review article

Influence of Staff Behavior on Infectious Risk in Operating Rooms: What Is the Evidence?

Gabriel Birgand, PharmD, PhD;[1,2,3] Philippe Saliou, MD;[4] Jean-Christophe Lucet, MD, PhD[1,2,3]

summary. A systematic literature review was performed to assess the impact of surgical-staff behaviors on the risk of surgical site infections. Published data are limited, heterogeneous, and weakened by several methodological flaws, underlying the need for more studies with accurate tools.

objective. To assess the current literature regarding the impact of surgical-staff behaviors on the risk of surgical-site infection (SSI).

design. Systematic literature review.

methods. We searched the Medline, EMBASE, Ovid, Web of Science, and Cochrane databases for original articles about the impact of intraoperative behaviors on the risk of SSI published in English before September 2013.

results. We retrieved 27 original articles reporting data on number of people in the operating room (n = 14), door openings (n = 14; number [n = 6], frequency [n = 7], reasons [n = 4], or duration [n = 3]), surgical-team discipline (evidence of distraction; n = 4), compliance with traffic measures (n = 6), or simulated behaviors (n = 3). Most (59%) articles were published in 2009–2013. End points were the 30-day SSI rate (n = 8), air-particle count (n = 2), or microbiological air counts (n = 6); 11 studies were only descriptive. Number of people in the operating room and SSI rate or airborne contaminants (particle/bacteria) were correlated in 2 studies. Door openings and airborne bacteria counts were correlated in 2 observational studies and 1 experimental study. Two cohort studies showed a significant association between surgeon interruptions/distraction or noise and SSI rate. The level of evidence was low in all studies.

conclusions. Published data about the impact of operating-room behaviors on the risk of infection are limited and heterogeneous. All studies exhibit major methodological flaws. More studies with accurate tools should be performed to address the influence of operating room behaviors on the infectious risk.

Infect Control Hosp Epidemiol 2015;36(1):93–106

introduction

Surgical-site infections (SSIs) account for 14% to 20% of all healthcare-associated infections[1,2] and result in significant morbidity and mortality. SSIs were associated with a 2- to 11-fold increase in the risk of death.[3,4] Among patients with SSIs, the risk of death directly attributable to the infection varied from 33% to 77%.[5,6] In recent studies, the increase in hospital-stay length associated with SSIs ranged from 3.3 days after abdominal hysterectomy to 21 days after limb amputation, and the increase in mean cost per admission varied from 1000 € to 8000 €.[7,8]

Risk factors for SSIs fall into 3 main categories: patient-related characteristics such as age, diabetes mellitus, obesity, and other comorbidities; characteristics of the surgical procedure including contamination class, operative time, surgeon skill, prophylactic antibiotic therapy, and hypothermia control; and operating room (OR) environment. Surgical-site contamination is believed to occur chiefly during the perioperative phase, with the main sources of microorganisms being the patient's gastrointestinal and respiratory tracts and skin. Microorganisms may also originate from the OR staff or OR environment, although the transmission mechanisms remain unclear.[9–11]

Each individual naturally produces airborne particles, which can carry microorganisms. The number of airborne particles produced per person has been estimated at 100,000 per minute at rest and up to 30,000,000 during exertion.[12] A correlation between air contamination with microorganisms and wound contamination after total hip or knee surgery was reported in 1982.[13] More recently, proof was obtained that surgical wound contamination by *Staphylococcus aureus* could originate from the OR staff during cardiothoracic surgery.[14,15]

Preventive measures have been widely studied, and several guidelines are available.[6,16,17] These guidelines do not include specific recommendations about OR staff behaviors except for wearing a cap and scrub suit and for hand hygiene practices to decrease the risk of SSI due to exogenous microorganisms.

Affiliations: 1. French Institute of Health and Medical Research (INSERM), Infection, Antimicrobials, Modelling, Evolution (IAME), UMR 1137, F-75018 Paris, France; 2. Université Paris Diderot, IAME, UMR 1137, Sorbonne Paris Cité, F-75018 Paris, France; 3. Assistance publique–Hôpitaux de Paris (AP-HP), Hôpital Bichat, Infection Control Unit, F-75018 Paris, France; 4. Brest Teaching Hospital, Infection Control Unit, Brest, France.

Received June 5, 2014; accepted September 7, 2014

 0899-823X/2015/3601-0014. DOI: 10.1017/ice.2014.9

Restricting OR traffic has been advocated as a means of decreasing air contamination and wound colonization.[6,17,18] However, these recommendations are based on expert advice because no robust scientific evidence is available to substantiate them.

The aim of this study was to assess the current literature regarding the impact of surgical-staff behaviors on the risk of SSI.

METHODS

We followed Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines.[19]

Search Strategy

We conducted a systematic search for original articles in the Medline, EMBASE, Ovid, Web of Science, and Cochrane databases. The last search was run on September 16, 2013. We devised search terms tailored to each database (Appendix 1) that covered the areas of infection control and prevention, behavior, quality of care, SSI, and environmental contamination. We manually searched the issues published within the past 15 years in the following journals: *American Journal of Infection Control*, *Journal of Hospital Infection*, and *Infection Control and Hospital Epidemiology*; together with the abstracts published in these journals in 1999–2001. The references for all selected full-text articles and related reviews were scanned. Only English-language articles were selected. The literature search was performed by 2 authors working independently of each other (G.B. and P.S.).

Study Selection

All surgical procedures on patients of any age were considered. We included all studies that evaluated intraoperative physical OR-staff behaviors—that is, foot traffic, noise, door openings, and number of people in the OR; and intraoperative intangible OR-staff behaviors—that is, safety climate and lapses in discipline such as conversations. We considered both descriptive studies and studies that used an outcome such as the SSI rate or the count of airborne bacteria or particles. We did not include studies that obtained no original data; evaluated only preoperative or postoperative factors; or evaluated only surgical attire, drapes, or aseptic surgical technique.

Quality Criteria

The Integrated Quality Criteria for Systematic Review of Multiple Study Designs (ICROMS) unifies, integrates, and refines quality criteria for quantitative and qualitative studies.[20] We selected 10 ICROMS criteria to assess the quality of the included studies: clear aims and justification, protection against detection bias, reliable primary outcome measure, incomplete outcome data addressed with adequate follow-up, rigorous analysis, absence of selective outcome, limitation addressed, clear and substantiated conclusions, absence of other bias, and ethical issues addressed.

Data Collection Process

Each eligible article was assessed on the basis of the title and abstract then on the basis of the full text evaluated using the quality criteria. Two authors (G.B. and P.S.) independently reviewed the titles and abstracts, and disagreements were resolved by a third person (J.-C.L.). We developed a data extraction form that we tested on 10 randomly selected articles. Data from the included studies were recorded on the form by 2 reviewers (G.B. and P.S.) then subjected to further critical appraisal during a narrative synthesis. Statistical analyses were performed using EpiData, version 3.1 (EpiData Association), and Stata, version 10.0 (StataCorp).

RESULTS

Study Selection (Table 1 and Figure 1)

Our electronic and manual searches identified 2086 articles, of which 202 were preselected on the basis of the title; among them, 137 were excluded on the basis of the abstract, leaving 65 articles, of which 3 were irretrievable. We added 9 articles identified by manually searching the reference lists. Of these 71 articles, 3 were unrelated to OR behavior and 41 did not provide original data, leaving 27 studies for our analysis. The marked heterogeneity in the study objectives and designs precluded a meta-analysis.

