Fact vs. Fiction:
Clarifying Myths Regarding UV Room Disinfection

UVDI™

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Introduction

The emphasis and need for ultraviolet (UV) disinfection continues to grow in order to help prevent Healthcare-associated Infections (HAIs) and to combat the ongoing pandemic. Yet, despite its widespread implementation as an effective disinfection step, UV technology remains a complicated topic and a potential source of confusion for Healthcare professionals. This is, in part, due to the vast proliferation and marketing of UV devices with different designs, capabilities, and price points. Compounding this confusion is the lack of established industry standards for characterizing or certifying UV devices. This has contributed to false or misleading claims about the effectiveness and safety of UV devices offered in the market today.

This article distinguishes the 10 most common facts from fiction regarding UV room disinfection technology. In doing so, the article seeks to provide Healthcare professionals with a trusted reference source to aid safe and effective Infection Prevention practices. The following content will (1) identify common misperceptions regarding UV technology, device effectiveness and operational safety (2) clarify these misperceptions and (3) ultimately, inform the assessment, selection and successful implementation of UV room disinfection. The need for UV disinfection is expected to continue to grow and so, the imperative to distinguish Facts vs. Fiction is as firm as ever.

Overview | Ten Common Misperceptions and Questions About UV Technology

1. Do all UV wavelengths have the same germicidal efficacy?
2. Does all UV have the same broad spectrum efficacy to inactivate bacteria, viruses and fungi?
3. Are all UV devices equally effective?
4. As UV technology is well-established, is it necessary to have clinical evidence validating specific UV device performance?
5. Are UV room disinfection devices effective in reducing HAIs?
6. Do both single placement and multi-placement UV devices have the same effectiveness?
7. Is manual cleaning and disinfection needed if I use UV?
8. How long do UV device lamps actually last?
9. Doesn't UV light damage and degrade key healthcare equipment and materials?
10. Do UV room disinfection devices subject healthcare personnel and patients to harmful exposure?

Question 1 | Do all UV wavelengths have the same germicidal efficacy?

All UV wavelengths do not have the same germicidal efficacy. In fact, most microorganisms exhibit peak UV absorption around 265 nm wavelength, which results in maximum damage via inactivation of cell DNA.

The ultraviolet spectrum is a band of electromagnetic radiation at higher energies than visible light, split into four major categories: UV-A (315 - 400 nm), UV-B (280 - 315 nm), UV-C (200 - 280 nm), and vacuum UV (VUV, 100 - 200 nm). UV-C light in the 200 - 280 nm range has been proven to be the most germicidal in nature and has been used for microorganism disinfection for over a century, with applications in water, air, and surface treatment. UV-B and UV-A has shown significantly lower effectiveness (1000 times less) compared to UV-C wavelengths and is also more harmful to human skin and eyes. Blue light (405-420 nm) has shown some effect on bacteria only but is slower in nature.

