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REVIEW

Effectiveness of bundled behavioural interventions to control healthcare-associated infections: a systematic review of the literature

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Summary Attempts to address the growing problem of healthcare-associated infections (HAIs) and their impact on healthcare systems have historically relied on infection control policies that recommend good hygiene through standard and enhanced precautions (e.g. barrier precautions and patient isolation). In order for infection control strategies to be effective, however, healthcare workers' behaviour must be congruent with these policies. The purposes of this systematic review were to evaluate studies testing the effectiveness of interventions aimed at changing healthcare workers' behaviour (in reducing HAIs) and to summarize the findings of the studies with the highest quality scores. A total of 33 published studies met the inclusion criteria and were evaluated. Four of these earned a study quality score of $\geq$80%. In all four significant reductions in HAI or colonization rates were reported. Behavioural interventions used in these high quality studies included an educational programme (in four), the formation of a multi-disciplinary quality improvement team (three), compliance monitoring and feedback (two), and a mandate to sign a hand hygiene requirement statement (one). In all 33 studies, bundles of two to five interventions were employed, making it difficult to determine the effectiveness of individual interventions. The usefulness of 'care bundling' has recently been recognized and recommended by the Institute for Healthcare Improvement. Considering the multi-factorial nature of the HAI problem and the logistical and ethical difficulties of applying the randomized clinical trial approach to infection control research, it may be necessary to study interventions as sets of practices.

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Introduction

Healthcare-associated infections (HAIs) are a serious and growing problem at every level of the healthcare system. HAIs are associated with an increased attributable mortality, length of stay, and healthcare costs incurred by patients, insurers and healthcare facilities.[1] A growing proportion of HAIs are attributed to multiple-drug-resistant organisms (MDROs); for example, 60—70% of *Staphylococcus aureus* strains isolated among inpatients in many countries are resistant to meticillin and often several other first-line antibiotics.[2]

Strategies for tackling the growing problem of HAIs have historically relied on infection control policies that recommend good hygiene through standard precautions and enhanced precautions such as isolation for patients infected with an MDRO. For these interventions to be effective, provider behaviour must be uniformly congruent with the institutional policies. Additionally, there is lack of consensus among different guidelines for the recommended use of barrier precautions and isolation leading to a lack of clear standards for care, which may further increase the variability of provider behaviour in a single institution.

Our group recently conducted a systematic review of the literature evaluating the effectiveness of barrier precautions, patient isolation, and use of surveillance cultures. We noted an intriguing difference in the findings of three studies evaluating the effectiveness of glove use alone compared with glove and gown use.[3] In the two studies that found no difference in infection rates between the two groups, the glove and gown use was monitored and a compliance rate of 50—80% was reported.[4,5] In contrast, no monitoring or compliance rates were reported in another study in which a decrease in infection rates was found.[6] With high compliance, gloves alone appeared as effective as gloves and gowns. This observation raised the question as to whether the findings from studies assessing the impact of barrier precautions could be attributed to lack of efficacy (i.e. they don't work) or lack of effectiveness (i.e. they might work, but are not actually performed properly). Moreover, what is the impact of behavioural interventions to improve awareness and compliance with barrier precautions on rates of MDROs and other HAIs? Despite the publication of several recent reviews of infection control practices aimed at reducing HAIs, the impact of behavioural interventions has not been specifically summarized.[7,8] The purposes of this systematic literature review were to identify studies in which behavioural interventions to reduce HAI were evaluated, to assess the quality of these studies, to summarize the findings of the studies with the highest quality scores, and to make recommendations for future investigation.

Methods

Literature search

Databases were independently searched by two of the authors, including PubMed, Cochrane Database of Systematic Reviews, and Cochrane Central Register of Controlled Trials. The MeSH terms and key words linked with Boolean 'AND' logic included: 'nosocomial infection', 'healthcare associated infection', 'clinical practice', 'behaviour', and 'compliance', 'staff'. The search was limited to January 1, 2000 to June 1, 2006. The terms were searched in each database separately and in combination. Articles found through the database searches were then evaluated for relevance.

To be included in our final review, a paper met the following criteria: an intervention study written in English and published in a peer-reviewed journal; the outcome (dependent variable) of the study had to be HAI or colonization rates and the intervention (independent) variable had to be some form of behavioural intervention, defined as an education or quality assurance programme or monitoring and feedback of compliance with infection prevention and control practices. Specifically excluded from the review were studies in which changes in antibiotic ordering practices were used as the primary outcome.

