

Design, Simulation And Implementation Of A Disinfection System For The Operating Room With Ultraviolet Uv-C Light Diseno, Simulaci3n E Implementaci3n De Un Sistema De Desinfeccion Para Quir3fono Con Luz Ultravioleta Uv-C

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Abstract

This research evaluated the effectiveness of UV-C radiation (254 nm) in disinfecting operating rooms, in compliance with the ISO 14644-1:2015 standard, to reduce microbial and viral loads on critical surfaces such as walls, floors, and medical equipment. An experimental-simulated methodology was applied, aiming to design, simulate, and implement a UV-C disinfection system, considering physical, microbiological, and energy efficiency parameters.

ANSYS 2023 R1 Workbench, Fluent, and DIALux Evo software were utilized to create a 3D model of the operating room and simulate UV-C radiation distribution. The results demonstrated that UV-C irradiation effectively eliminated pathogens such as *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Clostridium difficile*, achieving the recommended germicidal dose by disrupting their genetic material. The simulation also identified areas of low irradiance, suggesting adjustments in lamp placement at a height of 1.50 m on the side walls, with six 40-watt lamps recommended for optimal coverage. From the ANSYS Fluent simulation, it was found that the lowest point of UV-C exposure reached 206 J/cm², surpassing the 100 J/cm² required to destroy the most resistant pathogen. The study determined an optimal exposure time of 10 minutes to ensure germicidal effectiveness on distant surfaces. Finally, the system was implemented and validated in the operating room of Shushufindi Basic Hospital, Ecuador, confirming the practical feasibility and effectiveness of the proposed UV-C disinfection system in real-world settings..

Keywords: UV-C, disinfection, simulation, operating room, efficiency.

Resumen

Esta investigación evaluó la efectividad de la radiación ultravioleta UV-C (254 nm) en la desinfección de salas de intervención quirúrgica (quirófanos), conforme a la norma ISO 14644-1:2015, con el objetivo de reducir la carga microbiana y viral en superficies críticas como paredes, pisos y equipos médicos. El estudio se desarrolló mediante una metodología experimental-simulada orientada al diseño, simulación e implementación de un sistema de desinfección basado en lámparas germicidas UV-C, considerando parámetros físicos, microbiológicos y de eficiencia energética. Se emplearon los softwares ANSYS 2023 R1 Workbench, Fluent y DIALux Evo para generar un modelo tridimensional del quirófano y simular la distribución espacial de la radiación UV-C. Los resultados demostraron que la irradiación UV-C alcanza dosis germicidas suficientes para inactivar patógenos frecuentes en entornos hospitalarios, tales como *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Escherichia coli* y *Clostridium difficile*, mediante la destrucción de su material genético. Las simulaciones identificaron zonas de baja irradiancia, lo que permitió optimizar la disposición de las lámparas en las paredes laterales del quirófano a una altura de 1,50 m, utilizando seis lámparas de 40 W. El análisis en ANSYS Fluent evidenció una dosis mínima de 206 J/cm², superior al umbral requerido para la inactivación del patógeno más resistente. Se determinó un tiempo óptimo de exposición de 10 minutos para garantizar el efecto germicida en las superficies más alejadas. Finalmente, el sistema fue implementado y validado en el quirófano del Hospital Básico de Shushufindi, Ecuador, confirmando la viabilidad práctica y eficacia del enfoque propuesto.

Palabras clave: UV-C, desinfección, simulación, quirófano, eficiencia.

