# Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus

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## Summary

Despite control eff orts, the burden of health-care-associated infections in Europe is high and leads to around 37 000 deaths each year. We did a systematic review to identify crucial elements for the organisation of effective infection-prevention programmes in hospitals and key components for implementation of monitoring. 92 studies published from 1996 to 2012 were assessed and ten key components identified: organisation of infection control at the hospital level; bed occupancy, staffing, workload, and employment of pool or agency nurses; availability of and ease of access to materials and equipment and optimum ergonomics; appropriate use of guidelines; education and training; auditing; surveillance and feedback; multimodal and multidisciplinary prevention programmes that include behavioural change; engagement of champions; and positive organisational culture. These components comprise manageable and widely applicable ways to reduce health-care-associated infections and improve patients' safety.

## Introduction

Health-care-associated infections (HAIs) affect millions of patients worldwide every year.[1,2] In the European Union (EU) alone, the estimated number of HAIs is 4 544 100 annually, leading directly to around 37 000 deaths and 16 million extra days of hospital stay.[3] Several evidence-based practice guidelines have been published in the pastdecade[4–12] but, despite evidence suggesting that good practice strategies are sufficient, hospitals struggle to comply.[13–17] The systematic review and evidence-based guidance on organisation of hospital infection control programmes (SIGHT) was funded by the European Centre for Disease Prevention and Control. Our objective was to provide evidence-based guidance on the organisation of infection-control programmes in hospitals. In particular, the review aimed to identify the most effective and generally applicable elements of acute-care infection-control and prevention programmes and to identify indicators of structure and process for monitoring. In contrast to more procedure-focused recommendations, we address mainly management and organisational features.

## Methods

The systematic review was done according to the PRISMA guidelines[18] at three participating institutions (University of Geneva Hospitals, Geneva, Switzerland; Imperial College London, London, UK; and University Hospital of Freiburg, Freiburg, Germany). We separated this project into two work packages: first, a systematic review to identify elements for the organisation of infection prevention programmes in hospitals and, second, the selection from these of key components, assessment of their implementation and EU-wide applicability, and allocation of process and structure indicators (figure 1).

### Search strategy and selection criteria

The search was stratified by five dimensions that we addressed separately: organisational and structural arrangements to implement infection-control programmes, including access to qualified infection-control professionals and the roles of management and advisory committees; targets and methods of HAI surveillance, outbreak management, and the role of feedback; methods and effectiveness of educating and training health-care workers (HCWs); effectiveness of interventions on behavioural change and quality of care, particularly in the context of multimodal prevention strategies; and overview and effectiveness of local policies and resources for standard and transmission-based isolation precautions (figure 1). We searched Medline, the Cochrane Controlled Trials Register, Embase, the Outbreak Database, PsychINFO, and the Health Management Information Consortium database for reports published between Jan 1, 1996, and Dec 31, 2012. Any landmark papers we found that were published before 1996 were also included. Studies in English, French, German, Italian, Portuguese, and Spanish were eligible when an English title or abstract was available. Studies were eligible for full-text review if they were done in acute-care settings in the context of infection control and were quantitative studies, such as randomised controlled trials, controlled clinical trials, case-control studies, controlled before-and-after studies, interrupted time series, non-controlled cohort studies, and non-controlled before-and-after studies, or qualitative studies if they were based on in-depth interviews, questionnaires, surveys, focus groups, and direct observations, irrespective of whether they were empirical or grounded in a recognised theory, or used mixed methods to combine quantitative and qualitative investigations. Reviews, letters, notes, and opinion articles that did not report primary data were excluded. Interventions related to community care, primary care, antibiotic prescribing, or a combination of these, were excluded, as were studies done in long-term care

settings. Antibiotic stewardship, cost-effectiveness, and occupational health were not addressed because these topics were elements of other European Centre for Disease Prevention and Control projects at the time of the study. Additional inclusion and exclusion criteria are summarised in the appendix.
Initial assessment was done by screening titles and abstracts against the inclusion and exclusion criteria. Reports without abstracts were read in full. 30% of the titles and abstracts and 100% of the full texts were assessed by a second reviewer. Disagreements were resolved by consensus or by a third reviewer if agreement could not be reached. Reference lists of relevant articles were searched to identify further studies. If the full text could not be obtained by any of the participating academic centres or by the European Centre for Disease Prevention and Control, the study was excluded from further analysis. Study origin was stratified by country income, as defined by the World Bank classification.[19]
We used the integrated quality criteria for systematic review of multiple study designs tool[20] to assess the quality of articles. This approach integrates criteria to evaluate quantitative and qualitative studies. The quality of evidence is graded on the basis of an overall score if the studies meet a set of specific criteria that are designed for each study (appendix).[21,22] Quality assessment was done by two reviewers for all studies (WZ, AH , MD, TG, FS, and LC). Disagreements were resolved by consensus and a third reviewer was consulted if agreement could not be reached. Quality of studies was graded as low (1), medium (2), or high (3).

**Data extraction**

An expert group was established, with independent and author members selected according to their area of expertise (infection control, patients' safety, public health, quality improvement, health policy, organisational theory, psychology, and sociology). Elements emerging from the systematic review were categorised under key components of infection control by the study group and presented to the experts, who checked each one for the validity of classification, assessed EU-wide applicability and ease of implementation, and defined structural and process indicators (figure 1). Evidence was graded as low (1), intermediate (2), or high (3) on the basis of the median value for the studies contributing to the component.
To score implementation and EU-wide applicability, the expert group considered potential barriers. For instance, implementation might be affected by budget and financial constraints, work cultural issues, work ethics, leadership, communication, educational background, personal experience, relative priority in the institution, and hospital-wide applicability. Potential barriers to EU-wide applicability might be a financial crisis, cultural issues, specifics of the health-care system, training opportunities for infection control, national safety programmes, and emigration of specialty professionals. Ease of implementation and EU-wide applicability were graded as low (1), intermediate (2), or high (3). Consensus about grading was reached with the Delphi method.[23]

**Role of the funding source**

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

Our search yielded 47 948 titles and abstracts and an additional 131 were added through cross-referencing. 92 articles were eligible for data extraction and analysis (figure 2, table 1, appendix).[15–17,24–112] Most evidence was from high-income countries, with only eight (8·7%) studies being from upper-middle-income or lower-middle-income countries.[28,29,42,58–60,71,107] 41 (44·6 %) studies had been done in Europe.

Ten components were identified as being crucial to effective infection control in hospitals: organisation of infection control at the hospital level; bed occupancy, staffing, workload, and employment of pool or agency nurses; availability of and easy access to materials and equipment and optimum ergonomics; appropriate use of guidelines; education and training; auditing; surveillance and feedback; multimodal and multidisciplinary prevention programmes that take into account principles of behavioural change; engaging champions in prevention programmes; and the role of a positive organisational culture (table 2).

### Organisation of infection control at hospital level

Seven studies included assessment of hospital organisation[17,115–120] and indicated that an effective infection control programme in an acute-care hospital must include nursing staff , a dedicated physician trained in infection control, microbiological support, and data management support. One study provided data on staff-to-bed ratios and indicated a maximum ratio of one nurse per 250 hospital beds.[17] Although this cutoff had been chosen a priori on the basis of previous data,[121–124] the study proved that less favourable ratios were associated with worse reductions in HAI rates.

The quality of the evidence was graded intermediate, but ease of implementation and EU-wide applicability were both rated high because surveys, such as the PROHIBIT survey (see http://www.prohibit.unige.ch), have shown that the ratio of infection-control nurses to beds is already established.

The identified structural and process indicators were regular reviews of surveillance, prevention programmes, and the number of outbreaks, and annual audits reviewed against appropriate staffing, goals, and sufficient budget allocation.

### Ward occupancy and workload

To ensure that ward occupancy does not exceed the capacity for which it is designed and staffed, the workload of frontline HCWs must be adapted accordingly, and the number of pool or agency nurses and physicians should be kept to a minimum. Transmission of and infection with meticillin-resistant *Staphylococcus aureus* (MRSA) was associated with bed occupancy in five studies,[32,74–76,78,113] and with low staffing and nurse-to-patient ratios in seven studies.[31,35,73,77,81,84,112] Three studies reported that higher numbers of permanent staff HCWs and improved nurse-to-patient ratios reduced HAI.[79,80,82] Inadequate adherence to hand-hygiene protocols was associated with low staffing levels in one study and with high workload in another.[83,100] Long work hours were associated with increased rates of HAIs in one study,[112] and MRSA infections with high workload in another.[73] Pool or agency nurses who worked on different wards as needs required were identified as a potential risk for bloodstream infections, especially catheter-associated bloodstream infections in intensive-care units.[36,72]

The evidence of staffing levels being a risk factor for HAI was graded high and intermediate for bed occupancy, workload, and high ratios of pool or agency nurses. Ease of implementation was rated as intermediate, restricted mostly by budget, lack of specialist nurses, and shortcomings in workforce management. EU-wide applicability was rated intermediate because of economic challenges to national health-care systems.

The identified structural and process indicators were regular assessment of the average bed occupancy at midnight, the number of frontline workers, and the proportion of pool or agency nurses.

**Materials, equipment, and ergonomics**

Hand-rub dispensers directly in the view of HCWs[24,63] and hand-hygiene facilities at the point of care both improved overall hand hygiene.[55,56,64,125] Limited access to hand hygiene facilities was a source of frustration to HCWs.[96,97] An easy-to-use pocket hand-rub dispenser attached to scrubs improved hand hygiene among anaesthesiologists.[50] Electronic reminders (pop-up windows) when physicians started to write an order for a patient who fulfilled the criteria for isolation precautions improved the prescribing of these measures.[48] Customised insertion kits for central venous catheters and carts stocked with appropriate materials helped to decrease rates of central-line-associated bloodstream infections.[51,102]

Evidence was graded intermediate and ease of implementation and EU-wide applicability were rated intermediate. Potential financial constraints could interfere with the provision of optimum equipment.

Regular audits, for instance to check the availability of hand rub, soap, and single-use towels, was identified as a process indicator.

**Use of guidelines, education, and training**

1158 HCWs in 40 hospitals stated that they knew about the update of a national guideline on hand hygiene, yet recommendations had been implemented in less than half of the hospitals visited in a national audit in the USA.[52] Physicians showed low adherence to maximum sterile barrier precautions for insertion of central venous catheters, despite strong recommendations to do so.[102] The introduction of a new guideline as part of a multimodal intervention strategy in settings without previous exposure to standardised protocols helped to improve hand hygiene and reduced rates of catheter-associated urinary-tract infections.[59,60,114] Attitudes towards guidelines were more positive among nurses than physicians and in paediatric intensive-care units than in adult intensive-care units.[101]

Evidence was graded intermediate and ease of implementation and EU-wide applicability were both rated high on the basis of the experts' own experience.

Regular review of accessibility to local guidelines and whether the contents of teaching programmes are based on the most updated documents were identified in the assessment of structural and process indicators.

**Team-oriented and task-oriented education and training**

Bedside teaching as part of a multimodal intervention,[65] simulation-based training,[27] and hands-on training workshops for physicians in training[62] reduced the rates of catheter-related bloodstream infections. Multidisciplinary focus groups were crucial to focusing infection-prevention programmes on the target of interest and contributed to improved adherence to hand-hygiene protocols and reduced rates of HAIs.[28,107,111] Qualitative studies showed that, although formal training is eff ective,[106] individual experience is perceived to be more important for infection prevention,[99] whereas strategies that used traditional approaches based on logic and reasoning were perceived as less likely to improve hand hygiene.[105]

The evidence for this key component was graded high, but ease of implementation was rated intermediate because of potential barriers, such as financial constraints or lack of teaching experience. The expert group emphasised that preparation of a multimodal and multidisciplinary strategy that involves HCWs at all levels requires leadership and good communication. EU-wide applicability was rated high.

Education and training programmes should be audited against predefined checklists that are revised over time to take into account local barriers and behaviour. Education and training should be combined with knowledge tests, competency assessments, or both.

**Standardisation of audits**

Auditing and personal feedback improves predefined process indicators for catheter insertion.[25] An audit of daily adherence to a bundled strategy to prevent ventilator-associated pneumonia and provision of weekly feedback on pneumonia rates led to reduced numbers of cases of ventilation-associated pneumonia.[43] Cases of bacteraemia caused by coagulase-negative staphylococci were reduced by internal audits on hand hygiene and catheter-hub care in neonates.[49] Audits in the form of assessments by peers and anonymous feedback effectively improved universal precaution measures,[29] and use of a comprehensive checklist covering a wide range of care practices reduced prevalence of all-cause HAIs by 7%.[30] Evidence was graded intermediate and ease of implementation was rated intermediate, mainly because of potential financial constraints, limited human resources, and lack of leadership and communication. EU-wide applicability was rated high.

Identified structure and process indicators were measurement of the number of audits done and regular assessment of validity of checklists against local and national guidelines.

**Prospective surveillance, feedback, and networks**

Participation in the German Hospital Infection Surveillance System (KISS) was associated with decreased rates of HAIs,[39,41,44–46,61,66,69] central-line-associated bloodstream infections,[45,46] ventilator-associated pneumonia,[45,66] urinary-tract infections,[69] and surgical-site infections.[39,41,44,45] Hospitals within the Dutch surveillance network, PREZIES, showed reduced rates of HAIs in years 4 and 5 of participation.[47] The 35 intensive-care units of the French REACAT network had reductions in catheter-related bloodstream infections over 5 years.[54] One qualitative study explored the rationale related to the importance of surveillance and feedback to stakeholders, and found they were very influential in the implementation of an infection-control programme targeting ventilator-associated pneumonia.[108]

The evidence was graded intermediate, and ease of implementation and EU-wide applicability were rated intermediate. Potential barriers to implementation were lack of leadership, restricted human resources for surveillance, and infection control being a low priority. EU-wide applicability was limited because not every country has an established surveillance network.

Regular measurement and assessment of the number and type of wards with established surveillance, including the strategy of providing feedback to HCWs, were identified as process indicators. Addition of participation in national and international surveillance initiatives to the hospital administration agenda was also suggested.

**Development of multimodal strategies and tools**

20 studies showed that multimodal strategies were helpful to improve hand hygiene.[16,26,28,34,42,53,55,56,60,67,68,70,71,86,89–91,99,109,111] Some programmes actively included opinion leaders and champions.[42,70,109] Two studies used the idea of positive reinforcement: in one HCWs were given chocolate bars or sweets when found to be correctly adhering to hand-hygiene protocols[34] and in another the principles of product marketing were applied to encourage HCWs to choose their own intervention from a range of tools.[53] Several factors were identified as affecting hand hygiene, such as accessibility to hand rub, role models, personal sense of responsibility, and emotional involvement.[99]

Eight studies investigated the role and effectiveness of multimodal strategies in reducing catheter-related and central-line-associated bloodstream infection. Seven were quantitative

intensive-care studies[15,33,51,57,65,70,92] and one was a qualitative study reporting factors of behavioural change in the context of peripheral venous lines.[93] All intervention studies used a multimodal approach in which bundles or comprehensive procedures were defined and promoted at various levels. Three studies focused primarily on catheter insertion,[33,51,57] one addressed catheter insertion and care,[15] and one focused on catheter care.[65] All seven quantitative studies showed improvement in central-line-associated bloodstream infections. Four studies also provided data about process indicators.[33,65,70,92]

Two studies addressed ventilator-associated pneumonia and showed that multimodal prevention strategies are successful if the programme is developed by a multidisciplinary task force, processes are closely monitored,[40] and a well structured business plan is used to engage all relevant stakeholders.[70]

Numbers of MRSA infections were reduced by use of a strategy bundle based on the principles of positive deviance to make infection control the responsibility of every stakeholder.[88]

Although the evidence was graded intermediate, ease of implementation and EU-wide applicability were rated high because the wide variety of effective strategies leaves room for local adaptation.

Identified structural indicators were that prevention programmes should be reviewed regularly against predefined checklists that take into account multimodality, local barriers, and aspects of behavioural change. An important process indicator was measurement of activities, such as adherence to hand-hygiene protocols or performance of medical procedures (eg, catheter insertion and care, care of ventilated patients, and placement of urinary catheters). Outcome indicators, such as catheter-associated urinary-tract infection, central-line-associated bloodstream infection, HAI, and ventilator-associated pneumonia, should also be measured.

**Identification and engagement of strategy champions**

In four studies champions had been engaged as part of a comprehensive and multimodal intervention strategy.[70,91,92,110] One well placed champion was helpful to implement a new technology, but more than one champion was needed when improvements required behavioural change.[94]

The evidence for this key component was graded high, but ease of implementation was rated as intermediate because unfavourable work cultures and lack of leadership might complicate the work of a champion, and suitable individuals could be difficult to identify in a hospital. EU-wide applicability was also rated as intermediate because local culture might interfere with the concept of allowing a champion room for action.

Prevention programmes that describe strategies about how frontline workers can be incorporated in the implementation process and inclusion of champions' names in the agenda of intervention progress meetings were identified as structure and process indicators.

**Creating a positive organisational culture**

Receiving training and instructional feedback from supervisors and management support for implementing safe work practices are perceived by HCWs to improve adherence to recommended care practices.[106] Adherence to guidelines is affected by knowledge, beliefs, motivation, and professional responsibility.[97] Inconsistency between managers' verbal and written commitments and their daily support of patients' safety issues has a negative effect.[95] Successful leaders are solution oriented and focus on cultivating a culture of clinical excellence.[103] Lack of management support provokes the perception of non-control in situations of high workload.[98] Communication between professional groups can be a barrier to or a facilitator of adherence to best practice.[104] Staff engagement, situations perceived as

overwhelming or stressful and chaotic, and hospital leadership are associated with knowledge, attitudes, and self-reported practices of MRSA prevention.[38] Education and leader ship engagement improve hand hygiene,[85] and peer pressure and role models are also important.[87] The success of intervention programmes is perceived differently by different professional groups, which should be taken into account in the design of infection-control initiatives.[37]

The evidence for the effects of a positive organisational culture was graded high. Ease of implementation was rated intermediate because work culture is difficult to change, particularly lack of leadership. EU-wide applicability, however, was rated high because barriers are mainly related to an individual organisation, and good examples of positive organisational cultures to draw from can be found in many places.

The expert group found that organisational culture can be measured at an individual level by work satisfaction questionnaires, at a ward or department level by turnover and absenteeism among HCWs, and at an institutional level by assessment of the response to stress or crisis management.

## Discussion

This broad systematic review identified a range of structural, organisational, and management components that are crucial to effective implementation of infection-control programmes in hospitals. Additionally, these components were put into a user's perspective by providing context about implementation and EU-wide applicability.

The formal proportion of one infection-control nurse per 250 hospital beds was established more than 30 years ago.[17] However, hospital settings have changed, and expert consensus now suggests that this rate should be around one nurse per 100 beds in acute care,[114,118] and one per 150–250 beds in long-term care.[114,118] Our review shows that infection prevention does not rely solely on a functional infection-control team, but also depends on hospital organisation, bed occupancy, staffing, and workload.[31,32,35,36,72–84,100,112] This message is crucial at a time when HCW posts are being cut. Sufficient availability and easy access to materials and optimised ergonomics improve best-practice performance.[24,48,50,51,55,56,63,64,96,97,102] Unfortunately, these features are not always respected, and a lack of professionals specialised in medical ergonomics could be having a negative effect on care of patients.

Dissemination of guidelines alone does not change behaviour.[52,102] Rather, they should be introduced in the form of educational and practical, evidence-based training.[59,60,114] Studies of education and training suggest that education should be team and task oriented and problem based, and are most effective when they include workshops, bedside teaching, and simulation-based training.[27,62,126] Multidisciplinary focus groups should be set up to aid adjustment of training programmes to suit local conditions.[65,125] Importantly, education should target specific socialisation processes and address barriers to behavioural change in all professional groups;[101,106] isolated lectures, when unaccompanied by other tools and leadership engagement, are ineffective.[127,128] High-quality auditing and timely feedback also help with the implementation of infection-prevention programmes.[25,43,49] Feedback is an essential component of surveillance programmes to raise awareness of HCWs about issues that need to be addressed, but also to promote an element of competition between hospitals.[129] Almost any process can be audited.

