

Mobile UV Disinfection: A Bright Spot in the Battle Against Hospital Acquired Infections

By Sam Guzman, American Ultraviolet

THE HIGH COSTS OF HOSPITAL ACQUIRED INFECTIONS

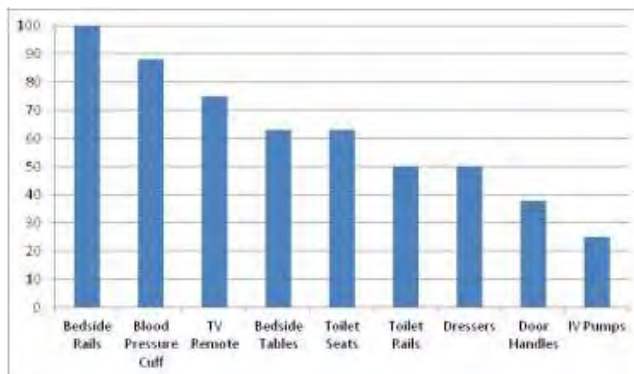
According to the Centers for Disease Control, one in 20 hospital patients will acquire a Hospital Acquired Infection (HAI). This rate continues to climb steadily and has increased by 36 percent over the past 20 years. In the United States, the CDC estimated roughly 1.7 million hospital-associated infections contribute to 99,000 deaths each year.

A 2007 CDC estimate of the overall annual direct medical costs of HAIs to U.S. hospitals ranges from \$35.7 billion to \$45 billion. Estimates of the economic benefits of prevention range from \$25.0 to \$31.5 billion, with an average cost per infection of \$13,973 and an increased cost to surviving patients of approximately \$40,000. For example methicillin-resistant *Staphylococcus aureus* (MRSA) has become endemic, even epidemic in many U.S. hospitals and has added 2.7 million extra days in the hospital with an average added cost of \$35,367 per incidence.

Total Health Care Cost From Hospital-Acquired Infections
Over 99,000 deaths per year in the United States
Increased ICU stay 8 days
Increased average hospital stay between 7.4 and 9.4 days
Total dollar cost between \$35 and \$45 billion
Average cost per infection of \$13, 973
Increased total cost per patient who survived approximately \$40,000

THE ROLE OF CONTACT SURFACES IN HAI TRANSMISSION

In the past, experts believed that the most significant source of hospital-acquired pathogens was the patient's



own flora. More recently however, the role of infection from contact with contaminated surfaces has been identified and empirically demonstrated to be a strong contributor to the transmission of Hospital Acquired Infections. For example, Weber, et al. (2010) found that an estimated 20 to 40 percent of nosocomial infections studied were a result of cross-infection via the hands of healthcare workers, and contact with “high-touch” surfaces. A 2007 study (by Boyce) of a Connecticut hospital revealed that 59 percent of the surfaces in rooms of patients studied were contaminated with MRSA. The chart shows the reported incidence of contamination on the most common surfaces tested.

TRADITIONAL METHODS OF CLEANING AND DISINFECTION ARE INSUFFICIENT AND COSTLY

Cleaning is the removal of soil and contaminants from surfaces, whereas disinfection relates to the inactivation of pathogens by use of a disinfectant. Microorganisms vary in their resistance to disinfectants, so agents must be chosen carefully for their effectiveness, particularly for *C. difficile* spores. Furthermore, the hospital environment is complex and often difficult to clean, and use of a cleaning agent that is not effective against the target organism can spread pathogens to other surfaces.



Numerous studies conclude that manual cleaning and chemical disinfection alone is inadequate to safeguard against HAI transmission on high-touch surfaces.

In their 2010 paper on the role of contaminated surfaces in the transmission of nosocomial pathogens, Otter et al., note that “cleaning and disinfection does not always eradicate pathogens from surfaces” and that “... it is difficult to determine whether it is the products, the procedures, or a combination of the two that is responsible for the failure to eradicate pathogens from surfaces.”

