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REVIEW

Transmission of health care-associated infections from roommates and prior room occupants: a systematic review

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Abstract: Pathogens that cause health care-associated infections (HAIs) are known to survive on surfaces and equipment in health care environments despite routine cleaning. As a result, the infection status of prior room occupants and roommates may play a role in HAI transmission. We performed a systematic review of the literature evaluating the association between patients' exposure to infected/colonized hospital roommates or prior room occupants and their risk of infection/colonization with the same organism. A PubMed search for English articles published in 1990–2014 yielded 330 studies, which were screened by three reviewers. Eighteen articles met our inclusion criteria. Multiple studies reported positive associations between infection and exposure to roommates with influenza and group A streptococcus, but no associations were found for *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus*, *Cryptosporidium parvum*, or *Pseudomonas cepacia*; findings were mixed for vancomycin-resistant enterococci (VRE). Positive associations were found between infection/colonization and exposure to rooms previously occupied by patients with *Pseudomonas aeruginosa* and *Acinetobacter baumannii*, but no associations were found for resistant Gram-negative organisms; findings were mixed for *C. difficile*, methicillin-resistant *S. aureus*, and VRE. Although the majority of studies suggest a link between exposure to infected/colonized roommates and prior room occupants, methodological improvements such as increasing the statistical power and conducting universal screening for colonization would provide more definitive evidence needed to establish causality.

Keywords: health care-associated infections, hospital roommates, prior room occupants, multidrug-resistant organisms

Introduction

Despite decades of infection prevention research and quality improvement initiatives, health care-associated infections (HAIs) remain common adverse events in hospitals and long-term care facilities.[1] Over 700,000 HAIs occur annually in the USA alone, leading to death in 6% of cases and costing the health care system 28–45 billion US dollars each year.[2–4] Recently, there has been renewed interest in understanding the role of the physical environment in the spread of HAIs.[5,6] Countless studies have reported that pathogenic organisms can survive on a variety of fomites in health care settings, including those at the patient bedside (eg, mattresses, linens, pillows, bedframes, bedrails), inside patient bathrooms (eg, toilets, floors, soap dispensers), and on medical instruments (eg, blood pressure cuffs, suctioning systems).[7–14] Moreover, the effectiveness of cleaning regimens has been called into question as a number of studies have reported that pathogens remain on hospital surfaces even after they have been disinfected in accordance with recommended protocols.[15–18] Pathogens that survive on

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fomites can subsequently be transferred from contaminated surfaces to patients through direct contact, indirect contact through the hands and gloves of health care workers, or by aerosolization of surface particles.[8,11,19–21]

Patients hospitalized with infections frequently contaminate their surrounding environments with pathogenic organisms; therefore, roommates and previous room occupants may serve as potential sources of exposure to other patients.[8,22] Yet, our understanding of how such exposures contribute to a patient's overall risk of infection remains limited, and the effects of these exposures may be dependent on a variety of factors unique to each organism species, such as their robustness to atmospheric conditions, susceptibility to cleaning agents, and virulence. Therefore, the aim of this study was to systematically review the literature describing organism transmission from concurrent roommates or previous room occupants in health care settings.

Methods

Inclusion criteria

This systematic literature review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.[23] Studies were included if they met the following criteria: 1) compared infection and/or colonization rates between patients known to be exposed to infectious roommates and/or prior room occupants and patients not known to be exposed, 2) were conducted in an acute or long-term health care setting, 3) were original research studies, 4) were published in English, and 5) were published from January 1, 1990 through December 31, 2014.

Search strategy

The literature search was conducted in February 2015 to ensure that all manuscripts published within the inclusion period had been indexed. All databases indexed within PubMed were searched using the following combination of keywords and Medical Subject Heading (MeSH) search terms linked with Boolean operators: ([MeSH {Patients' Rooms}] AND [MeSH {Infection Control Practitioners} OR MeSH {Infection Control} OR MeSH {Cross Infection} OR MeSH {Infection} OR MeSH {Wound Infection} OR MeSH {Surgical Wound Infection} OR Keyword {Infection}]) OR (Keyword [Prior Room Occupant*]) OR (Keyword [Roommate] AND Keyword [Transmission] OR Keyword [Infection*] OR Keyword [Outbreak*]).

Article selection, review, and quality scoring

Three reviewers (BC, CCC, and BL) independently assessed each article at all stages of the review and quality scoring processes. Discrepancies among reviewers were discussed as a group until a consensus was reached. First, the reviewers screened the titles and abstracts of all articles and eliminated those that were not relevant to the aims of the review. The remaining articles underwent full-text review to determine whether they met the inclusion criteria. A hand search of the references of all articles meeting the inclusion criteria was also performed. Articles meeting the inclusion criteria were scored according to a modified 20-item version of the Checklist for Measuring Study Quality developed by Downs and Black (Table 1).[24] Some measures were not applicable to all articles; these items were removed from the score denominator and not assessed for studies in which they were not relevant. Final scores were converted to percentages.