We highlight the importance of multimodal and multidisciplinary strategies for education and training. Additionally, HCWs from multiple levels and work categories should be integrated in the preparation and implementation of intervention programmes. Every study of sufficient quality used a unique intervention strategy and the study settings were generally different

and, therefore, the proportion of single components that had an effect on outcome success could not be determined. Nevertheless, the findings all point towards a comprehensive approach that includes adaptation and the use of a broad range of actions to overcome local barriers in the implementation process. An effective strategy needs to focus on individuals in the work situation and to address environmental, organisational, and individual barriers to adherence. Intervention programmes must have a strong behavioural component aimed at removing barriers, stimulating positive attitudes, and helping HCWs to manage workload, without compromising adherence and quality. They also need strong leadership and the involvement of staff at all levels.

Institutional leaders can make a difference, and leadership should be part of their professional responsibility. Educating senior executives about clinical issues and safety hazards and organising executive safety rounds on the wards have been proposed as means to engage them in patients' safety and enlist their support for infection prevention and control.[130] A positive organisational culture can only emerge through the genuine interest of leaders in the wellbeing of their staff and when the right people are in place. Inconsistencies between a manager's verbal and written commitments and what they practise are negatively perceived by HCWs and might work against the idea of showing support to frontline workers.[95] Whether the organisational culture is positive or negative depends on the perception of HCWs,[131] and the success of intervention programmes is perceived differently by different professional groups.[37] We identified the role of champions as a crucial component of effective infection control.[94,110] Champions can work around organisational barriers to change the work environment and thus shape organisational change due to their genuine enthusiasm and engagement. This component, therefore, is judged to stand alone. Champions, however, can be neither appointed nor mandated. Rather, they must be identified and given the support to act as such.

This study has limitations. First, we used the integrated quality criteria for systematic review of multiple study designs tool to assess study quality. This tool is not yet widely established, although it has been used already in several published systematic reviews.[20–22] It seemed to allow more data to be exposed than the more usual grading approaches because of the broader scope of studies eligible for inclusion, especially qualitative studies.

Second, although the three participating institutions and the European Centre for Disease Prevention and Control had access to a large number of journals through their respective libraries, many articles could not be accessed as the full text. This restriction was a result of the inclusive search terms and the aim to look for qualitative research in nursing journals. For the study update, we purchased all non-accessible manuscripts identified for dimensions one and three (organisational and structural arrangements to implement infection-control programmes, including access to qualified infection-control professionals and the roles of management and advisory committees, and methods and effectiveness of educating and training HCWs) to assess the full text. No further studies of sufficient quality were identified and, therefore, we are confident that the systematic review missed very few, if any, relevant high-quality studies.

Third, studies were only eligible if they had been published by Dec 31, 2012 (including electronic prepublication). To obtain an idea about the later evidence base we applied the SIGHT search terms to PubMed to identify studies published in 2013. We retrieved 4036 titles and abstracts, of which 65 addressed the ten key components and would have been potentially eligible for inclusion in this systematic review (appendix). Of these studies, 56 were about using multimodal strategies to improve hand hygiene or prevent HAIs, such as central-line-associated bloodstream infections, catheter-associated urinary-tract infections, or ventilator-associated pneumonia. Almost all clinical settings were represented, with an increasing number of studies being done in non-intensive-care units or hospital wide. Many

reports mentioned the role of multidisciplinary teams for preparation and implementation of infection-control interventions. Eight studies gave detailed information about the education strategy, addressed the benefit of clinical audits (three), reported success by participating in a surveillance strategy (two), and discussed staffing and ergonomics (one). Nine studies provided information about leadership and organisational culture. The findings suggest that the SIGHT key components are valid and that these themes are likely to be addressed in an increasing number of future studies.

SIGHT aimed to identify the most effective and generally applicable elements of infection prevention, and the strength of this project is that the studies forming the evidence base represent a rigorous selection from hundreds of papers to avoid those with limitations and methodological concerns. In this respect the integrated quality criteria for systematic review of multiple study designs approach was helpful because it consistently identified studies of low quality and with incomplete reporting. In view of the number of publications and the broad dimensions addressed by SIGHT, the small evidence base may seem surprising, but we believe it shows that further good quality studies with accurate reporting are needed to improve the quality of evidence for recommendations.

All key components are important and, although numbered for convenience, SIGHT does not prioritise any over another. Elements such as establishing infection control, providing functional equipment, or hiring more HCWs are more tangible than identifying champions or providing a positive organisational culture. Multimodality in the execution of prevention programmes and multidisciplinary preparation of these, team-oriented and task-oriented training, appropriate use of guidelines, and auditing can be applied in more sociocultural and economic backgrounds than sufficient availability of materials or participating in a surveillance network, because they offer room for adaptation. Individual hospitals should be encouraged to establish the key components that make sense in terms of the specific needs and resources identified through self-assessment.

## Conclusions

Infection prevention and control is a priority for patients' safety and should involve HCWs at all levels and be part of the hospital organisation as a whole.132 Staffing must be adequate to meet task requirements without leading to excessive workload. For prevention purposes, hospital infection-control programmes need to translate the key components into workable documents and programmes that take the local context into account. Programmes should be planned by multidisciplinary groups, take into account local guidelines, follow a multimodal intervention strategy that emphasises hands-on training, and be regularly assessed, and adjusted if necessary. Further research and accurate study reporting are needed to improve the quality of evidence, especially in countries with lower-middle and low incomes.

**Contributors**

Walter Zingg, Benedetta Allegranzi, and Didier Pitter wrote the grant application. Walter Zingg, Alison Holmes, Markus Dettenkofer, Federicia Secci, Benedetta Allegranzi, Anna-Pelagia Magiorakos, and Didier Pittet contributed to the concept and design of the study. Walter Zingg, Alison Holmes, Markus Dettenkofer, Tim Goetting, Federicia Secci, Lauren Clack, and Benedetta Allegranzi collected and interpreted the data. Alison Holmes provided the integrated quality criteria for systematic review of multiple study designs tool for study evaluation. Walter Zingg wrote the first draft of the manuscript, and all authors reviewed and contributed to subsequent drafts and approved the final version for publication.

## Declaration of interests

We declare no competing interests.

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**Figure 1.** Outline of the systematic review and component assessment

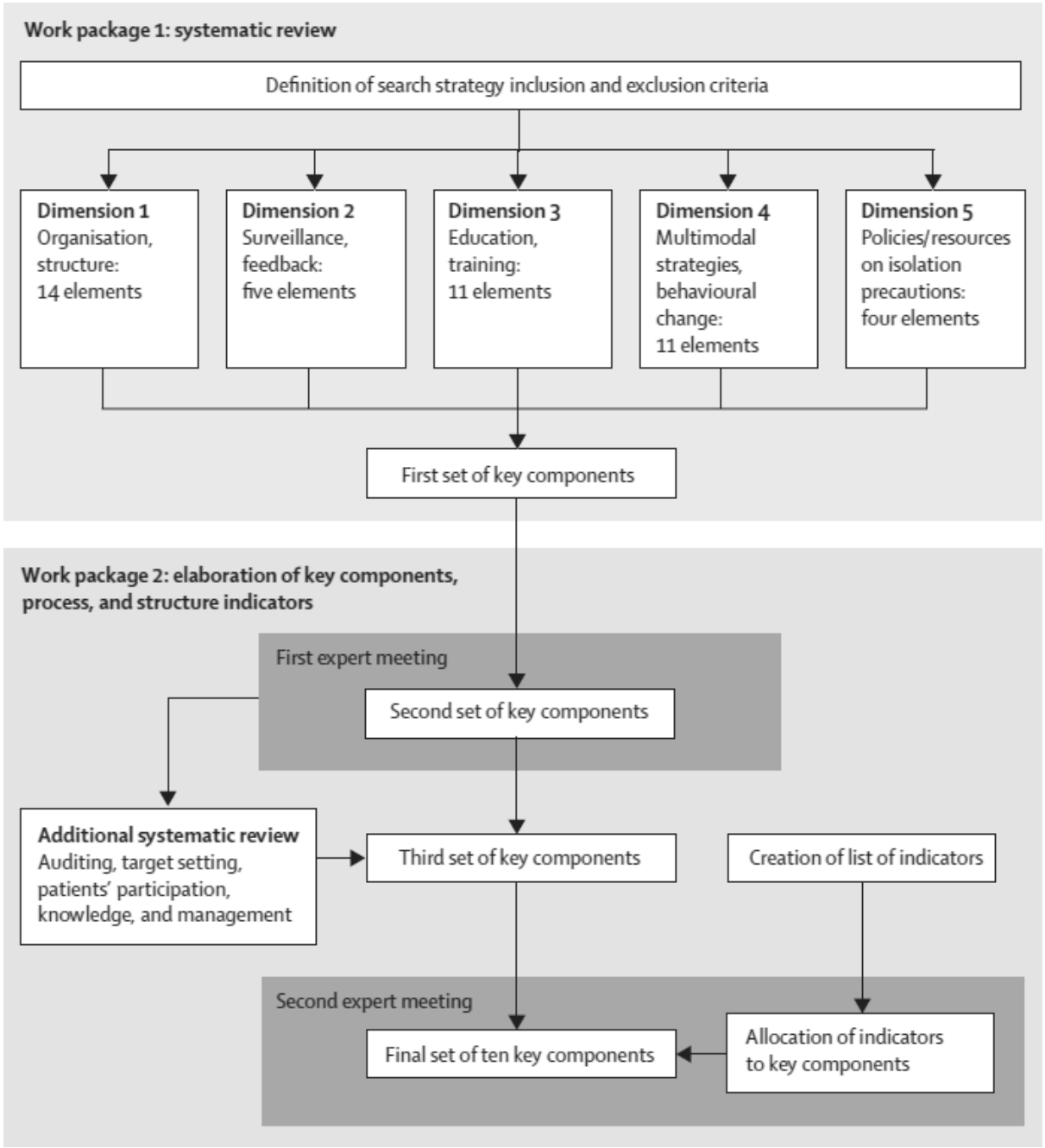

**Figure 2.** Systematic review profile

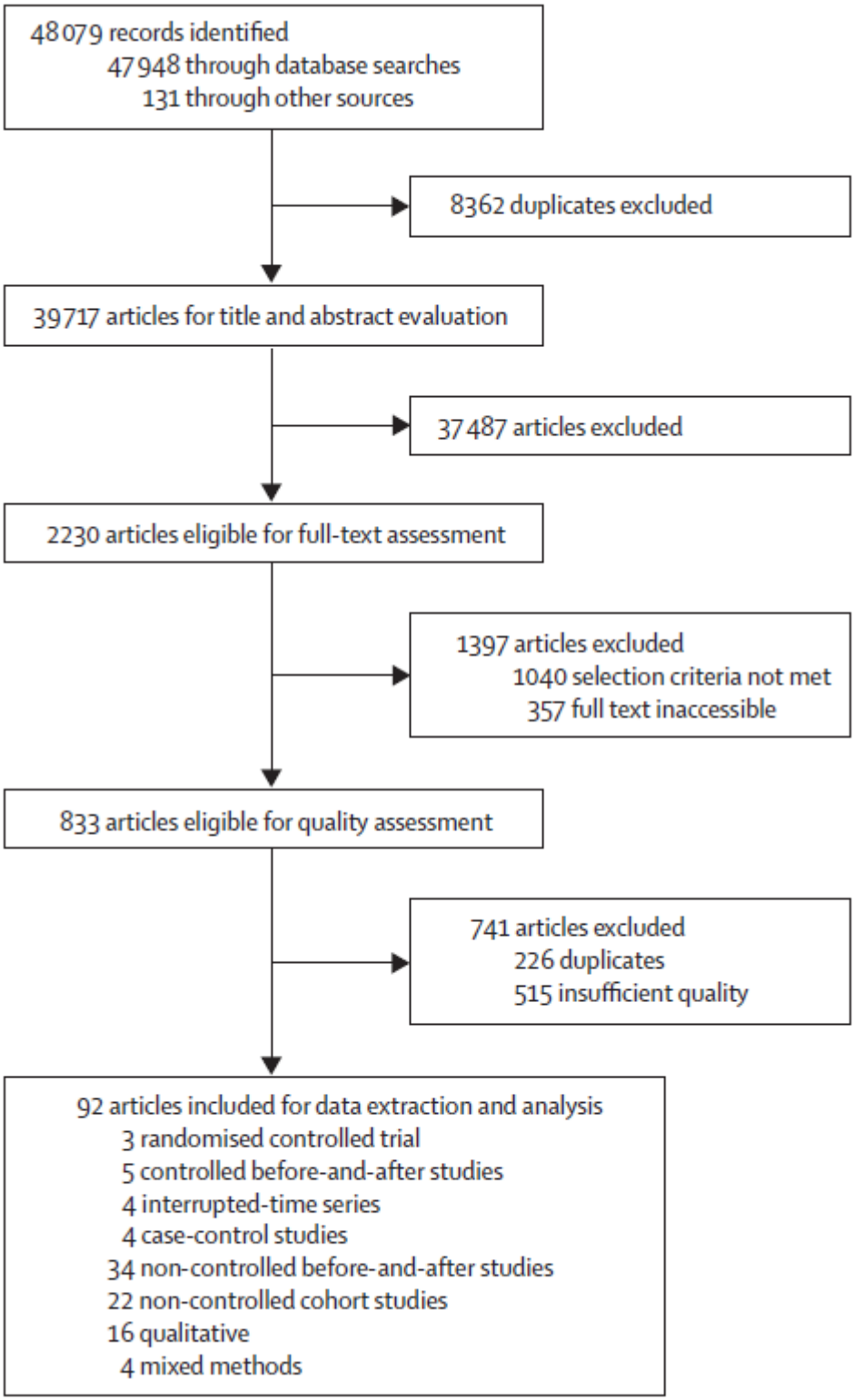

**Table 1.** Studies eligible for data extraction and analysis

| | Study quality grading* | Study design | Income | Infection control topic |
|---|---|---|---|---|
| Abela and Borg, 2012[85] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Alonso-Echanove et al, 2003[72] | 3 | Non-controlled cohort study | High | CLABSI |
| Andersen et al, 2009[31] | 2 | Non-controlled interrupted time-series | High | Health-care-associated infection |
| Bärwolff et al, 2006[39] | 2 | Non-controlled before and after study | High | Surgical-site infection |
| Barsuk et al, 2009[27] | 3 | Controlled before and after study | High | Bloodstream infection |
| Birnbach et al, 2010[24] | 3 | Randomised controlled trial | High | Hand hygiene |
| Blatnik and Lesnicar, 2006[73] | 2 | Non-controlled cohort study | High | MRSA |
| Bouadma et al, 2010[40] | 2 | Non-controlled before and after study | High | Ventilator-associated pneumonia |
| Borg, 2003[74] | 2 | Non-controlled cohort study | High | MRSA |
| Borg et al, 2008[32] | 2 | Non-controlled cohort study | High | MRSA |
| Brandt et al, 2006[41] | 2 | Non-controlled before and after study | High | Surgical-site infection |
| Brown et al, 2003[42] | 3 | Non-controlled before and after study | Upper-middle | Hand hygiene |
| Charrier et al, 2008[25] | 2 | Randomised controlled trial | High | Care processes |
| Cocanour et al, 2006[43] | 3 | Non-controlled before and after study | High | Ventilator-associated pneumonia |
| Costers et al, 2012[67] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Creamer, 2000[93] | 3 | Qualitative | High | Peripheral venous catheter care |
| Creedon, 2006[109] | 2 | Mixed-methods | High | Hand hygiene |
| Cunningham et al, 2006[76] | 3 | Non-controlled cohort study | High | MRSA |
| Cunningham et al, 2005[113] | 2 | Non-controlled cohort study | High | MRSA |
| Damschroder et al, 2009[94] | 3 | Qualitative | High | CLABSI, ventilator-associated |
| DePalo et al, 2010[33] | 2 | Non-controlled interrupted time-series | High | CLABSI, ventilator-associated |
| Doron et al, 2011[68] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Eggimann et al, 2000[15] | 2 | Non-controlled cohort study | High | CLABSI |

| | | | | |
|---|---|---|---|---|
| Elder et al, 2008[95] | 3 | Qualitative | Na | Perception of safety climate |
| Fridkin et al, 1996[77] | 2 | Non-controlled cohort study | High | CLABSI |
| Fuller et al, 2012[26] | 3 | Randomised controlled trial | High | Hand hygiene |
| Gastmeier et al, 2005[44] | 2 | Non-controlled before and after study | High | Surgical-site infection |
| Gastmeier et al, 2006[45] | 2 | Non-controlled before and after study | High | Ventilator-associated pneumonia |
| Gastmeier et al, 2009[46] | 2 | Non-controlled before and after study | High | Surgical-site infection |
| Gastmeier et al, 2011[69] | 2 | Non-controlled before and after study | High | Urinary-tract infection |
| Geubbels et al, 2006[47] | 2 | Non-controlled before and after study | High | Surgical-site infection |
| Grayson et al, 2011[86] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Haessler et al, 2012[87] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Haley et al, 1985[17] | 2 | Controlled before and after study | High | Health-care-associated infection |
| Harris et al, 2000[96] | 2 | Qualitative | High | Hand hygiene |
| Henderson et al, 2012[70] | 2 | Non-controlled before and after study | High | MRSA |
| Howie and Riley, 2008[78] | 2 | Non-controlled cohort study | High | MRSA |
| Hugonnet et al, 2007[79] | 3 | Non-controlled cohort study | High | Health-care-associated infection |
| Hugonnet et al, 2007[80] | 3 | Non-controlled cohort study | High | Ventilator-associated pneumonia |
| Hugonnet et al, 2007[81] | 3 | Non-controlled cohort study | High | Health-care-associated infection |
| Jain et al, 2011[88] | 3 | Non-controlled cohort study | High | MRSA |
| Jamal et al, 2012[89] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Jang et al, 2010[97] | 3 | Qualitative | High | Hand hygiene |
| Joshi et al, 2012[107] | 2 | Qualitative | Lower-middle | Organisational culture |
| Kho et al, 2008[48] | 2 | Non-controlled before and after study | High | Isolation precaution measures |
| Kilbride et al, 2003[49] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Kirkland et al, 2012[90] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Koff et al, 2009[50] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Koll et al, 2008[51] | 2 | Non-controlled before and after study | High | CLABSI |
| Larson et al, 2007[52] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Lederer et al, 2009[53] | 2 | Non-controlled before and after study | High | MRSA, hand hygiene |

| | | | | |
|---|---|---|---|---|
| L'Heriteau[54] | 2 | Non-controlled before and after study | High | CLABSI |
| Lines, 2006[98] | 3 | Qualitative | High | MRSA |
| Mark et al, 2007[82] | 3 | Non-controlled cohort study | High | Health-care-associated infection |
| Marra et al, 2010[28] | 3 | Controlled before and after study | Upper-middle | Hand hygiene |
| Mathai et al, 2011[71] | 2 | Non-controlled before and after study | Lower-middle | Hand hygiene |
| Mayer et al, 2011[34] | 3 | Controlled cohort study/ interrupted time-series analysis | High | Hand hygiene |
| McLaws et al, 2009[55] | 2 | Non-controlled before and after study | High | Hand hygiene |
| McLaws et al, 2009[56] | 2 | Non-controlled before and after study | High | MRSA |
| Moongtui et al, 2000[29] | 2 | Controlled before and after study | Upper-middle | Compliance with universal |
| Nicol et al, 2009[99] | 3 | Qualitative | High | Hand hygiene |
| Nijssen et al, 2003[83] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Parand et al, 2011[37] | 3 | Cross-sectional | High | Health-care worker perception of study effectiveness |
| Peredo et al, 2010[57] | 2 | Non-controlled before and after study | High | Bloodstream infection |
| Petrosillo et al, 2001[35] | 2 | Case-control | High | Hepatitis C virus infection |
| Pinto et al, 2011[108] | 2 | Qualitative | High | Health-care worker perception of study effectiveness |
| Pittet et al, 2000[16] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Pittet et al, 2004[100] | 2 | Cross-sectional | High | Hand hygiene |
| Pontivivo et al, 2012[91] | 2 | Non-controlled cohort study | High | Hand hygiene |
| Quiros et al, 2004[101] | 3 | Qualitative | High | Health-care-associated infection |
| Render et al, 2011[92] | 3 | Non-controlled cohort study | High | CLABSI |
| Robert et al, 2001[36] | 2 | Case-control | High | Bloodstream infection |
| Rosenthal et al, 2003[58] | 2 | Non-controlled before and after study | Upper-middle | Hand hygiene |
| Rosenthal et al, 2004[59] | 2 | Non-controlled before and after study | Upper-middle | Catheter-associated urinary-tract infection |
| Rosenthal et al, 2005[60] | 2 | Non-controlled before and after study | Upper-middle | Hand hygiene |

| | | | | |
|---|---|---|---|---|
| Rubinson et al, 2005[102] | 3 | Qualitative | High | Adherence to guidelines |
| Saint et al, 2009[110] | 2 | Mixed-methods | High | Hand hygiene |
| Saint et al, 2010[103] | 3 | Qualitative | High | Successful leadership |
| Schwab et al, 2007[61] | 2 | Non-controlled before and after study | High | Bloodstream infection |
| Sherertz et al, 2000[62] | 2 | Non-controlled before and after study | High | Catheter-related bloodstream infection |
| Sinkowitz-Cochran et al, 2012[38] | 3 | Cross-sectional | High | MRSA |
| Sinuff et al, 2007[104] | 3 | Qualitative | High | Guideline implementation |
| Sladek et al, 2008[105] | 3 | Qualitative | High | Hand hygiene |
| Thomas et al, 2009[63] | 2 | Non-controlled before and after study | High | Hand hygiene |
| Thomas et al, 2005[111] | 2 | Mixed-methods | High | Hand hygiene |
| Turnberg et al, 2009[106] | 3 | Qualitative | High | Respiratory precaution measures |
| Vicca, 1999[84] | 3 | Non-controlled cohort study | High | MRSA |
| Virtanen et al, 2009[112] | 3 | Mixed-methods | High | Health-care-associated infection |
| Whitby and McLaws, 2004[64] | 3 | Non-controlled before and after study | High | Hand hygiene |
| Yinnon et al, 2012[30] | 2 | Controlled before and after study | High | Health-care-associated infection |
| Zingg et al, 2009[65] | 3 | Non-controlled before and after study | High | CLABSI |
| Zuschneid et al, 2007[66] | 2 | Non-controlled before and after study | High | Ventilator-associated pneumonia |

MRSA=meticillin resistant *Staphylococcus aureus*. CLABSI=central-line-associated bloodstream infection.
*Graded with the integrated quality criteria for systematic review of multiple study designs tool.