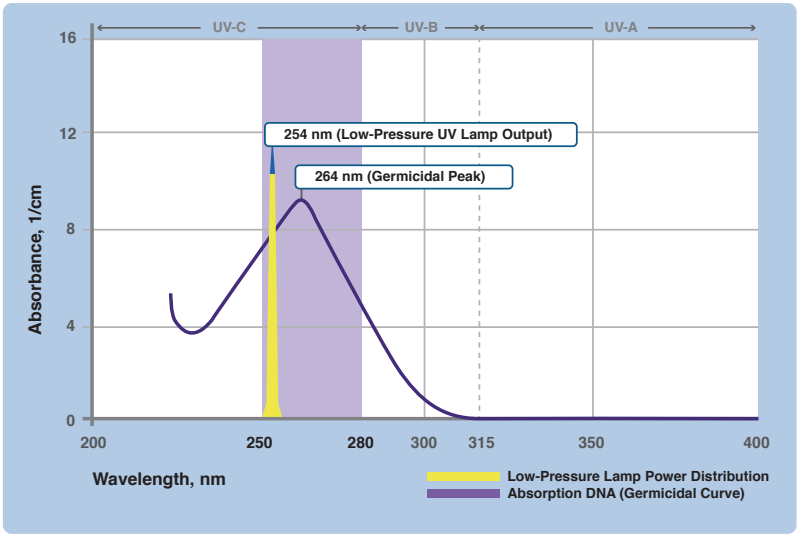

Figure 1. UV Wavelength and DNA Absorption Curve

In addition to having higher energy compared to other UV wavelengths, the main advantage of UV-C light is that the DNA and RNA of most microorganisms have a preferential absorption within these wavelengths and exhibit a peak around 265 nm. Low pressure mercury lamps emit almost all their spectral output at 254 nm, which is close to this absorption peak and therefore enjoy the most widespread use in all UV disinfection applications worldwide. At this wavelength, pyrimidine dimerization, the primary mechanism for microorganism inactivation by UV-C light, occurs. The formation of pyrimidine dimers leads to changes to the double helix structure, cell mutation and ultimately to the death of the cell.

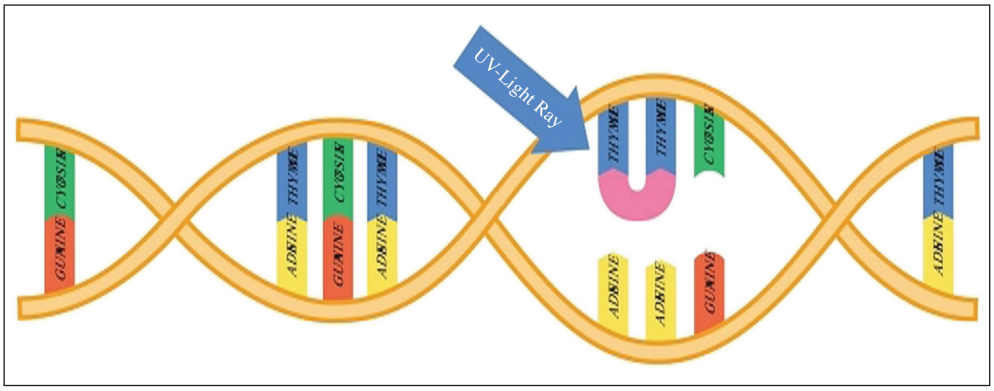

Figure 2. UV-C Inactivation Mechanism of DNA

Question 2 | Does all UV have the same broad spectrum efficacy to inactivate bacteria, viruses and fungi?

Ultraviolet germicidal irradiation for surface disinfection has been demonstrated to be highly effective at eliminating both vegetative microorganisms, including Methicillin-resistant *Staphylococcus aureus* (MRSA), Vancomycin-Resistant *Enterococcus faecium* (VRE), carbapenem-resistant *Enterobacteriaceae* (CRE) and *Acinetobacter baumannii*, spores, such as *C. difficile spores* and *fungi* such as *Candida auris* (Rutala, 2014, Maragakis, 2016, Donskey 2018). While the DNA structure of most microorganisms is damaged by UV-C light, their susceptibility is affected by their unique shape, cell structure and cell chemistry. In general, viruses are the easiest to inactivate compared to vegetative bacteria, spores and fungi – all of which require much higher UV energy (Kowalski, 2009). Therefore, coronaviruses are more readily killed by disinfectants than specific, high-risk microorganisms including MRSA, *C. difficile* spores or

Candida species, all of which are harder to kill and requires a much higher UV-C dose.

Thus, it is the required UV dose to inactivate a microorganism which forms the basis of design and application for all UV systems — and, as such, varies from device to device. It is important to note that the ability to emit a dose in itself is not sufficient to support efficacy claims against specific microorganisms; rather, it is critical for any device to have demonstrated the ability to apply that dose to inactivate microorganisms in independent laboratory testing as well as in published clinical studies. Therefore, it is essential for Healthcare professionals to evaluate individual UV manufacturer's independently generated evidence supporting individual device efficacy against specific microorganisms.

