Educational interventions for preventing vascular catheter bloodstream infections in critical care: evidence map, systematic review and economic evaluation

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Scientific summary

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Background

Bloodstream infections resulting from the use of intravascular catheters (catheter-BSI) are the most frequent infections in critical care units in England. Catheter-BSI increase patients' length of stay (LOS) in hospital and their risk of health complications and death, and impose a burden on health services in terms of bed occupancy and the additional costs of managing these infections and their complications. Annual costs to the NHS related to catheter-BSI in critical care units have been estimated at £19.1–36.2M. The majority of catheter-BSI are thought to be preventable using evidence-based educational interventions to ensure that doctors and nurses are committed to a culture of safety and follow best practice to achieve this. However, there is a lack of guidance as to which types of intervention might be most clinically effective and cost-effective in an NHS setting. We developed an evidence map, conducted a systematic review and performed an economic evaluation to assess the effectiveness and cost-effectiveness of educational interventions relevant to the prevention of catheter-BSI in critical care units in England.

Methods

Evidence map and systematic review of effectiveness

A two-stage process was followed: (1) development of a descriptive map of the key characteristics of studies evaluating educational interventions, followed by (2) a detailed systematic review of a subset of interventions.

Search strategies

Fifteen electronic bibliographic databases [including MEDLINE, MEDLINE In-Process & Other Non-Indexed Citations, Cumulative Index to Nursing and Allied Health Literature (CINAHL), EMBASE and Cochrane Collaboration databases] were searched from the period of database inception up to February 2011, with searches rerun in March 2012. Searches were not restricted by publication language. Bibliographies of systematic reviews and related papers were screened and experts contacted to identify additional published and unpublished references.

Study selection

Titles and abstracts were screened for eligibility by two reviewers independently using a priori pilot-tested criteria. Studies eligible for inclusion in the descriptive map were any primary research studies that included one or more planned educational interventions for preventing catheter-BSI, were conducted in critical care units, and reported the effect of the intervention(s) on the incidence density of catheter-BSI, mortality and/or LOS as an outcome. We defined education in a broad sense to include any means of information provision, and we defined catheter-BSI to include catheter-related and catheter-associated bloodstream infections (CABSIs) and their synonyms. Full papers were obtained for those titles and abstracts that appeared relevant and these were screened by two reviewers independently.

Descriptive map

Keywords were developed and systematically applied to included studies to produce a detailed map of the evidence base that was used to prioritise a subset of studies for inclusion in the systematic review in consultation with the project's expert Advisory Group (AG).

Data extraction and quality assessment

Two reviewers independently extracted data from the studies included in the systematic review using a pilot-tested data extraction form and independently assessed studies for methodological quality,

including risk of bias using prespecified criteria. Differences in judgement were resolved by discussion and involvement of a third reviewer if necessary.

Data synthesis

Studies were synthesised narratively and considered for meta-analysis.

Economic evaluation

A systematic review was conducted to identify economic evaluations of educational interventions for preventing catheter-BSI in critical care. Thirteen electronic bibliographic databases [including MEDLINE, MEDLINE In-Process & Other Non-Indexed Citations, CINAHL, EMBASE, Cochrane Collaboration databases and NHS Economic Evaluation Database (NHS EED)] were searched from the period of database inception up to February 2011, with searches rerun in March 2012. References identified were screened according to a priori criteria. Full papers were obtained for those titles and abstracts that appeared relevant and these were screened by two reviewers independently.

A decision-analytic economic model was developed to compare the costs and consequences of a central venous catheter (CVC) care bundle for the prevention of catheter-BSI against current clinical practice. The CVC care bundle was defined based upon the 'Keystone intensive care unit (ICU) project' conducted in Michigan, USA, and the 'Matching Michigan' programme in England. The CVC care bundle encompassed five elements, together with education: optimal hand hygiene, chlorhexidine skin antisepsis, maximal barrier precautions for catheter insertion, choice of optimal insertion site, and prompt catheter removal. Current clinical practice was defined as critical care that did not implement a CVC care bundle.

