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Implementation of MRSA Infection Prevention and Control Measures – What Works in Practice?

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1. Introduction

There have been increasing numbers of media reports about careless behaviour by healthcare workers, mainly involving insufficient cleaning practices and the absence of hand hygiene measures (Boyce, 2009). Although adherence to infection prevention and control measures has received a lot of attention in the media and in scientific literature, surprisingly little attention has been given to the implementation of the infection prevention and control strategies in healthcare practices. In the medical literature the focus is on the availability of national or regional MRSA surveillance data and guidelines for prevention and control. To date hardly any data has been made available about the kinds of interventions that have been successful in implementing infection prevention and control.

Research has shown that an intensive infection prevention programme could prevent about one-quarter to one-third of all hospital infections (Sengers et al., 2000). An example of such a successful policy is the 'search-and-destroy' strategy that has been introduced in the Netherlands, to prevent the spread and outbreak of infections caused by multi-resistant bacteria such as Methicillin Resistant Staphylococcus Aureus (MRSA). However, adherence to this policy still remains a problem. It is known from prior research (van Gemert et al., 2005; Verhoeven et al., 2009) that healthcare workers are insufficiently aware of infection control measures; they do not understand the rationale behind these measures and think that infection control is not their problem, that it is mainly an issue for hygiene experts.

Research in the social sciences has shown that improving safety in hospitals requires a tailored strategy to persuade people to change their attitudes and behaviours (Fogg, 2003). Furthermore, changing routines and habits in healthcare is not easy: it requires an integral approach, with activities addressing human behaviour, culture, incentives and other managerial reinforcement activities, and of course adequate information about safety regulations (Foy et al., 2001; Van Gemert et al., 2005; Verhoeven et al., 2009). A multifaceted implementation strategy might be a solution (Foy et al., 2001, Pittet et al.,

2000). Such a strategy should include interventions aimed at different levels: the management of healthcare institutions, the behaviour of healthcare workers and the quality of the infection control guidelines. However, what empirical evidence exists for a multi-faceted implementation strategy? And how successful are these strategies? To investigate this, we conducted a systematic literature review. This review will be used to develop an implementation strategy that fits the habits and culture of hospital-based healthcare workers (HCWs) in hospital care settings. In this review, we searched for empirical studies to investigate and identify effective implementation strategies for improving adherence to MRSA prevention and control measures. The following questions guided our review of the literature:

- What implementation strategies are used?
  - What is the foundation of these strategies (theories, experience, etc.)?
- What research designs were used to measure the effects of the implementation strategies?
- What effects are reported?
  - On adherence to the measures?
  - On the reduction of costs?
  - On the reduction of MRSA?

2. Method of the systematic review

The York protocol for systematic reviews (Centre for Reviews and Dissemination, 2001) was used to guide the review process. Literature searches were carried out in the online databases Scopus, ISI Web of Knowledge and the Cochrane Library. In addition, we hand-searched the indexes of the *Journal of Hospital Infection* (JHI), the *American Journal of Infection Control* (AJIC) and *Clinical Microbiology and Infection* (CMI) for relevant publications. We searched for studies describing the implementation of MRSA prevention or control measures. The publications were included in the review if they met the inclusion criteria listed in Table 1. Most important was that the publications described an implementation strategy and implementation outcomes. Two independent reviewers (NdJ, JW) applied the inclusion criteria to the publications in a title screening round, followed by an abstract and a full-text screening round. After each round, the reviewers compared their judgments and resolved discrepancies through discussion. The included studies are summarized in a data table, and the study features and results are summarized and compared. Due to the heterogeneity of the data and the limited number of included studies, no meta-analysis was performed.

3. Results of the systematic review

3.1 Article screening

The search strategy resulted in 661 potentially relevant publications (after duplicates were removed). The screening process and outcomes are shown in Figure 1; 29 publications were included in the review. The characteristics of these publications are summarized in Table 2. The characteristics and outcomes of the included studies are discussed in the following sections. The numbers we cite correspond to the publications summarized in Table 2.

Inclusion Criteria	
Publication Type	(Scientific) Journal article, published between 2005-2010
Scope of Studies	Implementation of an evidence-based MRSA prevention or control measure. The implementation strategy must be described.
Study Settings	Primary-/secondary-care facilities, long-term care facilities, nursing homes
Outcome measure	Implementation outcomes (mostly behavioural) must be given. • Behavioural (e.g. adherence to implemented measure, knowledge) • Clinical (e.g. prevalence rates, infection rates, deaths) • Organizational (e.g. changes in Length of Stay (LoS), expenditures, costs)

