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Perioperative COVID-19 Defense: An Evidence-Based Approach for Optimization of Infection Control and Operating Room Management

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Abstract and Introduction

Abstract

We describe an evidence-based approach for optimization of infection control and operating room management during the coronavirus disease 2019 (COVID-19) pandemic. Confirmed modes of viral transmission are primarily, but not exclusively, contact with contaminated environmental surfaces and aerosolization. Evidence-based improvement strategies for attenuation of residual environmental contamination involve a combination of deep cleaning with surface disinfectants and ultraviolet light (UV-C). (1) Place alcohol-based hand rubs on the intravenous (IV) pole to the left of the provider. Double glove during induction. (2) Place a wire basket lined with a zip closure plastic bag on the IV pole to the right of the provider. Place all contaminated instruments in the bag (eg, laryngoscope blades and handles) and close. Designate and maintain clean and dirty areas. After induction of anesthesia, wipe down all equipment and surfaces with disinfection wipes that contain a quaternary ammonium compound and alcohol. Use a top-down cleaning sequence adequate to reduce bioburden. Treat operating rooms using UV-C. (3) Decolonize patients using preprocedural chlorhexidine wipes, 2 doses of nasal povidone-iodine within 1 hour of incision, and chlorhexidine mouth rinse. (4) Create a closed lumen IV system and use hub disinfection. (5) Provide data feedback by surveillance of Enterococcus, *Staphylococcus aureus*, Klebsiella, Acinetobacter, Pseudomonas, and Enterobacter spp. (ESKAPE) transmission. (6) To reduce the use of surgical masks and to reduce potential COVID-19 exposure, use relatively long (eg, 12 hours) staff shifts. If there are 8 essential cases to be done (each lasting 1–2 hours), the ideal solution is to have 2 teams complete the 8 cases, not 8 first case starts. (7) Do 1 case in each operating room daily, with terminal cleaning after each case including UV-C or equivalent. (8) Do not have patients go into a large, pooled phase I postanesthesia care unit because of the risk of contaminating facility at large along with many staff. Instead, have most patients recover in the room where they had surgery as is done routinely in Japan. These 8 programmatic recommendations stand on a substantial body of empirical evidence characterizing the epidemiology of perioperative transmission and infection development made possible by support from the Anesthesia Patient Safety Foundation (APSF).

Introduction

Anesthesia professionals are poised to address the coronavirus disease 2019 (COVID-19) pandemic as they lead the global dissemination of an evidence-based, perioperative infection control program that can generate substantial reductions in perioperative pathogen transmission and associated infection development. Our programmatic recommendations stand on a substantial body of empirical evidence characterizing the epidemiology of perioperative transmission and infection development made possible by grant support from the Anesthesia Patient Safety Foundation (APSF) for studies conducted at Iowa, Dartmouth, and UMass Memorial Medical Center. Our specialty has acquired extensive expertise that yields preparedness for this pandemic. Prevention of pathogen transmission events is of paramount importance, especially considering limitations in availability of personal protective equipment (PPE) that we are currently facing.

Through ongoing collaboration with Dr Jeremiah Brown (Professor of Epidemiology at Dartmouth) and Randy Loftus (Associate Professor of Anesthesia at Iowa), we recommend and are prepared to assist with rapid adaption of a planned approach to attenuate perioperative transmission (section "Evidence-Based Perioperative Infection Control"). Through widespread adoption of these evidence-based approaches,[1] we can better protect our patients and our health care coworkers.

A simultaneous and related concern is operating room (OR) management considerations for patients without confirmation of COVID-19. In most US hospitals, routine COVID-19 testing is impractical, so that many if not all patients could be at high risk of viral carriage community spread. This could lead to environmental contamination and subsequent patient and provider workspace exposure. Dr Franklin Dexter outlines an evidence-based approach for perioperative management of such patients in section "OR Management Strategies in the COVID-19 Era."

In addition, in the near future, we will

1. provide a video demonstrating this multifaceted perioperative infection control bundle and
2. host a webinar for institutional implementation coaching. We, with the help of the Anesthesia Patient Safety Foundation (APSF) and American Society of Anesthesiologists (ASA), are committed to bringing all clinicians the tools to improve perioperative infection control.

Note: Our goal is to prepare the perioperative arena (preoperative, intraoperative, and postoperative) for optimized care of patients and provider protection (section "Evidence-Based Perioperative Infection Control") and for strategic OR management of patients who remain asymptomatic and are unaware of known exposures (section "OR Management Strategies in the COVID-19 Era"). While our recommendations can be applied to operative care of patients suspected or known to be infected with COVID-19, these patients represent only the tip of the iceberg. Testing every patient for COVID-19 has economic and logistic considerations that are likely to be unachievable in the short term and unsustainable for the long term. Even after establishing effective control of viral transmission over the next few months, we will need to be prepared for ongoing infections and resurgence as we resume normal operations involving the care of a wide variety of patients undergoing elective surgery.

