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REVIEW ARTICLE

SUNLIGHT AND SARS-COV-2: CAN SUNLIGHT AND UV EXPOSURE MITIGATE THE PROPAGATION OF COVID-19?

Alexandra Leclézio[1], Jared Robinson[1], Indrajit Banerjee[2,*]
[1]Medical Student, Sir Seewoosagur Ramgoolam Medical College, Belle Rive, Mauritius
[2]Department of Pharmacology, Sir Seewoosagur Ramgoolam Medical College, Belle Rive, Mauritius

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***Correspondence to:** Indrajit Banerjee, Department of Pharmacology, Sir Seewoosagur Ramgoolam Medical College, Belle Rive, Mauritius.*
Email: indrajit18@gmail.com

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ABSTRACT

Background: This review aims to assess the contributing role of sunlight on mitigating the propagation of COVID-19, and to assess how sunlight as well as artificial UV light may be a natural, more cost effective and eco-friendly method of disinfection which can be implemented in order to help to combat this rampant pandemic.

Methods: An extensive literature survey of English literature was conducted using Pubmed, Pubmed Central, Medline, Google Scholar and WHO Nepal Situation Updates on COVID-19. A combination of keywords was entered: "Sunlight" OR "Disinfection"; OR "Ultraviolet Rays"; OR "SARS-CoV-2"; OR "Coronavirus Disease 2019"; OR "COVID 19"; AND 'Nepal'.

Results: Sunlight is composed of UVA (95%) and UVB (5%) radiation, UVB is most effective to inactivate SARS-CoV-2 and does so by damaging the RNA genome of the virus, and increasing levels of reactive oxygen species in the air. SARS-CoV-2 is nullified by a UVB flux of 28 J/m2, and needs to be exposed for a sufficient duration depending on the time of day, season, geographic location or the specific locality, in order to be inactivated.

Conclusion: Developing countries could benefit from taking advantage of using sunlight as a cost-free and environmentally friendly method of disinfection. It is imperative that all countries capitalize on this method of disinfection, it is cost-free, easy and therefore can be implemented on a large scale with relative ease.

INTRODUCTION

The SARS-CoV-2 virus was first identified in China.[1] Today this tenacious virus has led to millions of infections and deaths worldwide.[2] The modes of transmission include spreading via respiratory droplets, aerosols, and direct contact.[3-4] It is at these levels that an intervention could assist in breaking the vicious cycle of SARS-CoV-2.[5] Environmental factors such as temperature, humidity, and sunlight influence the persistence of SARS-CoV-2.[6] This review aimed to discuss the contributing role of sunlight on mitigating the propagation of COVID-19, and how artificial UV light and sunlight may be used as a disinfectant in order to help combat this pandemic.

METHODS

A thorough in-depth search was performed using Pubmed, Pubmed Central, Medline, Google Scholar, Embase and WHO Nepal Situation Updates on COVID-19 databases. A combination of keywords was entered: "Sunlight" OR "Disinfection"; OR "Ultraviolet Rays"; OR "SARS-CoV-2"; OR "Coronavirus Disease 2019"; OR "COVID 19"; AND 'Nepal'. All of the related articles published in the respective were considered for this review.

RESULT

Humidity, temperature and SARS-CoV-2

The environmental forces which affect the survival of SARS-CoV-2 which are of interest to this study are: temperature, humidity and sunlight.[6] The degree to which each environmental factor plays a role must be delineated in order to identify how sunlight might influence the propagation of this pandemic. In a study conducted by Carleton T et al. reported that UV radiation reduces COVID-19 growth rates, significantly more than temperature or humidity.[7]

These findings were supported by another study conducted by Kormuth KA et al, wherein the Influenza A virus (also a respiratory virus) was equivocally infectious at various levels of relative humidity's tested, ranging between 23% to 98%.[8] Epidemiological studies have concluded that in winter, there was indeed an increase in mortality caused by influenza, however this increase was not entirely dependent on temperature and humidity, but may also be attributed to lifestyle changes, such as remaining indoors, for longer periods in a more crowded environment, leading to a higher transmission rate.[9, 10]