Study Characteristics

Of the 27 studies, 9 were published in infection-control journals, 12 in surgery journals, and 6 in quality-of-care or general journals (Table 2). Study dates ranged from 1978 to 2012 and most studies (16/27, 59%) were published during the past 5 years. The studies were performed in Europe (n = 19), North America (n = 5), Asia (n = 1), Australia (n = 1), and both France and Australia (n = 1). The outcomes fell into 5 categories: number of people in the OR (n = 14), door openings (n = 14: number [n = 6], frequency [n = 7], reasons [n = 4], or duration [n = 3]), OR discipline (interruptions/distraction of the surgical team; n = 4), compliance with traffic measures (n = 6), and experimental scenario-based studies (n = 3).

In 16 studies, the end points were the SSI rate (n = 8), air particle count (n = 2), or air bacteria count (n = 7); 11 studies were descriptive with no end point. The studies lasted 2 to 48 months, and most were done at a single center (22/27, 81%). The number of ORs surveyed varied from 1 to 70, with 23 to 3259 surgical procedures. Among the 24 observational studies, 17 collected behaviors by direct observation and 2 used an automatic device to count door openings. Two retrospective studies were based on OR chart review and 3 others on an undescribed data collection process. Study designs were

https://doi.org/10.1017/ice.2014.9 Published online by Cambridge University Press

TABLE 1. Summary of Included Studies Evaluating Intraoperative Staff Behavior and Its Impact on the Risk of Infection

Ref.	Study design	Observation	End point	No. of OR/ procedures	Type of surgery	No./Type of hospital	Results	Conclusion
No. of people in the OR/No. of door openings								
23	CS	Direct	None	3/26	Orthopedic	1/UH	2 phases: 83 and 102 DO/h; NoP, 11 (range, 7–15) and 11 (8–20)	All traffic should be considered essential.
22	CS	Direct	ABC	3/30	Orthopedic	1/UH	Median, 5 (range, 3–10) people. Correlation CFU/m^3 -traffic flow (r = 0.74), CFU/m^3 -NoP (r = 0.22); 32% unnecessary DO	Correlation ABC - DO
29	CS	Direct	None	Unknown /116	Orthopedic	1/UH	DO, 83.2; 41/h; 39/h. vs 50/h. for revisions ($P < 0.01$); 63.1% after skin incision; 47.3% with no reason.	Measures to reduce OR traffic may decrease 1 etiology of SSI.
31	CS	Direct	None	3/7	Orthopedic	3/PuH, PrH	DO, 27 to 169 and 68 to 169 entries/ exits per operation; 26 to 60/h (pediatric)	Theatre traffic can be substantial and need staff education
32	CS	Direct	None	Unknown	Orthopedic	3/PuH, PrH	Mean DO, 25.2/h in PrH to 60/h in pediatrics; Higher in adults	Difference public/private; – 13.5%; – 30% if signalization
24	RC	OR charts	SSI	1/181	Orthopedic	1/UH	NoP and surgeon position increased SSI rate	Impact of the NoP on the air microbial contamination
30	CS	Unknown	ABC	1/49	Orthopedic	1/PuH	Mean DO higher before incision, 26.2/h vs. 15.4/h after; Correlation DO - ABC (r = 0.55)	Close relationship between ABC and DO.
33	PC	Automatic	SSI	2/46	Cardiac	1/PuH	Mean DO: 92.9 (range, 45–205), 19.2 (6.4–38.2)/h, 31 min per case and 10.7% of every hour. Complex procedures ass. with higher DO	Trend toward increased SSI with increased level of DO.
25	CS	Direct	None	Unknown /799	General	49/All types	Mean NoP, 6; DO, 12 (percentile 75 = 15); >50 DO in 3% of operations; NoP higher in teaching hospitals ($P = 0.001$)	Feedback with HCW was an effective instrument to audit infection control practices
27	CS	Direct	None	13/717	General	1/UH	Mean NoP, 6.6 HCW and 3.1 for "clean" team; >90% of interventions with <10 HCW; Doors remained opened >50% of operative time in 36.3%	The no. of surgical personnel present in the OR was that expected for a typical operation in a teaching hospital.
26	CS	Direct	ABC/APC	3/23	Clean/ contaminated	1/UH	NoP at surgical cut, 7 (range, 5–8); DO, 56 (range, 22–97); No correlation; Positive correlation surgical technique/ APC >5 µm but not between NoP/dust level or DO/dust level	DO representing staff movement predicted a decreases APC and a raise of ABC

https://doi.org/10.1017/ice.2014.9 Published online by Cambridge University Press

TABLE 1. *(Continued)*

Ref.	Study design	Observation	End point	No. of OR/ procedures	Type of surgery	No./Type of hospital	Results	Conclusion
34	CS	Direct	None	Unknown /28	Clean/ contaminated	1/UH	DO, 13 to 316, 5 to 87/h; 30% to 50% during pre-incision period; 17% of the operative time; 27%–54% to give/get informations; 37%–57% by circulating nurse	The rate of traffic was remarkably high supporting the need for improvement.
21	RC	OR charts	SSI	Unknown /3259	Clean	1/UH	NoP 0 to 8: 26% SSI rate: 1.5% NoP 13–16: 22.2% → SSI rate: 3.8%	Correlation between NoP and SSI rate
28	CS	Direct	ABC/PC	8/165	Clean/ contaminated	1/UH	Mean NoP, 5 to 7; correlation NoP - PM10 (r = 0.37), NoP - ABC (r = 0.23), ABC - PM10 ($P < 0.01$)	NoP in the OR affect PM10 and APC; the PM level is associated with ABC
Discipline and distractions in the OR								
38	PC	Direct	SSI	Unknown /1032	General	1/UH	Intestinal anastomosis, duration >3 h, lapse in adherence to asepsis associated with increased SSI rate	Surgical team discipline in adhering to principles of asepsis is a risk factor of SSI
39	PC	Automatic	SSI	2/35	Abdominal	1/UH	Median sound levels, 43.5 (range, 26–60) dB in SSI group vs. 25 (range, 25–60) dB ($P = 0.04$)	Association between sound level and SSI
37	CS	Direct	None	1/30	Urology	1/UH	High frequency of distraction/ interruption linked to equipment, procedure and environment problems, telephones, beepers, and conversations.	Useful method for distinguishing normal interference and raising awareness of its origin for postoperative debriefing.
36	CS	Direct	None	1/50	General	1/UH	Mean distraction/interruption, 17/ h; Interference levels (62/h) correlated with DO (41/h) (r = 0.47, $P < 0.001$).	Need to measure interference and effect on surgical team performance.
Checklist, bundles, and compliance with control measures								
42	CS	Direct	None	1/30	Cardiac	1/UH	Compliance, 29%	Poor compliance with room traffic practices
43	CS	Unknown	SSI	2/118	Cardiac	1/UH	Compliance period 1 and 2, 62.5% and 71%, $P = 0.09$	Active monitoring practices resulted in decreased SSI rate
40	CS	Direct	bacteriology cultures	70/ Unknown	General	3/PuH	SSI rate decreased in the checklist group (4% to 3%, $P < 0.05$); no decrease in the control group; Traffic rules poorly followed (25%) especially for anesthetists	The use of detailed checklists and monthly reports was effective in reducing SSI rates.

