

Far UV-C Lights and Fiber Optics Induced Selective Far UV-C treatment against COVID-19 for Fatality-Survival tradeoff

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ABSTRACT The global pandemic of severe acute respiratory syndrome, COVID-19 has put the world to a standstill. Human mobility has turned into a threat which ultimately effects the livelihood of the homo sapiens. This work focuses on the usability of Ultraviolet (UV) on humans as an economical way of contesting against COVID-19. Specifically, far-UVC is presented as a promising candidate against COVID-19 since it can inactivate pathogens including viruses and bacteria without harming mammalian skin or eyes. Furthermore, the work also points out the applicability of far-UVC lights for public spaces and treatment of selective region in COVID-19 patients by using fiberoptic as the medium for high-risk cases where chances of survival are low and such treatment may avoid fatality due to the COVID-19.

INDEX TERMS COVID-19, Ultraviolet (UV), far-UVC, fiber optics, selective treatment

I. INTRODUCTION

COVID-19 is the respiratory disease which occurs due to the severe acute respiratory syndrome typically referred to as SARS-CoV-2 virus [1]. Around 100 years after the pandemic influenza of year 1918, COVID-19 has inevitably transformed 2020 into an era of pandemic and global lockdowns [2][3]. The global economies are struck with a downfall amidst the unavailability of task force, the homo sapiens. The global health care system has exhausted. Though, frontline warriors are around the clock exploring and experimenting for the cure, vaccination and diminishing of the virus. As the spread of COVID-19, worldwide without discrimination of race, cast, color or creed, the sought solution against COVID-19 need not only to be erradiate the disease but also, needs to be economical. Another important factor is the accessibility and reachability of the solution, specifically in the developing countries, in order to hault the assumptatic natured virus which owns enormous multiplicity feature and can thus, always impact globally.

Inorder to combat the multiplicity of COVID-19, ultraviolet (UV) devices are brought into use for decontamination of diverse surfaces such as hospital rooms, masks and even, buses. UV light has been demonstrated to be capable of destroying viruses, bacteria and fungi in hundreds of laboratory studies [4]. With respect to wavelength, UV radiation can be categorized as:

UVA having range of 400-320 nm, UVB having range of 320-290 nm and UVC having range of 290-200 nm). The UVA type of radiations leads to light brown tan after a small-time span; the consequent darkening occurs because of melanin, that gathers in the skin. The UVB radiation causes extreme sunburn, related with intensified erythema and edema, ache, and formation of blister in lesser than a day of exposure. UVC is referred to as a germicidal radiation which due to its effectiveness in killing microorganisms owns sterilization and biocidal features, as well [11].

Infact, UV blood irradiation (UBI) was widely used during 1940s to 1950s for treatment of various diseases such as septicemia, pneumonia, tuberculosis, arthritis, asthma and even poliomyelitis as figure 1 gives a peek into history[5]. Particularly, Far-UVC light, having range of 207–222 nm, has been investigated for efficiently inactivating bacteria without being toxic to bared mammalian skin. Far-UVC has strong absorbance in biological materials because of which it cannot pass through even the external human skin layers or eye; although, far-UVC can pass through and inactivate bacteria as well as viruses as their size is of micrometer or lesser.

Hence, this work motivates far-UVC as an accessible and cost-effective treatment for COVID-19 in humans. The work emphasizes that far UV-C lights and treating selective regions in COVID-19 patients through

Year	Form of UV
1845 Bonnet	Sunlight for tuberculosis arthritis
1855 Rikli	Thermal station for helio-therapy
1877 Downes and Blunt	Sunlight to kill bacteria
1904 Niels Finsen	Nobel Prize for UV treatments of skin conditions
1920s, Walter	High cure rate for erysipelas using Uvlight
1928	UBI for Septic abortion intricated by hemolytic streptococcus septicemia
Hancock and Knott	UBI for hemolytic streptococcal septicemia.
George P Miley	Use of process for treating thrombophlebitis, botulism, poliomyelitis, non-healing wounds, staphylococcal septicemia, peritonitis and asthma
1940	Infectious arthritis, septic abortion, uveitis, furunculosis, osteoarthritis, tuberculosis glands, chronic blepharitis, mastoiditis, chronic paranasal sinusitis, acne vulgaris, and secondary anemia

Table 1. UV treatment in History

fiber optics based far UV-C is a practical choice for patients where the survival chances are already low, and fatality because of COVID-19 could possibly be avoided using far UV-C. The major contributions of the work are as follows:

- The works focusing on far-UVC for healthcare are briefed.
- The significance and potential of far UV C for the decontamination of COVID-19 in humans is discussed.
- Relevant imperative research questions are highlighted.

