Design and Development of Smart and Safe Helmet for Inhibiting COVID-19 Virus Infection: A Simple Idea for Solving the Big Crisis

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Abstract: The coronavirus disease 2019 (COVID-19) has recently spread worldwide due to the SARS-CoV-2 virus and has been declared a pandemic. A possible solution to prevent or restrict the spread of the COVID-19 pandemic is proposed in this article. Uncontrolled spread of the virus through breathing is a major concern. It is ideal if the entry of the virus inside the human body is restricted, as prevention is better than cure. Use of a “Smart-HELMET” that allows uncontaminated air (virus/bacteria/microbes-free) to breathe is proposed. The design of the Smart-HELMET, its working mechanism, the chemistry and biology of the virus-cell interaction inside a human body are discussed in detail. The proposed “Smart-HELMET” prevents the spread of any respiratory illness through breathing. This is the need of the hour until a medicine/vaccine is made available in vivo condition.

Keywords: SARS-CoV-2, infection, coronavirus, epidemic, COVID-19, nanotechnology, public health.

1. INTRODUCTION

The ongoing outbreak of the severe acute respiratory syndrome (SARS-CoV-2)-associated respiratory infection, named coronavirus disease 2019 (COVID-19), is devastating, despite the precautionary measures taken across the globe. The International Committee on Taxonomy of Viruses (ICTV) [1, 2] named the disease and the virus COVID-19 and SARS-CoV-2, respectively. COVID-19 was first identified in the Wuhan city of China, in December 2019. Within a short span of 10 months, it was spread to more than 200 countries resulting in a pandemic. The most common symptoms are fever, dry cough, headache, sore throat, and sneeze [3, 4]. In the last two decades, there were two major coronavirus outbreaks which were named Severe Acute Respiratory Syndrome – Corona Virus (SARS-CoV) and Middle East Respiratory Syndrome – Corona Virus (MERS-CoV). The SARS-CoV human infection was reported in November 2002 in South China. 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stantaneously diagnoses COVID-19 at an early stage. Additionally, a huge man force is essential to provide health services to the infected without getting infected. However, quarantine is the only alternative that is currently being implemented across the world, and it cannot be a permanent solution. Social distancing and travel restrictions are the apparent solutions, along with quarantine.

This situation inspired the author to come up with the concept of “head quarantine”. Here, only a person’s head is quarantined using a Smart-HELMET allowing the person to work as usual without any other restrictions. This scientifically designed Smart-HELMET can deactivate coronavirus and any other biogenic pathogen that is considered a threat to mankind. This article depicts the present crisis of COVID-19 along with the structural features, infecting mechanism, and seriousness of SARS-CoV-2. Also, the design, working principle, and the advantages of the Smart-HELMET are highlighted. Smart-HELMET seems to be a viable solution without the panic and tension of quarantine.

2. BACKGROUND

2.1. Anatomy of a Coronavirus

The word ‘corona’ is derived from the Latin word “coronam” meaning “crown”. It is due to the presence of crown-like spike glycoprotein on the envelope of the virus. Corona belongs to the subfamily Orthocoronavirinae of the Coronaviridae family, and is classified into four classes: α-CoV, β-CoV, γ-CoV, and δ-CoV [9]. Literature [10] confirms that SARS-CoV-2 belongs to the class β-CoV. The recent scanning electron micrographs [11] confirm that the coronavirus (CoV) with the crown-like exterior is spherical/elliptic/pliomorphic in shape with a diameter in the range of 60 to 140 nm. The typical structure and electron microscope images of SARS-CoV-2 [12] are shown in (Fig. 2). (Fig. 2a) provides the internal and external morphology of SARS-CoV-2. The core consists of a single strand of RNA (positive sense genome typically 26,000 to 32,000 bases long) and nucleocapsid protein (N) encapsulated with envelope protein (E). The encapsulation is studded with membrane glycoprotein (M), hemagglutinin esterase (HE) protein, and a few spike glycoprotein (S) [13]. ‘N’ acts as an envelope around the RNA genome [14], hiding viruses from the human immune system’s interferons and RNA interference [11, 15-17]. ‘S’ is responsible for the infection. It gets connected with the receptor molecule of the host cell and fuses with the cell membrane. ‘M’ determines the shape of the virus and binds the inner content. ‘E’ controls the assembly, release, and infectivity of mature viruses.

(Fig. 2b) shows the transmission electron microscope (TEM) image of the SARS-CoV-19 virus by the National Institute of Allergy and Infectious Diseases' (NIAID) Rocky Mountains Laboratories (RML), USA [18]. The image confirms the morphology of SARS-CoV-19, as observed in (Fig. 2a). Images presented in (Fig. 2c-e) published by the National Institutes of Health, Maryland [19] shows the spike protein and spherical shape of the virus. These are the images of SARS-CoV-2 isolated from a patient in the U.S. and cultured in the lab. In (Fig. 2e), viruses are slightly distorted and oval-shaped [20, 21]. The new viruses formed and emerging out of the cell are depicted in (Fig. 2f and g) [21].

