ARHAI Scotland

Antimicrobial Resistance and Healthcare Associated Infection

NHS National Services Scotland

Rapid review of the literature – Ultraviolet light technology for decontamination of health and care settings in the context of COVID-19

Version 1.0

Version History

Version	Date	Summary of changes
1.0	20 November 2020	First draft of document

Contents

Aim

In light of the concern raised regarding the possible risk of aerosol transmission of SARS-CoV-2 in indoor settings with poor ventilation, it is essential that healthcare facilities increase and improve ventilation provision to ensure rapid removal of aerosols to reduce the risk of COVID-19 transmission. This is also essential for the reduction and dilution of potentially infectious aerosols following an aerosol-generating procedure. For settings where it is not possible to make any modifications to the existing ventilation system, or where mechanical ventilation is not provided, there has been a call to assess the effectiveness of ultraviolet-C (UVC) light disinfection technologies. The effectiveness of UVC technology for surface decontamination will also be assessed.

UVC light can be delivered from overhead (upper-room UVC disinfection) which disinfects the air within a space, or from a moveable device that is designed to disinfect surfaces within a room. UVC can also be installed within HVAC systems to irradiate recirculated air. UVC light is produced by the sun, absorbed by the earth's atmosphere and does not reach the earth. UVC can be generated from artificial sources including: low-pressure mercury lamps that produce continuous UVC with a peak wavelength of 254nm; pulsed xenon lamps that produce light with a much broader spectrum (200-230nm); mercury-free light-emitting diodes (LEDs) that emit a very narrow wavelength band of radiation (214 nm, 265 nm, or 273 nm), and far-UVC lamps that have a lower peak emission of around 222 nm.

The demand for UVC disinfection has spiked since the start of the COVID-19 pandemic due to media reports and advertising from UVC manufacturers that have lauded its effectiveness. In order to determine suitability for use in NHSScotland facilities, it is essential that the efficacy of UVC at inactivating SARS-CoV-2 is established, as well as any logistical and safety issues.

Objectives

The following research questions were assessed:

1. What evidence exists regarding the effectiveness of UVC light technology for environmental decontamination in health and care settings, specifically in regard to infection control of COVID-19?
2. Are there any safety considerations associated with the use of UVC light decontamination systems in health and care settings?
3. Are there any logistical considerations associated with using UVC light in health and care settings?
4. What does current guidance indicate regarding the use of UVC technology for environmental decontamination of health and care settings?

Methodology

A tailored search strategy was developed (see Appendix 1) which was processed in Medline and Embase on 29th October 2020. Additional grey literature searching was conducted online.

As this was a rapid review, evidence was critiqued by a single reviewer but not formally graded with the use of an appraisal tool.

Conference abstracts, animal studies and non-English language studies were excluded. The focus of the rapid review was on virucidal efficacy therefore due to the time constraints, studies assessing bactericidal efficacy were excluded. Studies testing UV decontamination of PPE were excluded. A date limit was set to exclude evidence published in the years pre-2000.

Results

A total of 270 papers were identified from the database search. These were screened for relevance and a total of 18 papers were included in the review. Hand searching identified 9 guidance documents for inclusion. Forty-four papers were identified that assessed bactericidal inactivation; these were excluded as per the stated methodology.

Evidence of effectiveness against SARS-CoV-2

Six papers were assessed that tested the effects of UVC on SARS-CoV-2;[1-5] five of these were experimental in-vitro studies, one was a summary report.[6] All the experimental studies reported on surface decontamination of SARS-CoV-2; none of the studies assessed air decontamination. It was not possible to summarise the collective findings of these studies due to the heterogeneity in methodology; the dose of UV, duration of exposure, and distance between the lamp and test isolate varied. Individually, these studies demonstrated efficacy under their varying experimental conditions, suggesting that further research into surface decontamination is warranted in real-life trials. Regarding the radiation level, only one study tested the effects of far-UVC (222nm UVC),[2] the others tested standard 254nm,[1, 5] deep UVC (280 ± 5 nm),[3] and pulsed xenon (200-280nm).[4] There were no studies identified that tested UVC technology in real-life settings. One evidence summary produced by Scottish academics to inform Scottish/UK governments appraised the historical and current evidence and concluded that upper room UVGI should be immediately installed in indoor public spaces with low air change rates and/or recirculated air.[6] However, this conclusion was made in the absence of a robust evidence base (studies referenced included experimental laboratory studies, animal studies and narrative reviews) and was judged to be expert opinion; the authors suggest that far-UVC is likely to be even more effective than standard UVC however this is theoretical and requires further research to confirm.[6]

