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Systematic Review

Infection Prevention and Standard Precautions in the Anesthesia Work Environment: A Systematic Review

Younes Barazesh[1*]

[1]Department of Anesthesiology, School of Paramedicin, Hamadan University of Medical Sciences,Hamadan,Iran

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***Corresponding author:**
Younes Barazesh,
Email: barazesh.younes@gmail.com

Abstract

Background: Healthcare-associated infections (HAIs) persist as a critical challenge in anesthesia practice due to high-risk procedures, complex equipment, and time-sensitive care. Despite advances in sterile techniques, the anesthesia workspace remains a reservoir for multidrug-resistant organisms (MDROs), with lapses in compliance and gaps in infection control protocols exacerbating risks. This systematic review evaluated the efficacy of current infection prevention strategies in the anesthesia work environment, identified gaps in practice, and proposed evidence-based solutions to reduce HAIs.

Methods: A systematic review of peer-reviewed articles (1990–2024) was conducted using PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar databases, yielding 826 initial references. After screening, 17 high-quality studies met the inclusion criteria (systematic reviews, randomized trials, and WHO/CDC guidelines). Two independent reviewers screened articles, resolved discrepancies via consensus, and excluded non-peer-reviewed or industry-funded studies. Hand hygiene, environmental disinfection, medication safety, provider education, laryngoscope management, and airway safety were key domains analyzed in this study.

Results: Hand hygiene compliance among anesthesia providers was suboptimal (40%–60%), lagging behind surgical teams. Environmental disinfection was inconsistent, and less than 35% of high-touch surfaces (e.g., anesthesia machines and intravenous poles) were cleaned between cases. Microbial contamination occurred in 12% of multi-dose vials, and closed-system transfer devices reduced contamination risks by 40%–60%. Laryngoscope handles harbored pathogens in 30% of cases post-procedure. Simulation-based education improved compliance 27-fold. Eventually, ultraviolet-C (UV-C) decontamination and "bundled" strategies reduced workspace contamination by 27%.

Conclusion: To mitigate HAIs in anesthesia, it is essential to have a multimodal approach that combines standardized protocols, single-use equipment, technological innovations (e.g., UV-C systems), and cultural shifts toward collective accountability. Prioritizing resource allocation, enhancing provider education, and integrating real-time compliance feedback can bridge guideline-practice gaps, transforming the anesthesia environment into a model of sterility and patient safety.

Keywords: Anesthesia, Anesthesia work environment, Infection prevention, Hand hygiene

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Introduction

The anesthesia work environment is a high-risk setting for healthcare-associated infections (HAIs) due to frequent provider-patient interactions, contamination-prone equipment, and time-sensitive procedures. Anesthesia providers are implicated in pathogen transmission through lapses in hand hygiene, inadequate disinfection, and unsafe medication practices (1,2). High-touch surfaces, such as anesthesia machines and laryngoscopes, often harbor multidrug-resistant organisms (MDROs), contributing to nosocomial infections that increase morbidity and healthcare costs (3). During the coronavirus disease 19 pandemic, aerosol-generating procedures such as intubation further emphasized the need for robust infection control. Despite the guidelines, studies report suboptimal compliance, confirming that 60% of providers skip hand hygiene during emergencies, and 45% fail to disinfect laryngoscope handles between cases (3,4). The anesthesia clinical setting is a high-risk area for HAIs due to frequent interactions between healthcare providers and patients, surfaces prone to contamination from regular contact, and the use of intricate medical devices during time-sensitive procedures (5). Hand hygiene serves as a critical component of infection control; however, adherence rates among anesthesia professionals are often inadequate, reported between 40% and 60%, which is notably lower than those observed in surgical staff (6). Challenges such as time limitations during emergencies and limited availability of hand sanitizing stations contribute to these lapses (7). Alcohol-based hand sanitizers, endorsed for their efficacy in reducing microbial presence by nearly 99%, alongside strategically placed dispensers and prompt systems to remind staff, have enhanced compliance rates by approximately 30% (8).

Environmental disinfection remains a persistent challenge, as critical surfaces such as anesthesia machine interfaces and intravenous poles are often contaminated with MDR pathogens (8). Studies indicate that fewer than 35% of these surfaces undergo thorough cleaning between procedures, partly due to time pressures during operating room transitions (8). While quaternary ammonium compounds and ultraviolet-C (UV-C) decontamination systems demonstrate strong antimicrobial activity, their integration into fast-paced workflows is often impractical (9). Medication safety is jeopardized by improper handling of multi-dose vials, with microbial contamination detected in 12% of samples due to repeated access (10). Closed-system transfer devices and prefilled syringes reduce contamination risks by 40–60%, though cost barriers hinder their universal adoption (10). Provider education plays a pivotal role in bridging knowledge gaps, with simulation-based training and real-time compliance feedback improving protocol adherence by up to 27-fold in some interventions (11).