Introduction

An appropriate disinfection of operating rooms is an essential part of patient safety and effectiveness of medical practises in hospitals, especially in the city of Riobamba [1]. They are vital facilities in any healthcare facility that are in constant contact with a broad variety of pathogens, which is why they are in urgent need of particular cleaning and sterilisation techniques to reduce the chances of nosocomial infections to a minimum level possible [2]. Healthcare-associated infections (HAIs), or hospital-acquired infections (HAIs), have been an issue of major concern in the entire world, and their prevention is of paramount importance to the well-being of both patients and the medical staff. The national rise of cases where microorganisms are resistant to the traditional disinfectants further reminds people of the necessity of a more effective and sustainable solution to the problem. This case is especially relevant to such countries as Ecuador, where the local health facilities have to struggle with the particular issues of the effective sterilisation practise maintenance. Therefore, new more effective disinfection methods are required which can be used to supplement and addition to traditional methods of hospital hygiene. The technology based on ultraviolet radiation (UV-C) is an effective substitute of conventional sterilisation techniques. The ability of UV-C light to eliminate or inactivate a wide range of pathogenic microorganisms is an innovative and effective method to microbiological control in local and national health facilities [3, 4]. The importance of minimally invasive technologies that are used on the international level and ensure the implementation of the rules of sanitation and meet the high standards of the germicidal one has increased. The potential of the UV-C radiation to produce substantial changes in the various

microbial load levels renders it a very crucial instrument in enhancing the practise of infection control, especially in areas such as operating rooms, which are highly critical.

UV-C radiation will work at 200-280nm and has been scientifically tested to be especially effective in the destruction of bacteria, viruses and fungi. The World Health Organisation (WHO) recognises the efficiency of UV-C light as a useful type of disinfection of microbes [5, 6]. The mechanism of action of the UV-C light is the disruption of the microbial DNA and RNA and therefore interrupts microorganism replication and causes it to come to a standstill. This is known as Ultraviolet Germicidal Irradiation (UVGI) and it works by forming dimers between adjacent bases on the microbial DNA or RNA which mask critical cellular functions of the cell (the organism) [7]. Inactivation of microorganisms is not the destruction of the microorganisms but the inability of the non-viability of the microorganisms thus they are unable to cause diseases to the organism of a host [8].

Among the high benefits of UV-C radiation is the capacity to decrease the microbial load within a closed environment, including an operating room. It is crucial especially in the context of the fact that UV-C systems do not have to come in direct contact with the surfaces, and there are no chances of being contaminated by coming into contact with disinfectants or cleaning agents. The efficacy of UV-C light in the disinfection process is, however, affected by a number of variables such as the intensity of the light, exposure period, and the distance in-between the light source and the disinfected surfaces among others [3]. These parameters have to be maximised so that, UV-C radiation can be used to attain the germicidal dose needed to effectively disinfect.

Computational simulation has turned out to be an important tool to advance the prediction of the behaviour of UV-C light in surgical settings, prior to physical execution. Such software as ANSYS 2023 R1 Workbench and Fluent can be used to create three-dimensional models of operating rooms and can simulate the interaction of UV-C radiation with objects and surfaces inside the room [9]. The simulations are used to find possible regions of under-coverage with radiation and maximise lamp positions. With structured or unstructured meshes (polyhedral or tetrahedral geometries), these simulations provide a precise study of the distribution of UV-C light and its effectiveness in destroying pathogens. According to research conducted internationally and domestically in the past, a connexion between a clean surgical space and a decrease in postoperative infections is obviously established, which is why the implementation of UV-C disinfection systems is crucial. Besides, UV-C lamps are capable of reducing the dependence of cleaning on manual cleaning, which is vulnerable to human errors, as well as aid in more regular and uniform disinfection procedures, which are subject to human error contamination [10]. This automation of disinfection processes not only makes the sterilisation process more effective but it also improves the efficiency of the surgical procedure as well by decreasing the time put between surgeries.

The current study follows a multidisciplinary methodology, which incorporates the concepts of engineering, medicine, microbiology, and simulation to suggest a predictive model of UV-C disinfection systems that may be tailored to the needs of different hospitals. The case study was conducted at the Basic Hospital of Shushufindi in Ecuador, which provides a real-life example of the implementation of UV-C technology in the hospital sterilisation measures. The research objective is to create an evidence-based, comprehensive framework that will be utilised to streamline disinfection practise in operating rooms, resulting in improved infections control and more sustainable hospital practises. The research aims at setting more effective disinfection strategies that can be adjusted to the needs of a particular hospital setting, comparing several UV-C lamp configurations, technologies, and exposure times.

