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Why Increased Surface Cleaning is Failing to Decrease HAI Rates

(A Design Science Approach to Reducing Hospital Acquired Infections)

- Albert M. Doolittle, Jr., SecCom Healthcare

Introduction

Design Science is a problem solving discipline introduced by Buckminster Fuller and has been adapted over the years to many diverse fields of study. As such, giving a succinct definition of Design Science is like the proverbial story of three blind men trying to describe an elephant by touch. Each defines an elephant based on where they touch and each description implies a completely different animal.

One key element of the Design Science is approaching today's problems from the perspective of a future 'Preferred State'- rather than looking forward from the present. The nuance of the two approaches is found within the solver's perspective. Traditional problem solving is constrained by present day thinking – kill all bacteria on surfaces. Design Science evaluates the present from the perspective of an ideal future – healthy people – and looks to the mechanisms of how people get sick.

Let's take the HAI problem as a case in point. Traditionally, HAIs are described as problems of surface contamination. Surfaces host HAI related pathogens so we clean/disinfect/sterilize them in order to eradicate the problem. If we find they still exist, we redouble our efforts. We zap whole rooms with high levels of UV-C radiation; we use stronger and harsher chemical disinfectants; we wash our hands more often; and of course we use more time and elbow grease in applying our solutions. This is a present day perspective because it focuses on the current problem – surface contamination - and seeks a solution for that problem. To do this, we produce, transport and use millions of liters of toxic chemicals, contaminate millions more liters of fresh water, waste paper and other materials and cause hospital costs to rise due to inefficient use of employees, rooms, and equipment.

There are flaws and limitations in present day solutions to surface contaminations. Terminal (Robot) UV-C room disinfection system requires time and an empty room. Wipes and chemicals have even greater issues. They require a specific amount of time for surfaces to remain wet; they are not effective for all pathogens, and they pose the risk for creating chemical resistant super-bugs. Hand washing programs have always been at the forefront of any HAI reduction program but the time and effort spent cleaning hands always competes with that time needed for patient care. In a 2012 paper, "*Nurse staffing, burnout linked to hospital infections*"[1], researchers found the stress of workloads can actually result in a reduction in hand washing and an increase in HAIs. As the article stated - "stress builds up and builds up and builds up until the giver of care just detaches ... all of a sudden they are doing work, but they are not even cognizant of what they are doing, they are so stressed". A dedicated staff can only get you so far. Pushed to burnout, staff morale and the quality of patient care will deteriorate.

The Problem

- HAI pathogens are for the most part spread by hospital service providers and employees – doctors, nurses, techs, food servers, and even cleaning staff as they move from room to room and patient to patient.

- Otherwise toxic disinfectant cleaners fail for reasons of either a HAI organism's resistance or insufficient application time. The burden from these failures is in the end, borne directly or indirectly by hard working employees.

- Employees find themselves stressed trying to balance time demands for cleaning against that needed to provide high quality patient care. Reducing job performance; reducing job satisfaction.

- The cycle of infection continues despite ever-growing expenditures to improve HAI reduction procedures and compliance. Hospitals are being financially incentivized yet at the same time finding themselves bearing more of the overall HAI costs as well as suffering penalties for insufficient improvements.

Intervention Point

Buckminster Fuller sought pathways to the Preferred State by finding intervention points (he called them trim-tabs) where maximum change could be achieved with minimum disruption of the status quo. It is not possible to kill all surface bacteria. What is needed is to find a specific, cost effective, point of intervention in the HAI cross contamination process that interrupts the transmission cycle (our trim-tab). This intervention point can be understood in much the same way used to establish the critical population percentage that must be vaccinated to prevent the spread of a disease. Here, inoculation blocks the ability for an infection to pass from one person to the other by creating population islands that are able to restrict transference by not providing a suitable number of people for a pathogen to survive and be passed on. In addition, inoculating a more vulnerable population eliminates the 'path of least resistance' and increases the effectiveness of vaccination programs.

