Annals of Clinical and Analytical Medicine

Effectiveness of Ultraviolet Systems in the Disinfection of Hospital Rooms

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Received 15/10/2022; revised 8/11/2022; accepted 18/11/2022

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Abstract

Introduction: Infection control procedures such as handwashing are of critical importance in addressing nosocomial infections; however, greater awareness of the hospital environment as a source of nosocomial pathogens has led to renewed focus on hospital cleaning and disinfection. Ultraviolet light (UVC; wavelength, 200-280 nm) has a germicidal effect on microorganisms in water, on surfaces, and in air, and it is used for disinfection both inside and outside hospitals. This review aimed at investigating the effect of UV on systems in the disinfection of hospital rooms.

Methods: The literature search results for CAT used the reference database Ovid. Using the search terms ("laminar air" OR "laminar air flow" OR "laminar air-flow" OR "laminar airflow" OR ultraclean OR "Ultraviolet Rays"[Mesh] OR "ultraviolet light" OR "uv rays" OR "uv light") and ("Operating Rooms"[Mesh] OR "General Surgery"[Mesh] OR "operating room" OR "operating suite" OR "operative suite" OR surgery OR surgical) were combined with ("Cross Infection") and identified 48 articles. Abstracts of all papers were independently reviewed by the author (RPE). We identified two prospective randomized controlled trials. Each of these was reviewed and items were removed manually that did not pertain to any surgery in an inpatient hospital operating room. Only interventional studies were included in this review.

Results: A Upper-room UVC systems do not require modification to ventilation systems, are low maintenance, and relatively easy to install. The use of upper-room UVC is also economical. In an actual room using upper-room UVC, the UVC fluence rate varies even within the upper-room, and the time spent in the upper-room varies from particle to particle. These data show that in a 'real world' test setup, upper-room UVC is highly effective for reducing the concentration of vaccinia virus aerosols.

Conclusions: It is really important first to check that the targeted micro-organisms absorb UVB and UVA at a rate sufficient for the selected PUVD system to perform a required work in order to justify higher costs of disinfecting only with UVB and UVA light. Certainly, such higher costs of disinfection-sterilizing with UVB and UVC light alone are well justified for many medical-hospital and food applications, since alternative sterilization methods may not be compatible with increasing demands of respective industries.

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Keywords: Ultraviolet, Disinfection, Spores inactivation, Antiseptic, Air cleaning

Introduction

To control the spread of pathogens in hospital environments, good hygienic routines are required to clean and disinfect surfaces contaminated with biological materials. Chemicals such as chlorine and 5% chloramine have traditionally been used in many countries to disinfect surfaces during final room disinfection. Chemical disinfection agents such as chlorine or chloramine may have reduced effect in the presence of organic materials. Chloramine disinfection of surfaces in rooms is always followed by standard hospital environmental cleaning, to remove the chemical agent. However, chemical disinfection is both time-and labor-consuming, and it might be harmful for staff and the environment [1]. The search for more environmentally friendly and healthier methods has therefore been under way for many years. Ultraviolet light is absorbed by organic materials, and its ability to penetrate is low. Ultraviolet light (UVC; wavelength, 200-280 nm) has a germicidal effect on microorganisms in water, on surfaces, and in air, and it is used for disinfection both inside and outside hospitals [2]. Ultraviolet light is lethal to bacteria, bacterial spores, viruses, mold, mold spores, yeast, and algae, but the doses needed to inactivate them vary [3].

Nosocomial infections affect over 2 million patients annually in the US . At least 5% of patients hospitalized in acute care institutions acquire an infection that was not present on admission. Pneumonia is the second most common nosocomial infection in the USA which together with surgical wound infections accounts for approximately 15% of all hospital-acquired infections [1]. Infection control procedures such as handwashing are of critical importance in addressing nosocomial infections; however, greater awareness of the hospital environment as a source of nosocomial pathogens has led to renewed focus on hospital cleaning and disinfection [3]. Whereas effective physical cleaning remains essential for infection control and aesthetic reasons, there has been an upsurge of interest in the development of new cleaning and decontamination technologies. In addition to environmental decontamination applications, other potential uses of violet blue light for infection control purposes such as skin and wound treatment have been highlighted in recent literature [4].

