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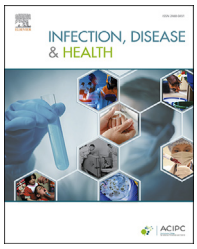

Review

Risk of organism acquisition from prior room occupants: An updated systematic review

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Abstract *Background:* Evidence from a previous systematic review indicates that patients admitted to a room where the previous occupant had a multidrug-resistant bacterial infection resulted in an increased risk of subsequent colonisation and infection with the same organism for the next room occupant. In this paper, we have sought to expand and update this review. *Methods:* A systematic review and meta-analysis was undertaken. A search using Medline/PubMed, Cochrane and CINHAL databases was conducted. Risk of bias was assessed by the ROB-2 tool for randomised control studies and ROBIN-I for non-randomised studies.

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Results: From 5175 identified, 12 papers from 11 studies were included in the review for analysis. From 28,299 patients who were admitted into a room where the prior room occupant had any of the organisms of interest, 651 (2.3%) were shown to acquire the same species of organism. In contrast, 981,865 patients were admitted to a room where the prior occupant did not have an organism of interest, 3818 (0.39%) acquired an organism(s). The pooled acquisition odds ratio (OR) for all the organisms across all studies was 2.45 (95% CI: 1.53—3.93]. There was heterogeneity between the studies (I^2 89%, $P < 0.001$).
Conclusion: The pooled OR for all the pathogens in this latest review has increased since the original review. Findings from our review provide some evidence to help inform a risk management approach when determining patient room allocation. The risk of pathogen acquisition appears to remain high, supporting the need for continued investment in this area.
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Highlights

- Admission to a room previously occupied by a patient infected +/- colonised with a pathogen is a risk factor for acquisition
- Continued investment and research in cleaning services in healthcare facilities is needed.
- Findings may help inform a risk management approach for determining patient room allocation.

Introduction

The hospital environment plays an important role in the transmission of pathogens and subsequent infection, by acting as a reservoir. Hospital pathogens can survive for prolonged periods of time, and unless removed through the cleaning process, can pose an ongoing risk of infection. Evidence from a previous systematic review and meta-analysis indicates that patients admitted to a room where the previous occupant had a multidrug-resistant bacterial infection resulted in an increased risk of subsequent colonisation and infection with the same organism for the next room occupant [1]. The findings from the systematic review imply that cleaning and disinfection practices when patients are discharged (terminal room cleaning), may be inadequate in reducing the risk of subsequent infection or colonisation [1].

Since the publication of the systematic review in 2015, there have been high quality studies demonstrating that improvements in cleaning and disinfection are possible, alongside decreased risk of healthcare associated infection [2—4]. Similarly, research has demonstrated that a cleaning bundles, which includes the use of disinfectants when and where required, are a cost-effective intervention for reducing the risk of healthcare associated infection [5]. Given that, there has been an increased focus on environmental cleaning and disinfection as one way to help reduce the risk of healthcare associated infection, we believe that this review is timely to update the evidence on prior room occupancy and risk of subsequent transmission to the next occupant. We acknowledge that a review on this topic has been published during this time [6]. However, the research question in that review differs to ours, in that our question is solely focussed on the risk from immediate prior room occupants to the next room occupant.

In this paper, we present findings from a systematic review and meta-analysis seeking to address the question; "What is the risk of pathogen acquisition for patients admitted to a hospital room where the prior occupant was colonised/infected with the same or similar hospital pathogen, compared against acquisition risk from a room where the prior occupant did not have a hospital pathogen?" We have also expanded the scope from the previous review to include important nosocomial viruses that responsible for causing respiratory and gastroenterological infection.

Methods

Study design

A systematic review and meta-analysis was undertaken with the findings reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] [7]. The protocol for the original review was registered on the international prospective register of systematic reviews (PROSPERO),registration number CRD42015016273. The methodology described in this protocol was used to update the previous systematic review [1].

