Protection against Hospital Acquired Infections Using Advanced Ultraviolet Disinfection Technology

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Ultraviolet Germicidal Irradiation (UVGI) has been widely accepted for over 50 years and recognized as a superior alternative to chemicals for the disinfection of drinking water. UVGI is today a well mastered cost effective disinfection technology that unlike antibiotics does not create any new resistant strains and as such creates no undesirable side effect. It has proven capable of deactivating all kinds of microorganisms by dimerization of the thymine pairs of their DNA or RNA. This paper explains and demystifies the fundamentals behind a new generation of software-driven smart automated UVGI devices and how they could be used to complete the sterilization process of operating rooms, patient rooms and hospital bathrooms. Automated systems have been widely adopted in other areas of healthcare to mitigate human errors. When commenting on the future of nosocomial infection control in 1998, Dr Robert Weinstein wrote: "Given the choice of improving technology or improving human behavior, technology is the better choice."

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Introduction

It is now recognized that contaminated surfaces have been utterly underestimated as a reservoir of nosocomial infections [1-3]. Some recent studies have clearly indicated that admission to a room previously occupied by a patient with Clostridium difficile, vancomycin-resistant enterococci (VRE), meticillin-resistant Staphylococcus aureus (MRSA), Acinetobacter baumannii

and Pseudomonas aeruginosa increases the infection probability for subsequent occupants by a factor of two or more[1,4-8]. Such statistics points to the fact that current cleaning and disinfection following the discharge of patients is far from being adequate and needs major improvement. The emergence rate of epidemic strain of C.-Difficile and other multidrug-resistant Gram-negative bacteria that can also survive on surfaces is a further motivation to improve hospital disinfection processes [9,10].

Current cleaning and disinfection using conventional methods relies heavily on a human operator to appropriately select and use a suitable agent and spread it to all target surfaces with a sufficient concentration and contact time. Any improvement of these conventional methods requires the modification of human action and behaviour, which is in practice extremely challenging, to say the least.

The use of new automated room disinfection systems based on the well-known germicidal properties of special ultraviolet light sources provides an alternative approach, which almost removes or greatly reduces reliance on the operator's ability [11-14]. Automated systems have been adopted widely in many other areas of healthcare to alleviate human error.

Indeed, commenting on the future of nosocomial infection control in 1998, Dr Robert Weinstein wrote: 'Given the choice of improving technology or improving human behavior, technology is the better choice [15].

Limitations of conventional cleaning and disinfection

Conventional cleaning and disinfection is actually accomplished by a human operator using all kinds of liquid detergent products. Several microbiological studies have shown that such conventional disinfection procedure rarely succeeds at eradicating pathogens from surfaces [17-20]. Problems associated with both 'product' and 'procedure' contribute to this, in particular, the reliance on the operator to repeatedly ensure adequate selection, concentration, distribution and contact time of the disinfectant. For example, a wide assessment of conventional cleaning in 36 hospitals using fluorescent markers has shown that less than 50% of high-risk objects in hospital rooms were disinfected after patient discharge [21].

As we all know, improving human behaviour is quite difficult but many valuable initiatives are often taken. Those include routine microbiological analysis of surface hygiene, the use of fluorescent markers or ATP assays to monitor the cleaning efficiency, provide feedback of cleaning performance and pursue educational training [5,11,16,21-23].
Monitoring and feedback can somehow improve the frequency of surfaces that are cleaned and reduce the level of environmental contamination [5,21,24,25,26-28]. However, no studies have evaluated the practical sustainability of those improvement initiatives. In fact, recent evidence indicates that simply changing the location of fluorescent dye spots has significantly reduced the proportion of cleaned surfaces from a level 90% down to about only 60%.

Summary of problems associated with actual conventional disinfection:

- Infectiveness of cleaning products against some pathogens; for example, many frequently used hospital disinfectants are not effective against C.-Difficile spores and norovirus [30,33,35].
- Toxicity to staff and/or the environment [30,31].
- Damage to hospital materials and equipment [30].
- Potential for biocide/antibiotic cross-resistance [32].
- Problems with cleaning/disinfection procedures include: Adequate distribution of the active agent, given the challenges of the complex hospital environment [21].
- Ensuring correct contact time for the microbial reduction achieved in vitro.[35]
- Repeatability of the process depends on the operator [21].
- Designation of responsibility for various items, particularly complex portable medical equipment [36].
- Compliance with protocols/policies from a sometime poorly paid, poorly motivated workforce [37].
- Inadequate training and education of personnel [37].
- Improper formulation/concentration of the disinfectant [32,38].
- Contamination of cleaning equipment [38,39].