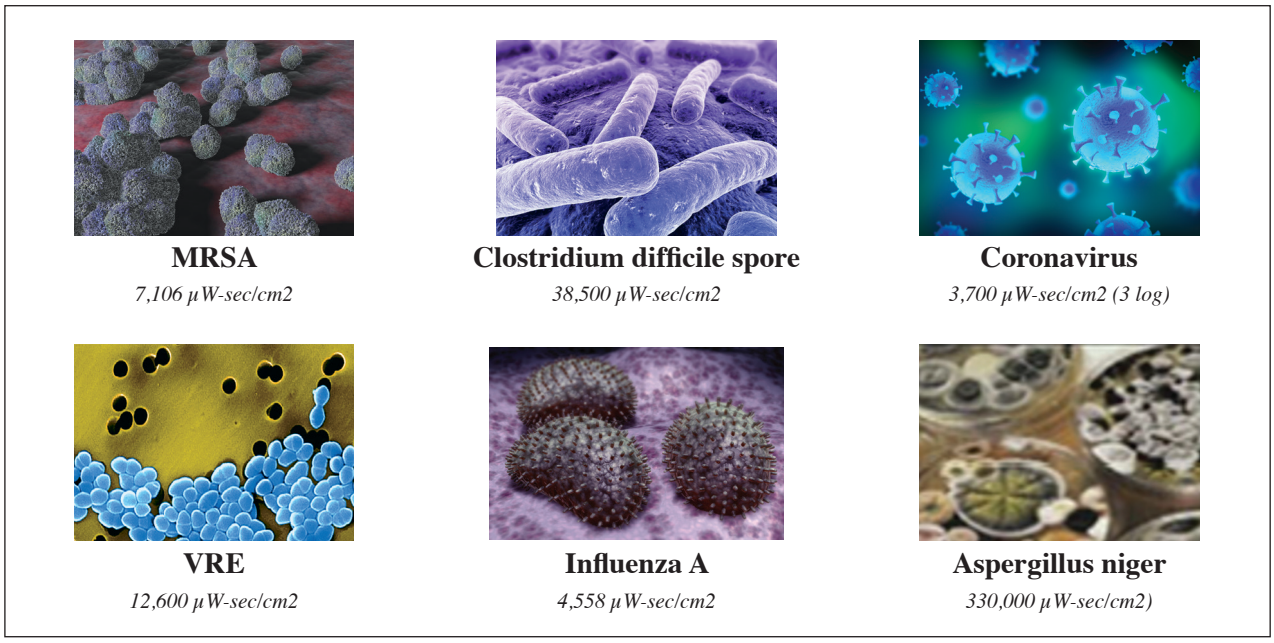

Figure 3. UV Dose Values Required to Inactivate Specific Microorganisms

Question 3 | Are all UV devices equally effective?

In a word, no. The proliferation of UV devices has exponentially expanded the number and type of microorganism efficacy claims made by many manufacturers. Devices come in various shapes, sizes and output power, and therefore their ability to deliver an effective dose can vary from one device to another. The true efficacy of a UV device primarily depends on the form factor, lamp type and wavelength, lamp configuration and output and other design features such as reflectors etc. Compounding the issue are several factors: the large discrepancy in the number of UV emitters required to run simultaneously, single or multiple placement criteria and the treatment times required by manufacturers to disinfect a typical patient room.

Because of this, and due to limited data on the UV dose requirements for different microorganisms and lack of industry standards, individual UV device efficacy claims from manufacturers should be scrutinized carefully. It is important to assess the specific evidence provided by device manufacturers to support the performance claims of their devices, such as the microbiological efficacy testing, the scope and type of studies performed in a laboratory or clinical setting.

Beyond a thorough understanding and assessment of device efficacy claims, it is key to examine the many other device features which contribute to overall performance, including Performance, Safety, Workflow for use and Maintenance requirements.

Question 4 | As UV technology is well-established, is it necessary to have clinical evidence validating specific UV device performance?

Given the aforementioned lack of industry standards to provide a common basis of support for UV device claims, it is essential to verify individual device performance claims via independent testing and clinical evidence. A valid inactivation claim should include details of the protocol used for the testing, including the exposure time used, distance of the device from the test microorganism and orientation of the UV-C device from the test microorganism. In addition, clinical studies should be reviewed to ensure the testing methodology is consistent with the device's specific usage protocols in actual hospital settings.

Efficacy claims can be supported by independent, accredited laboratory testing results and/or internal testing, often cited as 'data on file'. A third common, yet less rigorous practice is when manufacturers cite other companies' results or results from the clinical study literature in support of their own device.