Results

The database search returned 330 articles. No additional articles were identified from the hand search and no duplicates were found. Twenty articles were excluded during the title screening phase, and 223 articles were excluded during the abstract screening phase. The remaining 87 articles underwent full-text review, and 18 of these were determined to meet the inclusion criteria. Figure 1 describes the reasons for exclusion during the full-text review. Ten articles investigated the effects of exposure to infected or colonized roommates,[25–34] six investigated the effects of exposure to infected or colonized prior room occupants,[35–40] and two investigated both exposures.[41,42]

Study designs and definitions of exposures and outcomes

The articles in this review represent a range of observational and interventional designs, including retrospective and prospective cohort studies (n=11),[26,28–32,35,38–40,42] case–control studies (n=4),[25,27,33,34] and quasi-experimental studies (n=3).[36,37,41] The studies varied considerably in their definitions of exposure and outcome measures. Among studies that examined exposure to roommates with nonviral pathogens, four (44%) defined the exposure as having a roommate with a clinical infection[25–27,42] and five (56%) defined the exposure as having a roommate who was either infected or colonized.[31–34,41] Among studies that examined exposure to

Table 1 Assessment of study quality

Quality measure[a]	Yes (%)	No (%)	Cannot determine	Not applicable
1. Is the hypothesis/aim/objective of the study clearly described? Population, intervention or exposure, and outcome included? Yes=1; No=0 Note: Score may be based on study's main aim	18 (100)	0	0	0
2. Are the main outcomes to be measured clearly described in the introduction or methods section? Enough information provided to replicate study? Yes=1; No=0	17 (94)	1 (6)	0	0
3. Are the characteristics of the patients included in the study clearly described? General patient population and inclusion/exclusion criteria described? Yes=1; No=0 Note: Descriptive statistics not required	18 (100)	0	0	0
4. Is exposure of interest clearly described? Enough information provided to replicate study? Yes=1; No=0 Note: Score based on exposure of interest (ie, prior room occupant and/or roommate infection status)	15 (83)	3 (17)	0	0
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described? Most clinically relevant characteristics described=2; only a few general patient characteristics described=1; no characteristics described=0	Most described: 13 (72) Few described: 3 (17)	0	0	0
6. Are the main findings of the study clearly described? Results presented for all proposed analyses and outcome measures? Yes=1; No=0	18 (100)	0	0	0
7. Does the study provide estimates of the random variability in the data for the main outcomes? Confidence intervals, *p*-values, or other measures of standard error included? Yes=1; No=0 Note: Score based on analyses for roommate and/or prior room occupant exposures	18 (100)	0	0	0
8. Have the characteristics of patients lost to follow-up been described? If loss to follow-up is implied, are patients described or compared to those who participated? Yes=1; No=0 Note: If loss to follow-up not mentioned by authors, item scored as "not applicable" and removed from denominator	2 (11)	0	0	16 (89%)
9. Have actual probability values been reported for the main outcomes except where $p<0.001$? Yes=1; No=0	18 (100)	0	0	0
10. Were patients selected in a way that is representative of the source population the authors identified in the inclusion/exclusion criteria? All patients identified in the source population included=1; certain patients included in the source population systematically excluded (eg, patients who died, were transferred, refused participation, etc)=0 Note: Zero was scored if authors did not provide enough information to determine representativeness	16 (89)	0	2 (11%)	0
11. Were the staff, places, and facilities where the patients were treated representative of the treatment the majority of patients receive? Facility similar to other institutions of the same type? Yes=1; No=0 Note: Zero was scored if authors did not provide enough information to determine representativeness	17 (94)	0	1 (6%)	0
12. If any of the results of the study were based on "data dredging", was this made clear? All subgroup analyses described in methods section or noted as post hoc analyses=1; unplanned subgroup analyses presented and not noted as post hoc=0 Note: If study included no subgroup analyses, item scored as "not applicable" and removed from denominator	0	0	2 (11%)	16 (89%)

(*Continued*)

Table 1 (Continued)

Quality measure[a]	Yes (%)	No (%)	Cannot determine	Not applicable
13. Do the analyses adjust for different lengths of follow-up of patients, or in case–control studies, is the time period between the intervention and outcome the same for cases and controls? If follow-up is differential between groups, was this controlled for in the design or analysis? Yes=1; No=0 Note: If follow-up is same for all patients, item scored as "not applicable" and removed from denominator	8 (44)	6 (33)	0	4 (22%)
14. Were the statistical tests used to assess the main outcomes appropriate? Statistical tests minimally appropriate for the data and research questions? Yes=1; No=0	15 (83)	3 (17)	0	0
15. Were the main outcome measures used valid and reliable? Systematic, repeatable methods of case finding and appropriate lab definitions used? Yes=1; No=0 Note: Zero was scored if authors did not provide enough information to assess outcome measures	16 (89)	1 (6)	0	1 (6%)
16. Were the patients in different intervention groups or cases and controls recruited from the same population? Yes=1; No=0	18 (100)	0	0	0
17. Were the study subjects in different intervention groups or cases and controls recruited over the same period of time? Yes=1; No=0	18 (100)	0	0	0
18. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? Key confounders included in multivariable models? Yes=1; No=0 Note: Score based on exposure of interest (ie, prior room occupant and/or roommate infection status)	9 (50)	6 (33)	3 (17%)	0
19. Were losses of patients to follow-up taken into account? If loss to follow-up is reported, is an appropriate statistical method used to account for this? Yes=1; No=0 Note: If no loss to follow-up is reported, item scored as "not applicable" and removed from denominator. Zero was scored if authors did not provide enough information to assess loss to follow-up	1 (6)	1 (6)	16 (89%)	0
20. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is <5%? Power calculation included and adequate power reported=1; power calculation included and inadequate power reported or no power calculation mentioned=0 Note: Score based on exposure of interest (ie, prior room occupant and/or roommate infection status). Zero was scored if authors did not provide enough information to assess power	0	4 (22)	14 (78%)	0

Note: [a]Data collection tool from Downs and Black.[24]

previous room occupants, there was variation both in the determination of whether a previous occupant was infectious and in the timeframe during which they occupied the room. Four studies (50%) defined the exposure as a previous occupant who was infected or colonized,[35,38,39,41] two studies (25%) – both of *Clostridium difficile* – defined the exposure as a previous occupant with a history of infection,[40,41] and two studies (25%) did not specify.[36,37]

With regard to timing of the exposure, most of the studies implied that only the occupant immediately prior to the study subject was included, although only three articles stated this explicitly.[35,37,40] One study also analyzed exposure to any infectious patient who had occupied the same room within the previous 2-week period.[37] Finally, there was notable variation in the definition of study outcomes. Half of the articles used an outcome measure of infection,[25–30,32,40,42] while the other half used an outcome measure of infection or colonization.[31,33–39,41] Methods of case detection ranged from universal screening to sampling based on clinical indication.

