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## Effectiveness of contact precautions against multidrug-resistant organism transmission in acute care: a systematic review of the literature

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### SUMMARY

Contact precautions are widely recommended to prevent multidrug-resistant organism (MDRO) transmission. However, conflicting data exist regarding their effectiveness. Prior systematic reviews examined contact precautions as part of a larger bundled approach, limiting ability to understand their effectiveness. The aim of this review was to characterize the effectiveness of contact precautions alone against transmission of any MDRO among adult acute care patients. Directed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement, comprehensive searches of four electronic scientific literature databases were conducted for studies published in English from January 2004 to June 2014. Studies were included if interventional, original research, evaluating contact isolation precautions against MDRO transmission among inpatients. Searches returned 284 studies, six of which were included in the review. These studies measured four different MDROs with one study showing a reduction in transmission. Whereas studies were of high quality regarding outcome operationalization and statistical analyses, overall quality was moderate to low due to poor intervention description, population characterization and potential biases. Where compliance was measured ( $N = 4$ ), it presented a threat to validity because it included select parts of the intervention, ranged from 21% to 87%, and was significantly different across study phases ( $N = 2$ ). The poor quality of evidence on this topic continues to limit interpretation of these data. Hence, this conflicting body of literature does not constitute evidence for or against contact precautions. We recommend that researchers consider power calculation, compliance monitoring, non-equivalent concurrent controls when designing future studies on this topic.

### Keywords

Contact precautions; Infection control; Infection prevention; Multidrug-resistant organism; Nosocomial

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#### Conflict of interest statement

None declared.

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## Introduction

In 2014, the World Health Organization (WHO) declared antimicrobial resistance a worldwide problem that requires urgent action.<sup>1</sup> The WHO's report states that most global regions have high rates of resistance to antimicrobial drugs among bacteria such as *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Escherichia coli*, and that these bacteria are moreover frequently resistant to multiple antimicrobials.<sup>1</sup> Multidrug-resistant organisms (MDROs) are considered to be serious threats to global security as infections with these organisms have higher mortality than those of non-drug-resistant strains, and are more difficult and costly to treat.<sup>1-4</sup> Therefore, identifying and employing effective techniques to control the spread of MDROs is of high importance to manage health outcomes and reduce healthcare costs.<sup>3</sup>

Isolation precautions are the preferred technique to control transmission of pathogens with high morbidity, mortality, or epidemiological significance, but controversy remains regarding the effectiveness of isolation precautions.<sup>3,5-10</sup> This debate intensified following transmission of Ebola virus to healthcare workers despite use of isolation precautions.<sup>11</sup> Like Ebola virus, MDROs are spread through direct or indirect contact.<sup>3</sup> Therefore, contact precautions, which include isolation in a private room, if possible, and use of gowns and gloves, are recommended to reduce transmission of MDROs.<sup>6</sup>

However, evidence regarding the effectiveness of contact precautions against MDRO transmission is limited in methodology and content. Prior studies have predominantly reported outbreak scenarios and therefore lack equivalent control group(s) and are subject to performance bias.<sup>12,13</sup> Additionally, most have focused on methicillin-resistant *S. aureus* (MRSA) or vancomycin-resistant enterococci (VRE).<sup>13</sup> The effectiveness of contact precautions against emerging MDROs such as carbapenem-resistant *Acinetobacter baumannii* and  $\beta$ -lactamase-producing Enterobacteriaceae has not been established.<sup>14,15</sup> More evidence may have become available regarding emerging MDROs since publication of previous reviews. Previous systematic reviews of this topic are similarly limited in the types of MDROs studied and outcomes measured, and have had mixed results.<sup>13,16-18</sup> More importantly, contact precautions in all of these reviews were grouped with other infection control practices such as active surveillance.<sup>13,16-19</sup> Thus, gaps in the literature exist regarding effects of contact precautions alone and against emerging MDROs.<sup>14,15</sup>

The objective of this systematic review is to characterize the effectiveness of contact isolation precautions alone against transmission of any MDRO among adult patients from interventional studies in which contact precautions are not included bundled with other interventions. In order to increase consistency between included studies and to better isolate the effect of contact precautions, this review focuses on acute care, as other settings such as skilled nursing facilities have different potential for infection transmission.<sup>20</sup>

