schallom ME, Prentice D, Sona C, Micek ST, Skrupky LP. Heparin or 0.9% sodium chloride to maintain central venous catheter patency: a randomized trial. *Crit Care Med* 2012;40:1820-1826.
517. Bertolino G, Pitassi A, Tinelli C, et al. Intermittent flushing with heparin versus saline for maintenance of peripheral intravenous catheters in a medical department: a pragmatic cluster-randomized controlled study. *Worldviews Evid Based Nurs* 2012;9:221-226.
518. Rupp ME, Sholtz LA, Jourdan DR, et al. Outbreak of bloodstream infection temporally associated with the use of an intravascular needleless valve. *Clin Infect Dis* 2007;44:1408-1414.
519. Salgado CD, Chinnes L, Paczesny TH, Cantey JR. Increased rate of catheter-related bloodstream infection associated with use of a needleless mechanical valve device at a long-term acute care hospital. *Infect Control Hosp Epidemiol* 2007;28:684-688.
520. Maragakis LL, Bradley KL, Song X, et al. Increased catheter-related bloodstream infection rates after the introduction of a new mechanical valve intravenous access port. *Infect Control*

- Hosp Epidemiol* 2006;**27**:67-70.
521. Field K, Athan E, McFarlane C, et al. Incidence of catheter-related bloodstream infection among patients with a needleless, mechanical valve-based intravenous connector in an Australian hematology-oncology unit. *Infect Control Hosp Epidemiol* 2007;**28**:610-613.
522. Gillies D, O'Riordan L, Wallen M, Morrison A, Rankin K, Nagy S. Optimal timing for intravenous administration set replacement. *Cochrane Database Syst Rev* 2005;**4**:CD003588.
523. Department of Health. *Saving lives: a delivery programme to reduce healthcare associated infection including MRSA*. London: Department of Health; 2005.
524. Berenholtz SM, Pronovost PJ, Lipsett PA, et al. Eliminating catheter-related bloodstream infections in the intensive care unit. *Crit Care Med* 2004;**32**:2014-2020.
525. Pronovost P, Roth G, Bander J, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006;**355**:2725-2732.
526. Pronovost PJ, Sexton JB, Marsteller JA, et al. Sustaining reductions in catheter related bloodstream infections in Michigan intensive care units: observational study. *BMJ* 2010;**4**:c309.
527. Curran E, Harper P, Loveday H, et al. Results of a multicentre randomised controlled trial of statistical process control charts and structured diagnostic tools to reduce ward-acquired meticillin-resistant *Staphylococcus aureus*: the CHART Project. *J Hosp Infect* 2008;**70**:127-135.
528. Scales DC, Dainty K, Hales B, et al. A multifaceted intervention for quality improvement in a network of intensive care units: a cluster randomized trial. *JAMA* 2011;**305**:363-372.
529. Munoz-Price LS, Dezfulian C, Wyckoff M, et al. Effectiveness of stepwise interventions targeted to decrease central catheter-associated bloodstream infections. *Crit Care Med* 2012;**40**:1464-1469.
530. Bion J, Bellingan G, Patten M, et al. 'Matching Michigan': a 2-year stepped interventional programme to minimise central venous catheter-blood stream infections in intensive care units in England. *BMJ* 2013;**22**:110-123.
531. Halton KA, Cook D, Paterson DL, Safdar N, Graves N. Cost-effectiveness of a central venous catheter care bundle. *PLoS One* 2010;**5**:e12815.
532. Berwick D, Calkins D, McCannon C, Hackard A. The 100,000 lives campaign: setting a goal and deadline for improving healthcare quality. *JAMA* 2006;**295**:326-327.

