What Features of Educational Interventions Lead to Competence in Aseptic Insertion and Maintenance of CV Catheters in Acute Care?

A BEME Systematic Review

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Abbreviations

BNI – British Nursing Index database

CABSI – Catheter-acquired blood-stream infection

CI – Confidence intervals

CINAHL – Cumulative Index to Nursing and Allied Health Literature database

CME – Continuing medical education

CRBSI – Catheter-related blood-stream infection

CVAD – Central venous access device

CVL – Central venous line

Embase – Excerpta Medica database

ERIC – Educational Resource Information Center database

HMIC – Health Management Information Consortium database

Medline – US National Library of Medicine bibliographic database

MSBP – Maximal sterile barrier precautions

PEM – Printed educational materials

PsychLit – Psychology Literature database

RDRB – Research and Development Resource Base database

RR – Risk ratio

TIMElit – Topics in Medical Education (literature) database

Introduction

Intact skin is an effective barrier to the ingress of pathogenic micro organisms, yet the necessities of modern healthcare have increased the reliance on indwelling intravascular devices. These devices, which breach the skin defence, cause tissue damage and leave a foreign body in-situ, increase the risk of infection for patients. Intravascular devices are used for nutritional support, fluid replacement, drug administration, monitoring and renal replacement therapy. Central venous catheters, also referred to as CVCs, are intravascular devices whose tips terminate in a great vessel. They are almost ubiquitous in patients requiring critical care (*Eggimann, 2007*) and are also increasingly common outside the intensive environment and in the community (*Woodrow, 2002*).

In the UK, approximately 200,000 CVCs are inserted each year (*Worthington et al., 2005*). The National Survey of nosocomial blood stream infections completed in 2002 recorded over 10,000 episodes of bacteraemia, with a mean rate of 0.6 bacteraemia per 1000 patient days (*Health Protection Agency*). In this survey, CVCs were the commonest source of hospital-acquired bacteraemia. It is estimated by *Shapey et al., 2008*, that 6000 patients per year in England acquire a catheter related blood-stream infection (CRBSI). 70 % of all healthcare associated infections in a recent study were primary blood stream infections and nearly half of these were related to central venous catheters (*Smyth et al., 2008*).

In the USA, published rates of CRBSI vary in the intensive care setting from 1.0 to 5.6 per 1000 catheter days, and outside critical care from 0.5 to 2.04 per 1000 catheter days (*Provonost et al., 2006*). Although bloodstream infection is the most serious infectious sequelae of CVC insertion, other forms of infection are also common yet are subject to less national surveillance and scrutiny, such as skin and soft tissue infections of the exit site or tunnel. Risk factors for CRBSI include patient factors such as malnutrition (*Curtis, 2008*), poor skin integrity, immunosupression and existing infection (*Ranasinghe et al., 2008*) as well as device factors; location of device, number of lumen, type of catheter, duration of placement and type of dressing (*Ranasinghe et al., 2008, Maki et al., 2006*).

Healthcare worker variables are also significant, such as insertion technique and nurse to patient ratio. The organisms causing CRBSI vary according to the clinical setting but in all instances Gram-positive organisms predominate. Coagulase-negative staphylococci (CoNS) are the commonest organism associated with intravascular device infection and these organisms have been increasingly reported as the cause of blood stream infections in the UK (*Health Protection Agency*).

CoNS are the causative organism of CRBSI in 39% of cases and *Staphylococcus aureus* in 26% with Gram-negative bacilli and *Candida spp* in 14% and 11% respectively (*Woodrow, 2002*). The organisms gain entry to the catheter via a number of routes most often from colonisation of the skin at the exit site or from

colonisation/contamination of the catheter hub or the line access device. The organisms colonising these sites may have originated from the patient's own bacterial flora or may be introduced to the site on the hands of healthcare workers during insertion or catheter care (*Fletcher et al., 1999*). Rarely the infuscate can become contaminated giving rise to infection; in these situations outbreaks have occurred (*Goldmann et al., 1993*). It is also possible for the catheter to become infected as a consequence of bacteraemia from a focus distant to the device (*Elliott, 1988*). Interaction between the organism and the catheter surface involves a series of interrelated steps including adherence, persistence and dissemination. In-vitro the attachment of CoNS to catheter materials occurs rapidly (*Peters et al., 1982*).

The in-vivo situation is more complex as shortly after insertion the catheter is coated with serum and tissue proteins, which may increase the adhesion of specific organisms. Persistence of CoNS on catheters following attachment has been attributed to the production of extracellular polysaccharide by the organism. This biofilm coating provides not only physical protection but may also have immunomodulating properties to protect the organism from host defences (*Riber et al., 1995*). Apart from some exit site infections, characterized by erythema and purulent discharge, the clinical diagnosis of CRBSI can be difficult. Clinical signs have a poor correlation with confirmed CRBSI and the diagnosis often relies on the occurrence of a systemic inflammatory response in the presence of an intravascular device with no other focus for infection.

Although a consequence of modern healthcare, CRBSI represent a considerable burden on morbidity and mortality. Warren demonstrated an increased length of stay in intensive care attributable to CRBSI of 2.41 days and in hospital of 7.54 days (*Warren et al., 2006*). Although direct mortality figures for CRBSI are contentious, unadjusted mortality in the same study was significantly higher in the CRBSI patients than in controls (51% vs. 28%) (*Warren et al., 2006*). As pathogens acquire resistance mechanisms and multiply, resistant organisms become more prevalent (*Health Protection Agency*), and therefore morbidity and mortality are likely to increase, as will the cost. Many nosocomial infections are preventable and there are clear, evidence-based, guidelines published to optimise the care of patients who need central lines, designed to minimise the risk of infection (*EPIC, CDC, 2002*). These guidelines include the use of maximal sterile barrier precautions during insertion, hand decontamination, use of 2% alcoholic chlorhexidene for skin antisepsis, use of transparent semi permeable dressings and regular inspection of the insertion site. Implementation of these guidelines has resulted in significant and sustained reductions in CRBSI (*Provonost et al., 2002*), and cost (*Hu et al., 2004*). As a result both the Department of Health in the UK and the Institute for Healthcare Improvement in the USA have made the prevention of CRBSI key elements of their Saving Lives and 100,000 Lives campaigns respectively.

In recent years, guidance documents and legislation have been generated by the Department of Health to support the development and practice of infection prevention and control in the NHS (*Department of Health, 2002, 2003, 2005, 2006*). Prior to these initiatives, the most significant change was the publication of the Cooke report in 1995 (*Department of Health, 1995*). This report, which revised earlier guidance, was a milestone in the organization of infection control in hospitals and strengthened the surveillance of HCAI. Although this report did not directly address the issue of central line insertion and care, it provided a solid basis for the routine collection of infection surveillance data in hospitals. The date of publication of this report was established as the boundary of the search in the current review as publications prior to this date are unlikely to reflect current practice in infection prevention and including earlier studies may affect the generalisability of the results of the review and subsequent transference of these results into practice.

This systematic review aims to inform medical and healthcare professionals, trainers, educationalists and educational researchers on the most effective features of educational interventions that lead to competence in aseptic insertion and maintenance of CV catheters in acute care.

Previous reviews (*Cheater et al., 2001, O'Brien et al., 2001, Jamdveldt et al., 2006. Farmer et al., 2008, Gorman et al., 1998*) have focused on specific educational interventions, such as the use of printed educational materials (*Farmer et al., 2008*), audit and feedback (*Jamdveldt et al., 2006)* and reminders (*Gorman et al., 1998*) with no specific healthcare worker or sector target population. This review aims to address a specific proportion of the healthcare sector- healthcare workers responsible for insertion and maintenance of central venous catheters. It aims to be a focused attempt to unravel the most effective components of educational interventions in determining behavioural change in this subset of healthcare workers.

The majority of healthcare professionals regularly participate in continuing healthcare education to improve attitudes, knowledge, skill base or behaviour. Doctors spend on average, between one and three weeks a year attending educational meetings (*Frank 2000, Goulet 1998, Nylenna*, *2000*). In addition to educational meetings, healthcare professionals also utilise other educational means to improve their practice and ultimately improve patient outcomes. Although there are many ways individuals develop as professionals, such as the reading of scientific journals, accessing of web resources, following of national guidelines and attending scientific conferences, there is little consistent evidence to demonstrate how healthcare professionals' behaviour is influenced by educational delivery (*Fingerhut, 2005*).

Despite this inconsistency, educational interventions are a frequently used, costly and core method of dissemination of new knowledge within acute healthcare.

Arguably. it can be, not only difficult to measure the impact of different educational interventions but also the impact of each educational intervention on each occasion it is used (*Grimshaw et al., 2004*). Variation in selection and reporting of study design, outcome measures, healthcare professional characteristics and content and delivery of educational interventions themselves have lead to difficulties in dissemination and comparison of results, notably found by both *Davis (1995),* and *Oxman (1995)* whilst systematically reviewing the available evidence for continuing medical education.

These limitations aside, findings, both from primary research and systematic reviews, suggest that some interventions are the most effective at evoking change than others (*Davis 1995, Oxman 1995*), such as interventions guided and supported by patients and those using reminders. Dissemination of knowledge through peers or "opinion leaders" has also been found to be effective, a process known as 'academic detailing' (also supported by *Lomas et al., 1991*). The notion of academic detailing has been shown to lead to long term, significant and sustained alterations in healthcare professionals' behaviour (*Lomas et al., 1991, Everitt et al., 1990, Avorn et al., 1983, Schaffner et al., 1983, Ray et al., 1985, Ray et al., 1986*), providing that concurrent measures are introduced to ensure an applicable atmosphere for adoption of new practice (*Rogers, 1983*).

The results from systematic reviews investigating education with no additional interventions were found to be inconclusive (*Davis, 1995, Oxman, 1995*). Without reinforcement, formal educational conferences and activities including role playing and peer discussion were found to have only a small impact on altering behavioural patterns; a sobering fact when considering that (by self report) time spent by healthcare professionals attending such educational meetings, which are often mandatory, is second only to time spent reading (*Frank, 2000*).

There has been some work looking at the effects of educational interventions with regards to clinical practice. Research into the use of printed educational materials (PEM) indicates that their value as educational tools is varied: a positive impact on clinical practice has been shown using PEM to disseminate national guidelines (*Black 2002*) - providing environmental factors upon implementation were conducive to change - yet a systematic review investigating the effect of printed educational material showed only a small effect compared to no intervention (*Freemantle 1997*). It has been argued that PEM have value as educational tools when disseminating guidelines when such proposals do not require prior knowledge or skills, are grounded in evidence, are easily implemented within the work environment, and do not contradict values of the professionals involved (*Burgers 2003, Grol 1998*). Yet they may still reach a ceiling level with their effect.

A less time consuming, more widely used subset of education is provision of feedback to healthcare professionals. The effects of feedback have been found to be beneficial in changing behaviour (*Eisenberg, 1986, Billi et al., 1992, Manheim et al., 1990, Kroenke et al., 1990, Frazier et al., 1991, McPhee et al., 1989*) but have not been well researched in terms of effect on patient outcomes. In other studies, feedback has been shown to have little or no effect on physicians' practices (*Lomas et al., 1991*). The discrepancies between such findings suggest that feedback should be used in conjunction with other interventions to impact on healthcare professionals' behaviour and ultimately patient outcomes. This reinforces a recurring theme throughout the literature: multiple approach educational interventions appear to be most effective at changing behaviour. *Fox et al (*1989) identified that learning and change take place through a series of "impactors" or learning resources, thus such interventions should be individually tailored to specific problems, identified through observation of care practices and informed by local policy, and should be grounded in observational results and standardised measures.

This systematic review is needed to identify specific areas of educational change, with the aim of identifying the most effective method of changing practice related to the aseptic insertion and maintenance of CV catheters. This review aims to collate the best available evidence base in order to allow those managing education programmes to add consistency to the provision of their education delivery to ultimately produce significant and sustained reductions in CRBSI.

Objectives

The objective of this review was to determine individual features of educational interventions that impact on competence in aseptic insertion technique and maintenance of CV catheters by healthcare workers. To evaluate this, we looked at changes in infection control behaviour of healthcare professionals, and considered changes in the clinical welfare of patients involved and in service delivery (where appropriate), provided they could be related directly to the delivery method of the educational intervention. We considered all types of educational intervention involving healthcare professionals responsible for the insertion and maintenance of CV catheters, as detailed below.

Review Question

Following in-group discussion, and feedback from the BEME steering committee, we addressed the following review question:

What features of educational interventions lead to competence in aseptic insertion and maintenance of CV catheters in acute care settings?

In addition, we also explored the following questions:

- What are the effects of individual features of educational interventions on the skills of healthcare professionals and on the institutions in which they work?
- What characterizes the educational interventions that have been described?
- What are the methodological strengths and weaknesses of the reported studies?
- What are the implications of this review for service delivery, the teacher or trainer, the medical education researcher and for ongoing research in this area?

Review Methodology

Group Formation

A Topic Review Group (TRG) was formed comprising of members of the Evidence-based Practice Research Centre (EPRC) at Edge Hill University, Mersey Deanery NHS North West and the Royal Liverpool University Hospital. The collaboration between the EPRC, which is primarily concerned with advancing evidence-based practice through education, research and development, and these healthcare providers, whose primary aims are to assist the new Strategic Health Authority to create world-class health and healthcare systems in the North West of England, was selected to maximise expertise in both educational research methodology and practising clinical experience. The TRG consisted of two practising clinicians, and two research active members of University staff.

Pilot Process

In order to prepare for the BEME systematic review, a pilot process was undertaken. This was intended to determine the scope of the review, size of background literature, to refine the review question and to determine if adaptation of the BEME Coding Sheet (www.bemecollaboration.org/) would be suitable for use in the review.

Preliminary literature search

A scoping literature search was carried out to determine the size of background literature pertaining to the review topic and to develop a potential, encompassing search strategy for use in the final electronic literature searches.

This search was undertaken in July 2008, across Medline. Medline was chosen as the TRG expected that Medline would have the largest body of literature relating to CVCs and the most relevant publications. The pilot Medline search strategy is summarised the Appendix. Ovid Medline was used to determine MeSH search terms, and subject headings of relevant articles were examined to further develop the search strategy.

6035 articles were retrieved as a result of this search, of which the first 200 were screened for eligibility by the lead reviewer. It was apparent that the search strategy needed refinement, and as a result a new search strategy was established and piloted. The new strategy incorporated key phrases and additional subject headings found by examination of relevant studies, and when piloted yielded 1702 studies.

This strategy is summarised the Appendix, and forms the basis of the search used in the final review search. Following this search, two reviewers from the project reviewed the titles and abstracts of the first 200 of the 1702 articles identified by the search. This enabled confirmation that the lead reviewer had an appropriate balance of sensitivity and specificity for relevant evidence which could not be improved by second-screening, and that this researcher alone was able to select articles for further consideration from the main search.

Preliminary pilot of coding sheet

Members of the TRG met to discuss the suitability of the BEME Coding Sheet by piloting it on a number of studies fulfilling the inclusion criteria for review. It became apparent that there was enormous diversity in reporting style and details, and it therefore would not be appropriate at this stage to produce a simple categorical tool to extract data. A more comprehensive sheet was required, with more flexibility to report data as presented. A second coding sheet was devised with free-text reporting boxes for this purpose. This is provided in the Appendix.

We used a quality assessment checklist to supplement the coding sheet. A tick-box method of assessment (based on Shaw et al (in press) and adapted from Downs & Black (1998) and Kmet et al (2004)was adapted to incorporate various facets of study quality such as aims, participant selection and reporting of variables. This method of assessment yielded a quality assessment score for each paper. No study was excluded from the review based solely on quality assessment score.

The following inclusion and exclusion criteria were used:

Types of intervention:

An educational intervention was, for the purpose of this review, defined as a structured educational process intended to increase, improve or enhance the performance of the recipients with regards to the overall health or well being of their patients. Interventions considered for this review included, but were not limited to: courses; lectures; simulations; small group learning session(s); e-learning, curriculum-based learning; shadowing / mentoring; workshops and learning through educational material such as media, posters, handouts and other paper material.

Educational interventions considered were those designed to change staff behaviour with regards to one or more facet of catheter use, including but not limited to: general asepsis; selection of catheter type; selection of insertion site; maximal sterile barrier precautions during insertion; coetaneous antisepsis; catheter site care; catheter replacement strategies and general catheter management principles.

Interventions must have been both structured and educational in their nature to be included in this review. Other interventions such as a reduction in working hours or changes in rates of pay were not considered. Feedback alone or semi-structured educational methods, such as informal teaching were not considered.

Types of participants:

This review focused on the delivery of educational interventions relating to the aseptic insertion technique and maintenance of CV catheters in acute settings. Participants were healthcare professionals who had a responsibility as part of their job role to insert and/or maintain intravenous catheters under aseptic conditions, and had already been designated as 'competent' to do so by their job-role training. Participants were: specialist nurses; registered nurses; doctors; medical residents or other healthcare practitioners that had been specifically trained in regards to insertion and maintenance of CV catheters (as we recognised that, country to country, these labels may have differed).

Studies where the sole participant groups were students, paramedics, domestic staff, dentists, dieticians, hygienists, psychologists, psychotherapists, pharmacists, physiotherapists, occupational therapists, speech therapists, managerial staff, catering staff and support staff were excluded from the review. Studies with participants spanning both groups were included, but only the results from the inclusion participant list were considered.

It was deemed likely that the effectiveness of educational interventions targeting patients would be different to those targeting solely healthcare professionals. Given that the differing programmes to target healthcare professionals were already diverse in their delivery, it was agreed by the TRG that adding another comparator would complicate the report. All studies that did not focus solely on healthcare professionals were therefore excluded. Where studies had focused both on educational interventions delivered to healthcare staff and those delivered to patients, only the results of the healthcare professional intervention was reported and considered. If these were not reported separately from that of the patients, the study was excluded.

Study design:

Both non-comparative (audit, action-based research, case series, historical, narrative, observational and survey-based) and comparative (cross-sectional research, before and after studies, time series studies, non-randomised trials, randomised controlled trials, group randomised trials, case control trials, cohort studies and meta-analysis) research designs were considered for inclusion. General review articles and editorials were not considered but their reference lists were scanned to check all relevant materials were included.

Study setting:

Studies looking at the delivery of educational interventions for management and insertion of CV catheters in acute care settings were considered for the review, including but not limited to ICUs, haemodialysis units, transplant units, chemotherapy units, accident and emergency units, neonatal units and hospitals.

Comparators:

Any comparators were considered for inclusion in the review, including but not limited to use of a control group (e.g. other hospital area/ward), a differing educational intervention and use of differing healthcare groups.

Other inclusions and exclusions:

Studies relating to CV catheters used for administration of fluids, medication, blood components and/or total parental nutrition were included in the review. All studies relating to centrally placed venous catheters were included, regardless of mode of insertion or type of catheter present.

Table 1: Inclusion Criteria

Inclusion criteria	
Study design	• All study designs considered. • Studies conducted and published from 1995 onwards included.
Population	• Healthcare professional participants considered: specialist nurses, registered nurses, doctors, medical residents or other healthcare practitioners specifically trained in regards to insertion and maintenance of CV catheters OR • Contained one or more of the above groups for which results were recorded separately.
Educational Intervention	• Content documentable and repeatable. • Interventions run over defined time period. • Interventions designed to change staff behaviour with regards to one or more facet of CV catheter use.
Comparator	• Any, including but not limited to use of a control group, a differing educational intervention and use of differing healthcare groups.
Outcome Measures	• At least one outcome measure of aseptic central venous catheter maintenance/insertion practice. • Measured using Kirkpatrick's hierarchy (*Kirkpatrick, 1967*)
Setting of study	• Studies carried out in acute care settings considered.
Other inclusion criteria	• Centrally placed venous catheters, regardless of mode of insertion. • Catheters used for administration of fluids, medication, blood components and/or total parental nutrition.