## Methods

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.<sup>21</sup> Inclusion criteria for studies in this systematic review

were: (1) original research, (2) published in peer-reviewed, scientific journals, (3) in English, (4) involved human inpatients, (5) conducted in acute care settings, (6) outcomes were infection or colonization with one or more bacterial organisms identified as multidrug resistant by the US Centers for Disease Control and Prevention (CDC), (7) experimental or quasi-experimental design (i.e. interventional), and (8) with intervention of contact isolation precautions (as either the control or experimental exposure).<sup>3</sup> The components of contact precautions required for inclusion were: placement of the infected or colonized patient in a single room or in a cohort facility, application of standard precautions and disposable gown and glove use for close patient contact.<sup>6</sup> Searches were limited to the past 10 years (January 1st, 2004 to June 2014) to target the most recent literature (i.e. with emergent pathogen outcomes), including that published subsequent to national clinical guidelines. Editorials, correspondences, commentaries, letters, or proceeding papers were excluded. Studies in which the effectiveness of isolation precautions was indistinguishable from that of a larger intervention bundle were also excluded.

### Search strategy

With the help of a university librarian, searches of PubMed, Ovid Medline, EBSCO Cumulative Index of Nursing and Allied Health Literature (CINAHL) and Cochrane Central Register of Clinical Trials were conducted using the following terms: (1) isolation precautions, (2) multidrug resistance, (3) bacterial infections, and (4) healthcare-associated infection. The names of specific MDROs identified by the CDC were included as both keyword and medical subject headings (MeSH) terms, where applicable, to maximize search results.<sup>3</sup> Searches also included synonyms, related phrases, and pluralized terms (see Appendix A, Supplementary material online). Hand searches of reference lists were also conducted.

### Study selection

Two reviewers (C.C.C. and B.C.) screened search results to determine whether titles and abstracts met the inclusion and exclusion criteria. Full texts of articles were obtained and screened for eligibility when the title and abstract appeared to meet the criteria. All reasons for exclusion were recorded (Figure 1).

### Data abstraction

A data abstraction tool of relevant criteria from The Cochrane Collaboration data collection form for intervention review of randomized controlled trials (RCTs) and non-RCTs was tailored for use in this review.<sup>22</sup> C.C.C. pilot-tested the modified tool (see Appendix B, Supplementary material online) with two randomly selected eligible papers to confirm appropriateness of the tool and then used it to systematically collect data. These data included rationale for inclusion, methods, participants, intervention groups, outcomes, data and analysis, as well as funding sources, key conclusions, and reported conflicts of interest. C.C.C. contacted the publication's corresponding author if study details were unclear.

## Quality appraisal

Each study was appraised using the quality assessment tool that was developed, piloted, and employed by Aboelela and colleagues to review publications regarding isolation precaution effectiveness (see Appendix C, Supplementary material online).<sup>13</sup> This tool has items regarding sample representativeness, bias and confounding, description of the intervention, outcomes and follow-up, and statistical analysis, which are each ranked 1–4, where 4 is the highest quality. Each paper was assessed as to whether it addressed the aforementioned categories in a manner that was ‘completely adequate’, ‘partially adequate’, ‘inadequate, not stated or impossible to tell’ or ‘not applicable’. The authors performed component quality analysis independently and discussed results to consensus, as necessary.<sup>23</sup>

## Results

The search strategy described above returned 284 publications (Ovid: 165; PubMed: 112; CINAHL: 6; Cochrane: 1). Having excluding 129 duplicates, C.C.C. and B.C. reviewed the titles and abstracts of 155 remaining papers. Of these, 126 did not meet the inclusion criteria. The remaining 29 publications underwent full-text review. Hand search yielded four additional papers for eligibility assessment (Figure 1).