Evidence-based Perioperative Infection Control

Confirmed modes of viral transmission (eg, influenza A and severe acute respiratory syndrome [SARS]) are primarily but not exclusively contact with contaminated environmental surfaces (fomites) and aerosolization.[2–4] Viral pathogen survival on environmental surfaces extends for several days; COVID-19 can survive for at least 3 days on a variety of materials commonly encountered in ORs (eg, stainless steel, plastic).[5] Usual OR and recovery cleaning practices, especially for noncritical items such as near bedside equipment, are often inadequate.[6–8] This is a significant issue for both patients and providers because of current cleaning failures and/or lapses in practice that increase the risk of cross-contamination during patient care.[5–8]

Evidence-based improvement strategies for attenuation of residual environmental contamination involve a combination of deep cleaning with surface disinfectants and ultraviolet light (UV-C).[9–11] UV-C is proven to reduce bacterial and viral contamination across a variety of health care settings by addressing both surface and air column disinfection,[9,10] and this technology has been shown to reduce the incidence of both bacterial and viral health care–associated infections (HAIs).[10] Consensus however is that improved cleaning should include both surface disinfection and UV-C approaches because UV-C alone may be limited by shadowing (areas of the room that the UV-C light does not reach).[11] Similarly, surface disinfection procedures (ie, deep terminal cleaning) should also be supplemented with UV-C or equivalent technology because of human factors resulting in cleaning failure.[12]

While environmental cleaning is an important infection control consideration, our evidence-based approach for perioperative COVID-19 control should leverage a comprehensive understanding of the epidemiology of transmission for our health care arena. The epidemiology of intraoperative pathogen transmission is well characterized.[6–8] The incidence of *Staphylococcus aureus* transmission (a common cause of surgical site infections [SSIs]) is reported to be as high as 39% for the general perioperative arena.[13,16] Perioperative *S. aureus* transmission events are tightly associated with SSI development with 50% of *S. aureus* SSIs linked by whole-cell genome analysis to one of more intraoperative reservoirs.[14] Similarly, isolation of one or more Klebsiella, Acinetobacter, Pseudomonas, or Enterobacter (KAPE) pathogens from one more intraoperative reservoirs are associated with increased risk of a Gram-negative HAI development.[17] Intraoperative bacterial transmission relates to nadirs in hand hygiene compliance that occur during induction and emergence of anesthesia and correlate with peaks in environmental contamination.[18] As such, single modality improvement strategies (ie, hand hygiene alone) have been associated with a trend toward increased risk of infection.[19] Hand hygiene, while an important preventive measure, should not stand alone for control of perioperative spread of COVID-19. It is insufficient.

The solid foundation of published evidence generated during the past 12 years indicates that a multimodal approach is indicated to maximally attenuate high-risk intraoperative pathogen transmission events. Improved hand hygiene, environmental cleaning, vascular care, patient decolonization, and surveillance optimization should be used in parallel during the process of patient care as a multifaceted approach to improved perioperative infection control for both bacterial and viral pathogens.[7,8,13,17] The approach should involve improved provider hand hygiene leveraging proximity to the provider, improved frequency and quality of environmental cleaning, targeting of high-risk environments with UV-C, improved vascular care, improved patient decolonization, and surveillance optimization.

Roadmap to Evidence-based Perioperative Infection Control

Note: Recommendations for positioning of equipment are evidence-based and should be utilized.[1]

Step 1: Hand Hygiene

a. Leverage proximity to the provider: Place alcohol-based hand rubs on the intravenous (IV) pole to the left of the provider.[20] If alcohol-based hand gel or foam is not available, use chlorhexidine wipes and/or a dilute ethanol solution. There are over 350 hand decontamination opportunities during routine, intraoperative patient care.[18] Perioperative care has a high task-density that threatens hand hygiene compliance, especially during induction and emergence of anesthesia.[18] These are critical periods for viral and bacterial transmission to the surrounding patient environment. Using this approach will increase hand decontamination events 20-fold.[20]

b. Double glove during induction: Intubation is associated with transmission of particles in a simulated environment.[21] Double gloving can reduce transmission in a simulated environment.[21] Place dirty equipment in the zip lock bag in the wire basket (see below) and seal.

Step 2: Environmental cleaning: Improve organization and increase frequency and quality of cleaning.[22] This approach will substantially reduce the overall contamination of the work area.