Eligibility

Our review included publications that reported on randomised control, quasi-experimental, observational, cross-sectional and cohort studies which evaluate the risk of prior room occupancy on pathogen transmission. Studies must have examined exposure or acquisition in a hospitalised population where the prior room occupant was colonised or infected with a specific organism. Pathogens of interest were vancomycin-resistant *Enterococcus* (VRE) spp., *Acinetobacter* spp.,

Escherichia coli, *Klebsiella* spp., *Pseudomonas* spp., *Enterobacter* spp., *Proteus* spp., *Serratia* spp., *Enterococcus* spp., *Clostridioides difficile* (*C. difficile*), *Staphylococcus aureus* including Methicillin-resistant *S. aureus* (MRSA), *Citrobacter* spp., paramyxoviruses (respiratory syncytial virus, parainfluenza), rhinoviruses, adenoviruses, orthomyxoviruses (influenza), norovirus (Norwalk-like viruses) rotavirus or organisms that were extended-spectrum beta-lactamases (ESBLs) producing.

The exclusion criteria were publications that were conference abstracts, letters to the Editor (correspondence) or case studies; studies published outside the search timeframe; studies not published in English; non-peer reviewed literature; studies exploring risk in settings other than hospitals; and studies that did not examine hospitalised patients occupying a room where the previous occupant was colonised with a specific organism.

Information sources

MEDLINE/PubMed, Cumulated Index to Nursing and Allied Health Literature (CINAHL) and Cochrane were searched for publications ranging between January 1st 2005 and December 31st 2022. 1st January 2005 was chosen as the start date for this search strategy for two reasons. First, in a previous systematic review exploring this topic, their search commenced from 1st January 1984 [1]. The oldest published paper identified in that review was from 2005 [1]. Second, healthcare and in particular infection control practices have progressed significantly in the past two decades and we sought to present contemporary findings and risk.

The keyword search terms for the CINAHL search were 'prior room occupancy' OR 'occupancy' AND 'acquisition' AND the name of each specific organism. The keyword search terms for the MEDLINE/PubMed and Cochrane search were: 'acquisition' or 'cross infection' AND 'hospital' AND the name of each specific organism. The organisms names used in the searchers were: 'Vancomycin resistant enterococcus' OR 'Acinetobacter' OR '*E. coli*' OR 'Klebsiella' OR 'Pseudomonas' OR 'Enterobacter' OR 'Proteus' OR 'Serratia' OR 'Enterococcus', 'Clostridioides difficile' OR '*Staphylococcus aureus*' OR 'Methicillin resistant staphylococcus aureus' OR 'Citrobacter' OR 'Paramyxoviridae or paramyxoviruses (CINAHL) or parainfluenza (CINAHL)' OR 'respiratory syncytial virus' OR 'Rhinoviruses' OR 'Adenoviridae' or Adenovirus (CINAHL)' OR 'Orthomyxoviruses' OR 'influenza, human' OR 'Norovirus' OR 'Norwalk-like viruses (CINAHL)' OR 'Rotavirus'. The addition of the viruses is an expansion of organisms from the previous systematic review undertaken on this topic [1].

Study selection and data collection

Publications identified in the search were examined and assessed for relevance and appropriateness to the review question by one author. Initially, titles and abstracts were reviewed in Covidence [8], with non-relevant articles excluded. Ten per cent of the abstracts were crosschecked by a second researcher, and no discrepancies were identified. Full-text screening was sequentially undertaken independently by two researchers and each article was assessed against the inclusion and exclusion criteria in Covidence. Articles that met the inclusion criteria were included in the systematic review and meta-analysis. A manual search of the reference lists of all included articles was undertaken to identify additional studies. Where decisions regarding inclusion were open to disagreement, this was resolved by discussion with the research team.

Data collection

From the included studies, data were extracted utilising the Cochrane Collaboration's data collection form for randomised controlled trials (RCTs) and non-RCTs. Extracted data were crossed checked for accuracy by two researchers. Extracted data included year of publication, study duration, setting, design, organisms evaluated, confounders, events (control and intervention), denominator data (control and intervention), and reported risk. Where data from the included publications were not clear or available, we contacted the authors.