Specific examples of efficacy claims can include:
- 99.99% inactivation of SARS-CoV-2 in 5 minutes at 12 feet distance
- 99.99% inactivation of SARS-CoV-2 at a distance of 14 feet
- 99.99% inactivation of SARS-CoV-2 in 2 minutes
- Disinfects SARS-CoV-2

Peer-reviewed clinical studies for individual UV devices represent the highest level of rigor for efficacy data and should be used for benchmark evaluation. There are multiple types of peer-reviewed clinical studies; The most common types that can provide evidence of UV device effectiveness are: (1) HAI-reduction studies (2) efficacy in a clinical setting and (3) environmental bioburden reduction study. It is essential for Healthcare Professionals to seek out independently conducted, published clinical studies in addition to independent testing.

Question #5 | Are UV room disinfection devices effective in reducing HAIs?

Clinical studies have indeed proven that select UV disinfection devices can help reduce HAI rates.

HAI reduction studies represent the most significant impact on patient outcomes that a UV device can make, and accordingly require the most rigorous and lengthy study design. It is incumbent on infection preventionists to perform due diligence by reviewing the strength of HAI studies conducted for the devices under evaluation. Randomized and crossover study designs have proven to be most effective and meaningful in assessing the impact of the UV intervention. Two luminary HAI reduction studies involving UV-C devices are Dr. David Pegues' study at the Hospital of the University of Pennsylvania (Pegues, 2016) and the multi-state BETR-D study, conducted by the Duke Infection Control Outreach Network (DICON) and led by Dr. Deverick Anderson (Anderson, 2017).

In Dr. Pegues' study, the objective was to evaluate the impact of no-touch terminal room disinfection using a 254 nm UV-C whole room disinfecting device on *C. difficile* infection (CDI) rates in three hematology-oncology units. The study design was an interrupted time series with a comparison arm involving a 12-month baseline period followed by a 12-month UV intervention period. The study results showed a decline of the CDI rate by 25% on study units but an increase of 16% on non-study units as a positive result of the UV intervention.

The *Benefits of Enhanced Terminal-Room Disinfection* study, or BETR-D study, examined UV-C disinfection and its effect on epidemiologically important microorganisms. The study was conducted across nine hospitals over 28 months and showed a 30% reduction in the incidence of MDROs.

An exhaustive review and ranking of published UV-C-related HAI studies has been conducted by employing a quality

assessment criterion which included representativeness such as study population, inclusion and exclusion criteria, potential for bias, description of intervention, continuous monitoring, outcome assessment and rigor of statistical analysis (Marra 2017). The analysis showed that when all the studies were pooled, an average reduction of 36% in *C. difficile* infection rates and 58% reduction in VRE infection rates were achieved. This is strong evidence supporting the effectiveness of UV in reducing HAI rates.

Question #6 | Do both single placement and multi-placement UV devices have the same effectiveness?

The fact is that both single placement and multi-placement UV devices may be equally effective as long as the sufficient dose has been delivered to all the target surfaces. The total dose delivered to a target surface is a function of the UV intensity reaching the target area multiplied by the exposure time.

The intensity of UV irradiance is inversely proportional to the square of the distance between the UV lamp and the exposed surface, based on the "inverse square law," i.e., a surface at twice the distance from the UV device will receive only one-fourth of the intensity. The applied dose can therefore be increased by bringing the device closer to increase the intensity and/or by increasing the exposure time. One practical implication of the marked effect of distance on UV intensity is that short cycles of only a few minutes may be sufficient for devices that are placed in close proximity to the target surfaces and objects, whereas longer cycles may be required when the UV device is further away from target surfaces and objects.

It is important to note that UV-C operates by line-of-sight; it kills only what it can see. Surfaces which are "shadowed" from the UV-C light or receive indirect UV-C light from reflected walls and other objects in the room would require longer times to attain the target dose from the UV device. Walls, floors and ceilings are poor reflectors of UV (typically less than 10% reflective) and do not contribute much to the overall dose received by an object.

Important variables affecting the dose delivered to surfaces and the resulting log reductions of microorganisms include the amount of irradiance generated by the UV lamp(s), exposure (cycle) time, distance from the lamp to the exposed surface, the angle at which the UV strikes the surface and whether the surface is in direct line sight of the lamp or receives light that has been reflected off other objects (surfaces in shadowed areas).

While single placement protocols may be acceptable for small rooms or rooms with minimal obstructions or shadowed areas, studies have shown that multiple placements can result in better overall room coverage at shorter treatment times (Rutala, 2016). For either type, ensure that the manufacturer provides technology confirming a sufficient dose has been delivered to all target surfaces.