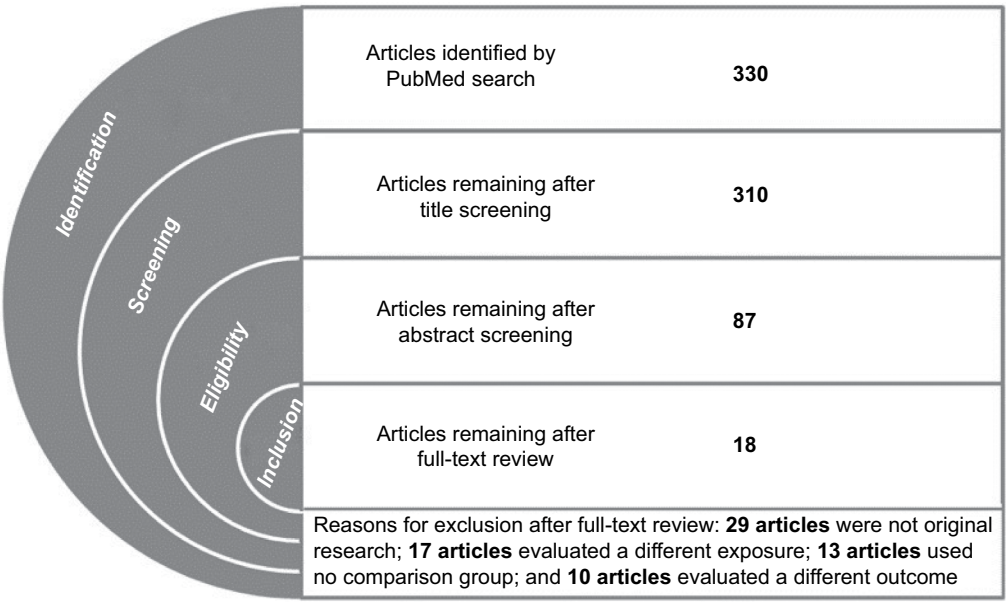

Figure 1 Identification, screening, eligibility, and inclusion of articles according to the PRISMA guidelines.
Notes: Three hundred and thirty articles were identified by database search and no additional records were identified from other sources. No duplicates were identified.
Abbreviation: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Findings of studies examining exposure to infected or colonized roommates

The 12 articles investigating the effects of exposure to infected or colonized roommates are described in Table 2 and their findings are summarized in Figure 2. Five studies evaluated bacterial pathogens that are transmitted by contact.[31,33,34,41,42] No significant associations between roommate exposure and infection with methicillin-resistant *Staphylococcus aureus* (MRSA), *C. difficile*, or *Pseudomonas cepacia* were identified.[31,33,42] Results for vancomycin-resistant enterococci (VRE) were inconsistent, with Bass et al[41] reporting a statistically significant positive association (hazard ratio [HR]: 18.8, 95% confidence interval: [5.4–66.2]) and Shorman and Al-Tawfiq[34] reporting a statistically significant negative association (odds ratio [OR]: 0.04 [0.004–0.4]).

Three studies conducted in long-term care settings examined group A streptococcus, which is transmitted by contact and droplet routes.[25,27,32] All three found significant positive associations between roommate exposure and infection, with ORs ranging from 2.0 (1.1–5.1) to 15.3 (2.5–110.9; point estimate not reported by Auerbach et al[25]).

Three studies examined exposure to roommates infected with viral pathogens.[28–30] Two studies of influenza conducted within the same long-term care facility found significantly elevated risks of infection among those with infected roommates (relative risk: 3.1 [1.6–5.8] for influenza A and relative risk: 2.6 [1.2–5.6] for influenza B).[28,29] One study evaluated transmission of hepatitis C, a viral bloodborne pathogen, in a liver transplant ward of an acute care hospital and found significantly increased odds of infection after sharing a room with an infected patient (OR: 12.0 [1.4–103.0]).[30] One parasitic pathogen spread by fecal–oral contact, *Cryptosporidium parvum*, was evaluated in an acute care human immunodeficiency virus ward and no association was found.[26]

Findings of studies examining exposure to rooms previously occupied by infected or colonized patients

The eight articles investigating the effects of exposure to rooms previously occupied by infected or colonized patients are described in Table 3 and their findings are summarized in Figure 3. All of the articles studied bacterial pathogens spread through contact transmission in acute care hospitals, with all but two[41,42] taking place in intensive care units. Nseir et al[39] found that exposure to rooms previously occupied by patients with *Acinetobacter baumannii* and *Pseudomonas aeruginosa* resulted in significantly higher odds of infection or colonization (OR: 4.2 [2.0–8.8] and OR: 2.3 [1.2–4.3], respectively), while the two studies that examined extended-spectrum beta-lactamase-producing gram-negative organisms found no association.[35,39] Effects of exposure to rooms previously occupied by patients with *C. difficile*, MRSA, and VRE were examined by at least two studies each. For each of these organisms, significant