2.2. Destruction of a Human Cell by SARS-CoV-2

A schematic representation of the mechanism of destruction of a healthy human cell by SARS-CoV-2 is given in (Fig. 3). The SARS-CoV-2, suspected to be originated from
animals, reaches the human body via the mouth, nose, or eyes. Then it enters the human cell through the chemical interaction of its spike protein (S) and angiotensin-converting enzyme 2 (ACE2) of the cell membrane [22, 23]. Once the virus is inside, it releases its genetic material, RNA. The infected cell reads the RNA released by the virus and begins to manufacture new proteins that help to replicate the virus. With infection in progress, the infected cells begin to produce more copies of the SARS-CoV-2. These newly formed viruses accumulate inside the cell and then get ejected through the cell membrane. Millions of SARS-CoV-2 are replicated by an infected cell before it dies. The new viruses continue the cycle. As a result, the virus-infected human lungs get accumulated with fluid and dead cells. This reduces the working efficiency of the lungs resulting in breathing difficulty, followed by failure of the respiratory system due to acute respiratory distress syndrome (ARDS) and death [24, 25]. It was found the transmission of the virus takes place through the cough and sneeze of an infected person. The virus can remain active from several hours to several days leading to unnoticed entry into the human body.

Fig. (2). (a) 3D representation of SARS-CoV-2 with a cross-sectional view, displaying the Spike protein, HE protein, viral envelope, and helical RNA [12]. (Image Credits: Scientific Animations, under a CC BY-SA 4.0 license.). (b-e) TEM images with false-coloring of SARS-CoV-2 emerging from host cells cultured in the lab. (f, g) Electron microscope images with false-coloring of SARS-CoV-2 virus from a patient in the US; the viral particles are colored yellow (f) and orange (g) as it emerges from the surface of a cell. (Image credit: (b - g) The National Institute of Allergy and Infectious Diseases (NIAID) Rocky Mountains Laboratories (RML) [18, 19, 21]. (A higher resolution / colour version of this figure is available in the electronic copy of the article).
The entry of the virus into the human body is predominantly through the nose, mouth, eyes, and ears. The possible solution to this problem is to prevent the entry of the virus into the human body through these entry points by wearing the Smart-HELMET.

3. DESIGN OF THE SMART-HELMET

Smart-Helmet is not a new concept and is being used for various other applications. The use of Smart-Helmet by astronauts for real-time monitoring of physiological parameters, scuba divers, and bikers is beneficial. Smart-Helmets with alcohol detection and cloud-enabled GPS tracking for accident monitoring are common. The incorporation of a biomedical sensing system for comprehensive real-time monitoring and displaying physiological parameters by astronauts during extra vehicular activities (EVA) was proposed by Ding-Yu Fei et al. [26]. Nidhi Upadhyay and coworkers [27] proposed a Smart-Helmet with the Internet of Things (IoT) based detection and monitoring of potholes and real-time location-based monitoring of air pollution. Very recently, M. N. Mohammed et al. [28] proposed a Smart-Helmet integrated with a thermal imaging system capable of detecting the coronavirus based on images captured by an IoT-enabled thermal camera without any human intervention. Furthermore, it is also integrated with a facial-recognition system, which can identify a person passing nearby, measure the body temperature, and display their personal information. However, the Smart-Helmet system proposed in this article will prevent the entry of the coronavirus into the human body. The concept of this Smart-Helmet capable of safeguarding people from airborne diseases is based on existing Smart-Helmets used for other purposes.

The proposed Smart-Helmet consists of (a) air suction pump, (b) air purification unit, (c) air cooling unit, (d) virus/bacteria and gas sensor, (e) air quality monitoring application, (f) air vent pump, and (g) power bank, as represented in (Fig. 4). Working of the Smart-Helmet is as follows:

- The air suction pump with flow control sucks air from the atmosphere into the air purification unit. This overcomes the disadvantage of suffocation generally faced by a person wearing a mask.
- The air purification unit consists of two sections, an optional UV or visible irradiated photocatalyst coated spiral tube and a spiral heating coil made of copper. The virus/bacteria present in the air are killed by the UV-visible light due to photocatalytic activity [29-33] in the first section. Furthermore, the UV-visible treated air passes through the section where the temperature is maintained between 100 and 300°C. In this temperature range, any kind of virus, including coronavirus, gets decomposed [34-37]. The decomposition of the virus is more effective if the air is exposed to high temperatures for a prolonged dura-
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tion, which can be achieved by adjusting the length of the spiral coil. Since the virus is made up of protein, it may decompose to oxides of carbon and hydrogen at temperatures around 300°C. As the heating coil is good enough to decompose the virus, the UV unit can be made optional. The air passing through these two stages mainly contains oxygen, carbon dioxide, water vapor.

