CHAPTER 9

ROOM VENTILATION SYSTEMS

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Checklist

1. Does the ventilation system in your operating room (OR) meet the standards given by NIOSH (National Institute of Occupational Safety and Health), ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), CDC (Centers for Disease Control and Prevention), and AIA (American Institute of Architects)?
2. Can the temperature be adequately regulated?
3. Can the humidity be adequately regulated?

Many regulatory institutions, such as NIOSH, ASHRAE, CDC, and AIA, have developed standards and guidelines for OR ventilation systems. As in any other environment, ventilation in the OR is an important issue. The OR has some special needs, however. The goals of the ventilation system are:

1. Comfort of the patient in the OR
2. Comfort of surgeons and other personnel in the OR
3. Control of the concentration of pollutants:

Chemical (anesthetic gases/volatile substances)
Physical (particulates/aerosols)

4. Ability to quickly raise or lower the temperature
5. Control of infections (microbiological pollutants)

There are various components of ventilation systems in the OR:

1. Ventilation
2. Heating and cooling
3. Humidity control
4. Waste anesthetic gas scavenging (see Chapter 7)

Ventilation

A ventilation system in the OR can be either a recirculating or non-recirculating system. A recirculating system is one that recirculates some or all of the inside air back to the OR suites or some other part of hospital, whereas in a non-recirculating system, all air brought to the room is conditioned, outside air. When a recirculating system is used, the air return duct should have a high efficiency particulate air (HEPA) filter built into the system. In an OR where inhalational anesthetics are used, there should be separate systems for ventilation, vacuum (patient and

surgical suction), and waste anesthetic gas disposal (WAGD). A recirculating ventilation system in the OR can be a problem if a passive WAGD system is in use. In a passive WAGD system, waste anesthetic gas from the anesthesia machine is directed to the room ventilation return duct that removes air from the OR. In a recirculating ventilation system, this waste anesthetic gas will mix with fresh air inflow and be returned to the same room or other areas of the facility. Thus, it is recommended not to use a passive WAGD system in new construction, and if it is used, ventilation should be the non-recirculating type. It is best to have a separate active WAGD system that is independent of both the ventilation and vacuum systems, and gases from the WAGD system need to be exhausted directly to the outside.

Infection control is critical in ORs. Studies have demonstrated that most of the causes of wound contamination in the OR are the result of the patient's skin flora and bacteria shed on airborne particles from the OR personnel.[1,2] Room ventilation affects the distribution of these airborne particles in four ways: total ventilation (dilution), air distribution (directional airflow), room pressurization (infiltration barrier), and filtration (contaminant removal). As the air flows of the room increases, the greater the dilutional effect on airborne particles. Balancing this phenomenon is that while increased flow increases the effectiveness of air exchange, resultant turbulent flow increases microbial distribution throughout the room. Low-velocity unidirectional flow minimizes the spread of microbes in the room. Directional flow can be inward, from the outside into the OR (negative pressure), or outward, from the OR to the outside (positive pressure). Negative pressure ventilation is used for highly infective rooms in the hospital (e.g., isolation rooms for tuberculosis patients) and positive pressure ventilation is used for protective environments (e.g., ORs and rooms with immunocompromised patients). Positive-pressure ventilation is used with a minimum differential pressure of 2.5 Kpa between the OR and the corridors. Rarely, if there is highly infective patient in the OR, negative-pressure ventilation might be used (if available). Most hospital ORs are currently designed with HEPA filtration systems to maximize removal of contaminants in the air.

Operating room ventilation systems should operate at all times, except during maintenance and conditions requiring shutdown by the building's fire alarm system. During unoccupied hours, air exchange can be reduced as long as positive pressure is maintained in each OR. Complete shutdown of the ventilation system may permit airflow from areas with less clean air into the relatively negative pressure area of the ORs.

Air is delivered to each OR from the ceiling, with downward movement toward several exhaust or return ducts near the floor. This design helps provide steady movement of clean air through the breathing and working zones. The AIA has specific guidelines for the location of outside fresh air inlets to minimize contamination from exhaust systems and noxious fumes. Fresh-air intakes (for instance, on the roof) are to be located at least 25 feet (7.62 meters) from exhaust systems and areas where noxious fumes may collect. Plumbing vents may end as close as 10 feet (3.05 meters) to the air intake system.