Evidence of virucidal effectiveness (non-SARS-CoV-2)

Five experimental studies were assessed that had virucidal inactivation as an outcome measure; four of these tested air decontamination,[7-10] one surface decontamination.[11] Unfortunately none of these studies tested UVC in real-life settings. It was not possible to summarise the findings of these studies due to the heterogeneity in methodology, UVC dose, and infectious agent tested (SARS-CoV, human coronavirus, murine coronavirus, vaccinia virus, H1N1 Influenza). Individually, these studies demonstrated efficacy under their varying experimental conditions, suggesting that further research is warranted in real-life trials, particularly for air decontamination.

Of note was one experimental study that used an aerosol irradiation chamber to test the efficacy of 222-nm far-UVC light to inactivate two aerosolised human coronaviruses (beta HCoV-OC43 and alpha HCoV-229E).[7] Low doses of 1.7 and 1.2 mJ/cm^2 inactivated 99.9% (3-log reduction) of aerosolised coronavirus 229E and OC43 respectively. The authors argue that as all human coronaviruses have similar genomic sizes, far-UVC light could be expected to show similar inactivation efficiency against other human coronaviruses including SARS-CoV-2. Based on these experimental results, the authors estimate that continuous far-UVC exposure in occupied public spaces at a dose of 3 mJ/cm^2 per hour would result in 99.9% inactivation in ~25 minutes, however a clinical trial is required to confirm this.

Evidence of effectiveness – infection rate as outcome measure

Four papers were assessed but all were excluded either due to methodological limitations or the fact that the infection rates were limited to assessment of bacterial inactivation.[12-15] One before/after observational study that tested a UVC robot within a long term care facility had respiratory system infection rates as an outcome measure however the methodological limitations meant that causation could not be proven; there was no certainty that the observed respiratory system infection rate decreases were due to the UVC treatment alone.[13]

Adverse effects

Seven papers were included; 2 guidance documents,[16, 17] 4 case studies that detail accidental exposure to overhead UVC lights,[18-21] 1 to a UVC robot.[22]

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) provides guidance on maximum exposure limits for UVC radiation, stating that exposure upon unprotected eyes/skin should not exceed 30 J/m^2 for radiation of 270 nm, the peak wavelength of the spectral weighting function for actinic UV hazard for skin and eye.[16] As the hazard effect of UV radiation depends on wavelength, the maximum exposure limit for radiation of wavelength 254 nm is 60 J/m^2. For radiation of 222 nm the maximum (actinic UV hazard) exposure limit is even higher, around 240 J/m^2.

The Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) as part of a European Commission in 2017, assessed the risks associated with UV radiation from lamps; concluding that due to the mode of action and induced DNA damage similarly to UVB, UVC is considered to be carcinogenic to humans.[17] However, currently available data at the time were insufficient for making a quantitative cancer risk assessment of exposure from UVC lamps. SCHEER advised that UVC lamps emitting radiation at wavelengths shorter than 240 nm need additional risk assessment of the associated production of ozone in the environment.[17]

In all case reports, measures had not been taken to prevent accidental activation of UVC lights. Accidental exposure events were reported in various healthcare settings (operating theatre, medical school, hospital room, pharmacy). Symptoms related to accidental exposure included foreign body sensation with intense tearing of eyes and erythematous rash on exposed body parts.

Logistics

Only two papers were identified and both describe some of the logistical challenges related to implementation of UVC surface disinfection devices (robot devices).[22, 23] The first study highlighted the operational challenges to implementation of UVC robot

devices in a trial conducted in a hospital; these included time pressures from bed control personnel, efficient room identification, negative perceptions from nurse managers, and patient discharge volume.[22]

The second was an experimental study conducted in a vacant burn ICU ward room (36m^2); disposable indicators and an electronic radiometer were positioned in different areas (locations and surfaces in frequent contact with the patient, staff, or both, and shadowed areas).[23] A UVC device (Tru-DTM-device) was centred in the room and operated on an automatic disinfection mode. The UVC radiation received in different areas varied greatly; surfaces at shorter distance and in the direct line of sight of the UVC device showed significantly higher UVC doses than surfaces in the shadow of equipment (p=0.019). To summarise, the UVC intensity received by a surface decreases exponentially the further the surface is from the lamp; consequently, as the distance between the lamp and the exposed surface increases, the log10 reduction of pathogens achieved decreases significantly.[24]