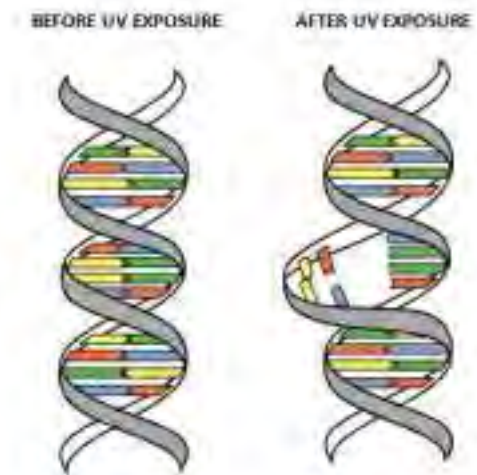
Several recent studies underscore the inadequacy of current cleaning and manual disinfection in hospitals. Carling, et al. (2010) report that nine studies of thoroughness of cleaning and disinfection, which included more than 62,500 high-touch surfaces in 103 different institutions and 142 study sites identified opportunities for improved cleaning in all venues, documenting that cleaning and disinfection must be improved across a broad range of U.S. healthcare settings as part of efforts to prevent transmission of pathogens.

Carling, et al. (2008) identified significant opportunities in all participating hospitals to improve the cleaning of frequently touched objects in the patients’ immediate environment. The overall thoroughness of terminal cleaning, expressed as a percentage of surfaces evaluated, was 49 percent (the range for all 23 hospitals in the study was 35 percent to 81 percent). There was significant variation in cleaning efficacy with respect to the cleaning of toilet handholds, bedpan cleaners, light switches and door knobs (mean cleaning rates less than 30 percent); sinks, toilet seats and tray tables were consistently relatively well cleaned (mean cleaning rates over 75 percent). Patient telephones, nurse call devices, and bedside rails were inconsistently cleaned.

By following all of the recommended steps, cleaning an occupied patient room should take approximately

25-30 minutes. A “terminal clean” after a patient is discharged or transferred requires 40-45 minutes. Unfortunately a 2011 survey of environmental services managers by UMF Corp. found that their departments were, on average, short by 5 to 9 full time employees. Even when the rooms are cleaned, the wrong cleaning materials are often employed. The Environmental Protection Agency said in 2009 that approximately one-third of 325 registered hospital disinfectants failed to meet its standards for effectiveness.

UV IS EFFECTIVE AT KILLING MICROORGANISMS



UV irradiation causes cleavage of peptide bonds in DNA and RNA, inactivating organisms.

Unlike most conventional hospital disinfectants, ultra-violet (UV) radiation does not inactivate microorganisms by chemical means. UV radiation inactivates organisms by the absorption of UV light, which causes a photochemical reaction that alters the cells molecular components. UV rays penetrate the cell wall of the microorganism reacting with nucleic acids and other vital cell constituents that results in the injury or death of the UV-exposed cells.

In this way, UV radiation is efficient inactivating many forms of bacteria, viruses and other pathogenic microorganisms. UV irradiation in the vicinity of 254 nanometers (nm) inactivates microorganisms by irreparably damaging their nucleic acid peptide bonds.

The germicidal effects of UV light involve photochemical damage to RNA and DNA within the microorganisms. DNA and RNA carry genetic information necessary for reproduction. Therefore, damage to either

of these substances can effectively sterilize the organism. The efficacy of UV in inhibiting the growth and survival of pathogens is responsible for the widespread adoption of UV purification of air and its use in water treatment facilities worldwide.

The degree to which the destruction or inactivation of microorganisms occurs by UV radiation is directly related to the UV dose. UV dosage is the product of the UV sources irradiance and exposure time. The UV dosage is calculated as:

$$D = I \cdot t$$

Where:

D = UV Dose, mW × seconds /cm²

I = Intensity, mW/cm²

t = Exposure time, seconds

A substantial amount of evidence indicates that when microorganisms are exposed to UV radiation, a constant fraction of the living population is inactivated during each progressive increment in time. This dose-death relationship for germicidal effect indicates that high-intensity UV energy over a short period of time would provide the same kill as a lower-intensity UV energy at a proportionally longer period of time. It should be noted however that the intensity of UV incident on the organism can be affected by a number of factors: the intensity of the lamp (which may diminish as it ages over time), the efficiency of the reflected UV energy, the distance between the light source and the organism, and the absorption due to any materials in between.

