Recent Advances in the UV Disinfection of Healthcare Facilities

By Brian Tande, PhD

The use of ultraviolet disinfection to combat healthcare associated infections has expanded significantly over the past several years. According to manufacturers' estimates, there are now over 600 portable UV disinfection units in use in the US and internationally. Their use is supported by a growing body of research demonstrating the effectiveness of these systems in disinfecting healthcare surfaces. The results of these studies are encouraging, though they are not entirely surprising when you consider that UV has been used successfully for decades for water, air, and surface disinfection.

Despite this long history, the use of portable UV systems in healthcare facilities is still relatively new and our understanding of its effectiveness is evolving. In many ways, a hospital room is a complicated environment and, because it differs greatly from other UV applications, it does present some unique challenges. Fortunately, much has been learned since the inception of portable UV systems, and users of these devices are beginning to educate themselves about ways to maximize their effectiveness. The purpose of this whitepaper is to provide infection preventionists and other hospital staff with the latest information about how to most effectively deploy UV disinfection systems in a healthcare setting. We'll start with some background information about how light behaves within a hospital room.

What happens to UV light in a hospital room?

A typical hospital room is filled with numerous objects- a bed, furniture, equipment, etc. These objects have complex shapes and are made up of a variety of different materials, such as plastic, wood, glass, fabrics, etc. The size and shape of the room as well as the type and location of the objects in the room all affect how the UV light gets dispersed, which in turn determines how completely the room is disinfected.

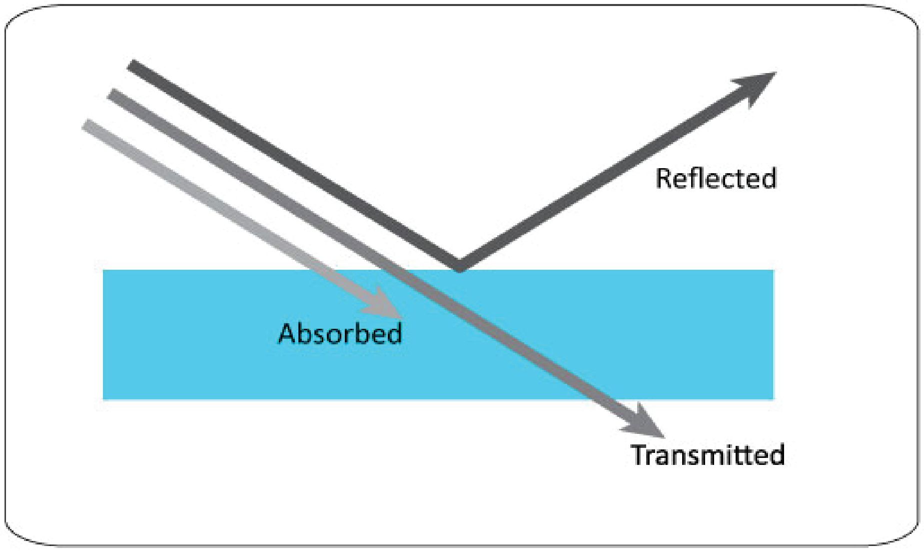

Figure 1. UV light is absorbed, transmitted, or reflected by surfaces.

When light hits a solid object, it can be absorbed, transmitted, or reflected (Figure 1). For most materials, a combination of these three phenomena occurs, and it can depend heavily on the wavelength of the light. In the case of germicidal UV, the vast majority of materials are strongly absorbing. For example, materials like white plastic, which reflects visible light and therefore looks bright to our eyes, will typically absorb greater than 95% of the UV, reflecting very little. This is true of most of the surfaces you will find in a typical room, including paint, vinyl wall coverings, or wood. Glass is another common material and also has interesting properties. While it transmits visible light, which is why we can see through it, it will strongly absorb short-wavelength UV. Metal surfaces often reflect UV, but how strongly they reflect depends on the type of metal and the degree of surface polish.