Methodology

The present study adopted a quantitative method with the experimental-simulated approach. The overall task was to design, simulate and roll out a UV-C light germicidal system of operating room disinfection using key parameters of physical design, microbiological efficacy and energy efficiency. The application of the system will take place at the operating room of the Shushufindi Basic Hospital which is situated at Sucumb'íos, Ecuador. The design of the methodology was aimed at the creation of a robust framework of UV-C disinfection that would comply with the international standards of safety and efficacy.

Phase 1: Collection of Technical Information

The initial step entailed gathering the necessary technical information to become familiar with the normal geometry of the operating theatres. This included the room size, furniture placement and surface characteristics in the operating room. These were very necessary physical components and layout that led to the development of an accurate three-dimensional model of the operating room. The model was developed with the help of SolidWorks that is a computer assisted design (CAD) software that helped to see in detail the organization of the operating room. It was a basic model applied in simulation of the dispersion of the UV-C radiation and this enabled the assessment of the way the radiation would interact with different objects and surfaces in the space [11].

Phase 2: Simulation of UV-C Radiation Distribution

Following the creation of the three dimensional model, the ANSYS programme, one of the popular software in fluid dynamics and heat transfer simulations were employed in simulating the distribution of UV-C radiations. In this step, the wavelength of 254 nm was used as UV-C since the wavelength was identified to be very effective in the inactivation of pathogens such as *Staphylococcus aureus* and *Escherichia coli*. An irradiance of 100 $\mu\text{W}/\text{cm}^2$ was applied, based on the recommendation of the World Health Organisation (WHO) on effective disinfection in hospitals settings [12]. This was to simulate the spread of the UV-C radiation in the operating room, where there may be low irradiance. These were critical areas to maximise on the right location of UV-C lamps, which would guarantee even disinfection on all the dangerous surfaces.

Phase 3: Optimization of UV-C Lamp Placement

The next phase involved the evaluation of the various UV-C lamp arrangements to identify the most appropriate arrangement of the lamp in terms of height and location in the operating room. In the configuration analysis, several factors that included irradiation on major surfaces have been taken into consideration including the operating table, surgical lights, walls and floors. As the furniture in the room can cause shadows that may decrease the performance of the UV-C radiation, it was also important to find out the best lamp position to ensure that the shadows are not cast on the room and that the areas with surfaces are exposed to UV-C radiation to the maximum extent possible [13]. The effect of lamp orientation and the amount of lamps needed to obtain optimum disinfection was also assessed in the study.

Phase 4: Evaluation of Germicidal Dose

The fourth phase entailed the assessment of the amount of germicidal to be used to disinfect all the critical surfaces in the operating room. The dose of UV-C energy needed to inactivate microorganisms was calculated as the germicidal dose directly based on reference value of inactivation of common pathogens. The dose of irradiance suggested by the past research was compared to the outcomes of the simulations. It was established

that 100 $\mu\text{W}/\text{cm}^2$ during 10 minutes was enough to obtain a 99.9 % inactivation of the common pathogenic microorganisms that were typical in operating rooms such as *Staphylococcus aureus* and *Escherichia coli* [13].

Phase 5: Compliance with Safety Standards

Simultaneously, the biological regulations of the safety of UV-C disinfection systems were analysed in order to ensure the safety standards of both the national and international level. The recommendations of the Occupational Safety and Health Administration (OSHA) and the World Health Organisation (WHO) were thoroughly inspected to make sure that the offered system will not place the staff exposed to destructive UV-C rays. The systems of UV-C disinfection must have certain safety mechanisms that will not expose people to the system accidentally, including presence sensors that will automatically switch the system off when people are detected in the room [14]. The measures are crucial in making sure that the system is within safe limits of operation to both hospital staff and the patients.