The most usual reasons for study exclusion were testing an intervention other than isolation precautions ( $N = 39$ ) or a bundled intervention ( $N = 9$ ); reviewing or presenting data that were not original ( $N = 28$ ); describing the prevalence of MDRO ( $N = 17$ ) or infection prevention practices ( $N = 14$ ); or examining isolation through observation alone ( $N = 16$ ). Of these, three attempted to estimate isolation precaution efficacy using mathematical models.<sup>24–26</sup>

## Characteristics of included studies

Six studies met the inclusion criteria and were included for the final review (Table I). Four studies were non-randomized quasi-experimental studies comparing pre- and post-intervention MDRO rates, whereas two studies had a repeated treatment design.<sup>27–32</sup> One study took place during an MDRO outbreak.<sup>27</sup> Studies included in this review had four different MDROs as primary outcomes, many comparators, and varying methods of identifying MDRO colonization and infection. These fundamental differences prevented meaningful use of meta-analysis to evaluate the effectiveness of contact precautions against MDRO transmission. The small number of studies included in the review and difficulty in identifying and locating unpublished studies also precluded us from an assessment of publication bias.<sup>33</sup>

**Population and setting**—Included studies were conducted in France, Great Britain, Israel, Hong Kong, and the USA.<sup>27–32</sup> Most studies were conducted in a single acute care centre ( $N = 5$ ); one study included two hospitals with analyses done by subgroup. Four settings were noted as academic centres, another as a tertiary care centre, and in one study the setting was not described.<sup>30</sup> Four studies took place in an intensive care unit (ICU); the other two applied their intervention throughout the whole hospital. Whereas most studies did not state inclusion or exclusion criteria for the individual patients, one indicated that all

hospital admissions were included, and another included those admitted to the ICU for >48 h.

**Interventions and comparisons**—Almost all papers offered a description of the intervention. Two papers described the intervention by citing CDC guidelines.<sup>29,30</sup> Variations to these practices and/or additional descriptions regarding the intervention were single-room isolation alone, staff cohorting, regular environmental cleaning and/or environmental cleaning at discharge and reserving healthcare devices (e.g. stethoscopes) for each infected patient.<sup>27,28,31</sup>

Most studies ( $N = 5$ ) compared the effectiveness of contact precautions with the effectiveness of another infection control intervention.<sup>27–31</sup> These included universal gloving, gowning without moving infected individuals to private rooms, and cohorting patients and staff.<sup>27–31</sup> Cohen *et al.* also included two additional phases of cohorting, which were increased surveillance in the ICU (phase 3) and active surveillance in the emergency department (phase 4).<sup>27</sup> Bearman *et al.* also performed active surveillance, but it was not clear who was subject to screening.<sup>29</sup> One study compared contact isolation precautions against no intervention to prevent transmission of MDRO colonization or infection.<sup>32</sup>

In most of the studies, the authors initiated isolation precautions at the time of a positive MDRO culture (i.e. isolation was not preemptive) and the precautions were initiated for either colonization or infection.<sup>29–32</sup> Some protocols included cohorting nurse staff members to care for the MDRO-positive patients.<sup>27,28,31</sup> One study mentioned that it was possible for patients to be removed from isolation if the patient was MDRO-negative for six months.<sup>27</sup> None of the publications included how long patients were observed to detect occurrence of the outcome. One publication noted that patients who were present during a study phase change were subsequently treated with the intervention of the new phase.<sup>31</sup>

Five studies used pretests and post-tests to compare interventions in the different phases, though most aggregated results by phase or by year.<sup>27,28,30–32</sup> Authors of one study compared MDRO infection rates between the pretest (phase 1) and the removed-treatment phase (phase 2), and phase 2 to the following phase where contact precautions were reintroduced (phase 3).<sup>32</sup> Another study included a concurrent group, though this was a non-equivalent control as MRSA incidence managed with contact precautions was compared to extended spectrum beta-lactamase (ESBL)-producing organism incidence managed with standard precautions (i.e. a different outcome was measured in each group).<sup>28</sup>

**Outcomes**—MDROs of interest in the included papers were MRSA, VRE, carbapenem-resistant *Klebsiella pneumoniae* (CRKP), and drug-resistant *A. baumannii*.<sup>27–32</sup> Three studies included measures of more than one MDRO: VRE and MRSA as primary outcomes and EBSL-producing organisms.<sup>28–30</sup> All of the papers' primary outcomes included colonization with the pathogen of interest in addition to active infection. However, screening procedures to identify cases differed substantially. One study tested the roommates, providers, and immediate environment of active cases to track pathogen spread (active, snowball sampling); another swabbed all patients for MDROs within 24 h of admission, weekly, at discharge, and as clinically indicated.<sup>27,31</sup> Two studies tested participants on admission and

then every four days or as clinically indicated; the other two tested for MDRO when deemed clinically necessary.<sup>28,29,30,32</sup>