TABLE 1. *(Continued)*

Ref.	Study design	Observation	End point	No. of OR/ procedures	Type of surgery	No./Type of hospital	Results	Conclusion
41	CS	Direct	SSI	Unknown /100	Vascular	1/UH	Bundle compliance improved from 10% in 2009 to 60% in 2011; DO had the lowest compliance: increase from 30% to 80%	Bundle improved compliance with 51% reduction of SSI rate.
35	CS	Direct	SSI	Unknown /100	Digestive	1/UH	Door movements had the lowest compliance: increase from 30% to 80%	Bundle improved compliance with 36% reduction of SSI rate.
49	CS	Direct	None	92/Unknown	All types	Unknown	38% surgeons, 40% nurses claimed paid little attention to DO and NoP; 62% surgeons, 64% nurses had good practices	Surgeons and nurses paid little attention to intraoperative behaviors
Experimental studies								
44	Sweating surgeon	–	ABC	1/10 simulations	Orthopedic	Unknown	Mean CFU on the operating table, 3.3 in the non-sweating phase vs. 6.9 in the sweating phase ($P < 0.05$)	The sweating surgeon is more likely to contaminate the surgical field
45	DO	–	ABC	Unknown	Unknown	PuH	Mean CFU/ft^2/h, 13.3 closed doors vs 24.8 open doors, 19.4 swinging doors. (19.4 vs. 13.3, $P < 0.05$)	Higher air microbial contamination with swinging doors than with closed doors
46	Movement	–	ABC	Unknown	Orthopedic	University	Significant risk of contaminant transport from the less clean zone to the ultra-clean zone	Movements through the laminar air flow increase the air bacterial contamination of the clean zone

NOTE. ABC, air bacterial count; APC, air particle count; CFU, colony-forming unit; CS, cross-sectional; DO, door openings; DO/h, door openings per hour; HCW, healthcare worker; NoP, no. of persons; OR, operating room; PC, prospective cohort; PM10, particulate matter 10 μm; PrH, private hospital; PuH, public hospital; RC, retrospective cohort; SSI, surgical-site infection; UH, university hospital.

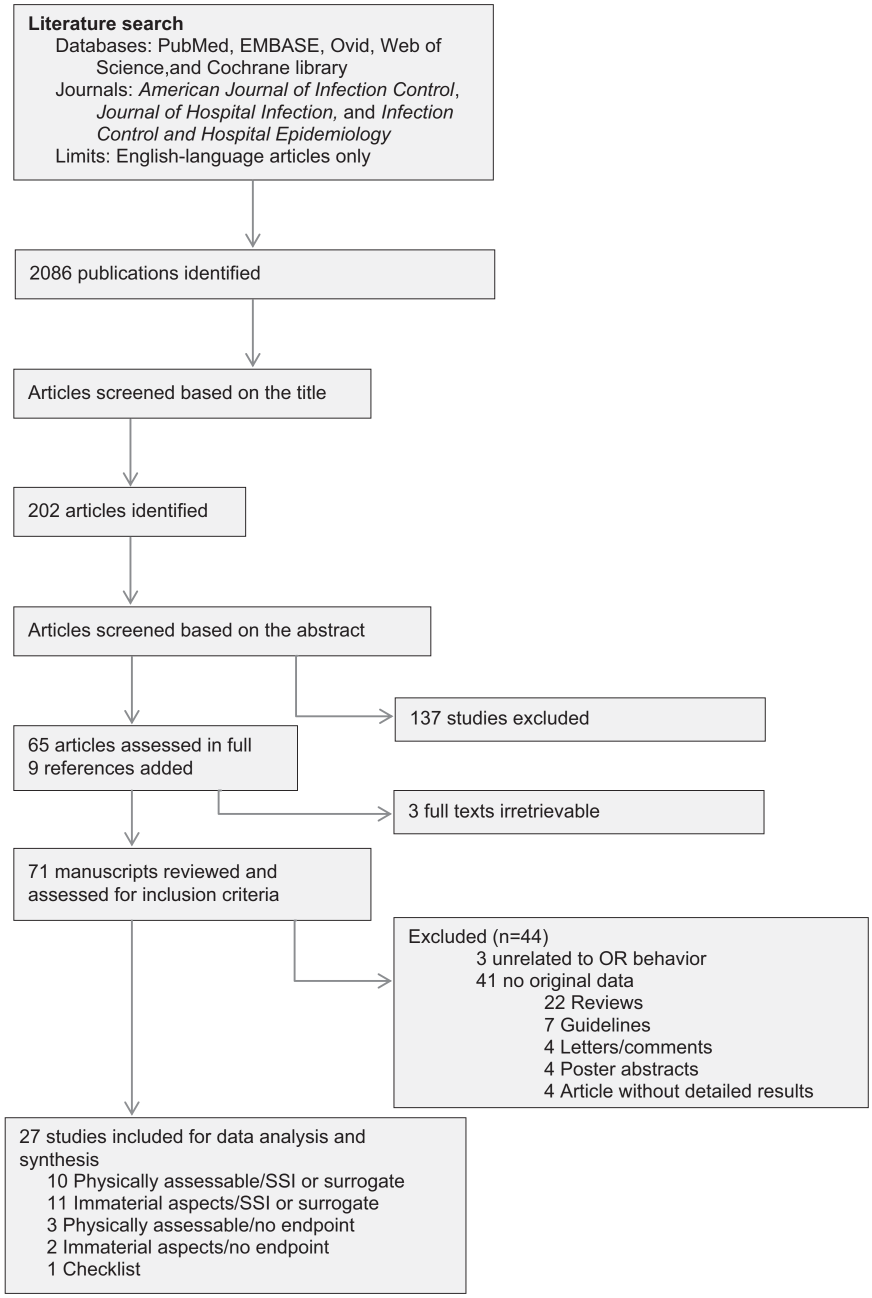

FIGURE 1. Flowchart of the search strategy.

cross-sectional (n = 19), prospective cohort (n = 3), experimental (n = 3), and retrospective cohort (n = 2).

Assessment of Study Methods

We assessed the quality criteria for the 24 observational studies (Table 2). The study aim and justification were clearly stated in most reports (21/24, 88%). However, most of the direct observations were performed by an observer in the OR (18/24, 75%). Some studies attempted to minimize bias by keeping secret the reason of the presence of an observer (n = 4) and others by using an automatic device (n = 2). The primary outcome measure was considered reliable in 4 (17%) of the 24 studies. The conclusions were clearly stated in 18 (75%) of the 24 articles.

Number of People in the OR

The number of people in the OR was assessed in 8 studies, of which 2 assessed the impact on SSI rates, 2 on airborne

https://doi.org/10.1017/ice.2014.9 Published online by Cambridge University Press

https://doi.org/10.1017/ice.2014.9 Published online by Cambridge University Press

TABLE 2. Criteria from Integrated Quality Criteria for Systematic Review of Multiple Study Designs Used to Assess Quality of the Studies Included in the Review

Ref.	Study	Clear aims and justification	Protection against detection bias	Reliable primary outcome measure	Incomplete outcome data addressed	Analysis sufficiently rigorous	Free of selective outcome reporting	Limitation addressed	Conclusions clear and justified	Free of other bias	Ethical issues addressed
21	Pryor & Messmer	Yes	No	Unclear	Unclear	Unclear	No	Yes	No	Unclear	No
22	Andersson et al.	Yes	No	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes
25	Castella et al.	Yes	No	Unclear	Unclear	Yes	Yes	No	Yes	No	No
43	Borer et al.	Unclear	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	No
39	Kurmann et al.	Yes	No	Yes	Unclear	Yes	No	Yes	Yes	Unclear	Yes
42	Tartari & Mamo	Yes	No	Unclear	Unclear	Unclear	No	Yes	Yes	Unclear	Yes
26	Scaltriti et al.	Yes	No	Unclear	Unclear	Yes	Yes	No	Unclear	No	No
29	Panahi et al.	Yes	No	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	Unclear
34	Lynch et al.	Yes	No	Unclear	Unclear	Yes	No	Yes	Yes	Unclear	Unclear
23	Parikh et al.	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	No
38	Beldi et al.	Yes	No	No	Unclear	Unclear	Yes	No	Yes	No	Yes
40	Yinnon et al.	Yes	No	Unclear	Unclear	Unclear	No	Yes	Yes	Unclear	Unclear
41	Van der Slegt et al.	Yes	Yes	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes
35	Crolla et al.	Yes	Yes	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes
28	Wan et al.	Yes	No	Unclear	No	Yes	Yes	Yes	Yes	Unclear	No
24	Babkin et al.	Yes	No	Unclear	Unclear	Unclear	No	Yes	Yes	Unclear	Unclear
30	Tjade & Gabor	No	Unclear	Unclear	Unclear	Unclear	No	No	No	Unclear	No
27	Durando et al.	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	No
33	Young & O'Regan	Yes	No	Yes	Unclear	Unclear	Yes	Yes	Yes	No	Unclear
37	Healey et al.	Yes	No	No	Unclear	Unclear	No	Yes	No	Unclear	Yes
49	Moro	No	Unclear	Unclear	Unclear	Unclear	Unclear	No	No	Unclear	No
36	Healey et al.	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
32	Accadbled et al.[a]	Yes	Yes	Unclear	Unclear	Unclear	Unclear	no	Yes	Unclear	Unclear
31	Rackham et al.	Yes	Yes	Unclear	Unclear	Unclear	No	No	Unclear	Unclear	No

[a]Oral presentation in congress.