**Table 2.** Key components and indicators identified by the systematic review

| | Key component | Indicators | Quality of evidence* | Ease of implementation | EU-wide applicability |
|---|---|---|---|---|---|
| 1 | An effective infection-control programme in an acute care hospital must include as a minimum standard at least one full-time specifically trained infection-control nurse per up to 250 beds, a dedicated physician trained in infection control, microbiological support, and data management support[17] | Continuous review of surveillance and prevention programmes, outbreaks, and audits; infection-control committee in place, inclusion of infection control on the hospital administration agenda, and defined goals (eg, HAI rates); and appropriate staffing and budget for infection control | 2 | 3 | 3 |
| 2 | Ward occupancy must not exceed the capacity for which it is designed and staffed; staffing and workload of frontline HCWs must be adapted to acuity of care, and the number of pool or agency nurses and physicians used kept to a minimimum[31,32,35,36,72–84,100,112,113] | Average bed occupancy at midnight, average numbers of frontline workers, and the average proportion of pool or agency professionals | 2 | 2 | 2 |
| 3 | Sufficient availability of and easy access to materials and equipment, and optimisation of ergonomics[24,48,50,51.55,56,63,64,97,102] | Availability of alcohol-based hand rub at the point of care and sinks stocked with soap and single-use towels | 2 | 2 | 2 |
| 4 | Use of guidelines in combination with practical education and training[52,59,60,101,102,1114] | Adaptation of guidelines to local situation, number of new staff trained with the local guidelines, teaching programmes are based on local guidelines | 2 | 3 | 3 |
| 5 | Education and training involves frontline staff and is team and task oriented[27,28,62,65,99,101,105–107,111] | Education and training programmes should be audited and combined with knowledge and competency assessments | 3 | 2 | 3 |
| 6 | Organising audits as a standardised (scored) and systematic review of practice with timely feedback[25,29,30,43,49] | Measurement of the number of audits (overall, and stratified by departments/units and topics) for specified time periods | 2 | 2 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Participating in prospective surveillance and offering active feedback, preferably as part of a network[39,41,44–47,54,58,61,66,69,108] | Participation in nationals and international surveillance initiatives, number and type of wards with a surveillance, regular review of the feedback strategy | 2 | 2 | 2 |
| 8 | Implementing infection-control programmes following a multimodal strategy, including tools such as bundles and checklists developed by multidisciplinary teams, and taking into account local conditions[15,16,26,28,33,34,40,42,51,53,55–57,65,67,68,70,71,86,88,89–92,93,96,97,99,109,111] | Verification that programmes are multimodal; measurement of process indicators (eg, hand hygiene, care procedures); measurement of outcome indicators (eg, HAI rates, MDRO infections and transmission) | 2 | 3 | 3 |
| 9 | Identifying and engaging champions in the promotion of intervention strategies[70,91,92,94,110] | Interviews with frontline staff and infection-control professionals | 3 | 2 | 2 |
| 10 | A positive organisational culture by fostering working relationships and communication across units and staff groups[37,38,85,87,95,98,103,104] | Questionnaires about work satisfaction, crisis management, and human resource assessments of absenteeism and HCW turnover | 3 | 2 | 3 |

See the appendix for detailed information about the studies and comments on the rating of evidence, ease of implementation and EU-wide applicability. HCW=health-care worker. HAI=health-care-associated infections. MDRO=multidrug-resistant organisms. *Median score is used.

# Appendix

**Supplementary table 1:** Inclusion and exclusion criteria and outcome measures used by the systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT)

| | *Inclusion/exclusion criteria* | *Outcome measures* |
|---|---|---|
| *1* | 1. Studies evaluating interventions to change or improve organisation or structure in a health-care setting with regard to the implementation or execution of infection control programmes.<br>2. Studies evaluating the effectiveness of infection control structures for the improvement of practices and HAI prevention.<br>3. Studies evaluating the role of hospital management and leadership for the improvement of infection control practices and HAI prevention.<br>4. Studies evaluating the role of staffing, workload, or work experience with regard to improved adherence with infection control practices.<br>5. Studies providing information about work processes in the context of patient safety and, specifically, HAI prevention.<br>6. Studies reporting qualitative research of HCWs' perceptions, attitudes, and beliefs about management, leadership, work climate, and culture in the context of HAI prevention. | 1. Adherence to infection control procedures, such as hand hygiene, device management (including appropriate use, insertion/removal of catheters), perioperative management, and HAI (HAI surveillance.<br>2. Shifts of nosocomial infections, such as HAI in general, CLABSI/CRBSI, VAP, UTI, and SSI.<br>3. Shifts in the incidence of MDRO and the rate of *Clostridium difficile* infection. |
| *2* | 1. Studies evaluating the effectiveness of feedback as a surveillance component, and those assessing surveillance as an instrument for outbreak detection and management.<br>2. Studies evaluating the surveillance of SSI, CLABSI/CRBSI, VAP, and UTI. | Surveillance of nosocomial infections was defined as "the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know". Since the successful implementation of surveillance is thought to reduce HAI, the infection rate was defined as a primary outcome. Therefore, studies reporting on improvement in infection prevention and control procedures due to surveillance or feedback were included. Various methods of surveillance, timeliness of data evaluation and feedback, and staff requirements for data collection were also included as outcomes. |
| *3* | 1. Studies evaluating education or training of HCWs in infection control practices.<br>2. Studies evaluating the effectiveness of specific training methodologies in HAI prevention, such as ex cathedra teaching, bedside teaching, focus groups, workshops, interactive teaching, knowledge questionnaires, simulation-based learning, written information, and audiovisual learning.<br>3. Studies evaluating the role of HCWs in infection control training. | 1. Adherence to infection control procedures, such as hand hygiene, device management (including appropriate use, insertion/removal of catheters), perioperative management, and HAI surveillance;<br>2. Shifts in nosocomial infections, such as HAI in general, CLABSI/CRBSI, VAP, UTI, and SSI.<br>3. Shifts of MDRO and the rate of *C. difficile* infection. |
| *4* | 1. Studies evaluating interventions intended to: 1) change HCWs' behaviour and/or work practices with regard to infection prevention and control programmes; 2) sustain such changes in behaviour and/or working practices; 3) improve compliance with infection prevention and control procedures/guidelines through behaviour change; 4) improve quality of care through infection control programmes; or 5) remove barriers to adherence to infection control procedures/guidelines.<br>2. Studies measuring how 1) barriers and/or facilitators to compliance with infection prevention and control procedures/guidelines and/or 2) HCWs' professional roles, perceptions, attitudes, beliefs, culture, views, experience, and behaviour regarding infection control impact on changes in HCWs' behaviour, e.g., improving adherence to infection control procedures/guidelines or quality of care. | 1. Shifts in behaviours and/or alteration of working practices of HCWs in terms of adherence (or enabling adherence) to infection control procedures/guidelines (i.e., quality of care).<br>2. Effectiveness and/or cost-effectiveness of behavioural change interventions in terms of improved adherence to infection control procedures/guidelines or quality of care.<br>3. Sustainability and/or long-term persistence of HCWs' compliance with infection control procedures/guidelines.<br>4. Improvements in quality of care indicators (as defined by the authors of the examined studies) following infection control behavioural change interventions.<br>5. Impact of changes regarding infection control on professional roles, perceptions, attitudes, beliefs, culture, views, experience, and behaviour of HCWs, and adherence to infection control procedures/guidelines. |
| *5* | 1. Studies evaluating resources for standard and transmission-based isolation precautions and the consequences of resource modification.<br>2. Studies evaluating resources of established policies in relation to their effectiveness in infection prevention. | Since the implementation of policies for precautions and delivering adequate resources to reduce HAI was considered important, infection rates, colonisation rates, and resistance were considered relevant outcomes. Reporting effectiveness of precautions due to policies or available resources was also included. Studies reporting surrogate markers, such as consumption of alcohol-based handrub, soap, or gloves were also included if such reporting was in the context of resource availability/modification, or policy change. |

**Abbreviations: CLABSI**: central line-associated bloodstream infection/s; **CRBSI**: catheter-related bloodstream infection/s; **HAI**: HAI/s; **HCW**: Health-care worker (s); **MDRO**: multidrug-resistant organism(s); **SSI**: surgical site infection/s; **VAP**: ventilator-associated pneumonia; **UTI**: urinary tract infection(s).

**Supplementary table 2:** Search terms of the systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT)

| **DIMENSION 1** |
|---|
| ***Medline (Via OVID)*** |
| #1 cross infection.mp. or exp Cross Infection/ |
| #2 infection control.mp. or exp Infection Control/ |
| #3 Nosocomial Infection.mp. |
| #4 Healthcare-associated Infection?.mp. |
| #5 HAI.mp. |
| #6 HCAI.mp. |
| #7 Catheter-Related Infection?.mp. or exp Catheter-Related Infections/ |
| #8 exp Catheterization, Central Venous/ |
| #9 CRBSI.mp. |
| #10 Catheter-Associated Infection?.mp. |
| #11 Methicillin-Resistant Staphylococcus Aureus.mp. or exp Methicillin-Resistant Staphylococcus aureus/ |
| #12 MRSA.mp. |
| #13 Clostridium Difficile.mp. or exp Clostridium difficile/ |
| #14 CDI.mp. |
| #15 Bacteremia.mp. or exp Bacteremia/ |
| #16 Pneumonia, Ventilator-Associated.mp. or exp Pneumonia, Ventilator-Associated/ |
| #17 VAP.mp. |
| #18 handwashing.mp. or exp Handwashing/ |
| #19 exp Decision Making, Organizational/ |
| #20 exp Efficiency, Organizational/ |
| #21 exp Health Facility Administration/ |
| #22 exp Hospital Administration/ |
| #23 exp Institutional Management Teams/ |
| #24 exp Management Audit/ |
| #25 exp Management Information Systems/ |
| #26 exp Models, Organizational/ |
| #27 exp Organizational Culture/ |
| #28 exp Organizational Innovation/ |
| #29 exp Personnel Management/ |
| #30 exp Program Development/ |
| #31 exp Total Quality Management/ |
| #32 leadership.mp. |
| #33 exp Infection Control Practitioners/ |
| #34 exp Administrative Personnel/ |
| #35 *"Organization and Administration"/ |
| #36 exp Infection Control/og [Organization & Administration] |
| #37 exp Organizational Case Studies/ |
| #38 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 or 16 or 17 or 18 |
| #39 exp Knowledge Management/ |
| #40 exp Organizational Affiliation/ |
| #41 exp Career Mobility/ |
| #42 exp Career Mobility/ |
| #43 exp Employee Discipline/ |
| #44 exp Employee Grievances/ |
| #45 exp Employee Incentive Plans/ |
| #46 exp Employee Performance Appraisal/ |
| #47 exp Management Quality Circles/ |
| #48 exp Negotiating/ |
| #49 exp Personnel Administration, Hospital/ |
| #50 exp Personnel Downsizing/ or exp Personnel Selection/ |
| #51 exp Personnel Loyalty/ |
| #52 exp "Personnel Staffing and Scheduling"/ |
| #53 exp Personnel Turnover/ |

#54 exp "Salaries and Fringe Benefits"/
#55 exp Staff Development/
#56 exp Workload/
#57 exp Workplace/
#58 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57
#59 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 39 or 40 or 58
#60 exp Hospital-Physician Relations/
#61 exp Professional Practice/
#62 Risk Management/
#63 Safety Management/
#64 59 or 60 or 61 or 62 or 63
#65 38 and 64
#66 limit 65 to (humans and yr="1996 -Current" and (english or french or german or italian or portuguese or spanish))

***PsycINFO (Via EBSCO)***

(DE "Health Care Administration" OR DE "Hospital Administration" OR DE "Management Personnel" OR DE "Clinical Methods Training" OR DE "Risk Management" OR DE "Leadership" OR DE "Transformational Leadership" OR DE "Management Decision Making" OR DE "Management Methods" OR DE "Management Planning" OR DE "Management Training" OR DE "Employee Benefits" OR DE "Bonuses" OR DE "Employee Assistance Programs" OR DE "Employee Health Insurance" OR DE "Employee Leave Benefits" OR DE "Employee Pension Plans" OR DE "Industrial and Organizational Psychology") AND ("Cross Infection" OR "Infection Control" OR "Nosocomial Infection" OR DE "Catheterization" OR "Healthcare-associated Infection" OR “HAI” OR “HCAI” OR “Catheter- Related Infection?” OR “Catheter-Related Infection” OR “Central Venous Catheterization” OR “CRBSI” OR “Catheter-Associated Infection” OR “Methicillin-Resistant Staphylococcus Aureus” OR “MRSA” OR “Clostridium Difficile” OR “CDI” OR “Bacteremia” or “Ventilator-Associated Pneumonia” OR “VAP” OR “handwashing”)

***Embase***

('organization and management'/mj OR 'hospital management'/exp OR 'organizational development'/exp OR 'organizational structure'/exp OR 'organizational efficiency'/exp OR 'leadership'/exp OR 'personnel management'/exp OR 'program development'/exp OR 'management audit' OR 'hospital administration' OR 'organizational efficiency' OR 'staff development' OR 'risk management'/exp) AND ('hospital infection'/exp OR 'cross infection'/exp OR 'infection control'/exp OR 'nosocomial infection'/exp OR 'healthcareassociated infection' OR 'hai' OR 'hcai' OR 'catheter-related infection'/exp OR 'catheter infection'/exp OR 'central venous catheterization'/exp OR 'crbsi' OR 'catheter-associated infection'/exp OR 'methicillin resistant staphylococcus aureus'/exp OR 'mrsa'/exp OR 'clostridium difficile'/exp OR 'cdi' OR 'bacteremia'/exp OR 'ventilator associated pneumonia'/exp OR 'vap' OR 'handwashing'/exp OR 'hand washing'/exp) AND ([english]/lim OR [french]/lim OR [german]/lim OR [italian]/lim OR [portuguese]/lim OR [spanish]/lim) AND [humans]/lim NOT [medline]/lim AND [embase]/lim AND [1996-2011]/py

**DIMENSION 2**

***Medline (Via OVID)***

#3 Search infection prevention [TIAB] OR infection control [TIAB]
#4 Search "Infection Control"[Mesh:NoExp]
#5 Search nosocomial infection* [TIAB]
#7 Search "Cross Infection"[Mesh]
#8 Search (hospital acquired [TIAB] OR healthcare acquired [TIAB] OR health care acquired [TIAB] OR healthcare associated [TIAB] OR health care associated [TIAB]) AND (infection [TIAB] OR infections [TIAB])
#9 Search HAI [TIAB] OR HCAI [TIAB]
#10 Search bacteremia [TIAB] OR bacteraemia [TIAB]
#13 Search "Bacteremia"[Mesh]
#14 Search (catheter associated [TIAB] OR catheter related [TIAB]) AND (infection [TIAB] OR infections [TIAB])

#15 Search CRBSI [TIAB]
#18 Search "Catheter-Related Infections"[Mesh]
#20 Search device associated infection* [TIAB]
#19 Search central line associated bloodstream infection* [TIAB]
#21 Search ventilator associated pneumonia [TIAB] OR VAP [TIAB]
#24 Search "Pneumonia, Ventilator-Associated"[Mesh]
#25 Search surgical site infection* [TIAB] OR SSI [TIAB]
#27 Search "Surgical Wound Infection"[Mesh]
#28 Search (methicillin resistant staphylococcus aureus [TIAB] OR meticillin resistant staphylococcus aureus [TIAB] OR MRSA [TIAB]) AND (infection [TIAB] OR infections [TIAB])
#32 Search clostridium difficile infection* [TIAB] OR CDI [TIAB] OR clostridium difficile associated diarrhoea [TIAB] OR CDAD [TIAB] OR clostridium difficile associated disease* [TIAB]
#33 Search (vancomycin resistant enterococcus [TIAB] OR vancomycin resistant enterococci [TIAB] OR VRE [TIAB]) AND (infection [TIAB] or infections [TIAB])
#34 Search surveillance [TIAB]
#38 Search ("Population Surveillance"[Majr:NoExp]) OR "Sentinel Surveillance"[Majr]
#39 Search (#3) OR #4
#40 Search ((((((((((((#5) OR #7) OR #8) OR #9) OR #10) OR #13) OR #14) OR #15) OR #18) OR #19) OR #20) OR #21) OR #24) OR #25) OR #27
#41 Search ((#28) OR #32) OR #33
#42 Search ((#39) OR #40) OR #41
#43 Search (#34) OR #38
#44 Search (#42) AND #43
#45 Search (#42) AND #43 Limits: English, French, German, Italian, Spanish, Portuguese, Publication Date from 1996/01/01 to 2010/12/31

**DIMENSION 3**

***Medline (via PubMed)***

("education"[MeSH Terms] OR Educat$[Text Word] OR Training[Text Word]) AND ("infection control"[MeSH Terms] OR "cross infection"[MeSH Terms] OR "cross infection"[Text Word] OR "infection control"[Text Word] OR "Nosocomial Infection"[Text Word] OR "Healthcare-Associated Infection"[Text Word] OR "Healthcare-Related Infection"[Text Word] OR HAI[Text Word] OR HCAI[Text Word] OR "catheter-related infections"[MeSH Terms] OR "catheter-related infection?"[Text Word] OR "catheter-associated infection?"[Text Word] OR "catheterization, central venous"[MeSH Terms] OR CRBSI[Text Word] OR "methicillin-resistant staphylococcus aureus"[MeSH Terms] OR MRSA[Text Word] OR "Methicillin-Resistant Staphylococcus Aureus"[Text Word] OR "clostridium difficile"[MeSH Terms] OR "Clostridium Difficile"[Text Word] OR CDI[Text Word] OR "bacteremia"[MeSH Terms] OR Bacteremia[Text Word] OR "pneumonia, ventilator-associated"[MeSH Terms] OR VAP[Text Word] OR "Ventilator Associated Pneumonia"[Text Word] OR "handwashing"[MeSH Terms]OR "handwashing"[Text Word]) AND ("humans"[MeSH Terms] AND (English[lang] OR French[lang] OR German[lang] OR Italian[lang] OR Spanish[lang] OR Portuguese[lang]) AND ("1996"[PDAT] : "3000"[PDAT]))