When 'nosocomial infection' was searched in combination with either 'behaviour', 'compliance', or 'clinical practice' 375 articles were found. When 'healthcare associated infection' was searched in combination with either 'staff' or 'clinical practice' 142 articles were found. Out of the total 517 articles found 36 were determined to be relevant and 33 fit the inclusion criteria. (See Appendix 1 for a complete list of studies reviewed.)

Assessing study quality

A quality assessment tool was adapted from a previously published review and was used to assess five domains of study quality: representativeness, bias and confounding, description of intervention, outcome assessment and statistical analysis.[9,10] Papers were evaluated for several forms of bias including

performance bias, selection bias, detection bias, attrition bias and investigator bias.[11] Papers were scored in each of the five quality domains and a final total score was calculated as a percentage of possible applicable points. Assessments of quality within each domain were scored as completely adequate, partially adequate, inadequate or not specified, and not applicable.[3] Each paper was independently evaluated by two reviewers: one content expert and one non-content expert, as recommended by the Cochrane Handbook.[12] Reviewers compared their assessments and inter-rater variability was resolved through discussion and consensus.

Results

Study characteristics

Of the 33 published studies (Appendix 1) that met the inclusion criteria, 51.5% ($N = 17$) were from North America and the others were from Europe ($N = 7$), South America ($N = 5$) and the Middle East or Asia ($N = 4$). The majority (90.9%) of studies were non-randomized intervention trials comparing pre- with post-intervention outcomes; three studies compared outcomes from different units in a single hospital. Most (81.8%) tested multiple interventions in acute care/intensive care unit (ICU) settings. In 48.5% of the studies two or three interventions were tested and in 33.3% of the studies four or five interventions were employed.

A variety of behavioural interventions were tested. The majority were educational interventions (84.8%) and half included the formation of a quality assurance team (often multi-disciplinary) aimed at reducing infection rates by influencing healthcare worker behaviour. Other frequently used interventions included compliance monitoring (21.2%), staff performance and/or compliance feedback (39.4%) and staff skills development and testing (36.4%). A vast majority of the studies (90.9%) reported either overall HAI rates or specific healthcare-associated MDRO infection rates as the primary outcome. Characteristics of studies are summarized in Table I.

Table I Characteristics of studies testing the effectiveness of behavioural interventions to prevent healthcare-associated infections (HAIs) ($N = 33$)

Characteristics	No. (%)
Location:	
USA	17 (51.5)
South America	5 (15.2)
Europe	7 (21.2)
Middle East/Asia	4 (12.1)
Design:	
Randomized clinical trial	0
Non-randomized intervention (pre—post comparison)	30 (90.9)
Non-randomized intervention (different unit comparison)	3 (9.1)
Setting:	
Acute care (general units)	4 (12.1)
ICU only	20 (60.6)
Entire hospital	9 (27.3)
No. of interventions:	
Single	6 (18.2)
Multiple	27 (81.8)
2—3 interventions	16 (48.5)
4—5 interventions	11 (33.3)
Type of intervention:	
Educational intervention	28 (84.8)
Compliance monitoring	7 (21.2)
Staff feedback	13 (39.4)
Staff testing or skills development	12 (36.4)
Introduction of a new product	5 (15.2)
Process control, quality assurance team	19 (57.6)
Computer prompts	4 (12.1)
Financial incentives	1 (3)
Leadership education	1 (3)
(ex. cohorting, change in contact precautions)	6 (18.2)
Outcomes assessed:	
Healthcare-associated infection rate:	
Bloodstream infections	8 (24.2)
Ventilator-associated pneumonia	3 (9)
Single organism infection (across body sites)	1 (3)
Multiple-drug-resistant organism	30 (90.9)
Overall HAI rate	30 (90.9)
Other outcome (ex. colonization rate, compliance with care, volume of new product used)	5 (15.2)

ICU, intensive care unit.