The model follows hypothetical cohorts of patients from their admission to the critical care unit and incorporates their risk of catheter-BSI and hospital mortality. Estimates are made of the long-term survival of patients after discharge from critical care and the total costs and quality-adjusted life-years (QALYs) gained for both cohorts, from which the model determines the cost-effectiveness of the CVC care bundle. Model parameters were derived from a systematic search of the literature on the natural history and epidemiology of catheter-BSI, health-related quality of life (HRQoL) and costs. Costs were derived from primary data from previous studies and NHS unit costs. The analysis was conducted from the perspective of the NHS and Personal Social Services, and has a lifetime horizon. Uncertainty around the model results was investigated through the use of deterministic and probabilistic sensitivity analyses.

Results of the evidence map and systematic review of effectiveness

A descriptive map of 74 studies meeting the inclusion criteria was produced. The results illustrate a predominance of North American trials of educational interventions. Studies have been conducted at a range of spatial and temporal scales with diverse types of educational intervention, ranging from individual short lectures conducted in single critical care units to multiyear regional-scale interventions that involved continuous quality improvement (CQI) approaches in over 100 critical care units. Nearly all studies used uncontrolled before-and-after study designs, with only two randomised controlled trials (RCTs) included.

Discussion with the project's AG enabled the prioritisation of a policy-relevant subset of studies for systematic review. To be included, studies had to have a clearly reported prospective design; focus on adult critical care units; and provide a definition of their catheter-BSI outcome.

A total of 24 studies met the inclusion criteria for the systematic review. Twelve studies were conducted in the USA, with only one in the UK. Nine studies were judged to be at high risk of bias. However, owing to poor reporting of the methodology, the majority of studies were judged to be at unclear risk of bias. Most studies did not report their methods of data collection. Quality criteria were not used to exclude studies from data synthesis but were taken into consideration when discussing whether studies

provided convincing evidence of clinical effectiveness. Owing to the wide heterogeneity of intervention types included in the systematic review, meta-analysis was inappropriate. Instead, incidence density risk ratios (RRs) with 95% confidence intervals (incidence of catheter-BSI expressed per 1000 catheter-days) calculated for each of the interventions were compared in a narrative synthesis.

Studies included in the systematic review were predominantly uncontrolled before-and-after studies. None of the controlled studies demonstrated clinical effectiveness. Assuming that observed changes in catheter-BSI rates in before-and-after studies were caused by the intended interventions, 12 of the 24 studies included in the systematic review reported interventions that appeared to be effective at reducing the incidence density of catheter-BSI (incidence density RRs statistically significantly < 1.0), six studies reported interventions that were clearly not effective, three lacked convincing evidence of effectiveness and three provided insufficient data to calculate incidence density RRs. Overall, there was no clear evidence that particular types of education were any more or less effective at reducing incidence densities of catheter-BSI. Interventions that included checklists, performance feedback and/or infection surveillance feedback were sometimes, but not always, clinically effective. An exception is that single lectures on infection prevention practices conducted in individual critical care units (assessed in two studies) were not clinically effective. Few studies reported effects of interventions on mortality or LOS, and no clear patterns were evident for these outcomes.

Nineteen studies reported qualitative or quantitative information on intervention processes including compliance of critical care staff with evidence-based practices. Starting compliance at study inception was highly variable. In the RCT, lack of initial data collection infrastructure appears to have been a barrier to effective implementation. Although evidence is limited to few studies, inappropriate staff attitudes appear to be a potential barrier to effective implementation of evidence-based practices for preventing catheter-BSI.

Of the interventions judged in the systematic review to be clinically effective, a regional-scale CQI programme conducted in 37 critical care units in Australia (the 'CLAB ICU project') was considered most relevant to current NHS practice. Clinical effectiveness data from this intervention were used to inform the economic model.

Results of the economic evaluation

Systematic review of cost-effectiveness studies

Three economic evaluations of educational interventions for prevention of catheter-BSI were included. However, none was appropriate for estimating the cost-effectiveness of an educational intervention for prevention of catheter-BSI in NHS critical care units in England.

Modelled cost-effectiveness analysis

The results from the model showed that the CVC care bundle would save 0.8 catheter-BSI and 0.3 lives compared with current clinical practice (per 100 patients admitted to the critical care unit), with an increased survival of 3.6 years and 2.7 QALYs. The incremental cost was –£573 per QALY gained and –£1976 per catheter-BSI averted, with negative values resulting from the CVC care bundle being both more effective and less costly than existing clinical practice (i.e. dominant). The cost saving largely arises from a reduction in the critical care LOS.