Last, while it is indeed true that both single and multi-placement devices can be effective, it is key to examine the practical conditions in which an individual device can reach peak effectiveness and whether those conditions integrate with existing workflow and operations. These conditions include the duration of room treatment times and the labor required to set-up and operate the devices.

Question #7 | Is manual cleaning and disinfection needed if I use UV?

UV disinfection is recommended as a complement to manual cleaning and disinfection. UV is a short wavelength and cannot penetrate through dirt and heavy soiling and liquids, while chemical disinfectants allow better cleaning in these situations. Manual cleaning is also useful for areas which are shadowed from the UV light. However, it has been well-documented that manual cleaning and disinfecting has limitations, with studies demonstrating only 30-50% of targeted surfaces are actually cleaned due to product and protocol breakdowns (Carling, 2008). This heightens the need for UV

disinfection to provide an extra layer of enhanced protection as an adjunct practice to manual (chemical) cleaning and disinfection.

Question #8 | How long do UV device lamps actually last?

A further area where UV device claims vary is the claimed useful life of the UV-C lamps themselves. Many UV manufacturers claim the maximum 'rated' lamp life span provided by the UV-C lamp supplier. This span reflects how long a lamp would maintain its effectiveness if it were to be switched on one time and not turned off for continuous 24/7 use. However, the application of these lamps for whole room disinfection is very different, as the lamps are not used continuously, but are subject to frequent on/off cycling conditions for different time periods. Frequent on/off cycling will wear the lamp filament over time, and therefore the useful lamp life will below the manufacturer's maximum rating. Taking this into account and with the advent of alternate UV-C light sources, it is recommended to consult the UV device manufacturer for data supporting their claims regarding the life of their lamps.

Question #9 | Does UV light damage and degrade key healthcare equipment and materials?

Testing has indicated UV-C devices will not damage hospital surfaces and equipment. Multiple factors contribute to these findings. UV-C is a short wavelength and does not penetrate deep into surfaces to cause any material damage. It is possible that surfaces changes might occur and if so, are generally cosmetic in nature, similar to normal fading over time. Such changes will not impact the function of the equipment or surface. However, repeated prolonged exposure associated with longer cycle times required by some UV devices can lead to some surface damage and should be monitored.

Question #10 | Do UV disinfection devices subject healthcare personnel and patients to harmful exposure?

UV-C devices can be safely implemented when used according to manufacturer instructions. Exposure to UV-C light above NIOSH exposure limits can cause temporary skin and eye discomfort, therefore UV-C room disinfection devices should only be used in unoccupied rooms. Possible exposure exceeding the exposure limits can be prevented by using proper personal protective equipment (PPE) to cover eyes and skin. Conversely, UV-C does not penetrate through ordinary glass, so viewers behind a window are protected.

All UV-C devices should be certified to meet the appropriate UL and NIOSH exposure limits electrical and human safety standards. In addition, devices should have proven safety features such as: appropriate built-in UV safety sensors for automatic shutoff when they detect human presence, door warning signs, remote operation capability, easy device maneuverability and lamps that are encapsulated in protective sleeves to prevent harm in the event of bulb breakage.

Summary and Recommendations

UV devices are not all the same and, as such, do not have the same performance, efficacy and safety. UV devices which have been evaluated closely using the proper vetting criteria can play a key role in reducing a healthcare facility's infection rates and enhancing the safety of patients and hospital workers. While assessment and selection does entail a rigorous amount of diligence into both device and manufacturer, this process does not need to be daunting if the right questions are asked and appropriate claims support sought. Select UV room disinfection devices have been proven to reduce HAIs in published, clinical studies and are equipped with necessary safety features for everyday use.

In closing, the most important criteria to consider for successful device selection and implementation should include the following:

Independently Proven Effectiveness

The device efficacy should be backed by scientific evidence in inactivating various MDROs and reducing HAI rates.

UV Dose Confirmation

Proven technology confirming a sufficient germicidal UV dose has reached any targeted surface.

User Safety Prioritized

Proven features to make the device easy and safe to operate, such as protected UV-C lamps, high-quality motion sensors and ease of mobility.

Operational Effectiveness

The device should be easy to set-up and operate to enable rapid room turnover and workflow integration for maximum utilization.

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