Outdoor-air intakes are to be as high as practical, with their bottoms at least 6 feet (1.83 meters) above ground level or, if on a roof, 3 feet (0.9144 meters) above roof level. Air that could otherwise be recirculated ("relief air") but is discharged to the outside to maintain building pressure is exempt from this separation requirement.

Using computational fluid dynamics analysis, a mathematical technique to comprehensively look at room airflow, Chen et al. showed that a higher air inflow rate and a larger air-inlet area are desirable for contaminant control, but these approaches are detrimental to the thermal comfort of the staff and patient.[3] Similar studies by Memarzadeh and Manning[4] as well as Memarzadeh and Zheng Jiang[5] led the AIA to recommend an air-change rate in an OR of 20 to 25 air changes per hour (ACH) for ceiling heights between 9 feet (2.74 meters) and 12 feet (3.66 meters); a ventilation system providing a single-directional flow regime, with both high- and low-exhaust locations; a face velocity of around 25 to 35 fpm (0.13 to 0.18 m/s) from a non-aspirating diffuser array (i.e., ceiling air inlets), provided that the array size itself is set correctly such that it covers at least the area footprint of the OR table plus a reasonable margin around it; and that if additional diffusers are required, they may be located outside this central-diffuser array. According to the AIA, up to 30% of the central-diffuser array may be allocated to non-diffuser items (e.g., medical gas columns, lights, and equipment booms.)

Some controversy exists between engineers and clinicians over the need for laminar airflow ventilation in the OR to further minimize airborne infection. Careful mathematical analyses of airflow suggest laminar airflow is not necessary when the previously noted recommendations are met. Clinical studies are confirmatory.[6,7] Similarly, the use of ultraviolet light to cleanse the room air is no longer recommended.[8]

Heating and Air Conditioning

Many studies have shown that keeping patients warm during the perioperative period is highly beneficial. Additionally, the comfort of the surgical team should be kept in mind. Recommended temperatures for ORs are between 68°F and 73°F during surgery and between 62°F and 80°F otherwise, and recommendations for the post-anesthesia care unit (PACU) are between 70°F and 75°F.[9]

Heating and air conditioning systems must allow the individual room temperature to be raised or lowered rapidly as needed for patient and surgeon comfort. This temperature change must be accomplished without a large overshoot in the desired temperature and can be accomplished with individual "reheat coils" in each OR. Care in how the room temperature is measured is important because in a very large room, a thermostat controlling the air temperature by measuring the air around a distant wall will not reflect the temperature around the surgical table. Some thought should be given to placing the thermostat in the middle of the room. A move to LED surgical lights, which produce significantly less heat, may make the temperature of the immediate surgical environment easier to control since it will more likely reflect the environment further away from the patient.

The use of devices to directly warm the patient also makes the room temperature less important, except when patient cooling is desired.

Humidity Control

Humidity control is important because decreased humidity may lead to damage in the respiratory tract and loss of body heat through evaporation of sweat. Excessive humidity is also undesirable for patient and staff comfort. Relative humidity should be approximately 30%-60% in most ORs and in the PACU.

Today, because of long procedures, multiple-layered gowning, and x-ray protection, many surgeons are requesting lower temperatures in the OR. These lower temperatures affect the moisture content of the air, as cooler air can hold less water vapor.

Obtaining specified temperature and humidity conditions can be a difficult, but not impossible, task. If all the factors that affect environmental conditions are taken into consideration, the goal is certainly achievable. Some key points to remember are:

1. Purchase a conditioning system with a tight single-point control thermostat and humidistat.
2. Buy a thermostat and humidistat suitable for OR application; be sure that they are properly positioned and routinely calibrated.
3. Ensure that the system has the capacity to handle the internal heat load and that it has sufficient air-handling capability to promote uniform air temperature and humidity.
4. Be mindful of the influences of heat loads (i.e., heat-generating OR equipment, including anesthetic and surgical equipment as well as patient- and fluid-warming devices) and try to minimize them.
5. Ensure that the system has adequate design capacity for extreme outside temperatures. As an example, many commercial buildings are designed to provide an interior temperature of 78°F with a maximum outside design temperature of 94°F. In other words, the system will provide a maximum of 16°F of cooling. If the outside temperature rises to 108°F, as may happen in some parts of the United States, the inside temperature will be no lower than 92°F.
6. Ensure that the conditioned space and ductwork are well-insulated with an uninterrupted vapor barrier.

Scavenging of Waste Gases (see Chapter 7)

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