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Review Article

Chemistry and Covid-19: A Review on the Central Role of Chemistry in the Understanding, Prevention, Diagnosis and Treatment of Covid-19

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Abstract

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by the newly discovered Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). On 30 January 2020, the World Health Organization declared the disease a Public Health Emergency of International Concern, and on 11 March 2020, it was declared as a pandemic. Research and development have been critical in combating the global disease crisis caused by COVID-19 where Chemistry plays an important part in everything from virus composition to pathogenesis, vaccine and treatment, and the creation of materials and procedures used by fundamental laboratories, virologists, and clinicians. Fundamental studies into the molecules that control viral formation and activity will speed up the development of treatments and vaccines for infectious diseases. Most fundamental chemistry-based scientific organizations and pharmaceutical companies are collaborating to gather more knowledge about SARS-CoV-2, develop better analytical methods, and design vaccines to alleviate the situation as soon as possible. To date, there are several COVID-19 vaccines available, all of them designed using the knowledge of chemical behavior of viruses and many screening techniques are developed based on their molecular nature. Hence, this review is an approach to clarify the nature, chemical aspects of viruses, virus protection using the Chemistry shield, and potential research possibilities, the effectiveness of siddha formulations, and food and nutrition from the perspective of chemical behavior.

Keywords: COVID-19; SARS-CoV-2; Chemistry; Prevention; Diagnosis; Medicine; Pandemic; Vaccines; Antiviral Drugs; Siddha Medicine; Oxygen; Food and Nutrition

Introduction

The COVID-19 pandemic has impacted everyone in one way or another. Functioning of educational and non-educational institutions, governments and companies around the world has been disrupted. Times like these need a constructive, flexible and visionary strategy. We are conscious of the expanded development of vital materials such as disinfectants, medical instruments, ventilators, safety devices, and personal protection equipment, intensive care facilities with medications and appliances, and safety garments. In learning anything from virus composition to pathogenesis, vaccine development and treatment, as well as in improving materials and procedures used by fundamental researchers, virologists and clinicians, chemistry has a vital role to play. Hence, this literature review aims to provide an overview of the important contributions of chemistry in understanding the viral structure and mechanism, prevention, development of diagnostic tools and treatment methods in the management of COVID-19.

The pandemic of covid-19

Throughout the history of mankind, infectious agents have remained our constant companion, wreaking havoc and ravaging lives. But epidemics and pandemics are newer occurrences as earlier humans lived in small, isolated communities with less contact with each other. When trade and travel increased, so did the spread of communicable diseases from one region to another.

Recent years have witnessed the emergence of several different viral outbreaks which are very difficult to contain, the latest being the current pandemic of COVID-19 caused by the SARS-CoV-2, a new member in the family of coronaviruses.

The first human coronavirus was identified as one of the causative agents of the common cold in the 1960s. Later, researchers found a group of similar human and animal viruses with crown-like spikes and named them coronaviruses (as corona is Latin for crown). Coronaviruses were regarded as non-fatal viruses until 2002 when an outbreak caused by the SARS (Severe acute respiratory syndrome) virus emerged in southern China and quickly spread to 28 other countries. Transmission of the virus occurred through direct contact with infected individuals after the onset of illness. More than 8000 cases were reported with around 770 mortalities [1,2]. In 2012, a less contagious but more deadly coronavirus called the Middle East respiratory syndrome (MERS) virus caused highly pathogenic respiratory tract infections in Saudi Arabia and other nearby countries in the Middle East region [1].

By the end of 2019, a new coronavirus was discovered in Wuhan, China and was named 2019 novel coronavirus (2019-nCov) by the Chinese researchers. The International Committee on Taxonomy of Viruses (ICTV) renamed the virus as Severe respiratory syndrome coronavirus 2 (SARS-CoV-2) and the disease that it caused as the Coronavirus disease 2019 (COVID-19) [3,4]. From China the disease quickly spread to all corners of the globe (Figure 1) and started the massive battle against the insufferable new coronavirus. The ongoing pandemic has more than 166,195,983 cases and at least 3,444,498 confirmed deaths as of 22 May 2021 [5,6].

Figure 1: Jurisdictions with cases confirmed as of May 22, 2021, 4:50 PM GMT+5:30.

Source: https://www.bloomberg.com/graphics/2020-coronavirus-cases-world-map/

Understanding the pathogenesis of covid-19

Before finding a solution to the pandemic problem, questions on the causative agent, infection mechanism and disease progression had to be answered. This didn't take long as advancements in science and technology enabled researchers all over the world to quickly get to know the new killer virus which the entire world was currently dealing with. Understanding the pathogenesis of the disease was crucial for designing preventive strategies, developing diagnostic tools and therapeutics and synthesizing vaccines. The knowledge and technological advancement of chemistry played a huge part in unveiling the facts about the virus and the way it worked.

Structural and biochemical characterization of SARS-COV-2

Coronaviruses (CoVs) are enveloped, single-stranded positive-sense RNA viruses belonging to the Coronaviridae family [7]. According to the genomic structure and phylogenetic association, coronaviruses have been categorized into the Coronavirinae subfamily, consisting of four genera, Alphacoronavirus (αCoV), Betacoronavirus (βCoV), Gamma coronavirus (γCoV) and Delta coronavirus (δCoV) [8]. Evolutionary pattern study of coronaviruses showed that αCoV and βCoV evolved from bats and mice, while γCoV and δCoV were found to be derived from avian sources [9]. When seen through electron microscope, the virus particles ranging in size from 70 to 90 nm are found in intracellular organelles, particularly in vesicles [10]. The RNA genome of SARS-CoV-2 is approximately 29.9 kb. As soon as the genome of the new virus was sequenced, researchers started synthesizing the viral proteins and elucidating their structures as this was necessary for developing therapeutics to target the viral proteins [11].