Bacteria such as C. difficile spores are a significant issue for infection control, particularly due to their prolonged survival in the environment, and their resilience to disinfection technologies is well documented [5]. The spores can be successfully inactivated by exposure to 405 nm light, but, as expected, significantly higher doses (w50 times) are required for inactivation compared to vegetative cells [6]. In addition to clinically relevant bacteria, the effectiveness of 405 nm light for microbial inactivation has also been demonstrated against bacterial species associated with foodborne infection including Listeria Campylobacter Shigella and Salmonella spp.; pathogens Helicobacter pylori

Chlamydia and Propionibacterium acnes; oral periodontal pathogens; and fungal organisms including moulds and yeasts such as Candida. To date, the effect of violate-blue light on viruses has not been fully determined; however, it is expected that, due to the hypothesized involvement of porphyrins in the inactivation mechanism, it is unlikely that viruses will be highly susceptible to light exposure alone, and may require the addition of photosensitizing material to enhance viricidal activity [7, 8].

Epidemiologic studies reveal the incidence and prevalence of periprosthetic joint infection (PJI) may be increasing [9]. A cross-sectional study reported an overall incidence of infection after THA of 0.88% in the United States with urban nonteaching hospitals accounting for the majority of these. In Europe, infection surveillance standards have been implemented and surveillance is becoming compulsory [10]. Another study revealed that one of the main routes of wound contamination and infection was the air in the operating room. This study examined the effect of conventional ventilation LAF ventilation with body exhaust suits, and LAF without body suits on surgical site infection after joint surgery[11]. This was compared with an earlier study at the same institution, that showed an increased early infection rate (3.9%) using horizontal LAF without exhaust suits. Studies examining UVL have studied a variety of ultraviolet intensities in association with other infection control methods and surgical techniques [12].

For several decades, environmental surfaces in hospitals were considered to play little or no role in the transmission of healthcare-associated infections. However, a growing body of evidence suggests that contaminated environmental surfaces can contribute to the transmission of healthcare-associated pathogens-such as vancomycin-resistant enterococci (VRE), methicillin-resistant Staphylococcus aureus (MRSA) Clostridium difficile Acinetobacter species, and norovirus-by serving as sources from which healthcare workers may contaminate their hands or perhaps by direct transmission to susceptible patients [13]. Accordingly, cleaning and disinfecting environmental surfaces in patient care areas are now recognized as important elements of infection control programs. Despite this, multiple studies have documented that housekeepers often do not clean surfaces as recommended. As a result, there is increasing interest in new technologies that can reliably decontaminate environmental surfaces in healthcare facilities. UV light has been used in air-handling systems and upper-room air-purifying systems to destroy microorganisms and can inactivate microorganisms on surfaces, but few studies have evaluated the potential use of UV light systems for decontaminating patient rooms in hospitals [14].

The effectiveness of UVL, specifically UVGI, for intraoperative infection control is not well defined in modern operating room environments. Several investigators have shown that UVL is reduces the risk of surgical site infection or has been used in conjunction with LAF or body exhaust techniques [15]. The latest CDC recommendations in 2003 recommended not using UVL to prevent surgical site infection . In 1999, the CDC suggested both ultraclean air and antimicrobial prophylaxis can reduce the incidence of surgical site infection in orthopaedic implant operations [16]. This review aimed at investigating the effect of UV on systems in the disinfection of hospital rooms.