Table 2: Exclusion Criteria

Exclusion criteria	
Study design	• Reviews and systematic reviews. • Studies published before 1995, or in which the study period was prior to 1995.
Population	• Studies where the sole participant groups were: students, paramedics, domestic staff, dentists, dieticians, hygienists, psychologists, psychotherapists, pharmacists, physiotherapists, occupational therapists, speech therapists, managerial staff, catering staff and support staff. • All studies not focusing solely on healthcare professionals, including studies using patients as sole participants. • Studies where results of inclusion healthcare worker groups could not be distinguished from exclusion healthcare professional groups.
Educational Intervention	• Interventions focused on patient education. • Interventions not educational in content, such as change in working hours or change in rates of pay.
Comparator	• No exclusion criteria applied.
Outcome Measures	• No recorded outcome measure of aseptic central venous catheter maintenance/insertion practice.
Setting of study	• Any setting other than acute care setting.
Other exclusion criteria	• Non-centrally placed catheters, including urinary catheters.

Outcome measures of study:

Only studies that used aseptic insertion site catheter maintenance/insertion as an outcome measure for effectiveness of delivery of educational intervention were considered. Effectiveness of delivery of educational interventions into maintenance/insertion of catheters used in response to infection already present were included in the review.

Assessment of outcome measures:

These will be based on modified Kirkpatrick's 1967 model of hierarchical outcomes at four levels, as illustrated in Table 3 Additional predetermined or secondary outcome measures were also accepted and recorded. Kirkpatrick's hierarchy was selected to provide a more comprehensive evaluation, in order to inform this review's development. This model has been used by other BEME review groups (e.g. *Issenberg et al., 2005*) and, once modified, fitted the outcome measures of the review.

Level 1: Reaction

This covers learner's views on the delivery and content of the educational intervention. This may take the form of verbal or written feedback immediately after the delivery of the intervention, and includes learner's views on presentation, organisation, content, teaching methods, time-tabling, materials used and quality of teaching.

Level 2a: Modification of attitudes and perceptions

This relates to any changes in reciprocal attitudes or perceptions between participant groups. This includes any changes in perceptions or attitudes by participants towards the value and/or use of the taught approach to caring for patients, and their condition, circumstances, care and treatment.

Level 2b: Acquisition of knowledge and skills

For knowledge, this relates to the acquisition of concepts, procedures and principles of aseptic CV catheter maintenance and insertion as a direct result of the delivery of the educational intervention.

For skills, this relates to the acquisition of thinking/problem-solving, psychomotor and social skills linked to aseptic CV catheter maintenance and insertion as a direct result of the delivery of the educational intervention.

Table 3

Kirkpatrick's Hierarchy(1967)

Level 3: Behavioural change

This relates to the transfer of principles of aseptic CV catheter maintenance and insertion to the workplace, such as support for change in behaviour in the workplace, or willingness of learners to apply knowledge and skills about aseptic CV catheter insertion and maintenance, obtained as a direct result of the delivery of the educational intervention, to their practice style.

Level 4a: Change in organisational practice

This relates to wider changes in the organisation/delivery of care, attributable to the delivery of an education intervention. These changes may be financial or organisational.

Level 4b: Benefits to patients / clients, families and communities

This relates to any improvements in the health and well being of patients as a direct result of the delivery of an educationalal intervention. Where possible, objectively measured or self reported outcomes will be used, including but not limited to health status measures, infection incidence, duration or cure rates, mortality rates, complication rates, readmission rates, continuity of aseptic CV catheter care and costs to carer or patient. These outcomes will be further determined by the literature found.

Table 3

Kirkpatrick's Hierarchy(1967)

Search Strategy

A comprehensive search was conducted to determine the body of literature pertaining to the review question across all sources relevant to healthcare education and best practise in a clinical context. This search was divided into two sections - an electronic search of relevant health and educational databases, and augmentation of this search using various methods. These will be summarised in detail below.

Searching of literature base

A comprehensive electronic search was carried out in August 2008.

In total, 16 electronic databases were searched. These were chosen to span clinical and educational databases, and are listed in the Appendix, along with the individual search strategies used for each. The initial, piloted strategy pertains to Medline, and was adapted for each database to reflect minor modifications specific to their vocabulary or search terms. Natural language terms were derived for those databases that did not recognise MeSH search headings, such as the National Research Register and Web of Science, and were based on synonyms of a combination of three relevant components - infection control, central venous catheters and education.

Medline records were substituted for duplicated records from other databases when identified due to their standardisation and level of detail. A total of 14,413 studies were retrieved, producing 9964 studies once de-duplicated. Only original research findings were included in the search - editorials and essays were excluded.

A two-stage process was employed to retrieve relevant articles. The lead reviewer (GC) and one other member of the review team (BS) initially screened all titles and abstracts, and eliminated all studies not relating to educational interventions for CV catheter insertion or maintenance. Any discrepancies were discussed with another member of the review team (JB), and a decision was reached. This resulted in 270 studies for which full text was obtained for all, 2.7% of the initial cohort.

A subsequent hand search of high yield journals was carried out (see the Appendix for full list of journals hand searched), followed by a search of reference lists of all

full-text studies, and hand search of the researcher's own files. This yielded a subsequent 43 studies, and cross-checking with the results of the electronic searching confirmed receipt of these studies in the initial electronic cohort.

These 270 full-text studies were independently reviewed by two members of the review team (GC and BS), seeking consensus from a third member (JB) when opinion as to suitability was divided. From this, 47 studies were identified as fulfilling all inclusion criteria and therefore suitable for inclusion in the review.

It cannot be said for certain that all relevant, high quality published material was obtained through the combination of electronic searching and hand searching of journals selected as the most likely robust publishers of related material. However, knowledge within the field of infection control, together with continued monitoring of evidence bases has led us to conclude that this review will encompass as much published material as possible to answer the review question based on the best available evidence, using systematic processes.

Quality assessment

Each full-text paper was doubly read and quality assessed by two members of the review team (GC and JB) to ensure maximum consistency. Quality was assessed using a tool based on that by *Shaw et al (in press)* and adapted from *Downs & Black (1998)* and *Kmet et al (2004)* adapted for use in this review (in the Appendix). Quality was expressed as a score in each of the following categories: Study aims; study design and sample characteristics; data analysis, results and conclusions yielding a percentage score relating to the study. To ensure maximal data, no study was excluded from the review based solely on quality score, although this was considered in the analysis of studies. Inter-reviewer dispute was low, with the resolution of differing opinions by a third member of the group (BS) required on only a handful of papers.

Coding

Each full text paper was coded by a member of the review team. A random sample of 20% of studies was doubly coded to ensure that appropriate, consistent and matching data were collected. No discrepancy was found between reviewers, thus it was deemed appropriate to singly code all. Data collected were entered into Microsoft Excel once collected.

Review analysis

Description of Studies

47 studies met the criteria for inclusion in this review. Of these, 35 were based in the USA, two each in Argentina, Sweden and Turkey and one each in the UK, France, Brazil, Italy, Japan and Mexico. 22 studies used both nurses and doctors (including postgraduate trainees) as participants, whilst 10 focused solely on doctors (*Britt et al.,2007, Ely et al., 1999, Higuera et al., 2005,Miranda et al., 2005 Ramakrishna et al., 2005, Salemi et al., 2000, Sheretz et al., 2000, Velmahos et al., 2004, Xiao et al., 2007, Young et al., 2000)*, 8 solely on nursing staff (*Ahlin et al., 2006, Bjornestam et al., 2000, Crawford et al., 2000, Dinc et al., 2000, East et al., 2005, Hatler et al., 2006, Kennedy et al., 2005, Thibodeau et al., 2007*), and seven on broadly defined "healthcare staff" (*Bhutta et al., 2007, Capretti et al., 2008, Centre for Disease Control and Prevention, 2005, Harnage, 2007, Price et al. 2002,, Render et al.,2006, Rosenthal et al,.2003).*

Outcome measures

25 studies measured a change in healthcare professional's behaviour (Kirkpatrick level 3) as an outcome measure (*Ely et al., 1999, Miranda et al, .2007, Ramakrishna et al., 2005, Ahlin et al., 2006, Crawford et al., 2000, East et al., 2005, Thibodeau et al., 2007, Xiao et al., 2007, Britt et al., 2007, Velmahos et al., 2004, Rosenthal et al., 2003, Render et al., 2006, Sheretz et al., 2000, Lobo et al., 2005, Bhutta et al., 2007, Harnage, 2007, Costello et al., 2008, Salemi et al., 2002, Tsuchida et al., 2007, Coopersmith et al., 2004, Wall et al., 2005, Warren et al., 2006, Berenholtz et al., 2004, Dinc et al., 2000, Higuera et al., 2005),* and 37 measured change in patient outcomes (Kirkpatrick level 4b) as an outcome measure (*Rosenthal et al., 2003, Render et al., 2006, Sherertz et al., 2000, Lobo et al., 2005, Bhutta et al., 2007, Harnage, 2007, Costello et al., 2008, Salemi et al., 2002, Tsuchida et al., 2007, Coopersmith et al., 2004, Wall et al., 2005, Warren et al., 2006, Berenholtz et al., 2004, Dinc et al., 2000, Higuera et al., 2005, Price et al, 2002, Frankel et al, 2005, Goeschel et al, 2006, Young et al., 2006, Capretti et al., 2008, Centers for Disease Control and Prevention, 2005, Curchoe et al., 2002, Gnass et al., 2004, Misset et al., 2004, Berriel-Cass et al., 2006, Coopersmith et al., 2002, McKee et al., 2008, Provonost et al., 2006, Schelonka et al., 2006, Warren et al. , 2003, Warren et al., 2004, Eggimann et al., 2000, Yilmaz et al., 2007, Bishop-Kurylo, 1998, Kennedy et al., 2005, Bjornestam et al., 2000, Hatler et al., 2006*). 15 studies evaluated both change in healthcare professionals' behaviour (Kirkpatrick level 3) and change in

patient outcome (Kirkpatrick level 4b) as outcome measures (*Rosenthal et al., 2003, Render et al., 2006, Sherertz et al., 2000, Lobo et al., 2005, Bhutta et al., 2007, Harnage, 2007, Costello et al., 2008, Salemi et al., 2002, Tsuchida et al., 2007, Coopersmith et al., 2004, Wall et al., 2005, Warren et al., 2006, Berenholtz et al., 2004, Dinc et al., 2000, Higuera et al., 2005).*

There was variation in outcome measures used. Of the 37 studies measuring change in patient outcomes, 29 used infection rates per 1000 CVC days as outcome measures. The remaining studies used measures such as infection rates per 100 parenteral nutrition days (*Kennedy et al., 2005*), comparison of infection rates per 1000 CVC days between intervention and control groups (*Higuera et al., 2005*), number of CRBSI cases pre-and post-intervention (*Harnage, 2007*), country-wide infection percentile values (*Goeschel et al., 2006*), microbial colonisation rates (*Dinc et al., 2000*), frequency and rates of bacteraemia present (*Bjornestam et al., 2000*), CRBSI rates per 100 patient months (Price et al., 2002) and time between onset of CRBSI occurrences (*Gnass et al., 2004*).

Of the 25 studies measuring healthcare professionals' behaviour, two relied on self reporting of behavioural change (*Ely et al., 1999, Ahlin et al., 2006*). 14 studies used compliance with policy as an outcome measure (*Costello et al.,2008, Harnage, 2007, Sheretz et al., 2000, Higuera et al., 2005, Render et al., 2006, Miranda et al., 2007, Xiao et al., 2007, Salemi et al., 2002, Bhutta et al., 2007, Coopersmith et al., 2004, Warren et al., 2006*), and 8 studies used improvement in observed practice as an outcome measure (*Britt et al., 2007, Thibodeau et al., 2007, Lobo et al., 2005, Tschuida et al., 2007*, *East et al., 2005, Velmahos et al., 2004, Ramakrishna et al., 2005, Miranda et al., 2004, Crawford et al., 2000, Warren et al., 2006*). Two studies reported no behavioural change attributed to education (*Wall et al., 2005, Rosenthal et al., 2007*).

Educational delivery

The format of the education varied between studies, creating eight groups of intervention:

Multimodal education with a demonstration - seven studies (*Ely et al., 1999, Ahlin et al., 2006, Sherertz et al., 2000, Harnage, 2007, Costello et al., 2008, Curchoe et al., 2002, Eggimann et al., 2000*).

Multimodal education with no demonstration - nine studies (*Thibodeau et al., 2007, Render et al., 2006, Lobo et al., 2005, Higuera et al., 2005, Provonost et al., 2006, Bishop-Kurylo, 1998, Bjornestam et al., 2000, Hatler et al., 2006, Centers for Disease Control and Prevention, 2005).*

Self-study - two studies *(East et al., 2005, Wall et al., 2005).*

Multimodal education with a simulator - four studies *(Ramakrishna et al., 2005, Velmahos et al., 2004, Britt et al., 2007, Miranda et al., 2007).*

Multimodal education with a video - five studies *(Bhutta et al., 2007, Frankel et al., 2005, Xiao et al., 2007, Salemi et al., 2002 Schelonka et al., 2006).*

Multimodal education with demonstration, self study module and behavioural intervention - two studies *(Coopersmith et al., 2004, Kennedy et al., 2005,).*

Multimodal education with self study module - ten studies *(McKee et al., 2008, Tschuida et al., 2007, Berenholtz et al., 2004, Yilmaz et al., 2007, Coopersmith et al., 2002, Warren et al., 2003, Crawford et al., 2000, Dinc et al., 2000, Warren et al., 2004, Warren et al., 2006)*

Mode of delivery of education not specified - eight studies *(Capretti et al., 2008, Rosenthal et al., 2003, Berriel-Cass et al., 2006, Young et al., 2006, Gnass et al., 2004, Misset et al., 2004, Price et al., 2002, Goeschel et al., 2006).*

Ten studies also used other interventions in addition to education, such as the use of a bundle (including a checklist) *(Berriel-Cass et al., 2006, Frankel et al., 2005, McKee et al., 2008, Provonost et al., 2006, Wall et al., 2005),* a stepwise intervention *(Bhutta et al., 2007),* or other additional interventions (*Lobo et al., 2005, Rosenthal et al., 2003, Tschuida et al., 2007, Bishop-Kurylo, 1998*).

Included studies are summarised in the Appendix.

Effects of interventions

Educational Intervention 1: Education, multimodal with demonstration

There were seven studies that investigated the effect of multimodal education with demonstration, with eight comparative groups *(Curchoe et al., 2002).* Of these, four measured behavioural change in healthcare professionals (Kirkpatrick level 3) *(Sheretz et al., 2000, Ely et al., 1999, Costello et al., 2008, Ahlin et al., 2006)*, and five measured change in patient or organisational outcome additionally (Kirkpatrick level 4b) (*Harnage et al., 2007, Curchoe et al., 2002, Sheretz et al., 2000, Costello et al., 2008, Eggimann et al., 2000)*. Three studies used both doctors and nurses as participants (*Eggimann et al., 2000, Costello et al., 2008, Curchoe et al., 2002*), one used nurses as a sole participant group (*Ahlin et al., 2006*), one used a multi-disciplinary participant group (*Harnage el al., 2007*), and two used doctors as a sole participant group *(Ely et al., 1999, Sheretz et al., 2000).*

All educational interventions contained the following components: education of staff, followed by demonstrations. Education of staff took several forms: Three studies specified classes (*Ahlin et al., 2006, Ely et al., 1999, Sheretz et al., 2000)*, two studies specified presentations (*Eggimann et al., 2000, Costello et al., 2008*),two specified in-service training (*Hatler et al., 2007, Eggimann et al., 2000*), one specified the use of posters (*Curchoe et al., 2002*), and another the use of educational cards (*Hatler et al., 2007)* and handouts (*Costello et al., 2008).*

Demonstrations are described as practical (*Sheretz et al., 2000, Ely et al., 1999, Costello et al., 2008, Ahlin et al., 2006, Curchoe et al., 2002, Harnage et al., 2007)* using mannequins and real patients.

Three studies also contained other components, in addition to education (*Costello et al., 2008, Harnage et al., 2007, Ahlin et al., 2006).* Other components of the interventions included: bundle kits (*Costello et al., 2008)*, change in supplies (*Costello et al., 2008, Harnage et al., 2007*), and feedback (*Costello et al., 2008*).

Kirkpatrick level 3:

Changes in behaviour were reported via the following outcome: change in adherence or compliance with policy (*Sheretz et al., 2000, Ely et al., 1999, Costello et al., 2008, Ahlin et al., 2006).*

Statistically significant behavioural changes occurred in three of the four studies (*Sheretz et al., 2000, Ely et al., 1999, Costello et al., 200,*). Accepted significance values ranged from 0.001 to 0.004. The fourth study (*Ahlin et al., 2006*) did not report

a statistically significant change in behavioural outcome, although changes in behaviour were reported.

Duration of follow up ranged from four months to nine months.

Kirkpatrick level 4:

Changes in organisational and patient outcome were reported via the following outcomes: Cost savings (*Sheretz et al.*), CRBSI rates per 1000 CVC days (*Costello et al., 2008, Curchoe et al., 2002, Sheretz et al., 2000, Eggimann et al., 2000*), time between infections (*Costello et al., 2008*), and number of infection cases (*Harnage et al., 2007*).

Statistically significant behavioural changes occurred in three of the five studies (*Costello et al., 2008, Curchoe et al., 2002, Sheretz et al., 2000*). Of the four studies measuring CRBSI rate per 1000 CVC days (*Curchoe et al., 2002. Sheretz et al., 2000, Costello et al., 2008, Eggimann et al., 2000*), three reported statistically significant results (*Curchoe et al., 2002. Sheretz et al., 2000, Costello et al.*). Accepted significance values ranged from 0.0003 to 0.01.

The study measuring time between infections (*Costello et al., 2008*) showed a statistically significant result (p 0.008). The study measuring risk factors for infection (*Provonost et al., 2006*) produced statistically significant results (p 0.01). The study measuring number of infection cases (*Harnage et al., 2007*) showed no statistically significant results.

Duration of follow up ranged from six months to 17 months, with 1 study reporting no data about length of follow up (*Curchoe et al., 2002).*

Estimated cost savings were reported by one study (*Sheretz et al., 2000*) at between $36000 and $800000.

Educational Intervention 2: Education, multimodal without demonstration

There were nine studies that investigated the effect of multimodal education without demonstration, with 10 comparative groups *(Render et al., 2006, Center for Disease Control and Prevention, 2005, Higuera et al., 2005).* Of these, three measured behavioural change in healthcare professionals (Kirkpatrick level 3) *(Lobo et al., 2005, Render et al., 2006, Higuera et al., 2005)*, and nine measured change in patient or organisational outcome additionally (Kirkpatrick level 4b) (*Center for Disease Control and Prevention, 2005, Lobo et al., 2005, Render et al., 2006, Bishop-Kurylo, 1998, Provonost et al., 2006, Bjornestam et al., 2000, Hatler et al., 2006, Higuera et al., 2005, Thibodeau et al., 2007*). Two studies used both doctors and nurses as participants (Lobo *et al., 2005, Provonost et al., 2006*), four used

nurses as a sole participant group (*Render et al., 2006, Bjornestam et al., 2000, Hatler et al., 2006, Thibodeau et al., 2007*), two used a multi-disciplinary participant group (*Bishop-Kurylo, 1998, Center for Disease Control and Prevention, 2005*), and one used doctors as a sole participant group *(Higuera et al., 2005).* Three studies educated team leaders for them to disseminate findings to other team members *(Thibodeau et al., 2007, Bishop-Kurylo, 1998, Provonost et al., 2006).*

All educational interventions contained the following components: education of staff using no demonstrations. Education of staff took several forms: Four studies specified classes (*Muto et al., 2005, Lobo et al., 2005, Bjornestam et al., 2000, Higuera et al., 2005)*, two studies specified meetings (*Render et al., 2006, Bishop-Kurylo, 1998*), one specified newsletters (*Hatler et al., 2006*), one specified nurse led programmes (*Thibodeau et al, 2007*), and one specified conference calls (*Provonost et al., 2006*).