## APPENDICES

### A.1 Systematic Review Process



### A.2 Consultation Process

The following organisations were approached for comment:

Advisory Committee on Antimicrobial Resistance and Healthcare Associated Infection  
 Association for Continence Advice  
 Association of British Healthcare Industries  
 Association of Healthcare Cleaning Professionals  
 British Association of Critical Care Nurses  
 British Association of Urological Surgeons  
 British Association of Urological Nurses  
 British Health Care Trades Association  
 British Infection Association  
 British Medical Association  
 British Society for Antimicrobial Chemotherapy  
 C-diff Support  
 Chartered Society of Physiotherapy  
 Foundation Trust Network  
 General Medical Council  
 Health and Safety Executive  
 Health Education England  
 Health Professions Council  
 Health Protection Scotland  
 Healthcare Infection Society  
 Healthwatch England  
 HPA Scotland  
 Infection Prevention Society  
 Intensive Care Society  
 Medicines and Healthcare Products Regulatory Agency  
 MRSA Action UK  
 NI Public Health Agency  
 NHS Confederation  
 NHS Trust Development Authority  
 Northern Ireland Executive  
 Nursing and Midwifery Council  
 Public Health England  
 Public Health Wales Health Protection  
 Royal College of Anaesthetists  
 Royal College of Midwives  
 Royal College of Nursing  
 Royal College of Pathologists  
 Royal College of Physicians  
 Royal College of Radiologists  
 Royal College of Surgeons of England  
 Royal Pharmaceutical Society of Great Britain  
 Royal Society of Medicine  
 Scottish Government  
 Spinal Injury Association  
 The Lee Spark Necrotising Fasciitis Foundation  
 The Patients Association  
 UK Clinical Pharmacists Association  
 Unison  
 Welsh Assembly Government

### A.3 Glossary

<b>Adenosine triphosphate (ATP)</b>	A chemical compound that contains ‘energy-rich bonds’ and is used by cells to store and deliver energy
<b>Aerobic organism</b>	An organism that requires free oxygen for life and growth
<b>Alcohol-based hand rub</b>	A hand decontamination preparation based on alcohol that, for the purposes of these guidelines, encompasses solutions, gels or wipes
<b>Antimicrobial</b>	A substance that kills or inhibits the growth of microorganisms
<b>Asepsis</b>	The absence of pathogenic microorganisms
<b>Antiseptic</b>	A substance that destroys or inhibits the growth of microorganisms and is sufficiently non-toxic to be applied to skin or mucous membranes
<b>Aseptic non-touch technique (ANTT)</b>	A framework for the aseptic technique based on the concept of defining key parts and key sites to be protected from contamination.
<b>Aseptic technique</b>	A carefully controlled procedure that aims to prevent contamination by microorganisms
<b>Bacteraemia</b>	The presence of microorganisms in the bloodstream
<b>Bacteriuria</b>	The presence of microorganisms in the urine. If there are no symptoms of infection, this is called ‘asymptomatic bacteriuria’
<b>Biofilm</b>	A complex structure comprising microorganisms and extracellular polymers that forms over surfaces, such as those in contact with water or tissues
<b>Bladder irrigation</b>	Continuous flow of a solution through the bladder to remove clots or debris
<b>Bloodborne virus</b>	A viral infection transmitted by exposure to blood and sometimes other bodily fluids. Bloodborne viruses include hepatitis B and C as well as human immunodeficiency virus
<b>Bloodstream infection (BSI)</b>	The presence of microbes in the blood with symptoms of infection
<b>Case-control study</b>	An analytical observational study that compares people with the disease of interest with a group of similar ‘control’ people who do not in order to determine potential causes or risk factors
<b>Case report</b>	A scientific article that describes an individual case in detail
<b>Case series</b>	A report describing a series of several similar events
<b>Catheter-associated urinary tract infection (CAUTI)</b>	The presence of symptoms or signs attributable to microorganisms that have invaded the urinary tract, where the patient has, or has recently had, a urinary catheter
<b>Catheter colonisation</b>	Microorganisms present on a surface of a catheter that could potentially lead to infection
<b>Catheter-related bloodstream infection (CR-BSI)</b>	An infection of the bloodstream where microorganisms are found in the blood of a patient with a central venous access device, the patient has clinical signs of infection (e.g. fever, chills and hypotension) and there is no other apparent source for the infection. For surveillance purposes, this often refers to bloodstream infections that occur in patients with a central venous access device and where other possible sources of infection have been excluded. A more rigorous definition is where the same microorganism is cultured from the tip of the catheter as grown from the blood; simultaneous quantitative blood cultures with at least a 5:1 ratio of microorganisms cultured from the central venous access device vs peripheral; differential time to positivity of at least 2 h for blood cultures cultured peripherally vs from central venous access device
<b>Catheter-related infection</b>	Any infection related to a central venous access device, including local (e.g. insertion site) and systemic (e.g. bloodstream) infections
<b>Central venous catheter (CVC)</b>	A vascular catheter inserted with the tip located in the superior vena cava. Central venous catheters are used for giving multiple infusions, medication or chemotherapy, temporary haemodialysis, monitoring of central venous pressure and frequent blood sampling
<b>Chlorhexidine</b>	An antiseptic widely used as a solution to disinfect and cleanse the skin, wounds or burns
<b>Cleaning</b>	Methods that physically remove soil, dust and dirt from surfaces or equipment

