G47: Does the frequency of operating room door opening influence the rate of surgical site infection (SSI)/ Periprosthetic joint infection (PJI) in major orthopedic surgery?

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Response/Recommendation: Yes, the number of door openings in the operating room (OR) is associated with increased airborne particle levels, and subsequent risk of surgical site infection (SSI) and/or periprosthetic joint infections (PJIs). The OR door should be opened as infrequently as possible.

Level of Evidence: Moderate

Delegate Vote:

Rationale:

Increased number of particles in the operating room (OR) air is thought to be directly linked to the rate of subsequent surgical site infection (SSI)(1). Thus, minimizing air-borne contamination in the OR is considered an important factor to reduce infections after major orthopaedic procedures (2–5). There is no agreement on the optimal method for monitoring air quality within the OR (6–10), and there is no consensus on the maximum concentration of air-borne particles that is "acceptable" in the OR (i.e. not associated with increased SSI risk) (11). Particle counting is technically less demanding and more easily implemented into practice, compared to microbiological sampling which requires microbiological cultures, and is thus the preferred method of quantifying air quality. Particle counting provides indirect insights into air quality (12) as it does not consider, whether particles are viable microbes, termed colony forming units (CFU) potentially causing infection, or just dead matter. However, studies have highlight the correlation between particulate matter and airborne viable bacterial counts(6). Therefore, the quality of air in the OR significantly affects microbial contamination levels (13,14). Microbial load in the OR is influenced by factors such as air filtration systems, laminar airflow (15), and frequency of door-opening (16). However, the most important source of contamination is human (11), the ultraclean air standard can only be found in an empty OR (17).

Laminar airflow systems, while designed to reduce particulate contamination, are susceptible to disturbance from door openings and human traffic, which can undermine their efficacy (18,19). Door openings are thought to elevate contamination through two principal mechanisms. Firstly, the number of door openings correlates with the number of staff present in the OR(20). Secondly, door openings disrupt the laminar airflow in the OR, increasing turbulence and facilitating spread of airborne particles and bacteria into the surgical field (15,16,19,21,22). Andersson et al. (19) highlighted a positive correlation between traffic flow, number of persons present and duration of surgery causing a 68% increase in CFU/m³. Experimental and observational research, along with simulation studies, have investigated the impact of OR traffic (23,24). Mears et al. (24) demonstrated that 77/191 TJAs experienced a loss of positive OR pressure due to door openings, allowing airflow to reverse from hallway into the OR. This disruption, though considered temporary, led to a total time of 9 minutes of doors being open per case, raising concerns about time required to restore pressurization. Conversely, Weiser et al. (16) found that single door opening did not compromise positive pressure but noted that simultaneous openings of two doors allowed outside air to enter. They suggested that OR contamination was more directly attributable to personnel activity rather than door openings alone. The presence of personnel and OR traffic measured by the frequency of door openings (DOs) have been consistently identified as significant contributors to the increased concentration of airborne particles in the OR (6,23,25,26). Observational studies have shown a clear association between the number of individuals present and the frequency of DOs, with a corresponding rise in aerosolized particles, 41% of those being CFUs (6).

Several investigations have examined the rate and causes of door openings during elective total joint arthroplasty (TJA) procedures (7,15,16,28). Reported door opening rates ranged from 0.19 to 0.65 per minute for primary TJAs and up to 0.84 per minute for revision TJAs, however there is wide variability in literature. Total number of door openings per case averaged between 13.4 (29) to 66 (4) for primary arthroplasties and 135 door opening for revision arthroplasties (4). The pre- and post-incision time periods (of a surgical case) saw the highest door opening frequencies (7,12). Operating room traffic flow during surgeries was categorized in a study, totalling 529 door openings during 30 operations (mean 18 door openings per case) (19), with 33.5% (177) categorized as necessary, 34.8% (184) as semi-necessary, and 31.7% (168) as unnecessary. Necessary door openings were most often due to retrieving instruments or materials (25.9% of total openings, n=137) and expert consultations (7.6%, n=40). Semi-necessary openings primarily involved surgical team transitions (14.4%, n=76) and breaks for lunch or coffee (20.4%, n=108). Unnecessary openings were often attributed to social visits (8.5%, n=45) or no detectable reasons (17.6%, n=93) (19). Another study found of 9657 cases reported that necessary door openings made up 8.4%, breaks were minimal at 1.5%, supplies contributed to 23.3%, social visits/information to 12.5%, and no reason was documented for a striking 47% (4). Overall, unjustified traffic was noted to be substantially high (12.5 % – 25%) across multiple studies (7,19).