Methods

The literature search results for CAT used the reference database Ovid. Using the search terms ("laminar air" OR "laminar air flow" OR "laminar air-flow" OR "laminar airflow" OR ultraclean OR "Ultraviolet Rays"[Mesh] OR "ultraviolet light" OR "uv rays" OR "uv light") and ("Operating Rooms"[Mesh] OR "General Surgery"[Mesh] OR "operating room" OR "operating suite" OR "operative suite" OR surgery OR surgical) were combined with ("Cross Infection") and identified 48 articles. Abstracts of all papers were independently reviewed by the author (RPE). We identified two prospective randomized controlled trials. Each of these was reviewed and items were removed manually that did not pertain to any surgery in an inpatient hospital operating room. Only interventional studies were included in this review.

Results and discussion

We identified two prospective randomized controlled trials. Each of these was reviewed and items were removed manually that did not pertain to any surgery in an inpatient hospital operating room. Vertical exponential design LAF air plenums have the shape of the end trumpet sitting front end down on the floor and air intake is at floor level. The early body exhaust suit design was inspired after astronaut suits and some were obtained from the Jet Propulsion Laboratory (JPL) [17]. The only randomized controlled trials of LAF were conducted on 8055 patients undergoing knee and hip surgery in a multi-center, multinational trial . This study included 99,230 operations (hip and knee arthroplasty, appendectomy, cholecystectomy, colon surgery, and herniorrhaphy) from 63 surgical departments participating voluntarily in the German hospital infection surveillance system (KISS) [18]. Participation in KISS is explicitly recommended by the German state authorities and post-discharge surveillance is strongly recommended, although a "gold standard" method to do so is not available [19]. The author participated as a member of a team of experts representing various specialties in the evaluation of a Virginia hospital that had suddenly suffered dramatically increased PJI rates when apparently adequate infection control was in place [20]. LAF operating room in 1974 is equivalent to $219,035.50 in 2009 dollars , whereas the actual cost today ranges from $60,000.00 to $90,000.00 for construction and installation of an exponential LAF system into a new operating room. Examples are the UK Health Technical Memorandum (HTM 2025) in the United Kingdom and territories and the German VDI Standards, both of which have resulted in LAF becoming a standard of care regulated by those countries [21].

In general, all of these pathogens share the following characteristics: ability to survive for prolonged periods of times on environmental surfaces, ability to remain virulent after environmental exposure, frequent contamination of the hospital environment, ability to colonize patients, ability to transiently colonize the hands of healthcare providers, and transmission via the contaminated hands of healthcare providers. Norovirus and C. difficile also are noted for a small

inoculating dose and relative resistance to antiseptics and disinfectants used on environmental surfaces. The pathogen is capable of surviving on hospital room surfaces and medical equipment for a prolonged period of time [22]. The frequency with which room surfaces are contaminated correlates with the frequency of hand or glove contamination of healthcare providers. Improved terminal cleaning of rooms leads to a decreased rate of individual patient colonization and infection. Improved terminal cleaning of rooms leads to a decreased facility-wide rate of colonization and infection. Improved terminal disinfection with a no touch method leads to a decreased rate of infection in patients subsequently admitted to a room where the prior occupant was colonized or infected. Hospitals that use UV-light disinfection after cleaning and disinfection standard protocol have actually significantly mitigated infection risks associated with environmentally mediated transmission routes [23]. In the BETR (Benefits of Enhanced Terminal Room Disinfection) study, the first randomized multi-center trial that compared the effectiveness of different disinfection strategies in rooms previously occupied by colonized/infected patients.