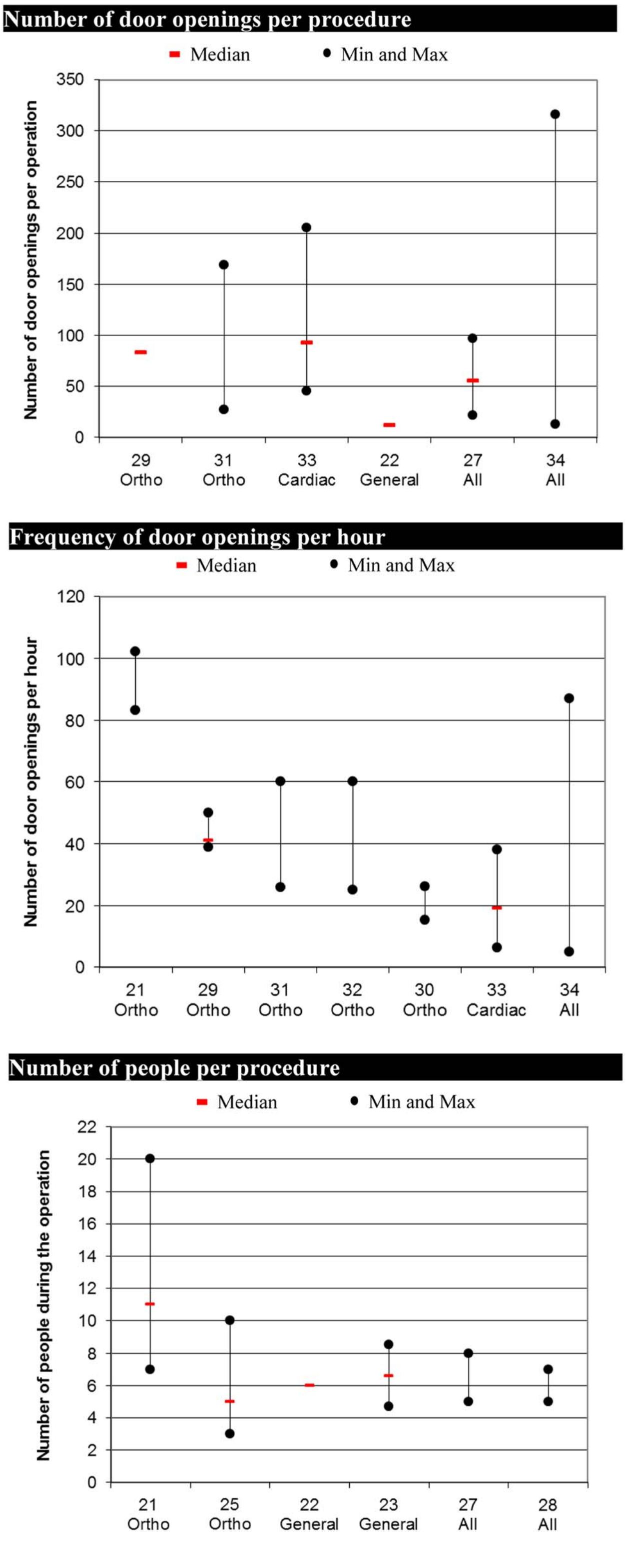

figure 2. Distribution of the number of door openings and people in the operating room according to studies.

particle or microbiological air counts; the remaining 4 studies were purely descriptive.[21–28] Results are displayed in figures 2 and 3.

In orthopedic surgery,[23] the number of staff members present during 26 surgical procedures varied from 3 to 20. Spinal surgery had the highest number (median [interquartile range], 14 [11–20] vs. 11 [7–15] in other specialties). In another study that assessed 181 procedures, having 3 surgeons present was associated with an increased risk of SSI (8/108, 7.4%) compared with 2 surgeons (2/72, 2.8%).[24] A small but significant correlation was found between the median number of people in the OR during orthopedic surgery (5; interquartile range, 3–10) and airborne contamination (total colony-forming units [CFU]/m^3 per operation, 60.4 ± 55.9, $r = 0.22$, $P = 0.04$).[22] In a retrospective study of 3259 clean surgical procedures, the number of people in the OR was fewer than 9 in 26% of procedures, 9 to10 in 26%, 11 to 12 in 23%, 13 to 16 in 22%, and more than 16 in 2%. As the number increased, the infection rate rose steadily, from 1.5% for fewer than 9 people to 6.9% for more than 16 people.[21] In 23 surgical procedures of all types, the median (range) number of OR staff at incision was 7 (5–8) and did not correlate with the particle count.[26] The number of OR staff attending 165 surgical procedures of various types showed a positive correlation with airborne particle and bacteria counts.[28]

Four studies were purely descriptive.[23,25,27,29] In a multicenter study in general surgery, the mean number of people was 6 or 7; for 5% of procedures, there were 5 to 7 surgical staff and for 6% there were 4 to 10 other personnel, with higher numbers in teaching hospitals ($P < 0.01$).[25] In another study, 645 (90%) of 717 surgical procedures were performed with fewer than 10 personnel in the OR; the mean ± SD was 6.6 ± 1.9 overall and 3.1 ± 0.8 for clean surgery.[27]

Door Openings

Eleven studies assessed the impact of door openings on infections. During total arthroplasties, mean door-opening frequency was 39/h for primary operations and 50/h for revisions, and 63% of the traffic occurred after the incision.[29] In 2 other studies, door-opening frequency was 83–102/h and 15–26/h, respectively.[23,25] Results are displayed in figures 2 and 3.

In a study of 49 clean orthopedic procedures, mean door-opening frequency was 26.2/h before the incision and 15.4/h after the incision.[30] Two multicenter studies of orthopedic procedures in various types of hospitals and patient populations showed door-opening frequencies of 26–60/h in pediatric scoliosis surgery and 46–55/h in adults undergoing total knee replacement, with a 52% decrease after staff education and door labeling.[31] In another study, mean door-opening frequency ranged from 25/h in a private hospital to 60/h in pediatric surgery and was higher for adults and public hospitals.[32]

In cardiovascular surgery, mean door-opening frequency was 19.2/h overall, with higher values in patients at greater risk for complications, and total time spent with the door open was 10.7% of the total operative time.[33] In other types of surgery, door-opening frequency varied from 5 to 87/h.[26,34] During 28 surgical procedures in 6 different specialties, mean