Ultraviolet Germicidal Irradiation Technology

Ultraviolet Germicidal Irradiation (UVGI) has been widely accepted for over 50 years and recognized as a complement to chemicals for the disinfection of drinking water. UVGI is today a well mastered cost effective disinfection technology that unlike antibiotics does not create any new resistant strains and as such creates no undesirable side effect. There has been no sign of adaptability of any microbes to UVGI even after almost half a century of use. The same thing cannot be said of chemical cleaners and for antibiotics!
Germicidal UV or UV-C has proven capable of deactivating all kinds of microorganisms by dimerization of the thymine pairs of their DNA or RNA.
The operating principle for surface decontamination is to deliver a specific dose of 254 nm wavelength light that has a deleterious effect on DNA. The germicidal UV dose is defined as the product of UV light intensity in microwatt/cm^2 multiplied by the exposure time in seconds. The resulting dose is thus expressed in microjoule/cm^2. Because of its important use in water disinfection for over 50 years, the UV susceptibility of a wide variety of microorganisms has been sampled and measured and there have been thus far no signs of emergence of resistance from any bacterial strains.

When used as a single unit, the device is generally placed in the centre of the room and frequently touched mobile items are arranged close to the device for optimal exposure. Because just like any other light, UV travels in straight lines, it is evidently not as effective in shadow areas out of direct line of sight.

For the above reason, some early UV devices manufacturers have recommend multiple cycles from different locations.34 This is not practical as it not only doubles and triples the disinfection cycle time but also requires an operator intervention and attendance between each move.

But akin to any lighting system, the use of two, three or more emission sources strategically placed to eliminate shadow zones is a much more effective strategy to keep the cycle time low. Also, the additive property of the superimposed UV fields emitted by each UV unit increases the overall intensity and hence contributes to reducing the disinfection cycle time.

Disinfection efficacy of UVGI

Disinfection levels of 6 Log (i.e 99.9999% or 1 survival per million) on C.Diff and MRSA have been achieved in lab tests.

The fact is that knowing the UV susceptibility constants of C. Diff, MRSA, VRE, KLEB, etc., it is relatively easy to determine the required UV intensity to reach a preset target disinfection level.
Measurement of the UV intensity field emitted as a function of the distance from a UV disinfection unit can be easily performed and then the required cycle time can be computed to deliver the desired UV dosage for a target disinfection level.
For example, given the tabulated UV susceptibility of the target bio-contaminants and the UV intensity, the required cycle times to reach 99.9999% disinfection i.e. 6 Log can be computed as in Table 1.

As shown in the table below, providing an adequately sized powerful pair of UVGI units, a disinfection cycle of 15 minutes is possible at distances up to 10 feet (3 m) away. If the maximum distance from the units is less than 5 ft (1.5 m), then only 5 minutes of disinfection time is required.

Not only a dual unit disinfection system minimizes shadow areas, but it also provides an enhanced overall irradiation field that allows for faster sterilization cycle. When tested in the lab, it showed >99.999% disinfection of C.-Difficile, VRE, and MRSA after only 5 minutes of exposure. In the case of very large rooms, three or four units can be used simultaneously to keep the cycle time short.

The complete disinfection cycle is fully automated and operated by wireless communication by using any smart phone or computer tablet such as ipad.
For safety, the units are equipped with eight (8) wide-range infrared motion sensors that will cause the units to shut down in the event someone would walk into a room undergoing a disinfection cycle.
The units have a built-in downloadable data logger that records each and every sterilization cycle performed at any given time and location.

Disinfection target :	ASPETIX TANDEM DISINFECTION PERFORMANCE CHART						
99,9999%	Distance =	5 ft	6 ft	7 ft	8 ft	9 ft	10 ft
	UV output in mW/cm2 =	1314	999	778	620	504	417
C.diff	*Exposure time required in Minutes :*	*4,6*	*6,0*	*7,7*	*9,7*	*11,9*	*14,4*
MRSA	*Exposure time required in Minutes :*	*1,2*	*1,6*	*2,1*	*2,6*	*3,2*	*3,8*
VRE	*Exposure time required in Minutes :*	*0,4*	*0,6*	*0,7*	*0,9*	*1,1*	*1,3*
Klebsiella pneumoniae	*Exposure time required in Minutes :*	*0,3*	*0,4*	*0,5*	*0,7*	*0,8*	*1,0*

Table 1. Aspetix tandem disinfection performance chart.

CONCLUSIONS

Given that conventional disinfection methods have inherent limitations that may be overcome through the use of a UVGI disinfection system. Strong evidence now exists that the level of terminal disinfection of clinical areas used by patients with pathogens associated with transmission from the environment should be increased in order to prevent environment-borne transmission between patients, and it is in this situation where new automated UVGI technology are most strongly indicated.
There are now clear evidences that automated UVGI technology is an effective adjunct to conventional methods of terminal disinfection, and that it can reduce transmission in endemic and epidemic settings. Just like it did so well for drinking water around the world in the last 30 years, it is likely that UVGI technology will become a cornerstone to raise the level of hospital infection control in the near future.

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