Five studies also used additional educational materials, such as posters, fact sheets and printed information *(Hatler et al., 2006, Lobo et al., 2005, Render et al., 2006, Provonost et al., 2006, Thibodeau et al., 2007).*

Seven studies also contained other components, in addition to education (*Hatler et al., 2006, Lobo et al., 2005, Bishop-Kurylo, 1998, Provonost et al., 2006, Higuera et al., 2005, Thibodeau et al., 2007, Render et al, 2006).*

Other components of the interventions included: discussions (*Lobo et al., 2005, Provonost et al., 2006, Thibodeau et al., 2007)*, change in supplies (*Lobo et al., 2005, Bishop-Kurylo, 1998, Provonost et al., 2006, Higuera et al., 2005, Thibodeau et al., 2007*), and feedback (*Hatler et al., 2006, Bishop-Kurylo, 1998, Provonost et al., 2006, Higuera et al., 2005, Render et al, 2006*). One study used rewards as incentives *(Hatler et al., 2006)*, and one study changed policy *(Thibodeau et al., 2007).*

One study used a rapid cycle approach (*Hatler et al., 2006*), and focused on reduction of ventilator acquired pneumonia in addition to central venous catheter infection rates.

Kirkpatrick level 3:

Changes in behaviour were reported via the following outcome: change in adherence or compliance with policy (*Lobo et al., 2005, Render et al., 2006, Higuera et al., 2005).*

Statistically significant behavioural changes occurred in two of the three studies (*Lobo et al., 2005, Higuera et al, 2005*). Accepted significance values ranged from 0.0000 to 0.001. The third study (*Render et al., 2006*) did not report a statistically significant change in behavioural outcome, although changes in behaviour were reported.Duration of follow up ranged from eight months to 12 months.

Kirkpatrick level 4:

Changes in organisational and patient outcome were reported via the following outcomes: Cost savings (*Hatler et al., 2006*), CRBSI rates per 1000 CVC days (*Lobo et al., 2005, Render et al., 2006, Provonost et al., 2006, Center for Disease Control and Prevention, 2005, Hatler et al., 2006, Higuera et al., 2005*), risk factors for infection (*Provonost et al., 2006*), bacteraemia or pathogen levels (*Lobo et al., 2005, Bjornestam et al., 2000*) and PICC replacement rates (*Thibodeau et al., 2007*).

Statistically significant behavioural changes occurred in five of the nine studies (*Muto et al., 2005, Lobo et al., 2005, Render et al., 2006, Provonost et al., 2006, Higuera et al., 2007*). Of the seven studies measuring CRBSI rate per 1000 CVC days (*Hatler et al., 2006, Bishop-Kurylo, 1998, Provonost et al., 2006, Center for Disease Control and Prevention, 2005, Higuera et al., 2005, Render et al, 2006, Lobo et al., 2005*), four reported statistically significant results (*Provonost et al., 2006, Higuera et al., 2005, Render et al, 2006, Center for Disease Control and Prevention, 2005*) . Accepted significance values ranged from 0.0001 to 0.05.

Of two studies measuring bacteraemia or pathogen levels (*Lobo et al., 2005, Bjornestam et al., 2000*), one showed a statistically significant result (*Lobo et al., 2005,* p 0.02). *Bjornestam et al., 2000* showed no effect from the intervention. The study measuring risk factors for infection (*Provonost et al., 2006*) produced statistically significant results (p 0.01). The study measuring PICC replacement rates (*Thibodeau et al., 2007)* did not show statistically significant results.

Duration of follow up ranged from eight months to 18 months, with one study reporting no data about length of follow up (*Thibodeau et al., 2007*).

Estimated cost savings were reported by one study (*Hatler et al., 2006*) at between $220150 and $1309000. This study also found a reduction in rates of VAP.

Educational Intervention 3: Self study

There were two studies that investigated the effects of self study, with no comparative groups *(Wall et al., 2005, East et al., 2005).* Of these, both measured behavioural change in healthcare professionals (Kirkpatrick level 3), and one measured change in patient outcome additionally (Kirkpatrick level 4b) (*Wall et al., 2005*). One used nurses as the sole participant group (East et al., 2005), and one used both doctors and nurses as the participant group (Wall et al., 2005).

Both educational interventions contained self study as the main educational component, though in different forms; Wall et al. (2005), used a mandatory Web-based tutorial, whilst East et al., 2005, used a paper-based self study module containing a poster and fact sheet. East et al., 2005 did not use additional interventions for the duration of the study period. Wall et al., 2005 also used a standardised nursing checklist, monitoring of practice and continuous monthly audit

and feedback. The effects of the education were not able to be differentiated from the additional interventions.

Kirkpatrick level 3:

Statistically significant behavioural changes occurred in one study (*East et al., 2005)* with accepted significance levels of less than 0.05. Duration of follow up ranged from between one and two months (Wall et al., 2005) to 12 months (East et al., 2005).

Changes in behaviour were reported via the following outcomes: Compliance with CVC policy (*East et al., 2005, Wall et al., 2005*) and number of CVCs inserted in femoral vein (*Wall et al., 2005*).

Kirkpatrick level 4:

Wall et al., 2005, also measured change in patient outcome, and reported a change, but no statistically significant reported difference pre-and post-educational intervention when analysing CVC infection rate rates per 1000 CVC days.

Educational Intervention 4: Multimodal education with a simulator

There were four studies that investigated the effect of multimodal education with a simulator, with seven comparative groups *(Ramakrishna et al., 2005, Miranda et al., 2007, Velmahos et al., 2004, Britt et al., 2007).* Of these, all measured behavioural change in healthcare professionals (Kirkpatrick level 3), and one measured change in patient outcome additionally (Kirkpatrick level 4b) (*Miranda et al., 2007*). All used medical residents as a participant group.

All educational interventions contained the following components: education of procedure prior to practical component, supervised practice of CVC insertion (using artificial simulator in three studies- *Miranda et al., 2007, Velmahos et al., 2004 and Britt et al., 2007*, and using real patient in simulation laboratory in 1 study- *Ramakrishna et al, 2005*.), and observation or instruction during and prior to insertion. No study used additional interventions for the duration of the study period. One study used self-study materials to supplement the educational intervention (*Velmahos et al., 2004*). This study also used the principles of Cognitive Task Analysis as a basis for the intervention.

Kirkpatrick level 3:

Statistically significant behavioural changes occurred in three of the four studies (*Ramakrishna et al., 2005, Miranda et al., 2007,, Velmahos et al., 2004)* with accepted significance levels ranging from >0.001 to 0.05). Duration of follow up ranged from 2.5 months to 3 years.

Changes in behaviour were reported via the following outcomes: number of IJCVLPs placed over 3 years post-intervention (*Ramakrishna et al., 2005*), likelihood of

success to perform insertion steps correctly (*Velmahos et al., 2004*), use of MSBP post-intervention (*Miranda et al., 2007*) and competence in placing central line (*Britt et al., 2007*).

Kirkpatrick level 4:

Miranda et al., 2007, also measured change in patient outcome, and found no statistically significant difference between control and intervention groups when analysing complication rates per 1000 CVC days (p=0.29).

Educational Intervention 5: Education, multimodal with video

There were five studies that investigated the effect of multimodal education with video, with seven comparative groups *(Xiao et al., 2007).* Of these, three measured behavioural change in healthcare professionals (Kirkpatrick level 3) *(Bhutta et al., 2007, Xiao et al., 2007, Salemi et al., 2002)*, and four measured change in patient or organisational outcome additionally (Kirkpatrick level 4b) (*Bhutta et al., 2007, Frankel et al., 2005, Salemi et al., 2002, Schelonka et al., 2002*). Two studies used doctors as the sole participants (*Xiao et al., 2007, Salemi et al., 2002*), one did not specify their participant group (*Bhutta et al., 2007*), and two used doctors and nurses as a participant group *(Frankel et al., 2005, Schelonka et al., 2006).*

All educational interventions contained the following components: education of staff and the use of videos. Education of staff took several forms: Three studies used videos as the main means of education (*Schelonka et al., 2002, Xiao et al., 2007, Frankel et al., 2005*), and two studies used videos in addition to other means of education (*Salemi et al., 2006, Bhutta et al., 2007*). One study used paper material as a control group (*Xiao et al., 2007*). One study specified the use of posters (*Bhutta et al., 2007*), and others the use of materials such as banners, posters and flyers (*Bhutta et al., 2007, Salemi et al., 2006)* and handouts (*Costello et al., 2008).*

Four studies also contained other components, in addition to education (*Bhutta et al., 2007, Frankel et al., 2005, Salemi et al., 2006, Schelonka et al., 2002).*Other components of the interventions included: stepwise programme instigation (*Bhutta et al., 2007)*, change in supplies (*Frankel et al., 2005, Bhutta et al., 2007*), and feedback (*Schelonka et al., 2002, Salemi et al., 2006*). *Salemi et al., 2006* also used rewards as incentives for staff.

Kirkpatrick level 3:

Changes in behaviour were reported via the following outcome: change in adherence or compliance with policy (*Bhutta et al., 2007, Xiao et al., 2007, Salemi et al., 2002).*

Statistically significant behavioural changes occurred in no studies, although changes in behaviour were reported.Duration of follow up ranged from 23 months to 24 months.

Kirkpatrick level 4:

Changes in organisational and patient outcome were reported via the following outcomes: CRBSI rates per 1000 CVC days (*Bhutta et al., 2007, Frankel et al., 2005, Schelonka et al., 2002*), and nosocomial infection rates per 1000 patient days (*Salemi et al., 2006).*

Statistically significant behavioural changes occurred in three of the four studies (*Bhutta et al., 2007, Frankel et al., 2005, Schelonka et al., 2002*). Of the three studies measuring CRBSI rate per 1000 CVC days two reported statistically significant results (*Bhutta et al., 2007, Frankel et al., 2005*). Accepted significance values ranged from 0.0001 to 0.001.

The study measuring nosocomial infection rates (*Salemi et al., 2006*) showed no statistically significant results, but did show a reduction in infection rates post-intervention.

Duration of follow up ranged from 23 months to 24 months, with three studies reporting no data about length of follow up (*Frankel et al., 2005, Salemi et al., 2006, Xiao et al., 2007).*

Estimated cost savings were not reported.

Educational Intervention 6: Multimodal education with demonstration and self study

There were two studies that investigated the effect of multimodal education with demonstration and self study *(Coopersmith et al., 2004, Kennedy et al., 2005).* Of these, both measured behavioural change in healthcare professionals (Kirkpatrick level 3) (*Coopersmith et al., 2004, Kennedy et al., 2005)*, and both measured change in patient outcome additionally (Kirkpatrick level 4b) (*Coopersmith et al., 2004, Kennedy et al., 2005*). Both used doctors and nurses as a participant group.

Both educational interventions contained the following components: education of healthcare staff, demonstration and self study module. No study used additional interventions for the duration of the study period. One study used parenteral nutrition for the focus of the intervention (*Kennedy et al., 2005).*

Kirkpatrick level 3:

Statistically significant behavioural changes occurred in both studies (*Coopersmith et al., 2004, Kennedy et al., 2005)* with accepted significance levels of between >0.001 and 0.05. Duration of follow up was 18 months.

Changes in behaviour were reported via the following outcomes: compliance in CVC site care (*Coopersmith et al., 2004)* and number of femoral vein insertions *(Kennedy et al., 2005).*

Kirkpatrick level 4:

Both studies looked at changes in patient or organisational outcomes (*Coopersmith et al., 2004, Kennedy et al., 2005)* and neither found a statistically significant outcome.

Cost savings were measured in one study (*Kennedy et al., 2005)* with reported savings of £7974, or £228 per patient.

Educational Intervention 7: Multimodal education with self study

There were 10 studies that investigated the effect of multimodal education with self study, with 12 comparative groups *(Berenholtz et al., 2004, Dinc et al., 2000).* Of these, eight measured behavioural change in healthcare professionals (Kirkpatrick level 3) (*Tschuida et al., 2007, Berenholtz et al., 2004, Yilmaz et al., 2007, Warren et al., 2003, Crawford et al., 2000, Dinc et al., 2000, Warren et al., 2004, Warren et al., 2006)*, and nine measured change in patient or organisational outcome additionally (Kirkpatrick level 4b) (*Tschuida et al., 2007, McKee et al., 2008, Berenholtz et al., 2004, Yilmaz et al., 2007, Coopersmith et al., 2002,Warren et al., 2003, Dinc et al., 2000, Warren et al., 2006, Warren et al., 2004*). Six studies used both doctors and nurses as participants (*Coopersmith et al., 2002, McKee et al., 2008, Warren et al., 2006, Warren et al., 2004, Warren et al., 2003, Yilmaz et al., 2007*), two used nurses as a sole participant group (*Crawford et al., 2000, Dinc et al., 2000*), and one used a multi-disciplinary participant group (*Berenholtz et al., 2004*).

All educational interventions contained the following components: education of staff prior to self study module and self study module. Education of staff took several forms: five studies specified lectures (*Warren et al., 2003, Warren et al., 2004, Berenholtz et al., 2004, Warren et al., 2006, McKee et al., 2008*), two studies specified classroom training (*Dinc et al., 2000, Crawford et al., 2000*), one specified demonstration (*Tschuida et al., 2007*), one specified in-service training through meetings and seminars (*Yilmaz et al, 2007*), and one specified modular education (*Coopersmith et al., 2002*).

Self-study took several forms: five studies used short self-study modules, with length ranging from nine pages to 20 pages (*Yilmaz et al., 2007, Warren et al., 2003, Warren et al., 2004, Warren et al., 2006, Coopersmith et al., 2002*), two studies used Web-based training modules for doctors only (*Berenholtz et al, 2004, McKee et al., 2008*), and three did not specify the format of self study in detail (*Tschuida et al., 2007, Crawford et al., 2000, Dinc et al., 2000*).

A written test was required in seven studies (*Yilmaz et al, 2007, Warren et al., 2003, Warren et al., 2004, Berenholtz et al., 2004, Warren et al., 2004, McKee et al., 2008, Coopersmith et al., 2002*). Two studies specified a minimum score to be obtained

before completion, and required re-completion of test until obtained (*Yilmaz et al., 2007, Warren et al., 2004*).

Eight studies also contained other components, in addition to education (*Tschuida et al., 2007, Berenholtz et al., 2004, Warren et al., 2003, Dinc et al., 2000, Warren et al., 2007, Warren et al., 2006, McKee et al., 2008, Coopersmith et al., 2002).*

Other components of the interventions included: posters (*Tschuida et al., 2007, Warren et al., 2006, Coopersmith et al., 2002, Warren et al., 2004),* fact sheets (*Warren et al., 2006, Coopersmith et al., 2002, Warren et al., 2004*), feedback (*Coopersmith et al., 2002, Warren et al., 2003, Warren et al., 2004, McKee et al., 2008*), bundle approaches (*Berenholtz et al., 2004, McKee et al., 2008*), and a promotional campaign (*Warren et al., 2004*).

The educational intervention used in one study (*McKee et al., 2008*) was based on another educational intervention (*by Berenholtz et al., 2004*). Both used principles of Cabana's conceptual model to ensure adherence to practice guidelines.

Kirkpatrick level 3:

Changes in behaviour were reported via the following outcomes: femoral vein placements (*Warren et al., 2003, Warren et al., 2004, Warren et al., 2006*), compliance with policy or guidelines (*Tschuida et al., 2007, Berenholtz et al., 2004, Dinc et al., 2000, Warren et al., 2006*), success rates (*Crawford et al., 2000*) and risk factors for insertion (*Yilmaz et al., 2007*).

Statistically significant behavioural changes occurred in three of the ten studies (*Warren et al., 2003, Warren et al., 2004, Warren et al., 2006*), all measuring femoral vein placements. Accepted significance values ranged from 0.001 to 0.002. No other studies reported statistically significant changes in behavioural outcomes, although changes in behaviour were reported for most studies.

One study found no correlation between CVC infection rate and dating of insertion site or visible blood on dressings.

Duration of follow up ranged from five months to 24 months, with two studies reporting no data about length of follow up (*Crawford et al., 2000, Dinc et al., 2000*).

Kirkpatrick level 4:

Changes in organisational and patient outcome were reported via the following outcomes: Cost savings (*Warren et al., 2003, Warren et al., 2004, Warren et al., 2006, Coopersmith et al., 2002, Berenholtz et al., 2002*), CRBSI rates per 1000 CVC days (*Tschuida et al., 2007,McKee et al., 2008, Coopersmith et al., 2002,Berenholtz et al., 2004,Yilmaz et al., 2007, Warren et al., 2003, Warren et al., 2004, Warren et al., 2006*), microbial colonisation rate (*Dinc et al., 2000*), time to onset of infection

(*Warren et al., 2003*), number of isolates (*Warren et al., 2004, Coopersmith et al., 2002*) and arterial catheter infection rates (*Yilmaz et al., 2007*).

Statistically significant behavioural changes occurred in of the seven of the ten studies (*Warren et al., 2004, Warren et al., 2006, Tschuida et al., 2007, Yilmaz et al., 2007, Dinc et al., 2000, McKee et al., 2008, Coopersmith et al., 2002*). Of the eight studies measuring CRBSI rate per 1000 CVC days (*Tschuida et al., 2007,McKee et al., 2008, Coopersmith et al., 2002,Berenholtz et al., 2004,Yilmaz et al., 2007, Warren et al., 2003, Warren et al., 2004, Warren et al., 2006*), six reported statistically significant results (*Tschuida et al., 2007, McKee et al., 2008, Coopersmith et al., 2002, Yilmaz et al., 2007, Warren et al., 2004, Warren et al., 2006*). Accepted significance values ranged from 0.001 to 0.05.

The one study measuring microbial colonisation rate (*Dinc et al., 2000*) showed a statistically significant result (p 0.05). The study measuring time to onset of infection (*Warren et al., 2003*) produced no statistically significant results (p 0.7). Neither study measuring number of isolates (*Warren et al., 2004, Coopersmith et al., 2002)* showed statistically significant results, and the study measuring arterial catheter infection rates (*Yilmaz et al., 2007*) showed a statistically significant decrease (p 0.001).

Duration of follow up ranged from 5 months to 24 months, with one study reporting no data about length of follow up (*Dinc et al., 2000*).

Estimated cost savings range from$336000 to $4358108 (*Warren et al., 2003* report $336000 to $574000, *Warren et al., 2004* report $ 103600 to $1573000, *Warren et al., 2006* report $148,844 to $2408000, *Berenholtz et al., 2004* report $3111381 to $4358108).

Educational Intervention 8: Delivery not specified

Eight studies did not specify how the educational intervention was delivered (*Capretti et al., 2008, Rosenthal et al., 2003, Berriel-Cass et al., 2006, Young et al., 2006, Gnass et al., 2004, Misset et al., 2004, Price et al., 2002, Goeschel et al., 2006*).