Ref.	Type of surgery	Behavior	End point	Number of procedures	r or r²	OR or RR	Negative relationship P < 0.05	Positive relationship P < 0.05	NS
25	Orthopedics	DO	ABC	30	0.74	-			
30	Orthopedics	DO	ABC	49	0.55	-			
27	All types	DO	APC	23	neg	-			
45	Unknown	DO	ABC	Unknown	-	-			
27	All types	NoP	APC	23	-	-			
28	All types	NoP	APC	165	0.37	-			
28	All types	NoP	ABC	165	0.45	-			
24	Clean	NoP	SSI	3259	-	-			
39	Abdominal	Noise	SSI	35	-	-			
38	General	Discipline	SSI	1032	-	2.02 (1.05–3.88)			
43	Cardiac	Bundle compliance DO	SSI	118	-	-			
40	General	Checklist DO	ATB/Culture	Unknown	-	-			
41	Vascular	Bundle compliance DO	SSI	100	-	0.57 (0.21–1.55)			
35	Digestive	Bundle compliance DO	SSI	100	-	0.64 (0.44–0.95)			
44	Orthopedics	Sweating	ABC	Unknown	-	-			
27	All types	Surgical technique	APC	23	0.48	-			

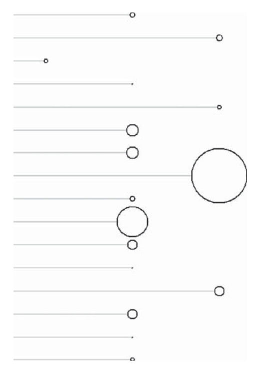

FIGURE 3. Studies assessing the impact of behaviors on environmental contamination and SSI rates.
The significance of the impact is displayed with bubble sizes indicating the number of procedures included.
NOTE. ABC, air bacterial count; APC, air particle count; DO, door openings; NoP, no. of persons; NS, non significant; OR, odds ratio; Ref, reference; RR, relative risk; SSI, surgical site infection.

door-opening frequency varied from 19/h in general surgery to 50/h in spinal fusion.[34] In Italy, the door was open during 223 (26%) of 856 surgical procedures in 49 hospitals[25] and for more than 50% of operative time in 260 (36.3%) of 717 surgical procedures at a university hospital.[27]

The main reasons for door opening in orthopedic surgery were a need for supplies (23.3%) or information (11.5%) and scrubbing (7.3%); the reason was unknown for 47.3% of openings. The largest contributors to door openings were the circulating nurse (26.0%) and equipment representatives (20.3%).[29] Of 529 door openings during 30 orthopedic surgical procedures, 169 were deemed unnecessary.[22] In another study, social talk, coffee breaks, and a need for equipment were potential reasons.[35]

In 2 studies, door opening correlated with surrogates of the infectious risk. High door-opening frequency and high traffic flow were associated with high air bacteria counts.[22] This study adjusted for confounders, including operative time and number of people.

In another study, door openings were negatively associated with air particle counts but positively associated with air bacteria counts.[26] Finally, 2 studies in general surgery linked the number of door openings to distraction and interruptions in the OR.[36,37]

Discipline and Distraction in the OR

Four studies evaluated intangible aspects of OR-staff behavior during general surgical procedures. Lapses in discipline such as switching staff members, hectic movements, loud noise, and presence of visitors were significantly associated with the SSI rate after 1032 surgical procedures.[38] In another study, in 36 patients, the median sound level during surgery was significantly higher for the 6 patients who developed SSIs and the sound level increased in both groups 60 min after the first incision.[39] Healey et al.[36,37] evaluated surgical-team interferences and distractions during operations. The mean number of interference events per operation varied from 13.6 to 20.5 in general surgery, with a mean of 17 to 27/h,[36,37] and the most frequent events were conversations and movements behind the video monitor during laparoscopic surgery; whereas the events with the highest recurrence rate were those related to the equipment. Distraction was most common among surgeons, followed by nurses and anesthetists. Mean cumulative work-interruption duration was 13% (range, 0.41%–50.17%) of the operative time.

Checklist, Bundles, and Compliance With Control Measures

Six studies evaluated the overall compliance of OR teams with traffic-control measures. A checklist including intraoperative behavioral criteria was used to improve practices and prevent SSIs. Monthly reports of practices were associated with a significant decrease in SSI rates in the checklist group, from 4% during the first month to 3% during the 11th month. Compliance with entry/exit rules during the surgery was only 25% and was lowest among anesthetists.[40]

Two studies by the same team assessed the impact on the SSI rate of a bundle of preventive measures including restricted door openings. In a study of vascular surgery, compliance with door-opening rules improved from 30% to 80% and the SSI rate decreased concomitantly by 51%.[41] Among the 4 preventive measures in the bundle, door-opening restriction raised the greatest challenges in achieving compliance. The other study evaluated digestive procedures and yielded similar results with a 36% decrease in the SSI rate.[35]

In a study of 30 procedures, compliance with traffic rules was only 29%.[42] Compliance improved from 62.5% to 71% in another study concomitantly with the implementation of other infection control practices during 118 heart surgery procedures.[43]

https://doi.org/10.1017/ice.2014.9 Published online by Cambridge University Press

Experimental Studies

Three studies simulated the impact of various behaviors. The number of bacteria deposited on 8 plates placed on the operating table during a simulated 30-min orthopedic surgical procedure by a nonsweating and sweating surgeon was 3.3 and 6.9, respectively.[44] Swinging doors were associated with higher airborne bacteria counts compared with constantly closed doors (mean, 19.4 vs. 13.3 CFU/ft^2; $P < 0.05$).[45] In the remaining study, intraoperative movements through the laminar air flow were associated with bacterial transport from nonclean to clean zones in orthopedic surgery.[46]

DISCUSSION

Several guidelines refer to specific behaviors as potential risk factors for SSI.[6,17,18] National recommendations emphasize the importance of discipline in the OR. For example, the National Institute for Health and Clinical Excellence guideline states, "Staff wearing non-sterile theatre wear should keep their movements in and out of the operating area to a minimum."[17] The Centers for Disease Control and Prevention guideline recommends keeping OR doors closed (grade IA) and allowing only necessary personnel into the OR (grade II).[6] The grade II rating of this last recommendation highlights the paucity of the available literature, although most experts consider OR discipline to be a major SSI prevention measure.[47] Thus, none of the guidelines provides detailed pragmatic recommendations about preventing environmental contamination and SSIs.

We identified only 27 original studies evaluating the impact of OR behaviors on the infectious risk. These studies were heterogeneous, failed to cover all relevant areas, and provided a low level of evidence. Their results suggest, however, an impact of surgical team behavior on the SSI risk and, therefore, opportunities for improvement.

Humans shed large amounts of particles and skin fragments[12] and constitute the main reservoir of air contaminants in the OR. Therefore, limiting the number of people and their movements may be a key factor in minimizing environmental contamination.

Door openings adversely affect air exchange, air quality, and positive pressure in the OR compared with adjacent rooms.[48] One study with a complex statistical analysis concluded that a greater door-opening frequency reduced air particles but also increased the presence of bacteria in the OR.[26] These results conflict with the hypothesis that microorganisms are vectored by air particles. By contrast, an observational study[22] and an experimental study[45] concluded that traffic flow and door opening increased the air concentration of microorganisms close to the surgical wound. Door opening is a cause of distraction and interruptions for the surgical team[36] and therefore contributes to the risk of adverse events during the operation. One of the main ways of improvement in the complex OR system is anticipation. The unnecessary entries/exits, estimated to be approximately 60% of the total, were mainly due to a lack of preparation and organization. Several easy elements could lead to improvement: the storage of components and frequently used instruments in the OR, a clear and advanced communication, a shift change of the surgical team prepared in advance, a sign on the door advising caution, proper education of OR team and visitors, and a robust audit process. The leadership of the surgeon and the head nurse is probably the cornerstone of the discipline and the organization in the OR.