Risk of bias assessments

Risk of bias was assessed by the ROB-2 tool for randomised control studies [9], and ROBIN-I for non-randomised studies [10]. Risk of bias assessments were conducted independently by two members of the research team. Discrepancies were resolved by a third researcher.

Effect measures and synthesis

Statistical analyses were undertaken using Review Manager software (Revman 5.4; Cochrane Collaboration, Oxford, UK). The pooled prevalence estimates [and 95% confidence interval (CI)] of acquisition were calculated. Sub-analysis by the different types of organism genus was undertaken. A random-effects meta-analysis model based on the DerSimonian and Laird method was used. This method incorporated study weights and the standard error of the estimate of the common effect. To quantify between-study heterogeneity of intervention effects, the I^2 statistic was used. Assessment of reporting biases was by visual examination of the funnel plot. A 0.05 level of significance was used without adjustment for multiplicity.

Results

Study selection

Following the removal of duplicate publications, 5175 studies were identified, with the titles and abstracts screened. Following a full text review and the application of inclusion and exclusion criteria, 12 papers from 11 studies were included in the review for analysis. One study, not included in our review, aimed at identifying the risk of prior room occupancy for *C. difficile* [11]. We excluded this study from our review, as our interpretation of this study was that it did not assess immediate prior occupancy — patients were considered exposed if they had occupied a contaminated room in the preceding 90 days or 365 days

[11]. The PRISMA flowchart summarises the screening process and reasons for exclusion (Fig. 1).

Study characteristics

A summary table of the included papers is detailed in Table 1. Two papers from the same randomised control trial were identified [2,3]. This study was the only randomised control trial included in our review, all other studies were non-randomised. The study undertaken by Datta et al. [12] was an extension of the study undertaken by Huang et al. [13], but included an intervention. Four studies examined outcomes that included two or more organisms [2,12–14]. Three studies were conducted outside the United States [14–16]; the remainder were conducted in the United States. Studies were published between 2005 and 2021.

Syntheses

The data from the Datta et al. study were not included in the meta-analysis as the baseline data provided had already been reported in a previous study [12,13]. Similarly, we used data from the Anderson (2017 publication) [2] for the purpose of synthesis. To assist in data synthesis, we contacted two authors to obtain and ensure correct data were used for the meta-analysis [2,17].

From 28,299 patients who were admitted into a room where the prior room occupant had any of the organisms of interest, 651 (2.3%) were shown to acquire the same species of organism. In contrast, 981,865 patients were admitted to a room where the prior occupant did not have an organism of interest, 3818 (0.39%) acquired an organism(s). The pooled acquisition odds ratio (OR) for all the organisms across all studies was 2.45 (95% CI: 1.53–3.93]. There was heterogeneity between the studies (I^2 89%, $P < 0.001$). The Forest plot is shown in Fig. 2.

Sub-analyses by organisms were undertaken and the results are presented in Fig. 2. There was a significantly higher risk of acquisition for patients admitted to rooms where the prior occupant had MRSA, *Klebsiella* species and or *E. coli* ESBL-producing Gram-negative bacilli (where identified within studies), *C. difficile*, *Acinetobacter baumannii* and norovirus. However, for several of these organisms (*Klebsiella* species and ESBL producing *E. coli*, *A. baumannii* and norovirus), the data were limited to one study.