SARS-CoV-2 contains four structural proteins (Spike, Envelope, Membrane, and Nucleocapsid) and sixteen non-structural proteins (nsp1-16) [12]. Structural biologists used X-ray crystallography and cryo-electron microscopy for unraveling the structures of the viral proteins. These two key tools were used for rapid and accurate data gathering and capturing and constructing 3D protein models.

Figure 2: Structure of SARS-CoV-2.

Source: Adapted from an image by Davian Ho for the Innovative Genomics Institute.

The stereochemistry of the various amino acids along with the hydrogen bonding between them is responsible for protein folding which gives them their functional properties. Some of the viral proteins function as catalysts to drive the chemical reactions of the biological processes inside their host cells for viral replication while others are involved in functions like protecting the viral genome or helping the virion to penetrate in to the host cells.

Infection mechanism

Viral infections start with the binding of the viral particles to the host cell surface receptors. Therefore, receptor recognition is an important factor in the cell and tissue tropism of a virus. The viral mode of entry into the host cells is similar in both SARS and SARS-CoV-2 where the spike protein plays an important role by binding to the angiotensin-converting enzyme 2 (ACE2) receptor [13]. The human ACE2 receptor is expressed on the epithelial cells of the lung and intestine, and to a lesser extent, in the kidney, heart, adipose tissues, and reproductive tissues. Once the spike protein is bound to the receptor, it is activated through proteolytic cleavage by a host protease near the junction between its S1 and S2 domains. The S2 domain N-terminus gets inserted into the cell membrane and the viral and cellular membranes fuse together. The viral genome is then transferred to the cytoplasm where viral replication occurs [14].

Figure 3: Infection mechanism of SARS-CoV-2.

Critical interactions between the viral spike and ACE2 receptor

Researchers have identified an extended network of salt bridges, hydrophobic and electrostatic interactions, and hydrogen bonds between the receptor-binding domain (RBD) of the SARS-CoV-2 spike protein and the ACE2 receptor using all-atom molecular dynamics (MD) simulations. The effect of mutations on these residues on the RBD was insufficient to destabilize the binding but reduced the average work to unbind the spike from the receptor. As the hydrophobic end of the RBD serves as the main anchor site and is the last to unbind from the cellular ACE2 receptor under force, it is proposed that blocking the hydrophobic surface with antibodies could prove to be an effective strategy to prevent the viral spike from interacting with the ACE2 receptor [16].

Figure 4: Atomic model of the SARS-CoV-2 S protein bound to the ACE2 receptor on the host cell.

(a) The structure of the full- membrane length S protein in complex with ACE2. (b) The structure of an S protomer with its RBD in the down and up positions. (c) MD simulations were performed for RBD of the S protein in complex with the PD of ACE2.

Source: Taka., *et al*. (2020) [16].

Role of chemistry in the prevention of SARS-COV-2 infection

Material scientists and analytical chemists are finding ways to eliminate contact transmission of the new coronavirus by fabricating effective personal protection gear, developing antiviral coating materials, as well as creating new chemical formulations for antiviral disinfection.

Surface disinfectants

SARS-CoV-2 is found on various common inanimate surfaces and their presence depends on temperature, pH and the humidity of the surrounding. The highly risky surfaces should be cleaned or mopped more often using proper disinfectants. The most important characteristics of the disinfectants are the low contact time combined with antiviral activity. In general, quaternary ammonium compounds (QACs), Hydrogen peroxide, Alcohol (ethanol, isopropyl alcohol, phenol), Aldehyde, Hypochlorous acid, Octanoic acid, Citric acid conjugate with silver ions, sodium hypochlorite and Sodium bicarbonate are the most common ingredients of disinfectants. Among them, disinfectants which include Alcohol, Ethanol (78% - 95%) and isopropanol (70% - 100%) are used as effective disinfectants because they have less toxic impact on human skin along with strong virucidal activity.

The disinfection ability of the QACs is because of their molecular structure in which the central nitrogen atom acts as the cation portion and is surrounded by the negatively charged halogen anions. Also, the QACs are divided into different classes due to the chemistry of the alkyl groups, the number of nitrogen atoms, the division of the carbon chain, and the presence of aromatic groups. All of these characteristics decide the antimycobacterial activity of QACs. This is because of the variations of the chain length, nuclear size, and the basicity of the ammonium complex. Moreover, the presence of nonpolar tails causes them to be strong against lipid-containing viruses such as the SARS-CoV-2. The long chains of the complexes increase the permeability because of the attachment of cationic portions to the negatively charged nucleic acids inside the capsid which cause the virucidal activity [17].