Enter infection control. This same concept can be applied to HAI reduction. In this case we substitute our immune population islands for a more appropriate equivalent – a permanently, or at least continuously, disinfected surface. In a similar manner, we improve the effectiveness of our plan by concentrating our efforts on more 'vulnerable' high-touch surfaces. Our goal then is to find a way to create and maintain continuously disinfected surfaces.

High-Touch Surfaces

As we have defined Hospital Acquired Infections (HAI) as a problem of surfaces, let's look at surfaces. We touch a lot of surfaces when we work in a hospital environment; we touch a **lot** of surfaces. To make things worse we are generally working within groups of others that are also touching the same surfaces. Touch is such an automatic action that for the most part we don't think about the many surfaces we are touching and certainly don't keep track of the number of times we touch each one. "*A Quantitative Approach to Defining "High-Touch" Surfaces in Hospitals*"[2] sought to quantify the touch activity in an ICU by cataloging the different surfaces and the number of time they were touched during a typical interaction. The data is shown below in Figure 1.

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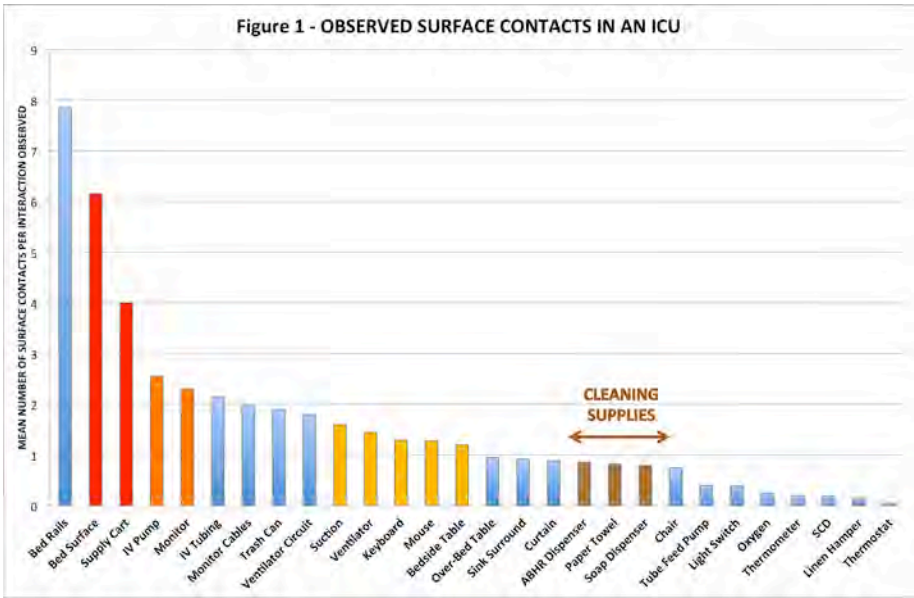

What immediately jumps out from the data is that many of the touched surfaces in an ICU are being touched 2 to 6 times more than the disinfecting supplies. This is not an indictment of clinicians or disinfection procedures, but merely bringing into focus the enormity of the job of keeping surfaces clean. It also offers yet another reason to suggest our ability to expand present day solutions has reached a wall.

Preferred State

Historically, HAIs have been considered a surface problem solved by killing pathogens resting on surfaces. While it is true that pathogens on surfaces (and hands) are the root cause of HAIs and comprehensive disinfection is a valid solution, contaminated surfaces are not the real cause of HAIs. Contaminated surfaces can exist all around a patient's room, or ICU, or for that matter, anywhere in a hospital. They do not become part of the HAI problem until they are touched. Touch is the problem!!! Touch is the actor that starts a chain reaction propagating cross-contaminations and eventually - HAIs.

