CH Air Quality as a Cornerstone of Sterile Technique

PODCAST

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Maintaining optimal air quality in the OR is a foundational element of sterile technique and a key contributor to reducing the risk of surgical site infections (SSIs).[1] The AORN "Guideline for sterile technique"[1] defines sterile technique as a coordinated set of actions intended to reduce environmental contamination and protect the sterile field. Because airborne particles can transport microorganisms that may settle into the sterile field or surgical site, effective management of OR air quality is a shared responsibility of the perioperative team, requiring coordination among personnel working in clinical, infection prevention, and facility engineering departments.[1]

Air quality alone does not determine SSI risk; however, the use of reliable ventilation systems combined with consistent implementation of evidence-based perioperative practices creates conditions that support perioperative environments with a lower degree of airborne contamination.[1] This article focuses on practical, guideline-aligned actions perioperative teams can take to support optimal OR air quality, including understanding ventilation systems, applying team behaviors to reduce airflow disruption, and participating in interdisciplinary air quality management programs that sustain safe practice over time. It is not intended to serve as an exhaustive reference for all related considerations, such as air sampling

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approaches, supplemental air-cleaning technologies, surgical smoke mitigation, or ventilation energy management.

PRACTICE POINT: Perioperative Airflow Systems

Operating rooms generally use either conventional (ie, turbulent or mixing) ventilation or unidirectional (ie, laminar) airflow systems.[2] Conventional systems deliver filtered air through multiple ceiling diffusers and mix it with room air. Unidirectional airflow systems are designed to move air downward in a uniform pattern over the sterile field.[2]

Although unidirectional airflow can reduce airborne particle counts over the sterile field, systematic reviews and meta-analyses have not shown that unidirectional airflow results in a consistent reduction in SSI rates when compared with conventional ventilation.[3,4] These findings reinforce an important principle for perioperative practice—ventilation design alone does not prevent infection.[1] These findings also highlight the importance of maintaining system performance and minimizing practice-related disruptions that interfere with intended airflow.[1]

Ventilation performance reflects the interaction of multiple factors, including air distribution, diffuser coverage, airflow velocity, exhaust placement, pressurization, and room use.[2,5,6] Research using a novel ventilation index (ie, a composite measure of OR ventilation quality that integrates airflow characteristics and design factors influencing turbulence) shows that high-quality overall ventilation performance is associated with lower SSI rates across some procedures (eg, total joint arthroplasty, cardiac, spinal).[7] Maintaining intended system performance and minimizing conditions that increase turbulence near the sterile field are essential for preventing SSIs.[1,7]

The American National Standards Institute (ANSI); American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); and American Society for Health Care Engineering (ASHE) provide *ANSI/ASHRAE/ASHE Standard 170*[2] and the Facility Guidelines Institute provides the *Guidelines for Design and Construction of Hospitals*.[5] These two documents inform building codes and collaborative facility design decisions.[2,5] The documents also define key OR ventilation parameters, including air changes per hour, filtration efficiency, temperature, humidity, and positive pressure relationships.[2,5] Perioperative construction and renovation projects are designed according the standards and guidelines in effect at the time of the project.

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The *ANSI/ASHRAE/ASHE Standard 170*[2] also outlines design features intended to reduce the risk of contamination of the sterile field, such as appropriate diffuser coverage and low wall–exhaust locations that support downward airflow patterns. When equipment placement or room setup obstructs supply or exhaust pathways, ventilation systems may no longer perform as designed, even when temperature, humidity, and pressure readings appear within range. Monitoring values alone do not fully characterize airflow patterns over the sterile field.[1,2]

The AORN "Guideline for design and maintenance of the surgical suite"[6] complements these standards and FGI guidelines by addressing perioperative-specific infrastructure considerations. The AORN guideline emphasizes collaboration among perioperative leaders, infection preventionists, and facilities and engineering professionals to ensure heating, ventilation, and air-conditioning (HVAC) systems are effectively designed, commissioned, and maintained. The AORN guideline also provides recommendations for responding to disruptions in HVAC performance to minimize contamination risk, including prompt identification and escalation of ventilation failures, implementation of interim risk-mitigation strategies, and coordination

of clinical and facilities decisions regarding room use until performance is restored.[6]

Air quality reflects the dynamic interaction of airflow, pressure, temperature, and humidity.[2,5] Practices such as propping doors open, overcrowding the OR, or blocking supply or exhaust vents can compromise airflow patterns and pressure relationships.[2,3]