More surprisingly, louder noise has been associated with a higher SSI rate.[39] Lapses in discipline were associated with an increased SSI rate in a careful study involving a multivariate analysis.[38] Such lapses might indicate either greater complexity of the surgical procedure or less attention to the procedure on the part of the surgical team. In complex procedures, more personnel are often needed, with as a result, a risk of lapse in discipline and an increase of environmental contamination. Thus, those cases may be at higher risk for SSI and constitute a potential confounder in the analysis.

In analyzing the 4 studies of preventive bundles, it is difficult to separate the possible role for traffic control from that of the other preventive measures.[35,40–43,49] However, the bundles, which included audits and feedback about compliance, were associated with a decrease in the SSI rate, and improvement of traffic control raised the greatest challenges.

Most studies using the SSI rate as the end point evaluated the impact of the number of people and their movements in the OR. The results suggest that increases in either or both are associated with higher SSI rates. A large retrospective study suggested an association between the number of people in the OR and the occurrence of SSIs, but this number was closely related to the operative time, which was the only significant variable in the multivariate analysis.[21] SSI is a multifactorial event associated with patient-related factors, type of surgery, compliance with preventive measures, and pathophysiologic events. A causal relationship with environmental contamination is therefore difficult to prove unless the analysis adjusts for the many confounding factors. In addition, improved OR discipline is most likely to affect the rate of SSIs due to exogenous microorganisms—that is, complicating clean surgery. SSIs are rare after clean surgery, and detecting an effect of improved OR discipline therefore requires long observation periods.

Four studies used air contamination (particle count, $n = 2$; or bacteria count, $n = 4$) as a surrogate for the SSI risk. However, the link between airborne contamination and SSI is unclear. For example, surgical wounds are often contaminated at skin closure, presumably by airborne microorganisms.[14] It is hoped that only a minor part of contaminated wounds lead to postoperative infection in patients.

Published studies about the impact of intraoperative behaviors on the risk of infection have several limitations. There were no control groups, and the end points were heterogeneous and of unclear validity, inducing a high risk of publication bias. In addition, 11 studies were purely descriptive. Of the 23 studies for which the data collection method was described, 19 relied on an observer in the OR during repeated cross-sectional surveys.

This method is prone to the Hawthorne effect and to inconsistency. Thus, in 1 study, traffic declined by 13.5% to 35% after the staff was informed that an observer was present in the OR.[31] Automatic recording during long periods can overcome this limitation.[33] Associations linking OR behaviors to the SSI risk can be assessed using either the SSI rate or surrogates such as air contamination. We found only 9 studies that used the SSI rate and 4 clinical studies that used air contamination.

Bundles of preventive measures have been developed to minimize the SSI risk.[50] Most of these measures target endogenous contamination; examples include skin preparation, surgical technique, prophylactic antibiotics, decontamination, and maintaining homeostasis. These measures have contributed to the dramatic decrease in SSI rates documented during the past 30 years. Little is known about preventing exogenous infections due to environmental contamination and OR behaviors. Recent studies suggesting that laminar airflow may not be superior over standard ventilation indicate an urgent need for studies evaluating the complex interplay between ventilation, number of people in the OR, movements, and door openings.[51] New tools for automatic data collection may help by providing objective long-term data on OR conditions. Automatic devices have been used to count door openings [33,39] but not the number and movements of people in the OR. Video systems may help to describe and understand movements during operations.[52]

In conclusion, published data about the impact of OR behaviors on the infectious risk are limited, heterogeneous, and weakened by several methodological flaws. More studies should be performed with accurate tools to address the influence of OR behaviors on the infectious risk.

ACKNOWLEDGMENTS

Financial support. None reported.

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

Address correspondence to Gabriel Birgand, Infection Control Unit, Bichat-Claude Bernard Teaching Hospital, AP-HP, 46 rue Henri Huchard 75018 Paris (gbirgand@gmail.com).

REFERENCES

1. Smyth ETM, McIlvenny G, Enstone JE, et al., on behalf of the Hospital Infection Society Prevalence Survey Steering Group. Four country healthcare associated infection prevalence survey 2006: overview of the results. *J Hosp Infect* 2008;69:230–248.
2. INVS. Enquète nationale de prévalence des infections nosocomiales, juin 2012, 2007. www.invs.sante.fr. Accessed May 12, 2014.
3. Engemann JJ, Carmeli Y, Cosgrove SE, et al. Adverse clinical and economic outcomes attributable to methicillin resistance among patients with *Staphylococcus aureus* surgical site infection. *Clin Infect Dis* 2003;36:592–598.
4. Kirkland KB, Briggs JP, Trivette SL, Wilkinson WE, Sexton DJ. The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs. *Infect Control Hosp Epidemiol* 1999;20:725–730.
5. Astagneau P, Rioux C, Golliot F, Brücker G, INCISO Network Study Group. Morbidity and mortality associated with surgical site infections: results from the 1997–1999 INCISO surveillance. *J Hosp Infect* 2001;48:267–274.
6. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol* 1999;20:250–278.
7. Defez C, Fabbro-Peray P, Cazaban M, Boudemaghe T, Sotto A, Daurès JP. Additional direct medical costs of nosocomial infections: an estimation from a cohort of patients in a French university hospital. *J Hosp Infect* 2008;68:130–136.
8. Plowman R, Graves N, Griffin MA, et al. The rate and cost of hospital-acquired infections occurring in patients admitted to selected specialties of a district general hospital in England and the national burden imposed. *J Hosp Infect* 2001;47:198–209.
9. Ayliffe GA. Role of the environment of the operating suite in surgical wound infection. *Rev Infect Dis* 1991;13(Suppl 10): S800–S804.
10. Whyte W, Hambraeus A, Laurell G, Hoborn J. The relative importance of routes and sources of wound contamination during general surgery. I. Non-airborne. *J Hosp Infect* 1991; 18:93–107.
11. Whyte W, Hambraeus A, Laurell G, Hoborn J. The relative importance of the routes and sources of wound contamination during general surgery. II. Airborne. *J Hosp Infect* 1992;22:41–54.
12. Hambraeus A. Aerobiology in the operating room: a review. *J Hosp Infect* 1988;11(Suppl A):68–76.
13. Lidwell OM, Lowbury EJ, Whyte W, Blowers R, Stanley SJ, Lowe D. Effect of ultraclean air in operating rooms on deep sepsis in the joint after total hip or knee replacement: a randomised study. *Br Med J (Clin Res Ed)* 1982;285:10–14.
14. Tammelin A, Hambraeus A, Ståhle E. Routes and sources of *Staphylococcus aureus* transmitted to the surgical wound during cardiothoracic surgery: possibility of preventing wound contamination by use of special scrub suits. *Infect Control Hosp Epidemiol* 2001;22:338–346.
15. Tammelin A, Hambraeus A, Ståhle E. Source and route of methicillin-resistant *Staphylococcus epidermidis* transmitted to the surgical wound during cardio-thoracic surgery. Possibility of preventing wound contamination by use of special scrub suits. *J Hosp Infect* 2001;47:266–276.
16. Société Francaise d'Hygiène Hospitalière. Gestion préopératoire du risque infectieux. 2013. http://nosobase.chu-lyon.fr/recommandations/sfhh/2013_gestion_preoperatoire_SF2H.pdf. Accessed May 12, 2014.
17. National Institute for Health and Clinical Excellence. Surgical site infection: prevention and treatment of surgical site infection. 2008. http://www.nice.org.uk/guidance/cg74. Accessed May 12, 2014.
18. Société Francaise d'Hygiène Hospitalière. La qualité de l'air au bloc opératoire. 2004. http://www.sf2h.net/publications-SF2H/SF2H_recommandations-gr-air-2004.pdf. Accessed May 12, 2014.
19. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLOS Med* 2009;6:e1000100.