Table 1. Inclusion Criteria

Fig. 1. Results of the screening process

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
1: Baldwin, et al., 2010, Ireland	Educational meetings Local opinion leaders Audit and feedback Technology supported <i>Implementation foundation</i> Theoretical: absence of IC research in nursing home setting <i>Infection control measure</i> Hand hygiene Environmental hygiene Personal protective equipment <i>Design</i> RCT	Behavioural <i>In-person observations</i> Mean audit score was higher in the intervention than in the control at 12 months. Clinical MRSA positive screenings were similar in intervention and control at 12 months. MRSA prevalence rates among staff were similar in intervention at 12 months and 12 months.
2: Bassetti, et al., 2009, Italy	Audit and feedback AB permission Formulary restrictions Clinical multidisciplinary teams <i>Infection control measure</i> Medication <i>Design</i> Time series design	Behavioural Significant reduction in cephalosporins use. Significant increase in ciprofoxacin use. Clinical Significant reduction in MRSA due to intervention. An increase in susceptibility to piperacillin/ tazobactam observed in P. aeruginosa isolates ceased after the change in antibiotic use. Increase in susceptibility to ciprofloxacin in K. pneumoniae isolates, although an abrupt change in the percentage of susceptible isolates was observed after intervention. Decrease in susceptibility to piperacillin/tazobactam and imipenem observed, as well as an increase in susceptibility to ciprofloxacin in P. aeruginosa isolates during the surveillance period, with no significant changes due to intervention.
3: Burkitt, et al., 2010, United States	Educational meetings Reminders Mass media Technology-supported <i>Implementation foundation</i> Theoretical: lack of measurement of actual changes in knowledge due to education <i>Infection control measure</i> Hand hygiene Personal protective equipment Patient screening Patient isolation <i>Design</i> Before and after design	Behavioural <i>Questionnaires</i> Significant increase in proportion of respondents who reported using soap and water to clean their hands. Significant increase in mean number of knowledge questions correct. Significant increase in proportion of respondents who agreed that hand hygiene was a problem in their unit. Significant increase in proportion of respondents who reported using proper hand hygiene and contact precautions. Significant decrease in job satisfaction. Significant increase in proportion of respondents reporting using prevention practices. Significant increase in proportion of respondents reporting a decrease in hand hygiene, primarily because they feared that hand rubs or soap would dry their hands or they forgot to perform hand hygiene.

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
4: Camins & Fraser, 2005, United States	Distribution of educational materials	Behavioural <i>Observations in person</i> Hand hygiene compliance increased from 1st to 4th quarter of study (baseline observed compliance not given).
	Educational meetings	
	Local opinion leaders	
	Audit and feedback	
	Reminders	
	Rewards	
	<i>Implementation foundation</i>	
	Theoretical: CDC Hand Hygiene Task Force recommendations	
	<i>Infection control measure</i>	
	Hand hygiene	
5: Carboneau, et al., 2010, United States	<i>Design</i>	Behavioural <i>Observations in person</i> Hand hygiene compliance increased from 17-months pre-intervention to 17-months post-intervention. Clinical Decrease in MRSA-positive cases from 17 months pre-intervention to 17 months post-intervention, with a decrease in invasive MRSA cases. Financial Net dollar savings due to MRSA infection prevention of US \$1,000,000 (from 2006 to September 30, 2007) 41 MRSA infections were prevented during study period, the equivalent of a savings of \$354,276, a net hard-dollar savings of \$276,500 (after accounting for increased hand sanitizer costs of \$40,000 per year).
	Before and after design	
	Distribution of educational materials	
	Educational meetings	
	Local opinion leaders	
	Audit and feedback	
	Reminders	
	Mass media	
	Changes in physical structure, facilities and equipment	
	Technology-supported	
6: Cheng et al., 2009, China	<i>Implementation foundation</i>	Behavioural <i>Observations in person</i> Increased hand hygiene adherence. Increased use of alcohol-based hand rub. Clinical Decreased MRSA infection rates Change in ICU onset MRSA infections between phase 1 and phase 2 (hand hygiene campaign) and phase 3 (hand hygiene campaign).
	Theoretical: prior research solutions, including scientific articles and at other hospital	
	<i>Infection control measure</i>	
	Hand hygiene	
	<i>Design</i>	
	Before and after design	
	Educational meetings	
	Educational outreach	
	Audit and feedback (trained auditors)	
	Reminders	
7: Cheng et al., 2009, China	Mass media	Behavioural <i>Observations in person</i> Increased hand hygiene adherence. Increased use of alcohol-based hand rub. Clinical Decreased MRSA infection rates Change in ICU onset MRSA infections between phase 1 and phase 2 (hand hygiene campaign) and phase 3 (hand hygiene campaign).
	Clinical multidisciplinary teams	
	Changes in physical structure, facilities and equipment	
	<i>Infection control measure</i>	
	Hand hygiene	
	Patient isolation	
	<i>Design</i>	
	Before and after design	
	Time series design	