- The hot air leaving the purification unit is passed through a cooling unit consisting of a nanomembrane [38-40] to filter the decomposed virus/bacterial debris before it is inhaled.
- The cooled air is made to pass through a sensor [41], which confirms the absence/presence of virus/bacteria, and also measures the quality of oxygen in the air before inhaling.
- The sensor is linked to a mobile phone-based IoT enabled air quality monitoring application [42, 43], and the information is also displayed on the helmet screen confirming that the person is breathing virus/bacteria-free air.
- A mechanism is required to pump out the air exhaled by the person. A vent pump is used for this purpose.
- This Smart-HELMET consumes power and that power is supplied using a suitable built-in power bank.

 UV light with a wavelength between 200 and 300 nm (germicidal UV spectrum) is found to be very effective in deactivating viruses and bacteria [44-46]. The UV irradiation damages the chemical structure of genomes (DNA and RNA) present in viruses/bacteria/protozoa by breaking bonds and forming photo dimeric lesions [47-50]. Wiggington et al. revealed that UV radiation of 253.7 nm can damage viral RNA contributed to site-specific protein [51]. Furthermore, Tsuyoshi Tanaka et al. investigated the inactivation mechanism of a single-stranded RNA non-enveloped virus using UV-C (100 to 280 nm) radiation with different wavelengths [52]. Similarly, there is substantial evidence that by heat treatment, the virus or bacteria can be killed completely.

![Fig. (4). Schematic representation of scientifically designed Smart-HEMET for preventing infection from deadly viruses. (A higher resolution / colour version of this figure is available in the electronic copy of the article).](image-url)
4. SMART-HELMET WORKING MECHANISM

Along with carrying genetic information, RNA molecules in cells also execute many important biological functions such as ligand binding and tertiary folding initiation of proteins [53]. These RNA and other structural components of viruses cannot sustain the temperature above 100°C [54-56]. Therefore, by passing the air through UV irradiated tubes followed by heated (100 to 300°C) copper coils, as shown in (Fig. 5), the virus/bacteria and other pathogens are killed. The debris of the decomposed virus is mostly oxides of carbon, hydrogen, nitrogen, and sulfur (Step 4, Fig. 5), as the proteins of the virus are mostly made of these elements. This debris is filtered by the nano-adsorbents present in the membrane of the cooling unit (Step 5, Fig. 5). There are various demonstrated nano-adsorbents such as nano MgO [57], Nano-CaO–ZnO [58], CaO [59], N-doped reduced graphene oxide@TiO₂ [60], for CO₂ adsorption; nano-CuO-Fe₂O₃/TiO₂ [61], graphene and N-doped graphene [62], N-doped carbon spheres [63], nano GaN [64] for SO₂ adsorption; carbonaceous adsorbents containing silver nanoparticles [65], urea-modified ordered mesoporous carbon [66], for NO₂ adsorption; and goethite [67] for phosphate ion adsorption. These nano-adsorbents can be used to design the nanomembrane. Furthermore, the quality of air, presence or absence of virus, bacteria, and oxides of C, H, N, etc. are confirmed by gas sensors (Step 5, Fig. 5). The usual rate of respiration in a healthy human is 10 – 20 breaths per min (0.16–0.33 Hz). The required inflow and outflow of air can be set with the help of the flow control mechanism in the suction pump and the vent pump, respectively. The Smart-HELMET should be made airtight to prevent the entry of air at points other than the designated entry point. Microphones and speakers should be suitable placed for convenient communication. This conceptual design of Smart-HELMET, when comes out as a product, can save humanity from the COVID-19 crisis without the need for quarantine. However, the position of components, dimension, specifications, additions/deletions can be made suitably to enhance its efficiency, ergonomics, safety, viability, and affordability [68].

Fig. (5). Schematic representation of the working mechanism of the Smart-HELMET. (A higher resolution / colour version of this figure is available in the electronic copy of the article).
CONCLUSION

The entire world is under distress due to the uncontrolled spread of COVID-19 by the SARS-CoV-2 virus. Currently, quarantine and social distancing have proved to be the best solution to prevent this crisis. However, the quarantine cannot be a permanent solution as it has a deep impact on the global economy. The development of a vaccine is time-consuming. Therefore, instead of quarantining mankind, this COVID-19 crisis can be effectively addressed by using the Smart-HELMET. By understanding the chemistry and biology of SARS-CoV-2, the Smart-HELMET is conceptually designed based on the available literature. This innovative "Smart-HELMET" is completely based on proven concepts and available resources. It should not take much effort to bring it to the market. Affordability can be increased by mass production. The collective effort of the government and industries can make this possible within a short period. Humanity can be brought back to its normal lifestyle with the help of this Smart-HELMET.

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CONFLICT OF INTEREST
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