Because of the prevalence of UV-absorbing materials in a hospital room, almost all of the light that leaves a UV disinfection lamp will be absorbed by the first object it hits. This means there is very little reflected light bouncing around a typical room. Since the laws of physics tell us that light can only travel in a straight line, all hospital rooms will have some surfaces that are shadowed, occluded, obscured, or otherwise do not see the full intensity of UV light from the device. As a result, the effectiveness of UV disinfection is reduced and microbes may remain viable on those surfaces, ready to infect another patient or healthcare worker.

This is a challenge common to all UV disinfection devices, regardless of the type of light source or the presence of light sensors. Effectiveness data provided by device manufacturers usually includes log-reduction measurements for test samples placed in direct line of sight of the device. And, unfortunately, this is the data often used to determine the cycle time of the device. The actual dose received by a shadowed or occluded surface can be lower by a factor of a hundred or even a thousand. Surfaces that are not directly exposed to the lamp, such as on the back of the headboard or a bed rail, receive significantly less UV light, often much less than an adequate dose.

The strong absorbance of UV by materials in hospital rooms creates another critical disadvantage. The intensity of a UV device is limited by the electrical power available to it by a standard wall outlet. Most devices are designed to try to make full use of this power and maximize the lamp wattage. However, when over 95% of the light is absorbed by the first object it hits, much of that light is effectively being wasted.

Maximizing the effectiveness of UV

While we are restrained by the laws of physics, we can use our knowledge of it to find ways to dramatically improve UV disinfection in healthcare environments. We'll highlight two recent developments that help healthcare facilities make the most out of their UV devices. The first is the invention of UV-reflective coatings. The second is the development of a computer simulation tool that allows for the prediction of UV intensity throughout a hospital room.

UV-Reflective Coatings

Recently, Lumacept, Inc. introduced coatings that strongly reflect germicidal UV light. These coatings look and act just like traditional wall or ceiling paint, but rather than absorb almost all of the UV light, they reflect most of it. By better dispersing UV light, surfaces that would otherwise be in shadow can receive over 14 times more UV (Figure 2). The benefits of this have been demonstrated by several recent peer-reviewed studies. What an infection preventionist can expect to gain depends on the type of device being used.

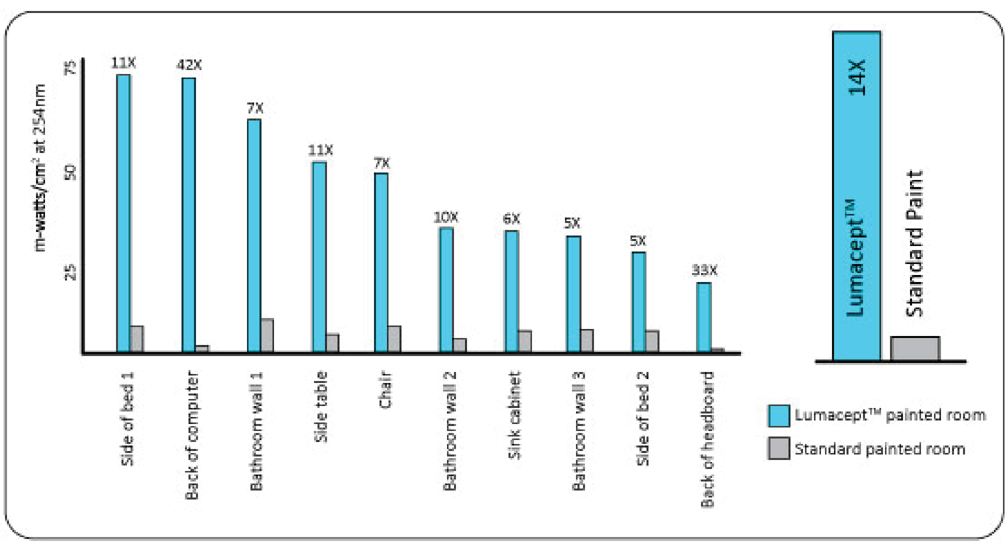

Figure 2. Measurements of UV intensity were taken on various indirect surfaces throughout a hospital room, both with and without the use of Lumacept UV-reflective coatings.