**Analyses**—Two of the papers used Student's *t*-test and  $\chi^2$  or Fisher's exact test to compare continuous and categorical variables, respectively.<sup>29,30</sup> Others used a Cox proportional hazards model, Poisson multiple regression analysis, or segmented linear regression (including change-point analysis).<sup>27,28,31,32</sup> Two studies reported power calculations to ensure sufficient sample size to detect the anticipated change in infection rate, though in one of these studies the data analysis plan was amended and the power calculation was not changed to reflect the new strategy.<sup>29,31</sup>

**Study conclusions**—Five out of the six studies concluded that contact precautions did not represent a statistically significant improvement in MDRO infection control beyond that of the comparator(s).<sup>27,29–31</sup> However, one showed a decreased colonization rate of drug-resistant *A. baumannii* during periods of contact precautions use compared to a period with no patient isolation (relative risk: 0.5; 95% confidence interval: 0.40–0.64;  $P < 0.001$ ).<sup>32</sup>

### Quality appraisal

Quality of the included papers ranged widely. Whereas overall quality could be considered moderate for each paper, poor performance on key quality items such as bias and confounding limited usefulness of this body of literature. Table II displays a visual representation of each paper's quality along the concepts identified by Aboelela *et al.* All had at least one quality concept that showed clear opportunity for improvement. Gabaguidi-Hoare *et al.* did not have a portion of the quality appraisal tool that was deemed 'inadequate', but had more 'not applicable' items on the quality assessment tool. The following sections outline the rationale for the quality assessment of each paper.

**Representativeness**—Excepting Cepeda *et al.* which provided extensive details of the study setting, inclusion and exclusion criteria, and patient population characteristics, representativeness of the included studies was difficult to determine given the poor quality of population and inclusion criteria descriptions. The reviewers determined that most descriptions of the sample population were inadequate or partially adequate because these descriptions, if included at all, frequently lacked immunocompromised status or device use among the included sample, which are known risk factors for infection.<sup>3,27–30</sup> Further, two studies explicitly stated the inclusion and exclusion criteria for enrolment of participants within these setting(s).<sup>31,34</sup> Given that outcomes appear to include the whole unit or hospital, where no criteria were stated, the reviewers assumed that all patients were included in the study and determined this criterion to be 'not applicable' on the quality score. Nevertheless, failing to state this fact represents poor transparency of reporting. All studies provided adequate information regarding setting characteristics, including size and type of facility, type of unit (if applicable) and the hospital location. It was not stated in any study how settings and units within these facilities were chosen for participation, potentially subjecting the included studies to selection bias.<sup>35</sup>

**Bias and confounding**—The six papers received their lowest evaluations on the quality measures related to bias and confounding. Regarding the potential for sampling and selection bias, the reviewers assumed that the entire facility or unit was included unless otherwise stated. Therefore, the quality criterion for comparing the sample population characteristics to that of a larger population was deemed ‘not applicable’.

The studies had wide quality variation in accounting for confounding interventions. The reviewers interpreted adequacy on this item as noting broad or systemic changes potentially affecting healthcare delivery and attempting to mitigate the effects of the confounder(s), where possible. Two studies were deemed completely adequate in this respect.<sup>28,31</sup> Cheng *et al.* identified the severe acute respiratory syndrome (SARS) epidemic and corresponding systemic change as a potential confounder in their study and revised the statistical analysis to account for resulting bias. Cepeda *et al.* mentioned that environmental services protocols remained unchanged throughout the study and monitored hand hygiene to ensure consistent adherence rates. One study was deemed partially adequate as the facility ICU underwent renovations that doubled the number of beds in preparation for phase 2 of the study, though the authors confirmed that nurse staff ratios were identical across the phases.<sup>30</sup> This suggests that new nursing staff may have been hired. Though the presence of new personnel may lead to performance bias, this was not addressed in study design.