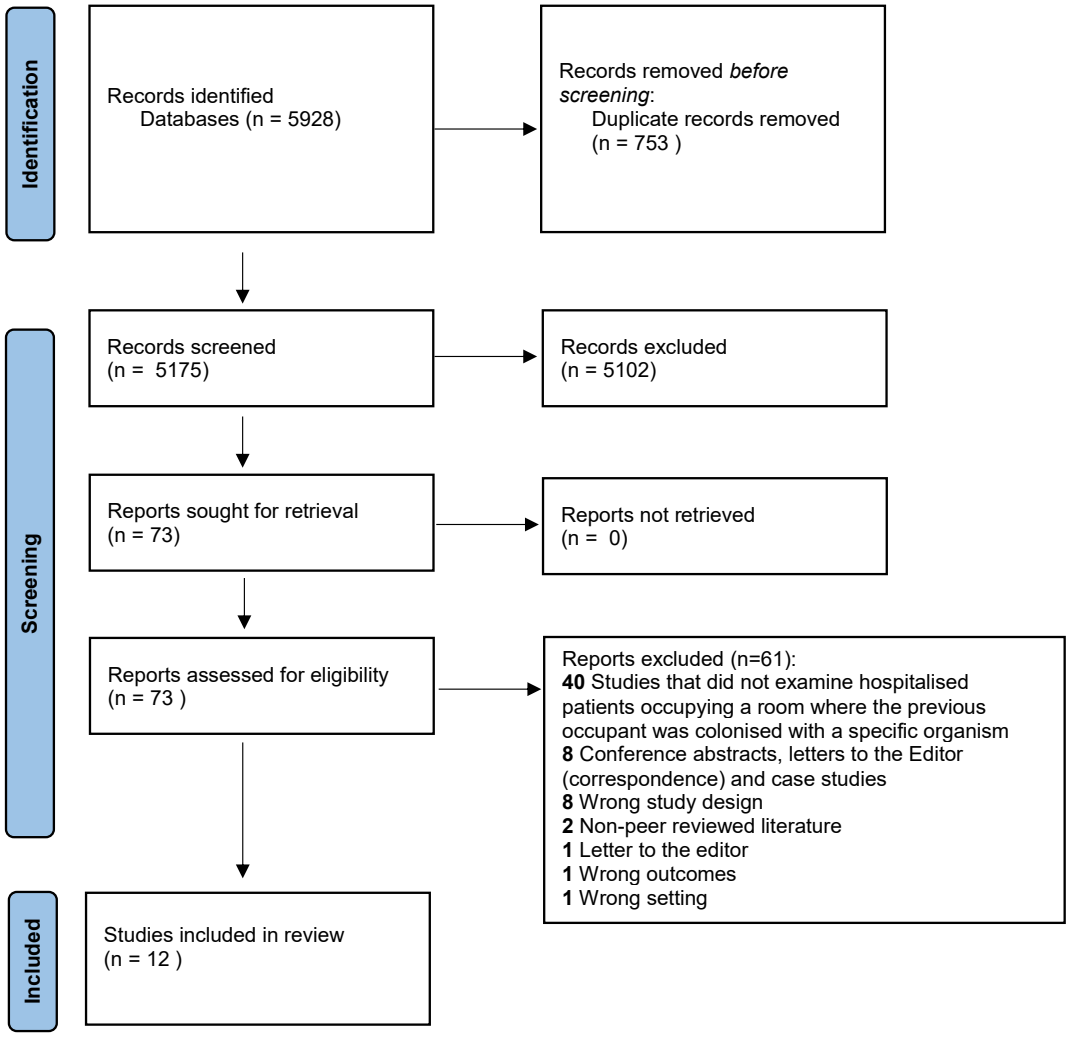

Figure 1 PRISMA flowchart summarising the search strategy.

Table 1 Overview of studies.

Study	Publication year	Study duration	Study setting (country)	Study design	Organisms evaluated
Huang et al. [13]	2005	20 months	USA	Cohort	VRE, MRSA
Mitchell et al. [16]	2014	24 months	Australia	Cohort	MRSA
Datta et al. [12]	2011	20 months	USA	Cohort	VRE, MRSA
Ajao et al. [24]	2013	93 months	USA	Cohort	ESBL-producing Gram negative
Drees et al. [20]	2008	14 months	USA	Cohort	VRE
Nseir et al. [14]	2011	12 months	France	Cohort	*A. baumannii*, ESBL-producing Gram negative *P. aeruginosa*
Shaughnessy [25]	2011	16 months	USA	Cohort	*C. difficile*
Zhou [19]	2019	72 months	USA	Cohort	VRE
Anderson [2,3]	2017 & 2018	28 months	USA	RCT	VRE, MRSA, *C. difficile*
Ford [17]	2016	93 months	USA	Cohort	VRE
Fraenkel [15]	2021	72 months	Sweden	Cohort	Norovirus

Note: VRE, vancomycin-resistant enterococci; MRSA, meticillin-resistant *Staphylococcus aureus*; ESBL, extended spectrum b-lactamase; *C. difficile*, *Clostridioides difficile*. Anderson 2017 and 2018 are the same study. Data from both of Anderson's papers were used to provide data to answer the research question.