Table 2 Summary and quality assessment of studies reporting associations between health care-associated infection and exposure to infected or colonized roommates

Author, quality score	Study period	Setting	Design	Subjects
Auerbach et al[25] Score: 83%	August 1989–February 1990	50-bed nursing home, North Carolina	Outbreak investigation and case–control	All residents who underwent diagnostic testing for GAS, excluding those who died from causes other than GAS
Bass et al[41] Score: 83%	March 2010–October 2010	34-bed hematology–oncology ward in 427-bed tertiary care teaching hospital, Melbourne, Australia	Quasi-experimental	All pts w/neg VRE rectal swab upon admission and no known history of VRE
Bruce et al[26] Score: 50%	August 1994–October 1996	Special Immunity Service ward for HIV-pos pts, Grady Memorial Hospital	Retrospective cohort	Exposed: all roommates of pts w/ *Cryptosporidium* stool sample and no prior history; unexposed: roommates of pts w/o *Cryptosporidium* matched by nearest CD4 count and hospitalization date
Chang and Nelson[42] Score: 94%	March 1987–August 1987	305-bed community hospital, Baltimore, MD	Retrospective cohort	All pts w/LOS >48 h
Deutscher et al[27] Score: 89%	October 2007–February 2008	57-bed long-term acute care hospital, New Mexico	Case–control	Cases: all pts w/incident GAS infection >48 h after admission; controls: randomly selected pts w/o GAS symptoms or cultures
Drinka et al[28] Score: 72%	1993–2000	Wisconsin Veterans Home, a 635-bed skilled nursing facility	Retrospective cohort	All residents
Drinka et al[29] Score: 76%	1992–1993 influenza season	Wisconsin Veterans Home, a 635-bed skilled nursing facility	Retrospective cohort	All residents
Forns et al[30] Score: 80%	August 2000–October 2002	Three-ward liver unit in tertiary care center	Prospective cohort	All pts w/neg anti-HCV screen upon ward admission
Furuno et al[31] Score: 95%	March 2005–September 2008	120-bed Baltimore Rehabilitation and Extended Care Center, 150-bed Perry Point VA Medical Center, 180-bed University Specialty Hospital, Maryland	Prospective cohort	All residents w/o history of MRSA colonization, ≥1 neg MRSA screen from anterior nares or skin breakdown at enrollment, LOS >7 days, and ≥1 follow-up culture
Greene et al[32] Score: 78%	January 2001–December 2001	120-bed long-term care facility, Georgia	Retrospective cohort	All residents
Pegues et al[33] Score: 72%	August 1989–September 1989	St Christopher's Hospital for Children, a 350-bed pediatric referral center, Philadelphia, PA	Case–control	Cases: CF pts w/initial isolation of *Pseudomonas cepacia* from respiratory secretions; controls: randomly selected CF pts w/neg *P. cepacia* sputum cultures
Shorman and Al-Tawfiq[34] Score: 76%	February 2006–March 2010	Tertiary care referral hospital, Damman, Saudi Arabia	Case–control	Cases: pts w/pos surveillance or clinical VRE cultures; controls: randomly selected pts w/neg clinical or surveillance VRE cultures

Abbreviations: BMI, body mass index; CF, cystic fibrosis; CHF, congestive heart failure; GAS, group A streptococcus; HCV, hepatitis C virus; HIV, human immunodeficiency virus; HR, hazard ratio; LOS, length of stay; MRSA, methicillin-resistant *Staphylococcus aureus;* neg, negative; OR, odds ratio; pos, positive; *P. cepacia, Pseudomonas cepacia*; pts, patients; PVD, peripheral vascular disease; RR, relative risk; VRE, vancomycin-resistant enterococci; w/, with; w/o, without.

N	Outcome	Exposure	Analysis	Results
37 roommate pairs	Symptomatic or asymptomatic GAS infection detected by culture or serology	Roommate w/symptomatic or asymptomatic GAS infection	Two-tailed Fisher's exact test	26 pairs concordant uninfected, 6 concordant infected, 5 pairs discordant p=0.0009
439 pts	Incident VRE colonization detected by rectal surveillance culture	Roommate w/VRE infection or colonization	Cox proportional hazard adjusted for prior bed occupant status and study intervention phase	HR: 18.8 (5.4–66.2)
74 pts (37 exposed, 37 unexposed)	Incident cryptosporidiosis	Roommate w/cryptosporidiosis	Unadjusted RR	RR undefined (one case in unexposed roommates, zero cases in exposed roommates)
2,859 pts	Incident *Clostridium difficile* diarrhea >48 h after admission and within 15 days of discharge	Roommate w/*C. difficile* diarrhea	Unadjusted RR	RR: 2.7 (0.6–7.0)
50 residents (11 cases, 39 controls)	Incident GAS infection >48 h after admission	Roommate w/GAS infection or colonization	Logistic regression adjusted for age, sex, BMI, death, admission to special care unit, LOS >4 weeks, admission from home, *C. difficile*, diabetes, CHF, hypertension, PVD, chronic renal failure/dialysis, malignancy, ventilator, cellulitis, nonsurgical wound, neg pressure	OR: 15.3 (2.5–110.9)
3,294 resident-seasons	Culture confirmed influenza A infection	Roommate w/pos influenza A culture	Unadjusted RR comparing exposed to pos roommate versus single room	RR: 3.1 (1.6–5.8)
489 resident-seasons	Culture confirmed influenza B infection	Roommate w/pos influenza B culture	Unadjusted RR comparing exposed to pos roommate versus single room	RR: 2.6 (1.2–5.6)
1,301 pts	Incident HCV infection assessed 6 months postdischarge	Roommate w/HCV infection	Unadjusted OR	OR: 12.0 (1.4–103.0)
Residential care: 286; rehabilitation care:157 residents	Incident MRSA colonization in anterior nares or site of skin breakdown	Roommate w/MRSA colonization	Residential care: Cox proportional hazard adjusted for antibiotic therapy and bedbound status; rehabilitation care: Cox proportional hazard HR adjusted for bedbound status and limited mobility status	Residential care HR: 1.4 (0.5–3.9); rehabilitation care HR: 0.5 (0.1–2.2)
125 residents	GAS infection or colonization	Roommate w/GAS colonization or infection	Unadjusted and Mantel–Haenszel RR (variables included in multivariable not described)	Adjusted RR: 2.0 (1.1–5.1); unadjusted RR: 2.1 (1.1–4.0)
28 pts (14 cases, 14 controls)	Pos *P. cepacea* culture in pts hospitalized ≥1 time between last neg and first pos culture	Roommate w/pos *P. cepacea* culture	Unadjusted OR	OR: 12.5 (0.6–607.0)
90 pts (30 cases, 60 controls)	VRE colonization or infection	Roommate with VRE infection or colonization	Unadjusted OR	OR: 0.04 (0.004–0.4)