Organization: Place a wire basket lined with a zip closure plastic bag on the IV pole to the right of the provider. Place all contaminated instruments in the bag (ie, laryngoscope blades and handles) and close. Designate and maintain clean and dirty areas.

Frequency: After induction of anesthesia, wipe down all equipment and surfaces with disinfection wipes that contain a quaternary ammonium compound and alcohol. Confirm your hospital's selected wipes have antiviral activity.

Quality: For improved routine and terminal cleaning, using a top-down approach, spray all surfaces and the anesthesia and circulating nurse work space—including but not limited to keyboards and mice—with a quaternary ammonium compound and wait the required time per agent utilized (typically 1–3 minutes). Then wipe with a dry microfiber cloth. This cloth should then be laundered. Wipe all surfaces and equipment again with the designated quaternary ammonium and alcohol surface disinfection wipes used above. This cleaning sequence is critical for achieving adequate bioburden reduction.

UV-C: Treat at-risk rooms defined by your hospital's surveillance. These treatments are typically 20–30 minutes and can be focused on the high-risk anesthesia work area and should also include the circulating nurse desk area that is likely to be contaminated and often excluded from cleaning procedures. If UV-C is not available, use the above cleaning process for a more extensive cleaning approach to at-risk environments (enhanced terminal cleaning). If your hospital does not have a surveillance process in place, use surveillance described below to guide strategic targeting.

Step 3: Patient decolonization: Patients are a proven reservoir of transmission, an obvious concern in the setting of COVID-19.[13–16] Respiratory secretions and droplets, resulting in direct (aerosolization during intubation) or indirect (contamination of surfaces followed by contact and transmission to eyes, nose, and/or mouth) modes of transmission, can lead to infection.[2–4] Microbes, viruses and bacteria, colonize our skin.[2–4] Apply standard PPE during procedures (N95 mask, gown, gloves, eye protection) for known cases. For known patients and/or patients with risk of exposure (presumptive positive, see surveillance below), use preprocedural chlorhexidine wipes, 2 doses of nasal povidone-iodine within 1 hour of incision, and chlorhexidine mouth rinse. Both agents have broad activity against bacteria and viruses that will serve to protect patients and providers from subsequent transmission. This approach (chlorhexidine wipes, nasal povidone-iodine, and chlorhexidine oral rinse) can be applied after patient induction/stabilization for emergent procedures.

Step 4: Vascular care: Intravascular catheters are in direct contact with the patient's intravascular space with contamination repeatedly associated with increased mortality and directly linked to infection.[7,8] Create a closed lumen IV system.[23,24] Open lumens should be outfitted with needleless, disinfectable devices, as open lumens are associated with increased risk of transmission compared to properly disinfected ports.[23] Improved hub disinfection reduces transmission to the patient and reduces infections.[24] Leverage proximity to the provider: place evidence-based disinfection caps for syringe and hub disinfection on the IV pole to the left of the provider.[24] Keep syringes free of the contaminated environment, disinfected, and ready for use. Scrub all ports before injection and keep covered with disinfecting caps during and after the procedure.

- Steps 1–4 above are for hospitals in this moment to improve perioperative infection control. The additional step below is for ongoing support of perioperative transmission control.

Step 5: Surveillance: All the above interventions are behavioral with variable compliance, prone to failure, and therefore require data feedback for maintenance of fidelity. This requires the use of evidence-based surveillance for system optimization and sustainability.[14–17] We currently use Enterococcus, *S. aureus*, Klebsiella, Acinetobacter, Pseudomonas, and Enterobacter spp. (ESKAPE) transmission as a fidelity marker for basic measures. This could be rapidly extended to COVID-19 with government and industrial participation.

Summary. Every anesthesia provider can start with steps 1–4. These are simple, evidence-based interventions designed and proven to protect patients and providers. This is especially critical given PPE deficits, community-associated spread of current pathogens, and likely ongoing transmission events. We should target these steps (1–4) and then proceed to a robust program of ongoing diligence and surveillance (step 5).

Or Management Strategies During the COVID-19 Crisis

In the setting of a viral pandemic, operative procedures are limited to essential interventions such as urgent and emergent procedures. Essential operations include a patient needing a biopsy to initiate medical or radiation treatments. Restriction of procedures has substantial clinical and management implications. Previous OR management reports have not defined the best strategy for assigning personnel and cases to ORs under these unique circumstances. Factors to consider are limited resources balanced with the simultaneous goal to minimize both patient and provider exposure to high-risk pathogen transmission and probable infection. We consider the likelihood of pathogen transmission during routine patient care to the surrounding environment as the most potent transmission vehicle in the OR.[8] Moreover, we now recognize the extended environmental survival of such transmitted pathogens (eg, at least 3 days for COVID-19).[5] Given these circumstances, how should one schedule essential cases to minimize short- and long-term risk of transmission to patients and their providers? In the analysis below, we describe the proper approach for management of patients in the COVID-19 era.

