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Journal of Hospital Infection

journal homepage: www.elsevierhealth.com/journals/jhin

Short report

First UK evaluation of an automated ultraviolet-C room decontamination device (Tru-D™)

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ARTICLE INFO

Article history:

Received 20 February 2013

Accepted 13 May 2013

Available online xxx

Keywords:

Decontamination

TRU-D

Ultraviolet-C (UV-C)

SUMMARY

Tru-D™ is an automated room disinfection device that uses ultraviolet-C radiation to kill micro-organisms. The device was deployed in six side-rooms and an operating theatre. **In a cleaned, unoccupied operating theatre, Tru-D eradicated all organisms from the environment.** Using artificially seeded Petri dishes with meticillin-resistant *Staphylococcus aureus*, multi-resistant acinetobacter and vancomycin-resistant enterococci, the mean log₁₀ reductions were between three and four when used at 22,000 µWs/cm² reflected dose. **The device was easy to transport and utilize, and able to disinfect rooms rapidly.** This appears to be a practical alternative technology to other 'no-touch' automated room disinfection systems.

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Introduction

The environment is increasingly recognized as an important reservoir for healthcare-associated infection (HCAI) pathogens especially meticillin-resistant *Staphylococcus aureus* (MRSA), multi-resistant acinetobacter (MRA) and vancomycin-resistant enterococci (VRE). Hand hygiene is of primary importance, but reducing the environmental load of these pathogens that can survive on critical touch points has also been shown to prevent cross-transmission and HCAI.¹ It is recognized that routine cleaning using manually applied chemical disinfectants is often suboptimal, particularly at touch points.² Hence, there is increasing interest in 'no-touch' automated room disinfection systems such as hydrogen peroxide systems and ultraviolet radiation.^{3,4}

Studies using ultraviolet-C (UV-C) radiation have established that a variety of bacteria including spore-forming organisms

can be killed through the destruction of DNA and RNA via pyrimidine dimerization.^{5,6} The Tru-D™ room disinfection device is a mobile, automated room disinfection device that uses UV-C irradiation to kill micro-organisms. This device has previously been reported to significantly reduce nosocomial pathogens in the healthcare environment such as MRSA, VRE and *Clostridium difficile*, making it an interesting potential alternative to systems such as vaporized hydrogen peroxide or dry-mist hydrogen peroxide for terminal disinfection of patient rooms.^{4,7} However, until recently this technology has not been available in the UK.

Methods

The Tru-D device was trialled in six side-rooms within an intensive therapy unit (ITU), an operating theatre and a ward isolation room (with an en-suite bathroom). Measurements were taken to calculate room volume and the time taken for disinfection was recorded at two settings: a reflected UV-C dose 12,000 µWs/cm² for vegetative bacteria, and a 'sporicidal' setting of 22,000 µWs/cm² as recommended by the manufacturer. **The device was placed in the middle of the room with furniture moved away from the walls to allow reflected**

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UV-C radiation to reach behind these items (Figure 1). The operator exited the room and activated the device using a handheld remote. A safety sensor was placed on the door triggering an immediate halt to the disinfection if the door was opened. UV-C does not penetrate normal glass windows and hence no other special precautions were necessary. The Tru-D device has eight sensors, located at equal distances in a ring formation at the top of the device, which measures the reflected UV-C from surfaces and walls of the room. **The device completes its disinfection cycle and automatically stops when all eight sensors have detected the threshold reflected UV-C dose.**

Efficacy of microbial killing

Direct contact plates

After routine cleaning in an operating theatre, tryptone soya agar (TSA) contact plates were applied to 15 touch surfaces on devices (anaesthetic machine, diathermy machine, stools, bins) and the floor, within areas in the direct line of sight of the Tru-D unit and those not directly in the line of site (shadow). TSA contact plates were then re-applied to surfaces directly adjacent to original sampling area at the end of the Tru-D disinfection cycle using reflected UV-C dose of $12,000 \mu\text{Ws}/\text{cm}^2$. The TSA contact plates were incubated aerobically at 37°C for 48 h and the total numbers of colony-forming units (cfu) before and after disinfection were counted.