Some studies were classified as inadequate due to inherent confounding in the study design itself, such as the addition of multiple ‘bundled’ interventions simultaneously.<sup>27</sup> Others were considered inadequate because potential confounders, such as changes in unit occupancy and hand hygiene adherence, were tracked, but differences across study phases or groups were not accounted for in the statistical analysis.<sup>29</sup> Further, Cohen *et al.* mentioned that national regulations for infection control changed during the course of the study, making it possible that a novelty effect may have presented a threat to construct validity.<sup>36</sup> Gbaguidi-Haore *et al.* mentioned no potentially confounding interventions and that study was therefore scored as ‘not applicable’ on this item.

The level of intervention compliance and quality of compliance monitoring in these studies was mixed and often inadequate. One did not track or report compliance.<sup>32</sup> Another reported compliance inconsistently across different phases of the study, and others recorded compliance for particular components of the intervention (e.g. gowning compliance among nurses, but not among other healthcare workers).<sup>27,28,31</sup> In contrast, both articles by Bearman *et al.* measured compliance for all components of the intervention and reported rates during each phase.<sup>29,30</sup> Given the compliance rates reported by these studies, compliance was determined to be completely and partially adequate, respectively.

**Description of intervention**—Half the studies’ intervention descriptions were completely adequate.<sup>28,31,32</sup> Those not deemed to be completely adequate lacked descriptions of the compliance monitoring process, whether gloves were donned upon contact with the patient’s immediate environment during isolation, and how compliance was enforced when enforcement was mentioned.<sup>27,30</sup> Bearman *et al.* was inadequate on this item as description of the survey component lacked critical information that would be needed to repeat these methods, including survey format and distribution.<sup>30</sup>

**Outcomes and follow-up**—The majority of the included papers had high-quality operational definitions and assessment description such that methods were reasonably repeatable.<sup>28–31</sup> Four of six papers completely addressed whether pre-intervention and intervention phase groups were equivalent in follow-up/attrition by showing that length of stay and/or death among participants was equivalent between phases.<sup>29–32</sup>

**Statistical analysis**—Statistical validity was generally acceptable in the included studies. Three studies' analyses were deemed 'completely adequate', as each included appropriate statistical methods, clear description of methods, and comparisons between groups.<sup>29,31,32</sup> The remaining papers were 'partially adequate' as they did not test for differences between groups or variability within them.

## Discussion

We reviewed six studies regarding the effectiveness of contact precautions against MDRO infections. Five of the six studies did not find significant association between contact precautions and reductions in MDRO transmission. One study investigating contact precautions for *A. baumannii* colonization or infection compared against no intervention demonstrated a reduction in the number of cases in phases where isolation precautions were implemented.<sup>32</sup>

Limitations of this review are that it does not include papers published in languages other than English or grey literature. As with all literature reviews, it is also subject to publication bias. However, our findings are consistent with previous literature. De Angelis and colleagues combined results of three studies (including Bearman *et al.*<sup>29</sup>) in a fixed effects model, despite differences in study interventions, and concluded that contact precautions were not effective against VRE acquisition.<sup>16</sup> Another limitation of our review, shared by previous literature, may be a failure to address droplet or airborne transmission of these bacteria, which may explain inconsistent effectiveness of contact precautions.<sup>37</sup> However, study quality regarding low compliance rates, bias and confounding, and failure to adjust for confounders and/or confirm equivalency between pre- and post-test groups, preclude ability to draw strong conclusions from this evidence base regardless of these studies' findings.<sup>12</sup>

## Implications for clinicians

The quality of this body of literature does not justify changes in practice. Conflicting data from studies with poor design and/or low compliance does not constitute evidence against contact precautions; rather, these data are inconclusive. Whereas the study that performed best on our quality score found no significance between contact precautions and not isolating patients, this study did not consistently assess intervention compliance in the various study phases.<sup>31</sup> The included study that showed a difference in MDRO transmission with use of contact precautions did not report compliance rates and could not be assessed for quality on any of the other bias and confounding items of the quality assessment tool.<sup>32</sup> Inconsistencies and absences in compliance monitoring and reporting make it impossible to tell whether protocols were completed as intended, threatening the internal validity of these studies.<sup>35</sup> The CDC recently faced similar difficulty interpreting health outcomes after two healthcare workers were infected with Ebola virus in Texas, as it was unclear whether



transmission had been due to inadequate isolation precaution protocols or to a protocol breach.<sup>38</sup> In practice, healthcare facilities should be regularly monitoring compliance, and investigating potential lapses when cross-transmission is documented, to potentially resolve systems-based inefficiencies. It is also important for researchers to monitor and report compliance to understand what effectiveness level can be reasonably expected in practice where compliance may be lower than in clinical studies. Given the quality of evidence presented here, it may be advisable that healthcare workers and administrators continue to devote focus and resources to improve components of contact precautions and other infection prevention techniques with strong effectiveness evidence, such as hand hygiene technique and compliance.<sup>3</sup>