Robustness of the model results was tested using a range of sensitivity analyses as well as a scenario analysis to explore the effect of different patient starting ages. The CVC care bundle ranged from remaining cost saving to no longer being cost saving, but in all cases it would be considered cost-effective at the standard cost-effectiveness threshold of £20,000 per QALY (worst-case results were all of < £5000 per QALY). The greatest variation in the sensitivity analyses was associated with two variables – catheter-BSI incidence rate and additional length stay in critical care for patients with catheter-BSI.

There is uncertainty in the model-based analysis relating to variation in implementation of the CVC care bundle, as some of the interventions included in the bundle (to be implemented on a regional or national basis) may already be partially implemented (by individual hospitals or critical care units). However, at the least favourable values tested in sensitivity analyses to reflect extremes of implementation (a relative risk of catheter-BSI with the CVC care bundle = 0.7 and baseline incidence density of 1 per 1000 catheter-days), the incremental cost-effectiveness ratio (ICER) remained below the threshold conventionally considered as cost-effective.

For England, with 90,000 critical care patients per year, the model estimates that implementing the CVC care bundle would reduce the number of catheter-BSI infections by > 700 [interquartile range (IQR) 482–914] and save 270 lives (IQR 184–348 lives) per year. The yearly additional cost to implement the intervention used in England would be £1.4M (IQR £1.2M–£1.5M). However, if the intervention was implemented, not only would the cost of implementation be recouped but there would be a net saving from implementing the intervention of £1.5M, largely as a result of the savings in costs related to reduced LOS (£2.4M, IQR £1.4M–£3.3M). The CVC care bundle remains cost saving up to an annual implementation cost of £2.7M (equivalent to £30 per critical care patient).

Conclusions

Literature searches indicate that the evaluation of educational interventions for prevention of catheter-BSI is an active area of primary research. Economic evaluation suggests that an educational intervention based on a CVC care bundle implemented in critical care units in England would be more effective and less costly than current clinical practice, even after allowing for heterogeneity of baseline clinical practices and heterogeneity of implementation. However, there is a need for more rigorous primary research studies to be conducted, as the current evidence comes predominantly from uncontrolled before-and-after studies that may not convincingly distinguish intervention effectiveness from secular trends. Clinical practices are being addressed by a wide variety of different educational strategies that do not draw upon pedagogic, theoretical or conceptual frameworks, and, consequently, do not provide generalisable lessons to inform national guidelines. A co-ordinated and harmonised approach to the provision of education, with the involvement of educationalists in the design of research studies, would improve the generalisability and comparability of educational interventions. Improvements in the reporting of the primary studies are needed, to enable judgements about risk of bias and confounding. Definitions of catheter-related and CABSIs are used inconsistently and should be standardised.

Recommendations for practice

NHS organisations should carefully consider whether existing practice for preventing catheter-BSI may be improved by implementing educational interventions in critical care units either at local or regional scales. Although it is not possible to be specific about which type of intervention may be most appropriate, economic evaluation suggests that a variety of approaches could be cost-effective or cost-saving. Consideration should be given to the need to adopt standard definitions of CABSI and catheter-related bloodstream infection, and apply and report these consistently. When clinical practice is delivered within a research setting, for example if interventions are intended to be implemented into practice while their effectiveness is monitored, consideration should be given to ensuring that the research design is appropriate for cause–effect relationships to be determined. Co-ordinated collection of surveillance data on catheter-BSI, mortality and LOS in critical care units, and the resources required to implement and sustain an intervention, would be helpful to inform future economic evaluations.

Recommendations for research

Future evaluations of educational interventions for preventing catheter-BSI should be rigorously designed to enable causal relationships to be established and any influences of secular trends on outcomes to be controlled. Appropriate designs could include RCTs and interrupted time series. When developing educational interventions for prevention of catheter-BSI, consideration should be given to: basing

interventions on robust educational and behavioural theory; involving educationalists; including process evaluations; and integrating a cost-effectiveness evaluation. Development of educational interventions for preventing catheter-BSI (and other infections) is likely to benefit from being co-ordinated at a national level, to ensure that valid and reliable pedagogical approaches are used, which are generalisable and inform national guidelines. Researchers should be encouraged to clearly report research studies of educational interventions to provide greater confidence about the validity and generalisability of the results and to fully identify the risks of bias and confounding. Updates to this review may help to clarify the extent of the growing evidence base and to ensure that the quality controls recommended above, if implemented, are effective.

Study registration

This study is registered with PROSPERO as CRD42012001840.

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