***PsycINFO (Via EBSCO)***

((DE "Education" OR DE "Curriculum" OR DE "Higher Education" OR DE "Nursing Education" OR DE "Personnel Training" OR DE "Education" OR DE "Teaching" OR DE "Teaching Methods" OR DE "Training")) AND ("Cross Infection" OR "Infection Control" OR "Nosocomial Infection" OR DE "Catheterization" OR "Healthcare-associated Infection" OR “HAI” OR “HCAI” OR “Catheter- Related Infection?” OR “Catheter-Related Infection” OR “Central Venous Catheterization” OR “CRBSI” OR “Catheter-Associated Infection” OR “Methicillin Resistant Staphylococcus Aureus” OR “MRSA” OR “Clostridium Difficile” OR “CDI” OR “Bacteremia” or “Ventilator- Associated Pneumonia” OR “VAP” OR “handwashing”)

***EMBASE***

('training'/exp OR 'education'/exp) AND ('hospital infection'/exp OR 'cross infection'/exp OR 'infection control'/exp OR 'nosocomial infection'/exp OR 'healthcare-associated infection' OR 'hai' OR 'hcai' OR 'catheter-related infection'/exp OR 'catheter infection'/exp OR 'central venous catheterization'/exp OR 'crbsi' OR 'catheter-associated infection'/exp OR 'methicillin resistant staphylococcus aureus'/exp OR 'mrsa'/exp OR 'clostridium difficile'/exp OR 'cdi' OR 'bacteremia'/exp OR 'ventilator associated pneumonia'/exp OR 'vap' OR 'handwashing'/exp OR 'hand washing'/exp) AND ([english]/lim OR [french]/lim OR [german]/lim OR [italian]/lim OR [portuguese]/lim OR [spanish]/lim) AND [humans]/lim AND [embase]/lim NOT [medline]/lim AND [1996-2011]/py

**DIMENSION 4**

***Medline & HMIC (Via OVID)***

| | |
|---|---|
| #1 | infection control.mp. or exp Infection Control/ |
| #2 | ((infection adj control) or (infection adj3 prevention) or (infection adj3 management)).mp. |
| #3 | nosocomial infection?.mp. or exp Cross Infection/ |
| #4 | (hospital acquired infection? or healthcare associated infection? or health care associated infection? or healthcare-associated infection? or health care-associated infection? or HAI or HCAI).mp. |
| #5 | Methicillin Resistant Staphylococcus Aureus.mp. or Meticillin Resistant Staphylococcus Aureus.mp. or exp Methicillin-Resistant Staphylococcus aureus/ |
| #6 | MRSA.mp. |
| #7 | Methicillin-sensitive Staphylococcus aureus.mp. or Meticillin-sensitive Staphylococcus aureus.mp. |
| #8 | MSSA.mp. |
| #9 | clostridium difficile.mp. or exp Clostridium difficile/ |
| #10 | C-diff.mp. or CDI.mp. or CDAD.mp. or clostridium difficile infection.mp. or clostridium difficile associated disease?.mp. |
| #11 | catheter-related infections.mp. |
| #12 | bacter?emia.mp. or exp Bacteremia/ |
| #13 | (ventilator associated pneumonia or VAP).mp. |
| #14 | (device associated infection? or device-associated infection?).mp. |
| #15 | surgical site infection.mp. |
| #16 | *Disease Outbreaks/pc [Prevention & Control] |
| #17 | Handwashing/ |
| #18 | (control or prevention or management or guideline*).mp. |
| #19 | (hand? hygiene or hand washing or isolation or screening or precaution).mp. |
| #20 | decontamination.mp. |
| #21 | care bundle?.mp. or bundle?.mp. or high impact intervention?.mp. or multimodal.mp. or checklist?.mp. or care pathway?.mp. |
| #22 | behavio?r* change.mp. or planned behavio?r*.mp. |
| #23 | (decision making or intention? or attitude? or practic* or routine? or procedure? or work*).mp. |
| #24 | exp Decision Making/ or Intention/ or exp Health Personnel Attitudes/ or health personnel attitude?.mp. |
| #25 | (learning or training or education or knowledge).mp or exp Education/ or exp Staff Development/ or professional development.mp. |
| #26 | exp Learning/ or organizational learning.mp. |
| #27 | (workload or ((patient? adj1 staff) adj1 contact?) or practice improvement? or professional competence? or human factor).mp. |
| #28 | (use? adj2 medical device?).mp. |
| #29 | motivation.mp. or exp Motivation/ |

| | |
|---|---|
| #30 | (organizational culture or organisational culture).mp. |
| #31 | exp Organizational Innovation/ or organizational innovation.mp. or organisational innovation.mp. |
| #32 | (organisational change or organizational change).mp. |
| #33 | critical pathway?.mp. |
| #34 | nurs* practice pattern?.mp. |
| #35 | interven*.mp. |
| #36 | (guideline? adj3 implement*).mp. |
| #37 | exp Clinical Competence/ |
| #38 | clinical governance.mp. or exp Clinical Governance/ |
| #39 | treatment guideline?.mp. or best practice?.mp. |
| #40 | exp Guideline Adherence/ or ((guideline? adj adherence) or (guideline? adj compliance)).mp. |
| #41 | exp Clinical Audit/ or audit.mp. or feedback?.mp. |
| #42 | exp Guidelines as Topic/ |
| #43 | Quality Improvement/ or quality improvement?.mp. |
| #44 | (service improvement or improvement methodolog*).mp. |
| #45 | exp Health Personnel/ or (health personnel or healthcare professional? or healthcare worker?).mp. |
| #46 | (clinical staff or medical personnel or clinical personnel).mp. |
| #47 | Infection Control Practitioners/ or infection control practitioner?.mp. or infection control nurse?.mp. or infection control team?.mp. |
| #48 | exp Medical Staff, Hospital/ or (hospital staff or hospital personnel or hospital worker?).mp. |
| #49 | exp Nurses/ or (nurse? or nursing staff or nursing student?).mp. |
| #50 | exp Personnel, Hospital/ |
| #51 | exp Physicians/ or (physician? or doctor? or clinician? or surgeon? or resident? or medical student?).mp. |
| #52 | community healthcare.mp. or community service?.mp. or exp Community Health Services/ or community health care.mp. or community care.mp. |
| #53 | exp Primary Health Care/ or exp Family Practice/ or exp Community Health Centers/ or health centre.mp. or GP practice.mp. or general practice.mp. or family practice.mp. or primary care.mp. or primary healthcare.mp. or primary health care.mp. |
| #54 | Family Physicians/ or General Practitioners/ or Primary Care Physicians/ or Hospitalists/ or (general practitioner? or family practitioner? or family doctor? or primary care doctor?.mp. or primary care physician?.mp.).mp. |
| #55 | 52 or 53 or 54 |
| #56 | 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 or 16 or 17 |
| #57 | 18 or 19 or 20 or 21 |
| #58 | 56 and 57 |
| #59 | 1 or 2 or 58 |
| #60 | 22 or 23 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 |
| #61 | 36 or 37 or 38 or 40 or 41 or 42 or 43 or 44 |
| #62 | 60 or 61 |
| #63 | 45 or 46 or 47 or 48 or 49 or 50 or 51 |
| #64 | 59 and 62 and 63 |
| #65 | 64 not 55 |
| #66 | limit 65 to (yr="1996 - 2010" and (english or french or german or italian or portuguese or spanish)) |
| #67 | remove duplicates form 66 |

**DIMENSION 5**

***Medline (Via PubMed)***

#1 Search "resource" OR "resources"
#5 Search ("Health Resources"[Mesh] OR "Resource Allocation"[Mesh] OR "Health Manpower"[Mesh]) OR "organization and administration" [Subheading]
#6 Search "requirement" OR "requirements"
#7 Search "policy" OR "policies"
#9 Search "Policy Making"[Mesh] OR "Health Policy"[Mesh] OR "Economics"[Mesh]
#10 Search "strategy" OR "strategies"
#11 Search (((((#1) OR #5) OR #6) OR #7) OR #9) OR #10
#12 Search standard precaution*
#13 Search "universal precaution"
#14 Search "universal precautions"
#16 Search "Universal Precautions"[Mesh]
#17 Search "hand hygiene"
#18 Search hand disinfection
#19 Search "transmission based precautions"
#20 Search "transmission based" AND "precautions"
#21 Search "droplet precautions"
#22 Search contact precaution*
#24 Search airborne precaution
#25 Search airborne precautions
#26 Search "isolation precaution"
#27 Search "isolation precautions"
#29 Search "Patient Isolation"[Mesh]
#30 Search ((((((((((((#12) OR #13) OR #14) OR #16) OR #17) OR #18) OR #19) OR 20) OR #21) OR #22) OR #24) OR #25) OR #26) OR #27) OR #29
#31 Search hospital acquired infection*
#32 Search healthcare associated infection*
#33 Search nosocomial
#35 Search "Cross Infection"[Mesh]
#36 Search "infection control" OR "infection prevention"
#39 Search "prevention and control" [Subheading]
#40 Search clostridium difficile
#41 Search MRSA
#42 Search VRE
#43 Search "vancomycin resistant enterococcus" OR "vancomycin resistant enterococci"
#44 Search (((((((#31) OR #32) OR #33) OR #35) OR #36) OR #39) OR #40) OR #41) OR #42) OR #43
#45 Search (#11) AND #30
#46 Search (#45) AND #44
#47 Search (#45) AND #44 Limits: English, French, German, Italian, Spanish, Portuguese, Publication Date from 1996/01/01 to 2010/12/31

**ADDITIONAL SEARCHES**

**Auditing**

(“Clinical Audit” [MeSH Terms] OR “Management Audit” [MeSH Terms] OR “audit*” [Text Word] OR “auditing” [Text Word]) AND ("infection control"[MeSH Terms] OR "cross infection"[MeSH Terms] OR "cross infection"[Text Word] OR "infection control"[Text Word] OR "Nosocomial Infection"[Text Word] OR "Healthcare-Associated Infection"[Text Word] OR "Healthcare-Related Infection"[Text Word] OR HAI[Text

Word] OR HCAI[Text Word] OR "catheter-related infections"[MeSH Terms] OR "catheter-related infection?"[Text Word] OR "catheter-associated infection?"[Text Word] OR "catheterization, central venous"[MeSH Terms] OR CRBSI[Text Word] OR "methicillin-resistant staphylococcus aureus"[MeSH Terms] OR MRSA[Text Word] OR "Methicillin-Resistant Staphylococcus Aureus"[Text Word] OR "clostridium difficile"[MeSH Terms] OR "Clostridium Difficile"[Text Word] OR CDI[Text Word] OR "bacteremia"[MeSH Terms] OR Bacteremia[Text Word] OR "pneumonia, ventilator-associated"[MeSH Terms] OR VAP[Text Word] OR "Ventilator Associated Pneumonia"[Text Word] OR "handwashing"[MeSH Terms]OR "handwashing"[Text Word] OR “hand hygiene”[Text Word] OR “handrub*”[Text Word] OR “hand rub”[Text Word] OR “handrub” [Text Word])

**Patient Participation**

(“Patient Participation”[MeSH Terms] OR “patient empowerment”[Text Word] OR “patient empowering”[Text Word] OR ”empowering patients”[Text Word]) AND ("infection control"[MeSH Terms] OR "cross infection"[MeSH Terms] OR "cross infection"[Text Word] OR "infection control"[Text Word] OR "Nosocomial Infection"[Text Word] OR "Healthcare-Associated Infection"[Text Word] OR "Healthcare-Related Infection"[Text Word] OR HAI[Text Word] OR HCAI[Text Word] OR "catheter-related infections"[MeSH Terms] OR "catheter-related infection?"[Text Word] OR "catheter-associated infection?"[Text Word] OR "catheterization, central venous"[MeSH Terms] OR CRBSI[Text Word] OR "methicillin-resistant staphylococcus aureus"[MeSH Terms] OR MRSA[Text Word] OR "Methicillin-Resistant Staphylococcus Aureus"[Text Word] OR "clostridium difficile"[MeSH Terms] OR "Clostridium Difficile"[Text Word] OR CDI[Text Word] OR "bacteremia"[MeSH Terms] OR Bacteremia[Text Word] OR "pneumonia, ventilator-associated"[MeSH Terms] OR VAP[Text Word] OR "Ventilator Associated Pneumonia"[Text Word] OR "handwashing"[MeSH Terms]OR "handwashing"[Text Word] OR “hand hygiene”[Text Word] OR “handrub*”[Text Word] OR “hand rub”[Text Word])

**Target Setting**

(“target*” [Text Word] OR “target setting” [Text Word] OR “goal setting” [Text Word] OR Goals [MeSH Terms] OR “organizational objectives” [MeSH Terms]) AND ("infection control"[MeSH Terms] OR "cross infection"[MeSH Terms] OR "cross infection"[Text Word] OR "infection control"[Text Word] OR "Nosocomial Infection"[Text Word] OR "Healthcare-Associated Infection"[Text Word] OR "Healthcare-Related Infection"[Text Word] OR HAI[Text Word] OR HCAI[Text Word] OR "catheter-related infections"[MeSH Terms] OR "catheter-related infection?"[Text Word] OR "catheter-associated infection?"[Text Word] OR "catheterization, central venous"[MeSH Terms] OR CRBSI[Text Word] OR "methicillin-resistant staphylococcus aureus"[MeSH Terms] OR MRSA[Text Word] OR "Methicillin-Resistant Staphylococcus Aureus"[Text Word] OR "clostridium difficile"[MeSH Terms] OR "Clostridium Difficile"[Text Word] OR CDI[Text Word] OR "bacteremia"[MeSH Terms] OR Bacteremia[Text Word] OR "pneumonia, ventilator-associated"[MeSH Terms] OR VAP[Text Word] OR "Ventilator Associated Pneumonia"[Text Word] OR "handwashing"[MeSH Terms]OR "handwashing"[Text Word] OR “hand hygiene”[Text Word] OR “handrub*”[Text Word] OR “hand rub”[Text Word])

**Knowledge Management**

The search term "knowledge management" in combination with infection control terms did not return any results. "Knowledge management" as text word revealed more than 400 hits; however, these returned articles were usually not addressing how to deal with knowledge within an institution. Consequently, we searched for "knowledge management" as a MeSH term, which resulted in 54 hits.

**Supplementary table 3:** Decision matrix of the Integrated Quality Criteria for Review of Multiple Study Designs (ICROMS)

| | | | Study Design** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quality Criteria | Specific Criteria* | RCT | CBA | CITS | NCITS | NCBA | Prospective Cohort | Qual |
| 1 | Clear aims and justification | A. Clear statement of the aims of the research? | ✓✓ | ✓✓ | ✓✓ | ✓✓ | ✓✓ | ✓✓ | ✓✓ |
| | | B. Rationale for number of pre- and post-intervention points or adequate baseline measurement | x | x | ✓ | ✓✓ | ✓✓ | x | x |
| | | C. Explanation for lack of control group | x | x | x | ✓ | ✓ | x | x |
| | | D. Appropriateness of qualitative methodology | x | x | x | x | x | x | ✓ |
| | | E. Appropriate study design | x | x | x | x | x | x | ✓✓ |
| 2 | Managing bias in sampling or between groups | A. Sequence Generation | ✓✓ | x | x | x | x | x | x |
| | | B. Allocation Concealment | ✓✓ | x | x | x | x | x | x |
| | | C. Justification for sample choice | x | x | x | ✓✓ | ✓✓ | x | x |
| | | D. Intervention and control group selection designed to protect against systematic difference/selection bias | x | ✓✓ | x | x | x | x | x |
| | | E. Comparability of groups | x | x | x | x | x | ✓✓ | x |
| | | F. Sampling and recruitment | x | x | x | x | x | x | ✓✓ |
| 3 | Managing bias in outcome measurements and Blinding | A. Blinding | ✓✓ | x | x | x | x | x | x |
| | | B. Baseline measurement – protection against selection bias | x | ✓✓ | x | x | x | x | x |
| | | C. Protection against contamination | x | ✓✓ | x | x | x | x | x |
| | | D. Protection against secular changes | x | x | ✓✓ | x | x | x | x |
| | | E. Protection against detection bias: Blinded assessment of primary outcome measures | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | x |
| | | F. Reliable primary outcome measures | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | G. Comparability of outcomes | x | x | x | x | x | ✓✓ | x |
| 4 | Managing bias in follow-up | A. Follow-up of professionals (protection against exclusion bias) | ✓ | x | x | x | x | x | x |
| | | B. Follow-up of patients or episodes of care | ✓ | x | x | x | x | x | x |
| | | C. Incomplete outcome data addressed | ✓ | ✓ | ✓ | ✓ | ✓ | ✓✓ | ✓ |
| 5 | Managing bias in other study aspects | A. Protection against detection bias: Intervention unlikely to affect data collection | ✓ | ✓ | ✓ | ✓ | ✓ | x | x |
| | | B. Protection against information bias | x | x | x | x | x | ✓ | x |
| | | C. Data collection appropriate to address research aims | x | x | x | x | x | x | ✓ |
| | | D. Attempts to mitigate effects of no control | x | x | x | ✓✓ | ✓✓ | x | x |
| 6 | Analytical rigour | A. Sufficient data points to enable reliable statistical inference | x | x | ✓✓ | x | x | x | x |
| | | B. Shaping of intervention effect specified | x | x | ✓ | x | x | x | x |
| | | C. Analysis sufficiently rigorous/free from bias | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 7 | Managing bias in reporting/ ethical considerations | A. Free of selective outcome reporting | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | B. Limitations addressed | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | C. Conclusions clear and justified | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | D. Free of other bias | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | E. Ethics issues addressed | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

*Applicability of quality criteria to each study design: ✓ = Criteria to be included in quality assessment for Study Design; ✓✓ Mandatory criteria to be met quality assessment; x = Criteria not to be applied in quality assessment for Study Design.