Halogen compounds are another main class of disinfectants (hypochlorous acid, hypochlorite ions). One of them (sodium hypochlorite) is prepared as follows:

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$$

$$HOCl + NaOH \rightarrow NaOCl + H^+$$

HOCl has more biocidal potency compared to NaOCl. This is because of the unsaturated lipid layering which increases the cellular permeability. Furthermore, it is a stronger oxidizing agent than sodium hypochlorite. However, 1:1000 dilution of 5% sodium hypochlorite is used as usual for mopping nonporous surfaces. Other disinfectants (peroxides and superoxides) act by inducing the generation of free radicals such as superoxide ion, hydroxyl ion, peroxyl ion etc. Peroxide and superoxides-based disinfectants are considered the best disinfectant for the terminal disinfectant category. In addition, it was experimentally proved that ethanol, isopropanol, 45% isopropanol with 30% n-propanol, formaldehyde, povidone-iodine (H_2O_2) effectively inactivated coronavirus at various strengths. Overall, all disinfectants are chemical compounds that make chemical reactions to inactivate coronavirus present on different types of surfaces [17].

Developing antiviral coatings for surfaces

SARS-CoV-2 particles from the respiratory droplets of infected people can survive on surfaces for a substantially longer duration of time. Researchers have proposed the use of various materials as coating on surfaces which could disrupt the virus. A chemical coating consisting of cuprous oxide (Cu_2O) particles bound with polyurethane was found to be effective in deactivating the SARS-CoV-2 virus. The coating mixture could be easily painted on doorknobs, desktops, bus seats and glass and stainless steel surfaces. After 1 hour of coating, there was a 99.9% reduction in the viral titer and the coating also performed well in the cross-hatch durability test and remained intact and active after 13 days of being immersed in water or after exposure to multiple cycles of exposure to the virus and disinfection [18].

Figure 5: A regular doorknob and a doorknob coated with Cuprous oxide-polyurethane coating mixture

Source: Behzadinasab., *et al.* (2020) [18].

Hand hygiene

Alcohol-based hand sanitizers, and hand washing are crucial for hand hygiene. Alcohol has a good biotic potency, but the strength of the disinfection property of the alcohol depends on the strength and the type of alcohol. The antiviral activity of various alcohols is measured from the viral infectivity index. According to the viral infectivity index formulation, ethanol (85% v/v), glycerol (0.725% v/v) and hydrogen peroxide (0.125% v/v) have better antiviral activity compared to isopropanol (75% w/w) and glycerol (0.725% v/v). Moreover, the alcoholic concentration below 50% has negligible biocidal activity. Alcohols with higher concentrations (>90) have high contact time. Therefore, they seem to be ineffective [17].

Further, the efficacy of alcohol-based disinfectants is powered by the addition of inorganic or organic acids like citric acid, L - lactic acid, peroxyacetic acid, fumaric acid, phosphoric acid, etc. Here, the incomplete dissociation of organic acid causes the high penetration power of disinfectant which helps to work properly. With a mean log10 reduction value of > 4 on a 30 s exposure duration, a 55 percent ethanol concentration mix with 0.7 percent v/v phosphoric acid displays significant virucidal activity. Observations with 73.5 percent ethanol + 0.2 percent peracetic acid, 78.8 percent ethanol + 0.1 percent citric acid + 1 percent lactic acid, and 73.5 percent ethanol + 0.2 percent peracetic acid with mean log10 reduction values > 4 on exposure period of 30 s were similar [17]. Therefore, ethanol (60%-70%), isopropanol (70%-72%) have effective disinfectant ability. Hence, WHO has recommended the public to use alcohol-based sanitizers frequently [14]. However, with the use of sanitizers, people have to be careful because the frequent use of alcohol sanitizers can destroy the oil layers of the skin. As a result, the pathogens easily enter the deep layers of the skin and infect people. Then, it will not be preventive care anymore. Therefore, it is better to be careful with it.

Green hand sanitizers are getting popular day by day. Green sanitizers include ingredients which are collected from natural sources. They are available in both gel and liquid foam and kill more than 99% of gems, and do not damage the skin and provide smooth moisture. These sanitizers are fragrance free and dye free [19].

In contrast, washing hands with soaps have more advantages than the use of alcohol-based sanitizers due to the zero-fire hazard capability. The soaps we use have compounds called surfactants, which can inactivate germs like coronavirus in the skin. Mainly, soaps are composed of salt of fatty acids with solid fat (olive oil, coconut oil, palm oil, rice bran, sunflower seed oils, and lard), emollient and texture enhancer (glycerin, sorbitol), surfactant (sodium lauryl sulfate alkyl benzene sulfonate alkyl phenol ethoxylate linear alkyl sulfonate) and water softener (Penta sodium penetrate, tetrasodium etidronate, and tetrasodium EDTA). Each soap molecule contains a long hydrocarbon chain and a nonpolar anionic carboxylated head. The non-polar head binds with the phospholipid layer of the viral envelope. When hands are washed with water, the coat of the virus is broken and destroyed. In soap lather, a combination of molecules assembles into bubbles called micelles that trap viral matter and other biomaterials and rinse them.

Figure 6: Schematic diagram of how soap reacts with virus
Source: Earar*., et al.* (2020).

The effectiveness of the soap depends upon the chemistry and composition of fats. Furthermore, the length of the hydrocarbon chain and the unsaturation of fatty acids are responsible for the cleansing ability of the soaps. Soaps with short hydrocarbon chains show considerable lathering potential due to high water solubility, but the hydrocarbon chains < 10 shows low lathering potential with objectionable odor and skin irritation. In contrast, fatty acids with long chains prove high cleaning properties with low lathering ability due to poor water solubility. In particular, fatty acids like palmitic acid, stearic acid, oleic acids, etc provide more preventive care against COVID -19. Therefore, the chemical composition of soap is essential for the effective preventive care of hand hygiene against the SARS-CoV-2. It is recommended to wash hands with soap for 20 seconds [17]. Sanitizers also made from natural resources. Recently, In Indonesia, scientists showed a simple way of producing hand sanitizer from fermented palmyra toddy (The Jakarta Post (2020, April 9).