20. Edwards R, Charani E, Sevdalis N, et al. Optimisation of infection prevention and control in acute health care by use of behaviour change: a systematic review. *Lancet Infect Dis* 2012;12:318–329.
21. Pryor F, Messmer PR. The effect of traffic patterns in the OR on surgical site infections. *AORN J* 1998;68:649–660.
22. Andersson AE, Bergh I, Karlsson J, Eriksson BI, Nilsson K. Traffic flow in the operating room: an explorative and descriptive study on air quality during orthopedic trauma implant surgery. *Am J Infect Control* 2012;40:750–755.
23. Parikh SN, Grice SS, Schnell BM, Salisbury SR. Operating room traffic: is there any role of monitoring it? *J Pediatr Orthop* 2010;30:617–623.
24. Babkin Y, Raveh D, Lifschitz M, et al. Incidence and risk factors for surgical infection after total knee replacement. *Scand J Infect Dis* 2007;39:890–895.
25. Castella A, Charrier L, Di Legami V, et al.; Piemonte Nosocomial Infection Study Group. Surgical site infection surveillance: analysis of adherence to recommendations for routine infection control practices. *Infect Control Hosp Epidemiol* 2006;27:835–840.
26. Scaltriti S, Cencetti S, Rovesti S, Marchesi I, Bargellini A, Borella P. Risk factors for particulate and microbial contamination of air in operating theatres. *J Hosp Infect* 2007;66:320–326.
27. Durando P, Bassetti M, Orengo G, et al.; Surgical Audit Team of the San Martino University Hospital of Genoa. Adherence to international and national recommendations for the prevention of surgical site infections in Italy: results from an observational prospective study in elective surgery. *Am J Infect Control* 2012;40:969–972.
28. Wan G-H, Chung F-F, Tang C-S. Long-term surveillance of air quality in medical center operating rooms. *Am J Infect Control* 2011;39:302–308.
29. Panahi P, Stroh M, Casper DS, Parvizi J, Austin MS. Operating room traffic is a major concern during total joint arthroplasty. *Clin Orthop* 2012;470:2690–2694.
30. Tjade OH, Gabor I. Evaluation of airborne operating room bacteria with a Biap slit sampler. *J Hyg (Lond)* 1980;84:37–40.
31. Rackham M, Sutherland LM, Mintz A, Cain CMJ, Cundy PJ. Theatre traffic: is your theatre a tearoom? Abstract. *J Bone Joint Surg Br* 2010;92-B(Supp 1):205.
32. Accadbled F, Louis D, Rackham M, Cundy P, Sales de Gauzy J. Opening the doors to the operative theatre. Abstract. *Orthopaedic Proceedings* 2011;93-B:518.
33. Young RS, O'Regan DJ. Cardiac surgical theatre traffic: time for traffic calming measures? Interact. *Cardiovasc Thorac Surg* 2010;10:526–529.
34. Lynch RJ, Englesbe MJ, Sturm L, et al. Measurement of foot traffic in the operating room: implications for infection control. *Am J Med Qual* 2009;24:45–52.
35. Crolla RM, van der Laan L, Veen EJ, Hendriks Y, van Schendel C, Kluytmans J. Reduction of surgical site infections after implementation of a bundle of care. *PLOS ONE* 2012;7:e44599.
36. Healey AN, Sevdalis N, Vincent CA. Measuring intra-operative interference from distraction and interruption observed in the operating theatre. *Ergonomics* 2006;49:589–604.
37. Healey AN, Primus CP, Koutantji M. Quantifying distraction and interruption in urological surgery. *Qual Saf Health Care* 2007;16:135–139.
38. Beldi G, Bisch-Knaden S, Banz V, Mühlemann K, Candinas D. Impact of intraoperative behavior on surgical site infections. *Am J Surg* 2009;198:157–162.
39. Kurmann A, Peter M, Tschan F, Mühlemann K, Candinas D, Beldi G. Adverse effect of noise in the operating theatre on surgical-site infection. *Br J Surg* 2011;98:1021–1025.
40. Yinnon AM, Wiener-Well Y, Jerassy Z, et al. Improving implementation of infection control guidelines to reduce nosocomial infection rates: pioneering the report card. *J Hosp Infect* 2012;81:169–176.
41. Van der Slegt J, van der Laan L, Veen EJ, Hendriks Y, Romme J, Kluytmans J. Implementation of a bundle of care to reduce surgical site infections in patients undergoing vascular surgery. *PLOS ONE* 2013;8:e71566.
42. Tartari E, Mamo J. Pre-educational intervention survey of healthcare practitioners' compliance with infection prevention measures in cardiothoracic surgery: low compliance but internationally comparable surgical site infection rate. *J Hosp Infect* 2011;77:348–351.
43. Borer A, Gilad J, Meydan N, et al. Impact of active monitoring of infection control practices on deep sternal infection after open-heart surgery. *Ann Thorac Surg* 2001;72:515–520.
44. Mills SJ, Holland DJ, Hardy AE. Operative field contamination by the sweating surgeon. *Aust N Z J Surg* 2000;70:837–839.
45. Ritter MA. Operating room environment. *Clin Orthop Relat Res* 1999;369:103–109.
46. Brohus H, Balling KD, Jeppesen D. Influence of movements on contaminant transport in an operating room. *Indoor Air* 2006;16:356–372.
47. Woodhead K, Taylor EW, Bannister G, Chesworth T, Hoffman P, Humphreys H. Behaviours and rituals in the operating theatre: a report from the Hospital Infection Society Working Party on Infection Control in Operating Theatres. *J Hosp Infect* 2002;51:241–255.
48. Tang JW, Eames I, Li Y, et al. Door-opening motion can potentially lead to a transient breakdown in negative-pressure isolation conditions: the importance of vorticity and buoyancy airflows. *J Hosp Infect* 2005;61:283–286.
49. Moro ML. Health care-associated infections. *Surg Infect* 2006;7 (Suppl 2):S21–S23.
50. Coello R, Charlett A, Wilson J, Ward V, Pearson A, Borriello P. Adverse impact of surgical site infections in English hospitals. *J Hosp Infect* 2005;60:93–103.
51. Gastmeier P, Breier A-C, Brandt C. Influence of laminar airflow on prosthetic joint infections: a systematic review. *J Hosp Infect* 2012;81:73–78.
52. Birgand G, Azevedo C, Toupet G, et al. Attitudes, risk of infection and behaviours in the operating room (the ARIBO Project): a prospective, cross-sectional study. *BMJ Open* 2014;4:e004274.

APPENDIX 1

Medline search algorithm

The following search algorithm was developed to search the database using Boolean operators and the asterisk symbol (*) as truncation:

("Operating Rooms/standards"[Mesh] OR "Operating room*" OR "Operating theatre*") AND (("Health Knowledge, Attitudes, Practice" [Mesh] OR "Foot traffic*" OR "Door opening*" OR "Theatre traffic*" OR "Behavior*" OR "Behaviour*" OR "discipline*" OR "attitude*" OR "traffic*" OR "Operating room traffic*")) OR ("Patient Safety" [Mesh]

OR "Operating room traffic*" OR "safety climate*" OR "safety culture*" OR "safety attitude*" OR "safety intervention*")) AND (("Surgical Wound Infection/prevention & control" [Mesh] OR "Surgical Wound infection/etiology" [Mesh] OR "Air Microbiology" [Mesh] OR "Infection Control/methods" [Mesh] OR "Equipment Contamination/prevention & control" [Mesh] OR "Surgical Site Infections*" OR "Air sampling")) OR ("Operating room traffic" OR "Door opening*" OR "Theatre traffic*" OR "Foot traffic*") OR (("Surgical Wound Infection/prevention & control" [Mesh] OR "Surgical Wound infection/etiology" [Mesh] OR "Air Microbiology" [Mesh] OR "Infection Control/methods" [Mesh] OR "Equipment Contamination/prevention & control" [Mesh] OR "Surgical Site Infections*" OR "Air sampling") AND ("Patient Safety" [Mesh] OR "Operating room traffic*" OR "safety climate*" OR "safety culture*" OR "safety attitude*" OR "safety intervention*")).