The incidence of new colonization and infections in new hospitalized patients, demonstrated that the addition of UVC disinfection treatment to the standard protocol had a direct protective effect on the risk of acquiring C. difficile and vancomycin-resistant Enterococci [24]. When the robot is operated in accordance with the procedures, the ozone produced is far below the Occupational Safety and Health

Administration OSHA short-term exposure limits (0.1 ppm/8 h), however the manufacturer recommends using the robot in rooms with a system of ventilation, where possible. On this OT samples were taken before and after the SOP. This has allowed us to eliminate any overestimates of treatment efficiency, due to the cumulative effect of UVC radiation. In a room where a patient with ESBL-K. pneumoniae gastrointestinal colonization was hospitalized for a week, after patient discharge, we detected ESBL-K. pneumoniae on a tray table, but not after SOP [25]. Although less germicidal than UVC light, violete-blue light with wavelengths in the region of 405 nm has proved effective for inactivation of a range of microbial species, and exploitation of these wavelengths may provide alternative methods of antimicrobial treatment for infection control applications [26]. Investigations into the mechanism of action of 405 nm violete-blue light indicate that photodynamic inactivation occurs as a result of the photo-excitation of intracellular porphyrin molecules within the exposed bacterial cells. Vegetative cells of C. difficile are particularly sensitive to inactivation, and this is likely to be due to this organism being an obligate anaerobe, giving it increased sensitivity to oxidative damage [27]. Although the germicidal efficacy of blue light is lower than that of UV light e UV inactivation typically required doses of the order of milli-joules rather than joules, as is the case with violete-blue light e significant bacterial inactivation can still be demonstrated, with up to 9-log 10 orders of reduction being achieved by Maclean et al. A major advantage of violete-blue light inactivation is that the susceptibility of strains isolated from the clinical environment is similar to their laboratory type strain counterparts, i.e. clinical isolates do not show enhanced resistance and thus can be inactivated by 405 nm light with no inherent problems. The output of the antimicrobial light has been set to ensure, with reference to international guidelines, that the light source does not pose a blue light hazard and is safe for use in occupied environments [6]. Although biocidal, the 405 nm wavelengths are well below the blue light wavelengths which can impact on human health, particularly in the region of 440 nm which is associated with photoretinitis, and 480 nm which influences mood and circadian rhythm in humans

Multiple infection control measures have improved periprosthetic joint infection (PJI) rates substantially, but there are no data to suggest that other infection control methods are not additive. A recent evaluation of prophylactic antibiotics concluded that as a result of the current low prevalence of PJI, any intervention designed to further reduce infection is difficult and expensive requiring a large number of study patients [28]. The lack of high level of evidence from a randomized trial is not, however, proof of ineffectiveness. Although a definitive study that could define the absolute clinical benefit of these technologies has yet to be proposed, the existing evidence remains compelling. A systematic review of available studies contributes contemporary data to consider when deciding whether to use these technologies. How these technologies are used and their limitations need to be explored to implement or use one of these technologies to good effect because the data show they can be harmful if used inappropriately.

The undeniable effectiveness of ultraclean air ventilating systems in reducing both the numbers of airborne bacteria in the operating room and the incidence of sepsis after this type of operation,7'* together with the proven value of antibiotic prophylaxis, has limited interest in the possibilities of control by irradiation [29]. A study made an extensive and detailed study of the possible harmful effects of this, including wound healing and decomposition of anaesthetic vapours, but with careful attention to shielding the skin and eyes of the patient and staff, no untoward consequences were observed, except for some decomposition of halothane.

Conclusions

Upper-room UVC systems do not require modification to ventilation systems, are low maintenance, and relatively easy to install. The use of upper-room UVC is also economical. In an actual room using upper-room UVC, the UVC fluence rate varies even within the upper-room, and the time spent in the upper-room varies from particle to particle. These data show that in a 'real world' test setup, upper-room UVC is highly effective for reducing the concentration of vaccinia virus aerosols. Thus it is really important first to check that the targeted micro-organisms absorb UVB and UVA at a rate sufficient for the selected PUVD system to perform a required work in order to justify higher costs of disinfecting only with UVB and UVA light. Certainly, such higher costs of disinfection-sterilizing with UVB and UVC light alone are well justified for many medical-hospital and food applications, since alternative sterilization methods may not be compatible with increasing demands of respective industries.

Conflict of interests

The authors declared no conflict of interests.

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