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
7: Davis, 2010, United Kingdom	Reminders Mass media <i>Duration</i> 6 months <i>Infection control measure</i> Hand hygiene <i>Design</i> Before and after design	Behavioural <i>Video observations</i> Significant increase in hand hygiene compliance of HCWs but no significant increase for patients. Clinical Decrease in MRSA incidence (from 2 to 0 cases during 6-month period). MRSA incidence (from 0 to 2 cases during 6-month periods).
	Educational meetings Educational outreach Audit and feedback Reminders Mass media Changes in physical structure, facilities and equipment <i>Implementation foundation</i> Empirical: existing programme to limit the spread of MRSA was not effective <i>Infection control measure</i> Hand hygiene Patient screening <i>Design</i> Before and after design Time series design	Behavioural Increase in use of waterless alcohol-based hand disinfectants. In 2004, the use of alcohol-based hand disinfectants was twice as high as in 2003. <i>Questionnaire</i> 46% of 450 employees declared they had attended at least one educational meeting. Number of patients screened on admission or after intra-hospital transfer. Clinical Decrease in the incidence of newly acquired MRSA infection. Decrease in the incidence of risk of acquisition. Decrease in proportion of acquired MRSA. Number of MRSA carriage on admission did not increase. Proportion of MRSA/total S. aureus within the first 48 hours of admission.
9: Fowler, et al., 2010, England	Audit and feedback Reminders <i>Implementation foundation</i> Theoretical: systematic reviews on improving AB prescribing and feedback <i>Infection control measure</i> Medication <i>Design</i> Time series design	Behavioural Significant decrease in targeted ABs: Cephalosporins and Amoxicillin. Significant increase in the long-term trend of benzyl penicillin. Significant increase in level of amoxicillin. Non-significant change in trend (not reversed long-term). Non-significant change in level and trend of trimethoprim. Clinical Significant decrease in CDI (clostridium difficile infection) and mortality. Non-significant change in MRSA infections. Non-significant change in crude mortality. Financial No change in length of stay throughout study.

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
10: Gagné, et al., 2010, Canada	Distribution of educational materials Educational outreach Patient-mediated interventions Mass media <i>Implementation foundation</i> Empirical: own observation that MRSA kept spreading despite staff decontamination <i>Infection control measure</i> Hand hygiene <i>Design</i> Before and after design	Behavioural <i>Observations in person</i> Increase in overall staff hand hygiene compliance. Clinical Decrease in MRSA infections vs. positive screenings. Decrease in MRSA infections. Financial Based on comparative year, 51 cases of infection were prevented, resulting in savings of CAN\$688,843.
11: Gillespie, et al., 2007 Australia	Audit and feedback Reminders Mass media Changes in physical structure, facilities and equipment <i>Infection control measure</i> Hand hygiene Patient screening <i>Design</i> Before and after design	Behavioural Exact compliance rate unclear, but all staff/family entering ward achieved compliance; compliance is assumed to be close to 100%. Clinical MRSA acquisition rate decreased. Resistance increased, due to a clonal outbreak of rifampicin-resistant MRSA.
12: Goodman, et al., 2008, United States	Educational meetings Audit and feedback Changes in physical structure, facilities and equipment <i>Implementation foundation</i> Other: development of a novel and nontoxic tracking marker that is visible only under UV lamp <i>Infection control measure</i> Environmental hygiene <i>Design</i> Before and after design	Behavioural <i>Observations in person</i> Mark removal was more frequent during the intervention period. Additional predictors of mark removal included type of ICU and patient acuity. No difference in the effect of the intervention between surgical and medical ICUs. Clinical Type of ICU was predictive of positive surface-culture results. Multivariate models showed significant intervention effect, with 10% reduction in VRE contamination when cultures were used as the unit of analysis. No direct association between the removal of the mark from the surface culture would yield MRSA or vancomycin-resistant strains. Multivariate models assessing the proportion of marks removed showed that for every 10% increase in the proportion of positive cultures for every 10% increase in the proportion of

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
13: Grayson, et al., 2008, Australia	Distribution of educational materials Educational meetings Audit and feedback Mass media Technology-supported <i>Implementation foundation</i> Empirical: prior success of a single-site HHCCP <i>Infection control measure</i> Hand hygiene <i>Design</i> Before and after design Time series design	Behavioural <i>Observations in person</i> Pilot programme: significant increase in hand hygiene compliance; other sites showed some transient declines in compliance (related to the pilot programme). Pilot programme: alcohol-based hand rubs (ABHRS) increased hand hygiene compliance. <i>Observations in person</i> State-wide: significant increase in hand hygiene compliance. <i>Material use</i> State-wide: ABHRS increased, but correlated only roughly with hand hygiene compliance. Clinical Pilot group: significant decrease of patients with MRSA bacteremia and number of clinical MRSA cases. State-wide: decrease in patients with MRSA bacteremia. Significant decrease in the number of clinical MRSA isolates, HHCCP.
14: Harrington, et al., 2007, Australia	Educational meetings Audit and feedback <i>Duration</i> 24 months <i>Infection control measure</i> Hand hygiene Other (sign put up in case of MRSA) <i>Design</i> Time series design	Behavioural <i>Observations in person</i> Overall rate of usage of the standard of all products increased. Clinical New patients with MRSA in the ICU decreased. Hospital-wide rate of new patients with MRSA decreased. MRSA central line-associated bloodstream infection (CLABSI) decreased. Decrease in hospital-wide rate of episodes of MRSA bacteremia.
15: Holder & Zellinger, 2009, United States	Educational meetings Educational outreach Local opinion leaders Audit and feedback <i>Duration</i> 2 months <i>Infection control measure</i> Medication (chlorhexidine baths) <i>Design</i> Time series design	Behavioural <i>Patient documentation</i> Compliance with bathing procedure increased. Clinical Bloodstream infection (BSI) rates decreased after implementation of procedure. Rate of MRSA/VRE colonization decreased after implementation of procedure. Financial 75% reduction in BSIs over 6 months and increased costs per patient day of \$1.56 million per year if chlorhexidine baths were used in all patients.