The rest of this paper is organized as follow. Section II highlights the works which are target UV for healthcare. In Section III, the potential of Far-UVC for humans are discussed and research questions are raised by Section IV. Section V presents the conclusion of the paper.

II. RELATED WORKS

As an ancestral cure, the research of [5] emphasized that effectiveness UV treatments has been forgotten with passage of time. The work is motivated by emergence of antibiotic-resistant-bacteria and promotes UltraViolet Blood Irradiation (UBI) as an immune-modulating therapy. It also highlighted major works which had previously utilized UV for health-related issues.

However, the current literature reflects a rise of explorations on a particular range of UV referred to as the far -UVC. The study of [6] establishes that far-UVC, 224-nm UV radiation, UV₂₂₄, supplied from laser over an optical diffuser happens to be viable retort for decontamination of susceptible area, for example skin penetrating medical devices, catheters or drivelines. The novel study showed that far-UVC irradiation supplied by usage of fiber optics is favorable technology to prevent

infections instigated through contamination by bacteria. A good example of the technology is to use laser for conveyance of far-UVC light by means of an optical fiber and radiated from diffuser is remarkable. In [7], extremely low doses of far-UVC light were competently used to deactivate airborne viruses conveyed by aerosols. By use of 222-nm UV radiation (UV₂₂₂), [8] investigated that how UV₂₂₂ eradicates cultivating bacteria and spores, and the factors which are imperative for allowing cells and spores to defy the effects of this radiation. UV₂₂₂ is theoretically a safer alternate to UV₂₅₄ which is frequently utilized for surface sanitization. For in vitro investigation of [9], laser generated far UVC light is carried using an optical diffuser for deactivating Methicillin-resistant Staphylococcus aureus (MRSA) on surface by means of far-UVC light from a laser conveyed using an optical diffuser. Analysis reflected that the exposure of far-UVC is ample to inactivate MRSA with a dosage equivalent to the one needed using a typical germicidal lamp. Results indicate that far-UVC competently deactivates airborne aerosolized viruses, with an extremely small dose of 2 mJ/cm² of 222-nm light inactivating >95% of aerosolized H1N1 influenza virus. The safe use of UV-based sterilization was developed in [10] where a far-UVC having single wavelength of 207, UV₂₀₇, was used for exterminating bacteria, without impairing the cells or tissues in human.

In other works, 254-nm UV radiation, UVC₂₅₄, was probed exposure-period dependently for the ultrastructural effects of on cells of lung in mole rats. Similarly, UVC₂₅₄ was used for pre-clinical study to demonstrate the capability of lightbased therapies - UVC and photodynamic therapy (PDT) during Ex vivo lung perfusion (EVL) to deactivate hepatitis C virus (HCV) in donor lungs. In a stepwise application of this technology to clinical transplantation, a clinical trial was

designed to assess effects of UVC treatment using NAT+ HCV donor lungs trailed by transplantation.

III. POTENTIAL OF FAR-UVC IN COVID-19 FOR HUMANS

The potential of far-UVC in humans against COVID-19 is three-fold: 1) far-UVC lights for public spaces 2) Far-UVC for selective treatment in high risk patients 3) Far-UVC for diverse range of sterilization purposes. We will discuss the first two here:

A. *Far-UVC lights for public space*

Antimicrobial aptitude of UVC ultraviolet light is widely accepted in history. However, owing to the health hazard related side effect, public spaces don't employ them as mean to kill viral infections. However, the work of [7] effectively shows that an extremely squat dosage of 2 mJ/cm² of 222-nm light deactivates greater than 95% of airborne H1N1 virus. The usage of overhead low-level far-UVC light in public spaces might present a nontoxic and effectual technique for controlling the spread of airborne-mediated microbial disease. Utilization of low-level far-UVC fixtures provision desired antimicrobial advantages with no human health related concerns which existed with conventional germicidal lamp UVGI associated human health concerns of conventional germicidal lamp. Hence, far-UVC lights are an economical candidate for the global pandemic of COVID-19. As COVID-19 spreads with asymptomatic feature, introduction of far-UVC lights is immensely important for a safer world. Investigations and guidelines are needed for placement of far-UVC lights in public settings which can be timely handled. Introduction of such an infrastructure which involves strategic placement of far-UVC lights will be effective for not only COVID-19, but all multi-drug-resistant variants of bacteria. Public locations for example, schools, hospitals, offices, schools, doctors' airplanes and airports might be considered here.