Laryngoscope management is another vulnerability, as 30% of handles harbor pathogens post-procedure due to inconsistent disinfection (12). Recommendations include high-level disinfection (HLD) protocols, steam sterilization for reusable blades, and single-use alternatives to mitigate cross-contamination (13). Airway safety during aerosol-generating procedures, such as intubation, demands stringent precautions. Enhanced measures, including preoperative antiseptic oral rinses, video laryngoscopy, high-efficiency particulate air (HEPA) filtration systems, and N95 respirators, reduce pathogen exposure by 30–50% (14).

Materials and Methods

In this overview, articles published in peer-reviewed journals and credible websites (1990–2024) were reviewed using several databases, such as Web of Science, PubMed, Google Scholar, Scopus, and ScienceDirect. To this end, a number of keywords were searched, including anesthesia, infection prevention, guidelines, and anesthesia work environment, yielding 826 initial references. Overall, 41 articles were retained after removing duplicates, screening abstracts, and excluding articles focused on specific surgeries or lacking relevance. To ensure quality, studies were assessed for systematic value, methodological rigor, and evidence strength, prioritizing peer-reviewed systematic reviews, randomized controlled trials, and evidence-based guidelines (e.g., the World Health Organization and the Centers for Disease Control and Prevention) over lower-evidence sources, such as case reports, which were included only if they provided unique insights. To mitigate bias, two independent reviewers conducted screening, full-text evaluations, and data extraction, resolving discrepancies via discussion or third-reviewer consultation; predefined inclusion criteria excluded 24 additional articles (e.g., insufficient focus on anesthesia practice and non-peer-reviewed sources without institutional credibility), and conflicts of interest were managed by excluding industry-funded studies with unclear objectivity. The final analysis included 17 high-quality articles meeting standards for methodological clarity, alignment with infection control guidelines, and relevance to the anesthesia work environment (Figure 1).

Results

Hand Hygiene

Hand hygiene is the cornerstone of infection prevention, yet compliance among anesthesia providers remains inconsistent. Studies report baseline adherence rates of 40–60%, rising to 85% with interventions such as alcohol-based rubs and educational campaigns (15,16). It was reported that anesthesia providers averaged 2.3 hand hygiene opportunities per case compared to 5.2 for surgical teams, partly due to workflow pressures (17). Alcohol-based solutions are preferred over soap and water in fast-paced settings, reducing bacterial load by 99% within 15 seconds (18). However, glove misuse (e.g., wearing gloves without handwashing) creates a false sense of security and increases contamination risk (19).

Barriers include time constraints, equipment accessibility, and lack of accountability. Tang et al demonstrated that wall-mounted dispensers near anesthesia stations improved compliance by 30% (20). Automated monitoring systems, such as electronic reminders, have shown promise in sustaining adherence (20,21).

Environmental Disinfection

The anesthesia workspace harbors pathogens on high-touch surfaces, including monitors, keyboards, and drug vial trays. MDROs such as *Staphylococcus aureus* and *Acinetobacter* survive on stainless steel and plastics for days, necessitating rigorous disinfection (22). Quaternary ammonium compounds and hydrogen peroxide-based wipes are effective but underutilized; one study found that only 35% of surfaces were cleaned between cases (23,24).

UV-C light systems reduce bioburden by 90% but require prolonged exposure times, limiting practicality (25). Challenges include rapid turnover between surgeries

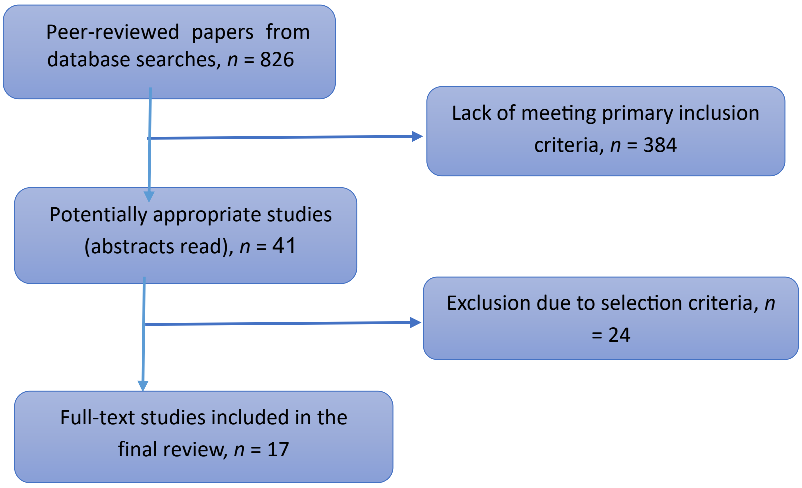

Figure 1. Flowchart of the Article Selection Process

and inconsistent cleaning protocols. Adams et al proposed "bundled" interventions, including designated cleaning checklists, color-coded wipes, and real-time audits, which reduced HAIs by 22% (26,27).