Even though it seems highly plausible, that high numbers of CFU/m³ increase the risk of SSI, this has never been scientifically proven to-date. Nevertheless, most studies assessing OR traffic, OR particle load and OR particle counting assume that SSI risk is linked to CFU concentration. Pulido et al. (21) emphasized the likely causal relationship between overall SSI rates and OR traffic, which could frequently be avoided, emphasizing the importance of timing and procedural practices during surgery to avoid traffic. Similarly, microbial and particulate contamination risk increases with procedural interruptions, highlighting the need for adherence to strict environmental controls (12).

Monitoring OR traffic and enforcing access restrictions during critical phases of surgery have been suggested as measures to mitigate these risks (30). Babkin et al. (5) identified surgical site infection rates following knee replacement, linking these to perioperative practices. Standardized infection control measures, including effective cleaning protocols and minimized OR interruptions, were highlighted as critical.

Conclusion:

While the direct correlation between door opening during surgery and increased infection rates is not definitive, it is clear that any disruption to the sterile environment can increase the potential for contamination. A large body of literature exists demonstrating the direct relationship between increased air-borne particles, OR traffic, door openings, and the total number of personal present in the OR. The OR door should be opened as infrequently as possible, and when it must be opened, precautions should be taken to minimize the risk of introducing pathogens into the sterile field. There exist no sufficiently large-scaled studies to scientifically demonstrate a critical threshold in the number of air-borne particles, and there are no clinical studies proving a direct relationship of air-borne CFU and infection risk.

Practical measures, such as limiting door openings through continuous education of OR personnel, warning signs outside doors (32), monitoring traffic (8), and optimizing ventilation systems, are essential for minimizing air-borne contamination (7). Studies investigating OR traffic and door openings recommended to limit door openings. Strategies to limit OR traffic include avoidance of unjustified traffic through organizational and procedural optimization, staff information (33) and information/warning signs (34,35). Future studies should investigate the direct relation between MCP/m^3 and PJI rates to establish potential thresholds.

References:

1. Cristina ML, Sartini M, Schinca E, Ottria G, Spagnolo AM. Operating room environment and surgical site infections in arthroplasty procedures. J Prev Med Hyg. 2016 Sep;57(3):E142–8.
2. Agodi A, Auxilia F, Barchitta M, Cristina ML, D'Alessandro D, Mura I, et al. Operating theatre ventilation systems and microbial air contamination in total joint replacement surgery: results of the GISIO-ISChIA study. J Hosp Infect. 2015;90(3):213–9.
3. Pokrywka M, Byers K. Traffic in the operating room: a review of factors influencing air flow and surgical wound contamination. Infect Disord Drug Targets. 2013;13(3):156–61.
4. Panahi P, Stroh M, Casper DS, Parvizi J, Austin MS. Operating room traffic is a major concern during total joint arthroplasty. Clin Orthop Relat Res. 2012;470(10):2690–4.
5. Babkin Y, Raveh D, Lifschitz M, Itzchaki M, Wiener-Well Y, Kopuit P, et al. Incidence and risk factors for surgical infection after total knee replacement. Scand J Infect Dis. 2007;39(10):890–5.
6. Stocks GW, Self SD, Thompson B, Adame XA, O'Connor DP. Predicting bacterial populations based on airborne particulates: a study performed in nonlaminar flow operating rooms during joint arthroplasty surgery. Am J Infect Control. 2010 Apr;38(3):199–204.
7. Pada S, Perl TM. Operating room myths. Curr Opin Infect Dis. 2015 Aug;28(4):369–74.
8. Birgand G, Azevedo C, Rukly S, Pissard-Gibollet R, Toupet G, Timsit JF, et al. Motion-capture system to assess intraoperative staff movements and door openings: Impact on surrogates of the infectious risk in surgery. Infect Control Hosp Epidemiol. 2019;40(5):566–73.
9. Tham KW, Zuraimi MS. Size relationship between airborne viable bacteria and particles in a controlled indoor environment study. Indoor Air. 2005 Jun;15(s9):48–57.
10. Albertini R, Coluccia A, Colucci ME, Zoni R, Affanni P, Veronesi L, et al. An overview of the studies on microbial air contamination in operating theatres and related issues over time: a useful tool for a multidisciplinary approach. Acta Biomed. 2023;94(S3):e2023149.
11. Parvizi J, Barnes S, Shohat N, Edmiston CE Jr. Environment of care: Is it time to reassess microbial contamination of the operating room air as a risk factor for surgical site infection in total joint arthroplasty? Am J Infect Control. 2017 Nov 1;45(11):1267–72.
12. Cristina ML, Spagnolo AM, Sartini M, Panatto D, Gasparini R, Orlando P, et al. Can particulate air sampling predict microbial load in operating theatres for arthroplasty? PLoS One. 2012 Dec 21;7(12):e52809.
13. Montagna MT, Rutigliano S, Trerotoli P, Napoli C, Apollonio F, D'Amico A, et al. Evaluation of Air Contamination in Orthopaedic Operating Theatres in Hospitals in Southern Italy: The IMPACT Project. Int J Environ Res Public Health [Internet]. 2019;16(19). Available from: http://dx.doi.org/10.3390/ijerph16193581
14. Rezapoor M, Alvand A, Jacek E, Paziuk T, Maltenfort MG, Parvizi J. Operating Room Traffic Increases Aerosolized Particles and Compromises the Air Quality: A Simulated Study. J Arthroplasty. 2018;33(3):851–5.
15. Smith EB, Raphael IJ, Maltenfort MG, Honsawek S, Dolan K, Younkins EA. The effect of laminar air flow and door openings on operating room contamination. J Arthroplasty. 2013 Oct;28(9):1482–5.
16. Weiser MC, Shemesh S, Chen DD, Bronson MJ, Moucha CS. The Effect of Door Opening on Positive Pressure and Airflow in Operating Rooms. J Am Acad Orthop Surg. 2018;26(5):e105–13.