Certainty of evidence

The risk of bias assessments using ROB-2 for the randomised control studies are shown in Fig. 3, while the risk of bias assessment for non-randomised studies and potential confounders for each study are included in the supplementary material.

Discussion

Since the previous review on this topic, there have been no major changes to the 'headline' notion that admission to a room previously occupied by a patient infected and/or colonised with a pathogen is a risk factor for acquisition. The pooled OR for all the pathogens in this latest review has increased to 2.45 (95% CI: 1.53—3.93] from 2.14 (95%CI 1.65—2.77) [1]. One explanation for this increase could be due to the sample size of included studies, which contribute significant weight to the overall findings. Findings from our review do not confer causation, i.e. that the previous occupant transmitted an identical pathogen to the next occupant. There are many mechanisms by which pathogens can be transmitted [18]. Genomic sequencing can be used to specifically answer this question. Nonetheless, our review continues to support the need for a clean environment to reduce the risk of healthcare associated infections.

The review identified a paper with a pathogen not captured in the previous review, i.e. norovirus [15]. Unadjusted analysis from this paper suggests an increased risk of norovirus for the next occupant, but not in multi-variate analysis (OR 1.86, 95%CI 0.73—4.73). Sequencing suggested that two of the five exposed patients with acquired norovirus infection were infected by identical strains to the prior room occupant [15]. Environmental sampling was not undertaken as part of this study.

In the case of VRE, findings from our review have identified two studies that did not show a significant increase in risk [17,19], while three studies did [2,13,20]. Pooled analysis of the five studies did not indicate an increased risk. This finding is interesting when comparing it with data from trials that have evaluated environmental cleaning interventions to reduce VRE. A recent review summarised the evidence for interventions in the healthcare environment on patient colonisation and healthcare associated infections with multidrug-resistant microorganisms [21]. In that review, only three studies were identified as having an 'A grade' quality score [2,4,22]. Interestingly, all three studies included VRE infection as one of the outcomes. Two of the three studies were randomised control trials [2,4], and the remaining one was a cluster controlled crossover trial [22]. All three studies showed a significant reduction in the rate of VRE incidence in the intervention arm and all three had different interventions. These findings suggest that improving cleaning (in a variety of forms), reduces the risk of VRE, and yet, pool data in our review was not conclusive with respect to the risk of VRE from prior room occupants. This demonstrates the potential limitations of observational based studies.

Studies in our review are subject to different types of bias and confounders (Fig. 3 and supplementary material; Tables 1 and 2). Control measures such as contact precautions for patients with MRSA and VRE are likely to vary between studies. Measures to improve hand hygiene compliance, screening of patients, variations in cleaning practice, antimicrobial use and enhanced cleaning during outbreaks, will play a role in the risk of transmission of pathogens from the environment.

There were papers not included in our review that were related to the research question [11,18,23]. The reasons for exclusion included situations where data were not limited to the immediate prior room occupant, case control studies, or data for exposure/non exposure could not be calculated.