Personal protective equipment (PPE)

Prevention of COVID-19 basically relies on the use of PPE which includes gloves, face masks/respirators, goggles/face shields, and gowns.

Face masks/respirators

WHO has declared that the COVID-19 may be an airborne infection. Hence, it can be transmitted through respiratory droplets that release to the air. Those droplets spread around 1m from a diagnosed person's cough or sneeze. Droplets (aerosols) which have the diameter > 5 - 10, enter the body through the mouth or nose, and spread into the epithelial layer of the upper respiratory and gastrointestinal tract. Therefore, physical barriers (masks, face and mouth protector etc.) can reduce the risk of spreading the droplets.

Figure 7: Types of Masks and their protection efficiency.
Source: varsoyhealthcare.com.

N–95 (four layers) type of face mask is recommended by WHO [19]. The first layer includes spun-bond polypropylene with a citric acid coat that restricts the penetration of macromolecules of size > 0.5 micron and traps the microparticulates of size < 0.5 microns. The second layer is an antiviral layer that contains rayon with copper and zinc ions that will kill the trapped virus. The barrier layer is the third layer composed of non-woven melt blown polypropylene to filter out the particulates less than 0.3 microns. The last layer that contains spun-bond polyene is fluid resistance. The sialic acid of the first layer binds to the spike proteins of the viruses. The metal ions of the second layer disrupt the membrane integrity, damage DNA/RNA and essential proteins. Apart from it, some masks have an extra layer with activated charcoal as a strong adsorbent layer. It traps and inactivates the virus particles by absorbing the surrounding moisture.

A team of researchers have reported the development of a universal, antiviral, and antibacterial lignin-based, photopolymerizable, and antimicrobial coating (using lignin 2,2′,4′-terpyridine methylammonium chloride (LTMAC) and lignin adenine hexyl ammonium chloride (LAHAC)) that can be dip-/spray-coated over conventional mask fabrics to exhibit antimicrobial activities (Figure 8) [20]. This coating on masks is highly effective and rapidly inactivates multiple types of viruses, i.e., human (alpha/beta) coronaviruses, the influenza virus, and bacteria, irrespective of their modes of transmission (aerosol or droplet) [20].

Figure 8: Synthesis and characterization of antimicrobial coating materials and fabrication of antimicrobial face mask fabrics.

(A) Schematic representation of the UV cross-linked, antimicrobial coating on the surface of the face mask. (B) Synthesis of lignin conjugated 2,2′,6′,2″-(terpyridine-1-methylammonium chloride-1-yloxy) methyl epoxide (LTMAC) and the corresponding 1H NMR (i) and synthesis of lignin conjugated hexyl adenine epoxide (LAHAC) and 1H NMR spectra of the product (ii). (C) FTIR spectra of the fabricated spunbond PP fabrics with UV cross-linked, LTMAC, and LAHAC-based hydrophobic (HYD) and hydrophilic (HPL) antimicrobial polymer coatings (i), melt-blown (ii), and spunbond-N95 (iii).

Source: Kumaran., *et al.* (2021) [20].

Goggles/face shields

WHO recommends wearing protective transparent glass with zero power, and well-fitting goggles/face shields which cover the whole area properly. Effective goggles made up of acetate, propionate, and polycarbonate offer good visual clarity and optical quality with less eye strain. Lighter, easy-to-use and ergonomic medical face shields can be assembled without extra components (such as elastic bands, softening materials, and clips) using Additive Manufacturing Technology [21].

Surgical gowns and aprons

Surgical gowns are prepared from water-resistant Nylon 6,6 material with a silicone coating that can be laundered and re-used up to 50 times [19]. A wide variety of metal and metal oxide nanoparticles (such as silver, copper, titanium, gold, and zinc) have been introduced as antiviral agents because of their unique physicochemical properties due to their small size and high specific surface area, which enable them to interact with viruses and other micro-organisms [22]. These nanomaterials are being used in the development of protective clothing.

Chemistry in the diagnosis of covid-19

It may seem that the field of disease diagnostics is mainly run by microbiologists but chemists are behind the design, development and validation of a large number of diagnostic tools.

Early detection of SARS-CoV-2 infection is very much important as delayed diagnosis leads to minimal control of disease progression and transmission. There are a number of nucleic acid- and protein-based diagnostic tests currently available for COVID-19. The most preferred initial diagnostic test is nucleic acid amplification testing (NAAT), most commonly with a reverse-transcription polymerase chain reaction (RT-PCR) assay [23].

The protein-based diagnostic tests are of two types namely, the Antigen test and the Antibody test. Antigen tests can detect the presence of viral proteins in the sample. Just like the RT-PCR test, these tests are able to identify a current infection. The IgM/IgG antibody tests indicate whether a person had SARS-CoV-2 infection in the recent past.

So far the Indian Council of Medical Research (ICMR) has validated 72 Antigen based rapid test kits and found 22 kits to be satisfactory (Table 1). Similarly, ICMR has validated 186 Antibody based rapid test kits and found 28 kits to be satisfactory (Table 2) [24,25].