17. Harp JH. Observational study of sterile field bioburden levels during orthopedic arthroplasty surgery in operating rooms complying with current United States ventilation specifications. Am J Infect Control. 2023 Jul;51(7):758–64.
18. Birgand G, Toupet G, Rukly S, Antoniotti G, Deschamps M-N, Lepelletier D, et al. Air contamination for predicting wound contamination in clean surgery: A large multicenter study. Am J Infect Control. 2015 May 1;43(5):516–21.
19. 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(8):750–5.
20. Hanssen AD, Rand JA. Evaluation and treatment of infection at the site of a total hip or knee arthroplasty. Instr Course Lect. 1999;48:111–22.
21. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: The incidence, timing, and predisposing factors. Clin Orthop Relat Res. 2008 Jul;466(7):1710–5.
22. Coury JG, Lum ZC, Dunn JG, Huff KE, Lara DL, Trzeciak MA. Operating Room and Hospital Air Environment. Orthopedics. 2021;44(3):e414–6.
23. Lansing SS, Moley JP, McGrath MS, Stoodley P, Chaudhari AMW, Quatman CE. High Number of Door Openings Increases the Bacterial Load of the Operating Room. Surg Infect (Larchmt). 2021;22(7):684–9.
24. Mears SC, Blanding R, Belkoff SM. Door opening affects operating room pressure during joint arthroplasty. Orthopedics. 2015 Nov;38(11):e991-4.
25. Tjade OH, Gabor I. Evaluation of airborne operating room bacteria with a Biap slit sampler. J Hyg (Lond). 1980 Feb;84(1):37–40.
26. Malinzak RA, Ritter MA. Postoperative wound infection: 35 years of experience. Orthopedics. 2006 Sep;29(9):797–8.
27. Ritter MA, Eitzen H, French ML, Hart JB. The operating room environment as affected by people and the surgical face mask. Clin Orthop Relat Res. 1975 Sep;111(111):147–50.
28. Patel PG, DiBartola AC, Phieffer LS, Scharschmidt TJ, Mayerson JL, Glassman AH, et al. Room Traffic in Orthopedic Surgery: A Prospective Clinical Observational Study of Time of Day. J Patient Saf. 2021;17(3):e241–6.
29. Teter J, Guajardo I, Al-Rammah T, Rosson G, Perl TM, Manahan M. Assessment of operating room airflow using air particle counts and direct observation of door openings. Am J Infect Control. 2017 May;45(5):477–82.
30. Parikh SN, Grice SS, Schnell BM, Salisbury SR. Operating room traffic. J Pediatr Orthop. 2010 Sep;30(6):617–23.
31. Nooh A, Tanzer M, Alzeedi M, Lavoie-Turcotte T, Hart A. Traffic cameras-an effective and sustainable method of reducing traffic and airborne particles during arthroplasty surgery. J Arthroplasty. 2024 Jan;39(1):255–60.
32. Osborn NS, Hoehmann CL, McCormack R, Owens J. Operating Room Traffic in Total Joint Arthroplasty: One Simple Measure Toward Solving a Complex Problem. JB JS Open Access [Internet]. 2020;5(3). Available from: http://dx.doi.org/10.2106/JBJS.OA.20.00015
33. Hamilton WG, Balkam CB, Purcell RL, Parks NL, Holdsworth JE. Operating room traffic in total joint arthroplasty: Identifying patterns and training the team to keep the door shut. Am J Infect Control. 2018;46(6):633–6.
34. Erivan R, Villatte G, Haverlan A, Roullet CA, Ouchchane L, Descamps S, et al. Does a sign restricting operating room access reduce staff traffic in the surgical department? Orthop Traumatol Surg Res. 2024;103843.
35. Eskildsen SM, Moskal PT, Laux J, Del Gaizo DJ. The Effect of a Door Alarm on Operating Room Traffic During Total Joint Arthroplasty. Orthopedics. 2017;40(6):e1081–5.