Phase 6: Development of Operating Procedures

The final process was to elaborate on explicit operating procedures regarding the implementation of UV-C disinfection system. These were supported by the instructions of how to calibrate the UV-C lamps, the irradiance levels and the correct exposure time. The ability and correct operation of the system was made through the design of a standardised operating protocol that would guarantee the safety and the efficiency of this system. The UV-C disinfection system was also tested with respect to energy usage. The anticipated benefits such as the reduction in the rate of infection as well as the saving of costs were compared with the energy efficiency of the system. This analysis was necessary to determine the feasibility of the system, particularly in the long run sustainability within a hospital setting [15].

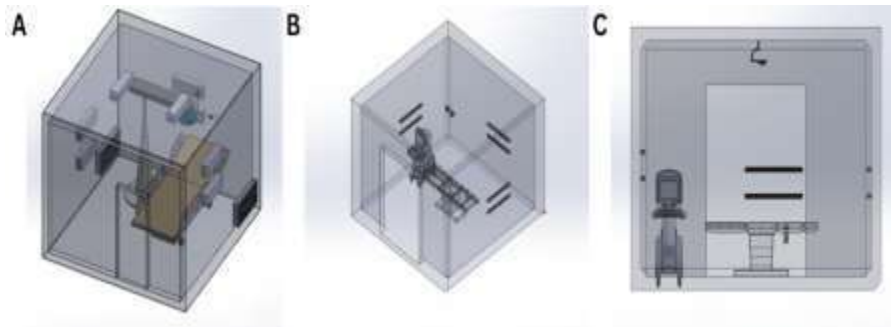
Results

The results of the research of the simulation and modelling were very important in testing the effectiveness of the UV-C disinfection system in the operating room. The simulation process involved a sequence of tools and methodologies in order to be confident that the UV-C light distribution was effectively predicted and its potential success in reaching the desired dose of germicidal light was achieved.

Simulation with SolidWorks and DIALux Evo

The first stage of the simulation was the 3D modelling using SolidWorks to consider the mechanical and electrical issues of the operating room design. This was made possible by the fact that the furniture arrangement and the materials used on the surface are part of the model and the interaction of the UV-C radiation with various objects in the room could be calculated accurately. The rounding of the corners in the room was also considered in order to maximise the coverage and have no uncovered areas in the room (Figure 1).

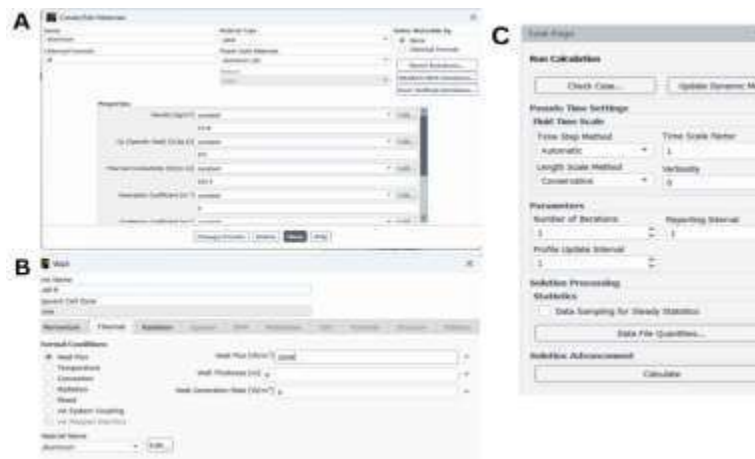
Figure 1. Simulation using SolidWorks and DIALux Evo for UV-C disinfection system. (A) System design modeling in SolidWorks. (B) Operating room with round corners. (C) Luminous flux distribution simulation in DIALux Evo for optimal UV-C coverage.