S. No.	Name of the kit	Name of the company
1.	STANDARD Q COVID-19 Ag	SD Biosensor, South Korea/ India
2.	Accucare COVID-19 Anti-gen Lateral Test Device	LabCare Diagnostics Ltd., Valsad (Gujarat), India
3.	BIOCARD Pro COVID-19 Rapid Ag test kit	Trivitron Healthcare Pvt. Ltd., Chennai (TN), India
4.	COVID-19 Ag Respi Strip (VTM)	Coris Bioconcept, Belgium
5.	VSTRIP COVID-19 Antigen Rapid Test	Panion and BF Biotech., Taiwan
6.	PCL COVID-19 Rapid FIA	PCL Inc, South Korea
7.	Sure status COVID-19 Ag Test	Premier Medical Corpora-tion, Valsad (Gujarat), India
8.	Angcard COVID-19 rapid Antigen Test kit	Angstrom Biotech Pvt. Ltd., Alwar (Rajasthan), India
9.	GenBody COVID-19 Ag rapid Test kit (POCT)	GenBody Inc., South Korea
10.	SENSIT Rapid COVID-19 Ag kit	Ubio Biotechnology Systems Pvt. Ltd., Kochin (Kerala), India
11.	COVID-19 Antigen Detec-tion Test	Meril Diagnostics, Vapi (Gujarat), India
12.	Alpine COVID-19 Antigen Rapid Test kit	Alpine Biomedicals Pvt. Ltd., Ambala (Haryana), India
13.	Standard F COVID-19 Ag FIA Test	SD Biosensor, South Korea
14.	Oscar CORONA Rapid Ag Test kit	Oscar Medicare Pvt. Ltd., Delhi, India
15.	ImmunoQuick COVID-19 Antigen Rapid Card test kit	ImmunoScience India Pvt. Ltd., Pune (Maharshtra), India
16.	iNSTAXPLOR™ COVID-19 Ag - Rapid Antigen Test	STRUmed Solutions Pvt. Ltd., Chennai (TamilNadu), India
17.	Panbio Covid Antigen Rapid Test	Abbott Rapid Diagnostics Division, Chicago
18.	EzDx COVID-19 Rapid Ag Test	ADVY Chemical Pvt. Ltd., Thane (Maharashtra), India
19.	Vitros SARS-CoV-2 Ag Test CLIA Kit	Ortho Clinical Diagnostics, Mumbai (Maharashtra), India
20.	SAIC-19 Ag Kit	Sri Sathya Sai Institute of Higher Learning, Anantpur (Andhra Pradesh), India
21.	FutureCare COVID-19 Ag detection Test kit	Medzome Lifesciences Pvt. Ltd., Solan (Himachal Pradesh), India
22.	Pathkit SIMPLE COVID-19 Ag Rapid Test	Pathkits Healthcare Pvt. Ltd., Gurugram (Haryana), India

Table 1: List of Antigen test kits approved by ICMR.

S. No.	Name of the kit	Name of the company
1.	Coronavirus (COVID-19) IgG/ IgMRapid Test	Voxtur Bio Ltd, Surat (Guja-rat), India
2.	COVID-19 IgM/IgG Antibody Detection Card Test	VANGUARD Diagnostics, Delhi, India
3.	Makesure COVID-19 Rapid test	HLL Lifecare Limited, Guru-gram(India) India
4.	ACCUCARE IgM/IgG Lateral FlowAssay kit	Lab Care Diagnostics India Pvt. Ltd,Mumbai (Maha-rashtra), India
5.	Abchek COVID-19 IgM/IgG Antibody Rapid Test	NuLifecare, Noida (UP), India
6.	One Step Corona Virus (CO-VID-19) IgM/IgG Antibody Test	Alpine Biomedicals, Ambala (Haryana), India
7.	COVID 19 IgM/IgG Rapid Test Kit(ver 2.0)	Medsource Ozone Biomedi-cals, Haryana, India
8.	Immuno Quick Rapid Test for Detection of Novel Corona-virus (COVID-19) IgM/IgG Antibodies	Immuno Science India Pvt. Ltd,Pune, India
9.	BMT COVID-19 IgG/IgM RapidTest Kit	BMT Diagnostics (Rafael Diagnostic), Israel
10.	One Step COVID-19 IgM/IgG Antibody	SIDAK Life Care Pvt. Ltd., NewDelhi, India
11.	Xamin COVID-19 Rapid Test Device	Diagnocure, Solan (HP), India
12.	ImmunoQuick COVID-19 IgG Rapid Test Device	ImmunoScience India Pvt. Ltd.
13.	PCL COVID-19 IgG/IgM Rapid Gold	PCL, Inc., Seoul, Republic of Korea(Hemogenomics Pvt. Ltd.)

