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Microbiology isolated from devices and tools used in anesthesia: A Review

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Abstract
Microorganisms are considered one of the most widespread neighborhoods on surfaces, devices and equipment, and among these devices are anesthesia devices that are used in surgeries, where these equipment are exposed to microbial contamination and thus cause great risks to humans, so these devices must be taken care of, cleaned and sterilized to eliminate microbes.

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1. Introduction

Infection prevention and control is a top priority for healthcare providers in order to ensure the safety of medical services. The anesthesia machine and equipment can act as a source of infections for various reasons, which can lead to hospital-acquired infections among patients. Contaminated devices or circuits of the anesthesia machine can serve as additional sources of infections. The use of vaporizers has been associated with outbreaks of hospital infections in the past. Additionally, waste anesthetic gas poses a potential hazard to hospital personnel. Various microorganisms have been found to contaminate the anesthesia machine and associated equipment. Contamination of devices during handling, due to poor adherence to guidelines, is common. A contaminated anesthesia machine can contaminate the fresh gas flow meter (oxygen, nitrous oxide, or medical air) due to positive pressure in the pipeline in the presence of a defective check valve. Several methods of decontamination have been advocated in the past, including the use of soap and water, 70% alcohol, hydrogen peroxide gas, or UV light. This review focuses on the microbiology isolated from devices and tools used in anesthesia. (Sharma *et al*. 2020, Bowdle *et al*. 2020, Li *et al*. 2021) [25, 3, 16].

The handling of the mannequin respiratory tract has shown the presence of a wide variety of contaminated microorganisms. Tubing of the anesthetic machine has been shown to be contaminated with bacteria across a wide range, showing variability. Despite being used by a single patient, the mask can become contaminated from the previously used patient's intraoral gas, either through contamination of the cavity of the Y port or by using a non-disposable mask with clogs in the ports of the silicone mask circuit, which can harbor pathogens. Hydrophobic filters in the hospital can also harbor pathogens, as healthcare professionals handling the device can accidentally contaminate the surface of the devices or the vent may not function correctly, causing the bioaerosol produced during the cancellation surgery to agglomerate with the sputum entering the filter. (Schmidt *et al*. 2020, Dexter & Loftus, 2024) [24, 10].

2. Microbial contamination in anesthesia devices and tools

The literature reports 15-65.3% of anesthesia equipment is contaminated. The sources of the microbial load in anesthesia equipment are patients during operation, exposure to air and the environment.

Body fluids, mistakes made during cleaning and disinfection, and biofilm microorganisms. The aim of this review is to provide a comprehensive and practical account of the various microorganisms isolated from anesthesia devices and tools. The most commonly isolated microorganisms from devices and tools in operating theaters are ordinary bacteria, especially Bacillus sp. and Staphylococcus coagulase negative. (Gouda *et al*. 2020, Stefani *et al*., 2022) [12, 30].

Microbiological contamination of any general surgery site can occur from several sources: patients operated on, exposure to air and room atmosphere, hospitals, healthcare personnel, number of days stayed in the recovery room, and errors in cleaning and sterilization of the room. All the types required for general anesthesia always come into contact with the patient, drugs, airways, and air. Besides functioning, issues of contamination on Friday are a matter of note because it is one of the days in which the greatest number of operations are carried out. It is necessary to consider carefully and sterilize several times because of coexisting and integrated contact between the operating layers. The liquid used in operating rooms paraphernalia that has been contaminated will lead to patient death. Liquid in the respiratory system can allow the growth of microorganisms, especially in the presence of mucus, so it will provide a good habitat for microorganisms. A tracheal intubation tube is a device that is in direct contact with the lungs, which are usually exposed to saliva and sedation, so microbiological contamination occurs in anesthesia. (Macedo *et al*. 2024, Sharma *et al*. 2020, Dexter & Loftus, 2024) [17, 25, 10].