Plastic Petri dishes seeded with multi-resistant clinical isolates

Suspensions containing clinical strains of MRSA, VRE, MRA and aspergillus were produced by inoculation into saline to McFarland 0.5–1 turbidity ($1.5\text{--}3.0 \times 10^8 \text{ cfu}/\text{mL}$). A sterile cotton-wool swab was used to spread a standard inoculum evenly on to plastic Petri dishes and allowed to desiccate. The inoculum used for each pathogen was adjusted so that approximately semiconfluent growth of each organism was recovered from the control plate. Seeded Petri dishes were then placed on surfaces (line of sight and shadow) and exposed to Tru-D at reflected UV-C doses of $12,000$ and $22,000 \mu\text{Ws}/\text{cm}^2$. Ten surfaces were selected in the operating theatre which

matched the direct contact plate locations, while six locations were selected in the ITU side-rooms which included the ventilator machine and infusion machine keypads, equipment trolley, chair and floor. Control Petri dishes were kept outside.

The TSA contact plates were incubated aerobically at 37°C for 48 h and the reduction in cfu (compared with the control) at each plate location was calculated. Mean reductions for each pathogen from all locations either in direct line of sight or shadow were expressed as both \log_{10} and percentage reductions.

Results

Ease of use and time for disinfection

Tru-D is a mobile device measuring about 2 m tall by 0.5 m wide, and can easily be transported by one individual. A slight odour was noticed upon entering the rooms following completion of the disinfection cycle but this quickly disappeared. It took on average 30–40 min to decontaminate single rooms at $12,000 \mu\text{Ws}/\text{cm}^2$ (for vegetative bacteria) and 60–90 min at the sporicidal setting ($22,000 \mu\text{Ws}/\text{cm}^2$) (Table I).

Microbial efficacy

Using direct contact plates, between 0 and 40 cfu/contact plate (median 10) were recovered from surfaces in the detergent-cleaned, unoccupied operating theatre. Following the use of the Tru-D unit (at $12,000 \mu\text{Ws}/\text{cm}^2$) no organisms were recovered from the environment.

Table II shows the mean \log_{10} and percentage reductions of MRSA, VRE, MRA and aspergillus from seeded Petri dishes. The device had the greatest efficacy in the line of sight and at the $22,000 \mu\text{Ws}/\text{cm}^2$ setting against all the pathogens (mean \log_{10} reduction: ≥ 4 ; 99.99% reduction). At the lower $12,000 \mu\text{Ws}/\text{cm}^2$ setting, this efficacy was maintained for MRA and MRSA but was slightly reduced for VRE (mean \log_{10} reduction: 3.5; 99.97% reduction).

At shaded locations the device demonstrated lower mean \log_{10} reductions for all the organisms at the $12,000 \mu\text{Ws}/\text{cm}^2$

Table I

Time taken for disinfection at two reflected ultraviolet-C doses in different rooms and an operating theatre

Site	Room size		Time taken (min)	
	Surface area (m^2)	Volume (m^3)	12,000 $\mu\text{Ws}/\text{cm}^2$	22,000 $\mu\text{Ws}/\text{cm}^2$
ITU Single Room A (1)	26	72	27	–
ITU Single Room A (2)	26	72	39	73
ITU Single Room B	29	80	31	–
ITU Single Room C	17	47	36	–
ITU Single Room D	21	59	32	–
ITU Single Room E	20	55	26	–
ITU Single Room F	22	59	–	93
Operating theatre	42	126	49	–
Stoke unit isolation room	16	39	–	60
Stroke unit ensuite bathroom	4	8	–	23

ITU, intensive therapy unit.



Figure 1. The Tru-D unit in operation.

Table II
Micro-organism reduction factors for seeded Petri dishes

Site	Organism	No. of locations sampled	Reflected UV-C dose ($\mu\text{Ws}/\text{cm}^2$)	Line of sight		Shadow ^a	
				Mean log ₁₀ reduction (% reduction)	Range	Mean log ₁₀ reduction (% reduction)	Range
Operating theatre	MRSA	5	12,000	≥ 4.0 (99.99%)	All ≥ 4.0	≥ 4.0 (99.99%)	All ≥ 4.0
	VRE	5	12,000	3.5 (99.97%)	2.8–4.0	2.4 (99.60%)	1.0–4.0
ITU single room	VRE	5	12,000	≥ 4.0 (99.99%)	All ≥ 4.0	2.3 (99.50%)	1.0–3.5
	VRE	5	22,000	≥ 4.0 (99.99%)	All ≥ 4.0	3.5 (99.97%)	2.5–4.0
	MRA	3	12,000	≥ 4.0 (99.99%)	All ≥ 4.0	1.7 (98.00%)	1.0–3.0
	MRA	3	22,000	≥ 4.0 (99.99%)	All ≥ 4.0	3.0 (99.90%)	2.0–4.0
	Aspergillus	3	12,000	≥ 4.0 (99.99%)	All ≥ 4.0	2.0 (99.00%)	1.0–3.0
	Aspergillus	3	22,000	≥ 4.0 (99.99%)	All ≥ 4.0	1.0 (90.00%)	1.0–1.0