14.	Rapid test - Corona Antibody (IgM/IgG)	Oscar Medicare Pvt. Ltd., (Delhi)India
15.	Edinburgh Genetics COVID-19 Colloidal Gold Immunoassay Testing kit IgG/IgM combined	Edinburgh Genetics, UK
16.	COVID-19 Rapid Test	BioPanda Reagents, UK Inbios (Delhi), India
17.	TRUSTline COVID-19 Ab RapidTest	Athenese-Dx Private Limited,Chennai (TamilNadu), India
18.	Corona virus (COVID-19) RapidTest	Beijing Zhangjian Antai DiagnosticTechnology, China
19.	Rapid Test for detection of IgM andIgG antibodies	Zephyr Biomedicals (A Division ofTulip Diagnostics Pvt. Ltd.)
20.	Corona IgG Ab detection Test (OSCOVID-IgG)	Oscar Medicare Pvt Ltd., (Delhi)India
21.	IgG Covimmuno Device	Zephyr Biomedicals (A Division ofTulip Diagnostics Pvt. Ltd.)
22.	EdgeXpress Covid-19 Ab detectionTest Kit (IgG/IgM)	Edge Pharma Pvt. Ltd., Mumbai(Maharashtra), India
23.	EzDxTM Covid-19 IgG/IgM RapidAntibody Test	Advy Chemicals Pvt. Ltd.
24.	Optra Shield COVID-19 (IgG) Rapid Test Kit	Oscar Medicare Pvt. Ltd.
25.	SARS-CoV-2 Antibody test (Lateral flow method)	Guangzhou Wondfo Biotech M R Roofs Private Ltd Abbott Laboratories Zydus Cadilla
26.	COVID-19 IgM/IgG Antibody Rapid Test	Zhuhai Livzon Diagnostics (CE-IVD)
27.	Biomedomics COVID-19 IgM IgGRapid Test	BioMedomics (CE-IVD), China
28.	Standard Q Covid -19 IgM/ IgG Duo test	SD Biosensor, Inc South Korea

Table 2: List of Antibody test kits approved by ICMR.

Most of the simple kits that have been developed for the diagnosis of COVID-19 are Lateral flow tests (LFTs), also known as lateral flow immunochromatographic assays. LFTs use a nitrocellulose membrane, labels or coloured nanoparticles, and antibodies. When a sample is added on the test device, it flows along, passing through the conjugate pad and onto the nitrocellulose membrane and then to the absorbent pad. The sample pad, which in some cases contains a filter to ensure controlled flow, acts as the first stage of the absorption process. The conjugate pad, which contains the conjugated labels and antibodies, will receive the sample. If the target protein is present in the sample, the immobilized conjugated antibodies and labels will bind to the target and continue to migrate along the test strip. As the sample moves along the device the binding reagents situated on the nitrocellulose membrane will bind to the target at the test line and result in a coloured line which means positive [26].

Figure 9: A NASA illustration of a lateral flow assay.

Source: http://exploration.nasa.gov/articles/images/homeplanet_3.jpg.

These lateral flow assays are based on the principle of paper chromatography and are now extensively improved. LFTs can be developed for both antigen detecting tests or antibody detecting tests as the underlying principle is the same.

Field-effect transistor (FET)-based biosensing devices can be used for highly sensitive and instantaneous measurements using small amounts of analytes. Seo., *et al.* (2020) have reported developing a FET-based device where the sensor is produced by coating graphene sheets of the FET with a specific antibody against SARS-CoV-2 spike protein and the device could detect the spike protein at concentrations of 1 fg/mL in phosphate-buffered saline and 100 fg/mL clinical transport medium. In addition, the FET sensor was able to successfully detect SARS-CoV-2 in culture medium (limit of detection [LOD]: 1.6 × 101 pfu/mL) and clinical samples (LOD: 2.42 × 102 copies/mL) [27].

Figure 10: Schematic diagram of COVID-19 FET sensor operation procedure.

Graphene as a sensing material is selected, and SARS-CoV-2 spike antibody is conjugated onto the graphene sheet via 1-pyrenebutyric acid N-hydroxysuccinimide ester, which is an interfacing molecule as a probe linker.

Source: Seo., *et al.* (2020) [27].

Surface-enhanced Raman spectroscopy (SERS) has a high enhancement factor and provides quantitative results with high specificity, sensitivity, and multiplex detection ability. Recently, researchers have developed a unique modality that is an integration of SERS with Lateral flow immunoassay technique for quantitative analyses of SARS-CoV-2 [28].

Nano-diagnostics hold great potential in COVID-19 management as nanoparticles with their outstanding characteristics would render additional advantages to the current approaches for rapid and accurate diagnosis [29]. Nanoparticles are used for developing Lateral Flow Assays (LFA), Colorimetric Nanosensors, Chip-Based Nanosensors and Fiber-Optical Sensors for SARS-CoV-2 detection [29].

Chemistry and covid-19 treatment

Solving an international health crisis such as the current COVID-19 pandemic requires the effort and expertise of researchers from all areas of Science and Technology. Chemists play an active role in medicinal biology as most of the drug compounds are synthetic compounds. It was a team of chemists who identified the experimental drug Remdesivir as an option to treat SARS-CoV-2 infection [30]. Modern biology, chemistry and medicine have branched out from the ancient science of alchemy. In the traditional medicine system of South India known as the 'Siddha System of Medicine', chemistry had been found well developed into a science auxiliary to medicine and alchemy [31]. Along with allopathic medicine, Siddha practices are also followed in India for the treatment of COVID-19.

Development of antiviral drugs against SARS-CoV-2

Millions of lives have been saved as a result of new medications, which have also enhanced human quality of life. Pharmaceutical researchers and healthcare professionals have made significant contributions to the discovery and development of safe and effective medicines. The drug discovery and development (DDD) process comprises the entire processes of creating and bringing a novel treatment to market. The DDD process is expensive, time-consuming, risky, and difficult, and it takes hundreds of thousands of professionals, including molecular biologists, medicinal chemists, and clinicians, to bring out a successful drug [32].