Since UV intensity generally decreases as the square of the distance, the dimensions of the hospital room is a critical factor when irradiating objects from afar and so the dose calculation must be made with particular attention to this factor.

The following are incident energies of germicidal ultraviolet radiation at 253.7 nanometers wavelength necessary to inhibit colony formation in microorganisms (90%) and for 2-log reduction (99%):

Bacteria	Energy Dosage of Ultraviolet radiation (UV dose) in μWs/cm ² needed for kill facto	
	90% (1 log reduction)	99% (2 log reduction)
Bacillus paratyphus	3,200	6,100
Bacillus subtilis spores	11,600	22,000
Bacillus subtilis	5,800	11,000
Clostridium tetani	13,000	22,000
Corynebacterium diphtheriae	3,370	6,510
Escherichia coli	3,000	6,600
Micrococcus candidus	6,050	12,300
Micrococcus sphaeroides	1,000	15,400
Mycobacterium tuberculosis	6,200	10,000
Neisseria catarrhalis	4,400	8,500
Proteus vulgaris	3,000	6,600
Pseudomonas aeruginosa	5,500	10,500
Pseudomonas fluorescens	3,500	6,600
Shigella paradysenteriae	1,680	3,400
Staphylococcus aureus	2,600	6,600
Staphylococcus lactis	6,150	8,800
Streptococcus viridans	2,000	3,800
Virus	90%	99%
Bacteriophage - E. Coli	2,600	6,600
Infectious Hepatitis	5,800	8,000
Influenza	3,400	6,600
Poliovirus - Poliomyelitis	3,150	6,600
Tobacco mosaic	240,000	440,000

UV SHOWS PROMISING RESULTS IN HOSPITAL TRIALS

As more effective and cost-efficient mobile UV sources have emerged in response to the HAI problem, several recent field studies have affirmed UV's effectiveness in a hospital disinfection setting.

A 2010 study (by Rutala et. al.), was carried out in an acute care tertiary hospital in North Carolina. First, Formica sheets contaminated with approximate organisms of MRSA, VRE, multidrug-resistant (MDR) or *Clostridium difficile* spores were placed in a hospital room, both in direct line of sight of the mobile UV device and behind objects. After timed exposure, the presence of the microbes was assessed. During phase 2, specific sites in rooms that had housed patients with MRSA or VRE

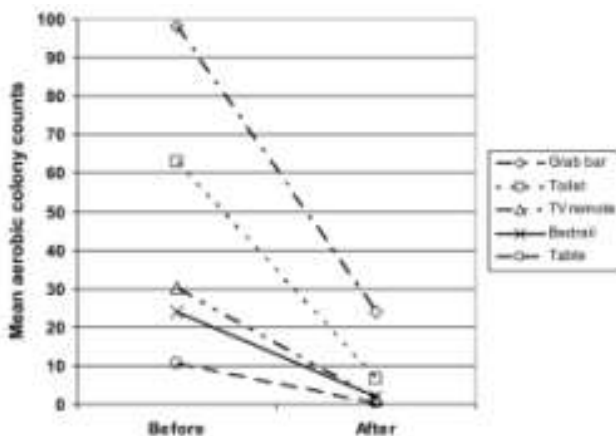
infection were sampled before and after UV irradiation. After timed exposure, the presence of MRSA and VRE, and total colony counts were assessed.



Mobile disinfection units have begun to prove their efficacy in widespread clinical trials.

The effectiveness of UV radiation in reducing the counts of vegetative bacteria on the Formica surfaces was more than 99.9 percent within 15 minutes, and the reduction in *C. difficile* spores was 99.8 percent within 50 minutes. In rooms occupied by patients with MRSA, UV irradiation of approximately 15 minutes duration resulted in a significant decrease in total CFUs per plate for all organisms. The investigators conclude that UV was effective in eliminating bacteria on contaminated surfaces both in the line of sight and behind objects within approximately 15 minutes and in eliminating *C. difficile* spores within 50 minutes with average total log reductions of organisms ranging from 2.79 to 3.94 log-10.