Evaluation of study quality

There were a number of design deficiencies in a majority of the studies reviewed, including a lack of: (a) full description of study population, setting, and interventions; (b) attention to changes in study population or setting over time; (c) a clearly defined and consistent outcome assessment procedure; and (d) proper description and use of statistical methods. Of the 33 studies evaluated, four (12.1%) earned quality scores of $\geq$80% or higher (Table II). All four used non-randomized pre—post test designs testing multiple interventions in an ICU. Two studies were conducted in the USA,[13,14] one in Russia,[15] and one in Mexico.[16] In all four

Table II Studies with quality scores ≥80% testing the effectiveness of behavioural interventions to prevent healthcare-associated infections (HAIs) ($N = 4$)

Study	Setting and study population	Design	Intervention(s)	Major findings
Brown *et al.* (2003)[15]	Four 6-bed units in a neonatal intensive care ward in Russia	Non-randomized intervention (pre—post comparison)	Three time periods (average 60 days each). First period: baseline. Second period: addition of ethanol-based hand antiseptic and a single mandatory education session. Third period: formation of a multi-disciplinary quality improvement team, individual hand hygiene (HH) staff instruction, feedback on HH compliance, and staff mandated to sign HH requirement statement	No significant change in hand hygiene (HH) compliance (period 1 vs 3 of study) before direct or invasive contact with patients. Significant increase in the use of alcohol antiseptic use (period 1 to 2, $P = 0.001$; period 2 to 3; $P < 0.00001$). Incidence of colonization with *Klebsiella pneumoniae* markedly reduced
Coopersmith *et al.* (2002)[13]	Eighteen-bed surgical/burn/ trauma intensive care unit in an urban US teaching hospital	Non-randomized intervention (pre—post comparison)	Formation of a multi-disciplinary quality improvement team, design of an educational module based on observed staff practices, focus of education on a self-study module, and a 20-question exam taken before and after self-study module	A significant reduction in primary bloodstream infections (66% reduction, $P < 0.0001$)
Coopersmith *et al.* (2004)[14]	Surgical intensive care unit in an urban US teaching hospital	Non-randomized intervention (pre—post comparison)	Formation of a multi-disciplinary quality improvement team, development of an auditing tool based on observed staff practices, education programme including lectures and hands-on demonstrations	Decreased rate of Catheter-related-bloodstream-infection (CRBSI) (3.4—2.8/ 1000 catheter days; $P = 0.40$). Mixed compliance findings: significant decreases in documenting dressing dates and stop-cock use (10 and 46% increases respectively; $P = 0.001$), non-significant trends in HH and barrier precaution use
Higuera *et al.* (2005)[16]	Two level III adult intensive care units in public university hospital in Mexico	Non-randomized intervention (pre—post comparison)	Education programme and performance feedback in the form of monthly charts of compliance with HH and invasive device care	Significant increase in compliance with HH and device care (99.24 vs 86.69%; $P < 0.0001$). Significant decrease in IVD BSIs (19.5 vs 46.3/1000 IVD days; $P = 0.0001$)

studies an educational intervention was implemented, in three studies multi-disciplinary quality improvement teams were also formed,[13–15] two included staff performance feedback,[14,15] and one also included the addition of ethanol-based hand antiseptic and individual skills development.[15]

In the four studies that received the highest quality scores, significant reductions in HAI or colonization rates were reported. One study demonstrated a reduction in the incidence of *Klebsiella pneumoniae* colonization while the other three reported significant reductions in bloodstream infection rates.[13,14–16] Changes in healthcare workers' compliance rates varied, however; and in one of the four studies there was no report of compliance monitoring.[13] One of the other three reported a significant increase in compliance with infection control practices (hand hygiene and proper intravascular device care), but the two others reported mixed findings.[16] Coopersmith reported significant decreases in documentation of dressing dates and stop-cock use (10 and 46% increases respectively; $P = 0.001$) and non-significant trends in hand hygiene and barrier precaution use.[14] Brown *et al.* found no significant change in hand hygiene compliance before direct patient contact or contact involving an invasive procedure; however, they did report significant increases in the use of alcohol antiseptic use over time ($P < 0.001$).[15]

Discussion

Assessing 'care bundles'

The Institute for Healthcare Improvement (IHI) and other groups have moved in the direction of recommending the use of 'care bundles' defined as, 'the bundling together of several scientifically grounded elements essential to improving clinical outcome', to reduce rates of HAI (http://www.ihi.org/IHI/Topics/CriticalCare/IntensiveCare/ImprovementStories/BundleUpforSafety.htm). These care bundles include three to five practices considered as a cohesive unit. Each component of the care bundle should be well defined and based on strong evidence from at least one systematic review of multiple well-designed randomized controlled trials or from at least one properly designed randomized controlled trial.[17] The concept is that considering the multi-factorial nature of disease transmission, several effective practices should be used in combination in order to have a greater impact on rates of HAI compared to their use individually.