Let's create a timeline for our hands touching surfaces. A typical cross-contamination timeline looks something like the illustration below. The surface is cleaned and relatively soon after, contaminated. From that moment on, it becomes the cross-contamination "initiator zero". As we know from the previous discussion, there is a good chance that many other surfaces will be touched after "initiator zero" before hands or surfaces are cleaned again. Disinfecting an "initiator zero" surface simply passes the "zero" label down to the next touched surface. It should be noted that in today's HAI surface-centric reduction strategies, hands and physical surfaces should both be considered surfaces for no other reason than the fact that they both bear pathogens and are cleaned at roughly the same frequency. The fact that hands are the agent of touch is lost in the long timelines. There is no acknowledgement of the quantity of individual touches; no acknowledgement of the multitude of surfaces being touched and that fact serves to disconnect the hand as an agent and make it as yet another surface.

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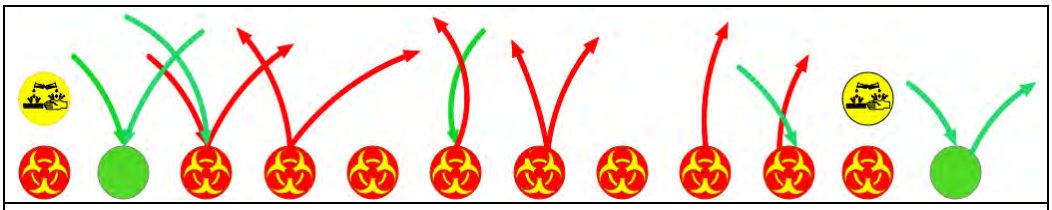


Surface-Centric Disinfection Timeline

Now go back to our intervention point. Below is a touch-centric disinfection timeline using our concept of creating un-safe harbors for pathogens by continuously disinfecting high-touch surfaces. Admittedly it is probably unrealistic to expect to disinfect a surface after each and every touch but keep in mind that the Preferred State **is** idealistic, optimistic.

In Fuller's case, he often sought a preferred future and found or created pragmatic, practical ways to achieve that future. Our preferred solution becomes one of disinfecting 'surfaces' after each touch but we too have to balance our solution between idealisms and pragmatism. In reality, a worst-case variation of our Preferred State timeline - disinfecting only at the initial and final touches - would be identical to our present day timeline shown above.

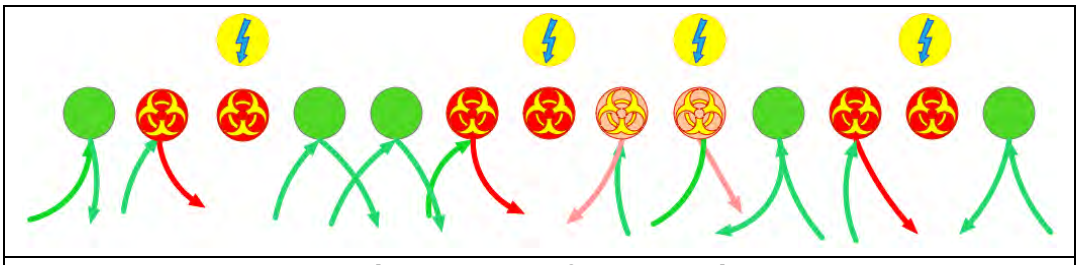
Looking at the touch-centric timeline below, one can see a pattern similar to the vaccination based disease prevention model. By increasing the rate of disinfection of high-touch surfaces, they approximate our idealized continuously clean surfaces. As usage patterns will restrict our ability to keep all surfaces clean, if a significant percentage can be maintained clean over longer periods of time, pathogens transferred by way of our "surface island' are significantly reduced.

It is important to note that neither of the above models considers the fact that multiple surfaces are involved - each with separate, distinct timelines. The presence of multiple surfaces is extremely significant to the efficacy of both models and will be discussed in detail later. Suffice it to say that multiple surfaces have a huge, positive impact on our touch-centric disinfection model.