Similar results were reported by in 2011 (by Boyce, et al.). Researchers from the Hospital of Saint Raphael in Connecticut and the Yale University School of Medicine found that a mobile ultraviolet light unit significantly reduced aerobic colony counts and *C. difficile* spores on contaminated surfaces in hospital patient rooms. Their research was published in the journal Infection Control and Hospital Epidemiology.



Boyer, et al. demonstrated the effective use of UV against a range of common HAI organisms.

An automated mobile UV light unit was placed in 25 patient rooms after patient discharge. Aerobic colony counts were calculated for each of five standardized high-touch surfaces in the rooms before and after UV light disinfection. *Clostridium difficile* spore log reductions achieved were determined using a modification of the American Society for Testing and Materials (ASTM) International E2197 test method.

Nerzandzic, et al. (2010) reported similar results from UV disinfection trials conducted in 2010 at a 202-bed Cleveland Veterans Affairs Medical Center acute care hospital. The investigators examined the efficacy of environmental disinfection using a mobile UV device in the rooms of hospitalized patients. The investigators found that UV disinfection was effective in killing *C. difficile* spores, MRSA and VRE inoculated onto surfaces in the laboratory and in hospital rooms. Disinfection of hospital rooms reduced the frequency of positive MRSA and VRE cultures by 93 percent and of *C. difficile* cultures by 80 percent on common high-touch surfaces.

In addition to their findings the researchers reported “the automated UV light device was easy to use and required only a few minutes to set up. It does not require constant monitoring by the operator because the device turns itself off when a cycle has been completed and does not require sealing of air conditioning or heating vents or doors. However, it is important to emphasize that pre-cleaning of rooms by housekeepers is necessary to reduce gross contamination of surfaces because UV light does not penetrate most substances.” The conclusion that UV disinfection along with manual cleaning and chemical disinfection provides the best safeguard against HAI transmission has been proffered recently by others.

	Exposure Time	CFU Reduction
MRSA	14 minutes	3.63 x 10 ⁶ 6.56 log-10
<i>C. diff</i>	41 minutes	4.17 x 10 ⁶ 6.62 log-10

Laboratory test results of the American Ultraviolet ARTZ unit against MRSA and *C. diff*.

“Research shows that UV light is effective at decontaminating a room environment, but this is just one of many fronts when it comes to controlling spread of *C. diff*,” says Ghinwa Dumyati, M.D., an associate at a Rochester hospital. “Our being able to trial these

new UV machines is just one more piece of a multi-pronged, cross-hospital campaign to cut the number of *C. diff* infections in Rochester hospitals.”

“We still do the manual cleaning -- that hasn’t changed. But the UV light gets what we didn’t get,” reports Kathy Rhodes, coordinator of infection prevention for Texas Health Harris Methodist Hospital in Fort Worth after introducing mobile UV disinfection. (Fort Worth Star-Telegram, May 2012).

THE DESIGN OF MOBILE UV DISINFECTION SYSTEMS

Special care and attention must be paid to designing a mobile UV disinfection unit for use in a healthcare and hospital setting. The machinery must be easy to transport, simple to operate and capable of being run by non-technical personnel with a wide range of ability and training.

Safety

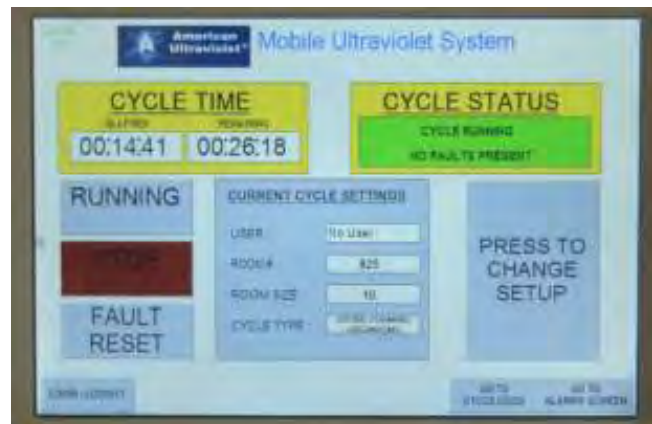
Paramount is the safety of patients and personnel from potential injurious UV exposure. While momentary incidental exposure has no serious health effects, extended UV exposure is linked to eye and skin damage. The equipment should incorporate a safeguard, which prevents startup when a person is present in the target area, or shuts down the unit immediately if someone were to enter while the equipment is operating. A 360 degree combination infrared sensor and motion detector is used for this purpose.