APPENDIX

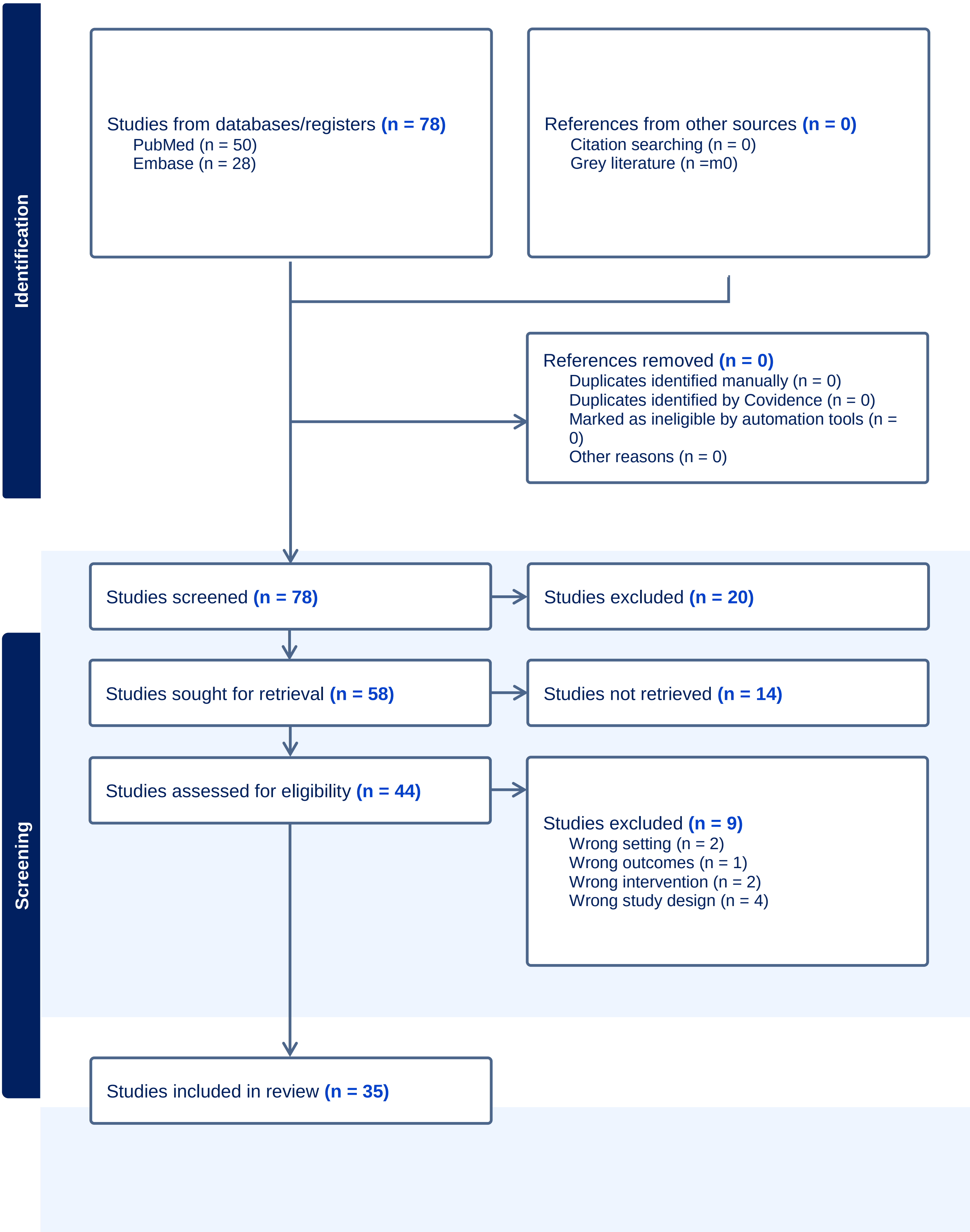
Appendix 1: Search string for advanced search (Pubmed)

(((arthrodesis[mh] OR arthroplasty[mh] OR orthopedic procedures[mh:noexp] OR spinal fusion[mh] OR arthrodes*[tw] OR arthroplast*[tw] OR "orthopaedic operative"[tw] OR "orthopedic operative"[tw] OR "orthopaedic procedure*"[tw] OR "orthopedic procedure*"[tw] OR "orthopaedic surger*"[tw] OR "orthopedic surger*"[tw] OR "orthopaedic surgical"[tw] OR "orthopedic surgical"[tw] OR "hip replacement*"[tw] OR "joint replacement*"[tw] OR "knee replacement*"[tw] OR "shoulder replacement*"[tw] OR ((hip[tw] OR joint[tw] OR knee[tw] OR orthopaedic[tw] OR orthopedic[tw] OR shoulder[tw]) AND (implant*[tw] OR prostheses[tw] OR prosthesis[tw] OR prosthetic*[tw])) OR ((cervical[tw] OR lumbar[tw] OR spinal[tw] OR spine[tw]) AND (fusion*[tw] OR implant*[tw] OR instrumentation*[tw]))) AND (infections[mh:noexp] OR prosthesis-related infections[mh] OR surgical wound infection[mh] OR infection*[ti] OR PJI[ti] OR PJIS[ti] OR SSI[ti] OR SSIS[ti] OR "joint infection*"[tw] OR "periprosthesis infection*"[tw] OR "periprosthetic infection*"[tw] OR "prosthesis infection*"[tw] OR "prosthetic infection*"[tw] OR "surgical site infection*"[tw] OR "surgical wound infection*"[tw])) AND ((((1990:3000/12/12[pdat]) AND (english[LA])) OR (randomized controlled trial [pt] OR controlled clinical trial [pt] OR randomized [tiab] OR placebo [tiab] OR drug therapy [sh] OR randomly [tiab] OR trial [tiab] OR groups [tiab])) NOT (animals [mh] NOT humans [mh]))) AND ((operating rooms[mh] OR "operating room*"[tw]) AND ("door motion*"[tiab] OR "door movement"[tiab:~2] OR "doors movement"[tiab:~2] OR "door movements"[tiab:~2] OR "doors movements"[tiab:~2] OR "door open"[tiab:~2] OR "doors open"[tiab:~2] OR "door opening"[tiab:~2] OR "doors opening"[tiab:~2] OR "door openings"[tiab:~2] OR "doors openings"[tiab:~2] OR (traffic[tiab] NOT (road*[tiab] OR "traffic accident*"[tiab]))))