Sunight and COVID-19 pandemic

Ultraviolet radiation derived from Sunlight has been demonstrated to be the most potent viricidal and germicidal physical element in the natural environment.[11-12] Although population size, public health and control measures play a significant role in the nature of the global spread of COVID, the environmental role of solar exposure, has been postulated to be a major benefactor in the persistence of COVID-19 in the Northern latitudes, where it spread rapidly during the winter of 2019-2020, and relatively lower COVID-19 cases were recorded in the Southerly latitudes which receive a greater amount of solar radiation during the same time period.[13]

Sunlight - it's composition

Sunlight can be described as a spectrum of light divided into: UVA (315-400nm), UVB (280-315 nm) and UVC (100-280nm) radiation.[14] However, the bandwidth of UV light which reaches the surface earth (terrestrial UV), is comprised of UVA (95%) and UVB (5%) only.[14] The remainder of the radiation is blocked by oxygen and atmosphere, which is in fact beneficial as UVC (although a potent viricidal agent) is known to have potential phototoxic effects.[15]

Sunlight and photoinactivation

Photoinactivation of viruses by ultraviolet light has the following mechanism: ultraviolet light breaks the bonds of pathogens (bacteria, protozoa, all viruses) and forms photodiameric lesions in both RNA and DNA.[16] This damages the genome of the pathogen permanently.[17] Transcription and replication of the virus is not possible, and inevitably, the inactivation of the virus occurs.[18] More specifically, direct UV damage occurs when UV light is between 200-300 nm.[19, 20]

UV radiation has an antiviral impact based on the formation of reactive oxygen species (ROS) and O_3 leading to a reduced viability of aerosolized SARS-CoV-2 in the air.[21, 22]

UV sensitivity of SARS-CoV-2

UVC is a widely used germicide for all viruses, and furthermore, studies have been conducted to demonstrate its effect on SARS-CoV-2.[23] It was demonstrated that germicidal artificial UVC light (which is not a component of natural terrestrial light) did indeed inactivate this virus.[24-28] The effects of naturally occurring sunlight (containing 95% UVA and 5% UVB), were researched for the first time in July 2020 by the American study at the National Biodefense Analysis and Counter measures Centre (Ratnesar-Shumate, et al) where SARS-CoV-2 was demonstrated to be inactivated by simulated sunlight.[29] In this study 90% of the infectious virions in artificial saliva were inactivated every 6-8 minutes, when allowed to dry on a surface made of steel, or when aerosolized or when exposed to sunlight representative to that of the 40°N latitude during its summer solstice.[29] This information unlocks a plethora of possibilities for sunlight, a naturally occurring element, to be used as a sanitary measure to combat this rampant pandemic.

The UV dose needs to be sufficient to render the SARS-CoV-2 virus inept which is surrounded by materials in aerosols created by COVID-19 patients which has been shown to shield the virus from UV.[29-32] The amount of UVB flux from the sun required for 99% inactivation of SARS-CoV2 is 28J/m^2; and thus SARS-CoV-2's UV sensitivity was calculated to be $D_{1,}$ which corresponds to the amount UV fluence that creates one lethal hit to the virus, resulting in 1% survival.[33]

Sunlight exposure: duration required for viral inactivation

For natural solar exposure to meet the viricidal UV dose requirement, SARS-CoV2 needs to be exposed to the sun for varying amounts of time, depending on the time of day, season, cloud coverage, air pollution, latitudes and geographic location.[33]

Time of day: 35% of the daily UVB exposure occurs in a period lasting 120 mins around noon, and this is therefore the best time of the day for viral inactivation to be achieved.[34]

Geographical location: The 'noon time UVB flux' however, has varying values (measured in J/m^2/min) depending on the geographical location of the area and it's latitudes in relation to the equator; this has been quantified by a study conducted in the United States.[33] It states that Miami (latitude 25.8°N), experienced more solar flux (0.51/14 J/m^2/min), than Seattle (latitude: 47.6°N, solar flux: 0.26/27), or other cities with similar latitudes, at the same time of the year (during the Summer Solstice).[33]