<b>Clinical waste</b>	Waste material that consists wholly or partly of human or animal tissue, blood or body fluids, excretions, drugs or other pharmaceutical products, swabs/dressings, syringes, needles or other sharp instruments
<b>Closed urinary drainage system</b>	A system where a urinary catheter is connected via tubing to a collecting bag. The system relies on gravity to drain the urine
<b>Cohort study</b>	A prospective or retrospective follow-up study where groups to be followed-up are defined on the basis of presence or absence of exposure to a risk factor or intervention
<b>Colonisation</b>	Microorganisms that establish themselves in a particular environment, such as a body surface, without producing disease
<b>Colony-forming unit (cfu)</b>	An estimate of the number of viable bacterial cells made by counting visible colonies derived from the replication of a single microbial cell
<b>Cross-infection</b>	Transmission of a pathogenic organism from one person to another
<b>Crossover trial</b>	A comparison of the outcome between two or more groups of patients that are exposed to different regimens of treatment/intervention where the groups exchange treatment/intervention after a pre-arranged period
<b>Decontamination</b>	A process that removes hazardous substances, including chemicals or microorganisms
<b>Detergent</b>	A cleansing agent that removes dirt from a surface by bonding with lipids and other particles
<b>Disinfection</b>	A process that reduces the number of pathogenic microorganisms to a level at which they are not able to cause harm, but which does not usually destroy spores
<b>Droplet nuclei</b>	Particles 1-10 µm in diameter comprising the dried residue formed by evaporation of droplets coughed or sneezed from the respiratory tract
<b>Dysuria</b>	Difficult or painful urination
<b>Encrustation</b>	Urinary proteins, salts and crystals that adhere to the internal and external surface of a urinary catheter
<b>Engineering controls</b>	The use of equipment designed to prevent injury to the operator
<b>Enteral feeding</b>	Administration of nutrients into stomach or other part of the gastrointestinal tract using tubes
<b>Exogenous infection</b>	Infections caused by microorganisms acquired from another person, animal or the environment
<b>Expert opinion</b>	Opinion derived from seminal works and appraised national and international guidelines
<b>Gram-negative/-positive bacteria</b>	The type of bacteria as identified by Gram's staining method. Gram-positive bacteria appear dark blue or purple under a microscope. Such bacteria have a thick layer of peptidoglycan on their cell walls. Gram-negative bacteria appear red under a microscope and have an outer layer of lipoprotein and a thin layer of peptidoglycan
<b>Guidewire</b>	A wire used to facilitate insertion of the intravascular catheter into the body
<b>Haemothorax</b>	Blood in the pleural cavity, usually due to injury. If the blood is not drained, it may impair the movement of the lungs or become infected
<b>Haematogenous seeding</b>	Microorganisms causing infection establish infection at another body site as a result of being transferred in the bloodstream
<b>Hand decontamination or hand hygiene</b>	The use of soap and water or an antiseptic solution to reduce the number of microorganisms on the hands
<b>Hawthorne effect</b>	A phenomenon in which the participants change their behaviour or performance in response to being studied
<b>Healthcare-associated infection (HCAI)</b>	Infection acquired as a result of the delivery of health care either in an acute (hospital) or non-acute setting
<b>Healthcare worker</b>	Any person employed by a health service, social service, local authority or agency to provide care for sick, disabled or elderly people
<b>Heterogeneity</b>	Variability, difference