Ergonomics and Controls

The UV mobile disinfection unit should be lightweight enough to permit any hospital employee to relocate the machine without help. The provision of easy rolling casters, convenient wrap-around handrails, and a lightweight and anti-tip design permit single operator setup and use. The controls utilize a graphic, Windows-type graphic interface which provides simple touch-screen data entry. The unit can be pre-programmed with each room number so that the room’s internal dimensions are recalled for use. Other menu choices include the operator ID number and type of cleaning desired. The unit’s internal dose calculator selects the UV exposure parameters that are optimized for the task selected.

Design of a Second Generation UV Mobile Disinfection System	
Ease of Operation	<ul style="list-style-type: none"> • Menu driven graphic interface • Pre-Programmed Parameters for Room Size and Level of Disinfection
Worker Safety	<ul style="list-style-type: none"> • Automatic shutdown if workers present • 360° Heat & Motion detection
Ergonomics	<ul style="list-style-type: none"> • Lightweight, tip-resistant design • Transported and setup by a single operators • Ergonomic handles, casters, controls
High Efficacy	<ul style="list-style-type: none"> • Pre-Programmed for multiple log reduction across all popular HAI organisms (e.g. <i>S. aureus</i>, <i>C. difficile</i>) • Smart algorithm adjusts for room size
Monitoring & Audit	<ul style="list-style-type: none"> • Records the outcome of all runs. Provides audit report on time, operator, duration. • Backup on removable storage for integration with other reports and audits.
Cost Effectiveness	<ul style="list-style-type: none"> • Low maintenance cost. Long lamp lifetime. Simple maintenance to reduce downtime.

Robust Design and Ease of Maintenance



Graphic, touch-screen interface used on a wireless PC tablet provides simple remote control of the mobile UV disinfection equipment.

The mobile UV unit is designed for constant use in a harsh commercial environment and can be maintained easily with no more than simple hand tools. The UV lamps for example are easily removed, with all connections at one end to make replacement simpler. A single power cable is all that must be connected to operate the unit. The wireless tablet PC controller contains all of the necessary user controls.

Administrative and Supervisory Features

Each time the mobile disinfection unit is activated, a log is created including the operator ID, the machine settings and the results of each run providing a complete audit trail. Incomplete runs are easily identified from successful ones. Password protection provides the capability to differentiate operators and limit access to management, maintenance or supervisory functions. The data log is stored on standard removable media so that the records may be archived or incorporated into other reporting software.

Cost Effectiveness

Since ROI frequently drives hospital spending decisions (including those affecting infection controls), the utilization of mobile UV disinfection equipment design should also be a cost-conscious effort. This process begins with an approach that optimizes UV exposure time to the room size and organism being targeted. The algorithm results in an exposure time that is optimal for the task, minimizing the turnover time for rooms requiring terminal cleaning (while at the same time ensuring the level of protection required is actually administered). Other considerations such as lamp replacement time and cost, must also be considered by incorporating durable, long-lifetime lamps that require minimal time or skill to change.

Summary and Concluding Remarks

The prevalence of Hospital Acquired Infections and the attendant costs are widely acknowledged as a persistent and growing concern for health care facilities. The direct human and economic costs, totaling millions of dollars and nearly 100,000 lives annually, along with the opportunity cost of millions of unnecessary days of hospitalization cry out for a better approach. The inadequacy of current manual cleaning and chemical disinfection procedures alone has been widely documented in field studies conducted throughout hospitals nationwide.



UV disinfection, a technique which has been universally adopted for air purification and by municipal water treatment facilities promises to provide additional safeguards against HAI transmission on high-touch surfaces in patient rooms, and other areas prone to pathogens.

Several in-depth studies conducted in hospital settings have validated the efficacy of mobile UV disinfection. Combined with manual cleaning, UV disinfection shows great promise to substantially reduce the occurrence of nosocomial diseases. Along with significant reductions in microorganism growth, UV disinfection provides several added advantages: it reaches into hard to clean areas, it is simple to administer and cost-effective.