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
16: Huang, et al., 2006, United States	Educational meetings Audit and feedback Reminders Rewards Changes in physical structure, facilities and equipment <i>Duration</i> Sterile CVC placement: 10 months. Alcohol-based hand rubs: 1 month. Hand hygiene campaign: 14 months. Routine surveillance: 12 months <i>Infection control measure</i> Hand hygiene Personal protective equipment Patient screening Patient isolation <i>Design</i> Before and after design Time series design	Behavioural <i>Observations in person</i> ABHR institution and hand hygiene campaign increased compliance and decreased thereafter. <i>Lab statistics (PD)</i> Routine MRSA surveillance caused increase in compliance at ABHR for admission and weekly nares cultures. Clinical Campaign to promote sterile CVC precautions caused substantial decrease in associated bacteremia in ICUs. Among the interventions, only routine ICU MRSA surveillance was associated with decrease in the incidence density of MRSA bacteremia. After 16 months, routine screening was associated with a decrease in incidence density in ICUs, in non-ICUs, and hospital-wide. Routine screening was associated with a decrease in hospital-acquired MRSA in non-ICUs, and hospital-wide. All findings were statistically significant. Routine surveillance caused significant reduction in MRSA colonization in the first and last halves of the intervention period, exclusive of the baseline period. Stable MRSA importation rate into ICUs. No significant secular trend and no impact of any infection control intervention on methicillin-susceptible S. aureus (MSSA) bacteremia.
17: Johnson, et al., 2005, Australia	Distribution of educational materials Audit and feedback Reminders Mass media Technology-supported <i>Implementation foundation</i> Theoretical: scientific articles <i>Duration</i> 36 months <i>Infection control measure</i> Hand hygiene Environmental hygiene Patient screening HCW screening Environmental screening <i>Design</i> Time series design	Behavioural <i>Observations in person</i> Overall hand hygiene compliance improved at 4 months, and remained high at 36 months. In individual sentinel areas, compliance rates improved significantly at 4 months post-intervention in all areas. Use of ABHRS products increased in all sentinel areas. Clinical MRSA colonization rates did not change in any of the sentinel areas. Worker MRSA colonization did not decrease in sentinel areas. Environmental contamination did not change significantly during the intervention. Significant decline in total clinical MRSA infections per 100 patient days. For patient episodes of MRSA bacteremia, the monthly rate of incidence during the pre-intervention period was static, but fell significantly in the post-intervention period. The monthly rate of MRSA bacteremia had decreased. Total clinical isolates per month of ESBLs increased during the intervention period, but had fallen by more than 90% by the 36th month of OCS.

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
18: Kho, et al., 2008, United States	Reminders Technology-supported <i>Implementation foundation</i> Theoretical: low compliance (delay) associated with manual/paper-based information systems; computerized reminders appear promising <i>Duration</i> 12 months <i>Infection control measure</i> Patient isolation <i>Design</i> Before and after design	Behavioural <i>Computer logs</i> Significant increase in proportion of correct contact isolation orders Mean time between ward arrival and isolation order decreased Acceptance of the reminder increased. <i>Questionnaire</i> 19/20 survey respondents reported that the reminder either helped or saved them time. 25/27 agreed with automatic contact isolation, and half of the respondents performed surveillance swabs. Clinical <i>Lab statistics</i> During the intervention period, the number of patients with MRSA reflected an increased ability of the IC service to both identify and treat trend of MRSA/VRE increased during the study (no significant difference in intervention Financial Annual isolation gown expenditures increased 23% from the \$167,000 to \$205,000). No calculations of cost savings in prevented nosocomial infections.
	Educational meetings Audit and feedback Reminders Mass media <i>Duration</i> 12 months <i>Infection control measure</i> Hand hygiene Patient screening: Active Surveillance Testing (AST) Patient isolation <i>Design</i> Before and after design	Behavioural Between groups: compliance in performing all study-related surveillance was higher in Surgical ICU (SICU), but the difference between the ICUs was not significant. Clinical AST detected MRSA in at least 137 of the 653 patients (21.0%). Patients who were positive in only 12 patients (1.8%). No significant overall improvement in detection rate when including MICU. No improvement in detection rate in patients admitted to Medical ICU (MICU). Inclusion of axilla and groin sites did not affect the MRSA detection rate at discharge, both overall and when the ICUs were analysed individually. Between groups: the rate of MRSA colonization detected by AST at discharge was higher in SICU than MICU. No significant difference in MRSA infection rate pre- and post-intervention when analysed individually. Less variability in MRSA rates post-intervention; the 95% CI around the mean was narrower than at pre-intervention. Septic shock at ICU admission was more common in MRSA-colonized patients. Financial Detection of MRSA at any point was associated with longer pre-operative antibiotic therapy, and longer ICU length of stay.