B. *Far-UVC for selective Treatments in Human*

UV radiation, implicitly, influence toxic effects on living beings. In [11], mole rats were exposed to UVC₂₅₄. In the tissue of rat lung fore-most detectable modifications existed after 14 days of exposure to UVC radiation. As already highlighted, far-UVC light can effectively deactivates bacteria with no damage to exposed mammalian skin. The biophysical reason is that the range of far-UVC light is not ample range to pass the the external layer (stratum corneum) of human skin. Also, far UV-C cannot penetrate the external tear layer of eye, because to its strong absorbance in biological materials. Though, as viruses as well as bacterias are typically have dimension of micron or even lesser size.

In many cases, the source of far-UVC light for example excimer lamp would not be ample for decontamination as implanted lines function as protecting for most of wound region. Moreover, the far-UVC light cannot pass through the skin to decontaminate within the wound. A possible answer to these circumstances is to direct light around and inside complicated geometries by use of fiber optics. The fiber optics, which can be paired with a far-UVC area laser as a source of light, could be maneuvered to send light to various regions around prone-to-infection area. Coupling the fiber optic with a diffusing element which is able to emit the light radially from the fiber would permit for application over a greater target area in the percutaneous areas which would not haven possible to expose otherwise. The development of such methodology for decreasing infection at skin entry are while being most probably safe for human exposure is important for the fight against drug-resistant bacteria, specially in hospital settings [9].

Current trends in far-UVC laser technology development have reflected potential for shrinking the size as well laser module's expense for suitability of large-scale adoption. Consider the example from Europe, Sharp Laboratories have developed condensed UVC lasers which are as small as the AA battery; although, the laser module utilized for the work was 10 cm × 10 cm × 70 cm having around 4 kg. Compact laser modules could empower the creation of decontamination systems using far-UVC technology which are effortlessly portable and hence capable of being applied to diverse range of applications [9].

In regards with COVID-19, far-UVC lasers for decontamination could be advantageous from enhanced light diffusing technology which is well suited for the application. Owing to complexity in functioning with wavelengths of far-UVC, greatly because of effects of solarization which decrease transmittance, commercially available optical parts are restricted. New diffusers that are greatly robust and highly compatible to unique biological locations which they will be utilized for will also enhance technology. Thus, the potential of far-UVC as safe, and effective technology that diminishes will for an antimicrobial tool which works.

In-vivomouse skin results consistent with prior investigations in a 3-D human skin tissue in vitro model [8] which also presented imperative skin damage after typical UV₂₅₄, but none after UV₂₀₇. The outcome readily interpretable with respect to limited range of 207 nm UV light which cannot pass through the stratum corneum surface layer of mouse or human skin; on the contrary, broad spectrum UVC from a 254 nm germicidal lamp can swiftly pass through the and dermis and epidermis. Prior works also recommended that UV₂₀₇ light and UV₂₅₄ from a germicidal lamp are approximately equitoxic to MRSA.

Moreover, recent investigations have reflected on an open wound with no protective layer of stratum corneum that its irradiation of an open wound with UVC light of 222 nm did not stimulate DNA damage for the target cells. However, the bactericidal was still under control.

Therefore, owing to its immense potential, a technique for fiber optics based far-UVC must be investigated for selective treatment of COVID-19. By using fiber optics as the medium, most suspected region such as organs in terms of locality of COVID-19, can be selectively treated with exposure to far-UVC.

IV. RESEARCH QUESTIONS

The major research questions whose answers need to seek in regards with use of far-UVC on humans in battle against COVID-19 are stated as follows:

1. What should the effective exposure time of far-UVC?
2. What frequency of far-UVC would be good enough against COVID-19?
3. What will be the associated side effects in humans in response to exposure with far-UVC?
4. Which fiber optic will be most suitable for the procedure?
5. How can this strategy of far-UVC be adopted for public places?

V. CONCLUSION

Far-UVC has immense potential as an economical way for treating COVID-19. High risk cases of COVID-19 where the chances of survival are already low, far-UVC can be employed as the last resort providing tradeoff between the fatality and survival. For high risk cases, exposure to far-UVC lights and treatment of selective regions using fiber optics induced far-UVC must be investigated to combat COVID-19 and probable pandemics for a safer tomorrow.

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