Today's mobile UV disinfection equipment is safe, ergonomic, easy to transport and simple to operate. It provides hospital and health care managers and administrators with a verifiable audit that helps ensure that the equipment is being used properly and that hospital standards are being maintained in order to reduce the significant costs that unchecked HAIs pose to their facilities' bottom line.

REFERENCES

Boyce, J. (2007), Environmental contamination makes an important contribution to hospital infection, *Journal of Hospital Infection*, 65(S2) 50–54

Boyce, J., Havill, N.L., Moore, B.A., (2011), Terminal Decontamination of Patient Rooms Using an Automated Mobile UV Light Unit. *Infection Control and Hospital Epidemiology*, Vol. 32, No. 8. August 2011

Carling, P.C., Briggs, J.L., Perkins, J., Highlander, D., 2006, Improved Cleaning of Patient Rooms Using a New Targeting Method, *Clinical Infectious Diseases* 2006; 42:385–8

Jagger, J. 1967. *Introduction to Research in Ultraviolet Photobiology*. Prentice-Hall Inc., Englewood Cliffs, NJ.

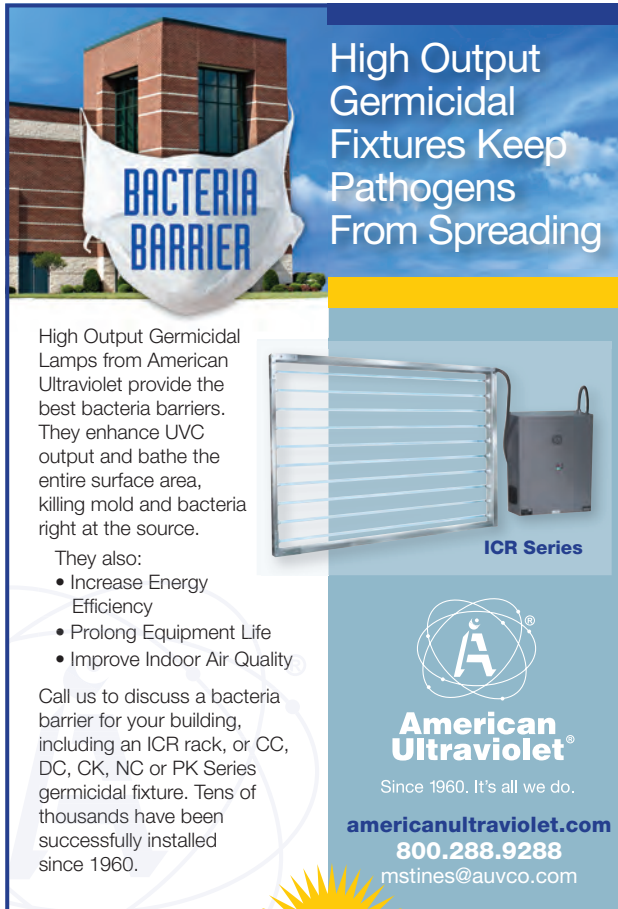
Klevens, R.M., Edwards J, Richards C.L., Hortan, T., Gaynes, R., Pollock, D., Cardo, D., (2007) Estimating Healthcare-Associated infections in US hospitals, 2002. *Public Health Rep* 2007; 122:160-166.

Levit, K. Stranges, E., Ryan, K., Elixhauser, A., HCUP Facts and Figures, 2006: Statistics on Hospital-based Care in the United States. Rockville, MD: Agency for Healthcare Research and Quality, 2008

Murphy, D., Whiting, J., (2007) Dispelling the Myths: The True Cost of Healthcare-Associated Infections, *APIC Briefing*, February 2007

Otter, J., Yezli, S., French, G.L., (2007) The Role Played by Contaminated Surfaces in the Transmission of Nosocomial Pathogens, *Infection Control and Hospital Epidemiology*, 32(7)

Rutala, W.A., Gergen, M.F., Weber, D.J., (2010), Room Decontamination with UV Radiation, *Infection Control and Hospital Epidemiology*, October 2010, 31(10)



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