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
20: Lederer, et al., 2009, United States	Distribution of educational materials Audit and feedback Reminders Mass media Clinical multidisciplinary teams <i>Implementation foundation</i> Theoretical and empirical: CDC recommendations and observed low compliance <i>Duration</i> 10 months <i>Infection control measure</i> Hand hygiene <i>Design</i> Before and after design Time series design	Behavioural Increased hand hygiene compliance with sustained rates greater than baseline Clinical MRSA healthcare-associated rate decreased, representing a 50% decrease in compliance.
21: Lee, et al., 2009, Canada	Educational meetings Technology-supported <i>Implementation foundation</i> Empirical: SARS outbreak in Toronto in 2003, the Ontario Ministry of Labour mandated an IC education programme for all Mount Sinai Hospital staff <i>Duration</i> 1 month <i>Infection control measure</i> Hand hygiene Personal protective equipment <i>Design</i> Before and after design	Behavioural Non-significant increase in hand hygiene compliance on inpatient ward Annual volume of ABHRS purchased by the hospital. Clinical Significant decrease in nosocomial MRSA acquisition rate per 1000 patient days Significant decrease in nosocomial MRSA acquisition rate per 1000 patient days
22: Liebowitz & Blunt, 2008, United Kingdom	Educational meetings Audit and feedback Clinical multidisciplinary teams <i>Implementation foundation</i> Theoretical: prior research, no studies have been published in which the use of both classes of antibiotics has been discouraged. No foundation for content educational activity. <i>Duration</i> 2 months <i>Infection control measure</i> Medication <i>Design</i> Time series design	Behavioural Hospital-wide decrease in level of dispensing of intervention antibiotics ICU-specific decrease in level of dispensing of intervention antibiotics Clinical Decrease in level of MRSA-positive screenings (no statistical significance) MRSA colonization in screening specimens from high-risk patients Decrease in level of MRSA-positive screenings (no statistical significance)

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
23: Madaras-Kelly, et al., 2006, United States	Reminders Technology-supported <i>Implementation foundation</i> Theoretical: The Society for Healthcare Epidemiology of America (SHEA) recommendations <i>Duration</i> 12 months <i>Infection control measure</i> Medication <i>Design</i> Time series design	Behavioural Non-significant decrease of overall AB use. Significant decreases in the use of several antibiotics. Significant differences between non-antibiotic variables: purchase of alcohol fo increased; the number of ventilator days, purchase of alcohol fo Total fluoroquinolone and levofloxacin use decreased significantly. Clinical Decrease in nosocomial MRSA infections (not statistically tested)
24: Miyachi, et al., 2007, Japan	Local opinion leaders Audit and feedback Mass media <i>Implementation foundation</i> Theoretical: prior research on link nurses in large hospitals <i>Duration</i> 76 months <i>Infection control measure</i> Hand hygiene Other, non-specified <i>Design</i> Before and after design	Behavioural Significant increase in arithmetic mean of monthly consumption of antibiotics. Clinical Percentage of MRSA in Staphylococcus Aureus increased. Monthly counts of new MRSA cases dropped in 15 of 25 wards. Significant decrease in the monthly number of inpatient admissions.
25: Nicastri, et al., 2008, Italy	Educational outreach Clinical multidisciplinary teams <i>Infection control measure</i> Medication <i>Design</i> Time series design	Behavioural Significant reduction of defined daily doses (DDD) of cephalosporins. A clinical audit 12 months after introduction of Antibiotic Stewardship showed >90% adherence by the physicians (no statistical test). Clinical Significant decrease of MRSA isolations. Significant correlation between MRSA monthly prevalence rate and third-generation cephalosporins. Significant reduction of isolation of MRSA from surgical site infections (SSI) (BSI). Significant decrease in MRSA prevalence among Staphylococcus aureus. Significant reduction of MRSA prevalence both in Staphylococcus aureus and respiratory specimens of patients affected by ventilator-associated pneumonia.
26: O'Brien, et al., 2008, United States	Educational meetings Reminders Technology-supported <i>Implementation foundation</i> Theoretical: SHEA recommendations <i>Duration</i> 12 months <i>Infection control measure</i> Patient screening <i>Design</i> Before and after design	Behavioural Post-IT admission culture rate in the telemetry unit was >91%. Intermediate Care unit. Employee satisfaction with the MRSA surveillance protocol was high. 80% of the respondents were “fully satisfied”, the remaining 12% were “satisfied”. Increased efficiency of staff time use. Clinical Overall decrease in the rate of MRSA acquisition in the pre-IT period was statistically significant. Significant decrease in 2 of 3 unit specific comparisons before and after implementation.