2.1. Sources of contamination

Contamination of anesthesia devices and tools, such as the anesthesia workstation, anesthesia ventilator, high- or low-pressure gas and breathing circuit, breathing bag, tracheal tube, heat and humidifier, laryngeal mask, airway filter, manual resuscitator, oral air, flow meter, and regulator pressure, is a significant concern in medical settings. Proper cleaning and disinfection of these equipment is crucial as they have been associated with the transmission of pathogenic microorganisms, leading to pulmonary infections, neonatal nosocomial infections, and contaminated endoscopes and bronchoscopes. (Sharma *et al*. 2020) [25].

There are three possible pathways through which microorganisms can enter. Firstly, patients who are susceptible to contamination can be affected during treatment. Secondly, the equipment and its accessories can become contaminated. Lastly, the inanimate environment can also be a source of contamination. To prevent contamination between patients, it is important to ensure sterile processing of the equipment. The goal of maintaining a clean work environment is to reduce the level of bioburden. While achieving absolute aseptic conditions is challenging, it is essential in preventing nosocomial diseases. Contamination is a significant problem in hospital services, and contaminated tools may be responsible for up to 4% of nosocomial disease transmission. (Ssekitoleko *et al*. 2020, Du *et al*. 2021) [29, 8].

The results of this study will help identify potential sources of contamination within anesthesia devices. Breathing systems, endotracheal tubes, flowmeter regulators, and heat and humidifiers can become contaminated through direct patient contact. One of the key objectives in anesthesia is to minimize complications related to equipment use. Contaminated anesthesia tools and devices can potentially affect patients and contribute to hospital-related infections. This review aims to explain the possible sources of contamination in frequently used anesthesia devices and tools, which are commonly employed in various anesthesia procedures. By addressing these factors, we can reduce patient complications, particularly nosocomial infections, and decrease overall morbidity, mortality, and perioperative risks. (Reynier *et al*. 2021, Sharma *et al*. 2020) [20, 25].

2.2. Common microorganisms isolated

The most common, or frequent, specifically microbial species that have been isolated are: Pseudomonas aeruginosa, Acinetobacter spp., Staphylococcus spp., Bacillus spp., Klebsiella spp., Escherichiae spp., Coagulase negative staphylococcus spp., Enterococcus spp., Citrobacter spp., Moraxella spp., Proteus spp. and most others, including: Enterobacter, Neisseria; diphtheroids, Ralstonia, Epidermophyton, Coryneform bacteria, Haemophilus, Propionibacterium, other staphylococci, Pneumocystis carinii, Acrophilia, Chryseomonas, Hemophilus influenzae; Proteus mirabilis, Serratia, Micrococcus species, other coagulase negative staphylococci, Achromobacter species, Streptococcus pneumoniae, Neisseria and Pneumococcus; Candida; non-tuberculous mycobacteria, Penicillium, Aspergillus, Cladosporium, Dermatophytes, non-pathogenic Neisseria and Alcaligenes. Among these studies, there is some variation in the species isolated. (Nazarchuk *et al*.2022, Soonthornsit *et al*.2023) [19, 28].

Examination of the environment around the operating table and its surfaces, machines, and tools, allows some indication of the air quality of the operating room. The anesthetist, operating room staff, and others can monitor the likely extent of inhalation with report of general operating room environmental microbe levels. Administering anesthetics safely and sterilely can protect against many of these infections. Knowledge of the potential pathogens in the vicinity, such as intimate indwelling items, such as ophthalmic kits, blood glucose monitoring tools, monitoring lines, transesophageal echocardiogram, urethral catheters, etc., could help an anesthetist prevent instrumentation-related infections. In this systematic review, we give a detailed overview of the microorganisms isolated from anesthesia and its relevant equipment in operating theaters. The microorganisms isolated include bacteria, such as Pseudomonas aeruginosa, viruses, and infections such as Herpes hepatitis virus, and coronaviruses, as well as many others. This information can inspire operating room staff to take greater care to prevent microbial contamination and infection. (Fernandez *et al*. 2024, Labovská 2021, Dexter & Loftus, 2024) [10, 15, 7].