Of these, one measured behavioural change in healthcare professionals (Kirkpatrick level 3) (*Rosenthal et al., 2003*, and eight measured change in patient or organisational outcome additionally (Kirkpatrick level 4b) (*Capretti et al., 2008, Rosenthal et al., 2003, Berriel-Cass et al., 2006, Young et al., 2006, Gnass et al., 2004, Misset et al., 2004, Price et al., 2002, Goeschel et al., 2006*).

Six studies employed multiple intervention approaches (*Rosenthal et al., 2003, Berriel-Cass et al., 2006, Young et al., 2006, Misset et al., 2004, Price et al., 2002, Goeschel et al., 2006).*

Kirkpatrick level 3:

Statistically significant behavioural changes occurred in the only study to consider behavioural change (Rosenthal et al., 2003), measuring compliance with policy (p 0.001).

Kirkpatrick level 4:

Statistically significant behavioural changes occurred in of the seven of the eight studies (*Capretti et al., 2008, Rosenthal et al., 2003, Berriel-Cass et al., 2006, Young et al., 2006, Gnass et al., 2004, Price et al., 2002, Goeschel et al., 2006*). Accepted significance values ranged from 0.001 to 0.4.

One study reported cost savings as a result of the intervention (*Young et al., 2006*), who estimated these to be between $460000 and $368000.

Percentage reduction in infection post-intervention

Percentage reduction in infection was calculated for all studies where appropriate. This is summarised in Table 5, and shown graphically for each educational intervention group in Figure 1. Percentage reduction in infection rates (usually measured as infections per 1000 CVC days) were calculated for 31 studies (*Sherertz et al., 2000, Harnage, 2007, Costello et al., 2008, Centers for Disease Control and Prevention, 2005, Curchoe et al., 2002, Eggimann et al., 2000, Render et al., 2006, Lobo et al., 2005, Provonost et al., 2006, Bishop-Kurylo, 1998, Hatler et al., 2006,Wall et al., 2005, Bhutta et al., 2007, Frankel et al., 2005, Salemi et al., 2002 Schelonka et al., 2006, Coopersmith et al., 2004, McKee et al., 2008, Tschuida et al., 2007, Berenholtz et al., 2004, Yilmaz et al., 2007, Coopersmith et al., 2002, Warren et al., 2003, Warren et al., 2004, Warren et al., 2006, Capretti et al., 2008, Rosenthal et al., 2003, Berriel-Cass et al., 2006, Young et al., 2006, Misset et al., 2004, Price et al., 2002).*

Reductions ranged from 18% (*Coopersmith et al, 2004)* to 100% *(Berenholtz et al., 2004, Harnage et al., 2007, Misset et al., 2004, Provonost et al., 2006).*

Table 4: Percentage reduction in infection rates following intervention

Author	Year of publication	Infection rate pre-intervention (CVC days, unless specified)	Infection rate post-intervention (CVC days, unless specified)	Percentage decrease in infection	Educational group
Ahlin *et al.*	2006	n/a	n/a	Unable to calculate	Education, multimodal with demonstration
Costello *et al.*	2008	7.8/1000	2.3/1000	71	Education, multimodal with demonstration
Curchoe *et al*.	2002	9.9-14/1000	2.1-5.3/1000	62	Education, multimodal with demonstration
Eggimann *et al.*	2000	9.2/1000	3.3/1000	64	Education, multimodal with demonstration
Ely *et al.*	1999	Not measured	Not measured	Unable to calculate	Education, multimodal with demonstration
Harnage	2007	11 cases	0 cases	100	Education, multimodal with demonstration
Sherertz *et al.*	2000	4.51/1000	2.92/1000	35	Education, multimodal with demonstration
Centers for Disease Control and Prevention	2005	4.31/1000	1.36/1000	68	Education, multimodal with demonstration

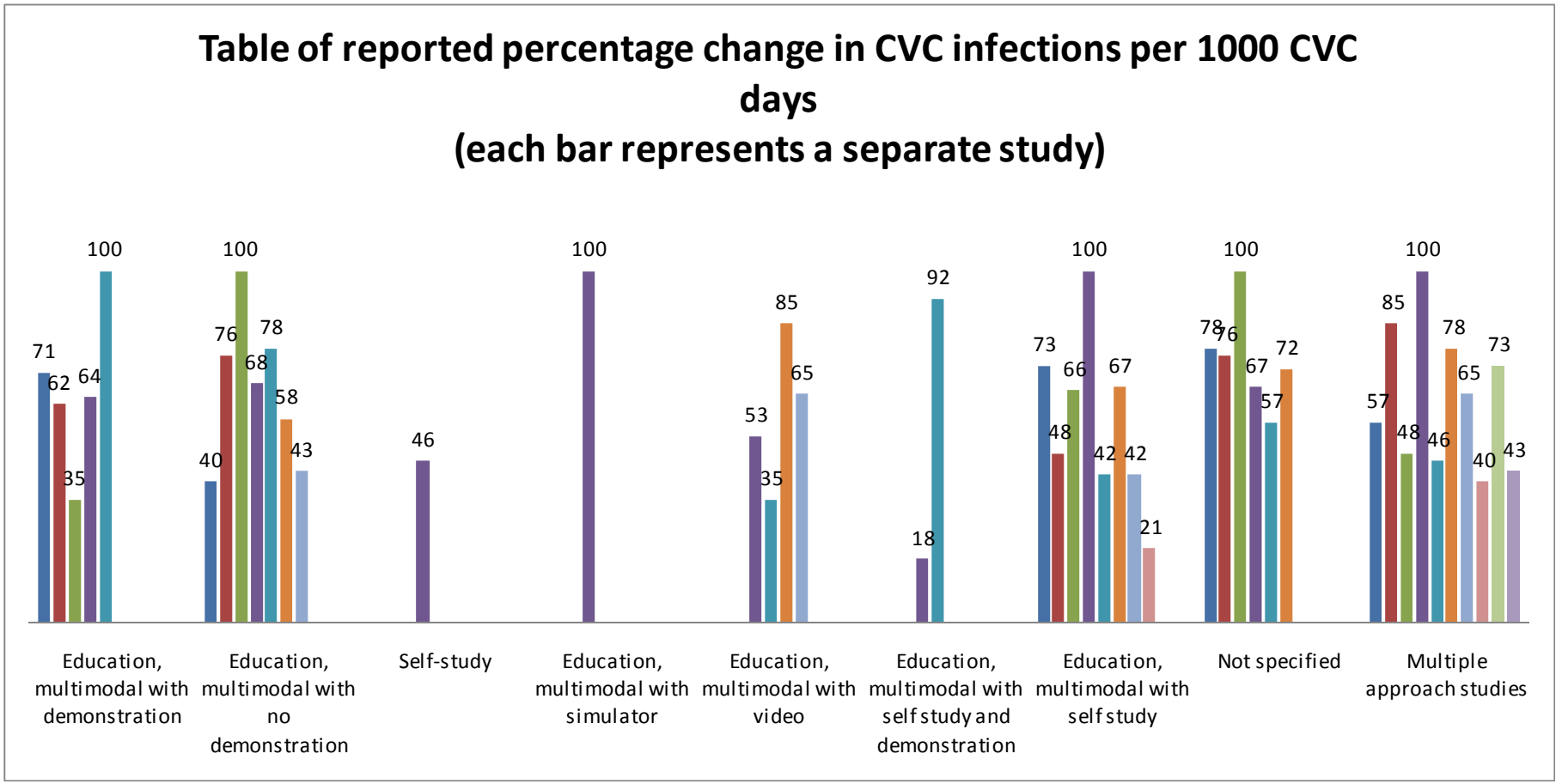
Kennedy *et al.*	**2005**	**7.06/100 PN days**	**0.6/100 PN days**	**Unable to calculate**	**Education, multimodal with demonstration. Self study module.**
Coopersmith *et al.*	**2004**	**10.8/1000**	**3.7/1000**	**66**	**Education, multimodal with demonstration. Self study module.**
Britt *et al.*	2007	Not measured	Not measured	Unable to calculate	Education, multimodal with simulator
Miranda *et al.*	2007	Not measured	Not measured	Unable to calculate	Education, multimodal with simulator
Ramakrishna *et al.*	2005	Not measured	Not measured	Unable to calculate	Education, multimodal with simulator
Velmahos *et al.*	2004	Not measured	Not measured	Unable to calculate	Education, multimodal with simulator
Frankel *et al.*	**2005**	**11/1000**	**1.7/1000**	**85**	**Education, multimodal with video**
Salemi *et al.*	**2002**	**3.0/1000**	**1.4/1000**	**53**	**Education, multimodal with video**
Schelonka *et al.*	**2006**	**8.5/1000**	**5.5/1000**	**35**	**Education, multimodal with video**
Xiao *et al.*	**2007**	**Not measured**	**Not measured**	**Unable to calculate**	**Education, multimodal with video**

Bhutta *et al.*	**2007**	**8.6/1000**	**3.0/1000**	**65**	**Education, multimodal with video**
Bjornestam *et al.*	2000	Not measured	Not measured	Unable to calculate	Education, multimodal without demonstration
Bishop-Kurylo	1998	12.2/1000	7/1000	43	Education, multimodal without demonstration
Hatler *et al.*	2006	12.8/1000	2.88/1000	78	Education, multimodal without demonstration
Higuera *et al.*	2005	46.3/1000 (average for control group)	19.5/1000 (average for intervention group)	Unable to calculate	Education, multimodal without demonstration
Lobo *et al.*	2005	20/1000	12.0/1000	40	Education, multimodal without demonstration
Provonost *et al.*	2006	2.7/1000	0/1000	100	Education, multimodal without demonstration
Render *et al.*	2006	1.7/1000	0.4/1000	76	Education, multimodal without demonstration
Thibodeau *et al.*	2007	Not measured	Not measured	Unable to calculate	Education, multimodal without demonstration
Crawford *et al.*	**2000**	**Not measured**	**Not measured**	**Unable to calculate**	**Education, multimodal without demonstration. Self study**

Berenholtz *et al.*	**2004**	**11.3/1000**	**0/1000**	**100**	**Education, multimodal without demonstration. Self study**
Coopersmith *et al.*	**2002**	**3.4/1000**	**2.8/1000**	**18**	**Education, multimodal without demonstration. Self study**
Dinc *et al.*	**2000**	**Not measured**	**Not measured**	**Unable to calculate**	**Education, multimodal without demonstration. Self study**
McKee *et al.*	**2008**	**5.2/1000**	**2.7/1000**	**48**	**Education, multimodal without demonstration. Self study**
Tsuchida *et al.*	**2007**	**4/1000**	**1.1/1000**	**73**	**Education, multimodal without demonstration. Self study**
Warren *et al.*	**2004**	**9.4/1000**	**5.5/1000**	**42**	**Education, multimodal without demonstration. Self study**
Warren *et al.*	**2003**	**4.9/1000**	**1.6/1000**	**67**	**Education, multimodal without demonstration. Self study**
Warren *et al.*	**2006**	**11.2/1000**	**8.9/1000**	**21**	**Education, multimodal without demonstration. Self study**

Yilmaz *et al.*	**2007**	**13.04/1000**	**7.6/1000**	**42**	**Education, multimodal without demonstration. Self study**
Young *et al.*	2006	11.3/1000	3.7/1000	67	Not specified
Rosenthal *et al.*	2003	45.9/1000	9.9/1000	78	Not specified
Berriel-Cass *et al.*	2006	7/1000	3.0/1000	57	Not specified
Capretti *et al.*	2008	11/1000	3.1/1000	72	Not specified
Gnass *et al.*	2004	No baseline	Fell to 2.7/1000	Unable to calculate	Not specified
Goeschel *et al.*	2006	Not reported	Not reported	Unable to calculate	Not specified
Misset *et al.*	2004	3.5/1000	0.0/1000	100	Not specified
Price *et al.*	2002	4.2/100 patient months	>1/100 patient months	76	Not specified
Wall *et al.*	**2005**	**7/1000**	**3.8/1000**	**46**	**Self study**
East *et al.*	**2005**	**Not measured**	**Not measured**	**Unable to calculate**	**Self study**

Figure 1: Table of percentage reduction in infection rates following intervention



Review Discussion

The inclusion of 47 studies illustrates the growth in literature pertaining to educational interventions for infection control within acute care. We have tried to obtain all relevant information for inclusion in this review. To minimise the risk of missing relevant papers, we adopted the approach of obtaining all full text papers for any potentially relevant abstracts.

Delivery of educational interventions related to CVC care were divided into eight groups for the purpose of this review. No group seemed to have a significant impact on changes in either patient care or healthcare professionals' behaviour compared to any other; all reporting some degree of statistically significant change for both patient outcomes, change in healthcare professionals' behaviour, or both. Multimodal education with self study and demonstrations appeared to have a statistically significant effect on healthcare worker behaviour, yet no statistically significant effect on patient outcome measures. In comparison, multimodal education using video appeared to have a statistically significant effect on patient outcome measures, yet no statistically significant effect on healthcare professional's behaviour. Both of these groups contained small numbers of studies, possibly accounting for this.

The group not specifying delivery of education appeared to have consistent, statistically significant improvements on both healthcare professional's behaviour and patient outcomes, possibly due to the large number of studies using multiple-intervention approaches within that group. These results lend support to the findings of *Fox et al. (1989*), who stated learning occurs through a series of "impactors", thus multiple-approach interventions are generally deemed to be most effective in changing behaviour. Previous research has indicated that the use of feedback changes behavioural patterns (*Eisenberg, 1986, Manheim et al., 1990)*, although the effect on patient outcomes has been variable. This review identified nineteen studies using feedback in addition to education as a means of improving patient outcome. Percentage improvement (usually reported as infection rates per 1000 CVC days) ranged from 21% to 100%. Those studies using a mixture of educational interventions as well as feedback seemed to have the best outcome. The two studies achieving 100% reduction in infection rates both combined feedback with other interventions (the use of a bundle approach, introduction of checklists to improve adherence to compliance, use of both printed educational material and formal educational meetings, and reinforcement of taught principles). Interestingly, neither used demonstrations in their technique, yet both employed a "train the trainer" approach, similar to that described by *Lomas et al., 1991* , termed academic detailing. Another three studies (with a high reduction in infection rates) also used these principles with the exception of checklists, printed educational materials, academic detailing and formal educational meetings. These results support the

finding of *Hulscher et al., (2002*), that audit and feedback combined with educational materials or meetings produce statistically significant improvements in behaviour when compared with no intervention. It may be difficult to identify the most effective part of the intervention.

Printed educational materials (PEM) as an educational intervention have been shown to be effective providing that no prior knowledge or skills are required, the information is grounded in evidence, the taught material is easily implemented and the content does not contradict values of healthcare professionals (*Burgers et al., 2003, Grol et al., 1998*). Twenty studies used PEM as a means of communicating information, either as a sole means or in conjunction with other interventions. Evidence from this review suggests that the effects of PEM cannot be isolated from the effects of other components. It is unlikely that the use of PEM alone would be an influential factor in improving behavioural patterns. This may be due to the complexity of the intended target behaviour, the lack of assessment of prior values and attitudes of healthcare professionals. Further research should be carried out to investigate the influence of prior attitudes or values on behavioural style, as improvement in infection control behaviour is a complex interaction of many factors.

Formal educational meetings, with and without demonstration, also yield mixed results when considering them in the context of this review. A wide range of percentage improvements in patient outcome are apparent within the 26 studies using formal educational meetings, ranging from 18% to 100%. Highest improvements occur when used in addition to other interventions, such as feedback, published evidence, practice opportunities and when supported by senior staff and peers. This finding supports the work of *Peloso et al., (2000)*, and again lends support to the conclusion that multiple interventions are more useful in terms of eliciting and sustaining behavioural change than single interventions (*Oxman et al., 1995, Grilli et al., 1994, Davis et al., 1995*).

Reminders have also been deemed effective means of behavioural change within healthcare professionals (*Gordon et al., 1998).* For the purpose of this review, only structured educational interventions were considered, thus reminders alone were not sufficient to comprise an educational intervention. This review found reminders in the form of both formal reminders: feedback (as discussed above), posters, surveillance, incentives, and checklists, and informal reminders: policy changes, informal surveillance or testing of skills. As most interventions used some form of reminder, it is difficult to identify the specific effects of these.

Few studies in this review used web-based resources as a means of delivering education. Using the internet as a platform would be a cost-effective means of educating staff, and could provide tailored, interactive learning pathways for professional education.

It is difficult to determine what, if any features of educational intervention delivery have the greatest impact on healthcare professionals' practice and behaviour. Although reasons for behavioural change following educational delivery have been hypothesised (*Bandura, 1977*), there is no research evidence base to support this. Decisions relating to delivery of educational interventions must be based on local and practical factors, and assess needs of individuals prior to education, include enabling materials to incorporate differing learning styles and supplementary material to ensure effective course delivery (*Davis et al., 1999*). Clinical case examples should be present, as should an opportunity for immediate practice to cement development and retention of knowledge and skills knowledge construction rather than didactic teaching.

Limitations of analysis

Out of 47 studies, six were deemed to be of low quality (a quality score of below 50%). See Appendix for individual quality scores. Overall, methodological reporting and quality was inconsistent. The intervention implementation strategy was often poorly reported. Few studies reported sufficient detail about study design. Concealment of allocation and blinding of professionals was also under-reported for the few studies that used control groups. Duration of follow up ranged from one week to 36 months, with insufficient reporting of length of follow up for numerous studies. Additionally, most studies did not provide data as to whether the intervention was mandatory or voluntary, and group size of participants was infrequently reported.

Whilst assessment of quality is a complex yet fluid concept, with no firm framework for assessment, measures were taken to ensure adequate reporting of quality using a standardised assessment tool (based on *Shaw et al (in press)* and adapted from *Downs & Black (1998*) and *Kmet et al (2004*)). Where no data was present, for example relating to group size, this was scored as "not reported" rather than "not present", and a quality score was calculated as a percentage to allow for as adequate a comparison between studies as possible. Despite this strategy, the factors reported above may still have lead to an under-reporting of degree of bias, and consistent variations in reporting may have prevented firm comparisons and made the drawing of conclusions difficult.

Few studies considered healthcare professionals' input in determining content and delivery of educational intervention, or evaluated knowledge and attitude change of healthcare workers. No study considered attitudes or personal values of healthcare professionals as basis for development of an intervention, tailored to that particular healthcare group, a factor indicated as pre-requisite for some interventions to be successful (*Burgers et al., 2003, Grol et al., 1998*). In a similar vein, no study assessed the motivation of healthcare workers to change as a contributing factor to the success of educational interventions, regardless of mode of delivery. It has been hypothesised that motivation alone may have a substantial effect on the success of

educational interventions when the topic is of low interest to healthcare workers (*Foy et al., 2002*). This may explain variations in success of interventions prior to 2000, as infection control became a vested public interest after this date. Differences in motivation between participants may affect the reported results, although this will be difficult to identify. This should be taken into consideration, both when generalising the results from this review and planning future research.

Theories of behavioural change also suggest the importance of motivation in changing practice (*Bandura et al., 1996, Green et al., 1998*), thus studies investigating educational interventions in response to an outbreak may have greater effect than those targeting day-to-day practice, due to increase in perceived seriousness of the education (*Price et al., 2002*).

All of these implications and limitations of analysis should be taken into consideration when interpreting this systematic review.

Implications for practice

This review has found relatively little implications for practice, however several conclusions can be drawn.

Firstly, educational interventions appear to have the most prolonged and profound effect when used in conjunction with audit, feedback and availability of new clinical supplies consistent with the content of the education provided. Secondly, educational interventions will have a greater impact if baseline compliance to best-practice is low. Thirdly, repeated sessions, fed into daily practice, using practical participation (such as the use of demonstrations, video education, use of simulator or self study materials) appears to have a small, additional effect on practice change when compared to education alone. Active involvement from healthcare staff, in conjunction with provision of formal responsibilities and motivation for change may change healthcare worker practice. Finally, dissemination of information through peers or higher management may have a small effect on practice change.