Touch-Centricity

Practically speaking, surfaces are the physical core of both our Preferred and present day solutions but the difference is more than a nuance. Present day is the surface; Preferred State is the action of touching – noun versus verb. 'Present day' is initiated when a surface is considered dirty; 'Preferred' when a surface is touched.

Idealism aside, disinfecting a surface or hands after each touch is impractical but then again let me remind you that it is okay for our Preferred State solution to start off as unrealistic, impossible, or impractical. The task now at hand is to tweak the solution until it is practical and doable. In other words – we aim high and then compromise later.



Touch-Centric Disinfection Timeline

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From the above, we identified an effective intervention point needing to be 1) touch-centric, 2) able to continuously maintain a clean high-touch surface, 3) necessarily work in close proximity to healthcare workers, and 4) require little or no user interventions. (Let's add requiring no user training just to add a little more difficulty in finding our solution.)

UV Angel

Ted Cole used this same Preferred State approach when he created his touch-centric solution to HAIs - **UV Angel**. Briefly described, **UV Angel** is a "touch-centric, low-cost, automatic, continuous, and fast acting surface disinfecting system that safely coexists with staff members in an active work environment".

UV Angel combines a Passive Infrared Sensor (PIR) and low-power UV-C radiation source with a computerized microcontroller. Available mounts include generics for keyboards, mice, tablets, laptops, and touchscreens as well as custom mounts for specific healthcare related products.

Mounted near a surface to be protected, the PIR sits out of the way and monitors activity on and around the watched surface. Any detected activity is considered a signal that the surface has been possibly touched. The surface is then flagged as 'contaminated' and the **UV Angel** attempts to initiate a disinfection cycle. Sixty–seconds (60) (programmable) following the last detected motion, the **UV Angel's** UV lamp is turned on for 6 minutes (again programmable) to start a disinfection cycle. If motion is again detected during the disinfection cycle, the **UV Angel** suspends the cycle and turns off the lamp. This process will repeat until a full disinfection cycle has been completed. At the end of a completed cycle, the surface will be considered clean. As a prophylactic measure, if no activity is detected after an hour has elapsed, the **UV Angel** initiates a maintenance cycle.

UV Angel Effectiveness

Multiple studies have proven the disinfection efficacy of **UV Angel's** short exposure times. In Figure 2, the default setting of (6) six-minutes was sufficient for Staphylococcus epidermidis levels to reach the minimum standard pathogen count (1,000) necessary to declare a surface "sanitized". Similarly, Staphylococcus aureus required a (10) ten-minute timeframe and complete disinfection occurring within two disinfection cycles.[3][4]

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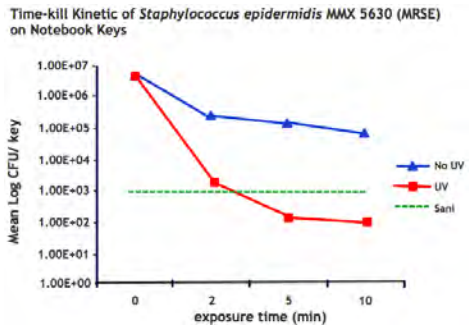

Figure 2

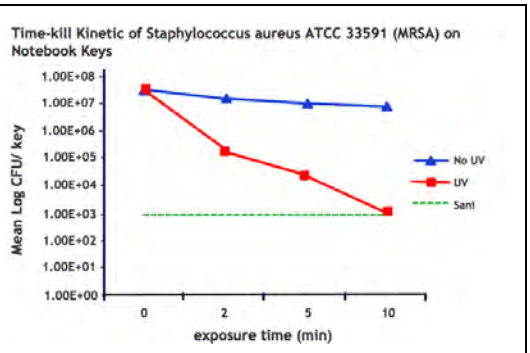

Figure 3

Clostridium difficile (CDiff) spores are problematic and barely controlled by chemical disinfectants and sanitizers. Figure 4 shows CDiff spore counts dropping to a "sanitized" level in approximately 7 minutes exposure with an effective kill after a (20) twenty-minute exposure. (Figure 4) Since the actual time needed is much longer than a typical **UV Angel** disinfection cycle, a follow-up experiment was conducted using (2) two 7.5-minute exposures separated by a (5) five-minute rest period. This latter experiment confirmed the ability of multiple disinfection cycles to destroy difficult to kill pathogens.(5)