Optical simulation with ANSYS SPEOS

The second round of simulation was centred on spreading of the UV-C radiation in the operating room by ANSYS SPEOS. This software played a major role in modelling of the reflective surfaces, determination of the effective intensity at critical positions, and the optimal positioning of the lamps. Figures 2 illustrate how simulation materials are created, the boundary conditions are set and calculations are initiated, which are essential to the determination of the radiation distribution and the contribution of reflective walls and surfaces.

Figure 2. Simulation using SolidWorks and DIALux Evo for UV-C disinfection system. (A) System design modeling in SolidWorks. (B) Operating room with round corners. (C) Luminous flux distribution simulation in DIALux Evo for optimal UV-C coverage.



The SPEOS simulation also gave a good representation of the intensity of UV-C radiation in the operating room, showing how the light scatters on both surfaces and the air volume (Figure 3). These visualisations served to make sure that the radiation was properly distributed and that it would reach sufficiently the critical surfaces required in effective disinfection.

Flow Simulation with SolidWorks

After the optical simulations, the SolidWorks Flow Simulation was applied to the distribution of UV-C light at the complete air volume of the operating room. This analysis

has taken into consideration the interaction between the UV-C radiation and the air that would aid to comprehend how the radiation would reach the surfaces and microorganisms in the air. The findings showed the locations of high radiation intensity and areas that could probably need extra placement of UV-C lamps (Figure 4).

Figure 3. Results and analysis of the optical simulation with ANSYS SPEOS. (A) Visualization of the UV-C radiation distribution across the operating room. (B) Graph depicting the simulation results and intensity at critical points.

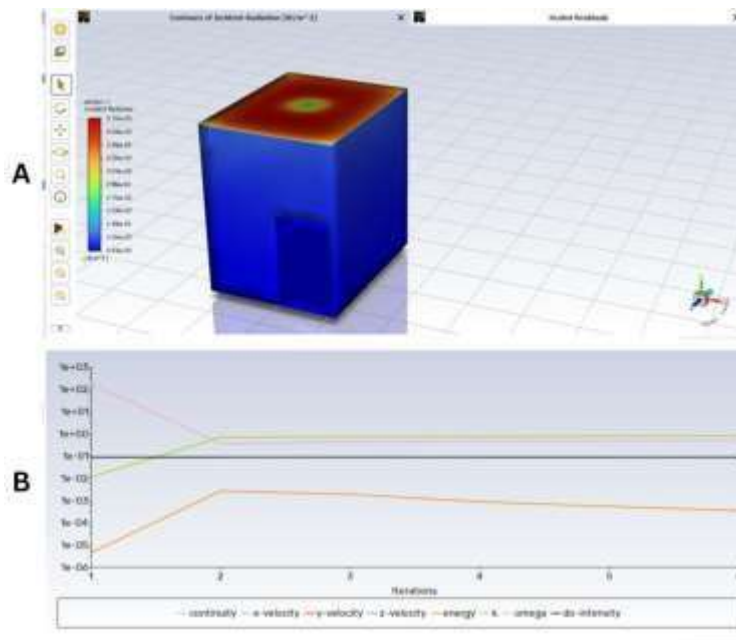
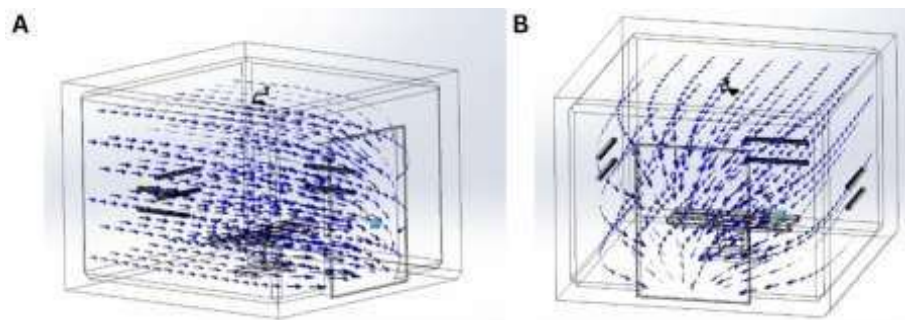


Figure 4. Flow simulation with SolidWorks for UV-C light distribution in the operating room. (A) Overview of the UV-C radiation distribution throughout the air volume. (B) Side view highlighting areas of high radiation intensity and potential gaps for additional lamp placement.