Medication Safety

Medication preparation and administration are critical infection vectors. Multi-dose vials, used in 70% of anesthesia workflows, are frequently contaminated during repeated access (28). Gupta et al identified microbial growth in 12% of opened vials, primarily *Enterococcus* and *Candida* (29). Single-use vials and prefilled syringes eliminate this risk but increase costs (30).

Intravenous tubing and stopcock manipulation are additional concerns. Sterile caps and closed-system transfer devices reduce contamination rates from 25% to 3% (31).

Continuous Education and Monitoring

Ongoing education initiatives strengthen adherence to infection control protocols. Research indicates that organized educational sessions, visual aids, and interactive workshops enhance compliance rates among anesthesia staff (32-35). Regular audits and constructive feedback further solidify effective practices, minimizing contamination risks in clinical settings (36).

Improving knowledge of how pathogens spread during surgery is critical for applying preventive strategies (4). Even with established guidelines and sensory cues, many hand hygiene opportunities are missed, indicating that it has not yet become routine practice for anesthesia teams. This gap underscores the necessity for targeted training (4). Research highlights that auditory prompts can increase hand hygiene compliance by 27-fold among these professionals, directly lowering infection rates (37).

However, transforming ingrained clinical habits remains challenging. Facility leaders must collaborate with anesthesia supervisors to design and implement a detailed, timely strategy. This process includes dedicating resources to staff education and adopting revised infection control standards (34,35). Tactically positioned visual reminders in workspaces also reinforce protocol adherence (38). When paired with continuous training, sensory cues, and evidence-based guidelines, these efforts help align anesthesia practices with current infection control standards (35).

Management of Contaminated Laryngoscope Blades and Handles in Intubation

Laryngoscopes are frequently contaminated with blood and pathogens, with 30% of handles testing positive for MDROs post-use (39). Despite guidelines recommending HLD, 40% of institutions only perform low-level wiping (40,41). Autoclaving blades between cases reduces contamination risk by 95%, but logistical delays hinder adoption (42).

Laryngoscope handles and blades are categorized as semi-critical medical devices due to their potential for disease transmission and require HLD at least (43,44).

While the handle does not directly touch the patient, it can become contaminated via the blade when detached (45,46). The connection point between the handle and blade acts as a conduit for transferring blood and microorganisms from the patient's airway. If anesthetists touch a contaminated handle, pathogens may spread to patients. Recent studies confirm widespread microbial presence on laryngoscope handles (47), with textured surfaces fostering greater bacterial growth compared to smooth designs (48). Experts advocate revising disinfection protocols to mandate rigorous cleaning of handles (49,50).

During intubation, anesthesiologists wear double gloves. After securing the breathing tube, the blade is sealed within the outer glove to isolate it. Discarding the outer glove leaves the provider with uncontaminated gloves, preventing cross-contamination of the workspace (34).

Post-procedure handles must undergo disinfection. Contaminated blades should be promptly detached and contained in gloves or designated disposal containers—

never reattached to the handle (33,36).

Limiting or Preventing Transmission of Infection in Airway Management

Airway management generates aerosols, posing risks for respiratory pathogens such as SARS-CoV-2. Pre-procedure mouth rinses with 1% hydrogen peroxide reduce viral load by 90% (32). *Personal protective equipment* (PPE), including N95 respirators and face shields, is critical but often improperly doffed (51).

Video laryngoscopy minimizes close contact and reduces intubation attempts, lowering aerosol exposure (52). Post-intubation surface decontamination and HEPA filters in anesthesia circuits further mitigate risks (53).

