Systematic Review / Meta-analysis

ANNALS OF MEDICINE & SURGERY

OPEN

Evidence-based guidelines on infection prevention and control in operation theatres for anesthetists in a resource-limited setting: systematic review/meta-analysis

Seyoum Hailu, MSc, Hailemariam Mulugeta, MSc, Timsel Girma, MSc, Amanuel Asefa, BSc, Teshome Regasa, MSc

Introduction: Surgical site infections and nosocomial infections are the most frequent source of prolonged hospital stay and cross-contamination of infection in the operating room. Despite the perception, the operating rooms are not sterile environments as it has sterile and nonsterile areas, as well as sterile and nonsterile personnel. The contaminated environment, like the anesthesia environment, is the most potent transmission vehicle for pathogens.

Objective: The objective of this review is to develop evidence-based guidelines on infection prevention and control in operation theaters for anesthesia care providers in a resource-limited setting.

Methodology: This review is reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. Articles published in the English language were searched from different sources to identify studies for the review using the keywords. Database search was done by using Boolean operators like AND, OR, NOT, or AND NOT from Cochrane review, Hinari, PubMed, Google Scholar, and Medline databases, and filtering was made based on the intervention, outcome, data on population, and methodological quality. The conclusion was made based on the level of evidence that was referred to by the Oxford Center for Evidence-Based Medicine.

Results: Generally, 1672 articles were identified through database searching strategies. Articles were searched by filtering systems such as publication year, level of evidence, and duplicates that were unrelated to the topics. Finally, 20 articles (9 randomized controlled trials, 4 meta-analyses and systematic reviews, 4 reviews, and 3 observational studies) were identified by using keywords from different databases by different search strategies from 10 July to 14 August 2022.

Conclusion: As primary patient patrols anesthetists face significant infection risk and also contaminate the operating room environment. Precautions that are practical, affordable, and efficient in the anesthesia setting are needed considering the limited availability of personal protective equipment.

Keywords: anesthetists, contamination, infection, operation room, resource-limited setting

Introduction

Surgical site infections (SSIs) and nosocomial infections are the most frequent source of prolonged hospital stay and cross-contamination of infection in the operation room (OR)[1]. Despite the perception, the operating rooms are not sterile environments as it has sterile and nonsterile areas, as well as sterile and nonsterile personnel[2]. An operating room is designed and equipped to provide care for patients with a range of conditions, or it may be designed and equipped to provide specialized care to patients with specific conditions[3]. The operating room (OR) environment includes healthcare tools and surfaces used within the anesthesia work environment (AWE), the surrounding air, as well as the patient, the anesthesia providers, and other professionals[4]. The surgeon, surgical assistant, and scrub nurse are considered sterile, while the anesthetist, circulating nurse, student, or observer is considered nonsterile[5]. Recent reports have shed light on three main causes of perioperative pathogen vectors: the anesthesia care provider, the operating patient, and the operative environment[4].

The contamination of the three potential sources of infection, such as environment, personnel, and air, profoundly contributes to the staggering rate of perioperative infection[6,7]. It is known

HIGHLIGHTS

- There are three main causes of perioperative pathogen vectors.
- Anesthetists face significant infection risk and also contaminate the operating room environment.
- Precautions that are practical, affordable, and efficient in the anesthesia setting are needed.

Department of Anesthesiology, Dilla University, Dilla, Ethiopia

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Dilla University, Dilla, Ethiopia. Tel.: +251968060649. E-mail: seyoumhailu44@gmail.com (S. Hailu).*

Annals of Medicine & Surgery (2023) 85:2858–2864

Received 31 October 2022; Accepted 3 April 2023

Published online 19 April 2023

http://dx.doi.org/10.1097/MS9.0000000000000689

that anesthesia care providers are pioneers in patient–professional interaction; the hands are the most common vehicles by which microorganisms are transmitted between patients. Nail varnish and pieces of jewelry hide bacteria and reduce the effectiveness of hand scrubbing[8]. Studies show that anesthesia providers contribute to the ongoing problem of healthcare-associated infection, a more efficient approach to operating room pathogen containment, especially during induction of anesthesia and extubation[9]. Residual contamination of laryngoscope blades and handles and airway devices with blood and mucus after use has been linked to infectious outbreaks. Contaminated environments like the anesthesia environment are the most potent transmission vehicle for pathogens[1]. Anesthesia providers are identified as the most noncompliant group in hand hygiene compliance across healthcare providers, which is directly linked to high-risk bacterial transmission events[10–12].