<b>Hyperalimentation</b>	The administration of nutrients intravenously, usually to individuals who cannot take food via the gastrointestinal tract
<b>Hypochlorite</b>	A chlorine-based disinfectant
<b>Implantable intravascular device</b>	A central venous access device that is tunnelled under the skin with a subcutaneous port or reservoir with a self-sealing septum that is accessible by needle puncture through intact skin
<b>Incidence</b>	The number of new events (e.g. cases of disease) occurring in a population over a defined period of time
<b>Indwelling urethral catheter</b>	A catheter inserted into the bladder via the urethra and left in place for a period of time
<b>Infection</b>	Microorganisms that have entered the body and are multiplying in the tissues, typically causing specific symptoms
<b>Intention-to-treat analysis</b>	An analysis in which the results of the study are based on initial treatment assignment and not on a treatment actually received
<b>Interrupted time series</b>	A study in which measurements from the group under investigation are taken repeatedly before and after the intervention
<b>Intravascular access device (IVAD)</b>	A device inserted into a vascular system in order to administer fluids, medicines and nutrients or to obtain blood samples. These include devices inserted peripherally, as well as those inserted into larger veins
<b>Invasive device</b>	Any device that requires insertion through skin or other normal body defences
<b>Luer connector</b>	A system of attaching catheters, syringes, tubes and any other components of IVAD to each other
<b>Meatus (urethral)</b>	External opening of the urethra
<b>MeSH</b>	Medical subject heading
<b>Meta-analysis</b>	The combination of data from several studies to produce a single estimate of an effect of a particular intervention
<b>Meticillin-resistant <i>Staphylococcus aureus</i> (MRSA)</b>	Strains of <i>S. aureus</i> that are resistant to many of the antibiotics commonly used to treat infections. Epidemic strains also have a capacity to spread easily from person to person
<b>Midline catheter</b>	A long peripheral venous catheter inserted in the antecubital vein and advanced to a vein in the upper arm. Designed for short-term (up to 4 weeks) intravenous access
<b>Mucosa</b>	A membrane lining many tubular structures and cavities such as respiratory tract
<b>Needle-free devices (also needleless intravascular catheter connectors)</b>	Intravascular connector systems developed to help reduce the incidence of needlestick injury while facilitating medication delivery through intravascular catheters. There are three types of needle-free connectors: blunt cannula (two-piece) systems, one-piece needle-free systems, and one-piece needle-free systems with positive pressure
<b>Needle safety device (also needle protection/prevention device)</b>	Any device designed to reduce the risk of injury associated with a contaminated needle. This may include needle-free devices or mechanisms on a needle, such as an automated resheathing device, that cover the needle immediately after use
<b>Needlestick injury</b>	The puncture of skin by a contaminated needle or other sharp medical device
<b>Neutropenia</b>	Abnormal decrease in the number of neutrophils in peripheral blood, which results in increased susceptibility to infections
<b>Nitrile</b>	A synthetic rubber made from organic compounds and cyanide
<b>Observational study</b>	A retrospective or prospective study in which the investigator observes participants, with or without control groups
<b>Organic matter</b>	Any derivative of a living or once-living organism
<b>Outbreak</b>	Two or more cases of the same disease where there is evidence of an epidemiological link between them
<b>Parenteral feeding (intravenous feeding)</b>	Administration of nutrients by an infusion into a vein