The 'care bundling' concept is reflected in many of the studies included in this review; an important difference, however, is the frequent lack of strong evidence of efficacy for each component of the bundle. In company with many infection control studies, each of the 33 studies included in this review tested bundles of two to five interventions.[7,8,11,18,19] A majority of these (22, 66.7%) introduced all of the interventions at once and compared outcome measurements pre- and post-intervention. Although the use of several interventions is a logical approach to the multi-factorial problem of disease transmission, a recurrent problem with this approach is the inability to evaluate the independent effects of any single intervention. In eight (24.2%) studies, investigators attempted to minimize this limitation by introducing interventions in series and measuring outcomes between each intervention. The idea of these studies is to keep layering interventions until a significant change in the outcome is observed; the 'effect' is then attributed to the last intervention introduced or to the cumulative effect of the combined interventions. Hence, the interdependent and independent effectiveness of various individual behavioural strategies remains unclear in such studies but the 'set of interventions' is assessed as a whole. Although this approach sheds more light on the effectiveness of single interventions, the sequential layering of interventions is vulnerable to confounding by environmental changes related to the passage of time (as in any pre–post test design).

In light of the unavoidable design limitations of many clinical trials to test behavioural interventions, a significant shift in perspective may be necessary when evaluating study outcomes. Clinical trials have historically been viewed from the perspective of traditional empiricism in which a single intervention is tested while keeping all other variables constant. While the traditional view of causality dictates that a single cause leads to a single effect, it may be appropriate to modify our definition of what constitutes a 'single cause'. The multi-factorial nature of interventions to prevent HAI implies that our definition of a 'single cause' be expanded to include a 'set of interventions', and the priority of researchers should then focus on identifying the most effective 'set of practices' composed of the fewest interventions financially and practically feasible to the greatest number of healthcare settings.

This trend toward the testing of sets of interventions in a single clinical trial has advantages and disadvantages. Studies that fail to characterize the independent effectiveness of any single

intervention may be difficult to interpret, and this contributes towards the confusion and lack of consensus across infection control guidelines and towards inconsistent practice standards. As a result, despite the financial and logistical investment required to implement behavioural interventions, healthcare institutions are left to make decisions regarding their own infection control policies in the absence of scientific consensus. Healthcare institutions have a responsibility to do all they can to prevent HAI and employ multiple care practices to do so. Intervention studies to reduce infections often employ quasi-experimental pre—post intervention designs because it is impractical or impossible to randomize patients to different strategies. Hence, it may be overly pedantic and logistically and/or ethically prohibitive to require that such clinical studies adhere to the same level of evidence as might be possible under more controlled circumstances.

If the infection prevention community is to identify successful 'sets of interventions', they must be studied in consistent, standardized ways. Unfortunately, the studies in this review used multiple and varied behavioural strategies. The education interventions, for example, included self-study modules, individual instruction, and lectures with hands-on demonstrations, all delivered in various ways and/or inadequately described so as to make them impossible to replicate in another setting. On the other hand, there were some shared characteristics of the multi-disciplinary teams that could be evaluated. The team members were usually interdisciplinary and included healthcare professionals from the institution in which the study took place; they had a baseline observation and data collection period to determine the infection control deficiencies, risks and needs, and they were instrumental in carrying out the interventions. These standard characteristics likely contributed to the success of the strategy.

Improving the evidence

The research community has much to learn from the 'care bundling' concept that can be applied to intervention studies designed to reduce rates of HAI. Considering the multi-factorial nature of the problem, it is likely that any effective solution will employ multiple care practices.[20] In light of this and the practical limitations of behavioural studies to reduce HAI, two goals adapted from the care bundling concept are advisable for future HAI prevention studies: (i) making concerted efforts to improve the conduct and presentation of quasi-experimental studies rather than primarily pre—post test designs in single institutions, and (ii) assuring that each set of interventions (i.e. care bundle) be evaluated as a cohesive unit using standardized, reproducible methods.

There are still many ways in which the quality of the design and reporting of quasi-experimental studies could be improved. Harris *et al*. noted that authors should: (a) justify why randomization was not used, (b) choose better quasi-experimental designs, such as including a control and performing more measurements pre- and post-intervention, and (c) clearly state the caveats of the quasi-experimental design so that conclusions are reached with appropriate caution.[21] Finally, each set of interventions employed in a well-designed study can be evaluated and considered as a cohesive unit.

Based on this literature review, we conclude that educational programmes and multi-disciplinary teams may be effective strategies to reduce rates of HAI. Future studies of such behavioural interventions must report rates of actual adherence to the practices if results are to be informative and move the field forward. We recommend that studies of sets of practices or interventions be conducted with sufficient rigor and standardization to strengthen their validity and to allow for replication by others.

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