The greatest number of microorganisms are there in heavily contaminated substances such as body fluids[8] and can be transported to OR through syringes, intravenous (i.v.) catheters, or i.v. lines and bacterial sources from patient caring nurses can be the source of SSI. Contamination of anesthesia machine surfaces with blood, mucus, and bacterial organisms after standard cleaning processes, residual microbial contamination of laryngoscopes, and microbial contamination from drug vials are potential sources of infection[4,13]. Perioperative hand hygiene is one of the most critical factors affecting the risk of SSI as well as the safety of medical staff. Theater staff should consider scrubbing their hands intensively, use of double gloves, and selecting surgical gowns before every case to reduce the number of bacteria on them[14]. Wearing a single pair of gloves and not changing them after intubation may contain blood and pathogens from the patient throughout the OR after anesthesia induction, and not routinely disinfecting the i.v. hub properly is some of the anesthetist's practice gaps that predispose to infection[15].

Microorganisms are commonly transported in surgical theater air from the OR environment and personnel in the room through breathing, coughing, and sneezing, whereby they may enter incision sites during surgical procedures and cause SSI[16,17]. Adequate operating room ventilation system with positive air pressure and laminar airflow; limited OR access for observers and nursing/medical students reduces SSIs[18]. Hand sanitizer or alcohol placement in proximity to the anesthesia provider to use whenever the breach happens also decreases risk[15].

The OR is a place where different professionals interact with the well-being of a patient by sharing their knowledge, equipment, ideas, and a lot of things. This interaction creates cross-contamination, which can spread pathogenic microorganisms from harbor to guest. The AWE has not been emphasized, being the main area and source of pathogen harbor and spread in the theater. Due to this fact, anesthetists need to know the rule to practice infection prevention and control strategies in the OR. There are infection prevention and control guidelines such as the CDC (Centers for Disease Control and Prevention) infection prevention guideline[19], WHO (World Health Organization) infection prevention guideline[20], and also EPI (Expanded Program on Immunization) Guideline developed by the Ethiopian Ministry of Health [21]. Although the CDC and WHO guidelines are OR based, they do not emphasize the AWE. The EPI guideline focuses on all hospital environments and describes some of the measures taken by the OR, but it does not say anything about the AWE.

The focus of this review is to develop an evidence-based guideline for infection prevention and control for anesthesia care providers for infection prevention from patient entry to the operation theater (OT) to discharge of the patient from the OR, which is mainly the responsibility of anesthetists. The review aims to make recommendations for clinicians that are needed to decrease and control the spread of infection in the OR by manipulating and appropriately using available resources and modification of daily practices which predispose to contamination of the OT.

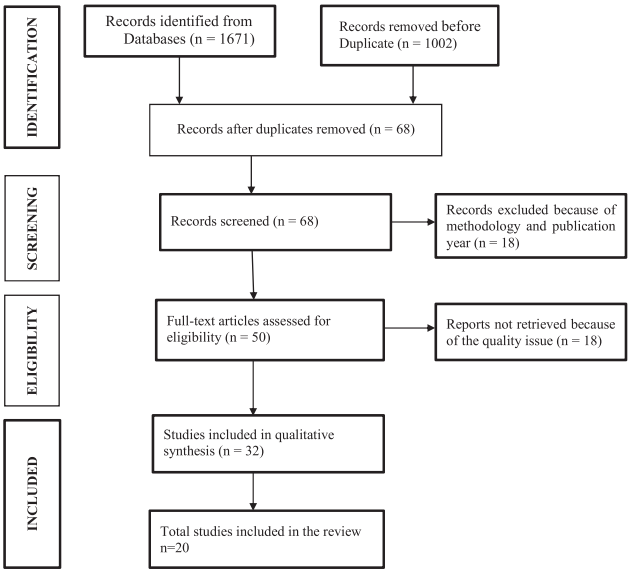

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.

Methodology

This review is reported based on Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol. Those articles published in the English language were searched from Cochrane review, Hinari, PubMed, Google Scholar, and Medline databases to identify studies for the review using the keywords (Anesthesia care providers, anesthetists, infection prevention, contamination, OR infection control, OT infection, and resource-limited setting by using Boolean operators like AND, OR, NOT or AND NOT). A lot of journals were obtained from a search engine; filtering was made based on the intervention, outcome, data on population, and methodological quality.

Inclusion and exclusion criteria

Studies that focus on the OR infection risks, prevention, and management, published in the English language between January 2000 and December 2022, were included in this systematic review, while articles on specific procedures, the study period before 2000, articles published in the predatory journal, studies with poor methodological quality and scored less than 50% on quality assessment were excluded.