Table 2. Characteristics of the studies included in the systematic review

Author, Year, Country	Implementation strategy	Reported Findings (behavioural, clinical, financial)
27: Peterson, et al., 2010, United States	Distribution of educational materials Educational meetings Educational outreach Local opinion leaders Audit and feedback Reminders Changes in physical structure, facilities and equipment Technology-supported <i>Implementation foundation</i> Theoretical: Institute for Healthcare Improvement's (IHI) five components to MRSA control <i>Duration</i> 24 months <i>Infection control measure</i> Patient screening <i>Design</i> Before and after design	Behavioural Screening compliance increased to >90%, and sustained >90% Clinical Decrease in MRSA transmission (from colonization to infection) Decrease in overall MRSA BSIs by the end of the first year. Financial Programme cost represented a net expense of \$15-\$16 per a patient, with a reduction of nearly \$1,200,000 in medical expenditures, with
28: Robert, et al., 2006, France	Distribution of educational materials Reminders Mass media <i>Implementation foundation</i> Theoretical: observational studies indicated that isolation precautions were poorly implemented outside ICUs <i>Duration</i> 3 months <i>Infection control measure</i> Patient isolation (Flagging records) <i>Design</i> Before and after design	Behavioural Within groups: medical and nursing staff reported that they were more compliant with isolation precautions than in the control period, and in 96% of cases in the control period. Medical and nursing records were flagged significantly more often in the control period. The set of four organizational measures was implemented more often in the control period. The same observation was made for each measure separately. When considering only ICUs and rehabilitation units, i.e. where there was a significant increase in the implementation of isolation precautions, use of gowns increased, use of dedicated materials increased, and proportion of MRSA patients in private rooms increased. There was no significant increase in the proportion of health care workers' status of patients or in the proportion of flagged records.
29: Thomas, et al., 2005, United States	Reminders Mass media <i>Implementation foundation</i> Theoretical: research on hand hygiene posters <i>Duration</i> 12 months <i>Infection control measure</i> Hand hygiene <i>Design</i> Before and after design	Behavioural Increase in hand hygiene compliance over all units. Participants agreed that, overall, posters had a positive influence on hand hygiene in all units. More so when poster displayed 'human qualities' or pictures of

3.2 Study design

Among the included studies, there was one randomized controlled trial (RCT) (1). In eight studies, a time series design was used (2, 9, 14, 15, 17, 22, 23, 25), and in fourteen studies a before and after design was used (3, 4, 5, 7, 10-12, 18, 19, 21, 26-29). Five studies applied a combination of time series and before and after design (6, 8, 13, 16, 20).

3.3 MRSA prevention and control measures

Different measures were implemented to prevent or control MRSA. In some studies a single MRSA prevention or control measure was implemented, in others a bundle of measures was implemented. *Hand hygiene* was implemented as a stand-alone measure in seven studies (4, 5, 7, 10, 13, 20, 29) and as part of a bundle of measures in eleven studies (1, 3, 6, 8, 11, 14, 16, 17, 19, 21, 24). *Environmental hygiene* was implemented as a stand-alone measure in one study (12) and as part of a bundle of measures in two studies (1, 17). The use of *personal protective equipment* such as gloves or gowns was implemented as part of a bundle of measures in four studies (1, 3, 16, 21); it was implemented as a stand-alone measure in none of the studies. *Medication*, or the correct use of antibiotics, was implemented as a stand-alone measure in six studies (2, 9, 15, 22, 23, 25); in none of the included studies was it part of a bundle of measures. In two studies (26, 27), *patient screening* was implemented as a stand-alone measure, and in six studies (3, 8, 11, 16, 17, 19) it formed part of a bundle of measures that was implemented. *HCW screening* was implemented only as part of a bundle of measures, in one study (17). *Patient isolation* was implemented as stand-alone measure in one study (28), and was part of a bundle of measures in five studies (3, 6, 16, 18, 19).

3.4 Implementation strategies and their foundation

Various strategies were used to implement the MRSA prevention and control measures. Most implementation strategies are set up because of the empirical observation of non-adherence to clinical guidelines, thus creating an impediment to successful MRSA control. The theoretical foundation of the chosen strategies is often unclear, or not specified.

Most studies, 24 out of 29, combined different elements (1-17, 19, 20, 22, 24, 25, 26, 27). In five studies the implementation strategy consisted of one component (18, 21, 23, 28, 29). The strategies used are summarized below:

- *Audit and feedback* was performed and given by trained nurses or auditors, infection control specialists, or multidisciplinary teams (nineteen studies: 1, 2, 4-6, 8, 9, 11-17, 19, 20, 22, 24, 27).
- *Reminders* were used in eighteen studies (3-9, 11, 16-20, 23, 26, 27, 28, 29), for example pop-ups, fluorescent tape drawing attention to hand-cleaning facilities, posters or messages clipped to patient charts.
- *Educational meetings* were held, for example to inform HCWs about the measure or to demonstrate new working methods or hygienic practices (seventeen studies: 1, 3-6, 8, 12-16, 19, 21, 22, 26, 27).
- *Mass media* were used in fourteen studies (3, 5-8, 10, 11, 13, 17, 19, 20, 24, 28, 29); posters, and to a lesser extent brochures or flyers, were used to remind or instruct HCWs about the implemented measures. Role models (hospital management or