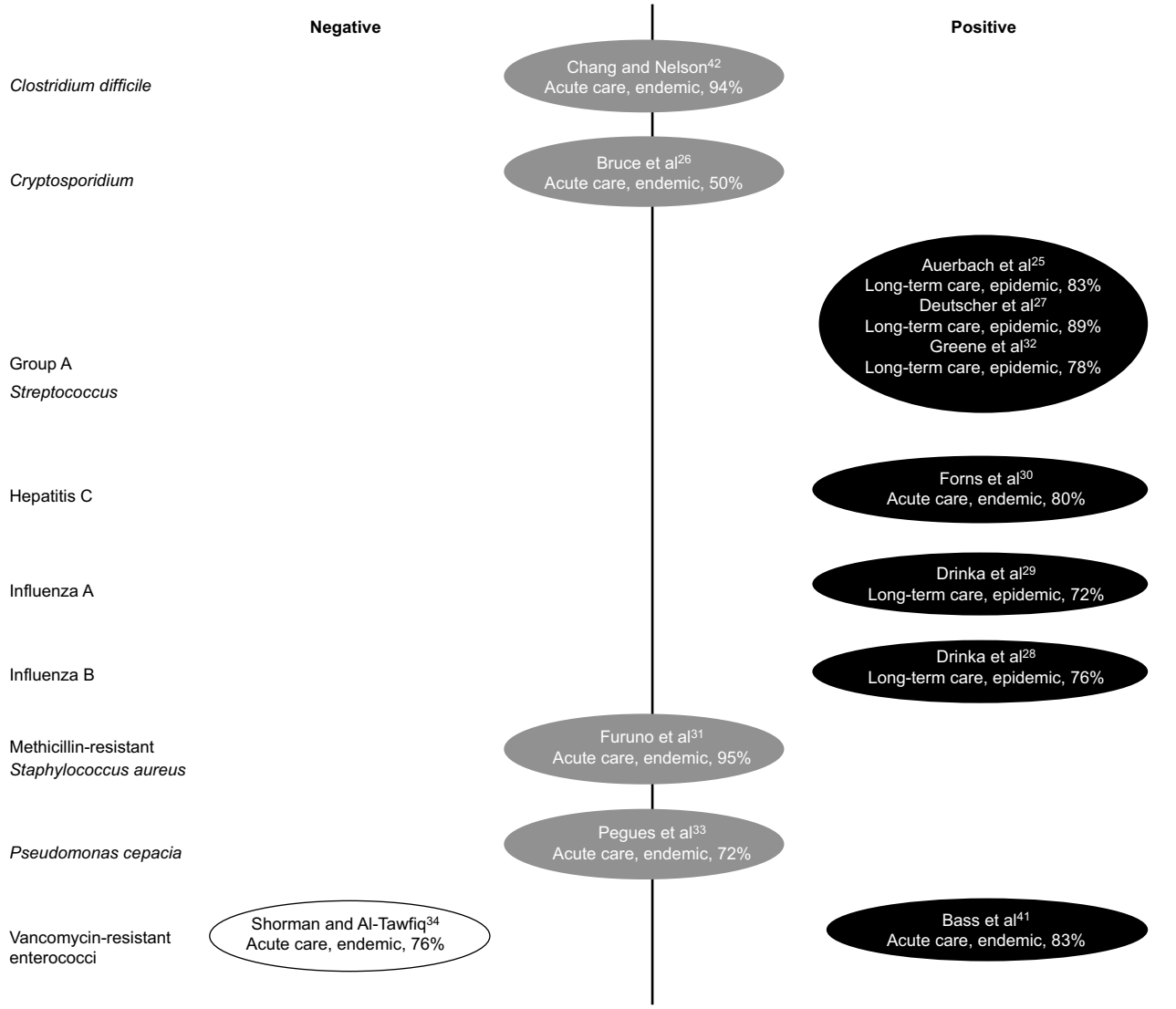

Figure 2 Findings of studies investigating the association between health care-associated infection or colonization and exposure to infected or colonized roommates.
Notes: Studies reporting significant positive associations are represented in black circles and those reporting significant negative associations are represented in white circles. Studies that did not find statistically significant associations are represented in gray circles. Circles display study authors, setting, investigation of endemic versus epidemic pathogen, and quality score.