Implications for research

Difficulties in between-study comparisons have been apparent when performing this review. In order to alleviate this problem and allow for future reviews to investigate and clarify factors relating to the effectiveness of delivery of education within healthcare, several implications for research must be taken from these findings.

Adequate group sizes are needed, with groups being large enough to measure the relatively small effects of each educational component with adequate specificity and accuracy. Reporting and performing of both allocation of concealment and adequate blinding must be implicit to allow for comparisons both within group and across studies. Sensitive, generalisable and validated measures are needed to allow for adequate determination of baseline knowledge, attitudes, motivation and behaviour

of healthcare workers, and for comparisons post-intervention. Before and after measurements are required, with sufficient follow-up periods to ensure longitudinal stability in results.

Of the 47 studies considered in this review, only one used within-study comparisons of effects of differing delivery on practice (*Xiao et al., 2007*). More within-study comparisons of conflicting modes of educational delivery are needed, in future research.

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APPENDICES
Table 5: Summary of Included Studies

Author	Year of publication	Study period	Country of study	Study setting	Type of intervention	Participant group	Kirkpatrick level	Quality score (%)
Ahlin *et al.*	2006	2002-2003 (12 months)	Sweden	1 haematology unit	Education, multimodal with demonstration	Registered nurses	3	81
Berenholtz *et al.*	2004	1998 to 2002 (60 months)	USA	1 Surgical ICU	Education, multimodal without demonstration. Self study module	Physicians, fellows, anaesthetists, surgery residents, pharmacists and nurses	3 and 4b	75
Berriel-Cass *et al.*	2006	2004 to 2006 (30 months)	USA	1medical ICU. 1 surgical ICU. 1 cardiac ICU. 1 cardiovascular ICU	Not specified	Physicians and nurses	4b	39
Bhutta *et al.*	2007	1998 to 2005 (60 months)	USA	1 paediatric ICU	Education, multimodal with video	Not specified	3 and 4b	60
Bishop-Kurylo	1998	1995 to 1997 (26 months)	USA	1 neonatal ICU	Education, multimodal without demonstration	Physicians, nurse practitioners and staff nurses	4b	21
Bjornestam *et al.*	2000	1995 (12 months)	Sweden	Children's hospital (intervention hospital wide)	Education, multimodal with demonstration	Registered nurses	4b	76
Britt *et al.*	2007	2005 to 2007 (24 months)	USA	Department of surgery	Education, multimodal with simulator	Surgical interns	3	56
Capretti *et al.*	2008	2003 to 2006 (34 months)	Italy	1 neonatal ICU	Not specified	Not specified	4b	85
Centres for Disease Control and Prevention	2005	April 2001 to March 2005 (48 months)	USA	42 hospitals with 69 ICUs	Education, multimodal with demonstration	Not specified	4b	48
Coopersmith *et al.*	2004	1998 to 2002 (32 months)	USA	1 surgical ICU	Education, multimodal with demonstration. Self study module. Behavioural intervention	Physicians and nurses	3 and 4b	75
Coopersmith *et al.*	2002	1998 to 2000 (36 months)	USA	1 surgical ICU	Education, multimodal without demonstration. Self study module	Physicians and nurses	4b	100
Costello *et al.*	2008	2004-2006 (31 months)	USA	1 paediatric cardiac ICU	Education, multimodal with demonstration	Nurses, physicians & healthcare staff	3 and 4b	84

Crawford *et al.*	2000	1995-1999	USA	Tertiary care hospital (department not specified)	Education, multimodal without demonstration. Self study module.	Registered nurses	3	31
Curchoe *et al*.	2002	2000 to 2001 (12 months)	USA	1 medical-surgical ICU	Education, multimodal with demonstration	Nursing staff and 1st year residents	4b	40
Dinc *et al.*	2000	1996 to 1997 (12 months)	Turkey	1 surgical ICU	Education, multimodal without demonstration. Self study module	Registered nurses	3 and 4b	88
East *et al.*	2005	2002 to 2003 (7 months)	USA	I Cardiovascular ICU	Self study.	Registered nurses	3	86
Eggimann *et al.*	2000	1995 to 1997 (25 months)	Switzerland	1 medical ICU	Education, multimodal with demonstration	Physicians, nurses and nursing assistants	4b	88
Ely *et al.*	1999	Not specified	USA	1 medical centre	Education, multimodal with demonstration	Incoming house officers	3	57
Frankel *et al.*	2005	2001 to 2003 (24 months)	USA	1 surgical ICU	Education, multimodal with video	2nd year residents and nurses	4b	54
Gnass *et al.*	2004	1997 to 2001 (57 months)	Argentina	1 medical-surgical ICU	Not specified	Physicians and nurses	4b	32
Goeschel *et al.*	2006	2003 to 2005	USA	77 hospitals with 127 ICUs	Not specified	First year residents and nursing staff	4b	40
Harnage	2007	2006 to 2007 (15 months)	USA	1 medical-surgical ICU. 1 trauma-neuro ICU	Education, multimodal with demonstration	Not specified	3 and 4b	50
Hatler *et al.*	2006	2003 to 2004	USA	1 medical ICU	Education, multimodal without demonstration	Registered nurses	4b	54
Higuera *et al.*	2005	2002 to 2003 (11 months)	Mexico	1 mixed ICU. 1 neurosurgical ICU.	Education, multimodal without demonstration	Surgical interns	3 and 4b	89
Kennedy *et al.*	2005	1999 to 2001 (approx. 24 months)	UK	University hospital, all adult areas.	Education, multimodal with demonstration. Self study module. Behavioural intervention	Physicians, nurses and untrained nursing staff (plus university based student nurses, excluded from analysis)	4b	82
Lobo *et al.*	2005	2002 (12 months)	Brazil	1 medical ICU	Education, multimodal without demonstration	Medical residents and nurses	3 and 4b	100
McKee *et al.*	2008	2001 to 2006 (61 months)	USA	1 paediatric ICU	Education, multimodal without demonstration. Self study module	Physicians and nurses	4b	81
Miranda *et al.*	2007	2004 to 2005 (4 months)	USA	Simulation laboratory	Education, multimodal with simulator	Internal medical residents	3	93
Misset *et al.*	2004	1995 to 2000 (60 months)	France	1 mixed ICU	Not specified	Physicians and nurses	4b	92

Price *et al.*	2002	1999 to 2002 (48 months)	USA	1 outpatient haemodialysis centre	Not specified	"Staff"	4b	
Provonost *et al.*	2006	2003 to 2006 (29 months)	USA	103 ICUs	Education, multimodal without demonstration	Physicians and nurses	4b	68
Ramakrishna *et al.*	2005	2000 to 2002 (23 months)	USA	Cardiac catheterisation laboratory	Education, multimodal with simulator	Internal medical residents	3	100
Render *et al.*	2006	2004 to 2006 (36 months)	USA	9 hospitals with 21 ICUs	Education, multimodal without demonstration	"Healthcare workers"	3 and 4b	76
Rosenthal *et al.*	2003	1999 to 2001 (27 months)	Argentina	2 mixed ICUs. 2 coronary ICUs.	Not specified	"Healthcare workers"	3 and 4b	73
Salemi *et al.*	2002	1999 to 2000 (17 months)	USA	1 medical-surgical ICU. 1 cardiac care unit	Education, multimodal with video	Physicians	3 and 4b	61
Schelonka *et al.*	2006	1999 to 2004 (50 months)	USA	1 neonatal ICU	Education, multimodal with video	Physicians and nurses	4b	100
Sherertz *et al.*	2000	1995 to 1997 (24 months)	USA	6 ICUs, 1 step down unit	Education, multimodal with demonstration	1st year residents (and medical students- results excluded)	3 and 4b	61
Thibodeau *et al.*	2007	2004 to 2005 (14 months)	USA	Medical Centre, no more details provided	Education, multimodal without demonstration	Registered nurses	3	68
Tsuchida *et al.*	2007	2000 to 2002 (32 months)	Japan	1 mixed ICU	Education, multimodal without demonstration. Self study module	Physicians and nurses	3 and 4b	68
Velmahos *et al.*	2004	2001 (2 months)	USA	Surgical skills laboratory	Education, multimodal with simulator	Surgical interns	3	100
Wall *et al.*	2005	2002 to 2004 (58 months)	USA	1 medical ICU	Self study.	Physicians and nurses	3 and 4b	54
Warren *et al.*	2003	1998 to 2000	USA	1 Medical ICU. 1 Surgical ICU.	Education, multimodal without demonstration. Self study module	Physicians and nurses	4b	96
Warren *et al.*	2004	2000 to 2003 (48 months)	USA	1 Medical ICU	Education, multimodal without demonstration. Self study module.	Physicians and nurses	4b	89
Warren *et al.*	2006	2002 to 2003 (24 months)	USA	5 Medical ICUs. 6 Surgical ICUs. 2 Mixed ICUs.	Education, multimodal without demonstration. Self study module	Physicians and nurses	3 and 4b	86
Xiao *et al.*	2007	2004-2005 (12 months)	USA	Urban trauma centre.	Education, multimodal with video	Surgical and emergency medicine residents	3	100
Yilmaz *et al.*	2007	2003 to 2004 (13 months)	Turkey	Patients with CVC (excluding neonatal) at Technical Medical School	Education, multimodal without demonstration. Self-study module.	Physicians, interns and nurses	4b	88
Young *et al.*	2006	2001 to 2003 24 months)	USA	1 mixed ICU	Not specified	Medical and surgical residents	4b	57

Table 6: Education Group 1: Education, multimodal with demonstration. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Ahlin *et al.*	2006	Education, multimodal with demonstration	Registered nurses	n/a	n/a	3	60.3% of nurses passed bedside examination with no deviations. All participants passed theoretical exam. No statistical significance found. 50.8% of nurses surveyed stated they always followed CVAD protocols.		81
Britt *et al.*	2007	Education, multimodal with simulator	Surgical interns	Not measured	Not measured	3	Improvement in time taken to insert line (1st line compared to 10th line; change from 43 minutes to 22 minutes on average). Increase in perceived confidence.	Training provided prior to insertion by interns.	56
Costello et al.	2008	Education, multimodal with demonstration	Nurses, physicians and all healthcare staff	7.8/1000	2.3/1000	3 and 4b	Compliance with insertion bundle increased from 87% to 94% in CICU and cardiac operating rooms, and with maintenance bundle from 85% to 99% in CICU	Part of sequential intervention, including education for physicians and nurses, introduction of CVL care bundle, infection control nurse position, real-time feedback about infection data, CVL insertion, maintenance and access bundles and daily goal sheets to emphasise timely CVL removal.	84
Ely *et al.*	1999	Education, multimodal with demonstration	Incoming house officers	n/a	n/a	3	After the educational intervention, concern for and awareness of proper methods of prevention of VAE improved ($p < .001$). At 6-month follow-up, reported use of the Trendelenburg position continued, but concern cited for VAE had returned to baseline.	Focus on venous air embolism as complication of insertion, maintenance and removal of CVCs.	57
Harnage	2007	Education, multimodal with demonstration	Not specified	11 cases	0 cases	3 and 4b	No description of behavioural change other than the practice identified in the bundle "enhance accepted behaviour practices related to CVC care and maintenance"	Use of bundle development- combination of behavioural practices and product technologies associated with lowering CRBSI.	50
Sherertz et al.	2000	Education, multimodal with demonstration	1st year residents (and medical students- results excluded)	4.51/1000	2.92/1000	3 and 4b	Documented use of full size sterile drapes increased from 44% to 65% ($p=0.001$). Increase in perceived need for full-size sterile drapes after intervention and decrease in perceived need for small sterile towels after intervention.	Estimated cost savings: between $63082 and $815309	61

Table 7: Education Group 1: Education, multimodal with demonstration. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Centres for Disease Control and Prevention	2005	Education, multimodal with demonstration	Not specified	4.31/1000	1.36/1000	4b		4 year, co-ordinated multi-institutional infection control intervention	48
Costello *et al.*	2008	Education, multimodal with demonstration	Nurses, physicians and all healthcare staff	7.8/1000	2.3/1000	3 and 4b	Compliance with insertion bundle increased from 87% to 94% in CICU and cardiac operating rooms, and with maintenance bundle from 85% to 99% in CICU	Part of sequential intervention, including education for physicians and nurses, introduction of CVL care bundle, infection control nurse position, real-time feedback about infection data, CVL insertion, maintenance and access bundles and daily goal sheets to emphasise timely CVL removal.	84
Curchoe *et al*.	2002	Education, multimodal with demonstration	Nursing staff and 1st year residents	9.9-14/1000	2.1-5.3/1000	4b		Part of sequential intervention, including increase in frequency of dressing changes and site care, reintroduction of alcohol swab sticks and education about aseptic technique and to review site care protocol.	40
Eggimann *et al.*	2000	Education, multimodal with demonstration	Physicians, nurses and nursing assistants	9.2/1000	3.3/1000	4b		Infections measured include microbially documented (28/2104 vs. 5/1050) and clinical sepsis bloodstream infections (73/2104 vs. 11/1050)	88
Harnage	1	Education, multimodal with demonstration		11 cases	0 cases	3 and 4b			
Sherertz *et al.*	2000	Education, multimodal with demonstration	1st year residents (and medical students-results excluded)	4.51/1000	2.92/1000	3 and 4b	Documented use of full size sterile drapes increased from 44% to 65% (p=0.001). Increase in perceived need for full-size sterile drapes after intervention and decrease in perceived need for small sterile towels after intervention.	Estimated cost savings: between $63082 and $815309	61

Table 7: Intervention Group 2: Education, multimodal without demonstration. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Higuera et al.	2005	Education, multimodal without demonstration	Surgical interns	46.3/1000 (average for control group)	19.5/1000 (average for intervention group)	3 and 4b	Compliance with following increased in intervention group compared to control group (p=0.000): Gauze dressing placement: (99.24% vs. 86.69%, RR 1.14, 95% CI 1.07-1.22). Proper use of gauze: (97.87% vs. 84.21%, 95% CI 1.09-1.24, RR 1.16) Documenting duration of admin set of vascular catheter: (93.85% vs. 40.69%, 95% CI 2.14-2.56, RR 2.34) Hand hygiene before patient contact: (84.9% vs. 62%, 95% CI 1.21-1.15, RR 1.37)	Crude unadjusted mortality: 48.5 per 100 discharges in intervention group vs. 32.8 per 100 discharges in control group (p=0.01, 95% CI 0.5-0.79, RR 0.68). Other components of intervention include performance feedback, use of guidelines, use of alcohol hand rub or hand washing with povidone iodine soap. Education also focused on UTI and VAP.	89
Lobo et al.	2005	Education, multimodal without demonstration	Medical residents and nurses	20/1000	12.0/1000	3 and 4b	Statistically significant (p=0.001) change in: Skin antisepsis with PVCI, hand washing before with chlorhexidine, glove use, line protection, hub disinfection, hand washing after with chlorhexidine, PVCI use when dressing. Hand hygiene compliance unsatisfactory even after intervention (55% compliance when manipulating, 68% when dressing).	Different distribution in pathogens following intervention (statistically significant reduction in *S. Aureus, p=0.02).* Compliance low in pre-intervention period, despite adequate knowledge. Primarily directed towards nurses. Low pre-intervention knowledge scores relating to skin preparation, disinfection of CVC and use of alcohol based product.	100
Render et al.	2006	Education, multimodal without demonstration	"Healthcare workers"	1.7/1000	0.4/1000	3 and 4b	Compliance with process adherence (use of sterile drape and gloves) increased from 0% (for bed-sized drapes) to 85-95%.	Randomised to either begin intervention in ICU or OR. Use of checklist to standardise insertion of central lines. Pre-packaged insertion trays and "accessory pack" bundle for insertion. Central line cart. Written policy change. Record of barriers and facilitators to change reported.	76
Thibodeau et al.	2007	Education, multimodal without demonstration	Registered nurses	Not measured	Not measured	3	Decrease in PICC replacements (9.9% per intervention vs. 9.3% post intervention). Decrease in amount replaced within 3 days (from 24.7% to 22.6%).	Train-the-trainer approach. PICC maintenance and flushing main subject. Other components of intervention included new physician order set, new policy to define best practice maintenance and flushing protocols. Power PICC introduced.	68

Table 8: Intervention Group 2: Education, multimodal without demonstration. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC days)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Bishop-Kurylo	1998	Education, multimodal without demonstration	Physicians, nurse practitioners and staff nurses	12.2/1000	7/1000	4b			21
Higuera et al.	2005	Education, multimodal without demonstration	Surgical interns	46.3/1000 (average for control group)	19.5/1000 (average for intervention group)	3 and 4b	Compliance with following increased in intervention group compared to control group (p=0.000): Gauze dressing placement: (99.24% vs. 86.69%, RR 1.14, 95% CI 1.07-1.22). Proper use of gauze: (97.87% vs. 84.21%, 95% CI 1.09-1.24, RR 1.16) Documenting duration of admin set of vascular catheter: (93.85% vs. 40.69%, 95% CI 2.14-2.56, RR 2.34) Hand hygiene before patient contact: (84.9% vs. 62%, 95% CI 1.21-1.15, RR 1.37)	Crude unadjusted mortality: 48.5 per 100 discharges in intervention group vs. 32.8 per 100 discharges in control group (p=0.01, 95% CI 0.5-0.79, RR 0.68). Other components of intervention include performance feedback, use of guidelines, use of alcohol hand rub or hand washing with povidone iodine soap. Education also focused on UTI and VAP.	89
Lobo et al.	2005	Education, multimodal without demonstration	Medical residents and nurses	20/1000	12.0/1000	3 and 4b	Statistically significant (p=0.001) change in: Skin antisepsis with PVCI, hand washing before with chlorhexidine, glove use, line protection, hub disinfection, hand washing after with chlorhexidine, PVCI use when dressing. Hand hygiene compliance unsatisfactory even after intervention (55% compliance when manipulating, 68% when dressing).	Different distribution in pathogens following intervention (statistically significant reduction in S. Aureus, p=0.02). Compliance low in pre-intervention period, despite adequate knowledge. Primarily directed towards nurses. Low pre-intervention knowledge scores relating to skin preparation, disinfection of CVC and use of alcohol based product.	100
Render et al.	2006	Education, multimodal without demonstration	"Healthcare workers"	1.7/1000	0.4/1000	3 and 4b	Compliance with process adherence (use of sterile drape and gloves) increased from 0% (for bed-sized drapes) to 85-95%.	Randomised to either begin intervention in ICU or OR. Use of checklist to standardise insertion of central lines. Pre-packaged insertion trays and "accessory pack" bundle for insertion. Central line cart. Written policy change. Record of barriers and facilitators to change reported.	76