The World Health Organization, in collaboration with regulatory authorities, is coordinating pharmaceutical scientists and clinicians to produce COVID-19 drugs in two ways: 1. Discovery of new compounds with antiviral activity, 2. Repurposing of existing drugs [33].

Several drugs have now been reclaimed for clinical trials depending on therapeutic and preventive evidence to produce COVID-19 medicines. Remdesivir, favipiravir, chloroquine/hydroxychloroquine, lopinavir/ ritonavir, and tocilizumab are some of the repurposed medications that have been chosen for clinical trials due to their antiviral, immune-modulatory, and/or anti-inflammatory properties [34].

Proper target selection is the initial stage in the Drug Discovery Process. A protein in the patient's body (such as enzymes or receptors) or a protein in the microorganism that causes the disease can be the target. Once the target is selected, a varied library of possible compounds is used to find hit molecules that can interact with the completely verified target. From the hit molecule, a promising molecule known as the lead chemical is selected and examined for its pharmacokinetic properties (absorption, distribution, metabolism, excretion) and toxicological characteristics (ADME/Tox characteristics) to determine the preliminary safety and efficacy profile of the compound [32,35]. The lead molecule is then optimized by changing its structure and physicochemical qualities to make it safer and much more efficient with fewer side effects [36]. The candidate drug is based on the improved lead molecule, and scientists develop a clear strategy and notion for the medicine's formulation, dosage form, and large-scale production [37]. Animal research, drug testing, and approval processes are all part of the drug development phase [37].

Remdesivir was approved for emergency use in the United States, Japan, and India to treat COVID-19 patients [38]. It was developed by Gilead Sciences, an American corporation, to treat hepatitis C and Ebola virus infections [39]. Remdesivir is an adenosine nucleoside triphosphate analog and its active metabolite interferes with the action of viral RNA-dependent RNA polymerase and evades proofreading by the viral exoribonuclease (ExoN), causing a decrease in viral RNA production [40].

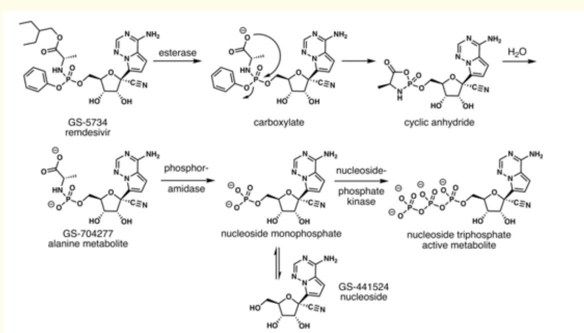

Figure 11: Activation of remdesivir into its active triphosphate metabolite.

Toyama Chemical created another antiviral medicine called favipiravir, which was used to treat severe influenza virus infection. Favipiravir was licensed as the first COVID-19 medicine in China by the Chinese National Medicines and Pharmaceuticals Administration (NMPA) in March 2020. On May 30, 2020, the Russian Health Ministry authorized a generic version of Favipiravir (Avifavir) as Russia's first anti-COVID-19 medicine [41]. Favipiravir is a pyrazine carboxamide derivative and its mode of its action is thought to be related to the selective inhibition of viral RNA-dependent RNA polymerase. It is a prodrug and its active form is favipiravir-ribofuranosyl-5'-triphosphate (favipiravir-RTP), which is available in both oral and intravenous formulations.

Figure 12: Schematic representation of the activation mechanism of favipiravir.

The antimalarial and anti-autoimmune medications chloroquine and hydroxychloroquine were dubbed "wonder cures," and the US Food and Drug Administration granted an Emergency Use Authorization to treat COVID-19 [42].

Tocilizumab, a protease inhibitor that inhibits human interleukin-6 receptors and affects inflammatory pathways, was first designed to treat osteoarthritis. Roche Pharma, a Swiss pharmaceutical firm, has begun clinical research with Tocilizumab for the treatment of COVID-19 (identifier NCT04335041 on ClinicalTrials.gov) [39].

The main laboratory of the Defence Research and Development Organisation (DRDO), the Institute of Nuclear Medicine and Allied Sciences (INMAS), in India developed the 2-deoxy-D-glucose (2-DG) drug and conducted clinical trials during the year 2020, with promising results concerning the recovery of severely affected COVID-19 patients [43,44]. Following the country’s second wave of COVID-19 that caused the most devastating surge in cases and deaths that the world had seen so far, the use of the drug was approved by the Drugs Controller General of India (DCGI) in May 2021 for the treatment of COVID-19 patients [43]. The 2-DG drug is an imitation of the D-glucose (dextrose) molecule. It is made by removing the oxygen molecule of the 2-hydroxyl group so that it is left with a hydrogen atom instead [45]. The drug's resemblance to the D-glucose molecule enables it to interfere in metabolic reactions involving the D-glucose molecule [46].

Figure 13: Number of coronavirus (COVID-19) clinical trials for drugs and vaccines worldwide as of May 20, 2021, by type.

Source: https://www.statista.com/statistics/1119086/coronavirus-drug-trials-by-type-worldwide/

Several clinical trials are currently being carried out for COVID-19. As of May 20, 2021, there were 2,077 trials testing treatments for COVID-19 worldwide [47].