Sensor-based devices. Some UV disinfection devices are designed to use UV sensors to measure the amount of light reflected back to the device. These measurements are taken in several directions and are used to determine the cycle time of the device. Lumacept UV-reflective coatings were tested with one such device and the results were published in *Infection Control and Hospital Epidemiology*.[1] It was determined that the use of reflective coatings reduced the cycle time of the device by 80%. For example, during a cycle used to disinfect MRSA, Lumacept coatings reduced the cycle time from 25 minutes to 5 minutes (Figure 3). MRSA samples were placed in 10 locations throughout the room so that the disinfection effectiveness could be determined. Despite the room being illuminated for 80% less time, there was no loss of overall effectiveness. The C. diff. results were similar: the cycle time was reduced from 44 minutes to 9 minutes, also with no loss of effectiveness.

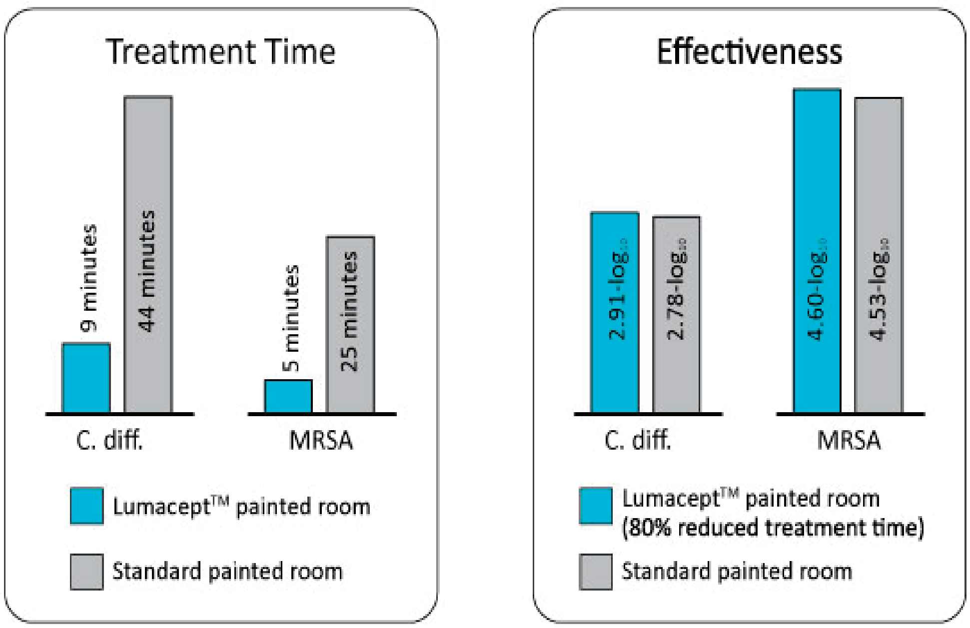

Figure 3. Results from a study of Lumacept UV-reflective coatings using a sensor-based device, showing an 80% reduction in treatment time with the same effectiveness.

Fixed-cycle devices. Other UV devices operate using a fixed cycle time. Based on the dimensions and layout of the room, the manufacturer will make a treatment suggestion, though they are often based purely on data from directly-illuminated surfaces. One fixed-cycle device was recently studied in a hospital setting both with and without Lumacept UV-reflective coatings. The cycle time was held constant at 5 minutes during the MRSA trials and at 10 minutes during the C. diff. trials. As reported in *Infection Control and Hospital Epidemiology* [2], the use of UV-reflective coatings significantly improved the performance of the device (Figure 4.)

1 Rutala, W.A., Gergen, M.F., Tande, B.M., Weber, D.J. Rapid hospital room decontamination using ultraviolet (UV) light with a nanostructured UV-reflective wall coating (2013) Infection Control and Hospital Epidemiology, 34 (5 SPL), pp. 527-529.