Season of the year: The same study notes that in winter, most cities in the United States did not receive an adequate dose of sufficient solar radiation to allow for the viral inactivation to reach 90%, during the 120 minute noon period, and therefore a longer amount of solar exposure time would be required during winter for successful photoinactivation of the virus.[33] On the other hand, during the summer solstice, most United States cities received enough UVB flux for 90-99% inactivation of the virus to be achieved after only 11-34 minutes of exposure to the 2 hour midday sun.[33]

Atmospheric interference: air pollution, cloud coverage, and haze, will also lead to the need for a longer viricidal sun exposure duration, as these factors will reduce exposure to antiviral UV radiations due to the increased opacity of particles suspended in the air as when compared to a clear day.[35]

It can therefore be concluded, that in order to use natural sunlight effectively as a viricidal tool against SARS-CoV-2, and for the viricidal solar exposure dose to be met, the duration of sun exposure must be appropriate to that particular time and place.[33]

Artificial UV light as a disinfectant method

Artificial UV lights are designed to emit UVC radiation which has a higher viricidal activity than that of natural sunlight (95% UVA and 5% UVB) leading to a greater likelihood of viral inactivation; this is demonstrated in a study where UVC from a Light Emitting Diode very rapidly inactivated >99% of SARS-CoV-2 virions within ten seconds.[36] Artificial UV lights are also not subject to the same environmental variations as solar UV exposure, and can therefore be used at any time of the day, or during low UV environments, such as European cities around the winter solstice[33]. Additionally, the amount and duration of UV radiation emitted from Artificial UV lights can be more accurately measured compared to the ever changing nature of solar UVR which can vary according to atmospheric interferences.[35]Another advantage is their portability and affordability, which makes them available for use at home as well as in hospitals in order to inactivate the virus in fomites, for example: food[37], medical equipment (phototherapy units)[38], technological devices (phones) [39], medical air [40], masks/ N95 respirators and other equipment [41- 42] and hospital waste/ waste water. [43] The general consensus being that artificial UV light (in the correct dose), can be relied upon as an effective viricidal tool to inactivate SARS-CoV-2 in this COVID-19 pandemic.[44]

Sunlight versus Artificial UVC light as a disinfectant

The downfall of artificial UVC lights however, are their potential phototoxic effects, which are of concern especially when used by untrained consumers at the home.[45] Furthermore, accidental skin damage has also been reported in hospital settings by experienced users, as a consequence of UV disinfection of N95 respirators.[46] The N95 respirators have also been shown to have decreased usability and integrity after repeated disinfection by artificial UVC lights.[47] Solar UV light on the other hand, has a lower phototoxic effect than UVC.[45] Solar UV radiation, when in adequate amount for viricidal effect, is an environmentally friendly, naturally occurring, cost-free disinfectant, which exerts it's viricidal effect over the entire outdoor environment.[48]

Sunlight as potential mitigating factor for pathogens on human skin

Sunlight should not be relied upon as a sanitizer for human skin, as the skin surface area would need to be exposed to the sun without sunblock for the required viral inactivation time on a daily basis, and overexposure to the sun can cause sunburn, skin cancers, eye diseases, and reactivation of persisting viruses such as herpes simplex virus 1. [49- 51] However exposure to the sun within the recommended amounts can have immune boosting and health promoting effects such as Vitamin D activation,[52]which releases nitric oxide[53] as well as activates molecules which affect the neuro-endocrine pathways,[55] activate molecules that mediate anti-inflammatory effects,[56] lower LDL-cholesterol levels [57], and improve cardiometabolic functions. [58-59] Therefore, these mediators could ultimately aid in preventing COVID-19 infections.[59] Spending time in the outdoors and sun exposed areas usually have more air convection than stagnant air indoors, which reduces the risk of transmission significantly.[60]

It has been highlighted in some research papers that the isolation and strict 'in house' lockdown measures where healthy people have less exposure to the sun, has not caused a significant and relevant decrease in infections per million inhabitants as opposed to settings where healthy persons were exposed to natural sunlight radiation.[61]

Although some studies show that UV-C is virucidal, [11] WHO has stated that there is not enough evidence to prove that exposure to a temperature higher than 25°C and sunlight kills SARS-CoV-2; [62] this suggests that further research needs to be done in this field. It is also important to mention, that a great complication of using sunlight as a mitigating factor for COVID-19 on human skin or fomites, is the fact that the measurement of adequate amounts and necessary virucidal UV dosage will be difficult on an individual basis.