Radiation Incidence and Germicidal Dose

The most important part of the simulation outcomes is the determination of radiation incidence (G) at different locations within the operating room, and the subsequent analysis of germicidal dose. The table 1 below shows the incidence of radiation at various points in the room. These values show the intensity of UV-C light to each point in the operating room. The maximum incidence of radiation was $4.99\text{E}3 \text{ J/m}^2$ at the highest point

of the exposure which was at the centre of the room. The lowest point of exposure in a less lit-up place was 2.06E3 J/m².

Table 1. ANSYS FLUENT values

Parameter	Value
1	4.99E3
2	4.69E3
3	4.40E3
4	4.11E3
5	3.82E3
6	3.53E3
7	3.23E3
8	2.94E3
9	2.65E3
10	2.36E3
11	2.06E3

The germicidal dose was determined by multiplying the radiation incidence (G) with the exposure time (T). These calculations were critical in either confirming the sufficiency of the UV-C light to inactivate the microorganisms that were found on the surfaces. The data indicated that the germicidal dose at all of the tested points was higher than the minimum dose to inactivate typical pathogens including *Staphylococcus aureus* and *Escherichia coli*, and those with greater resistance to the spores. At the peak of the exposure, the dose has been determined to be 353 J/cm², which is far much more than the dose necessary to disinfect even the most recalcitrant pathogens (Table 2. Likewise, the germicidal dose at the midpoint (353 J/cm²) and lowest exposure point (206 J/cm²) also offered adequate amount of energy to guarantee efficient disinfection of the surfaces. These results confirm the suitability of the UV-C system to full disinfection of the whole room, including those areas that might be normally difficult to reach.

Table 2. Pathogen values

Microorganisms	Minimum dose (J/cm ²)
Virus	3-10
Common Bacteria	10-50
Resistant spores	100

Percentage of Organism Destruction Over Time

A further analysis of the percentage of microbial destruction with time (Table 3) indicated that in 10 minutes of exposure to UV-C light, common pathogens that included *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* were killed to a significant degree up to 99.99% destruction. More resistant species, such as *Clostridium difficile* spores, were also reduced by 95% in 10 minutes, highlighting the strength of the UV-C system in obtaining high disinfection rates. Nevertheless, the findings also showed

that in the case of some more resistant spores where 100 J/cm^2 doses are required, some parts of the room might need more lamps or more exposure duration, which shows the significance of optimising the lamp location and exposure time.

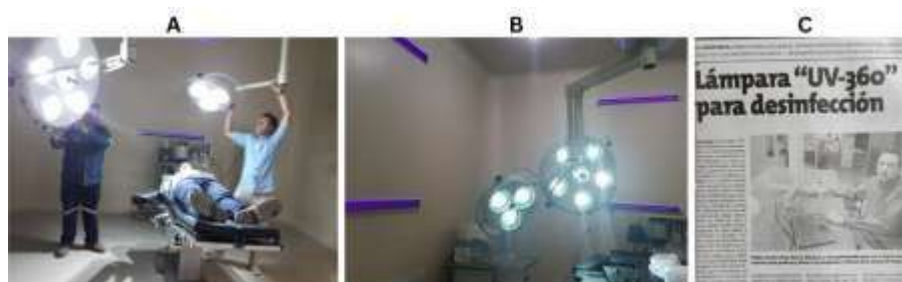
Table 3. Percentage of organism existence as a function of 5 time points