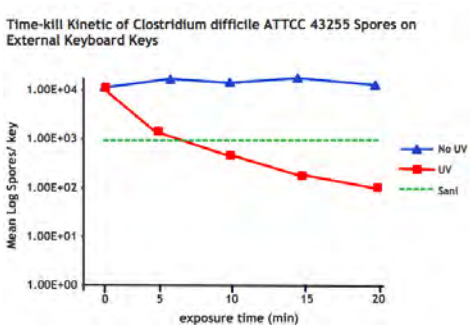

Figure 4

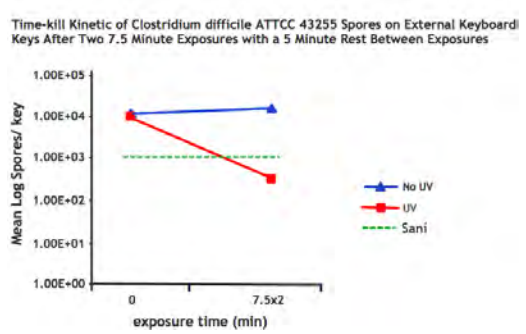

Figure 5

Earlier, it was stated **UV Angels** have a wide selection of mounts - running the gamut of commercial hospital healthcare products. Figure 6 identifies many of the surfaces having custom designed **UV Angel** mounts. However, the reason for this variety is more than just marketing. Touched in rapid succession, actively used surfaces will delay either the start or completion of their **UV Angel** disinfection cycle. This is actually not as a significant a problem as it would seem and the reason is easily explained using another science – Computer Science.

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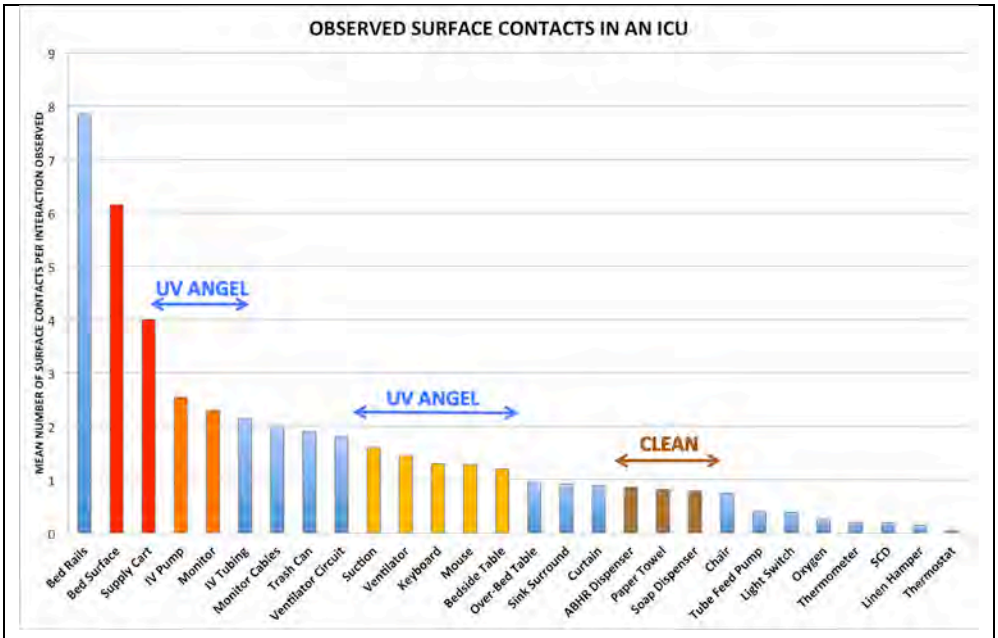