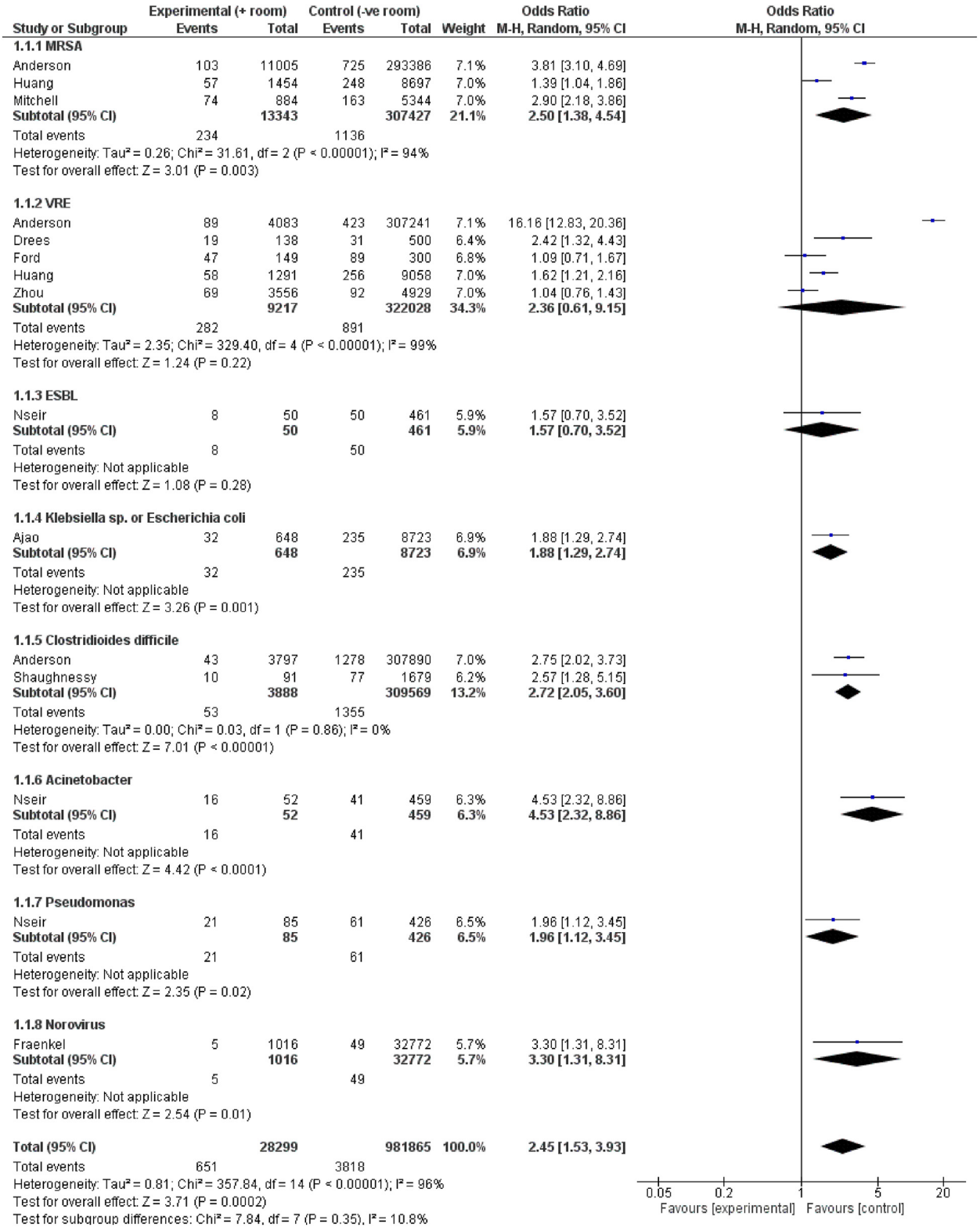

Figure 2 Forest plot for risk of acquisition from prior room occupants by organism, Note: M–H, Mantele Haenszel; VRE, vancomycin-resistant enterococci; MRSA, meticillin-resistant *Staphylococcus aureus*; Ajao et al.'s study involved extended spectrum b-lactamase producing Klebsiella or *Escherichia coli* organisms. Acinetobacter: *Acinetobacter baumannii*; Pseudomonas: *Pseudomonas aeruginosa*. It was not possible to separate Klebsiella species and *Escherichia coli* data in the Ajao et al. study. ESBL includes the organisms *Pseudomonas aeruginosa* or *Acinetobacter* Baumannii.