### Implications for researchers

Although the included studies have limitations that have been well described in the literature on this topic, such as lack of intervention allocation concealment, some demonstrate realistic opportunities for improvement in future studies. First, two of the included papers contained a power calculation.<sup>29,31</sup> As MDRO infections are rare events and most studies on this topic include small patient samples due to feasibility and cost concerns, future studies should also conduct a calculation to determine whether the study is adequately powered to detect differences in infection rates between intervention phases.<sup>12</sup> Second, four of the included studies attempted to control for time trends in healthcare-associated infections and other confounders through statistical analysis.<sup>27,28,31,32</sup> A concurrent, non-equivalent control, such as in Cheng *et al.*, may address this issue, but concurrent controls are not always feasible. In the future, longitudinal studies with multiple pre-intervention collection points could add even stronger evidence by directly measuring and accounting for infection trends that are not related to the intervention, as in Bearman *et al.*<sup>39</sup> Third, these studies differ from most previous publications by attempting to monitor intervention compliance.<sup>12,40</sup> Previous studies that monitored compliance demonstrated improved adherence (i.e. with hand hygiene) when an isolation precautions intervention was implemented.<sup>41,42</sup> However, this was not consistent with levels of compliance reported in the studies reviewed here.<sup>28-31</sup> Low compliance with contact precautions could be the reason that this intervention appears to be equally or less effective than other interventions.<sup>31</sup> This body of evidence demonstrates the implementation of a number of improvements in study design which, when combined in future studies, may yield substantially stronger evidence.

Another consideration for future studies is inclusion of patient-centred outcomes. Whereas benefits of isolation precautions are uncertain, adverse consequences of isolation precautions to the isolated individual, such as increased depression, anxiety, and anger, are well documented.<sup>43,44</sup> A number of papers returned in our search discussed negative consequences associated with isolation, but none of the included papers incorporated patient-centred measures such as anxiety and depression.<sup>10,12,40,44-46</sup> Considering that patient isolation is relatively resource intensive compared to other infection prevention activities, cost-utility analyses in future studies may be a good option to incorporate health outcomes, patient preferences, and costs to evaluate the effectiveness of contact isolation precautions against MDRO infection.<sup>47</sup>

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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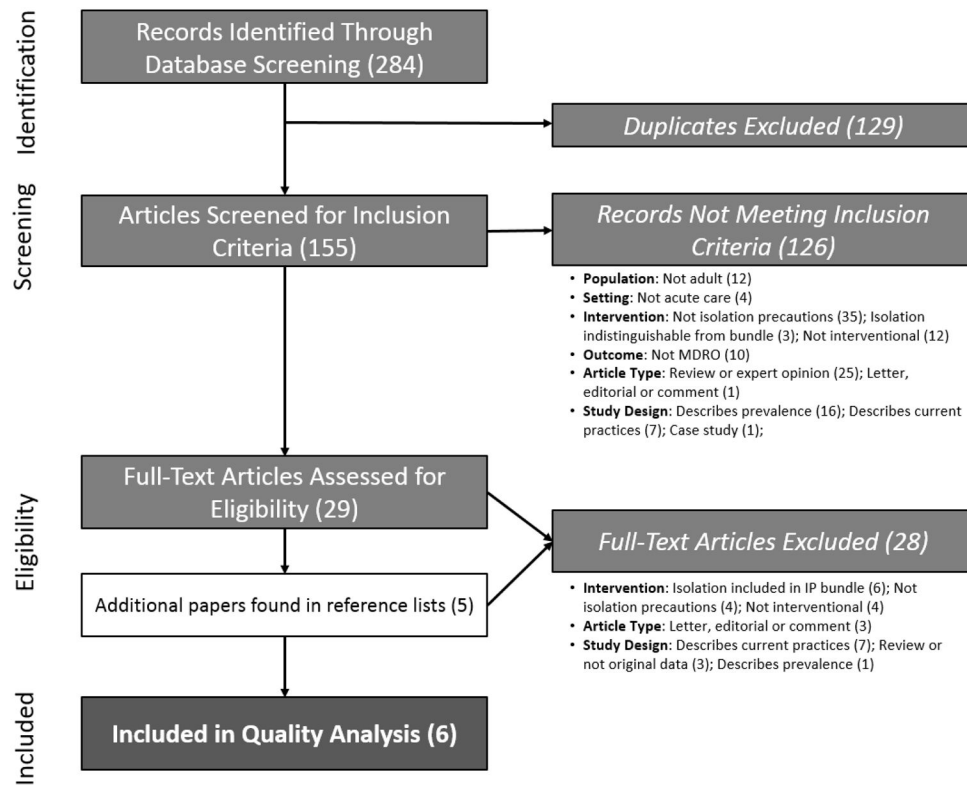
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**Figure 1.** Flow diagram of search results and eligibility analysis. Boxes on the left represent stages of evaluation of the publication returned through electronic database searches. The boxes on the right outline the number of articles excluded by the primary reason for exclusion. MDRO, multidrug-resistant organism; IP, infection prevention.