Figure 6

Multiple Angels on multiple surfaces are acting in a manner similar to parallel processors - each working separately, each having their own separate timeline and touch frequency. While a set of core high-touch surfaces may be slow to disinfect, peripheral surfaces – those not touched as often - will be more likely to stay in a disinfected state. A touch to these less used surfaces will quickly start a disinfection cycle and with fewer touches, complete that cycle and leaving a fully disinfected surface. The net effect is that a disinfected surface will always be present at any touch – contaminated or not. These less touched surfaces will have the potential for establishing a clean barrier around those surfaces more frequently touched. More importantly, these peripheral items are also more likely to already be in a disinfected state when leaving a patient's area - as opposed to being cleaned elsewhere or not at all.

Clinical Studies

Curtis Donskey, et al.[6] evaluated the UV angel in real-world conditions by placing UV Angels over 25 in-use keyboards. Steel plates contaminated with MRSA, carbapenem-resistant *Escherichia coli*, and *C difficile* spores were place on top of keyboards, 4 inches below UV Angels mounted at the top center of the keyboard.

Comparing cultures before and after activation, the UV Angel, Donskey reported – "As shown in Figure A, on steel disk carriers positioned on a key directly below the device, recovery of MRSA and NDM-1 *E coli* was reduced by >3 logs with a single 6-minute cycle, and further reduction was achieved with additional cycles. In contrast, 4 cycles of exposure (24 minutes total) were required to achieve >1 log reduction in *C difficile* spores. For MRSA, similar reductions were achieved when the carriers were placed on a key directly below the lamp versus 3 in lateral to the lamp. The reduction in MRSA was significantly reduced on carriers placed 9 in lateral to the lamp versus on the central key with 1 or 2 cycles of exposure, but not with 3 cycles (Fig B). Based on indicator strips and radiometric readings, there was no detectable UV-C penetration at 6 or 12 in distance lateral or anterior to the keyboard, above the bulb, or anterior to the bulb. As shown in Table 1, the UV-C device significantly reduced total aerobic bacterial counts on in-use keyboards. In addition, there was a significant reduction in recovery of potential pathogens after use of the device."

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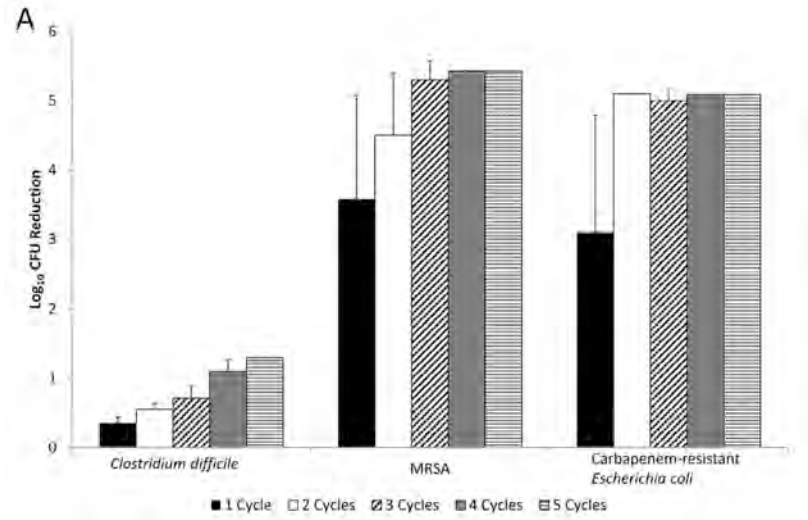
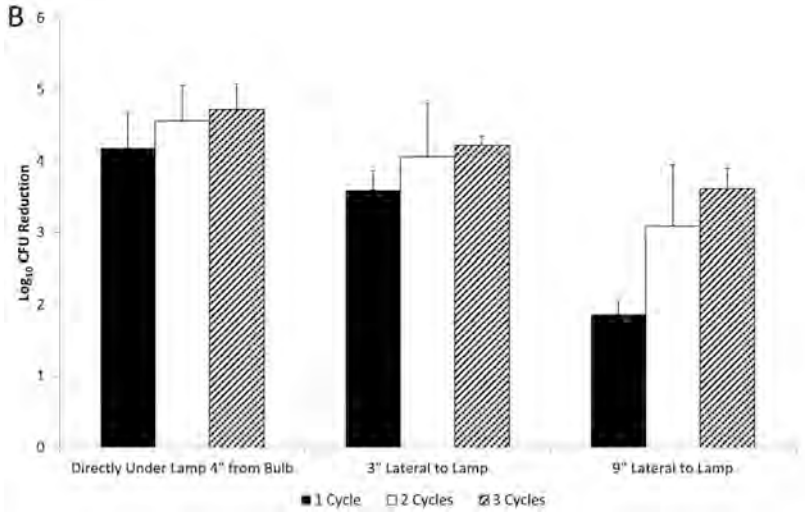