MRSA, methicillin-resistant staphylococcus aureus; VRE, vancomycin-resistant enterococci; MRA, multi-resistant acinetobacter; UV-C, ultraviolet-C.

^a Not in the line of sight.

setting (Table II). The mean log₁₀ reductions ranged from 1.7 (98.00% reduction) for MRA to >4.0 (99.99% reduction). At the 22,000 $\mu\text{Ws}/\text{cm}^2$ setting, mean log₁₀ reductions increased for both VRE (3.5) and MRA (3.0).

Discussion

Although this study was a small trial of the Tru-D device, it demonstrated the capability to significantly reduce key healthcare nosocomial pathogens (MRSA, VRE, MRA) in the hospital environment as well as demonstrating some activity against aspergillus. These results are similar to those of the other studies which showed consistent activity against MRSA, VRE and MRA.⁷ We were unable to assess the impact of UV-C on *C. difficile* but its effectiveness has been demonstrated in previous studies.^{7,8}

A recent study has shown greater reductions against seeded pathogens and biological indicators when using vaporized hydrogen peroxide compared with UV-C, particularly for locations not in the direct line of sight.⁸ However, there is ongoing debate regarding the required log₁₀ reductions for assessing the efficacy of automated room decontamination technologies. In healthcare environments, important pathogens can remain detectable after manual room decontamination, but usually at low levels. In this context, a >6 log₁₀ reduction is probably not necessary, and it is likely that infection risks can be significantly reduced by automated devices achieving $>99\%$ (>2 log₁₀) reduction of residual environmental pathogens.

Placement of the device in a central position within the room was important, and slight variations in location led to considerable differences in the disinfection times (Table I, ITU Single Room A).

The main advantages of this device are that it is simple to use, does not require monitoring during the decontamination process, and therefore can be operated by staff with limited training. Another advantage is that without the need to deactivate room ventilation or smoke detectors, it was significantly quicker compared with hydrogen peroxide, and we were able to disinfect three ITU single rooms within 3 h. However, the average room disinfection times were longer than those reported in previous studies.⁷

The device has some disadvantages. Standard cleaning of rooms with detergents before using Tru-D was important

because debris such as faecal material inhibits its killing effect. However, prior cleaning is also important for other 'no-touch' automated room disinfection systems such as vaporized hydrogen peroxide. Previous studies have also shown that UV-C does not penetrate sheets and curtains, and high levels of UV radiation can reduce the service life of materials such as plastics and fabrics.⁷ Finally, there remains a danger of exposure, to patients and staff, to UV-C, if the sensor does not trigger automatic discontinuation upon opening the door. This is particularly important if there are several entrances to the room being disinfected such as an operating theatre.

Our study had several limitations. It was performed in one institution and we only tested the device in a small number of single rooms and one operating theatre. A small number of surfaces was sampled in the operating theatre and this may not accurately reflect the true level of contamination. For seeded Petri dishes, the inoculum was approximated to achieve 10^4 – 10^5 colonies/plate. Ideally, replicate samples at each location using a variety of surfaces (plastic, stainless steel, formica, etc.) would have been performed.

In summary, UV-C is an emerging decontamination technology that is effective in reducing bacterial contamination in the clinical environment. There are significant advantages to using UV-C, and, based on the results of this study we would recommend using Tru-D at the higher reflected dose setting of 22,000 $\mu\text{Ws}/\text{cm}^2$ for terminal room disinfection in most healthcare settings.

Conflict of interest statement

Rapid Disinfection Services Ltd supplied the Tru-D unit as a free loan.

Funding sources

None.

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