**Study designs: RCT=Randomised controlled trial; CBA=Controlled before-after; CITS=Controlled interrupted time series; NCITS=Non-controlled interrupted time series; NCBA=Non-controlled before-after; Qual=Qualitative

**Supplementary Table 4:** Details of the studies analysed and synthesized by the systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT)

| | **Study aim and intervention features** | **Design and methods** | **Sample size and study duration** | **Study outcomes** |
|---|---|---|---|---|
| Abela et al., 2012,[85] Malta | To assess the impact of improved infrastructure after hospital relocation, education, performance feedback, and leadership (holding leaders accountable for outcome) on HH compliance. | NCC. Prospective observational study of three units in general medicine and surgery. | A total of 1807 HH opportunities. | Baseline HH compliance of 27.3% decreased to 14.5% despite the new facility with more favourable sink-to-patient ratio, but improved to 63% after education and leadership engagement. The latter had the biggest effect on compliance. The shift from handwashing (74.1% at baseline) to handrub (70.1%) contributed as well to the overall success. |
| Alonso-Echanove et al., 2003,[72] USA | The study assessed nurse staffing as a risk factor for CLABSI. | NCC. Eight ICUs at six geographically distinct hospitals. A number of patient variables were obtained as well as daily nurse-to-patient ratios and whether patients were cared for by a nurse assigned to the ICU or by a "float" nurse. | A total of 4535 patients with 8593 CVCs representing 56,627 catheter-days were observed over 24 months. | CVCs cared for by a float nurse for more than 60% were at significant risk for CLABSI (OR [95% CI], 2.75 [1.45-5.22]). |
| Andersen et al., 2009,[31] Norway | The study assessed workload in the context of increasing HAI prevalence ratios. | NCITS. Repeated quarterly prevalence surveys in a single centre. Individual patient data as well as administrative data were prospectively obtained. | A total of 57,360 patients were included during the 1991–2007. | After the reduction of HAIs in somatic wards before 2002 (p=0.001) there was an increase after 2002 (p=0.002). Total workload per work position was 27% higher in 2007 than in 2003, with a significant increase of total work load (p=0.024) after 2002. |
| Bärwolff et al., 2006,[39] Germany | The study determined whether HAI surveillance and feedback reduced the infection rate after caesarean delivery in hospitals participating in the German KISS system. | NCBA. The study assessed the rate of caesarean deliveries among hospitals participating in the German KISS HAI surveillance system for three years or more. The relative risk between the first and the third year of KISS participation was compared. | A total of 26 gynaecology/obstetric departments accumulating 17,405 caesarean deliveries reported 331 SSIs. | The SSI rate was reduced in the third year of KISS participation (1.6%) as compared to the first year (2.4%) (RR [95% CI], 0.63 [0.48-0.82]. KISS participation was an independent factor for SSI reduction (OR [95% CI], 0.64; [0.49-0.83]). |
| Barsuk et al., 2009,[27] USA | The aim of the study was to assess the effect of a simulation-based training for catheter insertion in an ICU. | CBA. Internal medicine and emergency medicine residents completed a simulation-based mastery learning programme in CVC insertion skills. The outcome of CRBSI was measured before and after the training and in a control ward during the entire study. | The total catheter-days before (16 months) and after (16 months) the intervention in the intervention and control units were 7809, 4524, 8060, and 3227, respectively. 92 residents were trained from December 2006 to March 2008. | CRBSI in the intervention unit decreased from 3.2/1000 catheter-days to 0.5/1000 catheter-days (IRR [95% CI], 0.16 [0.05-0.44]), while there was no reduction in the control ward (4.86/1000 catheter-days before; 5.26/1000 catheter-days after). |

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| Birnbach et al., 2010,[24] USA | The primary objective was to assess the effect of a handrub dispenser position on HH compliance using a mock-up of a proposed hospital room design. | RCT. Physicians were randomized in two groups (group 1 with the handrub dispenser adjacent to the patient so that it was clearly visible to anyone facing the patient's bed; group 2 with dispenser location across from the patient's bed near the door to the room). Physicians were unaware that the study was about HH compliance. | 52 physicians participated in the study. Physicians were randomly assigned into two groups: group 1 examined the patient with the dispenser in location 1, and group 2 examined the patient with the dispenser in location 2. | There was a significant difference between groups 1 and 2, in which 14 (53.8%) and 3 (11.5%) (p=0.0011), respectively, washed their hands before patient examination. |
| Blatnik et al., 2006[73] Slovenia | The study assessed the association of workload and staffing to MRSA transmission in an ICU. | NCC. The study prospectively observed MRSA transmission on a daily basis and modelled the transmission against bed occupancy and the scores of a therapeutic intervention scoring system (TISS). | A single centre ICU with 970 treated patients, accumulating 6876 patient-days over three years. | MRSA transmission was significantly associated with higher bed occupancy and higher TISS scores (P<0.001). |
| Borg, 2003,[74] Malta | The study investigated the association between bed occupancy and MRSA infections in regular wards. | NCC. Data of MRSA infection (screening and colonisation were excluded) and bed occupancy were obtained retrospectively from routine surveillance activities. | A single centre hospital of 900 beds with rooms of predominantly 4 or 8 beds. Surveillance over 24 months. | The association of MRSA infection and bed occupancy was significant (r=0.463; p <0:05) with MRSA infection following the seasonal trends of bed occupancy. |
| Borg et al., 2008,[32] Malta | The study investigated the impact of bed occupancy, particularly overcrowding, on the incidence of MRSA infection in general wards. | ITS. Data of MRSA infection (screening and colonisation were excluded) and bed occupancy were obtained prospectively from routine surveillance activities. | A single centre hospital of 900 beds. Surveillance of general medicine and surgical wards over 24 months. | Association of MRSA infection and bed occupancy were identified only for the medical wards at a lag time of two months (AR=0.032; IIR=0.033) where median bed occupancy was 110% (IQR 103-115%). No association was found for the surgical wards where median bed occupancy was 84% (IQR, 81-90%). |
| Bouadma et al., 2010,[40] France | The aim of the study was to assess the long-term effect of a multidisciplinary education and training strategy on VAP prevention. | NCBA. A multidisciplinary task force of five physicians (four ICU physicians; one infection control physician) and five nurses (three ICU nurses /two infection control nurses) was formed to develop a policy for VAP prevention. The task force designed an educational programme with eight preventive measures : 1) comply with HH; 2) comply with correct glove and gown use; 3) maintain adequate endotracheal cuff pressure; 4) ensure bed backrest elevation >30° (in the absence of medical contraindication); 5) avoid ventilator circuit disconnection and perform tracheal aspiration only when necessary; 6) provide good oral hygiene; 7) use an orogastric rather than a nasogastric tube; and 8) avoid gastric overdistension. | The study was done in a single centre. Pre-intervention and post-intervention periods included 882 and 871 ventilation sessions over a study duration of 75 months. | VAP incidence density was lower in the post-intervention period (26.1/1000 vs. 14.9/1000 ventilator-days; HR [95% CI], 0.56 [0.44-0.70]). |

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| Brandt et al., 2006,[41] Germany | The study evaluated whether SSI rates decrease as a result of performing active SSI surveillance (as participating centre to the German surveillance network (KISS). | NCBA. SSI surveillance was prospective using the US National Healthcare Safety Network surveillance definition and included 19 surgical types. | Data of 119,114 surgeries from 130 surgical departments were obtained over a study period of 90 months. | Compared with the first surveillance year, the risk for SSI decreased in years 2 and 3 (OR [95% CI], 0.84 [0.77-0.93]; and 0.75 [0.68-0.82]), but not in year 4. |
| Brown et al., 2003,[42] Russia | The study investigated the effect of a HH intervention programme on HH compliance, use of ABHR, and colonisation with *K. pneumoniae*. | NCBA. ABHR was provided for routine HH use. Eight weeks later, a quality improvement intervention was implemented, consisting of a review of interim data, identification of opinion leaders, posting of colonisation incidence rates, and regular feedback. | A total of 1027 HH events were observed during the care of 248 neonates in six NICUs over a study period of six months. | Overall HH compliance did not increase significantly over time (44% [T1], 42% [T2], and 48% [T3]); however, the proportion of ABHR use increased compared to hand washing ($p<0.001$), similar to HH compliance after glove removal (46% [T1], 48% [T2], and 69% [T3]; $p<0.001$). Colonisation rates for *K. pneumoniae*, *Enterococcus* spp., *Candida albicans*, and *Escherichia coli* decreased over time – with a significant reduction for *K. pneumoniae* from 21.5/1000 patient-days to 4.7/1000 patient-days. |
| Charrier et al., 2008,[25] Italy | The study aimed to evaluate the efficacy of an implementation strategy characterized by clinical–organizational, integrated audits followed by feedback and the presence of facilitators in the departments on nursing operators. | RCT. Ten wards of a single hospital were cluster-randomized into two groups of an intervention to improve the care of catheters (peripheral and central) and pressure ulcers. A number of process indicators (35) for correct catheterisation were assessed before and at four time points after the intervention by a standardised checklist. In the control group, checklists were completed by the operators on their own, whereas in the intervention group the operators were audited and received, feedback, in the presence of a facilitator. All operators were part of an auditor group and had been specifically trained in auditing techniques. | 160 nurses (74 in the standard intervention group and 86 in the audit group). Study duration was 18 months. | For 12 items, there was a significant increase (two-sided p value of 0.05) of compliance among the audit group compared to the standard group. |
| Cocanour et al., 2006,[43] USA | The aims of the study were to test the feasibility and effectiveness of a VAP bundle in an institution with VAP rates > 90% percentile of the US National Healthcare Safety Network surveillance system. | NCBA. A ventilator bundle was introduced in a mixed ICU including head of bed elevation, peptic ulcer prophylaxis, endotracheal tube suctioning, handwashing, getting the patient out of bed, oral care, glove and non-permeable apron use, use of sleeved Yankauers, changing nasogastric irrigation fluids daily, chlorhexidine baths twice weekly, and strict glucose control. The decrease in VAP occurred when compliance with the "bundle" was audited and feedback given to the staff on both a daily and weekly | A 690-bed university-affiliated hospital with a 20-bed mixed ICU. Study duration was 18 months with five months baseline, five months after bundle introduction, and eight months follow-up using audit and feedback. | VAP incidence density decreased from 22.3-23.7/1000 ventilator-days at baseline to 10.7/1000 ventilator-days after the introduction of audits ($p<0.05$). Rates stayed below the 25th percentile of the US National Healthcare Safety Network surveillance system thereafter. |

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| | | basis. | | |
| Costers et al., 2012,[67] Belgium | To test the effectiveness of a national HH promotion campaign. | NCBA. Four consecutive one-month campaigns were organised to promote HH in Belgian hospitals between 2005 and 2011. The campaigns included a combination of reminders in wards, educational sessions for healthcare workers, promotion of alcohol based hand rub use, increasing patient awareness, and audits with performance feedback. Prior and after each one month intervention period, the infection control teams measured HH compliance of healthcare workers by direct observation using a standardised observation form. | At least 92% of acute care hospitals involved in each campaign. A total of 149,041 opportunities for HH (74,581 before and 74,460 after the intervention period) were observed during the first campaign, 196,685 (111,176 before and 85,509 after) during the second campaign, 223,719 (111,476 before and 112,243 after) during the third campaign, and 168,922 (89,553 before and 79,369 after) during the fourth campaign. | Compliance with HH significantly increased from 49.6% before to 68.6% after the intervention period for the first, from 53.2% to 69.5% for the second, from 58.0% to 69.1% for the third, and from 62.3% to 72.9% for the fourth campaign. |
| Creamer, 2000,[93] Ireland | To examine nursing issues in relation to duration of peripheral venous catheter (PVC) cannulation in general wards in order to improve practice. | Qualitative. | Ten nurses. | PVC care. |
| Creedon et al., 2006,[109] Ireland | To observe HCWs' 'compliance with HH guidelines during patient care in an ICU in Ireland before (pre-test) and after (post-test) implementation of a multifaceted HH programme, and to investigate HCWs' attitudes, beliefs, and knowledge in relation to compliance with handwashing guidelines. | Mixed-methods. A convenience sample of nurses, physicians, physiotherapists, and care assistants (n=73 observational participants; n=62 questionnaire respondents) was used. Data (n=314 observations; 62 questionnaires) were analysed descriptively and cross-tabulated using chi-square (Pearson's) and Mann-Whitney statistical tests. | Large urban teaching hospital in Ireland with 344 beds. | HH compliance increased from 51% to 83% ($p < 0.001$). Knowledge was significantly better after the intervention. |
| Cunningham et al., 2006,[76] England | The study addressed the bed occupancy and turnover rates related to MRSA bacteraemia among English specialist trusts. | NCC. Data about bed occupancy, length of stay (to calculate turnover intervals) and MRSA were obtained from Department of Health Hospital Activity statistics, Hospital Episode Statistics, and the Department of Health for England & Wales. | Of a total of 45 specialist hospitals, the authors were able to match 40 trusts for bed occupancy and MRSA, and 38 trusts for bed turnover and MRSA. | Mean bed occupancy and turnover interval were 85% and 0.95 days, respectively. There was an inverse correlation between turnover interval and MRSA bacteraemia ($r=-0.32$; $p=0.049$), and a correlation between bed occupancy and MRSA bacteraemia ($r=0.46$; $p=0.006$). |
| Cunningham et al., 2006,[123] Northern Ireland | The study addressed the bed occupancy and turnover rates as related to MRSA bacteraemia among Northern Ireland trusts in 2003-2004. | NCC. Data about bed occupancy, length of stay (to calculate turnover intervals) and MRSA were obtained from annual hospital statistics in Northern Ireland and from the Communicable Diseases Surveillance Centre. | Data from 12 acute trusts in Northern Ireland in 2003 and 2004. | Mean bed occupancy and turnover interval were 83% and 1.1 days, respectively. There was an inverse correlation between turnover interval and MRSA bacteraemia ($r=0.67$; $p=0.01$), and a non-significant correlation between bed occupancy and MRSA |

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| | | | | bacteraemia (r=0.49; p=0.18). |
| Damschroder et al., 2009,[94] USA | The study addressed factors that influence the types and numbers of champions needed for effective implementation of evidence-based practices. | Qualitative. A number of telephone interviews were conducted to select hospitals for site interviews. Based on results, site visits were organised to interview more individuals. Interviews were semi-structured and transcribed verbatim for analysis. Interviewees were selected based on recommendations/mentioning in performed interviews. | Telephone interviews conducted in 2005–2006 with 38 individuals at 14 purposively selected hospitals. Based on findings from the telephone interviews, six hospitals were selected for site visits, which resulted in interviews with another 48 individuals in 2006–2007. | Single, intrinsically motivated champions can lead the implementation of a simple technology-focused change. More than one champion was needed when an improvement required individuals to change behaviour. Champions in hospitals with low-quality working relationships across units or professions had a particularly challenging time implementing behavioural change. |
| De Palo et al., 2010,[33] USA | The aim of the study was to test the efficacy of a state- wide collaboration and the "comprehensive unit- based safety programme" in the implementation of intervention bundles for the prevention of CLABSI and VAP. | NCITS. A state-wide ICU collaboration including participating hospitals (CEO, physician/nurse ICU heads), the Rhode Island Quality Institute, quality partners of Rhode Island, and the Rhode Island hospital association. The ICU initiatives were backed by hospital leaders and included defined bundle strategies for CLABSI and VAP prevention. | Conducted between January 2006 and June 2008 in all 23 ICUs in 11 hospitals in Rhode Island with a total of 263 ICU beds. | Mean CLABSI rate decreased 74% from 3.73/1000 catheter-days to 0.97/1000 catheter-days in the last quarter with a decreasing trend over time (p=0.003). The VAP rate fell from 3.44/1000 ventilator days to 2.92/1000 in the last study quarter. No significant time trend was detected for VAP reduction. |
| Doron et al., 2011,[68] USA | To assess the effectiveness of a pilot-tested multimodal HH intervention strategy. | NCBA. Roll-out of a pilot-tested comprehensive HH promotion programme with strong leadership support and dedicated financial resources. | A total of 14,844 HH opportunities were observed hospital-wide in a 425-bed academic centre. | Compared with the mean<br><br>HH compliance rate for the six months before the campaign<br><br>(72%), postcampaign HH compliance (mean = 94%) was significantly higher ($p <$ .0001). |
| Eggimann et al., 2000,[15] Switzerland | The aim of the study was to test a comprehensive, multimodal strategy for the prevention of bloodstream infections. | NCC. All internal guidelines for catheter insertion and care were revised based on the evidence in the literature. The implementation of the comprehensive prevention programme followed a multimodal strategy with workshops and bedside teaching and was carried largely by two champions (one physician, one nurse) from the ICU. | Single centre study in the medical ICU of a university-affiliated tertiary-care hospital with 18 beds. A total of 3154 patients were admitted between Oct, 1995, and Nov, 1997. | Microbiologically documented bloodstream infections decreased from 2.4/1000 device days to 0.8/1000 (RR [95% CI]: 0·31 [0·09–0·53]). Rates of respiratory and UTI remained unchanged. |
| Elder et al., 2008,[95] USA | The study aimed to explore perceptions of patient safety among nursing staff in ICUs following participation in a safety project that decreased HAI. | Qualitative. The study used focus groups, safety climate questionnaires, but also the results of safety checklists used by management on walkrounds. | In four US hospitals, 33 ICU nurses participated in eight focus group sessions. 92 nurses and managers completed questionnaires on safety climate. | Despite a recent intervention to reduce HAI and improve safety of central line placement, infection was relatively rarely mentioned. (Staff) nurses reported inconsistency between management's verbal and written commitment compared with their daily support of patient safety issues. Double checking and monitoring was |

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| | | | | mentioned the most performed "safety tasks" of nursing. |
| Fridkin et al., 1996,[77] USA | This study looked at risk factors for catheter associated (bloodstream) infections in a cohort in a surgical ICU that showed an unexplained rise in infection. | Case-control study. Upon identification of parenteral nutrition as the main driver of infection, other risk factors were analyzed in a case-control study. | A university affiliated VA-hospital with 230 beds. The case-control study included 15 cases and 19 randomly assigned controls. | A patient-to-nurse ratio of at least 1.26 (median for the entire study period) was significantly associated with the occurrence of CVC-BSI in a multivariate analysis controlling for study period, total parenteral nutrition, and assisted ventilation (RR [CI95%]: 2.2 [1.1-4.3]). |
| Fuller et al., 2012,[26] UK | To test a multimodal HH intervention strategy based on well-defined intervention theories by using a cluster-randomized trial design. | RCT. Cluster-randomized trial using a stepped wedge design. HH intervention was based on "goal and control" theories using direct and repeated feedback and positive reinforcement. | A total of 60 acute care units for the elderly and ICU's in 16 UK trusts participated in the study. | OR for compliance rose for both acute care unit for the elderly (1.67 [1.28–2.22]; p<0.001) and ICU's (2.09 [1.55–2.81]; p<0.001) equating to absolute increases of 10–13% and 13–18% respectively. |
| Gastmeier et al., 2005,[44] Germany | The study assessed the effectiveness of surveillance and monthly feedback on the outcome of infection among hip and knee prostheses in German hospitals. | NCBA. The study used the German KISS surveillance tool for prospective surveillance for hip and knee prostheses. | Study duration was 36 months. Only hospitals participating in the programme for a minimum of three years were eligible. Final results included 14 hospitals to assess the outcome of 15,457 hip prostheses and 21 hospitals with 9011 knee prostheses. | Compared with the first surveillance year, the risk for hip prosthesis infection in the year 3 of participation in KISS was significantly reduced (OR [95% CI], 0.59 [0.42-0.78]; the reduction of knee prosthesis infection was not significant. |
| Gastmeier et al., 2006,[45] Germany | The aim of the study was to investigate whether participation in the German national HAI surveillance system (KISS) reduces HAI. | NCBA. Three major HAIs were studied: VAP and CRBSI in ICUs, and SSIs in surgical units. | Data from Jan, 1997, until Dec, 2003, were analysed. Only hospitals participating at least 36 months in the surveillance programme were analysed; in total, 15 ICUs and 133 surgical units. | Comparing the infection rates in the year 2 with the year 1, the relative risks (RR [95% CI]) for VAP, CRBSI and SSI were 0.71 [0.66-0.76], 0.80 (0.72-0.90), and 0.72 [0.64-0.80], respectively. |
| Gastmeier et al., 2009,[46] Germany | The aim of the study was to assess the reduction effect due to participation in a HAI surveillance system for CRBSI, VAP, and SSI. | NCBA. ICUs and surgical units participating for at least three years were included. Over the period of the first three years, the last year was compared with the first year and time trend analyses were performed. Data were stratified into time periods when hospitals started their participation in the programme. | A total of 118, 52, and 97 ICUs accumulating 1,673,963 catheter days were analysed for CRBSI; a total of 104 and 46 ICUs accumulating 500,196 ventilator days were analysed for VAP; a total of 16, 12, and 11 hospitals accumulating 29,650 caesarean sections, 17,642 knee prostheses, and 19,148 endoscopic cholecystectomies were analysed. | RR (95% CI) of CRBSI reduction in the year 3 was 0.83 (0.75-0.91); the overall trend was significant for two of the three starting periods ($R^2$=0.133; p=0.023; $R^2$=0.169; p=0.013). RR (95% CI) of VAP reduction in year 3 was 0.80 (0.74-0.86); the overall trend was significant for the two starting periods ($R^2$=0.463; p<0.001; $R^2$=0.359; p<0.001). RR (95% CI) for caesarean section was 0.75 (0.61-0.93); for knee prosthesis 0.56 (0.38-0.82); for endoscopic cholecystectomy the RR was not significant. |