Discussion

The anesthesia work environment faces significant challenges in infection prevention due to workflow demands, inconsistent protocols, and human factors. Compliance gaps persist in hand hygiene, environmental disinfection, and laryngoscope management (54). Despite established guidelines, reliance on gloves without proper handwashing and time pressures during emergencies remains a critical barrier (55). Environmental disinfection strategies (e.g., UV-C systems and bundled interventions) require institutional commitment to standardized workflows. Medication safety depends on transitioning from multi-dose vials to single-use systems and closed-system transfer devices. However, cost barriers and poor compliance with port disinfection necessitate stricter enforcement of United States Pharmacopeia guidelines (56). Continuous education, simulation-based programs, audit-driven feedback, and radio-frequency identification monitoring systems are recommended to address accountability (34). Laryngoscope contamination requires strict autoclaving protocols and sealed storage to mitigate MDRO transmission (12). Airway management during aerosol-generating procedures requires standardized PPE use, video laryngoscopy, and post-procedural decontamination. A multimodal approach integrating technological innovations, protocol standardization, and cultural shifts is advocated to prioritize infection control (57). Future efforts should focus on cost-effective solutions (e.g., reusable UV-C equipment and biodegradable disposable covers) while addressing systemic barriers (e.g., time constraints and alert fatigue).

The anesthesia care setting is a high-risk area for HAIs due to frequent clinician-patient contact, heavily touched equipment, aerosol-producing procedures, and time-sensitive workflows. Although infection control practices have advanced, persistent compliance lapses across multiple areas continue to facilitate the spread of MDROs and pathogens. For instance, hand hygiene—a cornerstone of infection prevention—is frequently neglected by anesthesia teams during emergencies, high workloads, or overreliance on gloves as a substitute for handwashing. The reported adherence rates (40%–60%) among anesthesia providers, lagging behind surgical staff, underscore the urgency for accountability frameworks and behavioral modifications. Proven strategies, such as strategically placed sanitizer stations, real-time electronic monitoring, and tailored training programs, can enhance compliance but demand institutional investment (16,58).

Environmental contamination further exacerbates HAI risks, as anesthesia equipment (e.g., monitors, drug trays, and machine interfaces) often harbors pathogens. Surfaces made of plastic or metal can sustain MDROs (e.g., *Staphylococcus aureus* and *Acinetobacter* spp.) for extended periods. Nonetheless, research revealed that only 35% of these surfaces undergo thorough disinfection between procedures (59). Bundled interventions (e.g., UV-C light systems, checklists, and color-coded cleaning supplies) have reduced microbial loads by 90%, though adoption remains inconsistent. Addressing obstacles such as rushed room turnovers and inadequate staff training requires workflow automation and ongoing education (60,61).

Laryngoscope handles, contaminated in up to 30% of cases, exemplify equipment-specific risks. Although single-use blades reduce transmission, cost and logistical challenges limit their use. Autoclaving reusable devices, double-gloving during intubation, and sealed storage post-disinfection can mitigate risks (49,62).

Airway procedures, which generate aerosols, heighten exposure to respiratory pathogens (e.g., SARS-CoV-2). Preventive measures include pre-intubation antiseptic mouth rinses, video laryngoscopy to maintain distance, HEPA filters in breathing circuits, and reinforced PPE protocols. Post-procedure surface decontamination is equally critical to prevent fomite transmission (63,64).

Conclusion

HAIs in the anesthesia work environment persist as a critical challenge, driven by high-risk procedures, pathogen-prone equipment, and systemic gaps in compliance with infection prevention protocols. This systematic review underscores that while evidence-based guidelines exist, their implementation is hindered by workflow pressures, inconsistent practices, and resource limitations. Key findings revealed alarmingly low hand hygiene adherence (40%–60%), inadequate disinfection of high-touch surfaces, misuse of multi-dose medication vials, and laryngoscope contamination risks, all contributing to HAIs and MDRO transmission. However, sustained progress demands a holistic approach that addresses both systemic and human factors.

Drawing on broader research, leadership engagement and institutional culture shifts are pivotal. Studies emphasize that fostering collective accountability through transparent reporting and antimicrobial stewardship programs can curb MDRO proliferation. Human factor engineering—redesigning workflows and equipment layouts to minimize contamination risks—complements these efforts. The coronavirus disease 19 pandemic has accelerated the adoption of video laryngoscopy and enhanced PPE protocols, offering lessons for long-term practice improvement.

Future directions should prioritize cost-effective innovations (e.g., reusable UV-C equipment and biodegradable disposable covers) while addressing barriers such as alert fatigue and time constraints. Multimodal strategies—merging standardized protocols, continuous education, and technological integration—are essential to bridge the gap between guidelines and practice. By institutionalizing infection prevention as a non-negotiable component of patient safety, healthcare systems can transform anesthesia environments into models of sterility, safeguarding both patients and providers. Ultimately, success hinges on sustained commitment to cultural change, resource allocation, and interdisciplinary collaboration, ensuring that infection control evolves from a reactive mandate to an ingrained clinical reflex.

Ethical Approval

Ethical approval was not required for this systematic review, as it synthesizes existing published literature and does not involve direct human or animal subjects. Where applicable, all included studies were previously approved by their respective ethics committees.

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