Because the extent to which infectious agents must be reduced to prevent transmission is unknown, there are no widely accepted criteria or standard validation methods to determine the level of viral reduction that UVC devices should achieve to demonstrate efficacy. A criterion frequently used by many studies is the ability to produce a 99.9% (3 log10) reduction of microorganisms on surfaces. Variables that affect the amount of UVC delivered to surfaces and the resulting log10 reductions of pathogens achieved include the amount of irradiance generated by the UVC device, the distance from the device to the exposed surface, the angle at which the UVC strikes the surface, and whether the surface is in direct line of sight of the device or receives light that has been reflected off other objects (i.e. surfaces in shaded areas).[24] These factors must be taken into consideration when assessing the potential effectiveness of a UVC device, and require clinical trials in real-life settings to assess.

A further issue is how plastics and other materials may respond over time to UVC exposure, as certain materials are susceptible to UV degradation. It may be necessary therefore to select equipment, fixtures and fittings that are UV compatible.

The main logistical limitation is that a room cannot be occupied whilst UVC decontamination is being carried out; this will be an issue for facilities experiencing full occupancy and where patient turnover is high. Another logistical issue is that manual surface cleaning to remove soiling is required prior to UVC surface disinfection, therefore fallow times will still have to be adhered to prior to entry into the room to carry out manual cleaning. These logistical issues may limit the time-saving potential of UVC devices where they are being proposed as a solution to reduce fallow time following AGPs.

Current UVC guidance

Six guidance documents were assessed;[25-30] one was excluded as it was specific to the control of TB transmission.[29]

In 2015, Health Protection Scotland published a systematic literature review and practice recommendations for UVC light decontamination of healthcare environments.[28] The review concluded that whilst some products had the potential to be useful, there was insufficient evidence to advocate its use within the NHS at that time. The systematic literature review is due to be updated in 2021 by ARHAI Scotland.

The International Commission on Illumination (CIE) published a position statement in May 2020, acknowledging that, despite ongoing research, there was currently no published data on the effectiveness of UV against SARS-CoV-2.[30] The Position Statement only covers the wider issue of the safe use and application of UVC radiation for germicidal disinfection and states that more specific application guidelines as well as standard testing procedures need to be developed for the use of UVC as an adjunct to standard manual cleaning in hospitals.[30]

The Chartered Institution of Building Services Engineers (CIBSE) and the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) both published COVID-19 ventilation guidance but neither provide evidence of effectiveness for UVC inactivation of SARS-CoV-2.[25, 26] REHVA advise that special UVGI disinfection equipment may be installed in mechanical ventilation systems (return air ducts in systems with recirculation), or installed in room.[26] However,

whilst in-room air cleaners are easy-to-apply short term mitigation measures, ventilation system improvements to achieve adequate outdoor air ventilation rates are needed in the longer run. REHVA states that more information about UVGI equipment is currently under development by REHVA's COVID-19 Task Force.

CIBSE are more cautious, advising that UVC disinfection may be a viable solution in spaces where it is difficult to provide good ventilation but that where there is adequate ventilation, the cost benefit of using UVC may be limited and that it should not be used as an alternative to providing adequate ventilation.[25] Further, CIBSE states that there are currently still uncertainties about a variety of factors affecting UV performance including dosage and exposure time, and how these might depend upon the ventilation rate of outside air.[25] In addition, consideration will need to address the specific room and system configuration, air flow, distribution and humidity as well as the safe deployment of UVC for occupants and building operations personnel.[25] CIBSE state that there is a need for better data and case studies on successful real-world applications to support all of these technologies.