Species	2 min(%)	4 min(%)	6 min(%)	8 min(%)	10 min(%)
Staphylococcus aureus	85	96	99.5	99.9	99.99
Escherichia coli	90	98	99.9	99.99	99.99
Pseudomonas aeruginosa	80	94	99.0	99.8	99.90
Klebsiella pneumoniae	78	92	98.5	99.5	99.90
Clostridium difficile (Spores)	20	45	70	85	95

System Implementation

stage of the research was installation and validation of the UV-C disinfection system in the operating room of the Shushufindi Basic Hospital, Sucumb'íos, Ecuador. The system has gained acceptance because it has been shown to have the following benefits, which are minimised infection rates, and increase the disinfection capacity. The findings of the study were further supported by the media report about the successful application of the system at the hospital, which demonstrates that the proposed UV-C disinfection system can be practically applied in the conditions of the real hospital (Figure 5).

Figure 5. Implementation of the UV-C disinfection system at Shushufindi Basic Hospital, Ecuador. (A) Operating room setup at Shushufindi-Sucumb'íos Basic Hospital. (B) Installed UV-C disinfection system within the operating room. (C) Media coverage highlighting the UV-360 lamp-based disinfection system and its successful real-world application.



The simulation findings prove that the UV-C disinfection system is very effective in decreasing the microbial burden in the operating room. The estimations have shown that even the localities which were not exposed to UV-C radiations had adequate amount of radiation to guarantee the destruction of usual pathogens. The use of UV-C system is effective as the simulation data indicate that all the critical surfaces in the operating room could be disinfected effectively in a limited period of time and this greatly enhanced infection control and efficiency in the operations.

Discussion

The process of UV-C disinfection systems implementation in surgical theatres has proven to have enormous potential when it comes to reducing microbial bioload, especially in those locations that seem to be constrained by traditional cleaning processes. Through the simulations conducted on this research, it was established that the necessary dose of UV-C irradiation in the germicidal can be attained to eliminate part of the common pathogens such as *E. coli* and *Staphylococcus aureus* on important surfaces in the operating room. This observation goes hand in hand with the available literature that revealed the UV-C technology as a reasonable addition to the established cleaning protocols to provide a promising solution to the issue of hospital hygiene improvement and to mitigate the chances of healthcare-associated infections [16, 17].

The applicability of UV-C disinfection does not necessarily lie in the presence of the radiation, but several other factors are essential towards the effectiveness. The position of the UV-C lamps, the time of exposure and the intensity of the radiation are these. These parameters should be closely adjusted to achieve the maximum disinfection levels in a broad variety of operating room environments as we have seen in our simulations. The findings point to the need to have a properly developed system that considers the specifics of the layout in every room, the positioning of the furniture, and the distribution of UV-C light on all surfaces. This observation is supported by other works as they explain that improper positioning of lamps may lead to poor exposure with certain parts of the body being vulnerable to be contaminated by microbes [18, 19].

Consistent with this, the study found that there were spots in the operating room that were under irradiated and recommended the use of more lamps or changing the direction of the lamps to guarantee uniform distribution of the light. This is especially relevant in rooms with complicated layout and shadows cast by furniture or equipment might pose a hindrance to the efficiency of the disinfection process. The results agree with those of Cooper et al., who showed that UV-C disinfection must be strongly dependent on the geometry of the room to eliminate such dead zones of rooms [20]. The application of computational models as seen in this paper can help in prediction of the possible shadowed regions and the placement of lamps before the actual realisation of the physical system thereby streamlining the designing of UV-C systems and providing a comprehensive decontamination process.