In ORs with unidirectional airflow, the sterile field and instrument tables should remain within the zone beneath ceiling diffusers.[1] Equipment, overhead lights, and heat-generating devices should be positioned to minimize airflow disruption.[2] Studies show that surgical light geometry and personnel movement can disturb laminar airflow above the sterile field and increase turbulence near the operative site.[8,9]

KNOWLEDGE CHECK

Before the first robotic-assisted procedure of the day, a perioperative team prepares an OR equipped with a unidirectional airflow system return vents on all four walls, three overhead operating lights, and two suspended equipment booms. Maria, an RN circulator, verifies that temperature and humidity monitors show values that are within the expected ranges. Carlos, a float surgical technologist, brings additional equipment into the room. To keep the walkways clear, he places the devices in a compact manner (ie, one device touching the next) along the entire length of one wall. Aisha, a scrub person, positions the instrument tables beneath the ceiling diffusers. Dylan, an anesthesia professional, adjusts the overhead lights for optimal visualization and positions them at a 45-degree angle offset from the planned incisions, rather than directly above.

1. In this scenario, who did not follow the recommended practice point?

   a. Maria
   b. Dylan
   c. Aisha
   d. Carlos

PRACTICE POINT: Team Practices to Reduce Airflow Disruption

Human activity is a major source of airborne contamination in the OR. Increased numbers of personnel are associated with higher airborne particle counts and greater airflow disruption.[3,10] When clinicians begin opening sterile supplies, only essential personnel should be present in the OR.[1]

Door openings disrupt positive pressure in the OR, permitting the influx of air from adjacent spaces and increasing airborne contamination.[1,10,11] Results of one particle-count study demonstrated that door-opening events are associated with immediate increases in airborne particles, followed by a period of recovery as ventilation restores baseline conditions when the door remains closed.[11]

The degree of airflow disruption resulting from door openings varies by circumstance. Although any door opening disrupts airflow, evidence suggests that single door openings may have a lesser effect on pressure differentials than the simultaneous opening of multiple doors, which can substantially compromise OR air integrity and allow contaminated air entry.[11] Coordinating supply retrieval, minimizing unnecessary traffic, and avoiding simultaneous door openings support maintenance of optimal airflow and pressure relationships.[1]

Excessive movement, unnecessary activity, and frequent conversation increase particle dispersion and turbulence.[1] Scrubbed personnel should move deliberately and remain near the sterile field, and nonscrubbed personnel should avoid crossing between air diffusers and the sterile field.[1]

Particles from the environment (eg, skin squames, hair, dust) can become airborne in the OR and introduce risk for sterile field contamination. Surgical attire reduces the risk of release of skin squames and hair.[12] Environmental cleaning practices, including damp dusting before the first procedure, remove dust that may otherwise become airborne.[13]

KNOWLEDGE CHECK

Priya, an RN circulator, cares for a pediatric patient undergoing a spinal procedure with implants. Luca, a vendor who is essential to the procedure, enters the OR with the surgeon and plans to remain in the OR for the duration of the procedure. Approximately two hours after incision, Jamal, the OR charge nurse, enters the OR for a status update and to discuss plans for the next patient with Priya. Throughout the procedure, Miles, the anesthesia professional, obtains medications from the OR dispensing cabinet. Occasionally he contacts another anesthesia professional to bring medications that are not in the cabinet to the OR. The other anesthesia professional knocks on the door, opens it slightly, and passes the medication directly to Miles.

2. In this scenario, who did not follow the recommended practice point?

   a. Priya
   b. Luca
   c. Jamal
   d. Miles

PRACTICE POINT: Interdisciplinary Air Quality Management Program

Sustained OR optimal air quality depends on reliable systems and shared accountability rather than isolated actions. AORN recommends implementing strategies to reduce the risk of airborne environmental contamination; implementing a perioperative air quality management program is one potential strategy to reduce such contamination.[1]

When an air quality management program is initiated, an interdisciplinary team with a variety of expertise (eg, perioperative nurses, anesthesia professionals, surgeons, surgical technologists, infection preventionists, facilities maintenance personnel, HVAC engineers, industrial hygienists, environmental services professionals) should implement and sustain the air quality program.[1] Perioperative RNs play a central role in translating ventilation expectations into daily practice, identifying concerns, and escalating issues through established processes.[1] Effective programs include collaboration among perioperative clinicians, infection preventionists, and facilities and engineering personnel involved in ventilation system design, maintenance, and monitoring.[1]