positive associations were reported by one article (*C. difficile*, HR: 2.4 [1.2–4.5];[40] MRSA, OR: 1.4 [p=0.04];[36] VRE, HR: 3.8 [2.0–7.4][37]), with the remainder of articles finding no significant associations.[38,41,42]

Quality of included articles

Quality scores ranged from 50% to 95%, with the majority of articles scoring at or above 80% (median=83%, mean=82%). Table 1 provides a summary of scores for each item. All of the articles had clearly stated aims, adequate descriptions of study populations, appropriate control groups, and acceptable reporting of results. However, many of the studies did not appropriately control for confounding (50%, n=9), address differential follow-up between exposed and unexposed patients (33%, n=6), or use acceptable statistical methods (17%, n=3). In addition, some articles did not include sufficient or precise definitions of the exposures (17%, n=3) or outcomes (6%, n=1) under investigation. Notably, none of the articles reported a sample size calculation indicating adequate power to detect differences between patients exposed versus unexposed to infected/colonized roommates or prior room occupants.

Discussion

More than half of the articles identified in this systematic literature review reported at least one statistically significant

positive association between the infection/colonization status of a roommate or previous room occupant and the development of HAIs.[25,27–30,32,36,37,39–41] Only a single article identified a statistically significant negative association.[34] The remainder found no associations that reached statistical significance, though this may be due to the fact that they were insufficiently powered; none of the articles reviewed included a statement indicating that statistical power was adequate for the analyses presented. Another factor that may have contributed to findings of no association is that many studies included patients who were either infected or colonized as potential sources of exposure. Patients with symptomatic infections may shed greater amounts of infectious body fluids to surrounding fomites, compared with patients who are asymptomatically colonized.[43] Therefore, if a causal association does indeed exist, including both infected and colonized patients as potential sources of exposure may have driven findings toward the null, since exposure to colonized roommates and prior room occupants could present less risk to patients. Heterogeneity of the exposure may have also arisen from variation in the infection or colonization site of a roommate or prior room occupant. In a study of patients with MRSA, environmental contamination was more prevalent on fomites surrounding patients with positive wound or urine cultures, compared with patients who had positive blood or sputum cultures.[8]

The studies we reviewed revealed consistent findings for some pathogens (influenza, group A streptococcus) and inconsistent findings for others (VRE, MRSA, *C. difficile*). For endemic health care pathogens such as VRE, MRSA, and *C. difficile*, it may be difficult to isolate the effects of roommates and previous room occupants, since the exposure and outcome are common and may originate from multiple sources.[44] On the contrary, pathogens such as influenza and group A streptococcus are more commonly associated with outbreak scenarios, making it easier to single out the effects of particular exposures.[45] Other factors that may have contributed to inconsistent findings across studies are variations in how exposures and outcomes were defined and operationalized (eg, differences in case definitions, case finding methods, and timing of exposure).

While the inconsistency of findings for some of the organisms could be due to artifact, there may nevertheless be real differences in the effects of roommate and prior room occupant exposure based on the biologic characteristics of the infecting species. Microorganisms vary in their abilities to produce spores and survive changes to atmospheric temperature and moisture conditions.[46] In addition, some organisms favor specific sites of colonization or infection that may produce greater shedding of infectious material and higher potential for environmental contamination.[46] For example, a study of multidrug-resistant pathogens found that environmental contamination was more common surrounding patients with gram-positive versus gram-negative infections.[22] Furthermore, organism species differ in their resiliency to withstand cleaning agents and methods.[47,48]

The preponderance of evidence presented in this review suggests that there is a link between exposure to infected or colonized roommates and previous room occupants and the risk of HAIs. These findings present a number of practice and policy implications. First, the fact that patient rooms may serve as a reservoir for pathogens deposited by roommates and previous occupants highlights the importance of proper hand hygiene, not just for staff but for competent patients and their visitors as well.[49] To underscore this point, a molecular typing study demonstrated that 12% of patients who became newly colonized with MRSA while in the intensive care unit acquired a strain that most probably came from contamination in their immediate environment.[13] Second, these results emphasize the need for improved cleaning and disinfection of patient rooms, both during patients' hospital stays and upon their discharge. For patients with known infection or colonization, targeted daily and terminal cleaning procedures that are tailored to specific organisms may reduce environmental contamination and infection rates.[50] Enhancement of routine cleaning measures should not be limited to patients with known infection or colonization, however, since patients may contaminate their environments during incubation periods before the infections are detected or when colonization is not detected through active surveillance.

There were some limitations to this systematic review. It is possible that some studies which would have met the inclusion criteria were not identified. Only databases indexed in PubMed were included, so any unpublished reports and other gray literature would not have been detected by our search. Similarly, studies that found significant positive associations may have been more likely to appear in the literature due to publication bias. Our restriction to articles published in English may have also excluded some relevant papers. While a major strength of this study is its coverage of two and a half decades of literature, changes in the epidemiology of HAIs, infection control policies and procedures, and study methodology over time may have introduced some variability to the studies we reviewed. Lastly, we were unable to conduct a meta-analysis or provide a funnel plot because the studies assessed a wide variety of outcomes.