Table 9: Intervention Group 2: Education, multimodal without demonstration. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Bjornestam *et al.*	2000	Education, multimodal with demonstration	Registered nurses			4b		No reduction in rate of bacteraemia associated with intervention. Frequency of bacteraemia in study and control group did not significantly differ.	76
Hatler *et al.*	2006	Education, multimodal without demonstration	Registered nurses	12.8/1000	2.88/1000	4b		Estimated cost savings of between $220150 and $1309000 annually. 18% reduction in mean length of stay (from 4.4 to 3.59 days). Part of intervention to reduce VAP- reduction from 11.4/1000 days to 5.3/1000 days, estimated cost saving of between $11897 and $4342. Use of rapid cycle methods. Other components of intervention include charts of expected activities in each patient room, discussion of daily goals, posted goals, regular feedback, and incentives for staff.	54
Kennedy *et al.*	2005	Education, multimodal with demonstration. Self study module. Behavioural intervention	Physicians, nurses and untrained nursing staff (plus university based student nurses, excluded from analysis)	7.06/100 PN days	0.6/100 PN days	4b		Estimated cost savings of £7974, or £228 per patient. Increase in number of single lumen catheters used from 67% to 81%, and in number of tunnelled PN catheters (from 19% to 54%, $p<0.05$). Parenteral nutrition focus of study. Cost savings as primary aim of research.	82
Provonost *et al.*	2006	Education, multimodal without demonstration	Physicians and nurses	2.7/1000	0/1000	4b		Fall in infection rates sustained over 18 months post-intervention ($p<0.002$). Significant interaction between intervention and bed size, with intervention more effective in small hospitals (incidence rate ration 0.97, 95% CI 0.96-0.99, $p<0.001$). Other interventions include creation of central line chart, checklist to ensure adherence to infection control policy, stopping of providers in non-emergency situations, feedback regarding number and rate of CRBSI and discussion of CVC in daily rounds. Part of Michigan Health and Hospital Association Keystone Centre for Patient Safety and Quality ICU Project.	68

Table 10: Intervention Group 3: Self Study. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
East *et al.*	2005	Self study.	Registered nurses	Not measured	Not measured	3	Statistically significant improvement in per and post intervention test scores (from 60.9% to 84.6%, p<0.001, 95% CI data not given). Improvement in number of central line dressings performed "per policy", use of interlink injection site and overall passing score post intervention (p=0.007). No impact on dating of dressings (p=0.82)	Short length of follow up.	86
Wall et al.	2005	Self study.	Physicians and nurses	7/1000	3.8/1000	3 and 4b	No change in percentage of femoral vein CVCs inserted at end of study period.	CRBSI rate improved initially, and then fell 1 year post intervention. Re-emphasis on need for daily CVC maintenance. CRBSI rate again fell. Other interventions included standardised nursing checklist for CVC insertion, monitoring of hand hygiene, trainee supervision, use of MSBP and chlorhexidine, continuous feedback. Checklist was most emphasized part of intervention.	54

Table 11: Intervention Group 3: Self Study. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Wall *et al.*	2005	Self study.	Physicians and nurses	7/1000	3.8/1000	3 and 4b	No change in percentage of femoral vein CVCs inserted at end of study period.	CRBSI rate improved initially, and then fell 1 year post intervention. Re-emphasis on need for daily CVC maintenance. CRBSI rate again fell. Other interventions included standardised nursing checklist for CVC insertion, monitoring of hand hygiene, trainee supervision, use of MSBP and chlorhexidine, continuous feedback. Checklist was most emphasized part of intervention.	54

Table 12: Intervention Group 4: Education, multimodal with simulator. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Miranda *et al.*	2007	Education, multimodal with simulator	Internal medical residents	Not measured	Not measured	3	Residents in intervention group more likely to use mask (p=0.008) or large drapes (p=0.014). No statistically significant difference between complication rate between 2 groups (9.2/1000 CVC days in control group vs. 0/1000 CVC days in intervention group, p=0.29). No difference between veins used by the groups.	Minimal effect on knowledge, attitudes or behaviour. Knowledge returned to baseline post intervention.	93
Ramakrishna *et al.*	2005	Education, multimodal with simulator	Internal medical residents	Not measured	Not measured	3	Intervention group performed more IJCVLPs during the 3 years post intervention (17.8+/-8.4 vs. 9.8+/-6.3, p>0.001), and more independently performed IJCVLPs (31.2% vs. 11.6%, p=0.008). The mean number of successful IJCVLPs placed in final year was 8+/-4 in intervention group compared to 7+/-4 in control group (67.3% of all insertions placed by intervention group, p=0.07)	Use of simulators within laboratory as part of hospital, to teach residents without use of cadavers	100
Velmahos *et al.*	2004	Education, multimodal with simulator	Surgical interns	Not measured	Not measured	3	Total score post-intervention for intervention group was 11+/-1.86, statistically significantly higher than control group (8.64+/-1.82), p=0.03. Relative likelihood of performing 8 checklist steps correctly was two times higher in intervention group post intervention than in control group (95% CI 1.2-3.4, p=0.006). Intervention group required less needle punctures and less direction from resident physician.	Use of Cognitive Task Analysis principles to design intervention. Trend towards less time needed to complete procedure in intervention group, but not statistically significant (p=0.0149). Short follow up period of 2.5 months.	100

Table 13: Education Group 5: Education, multimodal with video. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Bhutta *et al.*	2007	Education, multimodal with video	Not specified	8.6/1000	3.0/1000	3 and 4b	Increase in compliance with hand washing (using disinfectant before patient contact) from 49% pre-intervention to 82% 60 months post intervention.	Initial increase in infection rates immediately post-intervention (from 5.6/1000 CVC days to 6.1/1000 CVC days), then reduction. Education renewed when infection rates rose, but no detail of how delivered. Stepwise intervention- MSBP for all CVCs (November 1998), antibiotic impregnated catheters (July 1999), hand washing campaign (July 2000), physical barriers between patient beds (April 2003), chlorhexidine skin disinfectant introduced (May 2003). Education introduced in 1999.	60
Salemi *et al.*	2002	Education, multimodal with video	Physicians	3.0/1000	1.4/1000	3 and 4b	Increased compliance with hand washing, from 19% pre-intervention to 68% post-intervention (19 months).	Intervention also targeted at reducing VAP rates- no reduction found. Nurse compliance with hand washing pre-intervention was 73% thus may have shamed physicians into increased compliance	61
Xiao *et al.*	2007	Education, multimodal with video	Surgical and emergency medicine residents	Not measured	Not measured	3	Study group (video/paper/control) and number of CVCs inserted throughout study predicted full compliance. Full compliance of video group higher than that of paper and control (14/19 or 74% compared to 18/54 or 33%, p=0.003, 95 CI 1.96-22.03).	Three groups used- control group (no additional education), video group (education presented in online video format) and paper group (education presented in paper format but with same content as video group). No longitudinal follow up due to short tenure on trauma services (1-3 months).	100

Table 14: Education Group 5: Education, multimodal with video. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Bhutta et al.	2007	Education, multimodal with video	Not specified	8.6/1000	3.0/1000	3 and 4b	Increase in compliance with hand washing (using disinfectant before patient contact) from 49% pre-intervention to 82% 60 months post intervention.	Initial increase in infection rates immediately post-intervention (from 5.6/1000 CVC days to 6.1/1000 CVC days), then reduction. Education renewed when infection rates rose, but no detail of how delivered. Stepwise intervention- MSBP for all CVCs (November 1998), antibiotic impregnated catheters (July 1999), hand washing campaign (July 2000), physical barriers between patient beds (April 2003), chlorhexidine skin disinfectant introduced (May 2003). Education introduced in 1999.	60
Frankel *et al.*	2005	Education, multimodal with video	2nd year residents and nurses	11/1000	1.7/1000	4b		Uses Six Sigma methodology- data driven quality improvement methodology to improve outcomes by reducing variation. Other interventions include exclusive use of antibiotic impregnated catheters, clinical management guideline algorithm, measurement system to track catheter dwell time, catheter insertion kit, site prep kit, control charts for stakeholders and clinical leaders.	54
Salemi et al.	2002	Education, multimodal with video	Physicians	3.0/1000	1.4/1000	3 and 4b	Increased compliance with hand washing, from 19% pre-intervention to 68% post-intervention (19 months).	Intervention also targeted at reducing VAP rates- no reduction found. Nurse compliance with hand washing pre-intervention was 73% thus may have shamed physicians into increased compliance	61
Schelonka *et al.*	2006	Education, multimodal with video	Physicians and nurses	8.5/1000	5.5/1000	4b		In years 2 and 3 of intervention, centre participated in RCT of immunoglobin to prevent sepsis- possible confounding of results. Incentives for compliance offered.	100

Table 15: Education Group 6: Education, multimodal with demonstration. Self study module. Behavioural intervention. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/ findings	Quality score (%)
Coopersmith *et al.*	2004	Education, multimodal with demonstration. Self study module. Behavioural intervention	Physicians and nurses	3.4/1000	2.8/1000	3 and 4b	Decrease in use of stopcocks (from 70% to 24%, p<0.001), increase in: use of MSB (from 50% to 80%, p=0.29 not statistically significant), proper dating (from 11% to 21%, p<0.001), hand hygiene (from 17% to 30%, p>0.99, not statistically significant).	Substantial fall in *E. facium* post intervention (from 27% to 5% of all bacteraemia). Low compliance rates pre-intervention, despite intervention site being site of previous educational intervention (Coopersmith *et al.,* 13). Behavioural intervention one component of intervention.	75

Table 16: Education Group 7: Education, multimodal without demonstration. Self study module. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Coopersmith *et al.*	2002	Education, multimodal without demonstration. Self study module	Physicians and nurses	10.8/1000	3.7/1000	4b		Population group was 95% nurses- aimed at nurses that maintain primarily. Change in pre and post test scores, from 78.3 to 89.9% (p<0.001, 95% CI 7.97-15.3). Average increase from 74% pre-test to 91.7% post-test (p<0.0001, 95% CI 13.8-21.5)	100
McKee *et al.*	2008	Education, multimodal without demonstration. Self study module	Physicians and nurses	5.2/1000	2.7/1000	4b		Last 22 months of follow-up free from infection. Increase in infection rates part-way through study- attributed to change from mechanical valves to positive displacement mechanical valves. Returned to mechanical valves and infection rates again dropped.	81
Warren *et al.*	2003	Education, multimodal without demonstration. Self study module	Physicians and nurses	4.9/1000	1.6/1000	4b		Estimated cost savings: between $336000 and $574000. Significant decrease in clinical sepsis, from 16% pre-intervention to 12% post-intervention (p=0.03). Percentage of CVCs inserted in subclavian vein increased from 25% to 41% (p<0.001). Cost of intervention estimated at $3500 in time and $500 in printed materials.	96
Warren *et al.*	2004	Education, multimodal without demonstration. Self study module.	Physicians and nurses	9.4/1000	5.5/1000	4b		Estimated cost savings of between $103600 and $157300. Statistically significant decrease in percentage of femoral vein placements post-intervention (26.3%+/-5.8% pre intervention vs. 20.4%+/-6.6% post intervention, p=0.002)	89
Yilmaz *et al.*	2007	Education, multimodal without demonstration. Self-study module.	Physicians, interns and nurses	13.04/1000	7.6/1000	4b		Post-intervention risk factors for CRBSI rates identified as insertion of CVC in emergency conditions (increase of 3.52 times), inexperienced personnel insertion (increase of 2.63 times) and lack of hand hygiene (increase of 84%).	88

Table 17: Education Group 8: Method not specified. Kirkpatrick Level 3:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Rosenthal *et al.*	2003	Not specified	"Healthcare workers"	45.9/1000	9.9/1000	3 and 4b	No increase in compliance with CVC site care through education alone. Education and feedback dramatically enhanced compliance with CVC site care (gauze presence increased from 53.02% to 96.53%, p<0.001, dating of IV administration set increased from 0.57% to 74%, p<0.001 and good gauze condition increased from 48.7% to 89.56%, p<0.001).	3 part intervention- part 1 consisted of active surveillance for IV device associated infections and compliance with IV site care, part 2 consisted of education for all healthcare workers in CVC care based on CDC guidelines and part 3 consisted of monthly performance feedback documenting rates of compliance with CVC care practice.	73

Table 18: Education Group 8: Method not specified. Kirkpatrick Level 4:

Author	Year of publication	Type of intervention	Participant group	Infection rate pre-intervention (per 1000 CVC days)	Infection rate post-intervention (per 1000 CVC rate)	Kirkpatrick level	Behavioural change	Other comments/findings	Quality score (%)
Gnass *et al.*	2004	Not specified	Physicians and nurses	No baseline	Fell to 2.7/1000	4b		Average time to onset of infection after catheter placement was 8+/-7.1days for PICCs, 10.9+/-7.5days for percutaneous, non-tunnelled jugular CVCs and 12.5+/-11.3days for percutaneous, nontunnelled subclavian CVCs.	32
Price *et al.*	2002	Not specified	"Staff"	4.2/100 patient months	>1/100 patient months	4b		Planned in response to outbreak. Intervention rates pre-outbreak were 0.7/100 patient months. Other components of intervention included use of chlorhexidine instead of povidone iodine, discontinuation of use of antimicrobial ointments containing polyethylene, use of gauze with tape instead of transparent dressings and removal of said products from unit to increase compliance. Outbreak suspected result of changes in ownership to private and cessation of bi-weekly infection control monitoring.	64
Rosenthal *et al.*	2003	Not specified	"Healthcare workers"	45.9/1000	9.9/1000	3 and 4b	No increase in compliance with CVC site care through education alone. Education and feedback dramatically enhanced compliance with CVC site care (gauze presence increased from 53.02% to 96.53%, p<0.001, dating of IV administration set increased from 0.57% to 74%, p<0.001 and good gauze condition increased from 48.7% to 89.56%, p<0.001).	3 part intervention- part 1 consisted of active surveillance for IV device associated infections and compliance with IV site care, part 2 consisted of education for all healthcare workers in CVC care based on CDC guidelines and part 3 consisted of monthly performance feedback documenting rates of compliance with CVC care practice.	73
Berriel-Cass *et al.*	2006	Not specified	Physicians and nurses	7/1000	3.0/1000	4b		73% of CRBSI cases were not implemented using bundle. Use of bundle meant longer period of time to acquire infection (change in average time from 5.8 days to 13.2 days)	39

Misset *et al.*	2004	Not specified	Physicians and nurses	3.5/1000	0.0/1000	4b		Also looked at VAP rates- fell from 7.9/1000days to 7.7/1000 days. Use of MSBP and type of skin disinfectant most correlated with CVC rates. Other components of intervention included daily examination of CVC area, use of povidone iodine, replacement of dressings every 48 hours and site of CVC insertion	92
Young *et al.*	2006	Not specified	Medical and surgical residents	11.3/1000	3.7/1000	4b		Introduction of customised CVC kit, including large sterile drape, chlorhexidine and alcohol solution. Estimated annual cost savings f $368000.	57
Goeschel *et al.*	2006	Not specified	First year residents and nursing staff	Not reported	Not reported	4b		Intervention part of Keystone ICU project: involving interventions to improve VAP, implement and evaluate communication tool in ICU, implement and evaluate CUSP and improve CRBSI rates. CRBSI intervention consisted of: 1) Education of staff members. 2) Creation of a central line cart. 3) Creation of a checklist to ensure compliance with policy. 4) Creation of new policy allowing nurse intervention in case of violation from policy. 5) Asking providers daily if central line can be removed. 6) Provision of feedback regarding CRBSI rates. Use 4E principles: engage, educate, execute and evaluate. 72 hospitals containing 108 ICUs participated in the initial phase of the study, being joined later by 5 hospitals containing 19 additional ICUs. Reduction in VAP and CRBSI, moving from 50th percentile in country prior to intervention to 10th percentile in country after intervention. 68 ICU teams completely eliminated CRBSI and VAP (6 months infection free).	40
Capretti *et al.*	2008	Not specified	Not specified	11/1000	3.1/1000	4b		Looks at nosocomial infection rate among very low birth weight infants. Hand washing main focus on educational intervention. After intervention, only 1 catheter infected (1.1%) compared with 5 (4.9%) pre-intervention. Statistically significant reduction in CVC colonisation rate between the 2 periods, from 16.6% (95% CI 10.5% -25.1%) of cultures pre-intervention compared to 5.8% (95% CI 2.2%-13.3%) of cultures post-intervention. Change in supplies from 0.5% triclosan to 4% chlorhexidine gluconate and alcohol based hand rub during intervention. Removal of hand jewellery necessary. Short nails recommended.	85

Table 19: Summary of excluded studies

Author	Title	Year of publication	Journal	Reason for Exclusion
Ahmad, *et al.*	A training model for central venous cannulation for everyman?.	2007	Journal of clinical anesthesia	No empirical research carried out
Anguera Saperas, *et al.*	[New strategy of actuation in central venous catheter and its influence in infection]	2004	Enfermeria Intensiva	Unable to obtain journal
Anonymous	Education at the island of Mallorca	2002	Deutsche Apotheker Zeitung	Unable to obtain journal
Aragon, *et al*.	Implementing best practice strategies to prevent infection in the ICU	2006	Critical care nursing clinics of North America	Did not fulfil inclusion criteria
Asai, *et al.*	Education, in addition to a thin material, encourages anaesthetists to wear gloves	2006	Acta Anaesthesiologica Scandinavica	Unable to obtain journal
Assanasen, *et al.*	Impact of 2 different levels of performance feedback on compliance with infection control process measures in 2 intensive care units	2008	American Journal of Infection Control	Did not fulfil inclusion criteria
Attar, *et al.*	Evidence-based prevention of catheter infection during parenteral nutrition.[see comment]	2001	Current Opinion in Clinical Nutrition & Metabolic Care	Did not fulfil inclusion criteria
Ault *et al.*	The use of tissue models for vascular access training - Phase I of the procedural patient safety initiative	2006	Journal of General Internal Medicine	No empirical research carried out
Barr, *et al.*	Outcomes in critically ill patients before and after the implementation of an evidence-based nutritional management protocol	2004	Chest	Educational intervention not present
Barton, *et al.*	A new approach to training in intravenous drug therapy.	2003	Nursing times	No empirical research carried out
Bent, *et al.*	The use of systematic reviews and meta-analyses in infection control and hospital epidemiology	2004	American Journal of Infection Control	No empirical research carried out
Berhe, *et al.*	Measurement and feedback of infection control process measures in the intensive care unit: Impact on compliance.	2006	American Journal of Infection Control	Educational intervention not present
Bijma, *et al.*	Preventing central venous catheter-related infection in a surgical intensive-care unit.	1999	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Bishop, *et al.*	Guidelines on the insertion and management of central venous access devices in adults	2008	British Journal of Intensive Care	Guidelines- no new data
Bonson, *et al.*	Designing and implementing an intravenous therapy book.	2006	Nursing times	No empirical research carried out
Bosonnet.	Total parenteral nutrition: how to reduce the risks	2002	Nursing times	No empirical research carried out