Or Management Problem Formulation

Our primary objective is to minimize the spread of infection and to achieve the lowest risk for patients and staff while caring for patients with unknown COVID-19 status at the time of anesthesia. Consider the assignment of anesthetic cases and staff (eg, anesthesiologists and certified registered nurse anesthetists) to ORs or non-OR locations under several conditions:

- The patient is not known to have COVID-19 (eg, undergoing cesarean delivery). Ideally a single OR would be set aside for all COVID-19 patients, in a corner of the surgical suite, with separate access, and revised to be negative pressure.[25]
- Shortages of PPE such as surgical masks and gowns are the principal constraint to elective surgery being performed. In addition, all posted cases are considered essential.
- There are insufficient test reagents/supplies (eg, viral transfer media) to screen all patients preoperatively for COVID-19, the false-negative rate is substantively large (eg, >1%), or the time to obtain results is beyond the point of proceeding for urgent procedures.

A consequence of the second condition noted above (shortage of PPE) is that there are enough ORs, surgeons (proceduralists), anesthesiologists, certified registered nurse anesthetists, and OR nurses to perform all cases promptly. This is unlike the normal situation wherein constraints on the care of such patients are most commonly surgeons (proceduralists) and/or rooms busy with other elective cases.[26] To complete our infection-control strategy, we relied on the online bibliography of OR management articles and recent review articles.[27–30] None of the articles considered the performance objective of reducing spread of infection.[28–32] Articles include the longer turnover times associated with cleaning when a patient has known infection, but reducing infections is nonetheless not the mathematical objective in these studies.[31,32] Readers will also note that the articles cited here are primarily from the fields of mathematics and engineering, and thus will not be found in PubMed.[28–32] Therefore, we included the online bibliography used by specialists in OR management.[27] Fortunately, complex mathematics is not required to solve the situation where the daily number of cases is less than the number of rooms available. While there may be restrictions on some procedures in some rooms, for convenience we will consider the important conceptual construct that cases could be completed while performing 1 case in each room.

The following 4 steps optimize staff and case assignments in this unique scenario:

First, to reduce the use of surgical masks and to reduce potential COVID-19 exposure to the greatest extent possible, use relatively long (eg, 12 hours) shifts. In other words, aim for as few different people as possible working daily in the surgical suite or procedural locations. For instance, if there are 8 ORs sharing 1 master ventilatory system and 8 essential cases to be done (each lasting 1–2 hours), the ideal solution is to have 2 teams complete the 8 cases in the available rooms. This contrasts sharply with the traditional 8 first case starts in 8 rooms with 8 teams of providers! The benefit to staff and the organization with the "infection-control" approach is that if a patient were found to have COVID-19 after surgery, fewer personnel were exposed.

Second, personnel doing terminal cleaning between each case[12] with the addition of UV-C (see section "Evidence-Based Perioperative Infection Control") can take 1–2 hours depending on whether there are 1 or 2 housekeepers and whether the UV-C machine needs to be moved within the room.[12] Therefore, the optimal strategy is to do 1 case in each OR, followed by terminal cleaning. Note that this does not mean literally that a room can be used just once a day. Rather, let anesthesia and nursing teams (and surgeons/proceduralists if they have >1 case) work in more than 1 room so that each room receives deep cleaning between cases.

Third, do not have patients go into a large, pooled phase I postanesthesia care unit because of the risk of contaminating facility at large along with many staff. Putting a surgical mask onto each patient would result in depletion of the supply of the protective equipment, an action that is inconsistent with the second condition above. Instead, have most patients recover in the room where they had surgery. This is done routinely in Japan—with the anesthesiologist recovering their patient—because few hospitals have a phase I postanesthesia care unit.[33] When the time of patient recovery was compared between a Japanese hospital where anesthesiologist recovery was routine practice versus the University of Iowa where there is a phase I postanesthesia care unit and nurses, the longest recovery time in Japan was briefer than the shortest recovery time in the United States.[34] Clinicians should consider selecting anesthetic drugs to minimize recovery times and possibly accomplish phase 1 recovery within the OR itself.[35,36] Consider, when appropriate, using peripheral nerve block instead of general anesthesia.[37,38]

Fourth, if the surgeon (proceduralist) will be operating later in the day and is scheduled for only 1 procedure, provide notification when there is the start of closure of the preceding case being done by the anesthesia and nursing team.[39] This communication reduces their total exposure time in the OR and should not limit workflow if the preceding patient will be recovered in the OR by the anesthesiologist or certified registered nurse anesthetist.

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