Table 1

Summary of the included evidence/studies.

Serial number	Author with the publication year	Country	Population	Study design	Sample	Key findings	Level of evidence
1	Birnbach *et al.*, 2015[14]	USA	Anesthesiology residents	RCT	41	There were statistically significant infection rates between gloved and nongloved anesthetists	1b, A
2	Birnbach *et al.*, 2015[15]	USA	Anesthesiology residents	RCT	45	Sheathing of the laryngoscope immediately after endotracheal intubation significantly reduced contamination of the i.v. hub, patient, and intraoperative environment	1b, A
3	Hunter *et al.*, 2017[13]	USA	Attending and resident anesthetist	RCT	42	Application of a barrier device to the anesthesia workstation during induction and intubation might reduce contamination of the intraoperative environment	1b, A
4	Lo Giudice *et al.*, 2019[25]	Italy	Operating room personnel	Observational study	308	Low adherence to international guidelines among the personnel	2b, C
5	Darouiche *et al.*, 2016[26]	USA	Patients undergoing total hip arthroplasty instrumented spinal procedures or vascular bypass graft implantation	RCT	300 patients	Reduction of airborne colony-forming units near surgical sites decreases infection risk	1b, A
6	Tsai *et al.*, 2016[27]	Taiwan	Surgical staff members	RCT	80 staff members	Conventional chlorhexidine scrub and waterless hand rub were superior to a conventional providence–iodine product in bacterial inhibition	1b, A
7	Webster *et al.*, 2010[28]	Australia	Participants undergoing elective or emergency surgery	RCT	827	Surgical site infection (SSI) rates did not increase when nonscrubbed operating room personnel did not wear a face mask	1b, A
8	Link *et al.*, 2016[6]	USA	The high and low-touch areas were observed	Observational study	Observation of 43 procedures	The five primary high-touch surfaces in order were the anesthesia computer mouse, OR bed, nurse computer mouse, OR door, and anesthesia medical cart	2b, C
9	Loftus *et al.*, 2011[9]	Lebanon	Anesthesia care providers	Prospective observational study	164	The contaminated hands of anesthesia providers serve as a significant source of patient environmental and stopcock set contamination in the operating room	1b, A
10	Bedianko-Bowan *et al.*, 2020[29]	Ghana	Patients undergoing abdominal surgical procedures	Prospective cohort	358	Changing behavior and practices in operating rooms is a key strategy to reduce SSI risk	2b, C
11	Romano *et al.*, 2020[17]	Italy	Operation theater in their operative life for 8 years	Prospective cohort study	1228 observations	Unidirectional airflow is better than multidirectional airflow	2b, C
12	Beldi *et al.*, 2009[1]	Switzerland	Patients underwent bowel preparation for colorectal surgery	Prospective cohort	1032 surgical patients	Extensive measures of antisepsis did not reduce the incidence of SSI	1a, A

i.v., intravenous; OR, operation room; RCT, randomized controlled trial.

Table 2

Summary of evidence used reviews and meta-analysis.

Serial number	Journal with the publication year	Country	Study design	Key findings	Level of evidence
1	Current Opinion in Anesthesiology 2016[30]	USA	Review	The best practice for postoperative infection control is a multimodal program that targets patients, providers, and environmental reservoirs in parallel	1a, A
2	Cochrane Database of Systematic Reviews 2010[8]	UK	Review	There is insufficient evidence to determine whether wearing nail polish affects the number of bacteria on the skin after scrub	1a, A
3	Critical Care Nursing Clinics of North America 2015[7]	USA	Review	Anesthesia providers have the potential to increase the patient's risk of developing an SSI	1a, A
4	The Lancet Infectious Diseases 2017[16]	Germany	Meta-analysis	The available evidence shows no benefit for laminar airflow compared with conventional turbulent ventilation of the operating room in reducing the risk of SSIs in total hip and knee arthroplasties, and abdominal surgery	1a, A
5	The Journal of Bone and Joint Surgery American volume 2018[31]	USA	Review	Operating room (OR) heating, ventilation, and air-conditioning (HVAC) systems play an important role in the reduction of airborne bacterial colony-forming units	1a, A
6	Anesthesia and Analgesia 2015[32]	USA	Review	Bacterial transmission in the anesthesia work area of the operating room environment is a root cause of 30-day postoperative infections affecting as many as 16% of patients undergoing surgery	1a, A
7	Indian Journal of Anesthesia 2013[33]	India	Review article	There is a need to develop evidence-based infection prevention and control programs and set national guidelines for disinfection and sterilization of anesthesia equipment which all the institutions should comply with	1a, A
8	Infection Control & Hospital Epidemiology 2020[34]	China	Meta-analysis	The impact of the type of operating room ventilation may have no influence on surgical site infection as a tool for decreasing its occurrence	1a, A

SSI, surgical site infection.