Table 3 Summary and quality assessment of studies reporting associations between health care-associated infection and exposure to infected or colonized prior room occupants

Author, quality score	Study period	Setting	Design	Subjects	N
Ajao et al[35] Score: 94%	September 2001–June 2009	Medical and surgical ICUs in University of Maryland Medical Center	Retrospective cohort	All pts ≥18 years w/o ESBL at hospital admission, neg ESBL screen at ICU admission, and ICU stay ≥48 h	9,371 admissions (7,651 unique pts)
Bass et al[41] Score: 83%	March 2010–October 2010	34-bed hematology–oncology ward in 427-bed tertiary care teaching hospital, Melbourne, Australia	Quasi-experimental	All pts w/neg VRE rectal swab upon admission and no known history of VRE	439 pts
Chang and Nelson[42] Score: 94%	March 1987–August 1987	305-bed community hospital, Baltimore, MD	Retrospective cohort	All pts w/LOS >48 h	2,859 pts
Datta et al[36] Score: 78%	September 2003–April 2005 and September 2006–April 2008	ICUs in 750-bed academic medical center	Quasi-experimental	All pts w/neg MRSA and/or VRE screening culture prior to ICU admission	MRSA: 16,345 pts (7,629 baseline, 8,716 intervention); VRE: 16,630 pts (7,806 baseline, 8,824 intervention)
Drees et al[37] Score: 94%	February 2002–March 2003	Medical and surgical ICUs, Tufts-New England Medical Center, Boston, MA	Prospective interventional crossover	All pts in ICU ≥48 h w/neg VRE screens within first 48 h of ICU admission and no known history of VRE	638 pts
Huang et al[38] Score: 94%	September 2003–April 2005	Eight adult ICUs, Brigham and Women's Hospital, Boston, MA	Retrospective cohort	All pts w/o pos MRSA or VRE surveillance cultures within 2 days of ICU admission	MRSA: 7,629 pts; VRE: 7,806 pts
Nseir et al[39] Score: 89%	December 2006–December 2007	30-bed medical/surgical ICU	Prospective cohort	All pts in ICU >48 h w/ neg MDR GNB screen at admission	511 pts
Shaughnessy et al[40] Score: 94%	January 2005–June 2006	20-bed ICU in 809-bed tertiary care hospital	Retrospective cohort	All pts w/o *Clostridium difficile* diagnosis in previous 3 months	1,770 pts

Abbreviations: APACHE II, acute physiology and chronic health evaluation II; ESBL, extended-spectrum beta-lactamase–producing organism; GLM, generalized linear mixed model; GNB, Gram-negative bacteria; HR, hazard ratio; ICU, intensive care unit; LOD, logistic organ dysfunction score; LOS, length of stay; MDR, multidrug resistant; MRSA, methicillin-resistant *Staphylococcus aureus*; neg, negative; OR, odds ratio; pts, patients; pos, positive; RR, relative risk; SAPS II, simplified acute physiology score II; VRE, vancomycin-resistant enterococci; w/, with; w/o, without.

Outcome	Exposure	Analysis	Results
Acquisition of ESBL-producing pathogen during ICU stay detected by clinical or surveillance culture	Immediate prior room occupant w/pos clinical or surveillance ESBL culture	Logistic regression adjusted for colonization pressure, renal disease, anti-MRSA, and anti-pseudomonal beta-lactam therapies	Unadjusted OR: 1.9 (1.3–2.7); adjusted OR: 1.4 (0.9–2.1)
Incident VRE colonization detected by rectal surveillance culture	Prior bed occupant w/ VRE colonization or infection	Cox proportional hazard adjusted for roommate status and study intervention phase	HR: 0.4 (0.1–1.2)
Incident *C. difficile* diarrhea >48 h after admission and within 15 days of discharge	Prior room occupant with *C. difficile* or roommate with prior *C. difficile* infection who is no longer symptomatic	Unadjusted RR	RR: 1.2 (0.3–3.4)
Incident MRSA or VRE acquisition	Prior room occupant	GLM adjusted for age, sex, pre-ICU LOS, prior occupant LOS, duration of room vacancy, clustering by ward, diabetes, end-stage renal and liver diseases, malignancies, immunocompromised status	MRSA: baseline OR: 1.4 (p=0.04), intervention OR: 1.1 (p=0.66); VRE: baseline OR: 1.4 (p=0.02), intervention OR: 1.4 (p=0.04)
Acquisition of VRE during ICU stay detected by surveillance culture	Prior room occupant (immediate and within previous 2 weeks)	HR adjusting for average colonization pressure and mean antibiotics per day	Immediate prior occupant HR: 3.8 (2.0–7.4); prior occupant within 2 weeks HR: 2.7 (1.4–5.3)
Acquisition of MRSA or VRE	Prior room occupant with MRSA or VRE colonization or infection	GLM accounting for clustering within ICUs and controlling for age, sex, LOS before ICU admission, prior occupant LOS, duration of room vacancy before occupancy, diabetes, end-stage renal and liver diseases, noncancer immunocompromised state, and malignancies	MRSA OR:1.4 (1.0–1.8); VRE OR: 1.4 (1.0–1.9)
Acquisition of *Pseudomonas aeruginosa* resistant to ceftazidime or imipenem, *Acinetobacter baumannii*, or ESBL-producing GNB	Prior room occupant w/pos MDR GNB screening or diagnostic culture	Logistic regression: MDR *P. aeruginosa* model adjusted for age, SAPS II, LOD, transfer from other wards, LOS prior to ICU admission, prior antibiotics, room occupancy rate, central venous, arterial, and urinary catheters, tracheostomy, sedation, percentage of days in the ICU with amoxicillin–clavulanate acid, piperacillin–tazobactam, fourth-generation cephalosporins, carbapenems, fluoroquinolones, aminoglycosides, mechanical ventilation, and LOS in ICU; *A. baumannii* model adjusted for SAPS II, LOD, admission type, prior antibiotics, colonization pressure, central venous, arterial and, urinary catheters, sedation, percentage of days in ICU with piperacillin–tazobactam, fourth-generation cephalosporins, and fluoroquinolones	MDR *P. aeruginosa* OR: 2.3 (1.2–4.3); *A. baumannii* OR: 4.2 (2.0–8.8); ESBL-producing GNB OR: 1.5 (0.6–3.5) Note: multivariable results not reported
Incident *C. difficile* infection >48 h after ICU admission and within 30 days of ICU discharge	Immediate prior room occupant w/history of pos *C. difficile* toxin results within 30 days prior to current occupant's ICU admission	Adjusted HR controlling for age, APACHE II, proton pump inhibitor, and exposure to antibiotics	HR: 2.4 (1.2–4.5)