3. Impact of microbial contamination in anesthesia practice

Anesthesia, although less invasive than some other branches of medicine, also carries some risks. One of the risks arising from the practice of anesthesia is related to microbial or environmental contamination of devices and tools. Some devices contain water and drugs contaminated with a wide variety of microorganisms. Inadequate cleaning of respiratory equipment may result in the patient's continuous exposure to a wide variety of anesthetic and surgical contaminants. Contaminated laryngoscope handles represent a risk of cross-transmission by healthcare workers during manipulation of this equipment. In anesthetic equipment, favorable conditions for biofilm formation, such as the presence of water, organic matter, and vapor, as well as the potential for selection of microorganisms that are more resistant to antimicrobial agents used for cleaning procedures, have been demonstrated. (Macedo *et al*. 2024, Sanchez, 2022, Branch & Amiri, 2020) [17, 23, 4].

In addition to permanent microbial contamination of the equipment, over time it has been reported that the use of water from storage tanks somewhere outside or in the operating room is a risk factor for the bacterial contamination of injectable local anesthetics, as well as the possibility of contamination of drugs at various compounding stages as additives in the insufflated system. The possibility of reducing the infection risk in anesthesia practice is great. The degree of compliance with infection prevention and control measures is one of the priorities of European and US health policy. It provides guidance, prescriptive standards, evidence-based practices and tools, and surveillance to improve infection prevention and control and patient safety overall. In recent years, there has been increasing research in the field of microbial contamination in anesthesia and devices, including in relation to COVID-19, with a focus on SARS-CoV-2 nasal contamination. (Manga *et al*. 2021, Slavik *et al*. 2020, Hu *et al*. 2021) [18, 27, 13].

3.1. Infection prevention and control measures

Preventing the transmission of microorganisms that can cause infections through anesthesia devices and other tools prevents the loss of patients' health and income, and also protects the reliability of the healthcare system. Thus, in parallel with technological developments, the attention given to the microbial content of devices and the adaptation of control measures in literature and similar protocols have increased. (Reynier *et al*. 2021, Sharma *et al*. 2020) [20, 25].

Reducing risks by creating protective strategies specific to every stage that may cause infection has received great attention in today's understanding of health management. Studies on this subject are vitally significant to policymakers. Infections caused by opportunistic microbes that can occur when immune and tissue resistance conditions weaken, highlight the importance of equipment formation and sterilization. (Josephs-Spaulding & Singh, 2021, Rowan *et al*., 2023) [14, 21].

Robust infection prevention and control are the keys to providing and creating safe environments for healthcare facilities and services by removing pathogenic microorganisms, eliminating the spread of these microorganisms, and using protocols effectively. Infection control aims to prevent the invasion of infectious microbes, reduce the development of opportunistic infections, or shorten the infectious process. This can happen in several ways, including cleaning the areas and materials directly contaminated with infectious microorganisms and reducing the chances of transmitting or transporting them to infectious agents. (Sharma *et al*. 2023, Ahmad & Alfouzan, 2021) [26, 1].

The purpose of disinfection and sterilization is to reduce the population of microorganisms to at-risk levels, or to remove unwanted microorganisms from a surface or piece of medical equipment in the hospital environment. In particular, biofilms are the main factor in the failure of the disinfection-sterilization process and the survival of microorganisms. (Carrascosa *et al*. 2021, Josephs-Spaulding & Singh, 2021) [5, 14].

3.2. Patient safety risks

Microbial species are isolated from different areas in the operating theater, and they include various surfaces in the anesthetic work environment, air, and ampoules operatively used on patients. However, the presence of bacteria implies several issues related to patient safety. When bacteria are spread from area to area, or from patient to patient, then infections might be transmitted. However, contaminations induced on a more internal level, non-sterility after cleaning, could contribute to pus, irritation, and increased risk of not yet evidence-based diseases. Patient safety, and staff safety as well, is the two variables hospitals try to address carefully. There are vaccinopathy risks when developing infections, and trauma is a risk for the patient, the staff member, as well as the hospital. (Vanlalruati *et al*. 2023, Sadrizadeh *et al*. 2021) [31, 22].