2 Rutala, W.A., Gergen, M.F., Tande, B.M., Weber, D.J. Room decontamination using an ultraviolet-C device with short ultraviolet exposure time (2014) Infection Control and Hospital Epidemiology, 35 (8), pp. 1070-1072.

This improvement was most pronounced on surfaces that would normally be shadowed.   For example, Lumacept helped increase the log-reduction for all surfaces from 3.56 to 4.50 for MRSA, but for indirect (shadowed) surfaces the improvement was even greater: from 2.74 to 4.21.

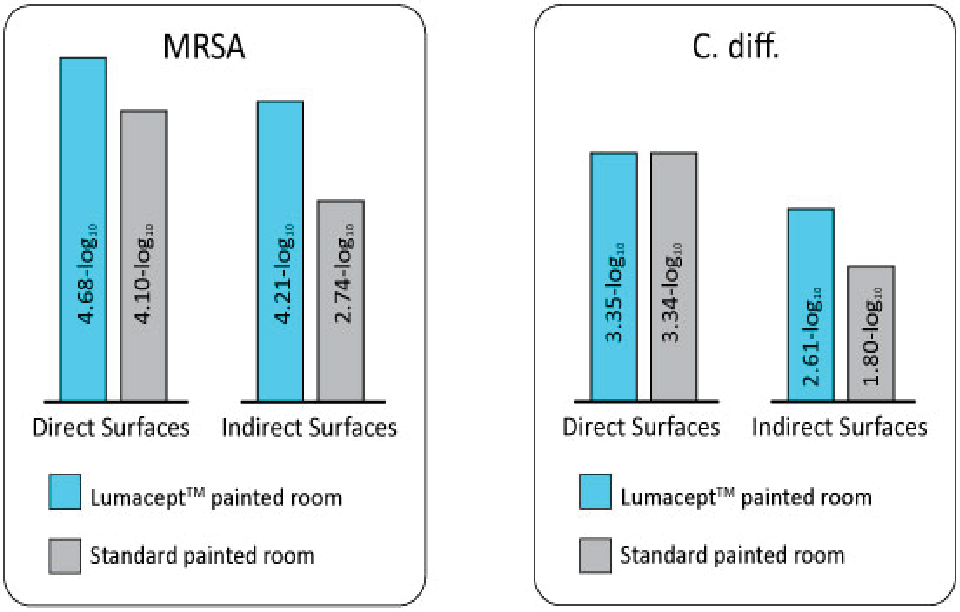

Figure 4. Results from a study of Lumacept UV-reflective coatings using a fixed-cycle device. These results show a significant improvement in log-reduction, especially for those areas not directly illuminated by the device.

So, depending on how a particular device operates, the benefits of Lumacept include a dramatically reduced cycle time, or a significant improvement in log reduction, especially for surfaces not directly illuminated by the device.

UV Simulations

Because UV light is invisible to humans, it's simply not possible for us to see where the light is hitting and where it is not. However, scientific measurements tell us that the UV received by a hospital room surface varies greatly based on the location and orientation of the surface. It is also strongly dependent on the location of the device. For these reasons it is difficult to know exactly where a device should be located and how long it should be run in order to achieve the greatest disinfection in the shortest total time. Unfortunately, generic recommendations from device manufacturers often fall short of this goal, as they cannot possibly account for all the variations in size, shape, and layout.

To optimize a treatment protocol for a room, one approach would be to measure the UV dose on many surfaces, and to repeat those measurements with different device locations. While this is certainly possible, it is a tedious process and is not practical to do for every room in a hospital. This is why Lumacept has developed a computer simulation tool that is capable of predicting the UV dose on any surface of a three-dimensional space. This tool, called LumaSim, is based on modern computer graphics techniques that have been modified to provide quantitative predictions of UV intensity. The accuracy of these predictions was demonstrated in a poster presented at APIC 2014.[3]

The benefit of LumaSim is that it allows a healthcare facility to truly understand, for the first time, which areas of a room are receiving a target dose and which are not. This can help infection preventionists know which areas may not be disinfected and, therefore, need more attention during manual cleaning. Further, it can be used to optimize a disinfection protocol to find the proper balance between maximizing treatment effectiveness and minimizing treatment time.