The Health and Safety Executive (HSE) COVID-19 disinfection guidance does not discuss efficacy of UVC at inactivating SARS-CoV-2, only advises on logistics and adverse effects; 'Rooms with complex configurations/interior designs may not be suitable for UV treatments due to the limitations of shadowing effects, unless multiple systems can be deployed. Similarly, very small spaces, such as small sanitary areas, may not be suitable for treatment via UV carousel as they need to be a minimum distance from walls etc to be deployed safely.'[27]

The UK Scientific Advisory Group for Emergencies (SAGE) reviewed the evidence for the application of UV disinfection technologies to microbial control in May 2020 and concluded that while there is 'good' evidence that upper room UVGI has potential to be used effectively to reduce microbial load in the air in occupied rooms, there is limited evidence for application against respiratory viruses in a real-world setting.[31] There was consensus that it should not be seen as an alternative to ventilation but is likely to be beneficial where ventilation can't be improved. SAGE concluded that far-UV technology is promising but is far too early in development to be applied in real-world settings without significant further research.

Conclusions

Overall, the evidence available regarding the effectiveness of UVC for SARS-CoV-2 disinfection and the prevention of COVID-19 transmission is extremely limited. Whilst experimental studies have demonstrated susceptibility of SARS-CoV-2 to UVC irradiation under controlled experimental conditions, there are no studies that have tested this technology in real-life settings. Further, there are no widely accepted criteria regarding the level of viral reduction that UVC devices should achieve to demonstrate efficacy. These evidence limitations should be addressed prior to investing in and rolling out this technology.

Further, there are a number of logistical and practical challenges that may hamper the implementation and reduce the effectiveness of UVC devices in situ. There are multiple variables that affect the amount of UVC delivered to surfaces and the resulting reduction of infectious agent achieved; these include the amount of irradiance generated by the UVC device, the distance from the device to the exposed surface, the angle at which the UVC strikes the surface, and whether the surface is in direct line of sight of the device or receives light that has been reflected off other objects (i.e. surfaces in shaded areas). These factors must be taken into consideration when assessing the potential effectiveness of a UVC device. Logistical challenges related to bedding-in of these devices (time management, training, compliance, material compatibility with UV), whilst surmountable, are also likely to be significant. A further issue is the safety aspects related to accidental exposure to UV irradiation; it is possible that overhead far-UVC technology may offer a potential solution for air disinfection (and may overcome the issue of having to vacate the room) however further research is required. As surface cleaning is required prior to UVC surface disinfection, UVC technology will not offer any time-saving benefits and can only be seen as an adjunct to standard environmental decontamination.

The overarching limitation of most UVC systems is that the room must be vacated whilst disinfection is taking place; any reductions in aerosol/surface contamination will be short-lived as once the room is re-occupied, potentially infectious viral particles may again be circulating. UVC air decontamination should therefore not be

used as a replacement for optimum ventilation provision, however it may have a future use for terminal decontamination and/or in rooms in which AGPs are carried out where improvements to the existing ventilation provision are not possible.

Recommendations

- The evidence limitations identified in this rapid review should be addressed prior to investing in and rolling out UVC technology in health and care settings.
- UVC air decontamination should not be used in place of optimum ventilation provision; research should focus on the potential provision of UVC air decontamination in rooms where AGPs are being carried out in which improvements to the existing ventilation system are not possible.
- UVC surface disinfection should not be used in place of standard environmental cleaning and decontamination.
- Assurance regarding effectiveness of specific UVC devices/systems for SARS-CoV-2 (and any additional infectious agents) should be obtained from the manufacturer and this should include proof of pilot trials conducted in health and care settings with reliable outcome measures.
- Standard testing procedures should be developed to allow consistent and reliable testing of UVC devices.

Appendix 1

The following search strategy was processed in Medline and Embase on 29th October 2020:

1. UV light*.mp.
2. ultraviolet light*.mp.
3. ultraviolet ray*.mp.
4. UV ray*.mp.
5. ultra violet light*.mp.
6. ultra violet ray*.mp.
7. 1 or 2 or 3 or 4 or 5 or 6
8. exp cross infection/
9. exp infection control/
10. exp disease transmission, infectious/
11. exp infection/
12. exp disinfection/
13. exp decontamination/
14. exp sterilisation/
15. exp sterilization/
16. 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15
17. health care.mp.
18. care home*.mp.
19. exp hospitals/
20. exp housekeeping, hospital
21. patient room*.mp.
22. ward*.mp.
23. 17 or 18 or 19 or 20 or 21 or 22
24. 7 and 16 and 23
25. limit 24 to english language
26. limit 25 to human
27. limit 26 to humans

28. limit 27 to yr="2000 -Current"
29. remove duplicates from 28

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