It is important to understand and subsequently deal with these risks. Longitudinal examination of the incident reports (2000-2019) in Sweden, related to incidents occurring in the operating theater, were focused on when either operations or monitoring, including anesthesia, had commenced. This period of time was defined as T0. Furthermore, according to the WHO guidelines TU5, different types of incidents were categorized and distributed into different elements; some were more sterility-related (E1, E2), while others were not. During this period, it was concluded that case-specific issues were likely the cause of the sterility issues and were not general matters. Hence, patient safety was not significant as the incidents were statistically insurmountable compared to the number of completed anesthetic work schedules. Careful cleaning with disinfection and, when applicable, sterilization is therefore crucial. (Connolly, 2022, Wahlsten *et al*., 2021, Dyreborg *et al*. 2022) [6, 32, 9].

4. Methods for microbial detection and monitoring in anesthesia equipment

Anesthesia treatment is executed in a contaminated environment, and the instruments and equipment used officially for this can act as potential vectors of microbial contamination. It is estimated that the cost of microbial contamination in healthcare settings and hospitals is a problem that must be solved. The great contribution of this review is in the analysis of the correct or better methodology for microbial sampling of anesthesia equipment – avoiding contamination and the microbial sampling and cleaning and disinfection methodology involved. Thus, it is proposed to proceed with the territorial categorization and medical devices, and devices used by the anesthesia staff and the selection of potentially pathogenic microorganisms transmitted during anesthesia. (Sharma *et al*. 2020, Beers, 2021) [25, 2].

Each method has its advantages and disadvantages. A modern and safer method of microbial detection is actually the system based on ATP monitoring with a trademark BIOLUM-ATP Hy-Lite II meter. Decontamination of these devices is necessary for anesthesia with specific protocols using products with a broad spectrum of action, as recommended by the CDC or manufacturers, because the control of contamination can trigger the appearance of nosocomial infections. In conclusion, there are a variety of methods for directly detecting the presence of microorganisms in anesthesia equipment, such as Petri dishes, filtration, swabbing, sonicating, and implant swabbing. It is important for a professional to be familiar with and understand the limitations of the various methodologies used in distinct clinical research settings (Fung, 2007) [11].

5. Conclusion and future perspectives

Our review provides a current overview concerning the principal microorganisms that could be isolated from key devices and tools used in anesthesia, with direct and indirect impact on the patient's safety. It revealed the compromised quality audits or regular controls of infrastructure, avoiding the contamination of medical gases and final cleaning and disinfection of important devices. In this context, a specific resolution from the NIHS exists, highlighting the importance of medical gas quality within a medical facility. The review gives a comprehensive insight into possible sources of contamination in anesthesia, from connection ports up to anesthesia medicaments and water for injections. We strongly recommend that for better infection control of patients, the cornerstone of all action plans might be the personal and perioperative hand hygiene.

From an actual state of the art, anesthesia medicament contamination might be reduced by using specific cartridges proposed by the manufacturer that impede needle access from the external environment. A trend on technical feasibility is also a needle-less connector of a syringe of medication, which opens when a spike is plugging into, thereby preventing the accidental drawing of air into an intravenous medication line. We can also suggest a re-engineering of anesthesia breathing circuits for expiratory valves. Although infection cases transmitted by drugs are rare, the contaminated medications can likely cause BSI or sepsis, which are important for general infection control. In parallel, policies may need to be put in place during formulation and renaming of drugs for anesthesia, in the same way as it was already established for drinking water and water for injection. This study also suggests the need for closer collaboration between European societies of Anesthesiology (ESA) and microbiology (ECM, ECCMID) to raise awareness and protect patients from this outbreak of anesthesia-related infections. Retrospective and/or forward-looking surveys in electronic format would also be useful to develop policies and practices that concern all countries around the world.

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