Moreover, this paper shows that the introduction of UV-C technology that has automated systems that control the time and utilisation of the lamps is rather important. The relevance of automation to the enhanced process of disinfection is relevant because the appropriate amount of UV-C light is applied and there is no probability of human error. In order to improve the overall biosafety, the automated systems with timers, sensors, and other control devices might also be applied to minimise the unreasonable exposure of individuals to the radiation as well [21]. It has been established that such systems have the ability to minimise human error and improve overall efficiency of the disinfection process since uniformity is ensured in treatments [16].

In addition, automated UV-C systems can be used to minimise the time interval between surgeries, other than maximising exposure. This is necessary in busy operating rooms where time-saving is the most important issue. Studies have established that UV-C systems that are automatically operated can reduce the process turn-around time by a very large margin when they are factored in together with the automated functions, which is essential in ensuring the operational efficiency of the hospital is maximised and the throughput of the patient is maximised as well [22]. Moreover, the employment of such systems will reduce the workload of the staff, as they will be able to concentrate on other areas of patient care without neglecting disinfection procedures. The application of UV-C technology is vital, and its integration into the existing hospital environment should be

adequately planned and taken into account with a lot of aspects. It is justified in the current study that there is the need to invest in good quality UV-C equipment which is supposed to be installed in the hospitals, calibrated and maintained. According to the findings of a study conducted by Cadnum et al. and Diab-El Schahawi et al., the effective application of the offered technology is greatly dependent on the effective implementation of the system design and the regular cheque-up of the operational system despite the fact that UV-C disinfection is an effective technology that is used to reduce the microbial contamination at the microscopic level of contamination reduction [23, 24].

It is imperative to mention that UV-C systems may significantly decrease the microbial load, but they cannot replace other tools of preventing infections, including manual cleaning, appropriate ventilation, and compliance with standard operating procedures. According to Jinadatha et al., UV-C disinfection systems are to be included in a wider infection prevention plan that involves regular cleaning and observation of the environmental conditions. Complementary qualities of these systems, also mean that hospital settings are as safe as possible to both patients and caregivers [25].

In conclusion, this work indicates that properly designed, calibrated, and equipped with automated control mechanisms, UV-C systems could turn out to be a significant contributor to the improvement of the disinfection procedure in operating rooms. Although the technology has significant potential advantages of minimising the microbial bioload and enhancing the level of operational efficiency, its effectiveness is determined by the appropriate configuration of the system and continuous management. Incorporating UV-C disinfection, together with other infection control measures, can help hospitals develop safer conditions of patient care and make their contribution to the overall initiative of preventing healthcare-associated infections. The potential of UV-C technology as a useful tool in infection control is likely to continue to increase as more studies are conducted to explore the best practises in the implementation of the technology.

Conclusion

UV-C has been demonstrated to be effective at decreasing microbial load on critical operating room surfaces, which is why it could be an effective solution to enhancing hospital disinfection methods. It was possible to discover the areas where the irradiance was most effective and, most importantly, areas that could need some modifications in the layout of the lamps to provide even coverage and eliminate blind spots because of simulation of the disinfection system which was conducted with the help of special software and application of the exact mesh (structured or unstructured, like in ANSYS Fluent) to design the three-dimensional model of the operating room. This puts into perspective the need to have prior design and optimization of the implementation, and how the quality of the meshing itself plays an important role in the accuracy of the simulation output. The fact that UV-C does not produce any chemical residues, but is able to inactivate a wide range of common and resistant pathogens, makes it a compelling alternative to traditional disinfection as sensitive as a hospital. To maintain the safety of the personnel and effectiveness of the disinfection process, automated systems should be used with the presence sensors and timers. Such mechanisms do not only help avoid direct exposure to radiation reducing the risks involved, but also help maximise disinfection cycles, which means that the correct amount of germicidal doses is used. By offering a strong ground to the adoption of UV-C disinfection systems, with a clear simulation methodology, that consists of both detailed modelling and sufficient meshing, this study will contribute to enhancing biosafety in operating rooms and, therefore, to the elimination of nosocomial infections, which is beneficial to patients and health personnel.

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