EMBASE search algorithm

'Operating room' OR 'Operating theatre' AND 'Health Knowledge' OR 'Attitude' OR 'Foot traffic' OR 'Door opening' OR 'Theatre traffic' OR 'Behavior' OR 'Behaviour' OR 'discipline' OR 'traffic' OR 'Operating room traffic' OR 'Patient Safety' OR 'Operating room traffic' OR 'safety climate' OR 'safety culture' OR 'safety attitude' OR 'safety intervention' AND 'Surgical Wound Infection' OR 'Air Microbiology' OR 'Equipment Contamination' OR 'Surgical Site Infection' OR 'Air sampling' OR 'Operating room traffic' OR 'Door opening' OR 'Theatre traffic' OR 'Foot traffic'

Ovid search algorithm

'Operating room' OR 'Operating theatre' AND 'Health Knowledge' OR 'Attitude' OR 'Foot traffic' OR 'Door opening' OR 'Theatre traffic' OR 'Behavior' OR 'Behaviour' OR 'discipline' OR 'traffic' OR 'Operating room traffic' OR 'Patient Safety' OR 'Operating room traffic' OR 'safety climate' OR 'safety culture' OR 'safety attitude' OR 'safety intervention' AND 'Surgical Wound Infection' OR 'Air Microbiology' OR 'Equipment Contamination' OR 'Surgical Site Infection' OR 'Air sampling' OR 'Operating room traffic' OR 'Door opening' OR 'Theatre traffic' OR 'Foot traffic'

Web of science search algorithm

TS = (Operating room) OR TS = (Operating theatre) AND TS = (Health Knowledge) OR TS = (Attitude) OR TS = (Foot traffic) OR TS = (Door opening) OR TS = (Theatre traffic) OR TS = (Behavior) OR TS = (Behaviour) OR TS = (discipline) OR TS = (traffic) OR TS = (Operating room traffic) OR TS = (Patient Safety) OR TS = (Operating room traffic) OR TS = (safety climate) OR TS = (safety culture) OR TS = (safety attitude) OR TS = (safety intervention) AND TS = (Surgical Wound Infection) OR TS = (Air Microbiology) OR TS = (Equipment contamination) OR TS = (Surgical Site Infection) OR TS = (Air sampling) OR TS = (Operating room traffic) OR TS = (Door opening) OR TS = (Theatre traffic) OR TS = (Foot traffic) AND TS = (Operating room) OR TS = (Operating theatre)

Cochrane search algorithm

(Operating room OR Operating theatre) AND (Health Knowledge OR Attitude OR Foot traffic OR Door opening OR Theatre traffic OR Behavior OR Behaviour OR discipline OR traffic OR Operating room traffic OR Patient Safety OR Operating room traffic OR safety climate OR safety culture OR safety attitude OR safety intervention) AND (Surgical Wound Infection OR Air Microbiology OR Equipment Contamination OR Surgical Site Infection OR Air sampling)

OR (Operating room traffic OR Door opening OR Theatre traffic OR Foot traffic)

JHI + American Journal of Surgery + Lancet + Injury + Safety Science

("Operating room" OR "Operating theatre") AND ("Health Knowledge" OR "Attitude" OR "Foot traffic" OR "Door opening" OR "Theatre traffic" OR "Behavior" OR "Behaviour" OR "discipline" OR "traffic" OR "Operating room traffic" OR "Patient Safety" OR "Operating room traffic" OR "safety climate" OR "safety culture" OR "safety attitude" OR "safety intervention") AND ("Surgical Wound Infection" OR "Air Microbiology" OR "Equipment Contamination" OR "Surgical Site Infection" OR "Air sampling") OR ("Operating room traffic" OR "Door opening" OR "Theatre traffic" OR "Foot traffic")

APPENDIX 2

List of Excluded Studies and Reasons for Exclusion

Author	Journal	Year	Category of article	Reason for exclusion
Pokrywka M	*Infect Disord Drug Targets*	2013	Review	No original data
Geubbels E	*Am J Infect Control*	2004	Major article	No original data
Woodhead K	*J Hosp Infect*	2002	Guidelines	No original data
Thompson KM	*Ann Surg*	2011	Major article	No original data
Mason SL	*Eur J Vasc Endovasc Surg*	2012	Major article	Unrelated to OR behavior (patient safety)
Tiwari KK	*Int CardioVascular Thor Surg*	2010	Letter	No original data
Greene LR	*Am J Infect Control*	2012	Brief report	No original data
Illingworth KD	*J Bone Joint Surg*	2013	Guidelines	No original data
Mangram AJ	*Inf Cont Hosp Epidemiol*	1999	Guidelines	No original data
Allo MD	*Surg Clin N Am*	2005	Review	No original data
Banerjee P	*Clin Orthop Relat Res*	2013	Letter	No original data
Matar W	*J Bone Joint Surg*	2010	Review	No original data
Humphreys H	*J Hosp Infect*	2009	Review	No original data
McConkey SJ	*Inf Cont Hosp Epidemiol*	1999	Major article	No original data
Adeli B	*J Bone Joint Surg*	2012	Review	No original data
Anderson DJ	*Inf Cont Hosp Epidemiol*	2008	Guidelines	No original data
Evans RP	*J Bone Joint Surg*	2009	Guidelines	No original data
Laufman H	*Bull N Y Acad Med*	1978	Review	No original data
Madhavan P	*Ann R Coll Surg Engl*	1999	Major article	No original data
Primus CP	*BJU Int*	2006	Comment	No original data
Riley MMS	*Am J Infect Control*	2012	Review	No original data
Harrop JS	Not published	2012	Review	No original data
Sandiford J	*Orthop Trauma*	2009	Review	No original data
Szychowski JM	Not published	2011	Poster	Poster abstract
Hale M	Not published	2012	Original article	Unrelated to OR behavior
Morris S	*J Bone Joint Surg*	2002	Original article	Unrelated to OR behavior
Fitzgerald RH	*Orthop Clin North Am*	1975	Review	No original data
Matt M	Not published	2005	Poster	Poster abstract
Bardowski L	Not published	2009	Poster	Poster abstract
Elbardissi AW	*Surg Clin N Am*	2012	Review	No original data
Weaving P	*J Perioper Pract*	2008	Review	No original data
Kapadia BH	*Expert Rev Med Devices*	2013	Review	No original data
Sturm LK	*Am J Infect Control*	2007	Poster	Poster abstract
Fitzgerald RH	*Arch Surg*	1979	Review	No original data
Kapadia BH	*Curr Orthop Pract*	2012	Review	No original data
Fitzgerald RH	*Geriatrics*	1976	Review	No original data
Uckay I	*J Hosp Infect*	2013	Review	No original data
Ayliffe GAJ	*Rev Infect Dis*	1991	Review	No original data
Macri IM	*Am J Infect Control*	2013	…	Not found
Manley M	*Surgery*	2011	Review	No original data
Howard JL	*J Arthroplasty*	2007	Review	No original data
National Institute for Health and Clinical Excellence	*NICE*	2009	Guidelines	No original data
Malinzak RA	*Orthopedics*	2006	Review	No original data
Ritter MA	*Clin Orthop Relat Res*	1975	…	Not found
Nelson RR	*Clin Orthop Relat Res*	1987	Review	No original data
Davies RR	*Lancet*	1962	…	Not found
AORN	*AORN*	2013	Guidelines	No original data

NOTE. OR, operating room.

https://doi.org/10.1017/ice.2014.9 Published online by Cambridge University Press