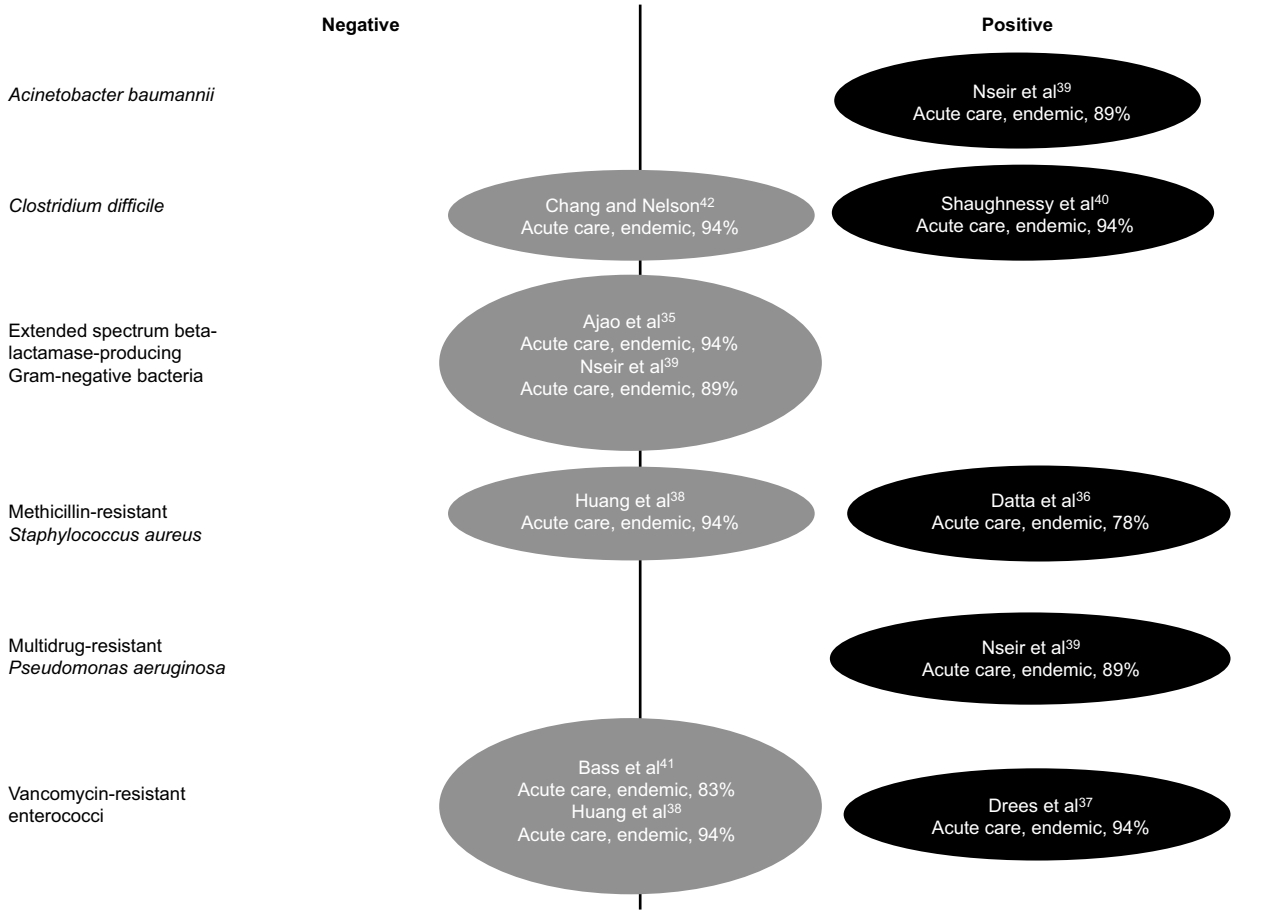

Figure 3 Findings of studies investigating the association between health care-associated infection or colonization and exposure to infected or colonized prior room occupants.
Notes: Studies reporting significant positive associations are represented in black circles. Studies that did not find statistically significant associations are represented in gray circles. No studies reported a significant negative association. Circles display study authors, setting, investigation of endemic versus epidemic pathogen, and quality score.

Notwithstanding these limitations, it is notable that the studies which reported significant findings were conducted across a range of institutions in several different countries across multiple decades. Presumably, the diverse study facilities employed a variety of cleaning products, methods, and infection control policies. Despite possible variations in practice, exposure to roommates and prior room occupants may have played a role in infection outcomes. Several gaps in the literature remain, however, specifically with regard to organisms that are endemic in health care settings and, therefore, difficult to associate with specific sources of exposure. The use of molecular typing would provide more definitive evidence concerning the role of roommates and prior room occupants in the epidemiology of HAIs.

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Disclosure

The authors report no conflicts of interest in this work.

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