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## A Wide-Angle View of Today's Whole-Room Disinfection Systems

Which automated surface-sterilizing technology best suits your needs?

Hellen Johnson



Pamela Bevelhimer, RN, BSN, CNOR

**ENVIRONMENTAL DISINFECTION** The persistent contamination of OR surfaces despite traditional cleaning and disinfection methods has led to the emergence of whole-room disinfection technologies.

The evidence is clear: to fully clean and disinfect the OR, manual cleaning alone just doesn't cut it. Despite your turnover team's best efforts to wipe and mop every inch of cart, counter, table and floor, studies show that up to half of all operating room surfaces will remain contaminated with pathogens — including multidrug-resistant organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) — when you wheel the next patient in. The shortcomings of manual cleaning have ushered in a new era of whole-room disinfection technology. Which whole-room system is right for your facility? Let's start by considering:

- **Throughput/turnaround time.** What is your average caseload? How quickly do you need an OR to be cleaned and disinfected? Do you aim for end-of-day, between-cases or continuous disinfection?

**Personnel/staffing.** Do you have staff available to oversee a technology that requires manual remote operation, room evacuation/sealing and device repositioning?

- **Ergonomics/space.** What distance must a device that you wheel from room to room cover? What are the entrance/exit dimensions through which you would need to maneuver a device? What is your storage capacity for a mobile device?

### Episodic disinfection



Pamela Bevelhymmer, RN, BSN, CNOR

**HARD TO KILL** A growing body of research has demonstrated that manual cleaning and disinfection of the operating room is suboptimal.

It helps to categorize whole-room disinfection technologies by their time-dependent mode of operation: Is it episodic or continuous?

Episodic disinfection includes mobile ultraviolet-C (UV-C) devices, hydrogen peroxide vapor (HPV) or mist systems, and ozone systems that provide disinfection within a discrete period of time in an unoccupied space because of safety concerns. You can deploy these devices at the end of the day or between cases, with varying "run" times.

- **Mobile UV-C systems.** There are 2 classes of mobile ultraviolet light systems: those with steady-state, low-pressure mercury bulbs that emit light at the 254nm wavelength, and those with xenon bulbs that emit short, high-intensity pulsed light encompassing the UV (100nm to 280nm) and visible (380nm to 700nm) range, the former requiring a slightly longer "run" time than the latter. Under optimal conditions, mobile UV-C systems provide highly effective surface decontamination. UV-C irradiation is potent against a broad range of bacteria, viruses and fungi, including multidrug-resistant organisms. Research has repeatedly shown an association between their use and significant reductions in surface contamination as well as healthcare-associated infections.

A few disadvantages to mobile UV-C systems: They're only safe for use in unoccupied spaces, limiting them to intermittent disinfection. And despite their "automated" nature, staff must deploy, maintain and monitor the units. While some facilities have the staff to assume this responsibility, others may find it prohibitive.

A larger concern: Not knowing if you've delivered the appropriate dose to all areas of a room. Some systems have remote sensors you can position throughout a room; if the adequate dose is not registered, you can reposition and redeploy the device. Others measure light reflected back to the device, but this isn't truly representative of the dose delivered throughout a space, as different surfaces reflect light to varying degrees. In Europe, you can place disposable dosimeters anywhere throughout a room to document the dose achieved in those locations.

This delivered-dose measurement is critical. Research has shown that UV-C disinfection is limited by the distance between the light source and the targeted surface — especially in shadowed areas or areas not in the direct line of light — and in the presence of organic matter.

A final concern: Repeated exposure to mercury-based UV-C light can result in degradation of some plastics and polymers.

- **Hydrogen peroxide vapors or aerosols.** Perhaps the greatest strength of hydrogen peroxide vapors or mists is their biocidal action. They effectively eliminate bacteria — including MRSA, *Mycobacterium tuberculosis*, vancomycin-resistant enterococci and multidrug-resistant *Acinetobacter* spp. — as well as viruses, fungi and sporofoms like *Clostridioides difficile* on surfaces and in air. Their abilities to disinfect the air is particularly valuable as research increasingly demonstrates the extent to which contaminated air plays a role in environmental infection

transmission. Specialized machines release the vapors or mists into the air of a sealed room, letting them reach and disinfect all surfaces, regardless of their distance from the unit.

A key drawback to hydrogen peroxide systems: They are toxic to humans, so the treated room must not only be unoccupied, but also tightly sealed so that no vapors or mists escape. Trained personnel are required to oversee a treatment, which can run as long as 2 to 3 hours, presenting logistical challenges for both OR and housekeeping staff.

Like UV-C, repeated exposure to hydrogen peroxide vapors and mists can corrode plastics and polymers. Also like UV-C, these vapors/mists can only provide intermittent disinfection, effectively addressing contamination during treatment, but not in between or during cases.

- **Ozone.** Ozone disinfection systems catalytically convert oxygen in the air into ozone, which is a highly potent biocide against vegetative bacteria in the air and on surfaces. Ozone quickly degrades back into breathable oxygen after use, but the concentration of ozone required for disinfection is toxic to humans, so the room must be unoccupied and sealed during treatment. These systems generally don't require a significant capital expenditure, but do require staff to oversee and operate. Ozone has also been shown to be corrosive to metals and rubber. This, in combination with its limited efficacy against bacterial spores and fungi, has hindered its widespread use in healthcare settings.