- leaders) were sometimes depicted, or HCWs were involved in the creation of the poster (11, 17, 29).
- *Technology* was used in ten studies (1, 3, 5, 13, 17, 18, 21, 23, 26, 27), in the context of education (PowerPoint presentations, training via DVD), electronic order forms, pop-ups assisting medication choice or screening of patients.
  - *Changes in physical structure, facilities and equipment* were applied in eight studies (4, 5, 6, 8, 11, 12, 16, 27). These changes included strategically placed hand disinfectant dispensers, equipping HCWs with pocket bottles of hand disinfectant, or new cleaning materials (cloths), the bundling of protective gear and the availability of a test kit for screening.
  - *Educational materials* were distributed in eight studies (4, 5, 8, 10, 13, 17, 20, 27). Brochures, newsletters or instructional pocket cards were given to HCWs, often focused on applying correct (hand) hygiene.
  - *Local opinion leaders* guided the implementation process in six studies (1, 4, 5, 15, 24, 27), sometimes by reinforcing good infection control, or acting as a link worker between the professions and management.
  - *Clinical multidisciplinary teams* were used in five studies (2, 6, 20, 22, 25) to guide the implementation of a MRSA control measure. Via cooperation or consultation these teams supported the measures taken, for example by approving antibiotic prescriptions.
  - *Educational outreach* was carried out in five studies (6, 10, 15, 25, 27) to teach HCWs on-site and sometimes on demand how to apply the implemented measure.
  - *Rewards* for correctly performing the implemented measures were given in two studies (4, 16), either to individuals directly after observing correct behaviour, or to groups based on periodic adherence results.
  - *A patient-mediated intervention* was implemented in one study (10); patients and visitors were actively addressed to perform the desired hand hygiene behaviour and motivate adherence among staff.
  - *AB permission/formulary* was applied in one study (2) where permission to use a certain antibiotic was required.

3.5 Outcomes

We classified the reported effects into three categories: adherence to the measures, reduction of costs and reduction of MRSA.

In twelve studies (1-3, 7, 9, 12, 13, 17, 18, 24, 28) significant improvements (e.g. fewer prescriptions for antibiotics, more correctly executed hand hygiene, reduced expenditure on materials) in adherence to the MRSA control measures were observed. Similar positive results were observed in fourteen studies (4-6, 8, 10, 14-16, 20, 22, 23, 25, 27, 29), although these results were not statistically tested. In one of the studies (16), negative effects were observed: adherence to the measures increased in the first year but decreased thereafter.

Acquiring a hospital-associated infection (HAI) results in a longer length of stay for the patient and poses many additional *costs*. Therefore, reductions in length of stay are an important outcome associated with decreased MRSA infection rates. Cost savings, or at least cost-neutral intervention effects, were observed in four studies (5, 10, 15, 27). On the other hand, increased isolation and increased expenditure also posed costs, as described in one

study (18). However, in this study, these increased costs were not compared to possible savings due to prevented infections. In another study (19), improved screening led to increased lengths of stay (pre-ICU and ICU), because MRSA detection increased.

In nine studies (8, 12-14, 16, 17, 21, 25, 26), significant clinical improvements were reported, including MRSA prevalence, MRSA infection rates and susceptibility rates. Positive effects were also observed in eleven other studies (2, 5, 7, 10, 11, 15, 20, 22-24, 27), although these results were not statistically tested.

4. Conclusion and discussion

The results of our review show that in most cases hygiene experts or an infection control team (nurse, infectologist, microbiologist) are the developers of implementation strategies. These strategies are driven by empirical observations and audits. The theoretical foundation of the chosen strategies is often unclear. No references to theories and models of human behaviour are made. However, some articles indicated that a literature search was carried out.

When looking at the implementation strategies, we can conclude that in most cases a multi-faceted strategy was carried out. This strategy entails a combination of several activities:

- Education or training modules for HCWs, sometimes mandatory, taking various forms (DVDs, PowerPoint presentations, posters, meetings, brochures) to improve hand hygiene and compliance with protocols.
- Inspections of the adherence to the safety programme and of hand washing behaviour via audits, on-site instructions, and observations by hygiene experts or trained auditors. Results were communicated to management and demonstrated via feedback meetings.
- Environmental interventions (red lines at the entrance to high-risk wards, talking walls) to remind HCWs to behave safely in that particular area and to provide antibiotic policy support via guidelines and cards.

The implementation pathway consists of *education-inspection-feedback* rounds; unfortunately it is unclear who is responsible for the management of the intervention strategies and who invests in these activities. No business model seems to underpin the entire implementation strategy.

To answer the research question about the effect of the implementation strategies, we reviewed the research designs that were used to measure their effects. In general, quasi-experimental designs (before and after and time series designs) underpin the research activities. Implementation outcomes are usually measured in a before-and-after design, where they do not concern antibiotic use, and therefore provide little insight into temporal changes in implementation results or adherence. HCWs are the main target group in the research designs. It is unclear who these designs seek to manage (researchers, HCWs, management) in their execution or whether a project manager is responsible for this. Trained nurses or infection control teams are sometimes used. In most cases quantitative instruments are used to measure the effects on knowledge and behaviour (questionnaires, self-reporting of behaviour, material use, and hand hygiene) and on a reduction in MRSA and antibiotic doses (lab statistics). The effects on cost/benefits were sometimes measured, addressing utilizations such as reduced length of stay. In general the outcomes are

promising. However, the extent to which the outcomes are related to the implementation strategies is not clear, except for the routine screenings and reduced MRSA rates. The outcomes on cost-savings are especially hard to analyse. It remains unclear what is measured, how it is measured and to what purpose. Long-term effects are almost never addressed.