Braun, *et al.*	Preventing central venous catheter-associated primary bloodstream infections: characteristics of practices among hospitals participating in the Evaluation of Processes and Indicators in Infection Control (EPIC) study	2003	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Burns.	The Vanderbilt PICC service: Program, procedural, and patient outcomes successes	2005	JAVA - Journal of the Association for Vascular Access	Did not fulfil inclusion criteria
Buttes, *et al.*	Drive down infection rates	2006	Nursing Management USA	No empirical research carried out
Byrnes, *et al.*	Prevention of catheter-related blood stream infection	2007	Current opinion in critical care	Did not fulfil inclusion criteria
Carlbom, *et al.*	Barriers to implementing protocol-based sepsis resuscitation in the emergency department--results of a national survey	2007	Critical care medicine	Educational intervention not present
Carrion*, et al.*	Accidental removal of endotracheal and nasogastric tubes and intravascular catheters.	2000	Critical care medicine	Educational intervention not present
Case.	Guidelines for good practice in central venous catheterization	1995	Journal of Hospital Infection	Guidelines- no new data
Christenson, *et al.*	Improving patient safety: Resource availability and application for reducing the incidence of healthcare-associated infection		Infection Control and Hospital Epidemiology	Did not fulfil inclusion criteria
Conn, *et al.*	Hospitals' dirty secret. New reports on hospital patient safety and infections reveal pattern of deadly and expensive, yet preventable, medical errors.	2006	Modern healthcare	No empirical research carried out
Cook.	Central venous catheters: preventing infection and occlusion	1998	British Journal of Nursing	No empirical research carried out
Cookson, *et al.*	Increased bloodstream infection rates in surgical patients associated with variation from recommended use and care following implementation of a needleless device	1998	Infection Control and Hospital Epidemiology	Educational intervention not present
Crawford, *et al.*	Peripherally inserted central catheter program	2000	Nursing Clinics of North America	Did not fulfil inclusion criteria
Csomos, *et al.*	Intensive care nurses' knowledge about the evidence-based guidelines of preventing centralvenous catheter related infection	2008	Orvosi hetilap	Educational intervention not present
Cunningham, *et al.*	Peripheral infusion ports for central venous access in patients with gynecologic malignancies	1996	Gynecologic oncology	Did not fulfil inclusion criteria
Daghistani, *et al.*	Prevention of indwelling central venous catheter sepsis	1996	Medical & Pediatric Oncology	Did not fulfil inclusion criteria
Darouiche.	Prevention of vascular catheter-related infections	1999	Netherlands Journal of Medicine	Did not fulfil inclusion criteria
De Andres, *et al.*	Continuing medical education	2004	Revista de la Sociedad Espanola del Dolor	No empirical research carried out
Depasse, *et al.*	A profile of European ICU nursing.	1998	Intensive care medicine	No empirical research carried out
Depledge, *et al.*	Providing IV therapy education to community nurses.	2006	British journal of community nursing	Did not fulfil inclusion criteria

Deshpande, *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	2005	Critical care medicine	Did not fulfil inclusion criteria
Do, *et al.*	Bloodstream infection associated with needleless device use and the importance of infection-control practices in the home healthcare setting	1999	Journal of Infectious Diseases	Did not fulfil inclusion criteria
Domm, *et al.*	Complications of central venous access devices in paediatric haemophilia patients	2003	Haemophilia	Did not fulfil inclusion criteria
Earhart, *et al.*	Reducing catheter-related bloodstream infections: An extended-care facility's process improvement experience	2006	JAVA - Journal of the Association for Vascular Access	Did not fulfil inclusion criteria
Earsing, *et al.*	Best-practice protocols: preventing central line infection.	2005	Nurs Manage	Educational intervention not present
Ellison, *et al.*	Standard precautions in the pediatric emergency department: knowledge, attitudes, and behaviors of pediatric and emergency medicine residents.	2007	Pediatric emergency care	Educational intervention not present
Engum, *et al.*	Intravenous catheter training system: computer-based education versus traditional learning methods.	2003	American Journal of Surgery	Did not fulfil inclusion criteria
Faber.	Program for training staff pharmacists in total parenteral nutrition	1991	American Journal of Hospital Pharmacy	Study published prior to 1995
Ferrell, *et al.*	Make computer-based training user-friendly.	2003	Nursing Management USA: IT Solutions Supplement	No empirical research carried out
Fitzsimmons, *et al.*	Central venous catheter placement: extending the role of the nurse	1997	Journal of the Royal College of Physicians of London	Did not fulfil inclusion criteria
Funk, *et al.*	Two-year trends of peripherally inserted central catheter-line complications at a tertiary-care hospital: role of nursing expertise.	2002	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Gaies, *et al.*	Assessing procedural skills training in pediatric residency programs	2007	Pediatrics	Did not fulfil inclusion criteria
Galway, *et al.*	Central venous access and handwashing: variability in policies and practices	2003	Paediatric nursing	Did not fulfil inclusion criteria
Gamulka, *et al.*	Evaluation of a unique, nurse-inserted, peripherally inserted central catheter program.	2005	Pediatrics	Did not fulfil inclusion criteria
Garris, *et al.*	First-year residency candidates' experience in various areas of pharmacy practice	2008	American Journal of Pharmaceutical Education	Educational intervention not present
Gurgueira, *et al.*	Outcomes in a pediatric intensive care unit before and after the implementation of a nutrition support team.	2005	Jpen: Journal of Parenteral & Enteral Nutrition	Did not fulfil inclusion criteria
Guzzo, *et al.*	Mentors decrease compliance with best sterile practices during central venous catheter placement in the trauma resuscitation unit.	2006	Surgical Infections	Educational intervention not present
Hadaway.	Best-practice interventions: keeping central line infection at bay.	2006	Nursing	Educational intervention not present
Hammarskjold, *et al.*	Central venous catheter infections at a county hospital in Sweden: A prospective analysis of colonization, incidence of infection and risk factors	2006	Acta Anaesthesiologica Scandinavica	Educational intervention not present

Hanchett.	Training simulators for IV education: Benefits, costs, and new opportunities	2002	Journal of Vascular Access Devices	No empirical research carried out
Hanssens, *et al.*	Improving oral medicine administration in patients with swallowing problems and feeding tubes.	2006	Annals of Pharmacotherapy	Did not fulfil inclusion criteria
Harrigan, *et al.*	Developing and implementing quality initiatives in the ICU: strategies and outcomes.	2006	Crit Care Nurs Clin North Am	Did not fulfil inclusion criteria
Harting, *et al.*	University HealthSystem Consortium quality performance benchmarking study of the insertion and care of central venous catheters	2008	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Hornsby, *et al.*	Cost losses associated with the "PICC, stick, and run team" concept.	2005	Journal of Infusion Nursing	Did not fulfil inclusion criteria
Huang, *et al.*	Beyond the comfort zone: residents assess their comfort performing inpatient medical procedures.	2006	American Journal of Medicine	Educational intervention not present
Huang, *et al.*	Impact of routine intensive care unit surveillance cultures and resultant barrier precautions on hospital-wide methicillin-resistant Staphylococcus aureus bacteremia	2006	Clinical Infectious Diseases	Educational intervention not present
Hughes.	Peripherally inserted central catheters: a collaborative, multidisciplinary approach.	2007	Cancer Nursing Practice	Did not fulfil inclusion criteria
Ihrig, *et al.*	Evaluation of the acceptability of a needleless vascular-access system by nurses	1997	American Journal of Infection Control	Did not fulfil inclusion criteria
Inwood.	Designing a nurse training programme for venepuncture.	1996	Nursing Standard	No empirical research carried out
Jacobson, *et al.*	Variables influencing intravenous catheter insertion difficulty and failure: an analysis of 339 intravenous catheter insertions.	2005	Heart & Lung	Did not fulfil inclusion criteria
Jain, *et al.*	Dissemination of the Canadian clinical practice guidelines for nutrition support: Results of a cluster randomized controlled trial	2006	Critical care medicine	Did not fulfil inclusion criteria
Jamtvedt, *et al.*	Audit and feedback: effects on professional practice and healthcare outcomes	2006		Educational intervention not present
Jensen, *et al.*	Using Simulation-Based Training to Improve Clinical Outcomes: Central Venous Catheter Placement as a Model for Programmed Training	2008	Seminars in Colon and Rectal Surgery	No empirical research carried out
Jeyanathan, *et al.*	Preventing infections associated with the insertion of central venous catheters: are we getting it right?	2008	Journal of Hospital Infection	No empirical research carried out
Karadeniz, *et al.*	Nurses' knowledge regarding patients with intravenous catheters and phlebitis interventions.	2003	Journal of Vascular Nursing	Did not fulfil inclusion criteria
Kidd, *et al.*	Barriers to and facilitators of implementing an intervention to reduce the incidence of catheter-associated bloodstream infections.	2007	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Kilbride, *et al.*	Implementation of evidence-based potentially better practices to decrease nosocomial infections	2003	Pediatrics	Did not fulfil inclusion criteria
Kim, *et al.*	Three-year follow-up of an outbreak of Serratia marcescens bacteriuria in a neurosurgical intensive care unit	2006	Journal of Korean medical science	Did not fulfil inclusion criteria

Kiwitt, *et al.*	The importance of a skill-oriented operationalized postgraduate training programme for the acquisition of optional training in special neurological intensive care	2006	Aktuelle Neurologie	Unable to obtain journal
Kruizenga, *et al.*	Effectiveness and cost-effectiveness of early screening and treatment of malnourished patients	2005	American Journal of Clinical Nutrition	Educational intervention not present
Labeau, *et al.*	Critical care nurses' knowledge of evidence-based guidelines for preventing infections associated with central venous catheters: an evaluation questionnaire.	2008	Am J Crit Care	Educational intervention not present
Lange*, et al.*	Impact of changes in catheter management of infectious complications among children with central venous catheters	1997	Infection Control & Hospital Epidemiology	Educational intervention not present
Larson, *et al.*	Dissemination of the CDC's Hand Hygiene Guideline and impact on infection rates	2007	American Journal of Infection Control	Did not fulfil inclusion criteria
Larson.	State-of-the-science-2004: Time for a "No Excuses		American Journal of Infection Control	No empirical research carried out
Leboucher, *et al.*	Effectiveness of an informative report on the prevention of nosocomial bloodstream infections in a neonatal intensive care unit	2006	Archives De Pediatrie	Foreign language study
Lenhard, *et al.*	An intervention to improve procedure education for internal medicine residents	2008	Journal of General Internal Medicine	Did not fulfil inclusion criteria
Linck, *et al.*	Neonatal peripherally inserted central catheter team. Evolution and outcomes of a bedside-nurse-designed program.	2007	Advances in Neonatal Care	Did not fulfil inclusion criteria
Livingston, *et al.*	If the gut works use it	2000	Nursing management	Did not fulfil inclusion criteria
Lizan-Garcia, *et al.*	Nosocomial infection surveillance in a surgical intensive care unit in Spain, 1996-2000: a time-trend analysis.	2006	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Loeb, *et al.*	Survey on the diffusion and impact of a consensus conference on sepsis from central venous catheters in a medical team.	1996	Annales Francaises D Anesthesie Et De Reanimation	Study published prior to 1995
Lu, *et al.*	[Increasing the executive rate of standard central venous catheter care]	2006	Hu Li Tsa Chih - Journal of Nursing	Foreign language study
Lucas, *et al.*	Impact of a bedside procedure service on general medicine inpatients: A firm-based trial	2007	Journal of Hospital Medicine (Online)	Did not fulfil inclusion criteria
Lundgren, *et al.*	Effect of education on evidence-based care and handling of peripheral intravenous lines.	1999	J Clinical Nursing	Did not fulfil inclusion criteria
Luque, *et al.*	Infections related to parenteral nutrition catheter	2000	Revista clinica espanola	Educational intervention not present
Maas, *et al.*	Central venous catheter-related bacteraemia in critically ill neonates: risk factors and impact of a prevention programme.	1998	Journal of Hospital Infection	Pre-1995 research
Macnab, *et al.*	Teaching pediatric procedures: The Vancouver model for instructing Seldinger's technique of central venous access via the femoral vein	2000	Pediatrics	Did not fulfil inclusion criteria
Magin, *et al.*	Getting down and dirty: The effect of an education program on the incidence of central venous catheter infections	2005	Clinical Pulmonary Medicine	Editorial

Mason, *et al.*	See one, do one, teach one--is this still how it works? A comparison of the medical and nursing professions in the teaching of practical procedures.	2003	Medical teacher	Did not fulfil inclusion criteria
McConnell.	Australian registered nurse medical device education: a comparison of simple vs. complex devices.	1996	J Advanced Nursing	Did not fulfil inclusion criteria
McGill, *et al.*	AV fistula rates: Changing the culture of vascular access	2005	Journal of Vascular Access	No empirical research carried out
McKay, *et al.*	Reducing catheter-related bloodstream infections through adherence to evidence-based practices in a medical intensive care unit (MICU)	2006	Journal of the Association for Vascular Access	Did not fulfil inclusion criteria
Memish, *et al.*	Comparison of US and non-US central venous catheter infection rates: evaluation of processes and indicators in infection control study	2003	American Journal of Infection Control	Did not fulfil inclusion criteria
Merkouris, *et al.*	Staffing and organisation of nursing care in cardiac intensive care units in Greece	2003	European Journal of Cardiovascular Nursing	Did not fulfil inclusion criteria
Mermel.	Prevention of central venous catheter-related infections: what works other than impregnated or coated catheters?	2007	Journal of Hospital Infection	No empirical research carried out
Miller.	Downsizing: use intravenous clinicians to maintain quality venous access care	1998	Journal of Intravenous Nursing	Educational intervention not present
Mizuta, *et al.*	[Local survey of practice patterns for barrier precautions during anesthesia practice]	2007	Masui - Japanese Journal of Anesthesiology	Foreign language study
Moreira, *et al.*	Efficacy of a program of prevention and control for methicillin-resistant Staphylococcus aureus infections in an intensive-care unit	2007	Brazilian Journal of Infectious Diseases	Did not fulfil inclusion criteria
Morgan, *et al.*	Implementing evidence-based nursing practice in the pediatric intensive care unit.	2007	Journal of Infusion Nursing	Did not fulfil inclusion criteria
Morritt, *et al.*	Handwashing practice and policy variability when caring for central venous catheters in paediatric intensive care.	2006	Australian Critical Care	Did not fulfil inclusion criteria
Mortlock.	Infection control	2001	Journal of Intravenous Nursing	Did not fulfil inclusion criteria
Nobile, *et al.*	Healthcare personnel and hand decontamination in intensive care units: knowledge, attitudes, and behaviour in Italy	2002	Journal of Hospital Infection	Did not fulfil inclusion criteria
O'Grady, *et al.*	Special report. Guidelines for the prevention of intravascular catheter-related infections	2002	Infection Control & Hospital Epidemiology	Guidelines- no new data
O'Grady.	On the road to avoiding adverse events: educational programs pave the way	2003	Critical care medicine	Did not fulfil inclusion criteria
O'Grady, *et al.*	Patient safety and the science of prevention: The time for implementing the Guidelines for the Prevention of Intravascular Catheter-Related Infections is now	2002	Critical care medicine	Guidelines- no new data
Olivier.	Real-time sonography with central venous access: the role of self-training...	2007	Chest	Did not fulfil inclusion criteria

Orsi, *et al.*	Surveillance and infection control in an intensive care unit	2005	Infection Control and Hospital Epidemiology	Did not fulfil inclusion criteria
Orto, *et al.*	Beyond the ICU: nursing's role in decreasing central venous CR-BSIs.	2000	Nursing Management USA	Did not fulfil inclusion criteria
Ozyazicioglu, *et al.*	The effect of nurse training on the improvement of intravenous applications.	2008	Nurse education today	Did not fulfil inclusion criteria
Penne.	Using evidence in central catheter care.	2002	Seminars in oncology nursing	Did not fulfil inclusion criteria
Peterson, *et al.*	Hospital-acquired infections as patient safety indicators.	2006	Annu Rev Nurs Res	Did not fulfil inclusion criteria
Pittet.	Improving adherence to hand hygiene practice: A multidisciplinary approach	2001	Emerging Infectious Diseases	Did not fulfil inclusion criteria
Pons, *et al.*	Nursing protocol for manipulation of haemodialysis catheters	1996	Edtna-Erca Journal	Did not fulfil inclusion criteria
Posa, *et al.*	Elimination of central line-associated bloodstream infections: application of the evidence	2006	AACN Advanced Critical Care	Did not fulfil inclusion criteria
Puntis.	Staff training: a key factor in reducing intravascular catheter sepsis	1991	Archives of Disease in Children	Study published prior to 1995
Ricard.	Catheters, infection, and videotapes	2007	Critical care medicine	Did not fulfil inclusion criteria
Richard-Smith, *et al.*	Reducing central line catheter infections in bone marrow transplant patients	1995	Nursing Clinics of North America	Did not fulfil inclusion criteria
Rijnders, *et al.*	Use of semiautomatic treatment advice to improve compliance with infectious Diseases Society of America guidelines for treatment of intravascular catheter-related infection: A before-after study	2003	Clinical Infectious Diseases	Did not fulfil inclusion criteria
Roberts, *et al.*	Simply a case of good practice. Avoiding catheter-related sepsis in total parenteral nutrition	1993	Professional Nurse	Study published prior to 1995
Rubinson, *et al.*	Why is it that internists do not follow guidelines for preventing intravascular catheter infections?[see comment].	2005	Infection Control & Hospital Epidemiology	Commentary on another article
Sabbaj*, et al.*	Ultrasonographic guidance for internal jugular vein cannulation: an educational imperative, a desirable practice alternative	2006	Annals of Emergency Medicine	Did not fulfil inclusion criteria
Safdar, *et al.*	A review of risk factors for catheter-related bloodstream infection caused by percutaneously inserted, noncuffed central venous catheters: Implications for preventive strategies	2002	Medicine	Educational intervention not present
Salgado, *et al.*	Increased rate of catheter-related bloodstream infection associated with use of a needleless mechanical valve device at a long-term acute care hospital	2007	Infection Control & Hospital Epidemiology	Did not fulfil inclusion criteria
Santarpia, *et al.*	Prevention and treatment of implanted central venous catheter (CVC) related sepsis: A report after six years of home parenteral nutrition (HPN)	2002	Clinical Nutrition	Did not fulfil inclusion criteria

Saqui, *et al.*	Telehealth videoconferencing: improving home parenteral nutrition patient care to rural areas of Ontario, Canada	2007	JPEN Journal of Parenteral & Eternal Nutrition	Did not fulfil inclusion criteria
Schelper, *et al.*	Nurses' educational session getting started in TPN	2002	Clinical Nutrition	Did not fulfil inclusion criteria
Schwartz.	Enhanced enteral and parenteral nutrition practice and outcomes in an intensive care unit with a hospital-wide performance improvement process.	1996	Journal of the American Dietetic Association	Did not fulfil inclusion criteria
Scocca, *et al.*	Initial experience of a nurse-implemented peripherally inserted central catheter program in Italy	2008	JAVA - Journal of the Association for Vascular Access	Did not fulfil inclusion criteria
Scolapio, *et al.*	Advances and controversies in clinical nutrition: The education outcome of a live continuing medical education course	2008	Nutrition in Clinical Practice	Did not fulfil inclusion criteria
Sheikh, *et al.*	Prevention of sepsis in neonatal intensive care unit (ICU)	1999	JK Practitioner	Educational intervention not present
Shumway, *et al.*	A comparison of nurse anesthesia practice types.	2000	AANA Journal	Educational intervention not present
Silva, *et al.*	Klebsiella pneumoniae outbreak in a cancer unit of a general hospital - Predisposing factors and evaluation of the impact of intervention measures	2005	Brazilian Journal of Infectious Diseases	Did not fulfil inclusion criteria
Smith, *et al.*	Clinical trial of interactive and videotaped educational interventions reduce infection, reactive depression, and rehospitalizations for sepsis in patients on home parenteral nutrition	2003	JPEN Journal of Parenteral & Eternal Nutrition	Did not fulfil inclusion criteria
Smith.	A care bundle for management of central venous catheters	2007	Paediatric nursing	Did not fulfil inclusion criteria
Snelling, *et al.*	Developing self-directed training for intravenous cannulation.	2002	Professional Nurse.2002 Nov.pp.137-42	Did not fulfil inclusion criteria
Spain, *et al.*	Infusion protocol improves delivery of enteral tube feeding in the critical care unit.	1999	Jpen: Journal of Parenteral & Enteral Nutrition	Educational intervention not present
Steinmann, *et al.*	Implementation of a novel on-ward computer-assisted surveillance system for device-associated infections in an intensive care unit	2008	International journal of hygiene and environmental health	Did not fulfil inclusion criteria
Suchner, *et al.*	Requirements for structure and function of a nutritional support team	2000	Anaesthesist	Did not fulfil inclusion criteria
Toltzis.	Antibiotic lock technique to reduce central venous catheter-related bacteremia	2006	Pediatric Infectious Disease Journal	Did not fulfil inclusion criteria
Trick, *et al.*	Computer algorithms to detect bloodstream infections	2004	Emerging Infectious Diseases	Did not fulfil inclusion criteria
van Tiel, *et al.*	Plan-do-study-act cycles as an instrument for improvement of compliance with infection control measures in care of patients after cardiothoracic surgery	2006	Journal of Hospital Infection	Did not fulfil inclusion criteria
Weissenfluh, *et al.*	Early enteral nutrition after abdominal trauma: Effects on septic morbidity and practicality	2006	Nutrition in Clinical Practice	Did not fulfil inclusion criteria
White, *et al.*	Enteral tube feeding training for nurses and care assistants.	2001	British journal of community nursing	Did not fulfil inclusion criteria