Methods of screening

Articles identified for retrieval were assessed by two independent authors for methodological quality before inclusion in the review, and the disagreements between the authors appraising the articles were resolved through discussion. The quality of meta-analysis and systematic review papers were evaluated as high and it is reported in line with AMSTAR (A MeaSurement Tool to Assess systematic Reviews) 2 criteria[22], while articles such as randomized controlled trials (RCTs), case–control, and cohort were appraised by the CASP (Critical Appraisal Skills Programme) appraisal tool[23]. This work is fully compliant with the PRISMA 2020 statement[24], and it has been registered on the research registry with a UIN of reviewregistry1467 (https://www.researchregistry.com/browse-theregistry#registryofsystematicreviewsmeta analyses/).

Results

Generally, 1672 articles were identified through database searching strategies. Articles were searched and filtered based on publication year, study design, language, and duplicates that were unrelated to the topics. Finally, 20 articles (6 RCTs, 2 meta-analyses and systematic reviews, 6 reviews, and 6 observational studies) were identified by using keywords from different databases by different search strategies from 10 July to 14 August 2022. The results of the search strategy were summarized with a PRISMA flowchart (Fig. 1). A summary of the included evidence/studies is presented in Tables 1 and 2 below. The conclusion was made based on the level of evidence that was referred from the Oxford Center for Evidence-Based Medicine (Table 3)[35].

Discussion

Operation theater environment and air contamination

The potential sources of infection in the OR are acceptably classified as environment, personnel, and air. The cleanliness and contamination level in the area should be maintained to reduce both the incidence of SSI, spread to hospital personnel, and the harmful effect on patients' and professional healthy. Lo Giudice *et al*.[25] have done an observational study comprising the use of surgical attire, the frequency of doors opening, and the number of staff in the operating room, which found no significant difference in traffic rate between SSI and non-SSI groups. According to Bohl *et al*.[18] there was a significant difference in main-door traffic rate between SSI and non-SSI groups ($P < 0.001$)[18] (3, b).

Microorganisms responsible for infections are commonly transported in surgical theater air, whereby they enter incision sites during surgical procedures and cause SSI. The flow of air in the OR can be affected by the layout and operational characteristics of the heating, ventilation, and air-conditioning (HVAC) system, door-opening events, and the movement of equipment and personnel[28]. The flow of air in the OR should be laminar rather than a turbulent flow, which increases the contamination of infection in the OR by spreading infection through the air. Some studies show that laminar airflow ventilation decreases the risk of SSI and contamination in OT by creating unidirectional airflow[16]. Air cleaning technologies, such as dilution with ventilation, unidirectional air distribution, pressure control, and air filtration, are usually adopted to create a clean surgical environment for the operating room in some resourceful areas[36].

The reasoning behind restricting OR traffic through the main door was based on the underlying theory of association between OR traffic and SSI rate: ORs are equipped to maintain positive air

Table 3

Level of evidence and grade of recommendation.

Level of evidence	Grading criteria	Grade of recommendations
1a	A systemic review of RCT including meta-analysis	A
1b	Individual RCT with a narrow confidence interval	A
1c	All or nonrandomized control trial	B
2a	A systemic review of cohort study individual cohort including low-quality RCT	B
2b	Individual cohorts including low-quality study	B
2c	'Outcomes' research; ecological studies	C
3a	A systematic review of case–control studies	C
3b	Individual case–control study	C
4	Case series poor quality cohort and case–control study	C
5	Expert opinion without explicit critical appraisal	D

RCT, randomized clinical trial.

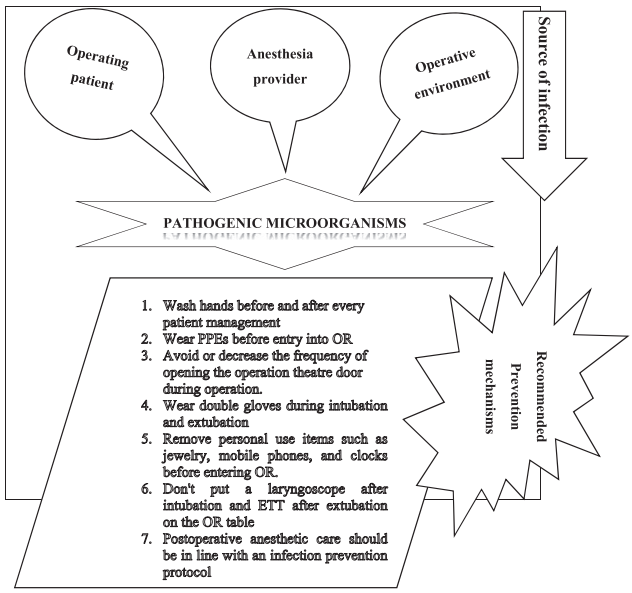

Figure 2. Flowchart on infection prevention and control in the operation theaters for anesthesia care providers in a resource-limited setting. ETT, endotracheal tube; OR, operation room; PPE, personal protective equipment.