Table 1

Summary of key characteristics of publications included in the systematic review

Article	Study design	Setting and population	Intervention and comparison	Primary outcome	Time horizon (dates)	Key conclusions
Bearman <i>et al.</i> <sup>30</sup>	One group pretest–post-test (two intervention phases)	Medical ICU at academic hospital (USA)	<ul style="list-style-type: none"> <li>Contact isolation (phase 1)</li> <li>Universal gloving (phase 2)</li> </ul>	Prevalence and incidence of MRSA or VRE colonization or infection	<ul style="list-style-type: none"> <li>Phase 1: three months</li> <li>Phase 2: three months (dates not stated)</li> </ul>	No differences in the proportion of patients acquiring VRE (1.4% vs 1.8%, $P = 0.19$ ) or MRSA (5.7% vs 5% $P = 0.92$ ) in the two study phases
Bearman <i>et al.</i> <sup>29</sup>	One group pretest–post-test (two intervention phases)	Surgical ICU at academic hospital (USA)	<ul style="list-style-type: none"> <li>Contact isolation (phase 1)</li> <li>Universal gloving (phase 2)</li> </ul>	Prevalence of MRSA or VRE	<ul style="list-style-type: none"> <li>Phase 1: six months</li> <li>Phase 2: six months (September 2008–September 2009)</li> </ul>	Compared with contact precautions, universal gloving with emollient-impregnated gloves, no statistically significant change in the rates of device-associated infection, CDI, or patient MDRO acquisition was observed
Cepeda <i>et al.</i> <sup>31</sup>	Repeated treatment	All inpatients with stay >12 h in three medical–surgical ICUs of two academic hospitals (Great Britain)	<ul style="list-style-type: none"> <li>Gowning and gloving, single room isolation (phases 1 and 3)</li> <li>Gowning and gloving, no single room isolation (phase 2)</li> </ul>	Incidence of MRSA colonization or infection	<ul style="list-style-type: none"> <li>Phase 1: three months</li> <li>Phase 2: six months</li> <li>Phase 3: three months (June 2000 to June 2001)</li> </ul>	Risks of acquiring MRSA were similar in the move and non-move phases; combined hazard ratio 0.73 (95% CI: 0.49–1.10), $P = 0.94$ one-sided and for hospital A and B individually [0.72 (0.44–1.17), $P = 0.91$ and 0.76 (0.37–1.58), $P = 0.77$ ]
Cheng <i>et al.</i> <sup>28</sup>	One group pretest–post-test with non-equivalent, concurrent control (three phases)	Patients of an ICU in one university-affiliated teaching hospital (Hong Kong)	<ul style="list-style-type: none"> <li>Cohorting (phase 1)</li> <li>Single room isolation and contact precautions (phase 2)</li> <li>Single room isolation with hand hygiene campaign (phase 3)</li> </ul>	‘Changes in the trend or level of incidence density of ICU onset infection due to MRSA’ (p. 3)	<ul style="list-style-type: none"> <li>Phase 1: 27 months</li> <li>Phase 2: 27 months</li> <li>Phase 3: 35 months (January 2002–June 2009)</li> </ul>	No difference in level or trend change of the incidence density of ICU onset infections due to MRSA and ESBL-producing organisms across different phases during the study period
Cohen <i>et al.</i> <sup>27</sup>	One group pretest–post-test (four intervention phases)	All inpatients of a tertiary care medical centre (Israel)	<ul style="list-style-type: none"> <li>Contact precautions (phase 1)</li> <li>Cohorting patients and staff and roommate screening (phase 2)</li> <li>Phase 2 plus ICU active surveillance (phase 3)</li> </ul>	CRKP colonization or infection ‘episodes’	<ul style="list-style-type: none"> <li>Phase 1: one year</li> <li>Phase 2: one year</li> <li>Phase 3: 15 months</li> </ul>	Contact precautions alone are not sufficient for controlling an outbreak of CRKP colonization and infection; Significant changes in incidence rate corresponding with phases 2 and 3