Woo, *et al.*	Compliance with infection control practice guidelines for central venous catheter insertion in the emergency department	2008	Annals of Emergency Medicine	Did not fulfil inclusion criteria
Worth, *et al.*	Catheter-related bloodstream infections in hematology: Time for standardized surveillance?	2007	Cancer	Did not fulfil inclusion criteria

Table 20: Completed Searches

Database		Search strategy	Searcher	Articles retrieved	De-duplication tota
National Library for Health	BNI	MeSH (Appendix 1)	G Cherry	444	
	CINAHL	MeSH (Appendix 1)	G Cherry	1482	
	Medline	MeSH (Appendix 1)	G Cherry	4680	
	Embase	MeSH (Appendix 1)	G Cherry	3616	
	HMIC	MeSH (Appendix 1)	G Cherry	38	
National Library for Health			G Cherry	**10260**	
Web of Science		Natural language (Appendix 2)	G Cherry	**3798**	**9547**
Cochrane Library		MeSH (Appendix 1)	G Cherry	355	9860
NHS Centre for Reviews and Dissemination (CRD)	Database of Abstracts of Reviews of Effectiveness (DARE)	MeSH (Appendix 1)	G Cherry	2	
	NHS Economic Evaluation Database (NHS EED)	MeSH (Appendix 1)	G Cherry	12	
	Health Technology Assessment (HTA)Database	MeSH (Appendix 1)	G Cherry	0	
NHS Centre for Reviews and Dissemination (CRD)			G Cherry	8	**9868**
ERIC		Natural language (Appendix 2)	G Cherry	0	**9868**
TIMElit		Natural language (Appendix 2)	G Cherry	81	**9948**
The National Research Register		Natural language (Appendix 2)	G Cherry	0	9956
COPAC		Natural language (Appendix 2)	G Cherry	7	9956
Grey Literature	openSIGLE	Natural language (Appendix 2)	G Cherry	4	**9960**
	BUBLE	Natural language (Appendix 2)	G Cherry	0	**9960**
British Library Catalogue		Natural language (Appendix 2)	G Cherry	4	9964

Journal	Year of search	Search strategy	Searcher	Articles retrieved	De-duplication total
Infection Control and Hospital Epidemiology	1995-2008	Hand search	B Shaw	9	
British Journal of Infection Control	1995-2008	Hand search	B Shaw	12	
American Journal of Infection Control	1995-2008	Hand search	B Shaw	8	
Pediatrics	1995-2008	Hand search	G Cherry	0	
Journal of Hospital Infection	1995-2008	Hand search	G Cherry	5	
Journal of IV Nursing (formally Journal of Infusion Nursing)	1995-2008	Hand search	G Cherry	0	
Journal for the Association of Vascular Access (JAVA)	1995-2008	Hand search	G Cherry	0	
Critical Care Medicine	1995-2008	Hand search	G Cherry	5	
Chest	1995-2008	Hand search	G Cherry	4	
Medical Education	1995-2008	Hand search	G Cherry	0	
Medical Teacher	1995-2008	Hand search	G Cherry	0	
Reference lists from included studies and reviews		Hand search	G Cherry	9	9997

Table 21: Search Terms Used

BNI Search Strategy

1	exp INFECTION CONTROL/
2	(cross ADJ infection).ti,ab
3	(infection ADJ control).ti,ab
4	(disease ADJ transmission).ti,ab
5	(universal ADJ precautions).ti,ab
6	exp BACTERIAL INFECTIONS/
7	sepsis.ti,ab
8	asepsis.ti,ab
9	bact*.ti,ab
10	hand*.ti,ab
11	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10
12	(central ADJ venous ADJ catheter*).ti,ab
13	(cv ADJ venous ADJ line* OR central ADJ line*).ti,ab
14	(cv ADJ venous ADJ access ADJ device*).ti,ab
15	(crbsi OR crbi OR cabsi OR catheter ADJ related ADJ blood* ADJ infection* OR catheter ADJ related ADJ bloodstream ADJ infection* OR catheter ADJ related ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ bloodstream ADJ infection* OR catheter ADJ associated ADJ blood* ADJ infection*).ti,ab
16	(cv ADJ catheter OR cv ADJ line*).ti,ab
17	exp "ENTERAL AND PARENTERAL NUTRITION"/
18	(parenteral ADJ nutrition).ti,ab
19	12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18
20	exp EDUCATION OTHER PROFESSIONS/ OR exp EDUCATION PRACTICAL EXPERIENCE/ OR exp INTERPROFESSIONAL EDUCATION/ OR exp NURSING EDUCATION/ OR exp MIDWIFERY EDUCATION/
21	exp EDUCATION METHODS/
22	(teaching OR education OR health ADJ education).ti,ab
23	exp HEALTH PROMOTION/
24	(education* ADJ intervention*).ti,ab
25	(train* OR educat* OR techniqu* OR instruct* OR pract* OR teach* OR course* OR learn* OR tutor*).ti,ab
26	20 OR 21 OR 22 OR 23 OR 24 OR 25
27	11 AND 19 AND 26

Medline, CINAHL, Cochrane Database of Systematic Reviews, DARE, HTA, NHSeed, Register of Controlled Trials

1	exp *CROSS INFECTION/
2	(cross ADJ infection).ti,ab
3	exp *INFECTION CONTROL/
4	(infection ADJ control).ti,ab
5	exp *DISEASE TRANSMISSION/
6	(disease ADJ transmission).ti,ab
7	exp *UNIVERSAL PRECAUTIONS/
8	(universal ADJ precautions).ti,ab
9	exp *SEPSIS/
10	sepsis.ti,ab
11	infection.ti,ab
12	exp *ASEPSIS/
13	asepsis.ti,ab
14	bact*.ti,ab
15	exp *BACTERIA/
16	hand*.ti,ab
17	exp *HANDWASHING/
18	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26
19	exp *CATHETERIZATION, CENTRAL VENOUS/
20	(central ADJ venous ADJ catheter*).ti,ab
21	(central ADJ venous ADJ line* OR central ADJ line*).ti,ab
22	(central ADJ venous ADJ access ADJ device*).ti,ab
23	(crbsi OR crbi OR cabsi OR catheter ADJ related ADJ blood* ADJ infection* OR catheter ADJ related ADJ bloodstream ADJ infection* OR catheter ADJ related ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ bloodstream ADJ infection* OR catheter ADJ associated ADJ blood* ADJ infection*).ti,ab
24	(cv ADJ catheter OR cv ADJ line*).ti,ab
25	exp *PARENTERAL NUTRITION/
26	(parenteral ADJ nutrition).ti,ab
27	29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35 OR 36
28	exp *EDUCATION, MEDICAL/ OR exp *EDUCATION, PROFESSIONAL/ OR exp *EDUCATION, NURSING/ OR exp *INSERVICE TRAINING/ OR exp *EDUCATIONAL MEASUREMENT/ OR exp *TEACHING/ OR exp *EDUCATION/
29	education.ti,ab
30	(health AND education).ti,ab
31	exp *HEALTH EDUCATION/
32	(education* ADJ intervention*).ti,ab
33	(train* OR educat* OR techniqu* OR instruct* OR pract* OR teach* OR course* OR learn* OR tutor*).ti,ab
34	38 OR 39 OR 40 OR 41 OR 42 OR 43
35	27 AND 37 AND 44

Embase

1	exp CROSS INFECTION/
2	(cross ADJ infection).ti,ab
3	exp INFECTION CONTROL/
4	(infection ADJ control).ti,ab
5	exp DISEASE TRANSMISSION/
6	(disease AND transmission).ti,ab
7	(universal ADJ precautions).ti,ab
8	exp SEPSIS/
9	sepsis.ti,ab
10	exp ASEPSIS/
11	asepsis.ti,ab
12	exp BACTERIUM/
13	bact*.ti,ab
14	exp HAND WASHING/
15	hand*.ti,ab
16	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15
17	exp CENTRAL VENOUS CATHETERIZATION/
18	(central ADJ venous ADJ catheter*).ti,ab
19	(central ADJ venous ADJ line* OR central ADJ line*).ti,ab
20	(central ADJ venous ADJ access ADJ device*).ti,ab
21	(crbsi OR crbi OR cabsi OR catheter ADJ related ADJ blood* ADJ infection* OR catheter ADJ related ADJ bloodstream ADJ infection* OR catheter ADJ related ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ bloodstream ADJ infection* OR catheter ADJ associated ADJ blood* ADJ infection*).ti,ab
22	(cv ADJ catheter OR cv ADJ line*).ti,ab
23	exp PARENTERAL NUTRITION/
24	(parenteral ADJ nutrition).ti,ab
25	17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24
26	exp MEDICAL EDUCATION/ OR exp VOCATIONAL EDUCATION/ OR exp NURSING EDUCATION/ OR exp IN SERVICE TRAINING/ OR exp EDUCATION/ OR exp TEACHING/
27	education.ti,ab
28	(health AND education).ti,ab
29	exp HEALTH EDUCATION/
30	(education* ADJ intervention*).ti,ab
31	(train* OR educat* OR techniqu* OR instruct* OR pract* OR teach* OR course* OR learn* OR tutor*).ti,ab
32	26 OR 27 OR 28 OR 29 OR 30 OR 31
33	16 AND 25 AND 32

HMIC

No.	Search term
1	exp CROSS INFECTION/
2	(cross ADJ infection).ti,ab
3	exp INFECTION CONTROL/
4	(infection ADJ control).ti,ab
5	(disease ADJ transmission).ti,ab
6	(universal ADJ precautions).ti,ab
7	sepsis.ti,ab
8	exp SEPSIS/
9	exp ASEPTIC TECHNIQUES/
10	exp BACTERIA/
11	bacteria.ti,ab
12	exp CLINICAL HANDWASHING/
13	hand*.ti,ab
14	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
15	exp INTRAVENOUS CATHETERS/
16	(central ADJ venous ADJ catheter*).ti,ab
17	(central ADJ venous ADJ line* OR central ADJ line*).ti,ab
18	(central ADJ venous ADJ access ADJ device*).ti,ab
19	(crbsi OR crbi OR cabsi OR catheter ADJ related ADJ blood* ADJ infection* OR catheter ADJ related ADJ bloodstream ADJ infection* OR catheter ADJ related ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ blood-stream ADJ infection* OR catheter ADJ associated ADJ bloodstream ADJ infection* OR catheter ADJ associated ADJ blood* ADJ infection*).ti,ab
20	(cv ADJ catheter OR cv ADJ line*).ti,ab
21	exp PARENTERAL NUTRITION/
22	(parenteral ADJ nutrition).ti,ab
23	15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22
24	exp MEDICAL EDUCATION/ OR exp PROFESSIONAL EDUCATION/ OR exp NURSING EDUCATION/ OR exp EDUCATIONAL TESTING/ OR exp TEACHING/
25	exp HEALTH EDUCATION/
26	(health ADJ education).ti,ab
27	(education* ADJ intervention*).ti,ab
28	(train* OR educat* OR techniqu* OR instruct* OR pract* OR teach* OR course* OR learn* OR tutor*).ti,ab
29	24 OR 25 OR 26 OR 27 OR 28
30	14 AND 23 AND 29

Search Terms used

Natural language terms used in National Research Register, COPAC, British Library Catalogue, OpenSIGLE, Web of Science

#1	(cross infection or infection control or disease transmission or universal precautions or sepsis or infection or asepsis or bact* or hand*)
#2	(central venous catheter* or central venous line* or central venous access device* or crbsi or crbi or cabsi or catheter related blood* infection* or catheter related bloodstream infection* or catheter related blood-stream infection* or catheter associated blood-stream infection* or catheter associated bloodstream infection* or catheter associated blood* infection* or cv catheter or cv line* or parenteral nutrition)
#3	(train* OR educat* OR techniqu* OR instruct* OR pract* OR teach* OR course* OR learn* OR tutor* or educational intervention*)
#4	1 AND 2 AND 3

Table 22: Assessment of Quality of Study

Qualitative Studies

Criteria		Yes (2/good)	Partial (1/fair)	No (0/poor)	N/A
Study aims					
1.	Is the hypothesis/aim/objective of the study clearly & sufficiently described?	Easily identified in introduction/method. Specifies: purpose, subjects/target population, and specific interventions/ associations under investigation.	Vague/incomplete reporting *or* some info has to be gathered from parts of the paper other than intro/background/ objective section.	Question or objective not reported/ incomprehensible.	
Study design & sample characteristics					
2.	Is the study design well described & appropriate? *(If study question not given, infer from conclusions).*	Design easily identified, well described and appropriate.	Design and/or study question not clearly described, *or* design only partially addresses study question.	Design does not answer study question *or* design is poorly described.	
3.	Is the method of intervention group selection described and appropriate?	Described and appropriate.	Selection methods not completely described, but no obvious inappropriateness. *Or* selection strategy likely introduces bias but not enough to seriously distort results.	No information/ inappropriate information provided *or* selection bias which likely distorts results.	
4.	Are the characteristics of intervention group clearly described (i.e. age range, occupation)?	Sufficient relevant demographic information. Reproducible criteria used to categorise participants clearly defined.	Poorly defined criteria *or* incomplete demographic information.	No baseline/demographic info provided.	
Criteria		**Yes (2/good)**	**Partial (1/fair)**	**No (0/poor)**	**N/A**
5.	Have the characteristics of participants lost to follow-up been described?	Losses adequately reported & not likely to affect results.	Losses not well reported, but small & not likely to affect results.	No information *or* losses large and likely to affect results.	No participants lost to follow-up.
6.	Are educational intervention(s) clearly described?	Defined and reproducible.	Partially defined, but insufficient detail to reproduce design.	Not described.	
7.	Is method of delivery of educational intervention and subsequent follow up clearly defined?	Sufficient relevant descriptive information. Reproducible criteria used to replicate intervention defined.	Poorly defined criteria *or* incomplete descriptive information.	No criteria/descriptive info provided.	
Data analysis & results					
8.	Are the main outcomes to be measured clearly described in the introduction/method?	Defined and measured according to reproducible criteria.	Definition leaves room for subjectivity, *or* not sure (i.e. not reported in detail, but probably acceptable). *Or* precise definition(s) are missing, but no evidence of major problems. *Or* instrument/mode of assessment(s) not reported.	Main outcomes first mentioned in results section. *Or* measures not defined/inconsistent/ poorly defined.	

9..	If possible, was an attempt made to blind those measuring the main outcomes of the intervention?	Assessor blind to intervention/study group.	Inadequate blinding: i.e. assessor may have been aware of group participant assigned to.	No attempt made to blind assessor.	Not possible/ appropriate – e.g. observational/ before & after study.
10..	Are population characteristics (if measured & described) controlled for and adequately described?	Appropriate control at design/analysis stage *or* randomised study with comparable baseline characteristics.	Incomplete control/ description. *Or* not considered but unlikely to seriously influence results.	Not controlled for and likely to seriously influence results.	
Criteria		**Yes (2/good)**	**Partial (1/fair)**	**No (0/poor)**	**N/A**
11.	Are the outcomes chosen to evaluate the intervention appropriate?	Appropriate outcomes selected and reported.	Some outcomes not relevant to assessing appropriateness of intervention.	Outcome measures do not evaluate intervention *or* poorly reported/not defined/inconsistent.	
12.	Are the main findings clearly described?	Simple outcome data (e.g. mean/prevalence) reported for all major findings.	Incomplete or inappropriate descriptive statistics.	No/inadequate descriptive statistics.	
13.	Are methods of analysis adequately described and appropriate?	Described and appropriate.	Not reported but probably appropriate *or* some tests appropriate, some not.	Methods not described and cannot be determined.	
14.	Are estimates of variance reported for the main results?	Appropriate estimates provided (SD/SE, confidence intervals).	Undefined *or* estimates provided for some but not all outcomes.	No information.	
15.	In trials/cohort studies, do analyses adjust for different lengths of follow-up, or in case-control studies, is the time between intervention and outcome the same for cases/controls?	Different lengths of follow-up adjusted for (e.g. survival analysis) and adequately described.	Different lengths of follow-up probably adjusted for but not adequately described.	Differences in follow-up ignored.	Cross-sectional design *or* same length of follow-up.
Conclusions					
16.	Are the conclusions supported by the results?	All conclusions supported by data.	Some of the major conclusions are supported by the data; some are not. *Or* speculative interpretations are not indicated as such.	None/few of major conclusions supported by the data.	

Table 23: Coding Sheet

Reference number	
Name of reviewer	
Author	
Year of publication	
Full citation	
Type of publication	
Study design	
Source of study	
Year of data collection	
Duration of study	
Study setting (location, size, type of acute care, department studied)	
Size of department: number of beds	
Staff:patient ratio	
Intervention setting (location, size, applicable to real life practice)	
Country	
Participants	
Was there a control group (if yes see below)	
Number of participants	
Type of participants	
% participation	
Drop out rate	
Mixed/single occupation group?	
Number prior CVC insertions	
Number post CVC insertions	
Control group	
Number of participants	
Type of participants	
Random allocation?	
% participation	
Drop out rate	
Mixed/single occupation group?	
Comparative with intervention group?	
Number prior CVC insertions	
Number post CVC insertions	
Patient group (intervention)	
Age (mean/SD)	
Sex (% males and females)	
Type of catheter present	
Length of catheterisation	
Length of hospital stay	
Type of catheter lumen	
Patient group (control)	
Age (mean/SD)	
Sex (% males and females)	
Type of catheter present	
Length of catheterisation	

Length of hospital stay	
Comparable with intervention group?	
Type of catheter lumen	
Educational intervention	
Duration of intervention	
Content of intervention	
Method of delivery	
Simulator used?	
Active participation?	
Practical component?	
Applicable to practice?	
Education on mistakes or new methods?	
Other components of intervention (non educational)?	
Able to differentiate from education?	
Changes in supplies made during intervention?	
Able to differentiate from education?	
Intervention voluntary?	
Control intervention	
Duration of intervention	
Content of intervention	
Method of delivery	
Simulator used?	
Active participation?	
Practical component?	
Applicable to practice?	
Education on mistakes or new methods?	
Other components of intervention (non educational)?	
Able to differentiate from education?	
Changes in supplies made during intervention?	
Able to differentiate from education?	
Intervention voluntary?	
Rationale for intervention	
Who was intervention developed by?	
Drive behind intervention	
Was intervention piloted?	
Was expert opinion sought for content?	
Assessment	
Structured?	
Were participants assessed pre/post intervention?	
How?	
Baseline knowledge assessed?	
How?	
Why?	
If observation used, who observed?	
Independent?	
Blind?	
Covert?	
How was intervention scored?	
Time period between intervention and assessment?	

Use of documented assessment measures?	
Time to complete assessment?	
Impact on performance eg appraisal	
Outcome measures	
Specified?	
If so, state primary and secondary	1.
Intervention developed to fulfil them?	
Statistical measures	
What were used?	
Significance values accepted?	
Results	
Document findings	
Comments of interest	
Quality score	
KP level	