<b>Particulate filter masks (or respirator masks)</b>	Face masks designed to protect the wearer from inhaling airborne particles including microorganisms. They are made to defined performance standards that include filtration efficiency. To be effective, they must be fitted close to the face to minimise leakage
<b>Pathogen</b>	A microorganism that causes disease
<b>Peer-reviewed research</b>	An independent assessment or evaluation of the research by a professional with knowledge of the field
<b>Percutaneous injury</b>	An injury that results in a sharp instrument/object (e.g. needle, scalpel) puncturing the skin
<b>Peripheral inserted central venous catheter (PICC)</b>	A vascular catheter inserted into the superior vena cava from the basilic or cephalic vein
<b>Personal protective equipment (PPE)</b>	Specialised clothing or equipment worn to protect against substances or situations that present a hazard to health or safety
<b>Phlebitis</b>	Inflammation of a vein
<b>Post-exposure prophylaxis</b>	Drug treatment regimen administered as soon as possible after an occupational exposure to reduce the risk of acquisition of a bloodborne virus
<b>Povidone iodine</b>	A topical preparation used for antiseptics of the skin in a form of solution or ointment
<b>Prevalence</b>	The number of events (e.g. cases of disease) present in a defined population at one point in time
<b>Prospective study</b>	Study in which people are entered into the research and then followed-up over a period of time with events recorded as they happen
<b>Peripheral venous catheter (PVC)</b>	A small, flexible tube placed into a peripheral vein for the safe infusion of medications, hydration fluids, blood products and nutritional supplements
<b>Quasi-experimental study</b>	Quasi-experimental research designs specifically lack the element of random assignment of participants (individuals or clinical settings/units) to the treatment or the control group. Randomisation minimises the risk that patients entered into the control and treatment groups will be different
<b>Randomised controlled trial (RCT) and non-randomised controlled trial (NRCT)</b>	An RCT is a clinical trial where at least two treatment groups are compared, one of them serving as the control group. Allocation to the group uses a random, unbiased method. An NRCT compares a control and treatment group but allocation to each group is not random. Bias is more likely to occur in an NRCT
<b>Resident (hand) flora</b>	Microorganisms that live in the deeper crevices of skin and hair follicles. These form part of the normal flora of the body and are not readily transferred to other people or objects, or removed by the mechanical action of soap and water. They can be reduced in number with the use of antiseptic soap
<b>Respirator</b>	See 'particulate filter masks'
<b>Retrospective study</b>	A study in which data are captured from historical records of exposures and disease
<b>Sepsis</b>	A severe, systemic reaction of the immune system to infection that can result in organ failure and death
<b>Severe acute respiratory syndrome (SARS)</b>	A severe form of pneumonia caused by a coronavirus
<b>Sharps</b>	Instruments used in delivering health care that can inflict a penetrating injury. Examples include needles, lancets and scalpels
<b>Spore</b>	A resistant structure produced by microorganisms that enable it to survive adverse conditions
<b>Sterilisation</b>	A process that removes or destroys all microorganisms including spores
<b>Surgical masks</b>	A mask that covers the mouth and nose to prevent droplets from the wearer being expelled into the environment. As they are also fluid repellent, they provide some protection for the wearer against exposure of mucous membranes to splashes of blood/body fluid
<b>Systematic review</b>	Research that summarises the evidence on a clear question according to a defined protocol using explicit and systematic methods to identify, select and appraise relevant studies and extract, collate and report their findings

<b>Systemic infection</b>	An infection where the pathogen is distributed throughout the body, rather than being concentrated in one area
<b>Terminal cleaning</b>	The decontamination of a room or patient area after a patient has been transferred or discharged in order to ensure that any dirt, dust or contamination by potentially pathogenic microorganisms is removed before use by another patient
<b>Thrombocytopenia</b>	A reduction in the number of platelets (thrombocytes) in the blood. This may result in bleeding into the skin, spontaneous bruising or prolonged bleeding after injury
<b>Thrombosis</b>	A clot in a blood vessel caused by coagulation of blood
<b>Thrombophlebitis</b>	Phlebitis (vein inflammation) related to a thrombus (blood clot)
<b>Transient (hand) flora</b>	Microorganisms acquired on the skin through contact with surfaces. The hostile environment of skin means that they can usually only survive for a short time, but they are readily transferred to other surfaces touched. Can be removed by washing with soap and water, and most are destroyed by alcohol-based hand rubs
<b>Urinary tract infection (UTI)</b>	The invasion of the tissues of the bladder by microorganisms causing symptoms or signs of infection such as dysuria, loin pain, suprapubic tenderness, fever, pyuria and confusion