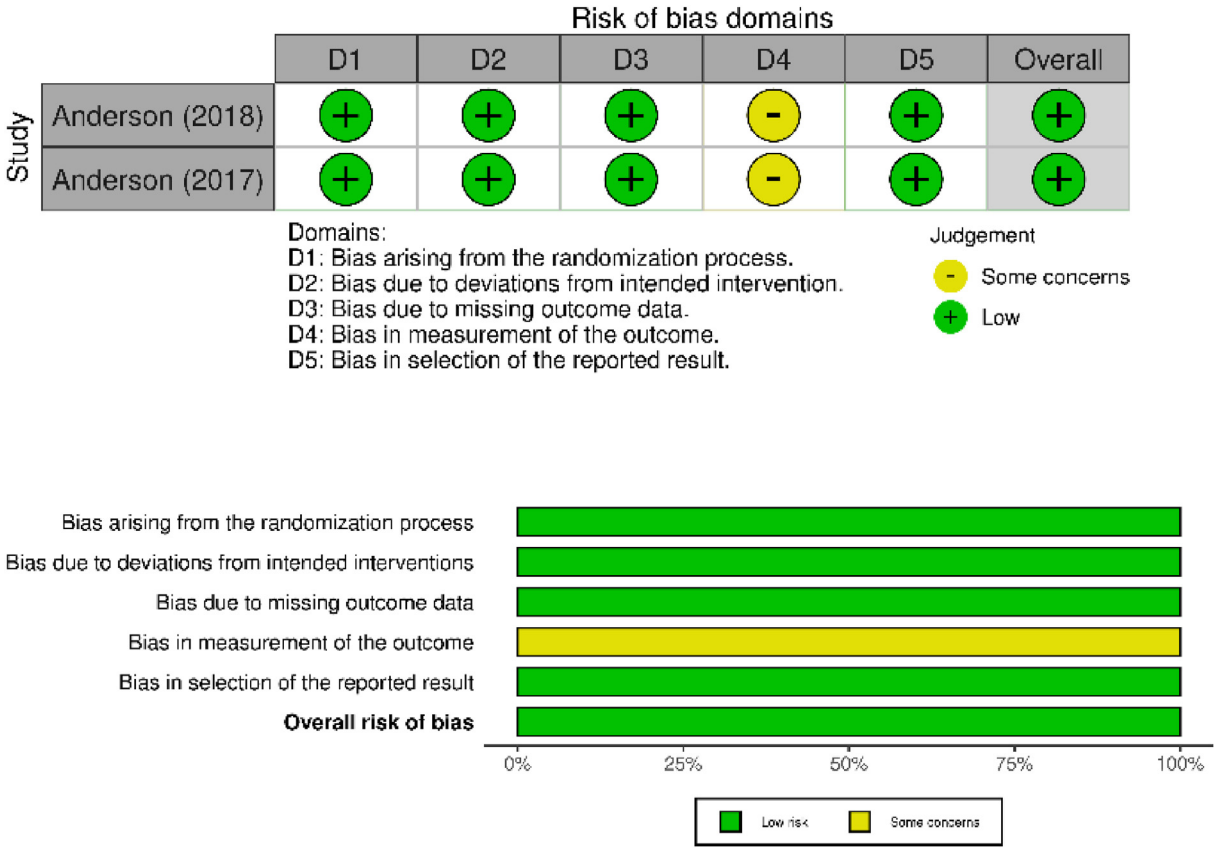

Figure 3 Risk of bias assessment randomised control trials included in the review.

Findings from our review provide some evidence to help inform a risk management approach when determining patient room allocation. This is pertinent to infection control professionals and those involved in bed management and patient flow. The risk of pathogen acquisition appears to remain high, supporting the need for continued investment in cleaning services in healthcare facilities as well as more research in this area. The role of airborne persistence, dispersal of organisms and subsequent acquisition are other areas that requires attention.

Authorship statement

BM and SD conceived and authored the original review underpinning this paper. BM, SF and JM lead the update of this review. All authors contributed to the review of this paper and provided critical input. All authors approved the paper for submission.

Conflict of interest

Authors on this paper have editorial affiliations. No author played any role at all, in the peer review or decision making processes associated with this paper.

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Provenance and peer review

Not commissioned; externally peer reviewed.

Ethics

This paper is a systematic review, therefore ethics approval is not required.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.idh.2023.06.001.

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