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# Issues and Opportunities with UV-C-based Room Disinfection Products

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It is well established in infection prevention practice that surfaces in hospital rooms are continually contaminated by infectious pathogens. The sources of these dangerous pathogens include people who enter the room with contaminated hands and compromised clothing, contaminated instruments and items that are brought into the room, and the current patient residing in the room. In addition, the air entering the room is not sterile and deposits pathogen containing fomites which settle onto surfaces adding to the degree of bio burden compromise.

It is also well established that the accumulated pathogens residing on the high-touch surfaces are then transferred onto bare or gloved hands and clothing of nurses, doctors, visitors and environmental workers when touched, which in turn puts patients at great risk since they or their immediate surroundings are consequently contaminated by touch transfer mechanisms. Hence, even perfect attention to between-patient-visit hand sanitation by healthcare workers (HCWs); 100% compliance, and effective sanitization of hands to  $-4 \log_{10}$  inactivation, (99.99%; which is not currently achieved), will leave the hands contaminated while performing tasks within the room. This situation is judged to be unavoidable.

Accordingly, the ultimate solution espoused by the World Health Organization (WHO) is hand sanitation immediately prior patient contact; the Five Special Moments ('FSM'), so that patients or the patient surround are not contaminated as a result of attention or care from a healthcare worker, attendant or a visitor. Currently, the use of alcohol rubs just prior to contact is recommended by WHO for hand sanitation despite the fact that during a shift 100 or more alcohol rub hand sanitations, each taking at least 30 seconds with a resulting almost one hour

dedicated to hand sanitation per shift, would be required. Moreover alcohol rub is not free of hand irritation and is totally ineffective on spores such as *C. diff* and some viruses. Hand washing is usually less effective, takes more time and is generally more irritating. There is no currently available product that can meet the WHO FSM requirement so it remains an objective, but not yet a reality.

As a response to problematic hand hygiene, a number of companies are now offering UV-C-based, room disinfection devices, which have as their purpose to supplement terminal cleaning. They nominally sanitize room surfaces in as little as 15 minutes, and by lowering the bio burden levels, help to minimize additional contamination of hands and clothing when the surfaces are contacted later. This sanitation process must be carried out in a vacant room due to the dangers UV-C poses to unprotected eyes, so it is generally performed only after patient discharge and cleaning by environmental workers.

To understand the efficacy of this approach, it is important to recognize that inactivation of pathogens, especially hardy *C. difficile* endospores, to the nominal  $-4 \log_{10}$  or 99.99% sanitation level in 15 minutes, typically requires a total UV-C dose at a wavelength of  $\lambda 253.7$  nm of about 900 joules/meter<sup>2</sup> in a 900 second period. Other pathogens such as *S. aureus* are more easily inactivated. This implies a continuous UV-C intensity of at least 1 watt/meter<sup>2</sup> incident on any surface. Keeping in mind that the UV-C intensity of the radiation from the source falls off with the square of the distance from the source; i.e., as  $1/\text{distance}^2$ , the intensity of the source of about 250 watts/ meter<sup>2</sup> at the tube surface is decreased at a distance of say roughly 10 feet from the UVC source to about 1 watt/meter<sup>2</sup>. That could be effective in sanitizing most of the room surfaces for normal incidence rays falling directly on the room

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surfaces. This would be the case for walls, which are actually not touch surfaces in most cases. However, most touch surfaces in the room are generally not perpendicular to the UV-C rays coming from the source. A desk or table or bed surface is in fact almost certainly at a large oblique angle to the UV-C rays. So for example the effectiveness of radiation incident at 45 degrees to the surface is reduced to 70.7% of its normal incidence value, reducing the achievable inactivation to less than 99.9% and for light directed parallel to the contaminated surface, to virtually no inactivation. Reflection off the ceiling is the only way flat surfaces can be illuminated. However, the trajectory is hardly ideal.

Accordingly, the walls of the room may be fully sanitized but certainly not the important high touch surfaces, missing the fundamental purpose of the entire exercise. Hence, the UV-C room sanitizer systems for this reason alone are ineffective for most pathogens. There is no easy fix for this inability to inactivate; fundamental optics work against effective UV-C exposure of a hospital room, and certainly the current generation of device designs do not sufficiently overcome this inherent limitation.

There is also the issue of how to deal with shadowed areas that still may be on the high touch surfaces. If UV-C disinfection is suppose to help rectify inadequate terminal cleaning, there is a built in assumption that most surfaces are still dirty. However, this important concern is almost never discussed. Soiled surface is a serious problem since most biofilm, settled dust, and human excrement or sputum is opaque to ultraviolet and will shield pathogens within or below the incident surface. There will be no improvement in the quality of the target surfaces if they are not fully cleaned prior to exposure to UV-C. Depending on the level of contamination, pathogens can clump together and become only partially transparent to UVC. There will be shielding of some of the pathogens to UV-C within the clump; reducing the received dose and the overall degree of inactivation achieved. This additionally undermines the purposes of room sterilization. However, the story gets worse. The material and texture of the underlying surface can play a role in reducing effectiveness.

Also there is no standard efficacy validation approach. There is a lack of an ongoing recertification and verification protocol that are common practice for other modalities used in hospital settings such as autoclaves and VHP gas sterilizers. Such approaches would help hospital make purchasing decisions and enable ongoing vigilance of effectiveness. Lastly, it would provide a platform to reinforce credibility.

Finally should be noted that such systems are expensive; in most cases exceeding \$50,000 per device. Maintenance is expensive and the systems have an annual operating cost of about \$25,000 or more plus labor amounting to perhaps another \$25,000 per year, for a total annual operating cost well above \$100,000. Assuming the systems can do 20 rooms per day or about 7,000 rooms per year, the additional cost, beyond terminal cleaning, of 'sanitizing' per room is about \$15. That would be a bargain if the system fully sanitized all touch surfaces and if the room remained sanitized during the stay of the next patient. Moreover, what does one do with double rooms? Both patients must be out of the room to attempt full room sanitation with UVC. Patient recovery is not that accommodating. Unfortunately, un-sanitized clothing and un-sanitized hands of HCWs, unsanitized visitors, and unsanitized maintenance staff all quickly build up the contamination level and put the patient at risk. In the end there is no ducking the WHO enunciated requirement that hands and clothing coming into contact with the patient and the patient surround must always be sanitized, preferably before each patient touch.

The upcoming October 28, 2014 IUVA Healthcare workshop will discuss and explore many of the benefits of such systems but also their limitations, and how new fast moving developments may overcome issues with the application of germicidal ultraviolet light to reducing contamination in hospitals leading to lowered rates of hospital associated infections creating new opportunities and improving patient and worker safety.