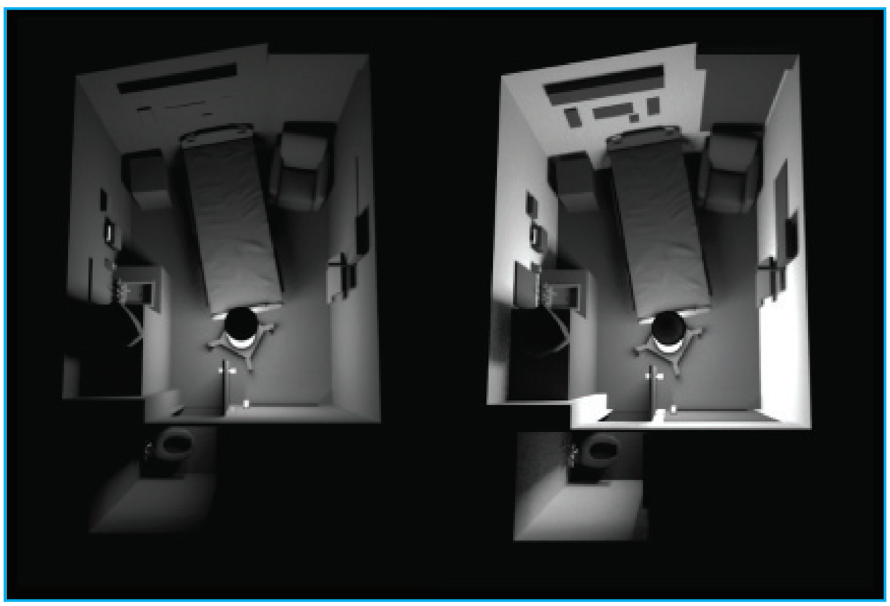

Figure 5. Images from a LumaSim 3D model showing the relative level of UV intensity in a typical hospital room. The room on the left has standard wall paint while the room on the right has UV-reflective paint.

Figure 5 demonstrates some of the capabilities of LumaSim. Here a 3D model of a room has been constructed and a UV device has been placed inside the room. The reflective properties of the material in the room can be adjusted. The image on the left shows the room with standard, UV-absorbing wall paint, while the image on the right is the same room painted with Lumacept on the walls. These images demonstrate qualitatively what areas the UV light is illuminating and what areas remain shadowed. From the software, quantitative values can be obtained and converted into measurements of UV irradiance. Because the simulation is fast, many of these “virtual experiments” can be run with the device in different locations. The results are then used to determine where and for how long the device should be run. Such a rigorous optimization is not practical to do without the help of computer simulations.

3 Tande, B.M., Rutala, W., Guerrero, D.M., Carson, P, Designing Healthcare Facilities to Maximize the Effectiveness of UV Disinfection, Association for Professionals in Infection Control and Epidemiology, 2014 Conference and Exposition, Anaheim, CA June 7-9, 2014.

Conclusions

As the adoption of UV disinfection continue to grow, so does the body of research into how to best use this technology. Here we have highlighted two recent advances: UV-reflective coatings and predictive computer simulations. Together, these developments allow a healthcare facility to get the maximum return on their investment in a UV device.

Lumacept, Inc. is a technology company dedicated to improving ultraviolet disinfection. We work with healthcare facilities to help them get the most out of their UV devices. Our novel coatings technology strongly reflects UV, which improves results by reducing treatment times and eliminating shadows. Our LumaSim computer simulation tool is used by hospitals to design care units and make UV disinfection protocols more effective. For more information, please visit www.lumacept.com.