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| Gastmeier et al., 2011,[69] Germany | investigation whether participation in KISS reduces UTI rates | NCBA. ICUs participating for at least three years were included. Over the period of the first three years, the last year was compared with the first year and time trend analyses were performed. Data were stratified into three time periods when hospitals started their participation in the programme | 267 ICUs accumulating 1906134 urinary catheter days were analysed for UTI | RR (95% CI) for UTI comparing first to third year of surveillance demonstrates significant decline when three periods are combined: RR 0.86 (0.77-0.96); surveillance effect smaller than demonstrated for VAP and BSI in previous KISS studies |
| Geubbels et al, 2006,[47] the Netherlands | The study aimed to estimate the effect of multicentre surveillance for nosocomial infections on SSI risk. | NCBA. Surveillance and analysis followed the described Dutch surveillance strategy PREZIES. Hospitals participating in this surveillance network were invited to provide data for this study. All surgical types of participating hospitals were included. The study applied post-discharge surveillance. | 37 of the 50 PREZIES hospitals (around 50% of all Dutch hospitals) provided data between 1996 and 2000 (6 to 60 months) totalling 21,920 procedures. | Adjusted (post-discharge surveillance, American Society of Anesthesiologists' (ASA) score, age, pre-operative hospital stay, surgical type, wound contamination class, surgery time, elective procedure, hospital size, teaching status, experience of surgeons) RR was not reduced in the second and third year of participation, but it was in the fourth (RR [95% CI], 0.69 [0.52-0.89]) and fifth (RR [95% CI], 0.43 [0.24-0.76]) years. |
| Grayson et al., 2011,[86] Australia | To improve HH compliance by using the WHO strategy. | NCC. Prospective observational study with repeated HH audits. | 917 622 HH opportunities in 521 hospitals. | HH improvement from 63.6% (95% CI, 63.2%–64.0%) to 68.3% (95% CI, 68.1%–68.5%) |
| Haessler et al., 2012,[87] USA | To assess peer pressure and role modelling in HH compliance. | NCC. Covert observation of medical teams upon their rounds. Assessment of HH compliance in the context of team members and entrance/exit order. | Nine medical teams in a large urban academic medical centre. Upon 123 patient encounters, assessment of 718 opportunities before and 744 opportunities after patient encounter. | If the first person entering a patient encounter performed HH, the mean compliance of the other team members was 64%, but was only 45% if the first person failed to perform HH. When the attending physician performed HH upon entering the patient encounter, the mean HH compliance was 66%, but only 42% if the attending physician failed to do so. |
| Haley et al., 1985,[17] USA | In 1974, the US Centers for Disease Control and Prevention (CDC) initiated the SENIC project with three major objectives: 1) to estimate the magnitude of the nosocomial infection problem in US hospitals; 2) to describe the extent to which hospitals had adopted the new infection surveillance and control programme approach; and 3) to determine whether and, if so, to what extent, this approach was effective in | CBA. Based on a pilot study in eight community hospitals, one full-time nurse in infection control per 250 beds was recommended. Based on the results of a questionnaire, surveillance and infection control activities of 3599 hospitals were stratified into groups of no activity to high activity in surveillance and infection control activities. A random sample of 338 hospitals was then selected. In these hospitals, further information was obtained by interviews and an additional questionnaire. In each selected hospital, a random sample | Among 338 hospitals in general medicine and surgery, a total of 169,518 at baseline and 169,526 patients after five years were analysed. In 1970 and 1975/1976 1,782,172 and 1,603,307 patient-days were accumulated, respectively. Adjustments: age, gender, underlying illnesses, medical service, catheterisation, respirator, type and duration of surgery, etc. Based on these variables, the change in a hospital's patient risk | Among high-risk patients, UTI, pneumonia (post-surgery), and bacteraemia were reduced significantly by 31%, 27%, and 15% by an infection control programme including one full-time infection control nurse per 250 beds, respectively. Among low-risk patients, UTI and pneumonia (medical patients) were reduced significantly by 44% and 13%, respectively. Additional tests regarding the infection control nurse to bed level revealed that HAI reduction rates declined |

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| | reducing nosocomial infection risks. | of 500 patients hospitalized in 1970 and in 1975/1976 (April-March) was selected for detailed patient chart analysis by external trained analysts (this approach was validated in pilot studies). Models included variables such as the degree of surveillance, infection control activity, infection control nurse to bed ratio, and infection-specific variables. SSI and UTI were divided in high-risk and low-risk patients, pneumonia into post-surgery and medical, but bacteraemia included all patients. | was calculated. Data from the American Hospital Association (nurse-to-patient ratio, hospital size, medical school affiliation, ownership of the hospital, geographical region) were used also for adjustments. Data for a potentially more lenient cut-off point than one full-time infection control nurse per 250 beds was explored in a model including additional hospitals with less favourable infection control nurse to bed levels. | sharply as the number of occupied beds per full-time-equivalent infection control nurse increased from 250 to 400 beds and then levelled off. The secular trends for SSI, UTI, pneumonia, and bacteraemia among the 33% of the hospitals that had no established infection control programmes showed significant increases of +13.8%, +18.5%, +9.3%, and +25.5%, respectively, between 1970 and 1975/1976. In the same period, hospitals with very effective infection control programmes had significant decreases for SSI, UTI, and bacteraemia of -48%, -35.8, and -27.6%, respectively. |
| Harris et al., 2000,[96] USA | The objective of this study was to gain information about self-reported compliance of HH; attitudes towards handwashing in different patient settings; and attitudes towards interventions aimed at increasing compliance in HH. | Qualitative. A 74-item questionnaire was developed by small group meetings and focus group sessions with nurses, physicians, and other HCWs before it was distributed in the hospital to be completed anonymously by attending physicians, medical and surgical residents, nurses, nursing aids, and physician assistants. | 199 HCWs (118 nurses; 32 physicians; 49 other health-care professionals) from two tertiary care centres with 26,000 admissions per year. The sizes of the hospitals were 320 and 22 beds, respectively. | 64% believed that they washed their hands as often as their peers. Patients with diarrhoea, acquired immune deficiency syndrome (AIDS) or patients on antibiotics led to increased handwashing. Relative to potential interventions, 76% reported that rewards for handwashing would have no effect, 73% reported that punishment would have no effect. and 80% reported that easy access to sinks and availability of washing facilities would lead to increased compliance. |
| Henderson et al., 2012,[70] USA | To achieve sustainable HAI reductions. | NCBA. A truly multimodal hospital-wide programme addressing MRSA acquisition, CLABSI, VAP, and respiratory viruses. The programme used a well structured business plan that engaged all relevant stakeholders. | Three years in a 450 bed hospital with 19,000 yearly admissions. | MRSA transmission was reduced from 3.02 to 2.5/1,000 patient days in the ICU and 2.54 to 2.0/1,000 in non-ICU. CLABSI was reduced from 1.3/1000 device-days to 0.6/1000. VAP disappeared. Respiratory viral infections increased. HH compliance reached 94%, all residents and fellows placing CVCs (291) were trained. |
| Howie et al., 2008,[78] UK | The aim of this study was to examine whether MRSA acquisition was related to workload as reflected by bed occupancy in an ICU where the unit was well staffed, but with patients in close proximity. | NCC. MRSA data of the ICU were examined retrospectively. Bed occupancy was based upon the date and time of the patient's admission and discharge. The frequency of new MRSA isolates at times of high bed occupancy was compared using a chi-squared test. | Survey of an 8-bed mixed ICU over 12 months. | There were 16 new MRSA infections during the study period. The frequency of MRSA acquisition (0.009 new acquisitions per patient per day) was significantly higher on days when the bed occupancy exceeded seven than when bed occupancy was lower (0.0059 new acquisitions |

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| | | | | per patient per day; p=0.015). |
| Hugonnet et al., 2007,[79] Switzerland | The objective of the study was to determine whether a low staffing level increases the infection risk in critical care. | NCC. Surveillance of HAI and parameters to be used in the analysis was performed prospectively. Primary outcome was any HAI and the main exposure variable was workload (24 h nurse-to-patient ratio). | This single centre study was done in the 18-bed medical ICU over a study period of 4 years (Jan, 1999 to Dec, 2002) including 1883 patients totalling 10,637 patient-days. | In total, 415 patients developed at least one HAI for an overall infection rate of 64.5 per 1000 patient-days. Median nurse-to-patient ratio was 1.9. Higher staffing was associated with a >30% infection risk reduction (IRR [95% CI]: 0.69 [0.50-0.95]). An estimated 26.7% of all<br><br>HAIs could be avoided if the nurse-to-patient ratio was maintained >2.2. |
| Hugonnet et al., 2007,[80] Switzerland | This study was done to determine whether low nurse-to-patient ratio increases the risk for VAP and whether this effect is similar for early-onset and late-onset VAP. | NCC. VAP surveillance was prospective. The definition of pneumonia followed the CDC definition. Pneumonia was considered to be VAP if it occurred from the day following intubation to five days after extubation. VAP was defined as early-onset when it occurred one to five days after intubation, and late-onset when it occurred from day six. Risk analysis was done using multivariate Cox regression. Adjustment was done for age, gender, admission diagnosis, the Charlson co-morbidity score, the APACHE II score at admission, nursing acuity severity score, nursing training level, use of invasive devices, and medication. Primary outcome was VAP and the main exposure variable was workload (24 h nurse-to-patient ratio). | This single centre study was done in the 18-bed medical ICU over a study period of 4 years (Jan, 1999, to Dec, 2002). 936 patients were ventilated. | A total of 209 ventilated patients developed 232 VAP episodes (37.6/1000 days at risk (95% CI, 33.2-42.4). High nurse-to-patient ratio was associated with a decreased risk for late-onset VAP (HR [95% CI], 0.42 [0.18-0.99)], but there was no association with early-onset VAP. |
| Hugonnet et al., 2007,[81] Switzerland | The aim of the study was to test a case-crossover and a case-time-control design on the same cohort to empirically evaluate the feasibility and validity of such designs in hospital epidemiology. | NCC. The authors compared a case-crossover design, a case-time-control design, and a cohort design to evaluate the effect of nurse staffing level on the risk of nosocomial infections. | This single centre study was done in the 18-bed medical ICU over a study period of 4 years (Jan, 1999, to Dec, 2002). Only patients hospitalised in the ICU for more than 7 days were included (366 patients). | A total of 14 patients developed an infection. Median nurse-to-patient ratio was 1.9. OR (95% CI) adjusted for central venous line, mechanical ventilation, urinary catheter, and therapeutic antibiotics for nurse-to-patient ratios <1.9/24 h and HAI of the cross-over design and the cohort design were 1.89 (1.16-3.07) and 1.47 (1.03-2.11), respectively. |
| Jain et al., 2011,[88] USA | To assess the effect of an MRSA bundle on MRSA colonisation and infection in all VA hospitals | NCC. An MRSA bundle including screening at admission, transfer and discharge; contact isolation precautions; HH. In addition, a "culture change" was achieved by positive deviance and in each hospital an MRSA manager was established. The goal of culture | 624 acute care facilities in 153 VA hospitals. 1,712,537 surveillance screening tests in 1,934,598 admissions to, transfers within, or discharges from acute care | Reduction of healthcare-associated MRSA infections from 1.64 to 0.62/1000 patient-days (p<0.001) in the ICUs; and from 0.47 to 0.26/1000 patient-days in non-ICU wards (p<0.001). |

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| | | change was to make infection control every stakeholder's responsibility. | units. | |
| Jamal et al., 2012,[89] Australia | To test the effectiveness of participating in a State-wide HH improvement programme on HH compliance and HAI. | NCC. Multimodal HH improvement programme based on the WHO-strategy emphasizing leadership, stakeholder engagement, and audits. | >35,000 HH observations over 5 years. | HH compliance improved from 23% to 87%; handrub consumption increased from 16 L to 51 L/1000 patient-days; There was a significant HAI-reduction; however, the study did not control for secular trends. |
| Jang et al., 2010,[97] Canada | The aim of the study was to understand the behavioural determinants of HH. | Qualitative. Focus groups were organized with a wide variety of HCWs (nurses, physicians, social workers, pharmacists, respiratory therapists, physiotherapists, infection control professionals, etc.) participating. Discussions were transcribed verbatim and analysed independently by three investigators. | A total of 17 focus groups were organized. | Factors influencing HH compliance include knowledge and beliefs, motivation (HH is performed for personal protection), external environment, and professional responsibility. Successful strategies to improve adherence to HH should incorporate: 1) educating HCWs on how to manage workload with guideline adherence; 2) addressing contaminated hospital equipment may improve compliance; and 3) convincing physicians to act as role models. |
| Joshi et al., 2012,[107] India | To study staff perceptions about HH promotion strategies in India. | Qualitative study. Focus group discussions with a selected number of frontline staff and administrators in a 530-bed rural teaching hospital. | Ten focus group discussions with 75 participants (14 medical students, 15 physicians, 14 nurses, 6 senior administrators, 9 nursing administrators, 17 cleaners). | Two themes emerged: 'inter-relationship of knowledge, beliefs, motivation, practices and needs' and 'roles and responsibilities for sustainable and efficient implementation of context-relevant approaches and interventions'. Participants also discussed organizational cultural changes such as 'distribution of responsibilities', 'delegation of authority for developing stronger team leaders' and 'need for implementation of plan, protocol and rules for infection control'. |
| Kho et al., 2008,[48] USA | The study tested whether an electronic reminder system directed to the treating clinicians, using centrally-updated, expert-derived electronic data, will improve contact isolation compliance rates. | NCBA. The study tested the introduction of an electronic reminder in form of a pop-up window to prescribe isolation if the patient fulfilled a predefined algorithm for having MRSA or VRE. The system was compared to a relatively heavy and obviously not very efficient system using paper lists, which had to be compared to new admissions. The main outcome was the proportion of correct prescription of contact isolation and time to prescription | A 264-bed primary care centre. A four-month baseline period was followed by a 12-month implementation phase. There were 5835 admissions during the four-month baseline period, and 17,961 admissions during the 12- month intervention period for a total of 23,796 admissions. | Compliance with isolation order overall increased from 33% to 89% ($p<0.001$); Time-to-isolation order decreased significantly from a mean of 16.6 h to 0. Most isolation orders (63%) were prescribed before the patient arrived in the ward. |

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| | | upon arrival in the ward and isolation order. | | |
| Kilbride et al., 2003,[49] USA | The study aim was to improve practice in HH, line management and to avoid false positive blood cultures among neonates. | NCBA. Three areas of improvement were identified: 1) handwashing, 2) line management, and 3) accuracy of diagnosis. For all areas, the NICUs elaborated strategies for quality improvement using Plan-Do-Study-Act cycles. Compliance with best practice was measured using audit forms for HH and line management. Primary outcome was bacteraemia due to coagulase-negative staphylococci. | Six NICUs participating in the US Vermont Oxford Network. Data were retrieved from 1997 until 2000. | Coagulase-negative staphylococci-related bacteraemia decreased from 24.6% 1997 to 16.4% in the last six months of 2000 with a RR (95% CI) of 0.67 (0.51-0.87). |
| Kirkland et al., 2012,[90] USA | To test the effectiveness of a multimodal strategy. | NCC. The study applied leadership accountability, surveillance and feedback, handrub availability, education and training and emphasized marketing and communication. | Hospital-wide programme over 4 years. Monthly HH opportunities of about 400. | HH compliance increased from 41% to 87% (p<0.01); HAI decreased from 4.8 to 3.3/1000 patient-days (p<0.01). |
| Koff et al., 2009,[50] USA | The aim of the study was to test whether improvement of intraoperative HH by anaesthesiologists results in less contamination of equipment and post-surgical site infections. HH improvement was tested by using a ready-to-use ABHR-dispenser that could be worn by the health-care provider. | NCBA. Two similar groups of surgical patients were tested in a before-after setting. The anaesthesia environment and the three-way stopcocks were swabbed for culture. HH compliance was done by direct observation in the control group and by electronic counting of the hand device in the intervention group. Operating theatres and thus, patients, were randomized in the baseline and the intervention period, respectively. SSI retrieved by chart analysis using CDC definitions. | A total of 114 patients were enrolled, of which 11 were analysed (three dropped out because of multiple operations): 58 in the control group, 53 in the intervention group. | HH compliance among attending physicians, defined as hand decontamination events per hour, significantly improved by using the portable ABHR device (0.19 vs. 7.1; diff. 6.9; 95% CI, 1.9-11.0; p=0.008). Stopcocks were less contaminated after surgery in the intervention group (7.5% vs. 32.8%; OR [95% CI]: 0.17 [0.06-0.51]; p<0.01). There were less SSI (3.8% vs. 17.2%; OR [95% CI]: 0.19 [0.00-0.81]; p=0.02). |
| Koll et al., 2008,[51] USA | This study tested the effectiveness of the implementation of a bundle strategy to reduce CLABSI among ICUs in a health-care network in New York. | NCBA. Hospitals of the network volunteered for participation. The CLABSI prevention bundle included five items published by the HICPAC in 2002, but also customised insertion kits. Implementation was prepared and conducted by local multidisciplinary groups. The hospital management had to confirm its support of the project. An external steering committee and infection control work group prepared, organized, and conducted the collaborative and organised site visits. An expert on-call service was established to further support hospitals. | A total of 49 ICUs from 36 hospitals participated with one or more ICUs. The intervention period was 33 months, but ICUs had to provide prospective surveillance data for at least three months before the intervention was started. Analysis was done either as means between baseline and intervention or as a comparison between the first and last three months of the intervention. | CLABSI reduction between the first and last three months of intervention was 46% (3.21/1000 catheter-days [98/28,705] vs. 1.72/1000 [55/28,688]; p=0.02). |
| Larson et al., 2007,[52] USA | The objective of the study was to evaluate the impact of the dissemination of the US CDC HH guidelines on HAI. | NCBA. One year after the release of the CDC HH guidelines, 40 hospitals were visited for two days to obtain information about local awareness and implementation. Hospitals had to have participated | A total of 40 hospitals with a distribution predominantly in the US northeast region were included. HAI data were obtained for 12 months | The HH guideline was widely disseminated and HCWs were aware of it. Fewer<br><br>than half of hospitals had |

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| | | in the US National Nosocomial Infection Surveillance (NNIS) system for HAI surveillance for at least three consecutive years before the CDC HH guideline was released. | until six months before the release of the guideline and for the 12 months after. | multidisciplinary programmes<br><br>to improve compliance, and, despite often widespread staff educational efforts, physicians were usually not included. CLABSI rates were lower in hospitals with higher rates of HH ($p<0.001$). VAP rates were significantly lower in settings with low implementation scores. The results emphasize the idea that dissemination of the guideline alone was not sufficient to change behaviour. |
| Lederer et al., 2009,[53] USA | The study tested whether an integrated approach to HH would result in a successful infection control programme by behaviour change. | NCBA. The study used "hard hitting" posters with the intent to both challenge the employees and inform about them of the importance of HH in patient care and the significant negative outcomes resulting from non-compliance. The marketing challenge was to help create a culture where non-compliance was unacceptable and patient safety became an individual employee responsibility. The study was multimodal, the units could choose from a range of interventions and the project was backed by the hospital administration. | A US non-profit-making health system with nine facilities with a total of 2650 beds. The study period was between Jan, 2006, and Dec, 2008. | HH compliance increased from 49% to 98%, and was sustained >90% for 26 months. The rate for HAI due to MRSA decreased from 0.52/1000 patient-days to 0.24/1000 patient-days. There was no indication whether this was significant. |
| L'Hériteau et al., 2007,[54] France | The aim of this study was to describe temporal trends of CRBSI incidence in a French network of volunteer ICUs. | NCBA. During a four-month surveillance period each year, all CVCs in place for more than 48 h were prospectively followed until removal or patient discharge. | From 2001 to 2005, 135 ICUs participated to at least one surveillance period. Overall, 11,703 CVCs in 9182 patients totalling 122,495 CVC-days were analysed. Thirty-five ICUs participated for three or more consecutive periods. | CRBSI incidence [95% CI] decreased from 4.46/1000 CVC-days [3.53-5.39)] in 2001 to 1.99/1000 CVC-days [1.44-2.54] in 2005. |
| Lines et al., 2006,[98] UK | The study examined the extent to which staff nurses feel that MRSA is out of control and that any attempts by them to control it were unnecessary. | Qualitative. The methodology included semi-structured interviews to examine the perceptions, attitudes and beliefs. | Ten senior staff nurses were interviewed. | Six participants believe that MRSA is out of control and state "why should they bother worrying about it". The study has established that a small section of experienced staff nurses perceive MRSA to be out of control and they are not overly concerned about its management. |
| Mark et al., 2007,[82] USA | This study determined whether the number of hours of care provided by RNs was related to mortality and complications in hospitalised children. | NCC. Administrative data were used. The primary sources of data were the California Office of State-wide Health Planning and Development (OSHPD) patient discharge data and its hospital annual disclosure reports. Complications were derived from | Retrospective data from 1996-2001; approximately 3,650,000 paediatric patients from 286 hospitals were analysed. | Change (% [95% CI]) in the count of post-operative septicaemia, with an additional resource-adjusted RN hour per patient day at the 25$^{th}$, 50$^{th}$, and 75$^{th}$ percentile. Values of resource-adjusted RN staffing were –3.8 [-4.4, -3.1], -3.6 [- |