pressure and laminar airflow, which minimize the amount of contaminant-laden air near the patient. Increased personnel traffic increases the shedding of airborne contaminants from skin and clothing, and increased door openings disrupt OR positive pressure and laminar airflow, allowing for dirtier corridor air to enter the OR and contaminate an open incision[37]. The ventilation system is affected by many factors, such as the position of the operating table, the number of the operating team, the surgical lamps, the type of personnel clothing systems, the surgical equipment, and the frequency of door opening[17]. According to a study, measured indoor temperature should range from 14 to 29° C, and relative humidity should from 13 to 80%[17].

Operation theater contamination through different equipment

The highest potential for pathogen spread and subsequent contamination in anesthesia practices is at the time of induction and emergence. Reducing early contamination of the anesthesia environment is a complementary step that relies less on individual practitioner compliance than does hand hygiene. The spread of secretions from the patient's mouth to the OR environment during intubation and extubation increases the contamination of the theater[15]. Both the laryngoscope handle and blade have been documented as at risk for being contaminated with blood, body fluids, and potentially pathogenic microorganisms during clinical use. The use of double gloves for intubation decreases the contamination of clean syringes, tubes, airways, and other equipment on the anesthesia table. The laryngoscope should be placed in prepared disinfectant solution after intubation, not on the anesthesia machine surface after use[13,14]. According to Birnbach *et al.*[14], the average number of contaminated sites for single gloves was significantly higher than the contamination with double gloves with no sheathing (3.2 [2.3–4.3]; $P < 0.001$) and with double gloves with sheathing (0.6 [0.3–1.2]; $P < 0.001$) (1a, A).

Operation theater contamination by personnel

Personal use items of doctors, anesthetists, and other OT personnel, such as mobile phones, wristwatches, and other pieces of jewelry, show a high percentage of bacterial contamination. The hands of anesthesia providers are contaminated immediately before patient care with a wide range of bacterial pathogens[13,38]. Hand washing is significantly lower before patient contact than after, which results in microbiological identification of contaminating organisms such as from fingertips, mobile phones, and wristwatches showed there is a significant number of predominant contaminating bacteria; *Staphylococcus aurous* although nosocomial pathogens like bacteria, viruses, and fungi can survive on inanimate surfaces for long periods[10,38].

Different personals who take part in the spread of infection, in addition to already known (patients), are nursing staff, anesthesia technicians, environmental services, observers, and contracted cleaning professionals those spread infections by contaminating breaches in cleaning ways[39]. High-touch areas and inanimate hospital environments are reservoirs for resistant organisms, and frequent contact with upper airway secretions and small volumes of blood leads to potential contamination of anesthesia providers and their surroundings[14].

Conclusion

Recent studies reported that there are three main sources of perioperative pathogen vectors: the anesthesia provider, the operative patient, and the operative environment. As primary patient patrols, anesthetists face significant infection risk and also contaminate the operating room environment. As compliance with the standard precaution among OR personnel is low, precautions that are practical, affordable, and efficient in the anesthesia setting are needed considering the limited availability of personal protective equipment (see Fig. 2).

Ethical approval

This Systematic Literature review has been exempted by the Institutional Review Board of Dilla University College of Medicine and Health Science from requiring ethical approval.

Consent

Literatures reviewed and cited appropriately.

Sources of funding

There is no financial support needed to write this systematic literature review.

Author contribution

All authors have made substantial contributions to conception and design and participated in the critical review and editing of the manuscript drafts for scientific merit and depth.

Conflicts of interest disclosure

There are no conflicts of interest.

Research registration unique identifying number (UIN)

1. Name of the registry: Research Registry.
2. Unique identifying number or registration ID: reviewregistry1467.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-theregistry#registryofsystematicreviewsmetaanalyses/

Guarantor

Seyoum Hailu.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Acknowledgments

We will acknowledge Dilla University for providing us the opportunity to write this scientific paper.

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