Due to several shortcomings in research designs, the overall impact of the implementation strategies could not be measured sufficiently. Shortcomings in the research designs include, for example, the one-sided focus on HCWs. We know from prior research (Verhoeven et al., 2009) and from behaviour change models that not only is a multifaceted strategy needed to change safety behaviour, but that a multi-perspective stakeholder view (HCWs, infection experts, patients, the safety policy of the management of the organization) is necessary to obtain insight into the cost/benefits of the implementation strategy and to discuss the long-term implications of the strategy for the organization and workflow (Kukafka et al., 2003). This requires a theory or innovation-driven approach that grounds the implementation strategy, enabling an assessment of which activities are successful for whom (patient, HCWs, management) and what the interaction effects of the different components of the strategy are.

Another shortcoming concerns the chosen study designs. Authors of the included studies refer to the difficulties in matching control and intervention groups, the high rates of drop-outs and the low volume of included respondents, and confounding factors that cannot be excluded. These shortcomings are well-known impediments related to RCTs and the self-reported behaviours. In fact, these shortcomings cannot be avoided due to the study of real-time behaviours and contextual factors that influence these behaviours. Therefore, these factors should not be regarded as nuisances, as the authors do; they are the key issues that are important in implementation studies aimed at changing culture and behaviour. For example, some authors reported problems in implementing the activities due to a lack of resources (a result of the economic downturn) to manage the implementation and problems with measuring the effects of each component of the implementation strategy due to financial constraints. A lack of transparent funding models and lack of management support made the participation of different institutes or wards in the research projects problematic, resulting in only small pilot projects being carried out. These financial barriers should not be reported as shortcomings; rather, these factors should be determined by the key stakeholders and considered as critical factors for changing behaviour and the culture of safety in hospitals or other institutions.

In addition, some authors reported a lack of commitment on the part of nursing personnel to participate in the implementation projects. It appeared that some personnel were uncertain about the implications of several measures. For example, they were concerned that patients would not feel as clean after being washed with wipes instead of soap and water. The level of commitment of HCWs and management is one of the main conditions for success in programmes for innovation or change. The impediments indicate that the implementation strategies are expert-driven rather than stakeholder-centred. Changing safety behaviour in hospitals is first and foremost a cultural problem of management and staff, which requires that implementation strategies should address that level.

How to improve the implementation strategies? Given the fact that the implementation strategies influenced the attitude and knowledge of HCWs in a positive way, that intentions to behave safely increased, and that MRSA rates decreased in several studies, the question is

how to boost the impact of the implementation strategies. *Education-inspection-feedback* rounds could be one way to do this.

Based on prior experience in infection management control and on information gathered from other studies of innovation management (Cain & Mittman, 2002; Rogers, 2003), we argue that the participation of staff and management is crucial to the development and implementation of interventions, to increase applicability, accountability and ownership and to create a fit between the proposed activities and the culture of the organization (Van Gemert et al., in press). In addition, both positive and negative incentives are needed to encourage staff to do the right things at the right times. Change agents and demonstration of best practices will improve the incorporation of safety behaviour. To enhance the transparency of the implementation programme and strategies, communication of results or key factors for success should be available to staff. Communication should include insights into results related to infection management (prevalence and incidence rates of MRSA, identification of increasing/decreasing trends), the business model underpinning the programme (resources, investments, additional costs) and benchmarking (how are we doing and what are others doing?). It is also important to demonstrate to the management and staff that the investment costs of the intervention can be less than the costs of not adopting an MRSA-infection control programme.

Another point of attention is the use of media to implement the strategies. Even though evidence of the usefulness and effectiveness of computerized decision support or reminders exists (Grimshaw et al., 2004), it is not often used. We found that in ten studies DVDs, PowerPoint presentations, educational programmes available online or on CD-ROM, and electronic alerts or reminders were used. This is rather remarkable in our Internet-driven world. Web-based communications systems in particular can increase staff knowledge and provide access to accurate, adequate and easy to understand information (Kreps & Neuhauser, 2010). In prior and on-going research projects aimed at cross-border infection control (MRSA-net; EurSafety Health-net) we developed stakeholder-driven, web-based communication systems, based on national infection control standards, to support staff and patient behaviours (see for example Verhoeven et al., 2009). This resulted in fewer errors, time savings and also appropriate behaviour by HCWs.

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Health care associated infection is coupled with significant morbidity and mortality. Prevention and control of infection is indispensable part of health care delivery system. Knowledge of Preventing HAI can help health care providers to make informed and therapeutic decisions thereby prevent or reduce these infections. Infection control is continuously evolving science that is constantly being updated and enhanced. The book will be very useful for all health care professionals to combat with health care associated infections.

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