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| | | Medstat's Complications of Care (COC) software system, which identifies patient risk groups and administrative records containing 37 potential complications. Nursing care requirements were assessed using the Medstat's resource demand scale index (RDScale). | | 4.3, -3.0], and -3.4 [-4.0, -2.8], respectively. Change (% [95% CI]) in the count of post-operative pneumonia were -2.3 [-3.7, -0.8], -2.1 -3.4, -0.7], and -1.7 [-3.0, -0.5], respectively. The reduction of UTI was only significant for the 75th percentile value (-1.7 [-3.0, -0.5]). |
| Marra et al., 2010,[28] Brazil | The study explored the effectiveness of a positive deviance strategy to improve HH in two step-down units. | CBA. The study applied a positive-deviance strategy to improve HH. | Two 20-bed, step-down units at a tertiary care, private hospital. Three periods of three months duration were distinguished: 1) baseline, 2) intervention in unit A (unit B was control), 3) intervention in both units. HH was counted by electronic counters, which were installed in the handrub dispensers. | The number of ABHR aliquots dispensed per 1000 patient-days in the 1st, 2nd, and 3rd study periods in unit A and unit B were 46,890 vs. 44,460 (p=0.75), 62,000 vs. 33,570 (p<0.01), and 57,930 vs. 43,980 (p=0.16), respectively. |
| Mathai AS et al., 2011,[71] India | To improve HH compliance by using a multimodal intervention strategy. | NCBA. The intervention included lectures, posters, but also direct feedback upon the many observation sessions. In addition, leaders in the unit actively promoted HH and handed out handrub to HCW and visitors who forgot them. Handrub was provided at the point of care. | A total of 1001 and 1026 HH opportunities before and after the intervention. | HH improved from 26% at baseline to 57% (p<0.001). All HCW groups improved significantly except physiotherapists, which had an already high HH compliance. |
| Mayer et al., 2011,[34] USA | The objective of the study was to improve and sustain the hospital-wide rate of HH compliance by implementing a comprehensive ongoing intervention programme at a feasible cost. | CCT/ITS. Six acute care units, one oncology unit, and five ICUs were stratified into four intervention groups. An intervention addressing cognitive behavioural factors and focused on behaviour modification through positive reinforcement and annually changing incentives was introduced sequentially among the units, of which six units entered the study 20 months after the start. | A total of 36,123 HH opportunities involving all categories of HCWs from 12 inpatient units were observed from Oct, 2000, through Oct, 2006. | The mean compliance rate ranged from 19% to 41% of 4174 opportunities at baseline, increased to the highest levels of 73%-84% of 6420 opportunities in 2004, and remained improved at 59%-81% of 4990 opportunities in 2006. All improvements within the units and comparisons across the units were significant. |
| Mc Laws et al., 2009,[55] Australia | The study described improvements in HH compliance after a state-wide HH campaign conducted in New South Wales public hospitals. | NCBA. Multimodal education strategy with staff champions, local leaders, engaging patients and families, and performance feedback. A baseline (pre-campaign) period was followed by a run-in period and 3 post-campaign periods. The strategy followed interventions published previously | The mean numbers of HH opportunities observed for the five observation periods among 208 public health-care facilities were 7747 (range, 6972–8251). | HH compliance increased significantly from the pre-campaign rate of 47% (3795/8057) to 58% (4041/6972) at the run-in period (p < 0.001). The average compliance rate of the post-campaign periods was 61% (14 335/23 448) (p < 0.001). |
| Mc Laws et al., 2009,[56] Australia | McLaws. This study focused on MRSA infection in the context of a multimodal HH | NCBA. Multimodal education strategy with staff champions, local leaders, engaging patients and families, and performance feedback. The clinical indicators | The study was performed among 208 public health-care facilities in New South Wales in 2008 and 2009. This study focused | Between the pre- and post-campaign periods, there was a 25% fall in MRSA non-ICU sterile site infections, from 0.60/10,000 bed-days to |

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| | campaign. | included four different site categories (ICU sterile site, ICU non-sterile site, non-ICU sterile site and non-ICU non-sterile site) and were expressed as the number of new HAIs per 10,000 acute care bed-days. | on MRSA infection. | 0.45/10,000 bed-days (p=0.027), and a 16% fall in ICU non-sterile site infections, from 36.36/10,000 bed-days to 30.43/10,000 bed-days (p=0.037). The rates of the other indicators did not change significantly. However, reductions of MRSA in non-ICU sterile sites were observed also in other parts of Australia and, thus, it cannot be assumed to be the result of improved HH compliance. |
| Moongtui et al., 2000,[29] Thailand | The purpose of this study was to evaluate the effectiveness of a peer feedback programme on handwashing and glove wearing among HCWs. | CBA. The peer feedback assessment tool used followed the structure of a validated universal precautions assessment tool. Peer observers rated the occurrence or non-occurrence of appropriate handwashing and glove wearing for their co-workers during the practice of actual patient care, for one hour or until a minimum of 15 opportunities had occurred. There was a baseline phase, an intervention phase, and a post-intervention phase. | The study was conducted at a 1200-bed tertiary hospital. The intervention and control groups included 36 and 55 HCWs, respectively. | Compliance of universal precautions increased in the intervention group from baseline to intervention (49.2% vs. 82.7%; p<0.001) but decreased to a level similar to the control group in the post-intervention phase (73.2%). |
| Nicol et al., 2009,[99] Australia | The study aimed to increase understanding of infection prevention practice in the acute care setting. | Qualitative. The study used the theory of planned behaviour. The study used semi-structured interviews of HCWs. Participants were included as long as no new relevant information to the purpose of the study was gained from the interviewees. | The study was performed in a general medical and surgical ward. A total of 33 nurses and 11 physicians, and two other HCWs were interviewed. | Individual experience is of greater importance than formal education in explaining HH behaviour. This indicates that exposure to vivid experience is a potential means to improving the power of existing training methods and increasing the propensity for instilling sustainable adequate HH habits. |
| Nijssen et al., 2003,[83] The Netherlands | The study addressed the association of compliance with cohorting and HH and HCW workload. | NCC. Workload was measured by the medicus workload measurement system. | The study was done in a 16-bed medical ICU. Patients were observed for 171 hours, during which 777 HCW-patient interactions were recorded. | Nursing workload was inversely associated with adherence to HH (correlation coefficient, −0.38; p=0.02). |
| Parand et al., 2011,[37] UK | To assess the difference of perception about a quality and patient safety initiative | Cross-sectional study using questionnaires, which were analysed quantitatively. The survey addressed perceptions programme elements, success factors and impact/sustainability of the UK Safer Patients Initiative. | A total of 635 surveys at 20 trusts including 442 clinical frontline workers and 113 senior managers. | Significant differences were found between the perceptions on a wide number of issues, including the frontline perceiving a larger improvement on the timeliness of care delivery ($t$ = 2.943, $P$ = 0.004), while managers perceived larger improvement on the culture within the organisation for safe, effective and reliable care ($t$ = -2.454, $P$ = 0.014). |

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| Peredo et al., 2010,[57] Spain | The study aimed to test the effectiveness of multiple system interventions to reduce CRBSI in an ICU. | NCC. | 16-bed medical-surgical ICU in a 500-bed teaching hospital from March, 2007, to December, 2007. Total patient-days and catheter-days in the baseline and post-intervention periods were 4289 patient-days, 3572 catheter-days and 4174 patient-days and 3296 catheter-days. | CRBSI incidence densities in the baseline and the post intervention periods were 6.7/1,000 catheter-days and 2.4/1000 catheter-days (RR [95% CI], 0.36 [0.16-0.80]. |
| Petrosillo et al., 2001,[35] Italy | The study assessed hepatitis C virus (HCV) incidence rates and identified determinants of Infection among haemodialysis patients in a multicentre study conducted in Italy. | Case-control. For each incident case, three controls negative for both HCV antibodies and HCV RNA were randomly selected. | The study included 58 haemodialysis units. At enrolment, HCV sero-prevalence was 30.0%. During follow-up, 23 new HCV cases were documented, with a cumulative incidence of 9.5 cases/1000 patient-years. | Independent risk factors for new HCV-infections were an HCW/patient ratio≤28.2 (OR [95% CI]: 5.4 [1.4-19.9]) and an HCV-prevalence of ≥30% (OR [95% CI]: 4.6 [1.4-15.0]). |
| Pinto et al., 2011,[108] UK | The study aimed at understanding the<br><br>perceived factors relating to the application of four clinical<br><br>care practices targeting VAP in the context of the UK « Safer Patients Initiative". | Qualitative study. Structured interviews of the stakeholders in 3 of the 4 trusts participating in the pilot phase of the UK "Safer Patients Initiative". The interviews of 45-60 minutes were transcribed verbatim and coded by at least two researchers based on best practice in qualitative research. | A total of 17 stakeholders were interviewed. | Consistent measurement of compliance with the four elements made the staff realize that their engagement in previous improvement work for ventilated patients was inadequate and motivated them to apply the introduced clinical practices more reliably. Feedback to experts and peers was perceived as a very influential aspect of the programme. Small tests of change (Plan-Do-Study-Act cycles), teaching sessions and daily goal sheets were quoted as particularly useful tools throughout the implementation of the four clinical care practices. |
| Pittet et al., 2000,[16] Switzerland | The study tested the effectiveness of a hospital-wide multimodal HH improvement strategy. | NCBA. The study occurred before HH was promoted. The intervention relied predominantly on changing HH from handwashing to the use of ABHR provided in individual bottles for pocket carriage, a poster campaign, and the visible commitment of the hospital administration. | Between 1994 and 1997, a total of 20,082 HH opportunities were observed in 2629 observation periods. | HH compliance increased from 47.6% (95% CI, 46.8-48.5%) to 66.2% (95% CI, 65.1-67.2%) (adjusted OR [95% CI], 1.92 [1.59-2.33]). Annual MRSA bacteraemia decreased from 0.74/10,000 patient-days to 0.24/10,000 patient-days (p>0.001). |
| Pittet et al., 2004,[100] Switzerland | The aim of the study was to identify risk factors for non-adherence and to assess beliefs and perceptions associated with HH among physicians. | Cross-sectional. The study used a qualitative approach to assess perceptions and beliefs of physicians towards HH, but also applied a quantitative analysis to assess risk factors for non-compliance. Only the quantitative part is assessed in this review. Primary outcome was HH | A total of 1883 HH opportunities of 63 physicians were observed. The activity index was estimated by the number of observed opportunities for HH per hour of patient care for each physician | An activity index of >5 HH opportunities/h was associated with less HH compliance (52.0% vs. 63.3%; p=0.03). |

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| | | compliance. | observation. | |
| Pontivivo et al., 2012,[91] Australia | To test the effectiveness of a multimodal "coaching" strategy on HH | NCC. Prospective cohort study using a multimodal strategy by principles of practice development, solution-focussed coaching and models of behaviour change. | 11,247 moments of HH within one year and among 8 units. | Overall increase of HH compliance from 62% to 72% with significant improve for nurses (from 70% to 80%) and physicians (from 43% to 63%). |
| Quiros et al., 2007,[101] USA | To assess attitudes of ICU staff members towards practice guidelines in general, and the CDC HH guideline in particular. | Qualitative. Attitudes of ICU staff members were correlated with staff and hospital characteristics, and the impact of staff attitudes towards the HH guideline was assessed by self-reported implementation of the guideline. | A total of 1359 ICU professionals (74% nurses, 17% physicians, 10% other professions) from 70 ICUs in 39 hospitals were included. | Significantly more positive attitudes towards practice guidelines were identified among nurses compared to physicians (regression coefficient: 2.53; p<0.001) and paediatric ICU staff compared to staff in adult ICUs (regression coefficient: 2.66 p<0.001). |
| Render et al., 2011,[92] USA | To reduce CLABSI-rates in all VA-ICUs. | NCC. Prospective observational study. Multimodal CLABSI prevention strategy with bundle, cart, checklist, leadership engagement, appointed champions, goals sheet and feedback. | 174 ICUs in 123 hospitals. Cumulative 833,173 catheter-days over 4 years. | CLABSI-reduction of 53% (from 3.8 to 1.8/1000 catheter-days) over 4 years (p<0.001). Increase in composite adherence to practice bundle from 85% to 98% with a strong inverse correlation (R=-0.81) with CLABSI rates. |
| Robert et al, 2000,[36] USA | To determine the risk factors for acquisition of nosocomial primary bloodstream infections in a surgical ICU. | Case-control. Nurse staffing varied during the study period. the study period was divided into an eight-month period with high regular-nurse-to-patient ratio (10.6 h/patient) and lower pool-nurse-to-patient ratio (2.2 h/patient) and a five-month period with a significantly decreased regular nurse-to-patient ratio (9.1 h/patient; p<.001) and an increased pool nurse-to-patient ratio (4.4 h/patient; p<0.001). | Twenty-eight patients with BSI (case-patients) were compared to 99 randomly selected patients (controls) hospitalised ≥3 days in the same unit. The overall primary BSI rate in the SICU was 4.6 per 1000 patient-days. | The pool nurse-to-patient ratio was higher for case-patients than for controls (median, 3.2 vs 2.8 nursing hours/patient-day;<br><br>p<0.001). |
| Rosenthal et al., 2003,[58] Argentina | The aim of this study was to test the effectiveness of an education strategy and performance feedback on CLABSI. | NCBA. The study included a baseline period, a shorter period of education, and a period using performance feedback (results of audits about the care of catheter insertion sites). The training strategy is not well described but the promoted procedures are reported to follow the US HICPAC recommendations. | The study was conducted in four ICUs of two medical centres in Argentina between April, 1999, and July, 2001. | Compliance with intravascular device site care (presence of gauze on intravascular device site, good gauze condition) was improved when performance feedback was introduced: 96.5% vs. 53.0%/56.2% (RR [95% CI], 1.72 [1.40-2.10]), 89.6% vs. 48.7%/43.2% (RR [95% CI], 2.07 [1.65-2.62]). |
| Rosenthal et al., 2004,[59] Argentina | The study tested the effect of education and performance feedback on compliance with catheter care and HH and on CAUTI rates. | NCBA. The study had a short pre-intervention phase and a longer intervention period. The implementation of the training strategy is not described in detail. However, it promoted best practices in urinary catheter care included in the HICPAC recommendations. At the same time, another study targeted HH | The study was done in a single centre with two 10-bed ICUs. In total, 1779 and 5568 urinary catheter-days were accumulated in the pre-intervention and the intervention period, respectively. A total of 1160 and 4241 HH observations were | The CAUTI rate decreased from 21.3/1000 catheter-days to 12.4/1000 catheter-days (RR [95% CI]: 0.58 [0.39-0.86]). HH compliance improved from 23.1% to 65.2% (RR [95% CI], 2.82 [2.49-3.20]). |

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| | | compliance in the same ICUs. | performed. | |
| Rosenthal et al., 2005,[60] Argentina | The study tested the effectiveness of a multimodal intervention for HH improvement on the overall rate of nosocomial infections in the ICU. | NCITS. The study used a multimodal approach of HH training with practical education and based on existing guidelines (US APIC guidelines). The study was divided into four time periods, a preintervention phase of four months, followed by three intervention phases. | The study was done in a single centre with two 10-bed ICUs. Between Sept, 2000, and May, 2002, a total of 4347 HH opportunities were observed. | HH compliance improved from 23.1% to 64.5% (RR [95% CI], 2.79 [2.46-3.17]) in the intervention phases. Nosocomial infections decreased from 47.55 per 1000 patient-days (104/2187) to 27.93 per 1000 patient days (207/7409) (RR [95% CI], 0.59 [0.46-0.74]). |
| Rubinson et al., 2005,[102] USA | The study aimed to identify the conceptual basis for obstacles to the use of maximal barrier precautions and chlorhexidine gluconate among internists to establish a framework for improvement, and to define targets for intervention. | Qualitative. A survey was mailed to 1000 internists in the US who were randomly selected from the membership list of the American College of Physicians–American Society of Internal Medicine. To ensure adequate national representation, sampling was stratified by four geographic regions. The questionnaire addressed a number of questions about the speciality, and experience of the internists and then focused on perception about the use chlorhexidine gluconate and maximal sterile barrier precautions in the insertion of CVC. | Of a total of 994 correctly sent questionnaires, 526 internists replied, of which 178 had recent CVC insertion experience (last 12 months). | Despite established efficacy, use of chlorhexidine gluconate for skin antisepsis is low among internists. "Availability" was the main factor influencing the selection of specific antiseptic agents. This underscores the importance of the role of administrators in making supplies such as chlorhexidine gluconate available. The study revealed that only a minority of participants who were aware of CDC guidelines were highly adherent to the use of maximal barrier precautions, leading to the understanding that knowledge of guidelines alone is insufficient to change behaviour. |
| Saint et al., 2009,[110] Italy | The aim of the study was to test the effectiveness of a multimodal HH improvement strategy emphasizing the use of champions. | NCBA. The study used individual training workshops where nurses were trained by nurses and physicians by physicians. Champions among nurses and physicians were identified and they visibly wore a badge saying "ask me if I have washed my hands". The study also emphasized the change from handwashing to handrubbing. Only the indication "before patient contact" was assessed by direct observation of HH. | During the six-month study period, a total of 3987 HCW-patient interactions were observed, 1526 physicians and 2461 nurses. | Overall, HH increased from 31.5% to 47.4% ($p<0.001$); adherence among nurses increased from 33.7% to 47.9% ($p<0.001$); adherence among physicians increased from 27.5% to 46.6% ($p<0.001$). |
| Saint et al., 2010,[103] USA | The study aimed to understand why some hospitals were engaged in HAI prevention activities while others were not. This analysis focused on the behaviour of leaders who are successful at implementing HAI prevention practices in their hospitals. | Qualitative. From a number of hospitals replying to a questionnaire about infection control activities, telephone interviews were conducted to select hospitals for site interviews. Interviews were semi-structured and transcribed verbatim for analysis. | Telephone interviews were conducted in 2005–2006 with 38 individuals at 14 purposively selected hospitals. Based on findings, six hospitals were selected for site visits, which resulted in interviews with another 48 individuals in 2006–2007. | Successful leaders focused on cultivating a culture of clinical excellence. Successful leaders were solution -oriented. Successful leaders inspired staff. Successful leaders thought strategically, while acting locally. |
| Schwab et al., 2007,[61] | The study tested whether participation in the | NCBA. Data were collected through the NEO-KISS | Twenty-four neonatology units met the selection | Incidence densities of BSI for the 1st, 2nd, and 3rd years were |