(A) Mean reduction (log_{10} CFU) in recovery of MRSA, New Delhi metallo-β-lactamase–producing, carbapenem-resistant *Escherichia coli*, and *Clostridium difficile* spores from steel carriers positioned on a computer keyboard directly below the UV Angel at a distance of 4 in from the ultraviolet-C decontamination device for 1, 2, 3, 4, or 5 six-minute cycles. [6]



(B) Mean reduction (log_{10} CFU) in recovery of MRSA from steel carriers positioned on a computer keyboard directly below the UV Angel ultraviolet-C decontamination device at a distance of 4 in from the bulb or 4 in below and 3 or 9 in lateral to the lamp for 1, 2, or 3 six-minute cycles. Error bars show SEM. *CFU*, colonyforming units; *MRSA*, methicillin-resistant *Staphylococcus aureus*.[6]

Since UV Angels are employed in an active work environment, further tests were conducted by Donskey to determine the levels of UV-C radiation energy both under and around the keyboard's periphery. The report noted "Because the device is intended to be used while personnel are in the same room, the potential for exposure of personnel to UV-C is a concern. Using UV-C indicator strips and a radiometric sensor, we did not find evidence that UV-C penetrated outside of the area immediately over the keyboard. In addition, the device consistently aborted UV-C cycles when movement into the area of the keyboard was detected."

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Conclusion

Direct surface sanitization has proven to be an effective method for controlling HAIs. However, refined protocols, or improved disinfectants will do little to overcome inherent limitations brought on by increased costs, increased demands on staff resources. There is evidence to suggest increasing these efforts could actually decrease their effectiveness in reducing HAIs.

UV Angel's touch-centric disinfection 'intervention point' approach to HAI reduction provides an opportunity to significantly reduce HAIs without encumbering the limitations of traditional reduction methods. **UV Angel** is a trailblazer for a new approach to reducing HAIs by disrupting the cross-contamination pathway while having a minimum impact on worker productivity and a huge impact on reducing HAI associated costs. **UV Angel's** touch-centric HAI reduction approach is a proven, low-cost, and safe adjunct to traditional programs and is available for implementation now.

References: (Available at http://www.seccomhealthcare.com)

[1] Jeannie Cimiotti (Lead Author) University of Pennsylvania School of Nursing, (August) *American Journal of Infection Control*

[2] Kirk Huslage, RN, BSN, MSPH; William A. Rutala, PhD, MPH; Emily Sickbert-Bennett, PhD; David J. Weber, MD, MPH, *Infection Control and Hospital Epidemiology*, the Journal of The Society for Healthcare Epidemiology of America (SHEA)

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[6] "Evaluation of a low-intensity ultraviolet-C radiation device for decontamination of computer keyboards"
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