Article	Study design	Setting and population	Intervention and comparison	Primary outcome	Time horizon (dates)	Key conclusions
Gbaguidi-Haore <i>et al.</i> <sup>32</sup>	Repeated treatment	Academic hospital (France)	<ul style="list-style-type: none"> <li>Phase 3 plus ED active surveillance (phase 4)</li> <li>Contact precautions, or cohorting if single room unavailable (phases 1 and 3)</li> <li>No isolation (phase 2)</li> </ul>	<i>Acinetobacter baumannii</i> colonization or infection	<ul style="list-style-type: none"> <li>Phase 4: seven months (March 2006–March 2009)</li> <li>Phase 1: three years</li> <li>Phase 2: three years</li> <li>Phase 3: two years (1999–2006)</li> </ul>	Implementation of isolation precautions was negatively associated with <i>A. baumannii</i> colonization incidence [RR: 0.50 (95% CI: 0.40–0.64); $P < 0.001$ ]

ICU, intensive care unit; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant enterococci; CDI, *Clostridium difficile* infection; MDRO, multidrug-resistant organism; CI, confidence interval; EBSL, extended spectrum  $\beta$ -lactamase; CRKP, carbapenem-resistant *Klebsiella pneumoniae*; ED, emergency department; RR, risk ratio.

Table II

Quality assessment results for each included paper<sup>a</sup>

Quality criterion	Bearman <i>et al.</i> <sup>30</sup>	Bearman <i>et al.</i> <sup>29</sup>	Cepeda <i>et al.</i> <sup>31</sup>	Cheng <i>et al.</i> <sup>28</sup>	Cohen <i>et al.</i> <sup>27</sup>	Gbaguidi-Haore <i>et al.</i> <sup>32</sup>
Representativeness						
Study population description	3	2	4	2	2	4
Inclusion/exclusion criteria	1	1	4	1	1	1
Location/setting description <sup>b</sup>	4	4	4	4	4	4
Bias and confounding						
Study population corresponded to larger population in all key factors	1	1	1	1	1	1
Masking	1	1	1	1	1	1
How similar was the assessment of outcomes between groups	1	1	1	1	1	1
Involvement from author	1	1	1	1	1	1
Accounted for confounding interventions	3	2	4	4	2	1
Compliance rate	4	3	2	2	2	1
Description of intervention						
Replication possible given descriptions of intervention	2	3	4	4	3	4
Outcomes and follow-up						
Outcome assessment procedure clearly defined	4	4	4	4	3	3
Groups equivalent in attrition/LOS/death/patient days	4	4	4	2	2	4
Statistical analysis						
Description and appropriateness of methods	4	4	4	4	4	4
Tested differences between groups and variability	2	4	4	2	2	4
LOS, length of stay.						

LOS, length of stay.

<sup>a</sup> Key: 1, not applicable; 2, inadequate, not stated; 3, partially adequate; 4, completely adequate. Columns represent each concept outlined on the quality assessment tool and each row represents an included paper.

<sup>b</sup> Added to quality assessment tool described by Aboelela *et al.* (2006).