Appendix 2: Search string for advanced search (Embase)

(((arthrodesis/exp OR arthroplasty/exp OR orthopedic-procedure/exp OR spinal-fusion/exp OR arthrodes*:ti,ab OR arthroplast*:ti,ab OR "orthopaedic operative":ti,ab OR "orthopedic operative":ti,ab OR "orthopaedic procedure*":ti,ab OR "orthopedic procedure*":ti,ab OR "orthopaedic surger*":ti,ab OR "orthopedic surger*":ti,ab OR "orthopaedic surgical":ti,ab OR "orthopedic surgical":ti,ab OR "hip replacement*":ti,ab OR "joint replacement*":ti,ab OR "knee replacement*":ti,ab OR "shoulder replacement*":ti,ab OR ((hip:ti,ab OR joint:ti,ab OR knee:ti,ab OR orthopaedic:ti,ab OR orthopedic:ti,ab OR shoulder:ti,ab) AND (implant*:ti,ab OR prostheses:ti,ab OR prosthesis:ti,ab OR prosthetic*:ti,ab)) OR ((cervical:ti,ab OR lumbar:ti,ab OR spinal:ti,ab OR spine:ti,ab) AND (fusion*:ti,ab OR implant*:ti,ab OR instrumentation*:ti,ab)))) AND (infection/exp OR prosthesis-infection/exp OR surgical-wound-infection/exp OR infection*:ti OR PJI:ti OR PJIS:ti OR SSI:ti OR SSIS:ti OR "joint infection*":ti,ab OR "periprosthesis infection*":ti,ab OR "periprosthetic infection*":ti,ab OR "prosthesis infection*":ti,ab OR "prosthetic infection*":ti,ab OR "surgical site infection*":ti,ab OR "surgical wound infection*":ti,ab)) AND (((1990-3000)/py AND [english]/lim) OR (randomized-controlled-trial/exp OR controlled-clinical-trial/exp OR randomized:ti,ab OR placebo:ti,ab OR drug-therapy/exp OR randomly:ti,ab OR trial:ti,ab OR groups:ti,ab)) NOT (animal/exp NOT human/exp)) AND ((operating-room/exp OR "operating room*":ti,ab) AND ("door motion*":ti,ab OR "door movement":ti,ab OR "doors movement":ti,ab OR "door movements":ti,ab OR "doors movements":ti,ab OR "door open":ti,ab OR "doors open":ti,ab OR "door opening":ti,ab OR "doors opening":ti,ab OR "door openings":ti,ab OR "doors openings":ti,ab OR (traffic:ti,ab NOT (road*:ti,ab OR "traffic accident*":ti,ab))))

Appendix 3: PRISMA Study Inclusion Flowchart



Included