#### Continuous disinfection

For continuous disinfection in both occupied and vacant spaces, consider upper room or shielded ceiling UV-C, visible light/high-intensity narrow-spectrum light and dry hydrogen peroxide systems.

- **Ceiling UV-C.** There are 2 primary categories of upper room UV-C systems. The most well-known are those that originally gained popularity for their efficacy in preventing tuberculosis transmission in the 1960s. These units are mounted to the upper walls or ceilings of a room in an effort to keep the UV-C beams above a room's occupants. Ventilated movement of air within the room brings infectious aerosols into the germicidal beam and delivers disinfected air back to the "breathing zone." Safety concerns, however, have limited the use of these systems as reports of irritation to eyes (photokeratitis) and skin (photodermatitis) have demonstrated that human UV-C exposure is occurring below the upper room zone.



Nancy L. Havill, MT(ASCP), MHA, CIC

**SEALED OFF** Hydrogen peroxide vapor's antimicrobial effect blankets a room, but requires a sealed space and a trained technician for safe use.

#### INVESTMENT STRATEGY

##### Making the Case for Whole-Room Technology

Some tips for building a case to acquire whole-room disinfection technology.

- **What's your rationale?** Show how the system you're advocating for matches your needs, based on caseload, turnaround time goals and staffing resources. For example, if choosing dry hydrogen peroxide, show how the automated and continuous disinfection matches your staffing limitations and need for rapid turnover. If you're choosing a mobile UV-C system, demonstrate the potential to address facility-wide disinfection needs by deploying the device for nighttime disinfection in other areas of the facility.

- **Develop an implementation plan.** If you choose an episodic disinfection technology, you might create an alert system that notifies the device operator when an OR is ready for disinfection.
- **Know the costs.** The capital costs of these systems can vary dramatically, reaching as high as hundreds of thousands of dollars for mobile UV-C devices or hydrogen peroxide vapor systems. What's the cost for maintenance and replacement parts?
- **Demonstrate ROI.** Show how reduced SSI rates would translate into direct savings. Studies have shown a single SSI on average costs \$20,781 while a periprosthetic joint infection can cost \$400,000 to \$475,000.

— Helen Boehm Johnson, MD

Newer ceiling UV-C systems have solved this exposure problem by drawing air into a ceiling-mounted unit with a shielded UV-C lamp inside. Air is drawn in through a filter, disinfected and blown out by an internal fan, helping to recirculate the disinfected air. These systems offer a novel way of treating contaminated air and improving air quality. Studies have shown their effectiveness against both bacteria and fungi in the air; however, the impact on surface contamination remains to be studied.

- **Dry hydrogen peroxide (DHP).** DHP has been used for decades by the military and agriculture industry for environmental disinfection, but has only recently been used in healthcare settings. DHP has the same biocidal potency against bacteria, viruses, fungi and sporeforms as hydrogen peroxide vapors and mists, but is able to achieve its biocidal effect at far more dilute concentrations because the hydrogen peroxide molecules don't have to compete with water molecules to attach to microorganisms. It's safe for human exposure and can be used continuously throughout the day. This means air and surface disinfection is occurring before, after and while a procedure is underway, and when an open instrument tray or surgical wound are vulnerable to the settling of contaminants.

You can place DHP systems in an existing HVAC system. Like hydrogen peroxide vapors and ozone, DHP can disinfect an entire room because air carries it to both high- and low-touch/center and remote surfaces. A recent study evaluating surface contamination of obscure, low-touch surfaces (those not likely to be addressed with manual cleaning) demonstrated a 93% reduction after just 7 days of DHP use and a 98% reduction at 30 days. This underscores the ability of DHP, much like hydrogen peroxide vapors, to achieve whole-room disinfection by reaching all surfaces within a space.

From an operational standpoint, DHP systems offer an advantage not only because they don't impact room turnover time — a critical factor for facilities with high caseloads — but also because, like upper room UV-C or visible light systems, they are truly automated and don't require staff to operate or oversee. They're also far less expensive than mobile UV-C or hydrogen peroxide vapor systems.

Drawback: DHP is less potent in the presence of water, so its efficacy is diminished on wet surfaces.

- **Visible or high-intensity narrow-spectrum (HINS) light .** The antimicrobial properties of visible light have been recognized for centuries and are thought to be the reason early hospital designs featured natural ventilation and exposure to sunlight. Because the most germicidal wavelengths of light fall in the UV spectrum (240nm to 260nm), healthcare facilities have been slow to adopt technologies using light in the visible spectrum. More recent research has shown, however, that systems generating narrow-spectrum light near the 405nm wavelength (which falls within the visible spectrum of 400nm to 700nm) inactivate a number of bacteria, including many common HAI-associated organisms. This inactivation appears to be species-dependent, though, with a general trend towards greater Gram-positive species susceptibility than Gram-negative species. Additionally, viruses are thought to have little susceptibility due to the mechanism of microbial inactivation.

Several studies over the past decade have shown effective reductions in environmental surface contamination in a number of healthcare settings, including one study that demonstrated use in the OR was associated with a concomitant reduction in periprosthetic joint SSIs — one of the costliest and devastating surgical site infections. To date, there have been no studies on air disinfection.

These ceiling-mounted systems contain a combination of violet and white light-emitting diodes (LED) to provide the necessary illumination. They are automated, and some are equipped with an occupancy sensor that lets the light switch to a higher and more germicidal dose of high-intensity narrow spectrum— or HINS — light when the room is unoccupied. Their ability to be used in an occupied space is a notable advantage over UV-C light. **OSM**