Solar radiation in Nepal

Nepal, a developing country, which could benefit from using sunlight as a sanitary measure to assist in combatting COVID-19. Nepal is located in the Southern Himalayas and has varying altitudes (100m in the south and 8,848.86 m in the northern part), as well as a varying amount of solar radiation across seasons. In winter the mean daily erythemal dose varied between 2.1 and 3.6 kJ/m^2, and in summer it varied between 4.6 and 9.7/m^2 this was calculated using the Total Ozone Mapping Spectrometer (TOMS) between 1996 and 2003.[61]

Timeline of COVID-19 in Nepal and seasons

The first case was recorded in January of 2020 after which the virus took 4 months to increase to a total of 100 cases (May,7,2020) and thereafter a short duration of twenty days to reach a total of 1000 cases.[61] The amount of daily new cases peaked during the low UV exposure winter period of 2020; in mid-October to mid-November where the daily new cases were at their highest, ranging between 1400- 5 743.[63] The daily new cases during the higher UV exposure Spring period after March 2021, decreased to a range of 46-167. [64]

Implementation of Solar exposure as preventative measure for COVID

Nepal has limited resources to allocate to medical infrastructure and care. The effective harnessing of natural sunlight would not only be an economical means of inactivating SARS-CoV-2 in Nepal, but would also help decrease the spread of the virus, thus decreasing the burden of new cases on the medical system. This would be particularly effective during summer, where the mean daily erythemal dose is 2.2-2.7 times higher than that in winter.[64] In winter, a combination of both artificial UVC lights (used with caution both at home and in the hospital), and natural sunlight when available, could be used as a disinfectant for fomites. Additionally, if there is high rainfall and cloud coverage during the summer months (which is expected in Nepal) [65], then artificial UV-C lamps can be used as an alternative to Sunlight exposure.

CONCLUSION

Humidity and temperature were found to have a lower influential role on SARS-CoV-2 survival outdoors as when compared to Solar UV radiation, which is the most viricidal physical element in the environment. Sunlight exerts its effect by damaging the RNA genome of the virus, preventing its replication, and leading to its inactivation. It also increases the level of reactive oxygen species in the air which could inactivate aerosolized suspended viral particles.

SARS-Cov-2 was demonstrated to be UVC sensitive while in blood products, and sensitive to UVB from simulated solar radiation, requiring a UBV flux of 28 J/m^2 for 99% inactivation. The sun exposure however, depends on a multitude of factors, namely time of day, season, cloud coverage, air pollution and geographical location.

Artificial UVC lights could be used as a viricide, in combination with solar disinfection in lower UV environments, however caution must be taken to prevent UVC's potential phototoxic and damaging effects on medical equipment, or whichever products are being treated.

Sunlight would be best used as a disinfection for fomites, but should not be relied upon as a sanitizer for human skin, as overexposure would have adverse effects. However controlled exposure to the sun has been demonstrated to boost individual immunity, suggesting that less severe lockdowns where healthy individuals are allowed to spend time outdoors, could be beneficial.

Expert opinion

Sunlight and UV exposure could be implemented as a sanitary measure globally, especially in higher UV environments. Where possible, persons having the facility to do so on their premises whether at home or at work, could be asked to expose fomites for sanitisation outdoors, in the 2-hour midday sun period, as a means of disinfection. For those not having such facilities, perhaps local authorities could propose a secure outdoor sanitising station for the use by its residents. Furthermore, people should be encouraged to spend time outdoors in the sun in a controlled manner to benefit from its immune boosting effects.

In its struggle to contain COVID-19, humankind has made great strides in the scientific field, in the rapid sequencing of the COVID genome and in the speed of development of vaccines. But a concerted effort is going to have to be made on all fronts, such as using the environment to our benefit, and being creative in our organisational abilities in fighting against the spread of this virus. The sun and the beneficial effects of sunlight, a powerful source of energy and a proven natural sanitiser, should be harnessed, and included in humankind's arsenal of tools in combatting this worldwide pandemic. It is imperative that all countries first world and third world alike capitalize on this method of sanitization, it is cost-free, easy and therefore can be implemented on a large scale with relative ease.

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