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| Germany | German NEO-KISS surveillance system results in lower rates BSI and pneumonia. | surveillance system. Participation in NEO-KISS was voluntary and confidential. Feedback was given biannually. Neonatal units had to participate in the KISS surveillance system for at least three consecutive years to be eligible for analysis. | criteria and data were obtained for 3856 patients resulting in 152,437 patient-days during their first three years of participation. A total of 1111 BSIs (38% CVC-associated), and 151 pneumonias (56% VAP) were identified. | 8.3/1000 patient-days, 7.1/1000, and 6.4/1000 (RR [95% CI], 0.76 [0.66-0.88]. The difference between 1st and 3rd year also was significant in an adjusted multivariate analysis (OR [95% CI], 0.73 [0.60-0.89]). The incidence densities of pneumonia for the 1st, 2nd, and 3rd years were 1.2/1000 patient-days, 0.8/1000, and 0.9/1000 (RR [95% CI], 0.73 [0.49-1.07]). |
| Sherertz et al., 2000,[62] USA | The study assessed the effectiveness of simulation-based hands-on training course for physicians completing their first postgraduate year and third year medical students. | NCBA. The study assessed the perception about evidence-based practices of catheter insertion among physicians and medical students. There was prospective CRBSI surveillance based on the CDC definitions. Analysis was done by six-month periods. The study was done among six ICUs and one step-down unit in a university-affiliated tertiary, care centre. | The infection control course was given three times in June 1996 (for 110 physicians and 107 medical students) and three times in June 1997 (for 95 physicians, 94 medical students, and 46 physician assistant students). | CRBSI incidence rates decreased from 4.51 to 2.92 infections per 1000 patient-days (p<0.001). |
| Sinkowitz-Cochran et al., 2012,[38] USA | To assess the association between organisational culture and knowledge, attitudes, and barriers in MRSA control. | Cross-sectional. The study used a pre-defined questionnaire with sections of knowledge, attitudes, and detected barriers in the field of MRSA control. The answers were correlated with a section about organisational culture, stratified into staff engagement, overwhelmed/stress-chaos, and hospital leadership. | A total of 16 VA hospitals participating in a MRSA prevention initiative accumulating 2314 questionnaires from nurses (43%), physicians (9%), and other HCW (48%). | Staff engagement, overwhelmed/stress-chaos, and hospital leadership were found to be associated with individual HCW knowledge, attitudes, and self-reported practices regarding MRSA prevention. |
| Sinuff et al., 2007,[104] Canada | The study aimed to determine perceived facilitators and barriers to guideline implementation and clinical adherence to guidelines in ICUs. | Qualitative. The authors conducted semi-structured interviews of ICU professionals to elicit attitudes and perceptions regarding the facilitators and barriers to adherence to guidelines in the ICU. All interviews were transcribed in duplicate using grounded theory to identify themes and develop a model to describe clinicians' views. | Interviews with 44 ICU clinicians among three university-affiliated hospitals were performed: 12 intensivists, two physician directors, 12 nurses, three nurse educators, three nurse managers, nine respiratory therapists, and three respiratory therapist educators). | Strategies suggested to improve clinicians' adherence to guidelines include: 1) a combination of reminders and continuing education, augmented with an audit and feedback system; 2) consider characteristics of the ICU itself, interprofessional communication, and factors intrinsic to guidelines themselves; 3) use informatics to maximise accessibility; and; 4) guidelines developed by multidisciplinary teams. |
| Sladek et al., 2008,[105] Australia | The objective of the study was to describe the association between compliance with and hygiene and the thinking style of physicians. | Qualitative. HH practices of physicians were observed in teaching hospitals. HH compliance rates were correlated with self-reported thinking styles. Physicians were observed by a trained observer during a ward round or outpatient clinic and were unaware that HH was under observation. The main outcome | In total, 32 physicians in two teaching hospitals were observed. | An overall mean compliance rate of 7.6% (standard deviation +/- 7.2%) was found. Faith in intuition (correlation, 0.46; p=0.004), faith in intuition (ability) (0.37; p=0.018,), and faith in intuition (favourability) (0.46; p=0.004) were significantly associated with HH |

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| | | measures were HH compliance and thinking style using a validated tool (rational-experiential inventory). | | compliance. |
| Thomas et al., 2005,[111] USA | The aim of the study was to implement a HH programme in an academic medical centre, using visual cues developed with periodic input from hospital staff. | Mixed-methods. A mixed-methods' approach was used actively involving frontline workers in designing an intervention strategy. In focus groups, they elaborated visual cues in the form of A3 posters. | The study was performed in five units (four ICUs, one emergency unit) of an academic centre. The 1st, 2nd, and 3rd periods provided eight, 16, and 16 dispensers, respectively. | HH compliance increased from 20% to 55% by actively involving frontline workers to design their own HH improvement programme and by competition between the units. Giveaways, microbial assessment of the environment, availability of material (for infection prevention in general), and between-unit competition by surveillance and feedback were identified as incentives for HH improvement in focus groups. |
| Thomas et al., 2009,[63] USA | The study aimed to determine the effectiveness of handrub dispenser placing. | NCBA. The study was divided in three periods: 1) control period with customary locations (e.g., on walls inside and outside patient rooms and adjacent to lavatories), 2) 1st experimental period providing suspended handrub dispenser over the patient bed, and 3) 2nd experimental period placing the dispensers at customary locations, but in greater quantity. The use of the dispensers was measured by daily total weight of consumed handrub. | The study was performed in a surgical ICU of a tertiary community hospital. | Handrub consumption in the 2nd period with conspicuous placement was significantly higher compared to the baseline period (in average 294.1g vs. 188.8g; p <0.001) and compared to the 3rd period, which only increased the number of dispensers (294.1g vs. 214.8; p <0.001). Visible location of handrub dispensers is more important than only an increase in number. |
| Turnberg et al., 2009,[106] USA | The study aimed to identify HCW and work site characteristics associated with HCWs' reported use of recommended respiratory precaution measures. | Qualitative. The study used a cross-sectional design by self-administered questionnaires. Variables determining compliance with respiratory precautions were the primary outcomes and were modelled in a multivariate analysis. | A total of 273 nurse professionals and 184 medical practitioners from five medical centres were invited to complete the questionnaires. | Receiving training was significantly associated with compliance with respiratory precautions for both professionals (OR [95% CI]: 2.5 [1.1-5.9]; 5.5 [1.2-25.8]). Other significant factors among nurses included male sex (2.2 [1.0-4.9]), having children (2.2 [1.2-3.9]), an orderly work place (2.0 [1.1-3.5]), and perception of risk (2.3 [1.2-4.5]). |
| Vicca et al., 1999,[84] UK | The study aimed at determining the association of workload and staffing on MRSA transmission. | NCC. Acquisition of MRSA in the ICU of a tertiary referral centre was monitored over a 19-month period. Nurse/staff-to-patient ratios were determined as well as the staffing level, which was defined as the total number of nurses per shift minus the total dependency score for that shift. Peak and trough levels on a daily basis were determined. | During the nine-month study period, 50 new MRSA cases were identified. | There were inverse correlations of daily MRSA transmission and mean staff-to-patient ratio (Corr [95% CI], -0.150 [-0·069/-0·229]), peak staff-to-patient ratio (Corr [95% CI], -0.145 [-0.064/-0.224]), mean nurse-to-patient ratio (Corr [95% CI], -0.146 [-0.065/-0.225]), and peak staffing level (Corr [95% CI], -0.147 [-0.066/-0.226). |
| Virtanen et al., | Association of workload, | Mixed-methods. The study | The prevalence survey was | HAI prevalence was 9.1%. A |

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| 2009,[112] Finland | stress, and collaboration with HAI rates. | correlated data obtained from a prevalence survey with data obtained from patient charts and from questionnaires completed by health-care professionals. The methodology of the prevalence survey was done as described by others. The questionnaire addressed work satisfaction (staffing, work stress, effort-reward imbalance, job control) and collaboration (communication, support from superiors, collaboration between supervisors) using established scores. Correlations between risk factors mentioned in the questionnaire and HAI was done by multivariate logistic regression. | performed in a total of 60 non-psychiatric wards among six hospitals (one university-affiliated, five regional hospitals). 1092 patient and 1159 staff survey replies (of 1515 addressed to health-care professionals) were analysed. | number of factors were identified to be associated with HAI such as workload >8.45/day (OR [95% CI], 2.74 [1.04-7.04]), poor collaboration with supervisors (OR [95% CI], 2.46 [1.38-4.38], and low trust between work unit members (OR [95% CI], 2.47 [1.38-4.42]). |
| Whitby et al., 2004,[64] Australia | The study aimed to determine the effect of improved infrastructure (a new hospital design ensured that no clinical activity could occur more than 5 metres from a sink. | NCBA. The study took place in a setting of complete hospital relocation. HH observations were performed 1 month before moving and 1 and 10 months after relocation. Only before and after patient HH opportunities were observed. Observers were hired from outside the hospital and they were specifically trained for the study purposes. | Observations were done in three wards (urology, infectious diseases, internal medicine), and in the ICU. The number of HH opportunities before patient contact before relocation and one and 10 months after relocation were 2040, 2030, and 1404, respectively. The number of HH opportunities after patient contact for the three study periods were 1961, 2115, and 1312, respectively. | Increase in handwashing frequency was observed in the second study period one month after transfer to the new hospital, by 24% ($p<0.001$) in the internal medicine ward, 16% ($p<0.001$) in the ICU and 9% ($p=0.003$) in the infectious diseases' unit. No sustained effect was detected in any of the units. |
| Yinnon et al., 2012,[30] Israel | To assess the impact of a comprehensive checklist as an audit tool. | CBA. Comprehensive checklists addressing a large number of care (HH, cleaning, procedures) used upon audits in selected units. Feedback was given immediately upon auditing. | Three intervention and three control units in three hospitals. A total of 3736 items were audited within 12 months. Prevalence survey before and after the intervention. | Baseline HAI prevalence was similar in the study and control departments: 37/345 (11%) and 26/270 (10%). In the last month, the prevalence in the study department decreased to 16/383 (4%) ($P < 0.01$); in the control it decreased insignificantly to 21/248 (8%). |
| Zingg et al., 2009,[65] Switzerland | The aim of the study was to test a multimodal intervention strategy in catheter care on CRBSI. | NCBA. The training programme targeting catheter care was prepared by a multidisciplinary group of infection control professionals and frontline nurses. The teaching strategy was hands-on and bedside. Primary outcome was CRBSI. Effectiveness was assessed by Cox regression analysis adjusted for a number of patient characteristics. | A total of 395 nursing staff and 34 medical staff from five ICUs were trained by bedside teaching modules. | CRBSI rates decreased from 3.9/1000 catheter-days to 1.0/1000 (adjusted HR [95% CI]: 5.08 [2.34-11.0]). Time to CRBSI was longer in the intervention period (median 9 days vs. 6.5 days; $p=0.02$). The rate of correct performance of HH practice increased from 22.5% to 42.6% ($p=0.003$). |
| Zuschneid et al., 2007,[66] Germany | The study tested whether participation in the German ICU-KISS surveillance system results | NCBA. Data were collected through the KISS surveillance system. Hospitals had to participate in the KISS surveillance system for at least | Twenty-nine medical-surgical, 18 medical, 20 surgical, 2 neurosurgical, and 2 paediatric ICUs met the selection criteria. | A total of 2043 VAP-cases were reported. The consecutive VAP-rates were 10.5/1000 ventilator-days, 8.7/1000, and 8.0/1000, respectively. |

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| | in lower rates of VAP. | three consecutive years to be eligible for analysis. | Surveillance data were available on 181,275 patients with 613,098 patient-days and 224,138 ventilator-days. | Reductions from the 1st to the 2nd year and from the 2nd to the 3rd year were 19% (RR [95% CI]: 0.81 [0.73-0.90]) and 24% (RR [95% CI]: 0.76 [0.68-0.85]). |

**Abbreviations**

**ABHR**: alcohol-based handrub; **CABSI**: catheter-associated bloodstream infection; **CAUTI**: catheter-associated urinary tract infections; **CBA**: controlled before-after study; **CDI**: *Clostridium difficile* infection; **CI**: confidence interval; **Corr:** Correlation; **CRCT**: cluster-randomized controlled trials; **CLABSI**: central line-associated bloodstream infection/s; **CRBSI**: catheter-related bloodstream infection/s; **CVC**: central venous catheter; **ECDC**: European Centre for Disease Prevention and Control; **HAI**: HAI/s; **HAP**: hospital-associated pneumonia; **HCW**: health-care worker; **HH**: Hand hygiene; **HR**: hazards ratio; **ICP**: Infection control professional; **ICU**: intensive care unit; **IQR:** Interquartile range; **INICC:** International Nosocomial Infection Control Consortium; **IRR:** Incidence rate ratio; **ITS**: interrupted time-series analysis; **KISS**: Krankenhaus Infektions Surveillance System; **MDRO**: multidrug-resistant organism/s; **MICU**: medical intensive care unit; **MRSA**: methicillin-resistant *Staphylococcus aureus*; **NCBA**: non-controlled before-after study; **NCC**: non-controlled cohort study; **NCITS**: non-controlled interrupted time-series analysis; **NICU**: neonatal intensive care unit; **OR**: odds ratio; **PPE**: personal protective equipment; **PVC**: peripheral venous catheter; **RCT**: randomised controlled trial; **RN**: Registered Nurse; **RR:** Relative risk; **SICU**: surgical intensive care unit; **SSI**: surgical site infection/s; **UTI**: urinary tract infection/s; **VA:** Veteran affairs health system; **VAP**: ventilator-associated pneumonia; **WHO:** world health organization.

**Supplementary table 5:** Studies published in 2013 and identified by the search terms of the systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT) – The listed studies fulfilled the inclusion criteria for fulltext sift but were not quality-assessed by the "integrated quality criteria for systematic review of multiple study designs" (ICROMS) tool

| KC | First author | Countries | Clinical setting | Infection control topic |
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| 1 | None | NA | NA | NA |
| 2 | Lemaster[1] | USA | Adult ED | CLABSI |
| 3 | Lemaster[1] | USA | Adult ED | CLABSI |
| 4 | None | NA | NA | NA |
| 5 | Ceballos[2] | USA | NICU | CLABSI, VAP |
| | Fisher[3] | USA | NICU | CLABSI |
| | Jeong[4] | South Korea | Adult ICU | CLABSI |
| | Khalid[5] | Saudi Arabia | Adult ICU | CLABSI |
| | Mukerji[6] | Canada | NICU | HH |
| | Muszynski[7] | USA | PICU | VAP |
| | Scholtz[8] | USA | Hospitalwide - Children | CLABSI |
| | Sinuff[9] | Canada | Adult ICU | VAP |
| 6 | Chandonnet[10] | USA | NICU | CLABSI |
| | Cherifi[11] | Belgium | Adult ICU | HH, CLABSI |
| | Hocking[12] | New Zealand | Adult ICU | CLABSI |
| 7 | Løwer[13] | Norway | Adult surgical departments | SSI |
| | Mertens[14] | Belgium | Adult ICU | VAP, CLABSI |
| 8 | Al Tawfiq[15] | Saudi Arabia | Hospitalwide | HH |
| | Allegranzi[16] | Costa Rica, Italy, Mali, Pakistan, Saudi Arabia | Hospitalwide | HH |
| | Arora[17] | USA | Adult ICU | CAUTI |
| | Barahona[18] | Colombia | Adult ICU | HH |
| | Berenholtz[19] | USA/Puerto Rico | Adult ICU | CLABSI |
| | Bion[20] | UK | Adult ICU | CLABSI |
| | Ceballos[2] | USA | NICU | CLABSI, VAP |
| | Chen[21] | USA | Hospitalwide | HH |
| | Cherifi[11] | Belgium | Adult ICU | HH, CLABSI |
| | Clarke[22] | USA | Hospitalwide | CAUTI |
| | Crews[23] | USA | Hospitalwide - Children | HH |
| | Dos Santos[24] | Brazil | Adult ICU | HH |
| | Eom[25] | South Korea | Adult ICU | VAP |
| | Esteban[26] | Spain | PICU | CLABSI |
| | Fisher[3] | USA | NICU | CLABSI |
| | Fisher[27] | Singapore | Hospitalwide | MRSA |
| | Freixas[28] | Spain | Non-ICU | CLABSI |
| | Fuller[29] | UK | Adult ICU/Acute care | HH |
| | Guanche-Garcell[30] | Cuba | Adult ICU | VAP |
| | Hocking[12] | New Zealand | Adult ICU | CLABSI |
| | Hong[31] | USA | Adult ICU | CLABSI |
| | Huang[32] | USA | Adult ICU | MRSA |
| | Huis[33] | The Netherlands | Hospitalwide | HH |

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| | Huis[34] | The Netherlands | Hospitalwide | HH |
| | Jaggi[35] | India | Adult ICU | CLABSI |
| | Jeong[4] | South Korea | Adult ICU | CLABSI |
| | Kanj[36] | Lebanon | Adult ICU | CAUTI |
| | Khalid[5] | Saudi Arabia | Adult ICU | CLABSI |
| | Kim[37] | South Korea | Hospitalwide | HH, MRSA |
| | Krein[38] | USA | Hospitalwide | CAUTI |
| | Leblebicioglu[39] | Turkey | Adult ICU | CLABSI |
| | Leblebicioglu[40] | Turkey | Adult ICU | CAUTI |
| | Lee[41] | France, Germany, Greece, Israel, Italy, Serbia, Scotland, Spain, Switzerland | Surgical wards | HH |
| | Lim[42] | Taiwan | Adult ICU | VAP |
| | Lin[43] | USA | Adult ICU | CLABSI |
| | Liu[44] | Taiwan | Adult ICU | CLABSI |
| | Liu[45] | Taiwan | Adult ICU | VAP |
| | Marra[46] | Brazil | Adult ICU | HH |
| | Mazi[47] | Saudi Arabia | Adult ICU, NICU, Burn unit | HH |
| | Mc Mullan[48] | USA | Hospitalwide | CLABSI |
| | Mehta[49] | India | Adult ICU | VAP |
| | Mermel[50] | USA | Hospitalwide | CDI |
| | Mukerji[6] | Canada | NICU | HH |
| | Muszynski[7] | USA | PICU | VAP |
| | Navoa[51] | Philippines | Adult ICU | CAUTI |
| | Osorio[52] | Colombia | Adult ICU | VAP |
| | Palomar[53] | Spain | Adult ICU | CLABSI |
| | Reichardt[54] | Germany | Hospitalwide | HH |
| | Rello[55] | Spain | Adult ICU | VAP |
| | Rosenthal[56] | Argentina, Brazil, China, Colombia, Costa Rica, Cuba, El Salvador, Greece, India, Lebanon, Lithuania, Macedonia, Mexico, Pakistan, Panama, Peru, Philippines, Poland, Turkey | Adult ICU | HH |
| | Rosenthal[57] | El Salvador, Mexico, Philippines, Tunisia | NICU | CLABSI |
| | Saint[58] | USA | Hospitalwide | CAUTI |
| | Scholtz[8] | USA | Hospitalwide - Children | CLABSI |
| | Sinuff[9] | Canada | Adult ICU | VAP |
| | Viana[59] | Brazil | Adult ICU | VAP |
| | Walz[60] | USA | Adult ICU | CLABSI |
| | Zhou[61] | China | NICU | VAP |
| 9 | None | NA | NA | NA |
| 10 | Al Tawfiq[15] | Saudi Arabia | Hospitalwide | HH |
| | Berenholtz[19] | USA/Puerto Rico | Adult ICU | CLABSI |
| | De Bono[62] | Europe | Variable | HAI |
| | Hong[31] | USA | Adult ICU | CLABSI |
| | Huis[63] | The Netherlands | Hospitalwide | HH |
| | Lin[43] | USA | Adult ICU | CLABSI |
| | Palomar[53] | Spain | Adult ICU | CLABSI |

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|---|---|---|---|
| Talbot[64] | USA | Hospitalwide | HH |
| Teixera[65] | USA | Adult SICU | VAP |

CAUTI: Catheter-associated urinary tract infection; CDI: *Clostridium difficile* infections; CLABSI: Central line-associated bloodstream infection; HH: Hand hygiene; ICU: Intensive care unit; KC: Key component; MRSA: Methicillin-resistant *Staphylococcus aureus*; NA: Not applicable; SICU: Surgical intensive care unit; VAP: Ventilator-associated pneumonia

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