When designing a perioperative air quality management program, the interdisciplinary team may consider a variety

of elements that address system characteristics and compliance as well as performance and maintenance. The elements may include the following:

- reviewing current evidence and professional guidance related to perioperative air quality;
- defining the program's scope, including rooms and locations covered;
- identifying the ventilation type, filtration level, and any supplemental air-cleaning technologies;
- verifying alignment with regulatory requirements and professional standards;
- confirming that the HVAC systems are operating as intended;
- verifying completion of routine maintenance;
- reviewing findings from scheduled and unscheduled maintenance events;
- understanding and monitoring the HVAC setback strategies; and
- verifying expected room pressurization.[1]

The interdisciplinary team may also address monitoring and evaluation, which may include

- establishing triggers for air quality sampling (eg, after maintenance or system failures, upward trends in SSI rates, changes in room use or practice);
- defining air quality testing processes, such as sampling type, conditions, locations, and reporting;

- establishing benchmarks for each location; and
- reviewing and interpreting results to guide improvement efforts.[1]

Although global consensus benchmarks for air quality measurement are not yet established, assessment tools, such as the Operating Room Ventilation System Assessment (ORVSA), provide structured approaches for evaluating ventilation performance.[14]

The interdisciplinary team members also may be tasked with functioning as change agents. They may observe work as performed to identify modifiable behaviors or set-up issues. The team members may review observational data and plan for system upgrades when performance expectations are not met. Finally, they may be asked to apply change management strategies, including educating, monitoring, providing feedback, and engaging with perioperative team members.[1]

Routine HVAC system hygiene and preventive maintenance support consistent air quality performance.[1,2] Monitoring strategies associated with pressure and carefully interpreted supplemental particle counting may be used after maintenance activities or when increases in infections are identified.[1,15] Because particle counts are not a direct measure of microbial contamination, facilities that use particle monitoring typically interpret results in the context of other ventilation performance data and, when indicated, microbial air sampling.[16] Monitoring data should be used to support quality improvement and shared learning rather than punitive actions.[1]

Education can help perioperative teams understand how ventilation systems function and how daily behaviors influence air quality. Sharing monitoring results transparently and reinforcing expectations promote professional accountability and support a culture of safety.[1]

KNOWLEDGE CHECK

Leaders of a perioperative department are implementing an interdisciplinary air quality management program that involves completion of a required educational activity on air quality concerns. Fatima, an RN circulator, completes the educational activity and, before the first procedure the next day, notices that a pressure sensor alarm in her assigned OR has been activated. She determines that the OR is not maintaining positive pressure relative to the corridor; she reports the finding according to the new facility policy and delays opening sterile supplies. Robert, a member of the facility engineering team, calls Fatima on the phone and tells her that repairs are in progress. When she asks how long the repairs will take, he tells her that he does not know.

Fatima calls Nina, the OR charge nurse, to update her on the situation. After hearing about the delay, Nina tells Fatima that Dr D, the surgeon, is standing at the charge desk. Nina asks Fatima to come to the desk; when Fatima arrives, she notices that Dr D appears to be very upset. Nina tells him that she can move him to another OR in approximately two hours. Dr D replies that he has to see patients in the office in two hours and demands to move forward in the designated and scheduled room.

3. In this scenario, who did not follow the recommended practice point?

   a. Fatima
   b. Dr D
   c. Robert
   d. Nina

Resources

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CONCLUSION

Air quality in the OR is an essential part of sterile technique. Ventilation design establishes the baseline, but daily practice and effective air quality management programs determine whether air quality is reliably maintained. Perioperative RNs play a critical leadership role in advocating and protecting patients by safeguarding OR air quality. Through a deep understanding of OR ventilation systems, vigilant minimization of environmental disruptions, and active participation in interdisciplinary air quality management, perioperative RNs exert direct control over conditions that influence contamination risk. Together, these practices underscore that safeguarding OR air quality is not a single intervention or isolated responsibility, but an ongoing, interdisciplinary effort that requires alignment among perioperative teams, infection prevention, and facilities partners to sustain safe practice over time.

Conflict of interest disclosures: *In the past 24 months, Erin Kyle has not had any financial relationships with any companies whose primary business is producing, marketing, selling, reselling, or distributing health care products used by or on patients.*

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Knowledge Check Answers:

1. In this scenario, Carlos did not follow the recommended practice point.
2. In this scenario, Jamal did not follow the recommended practice point.
3. In this scenario, Dr D did not follow the recommended practice point.

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