Effectiveness of siddha medicine in the treatment of COVID-19

Traditional treatment is an essential part of serving the world's healthcare needs. Siddha is a special medical method that originated in Tamil Nadu. The term "Siddha" literally means "known reality." Through keeping the balance between vatham, pitham, and kapam, Siddha medicine is said to relieve the disease's root cause [48]. Kudineer, mattirai, chooranam, parpam, chendurum, karuppu, and mezhugu are some of the Siddha formulations [49]. The herbal agents used in siddha system can be classified into three groups: thavaram (herbal product), thadhu (inorganic substances) and jangamam (animal products). The thadhu agents are further classified as: uppu (water-soluble inorganic substances that give out vapour when put into fire), pashanam (agents not dissolved in water but emit vapour when fired), uparasam (similar to pashanam but differ in action), loham (not dissolved in water but melt when fired), rasam (substances which are soft), and ghandhagam (substances which are insoluble in water, like sulphur) [50,51]. The material medica of Siddha system of medicine largely depends on drugs which are of metal and mineral origin and includes 11 types of metals, 25 varieties of salts, 64 numbers of mercurial, arsenical and sulphur compounds, and 120 kinds of minerals [52]. As the world is struggling to cope with the severe effects of SARS-CoV-2 infection without much success in antiviral drugs, the chemical and therapeutic diversity of the compounds used in Siddha medicine can be used as a source of templates for structure optimization programs designed to make new leads [52].

The Siddha system of medicine has played an active role in the management of COVID-19 in Tamil Nadu. Various COVID Care Centres and Post-COVID Care Centres were opened across the state for treating SARS-CoV-2 infected people [53]. The Siddha treatment for COVID-19 includes one or more formulations, such as adathodai manapagu, kabasura kudineer, thontha sura kudineer, vajra kandi chenduram, Visha Sura Kudineer (VSK), and Nilavembu Kudineer (NVK), are used during the initial days of infection in the procedure [54].

An open label two arm - randomized controlled interventional clinical study was carried out to evaluate the additional benefits of siddha drugs Vasantha kusumakaram mathirai, Thippili rasayanam, Adathodai manapagu and Kabasura kudineer compared to the allopathic standard treatment of care alone in COVID-19 asymptomatic, mild – moderate cases and the results showed that the Siddha add on Group patients recovered fast compared to the standard treatment Group [55]. Various clinical studies are being carried out for assessing the efficacy of Siddha formulations [56].

COVID-19 and nutritional chemistry

Nutritional chemistry is the process of analyzing the biochemistry of the human body in order to solve health problems. Before starting any nutrition or supplement program, it is important to consider all the body chemistry indicators, such as acid/alkaline balance, metabolic rate, stage of stress, immune system function, adrenal, hormone, and thyroid activity, mental and emotional balances [57]. The nutritional status of an individual is affected by various factors such as age, sex, health status, life style and medications. Optimal nutrition and dietary nutrient intake is essential to strengthen the immune system [58]. When the immune system is under attack, patients need special dietary requirements. Metabolic disorders like insulin resistance, diabetes and other immune autoimmune diseases weaken the immune response to viral infections, as evidenced by the increased incidence of COVID-19 in people with obesity, hypertension, diabetes, and autoimmune diseases [59].

SARS-CoV-2 infection triggers inflammation in the body. The immune response triggered by the host factors against the virus may lead to pulmonary tissue damage, functional impairment, and reduced lung capacity if uncontrolled. Damaged pulmonary interstitial arteriolar walls indicate inflammation. Inflammatory responses such as edema, inflammatory cell infiltration, severe exfoliation of alveolar epithelial cells, alveolar septal widening, damage to alveolar septa, and alveolar space infiltration have also been reported in cases of SARS-CoV-2 infection [60]. Also viral infections induces massive amount of free radicals [61]. Therefore, it is important to include nutrients which have anti-inflammatory and anti-oxidant properties in the diet of COVID-19 patients. Several nutraceuticals such as zinc, vitamin D, vitamin C, curcumin, cinnamaldehyde, selenium, lactoferrin, quercetin, etc. have a proven ability of boosting the immune system along with antioxidant and anti-inflammatory properties [62].

Antioxidants are essential to neutralize the harmful effects of free radicals. The antioxidant activities of several vitamins, trace minerals, and related coenzymes have been extensively researched and the deficiency of these nutrients are found to suppresses the immune functions in different ways and increases the susceptibility to infection and cancers [63]. In turn, disease condition leads to decreased levels of micronutrients by further lowering the levels of these essential nutrients [63]. Several clinical trials are being currently conducted to assess the effect of antioxidant, anti-inflammatory and immunity-boosting supplements on SARS-CoV-2 infected individuals.

Production of the life saving oxygen

In the battle against COVID-19, where patients develop pneumonia and hypoxaemia (low blood oxygen levels), oxygen has become one of the most essential life-saving supplies. For children and adults, a blood oxygen saturation level (SpO_2) of greater than 95% is considered healthy and less than 90% oxygen saturation is considered unhealthy [64]. Patients with oxygen deficiency are fitted with a nasal cannula (a surgical tube that passes into both nostrils) or a simple or reservoir face mask 1 to 15 litres (3.3 gallons) of oxygen per minute is supplied to complement a patient's normal breathing. For patients who require a higher volume of oxygen, a high-flow nasal cannula, a Continuous Positive Airway Pressure (CPAP) machine, or a ventilator may be used. In these cases, up to 100 percent of the oxygen a person inhales comes from the oxygen cylinder. In the case of a ventilator, a continuous supply of oxygen may be required to keep a patient alive [65].

The World Health Organization (WHO) has reported that more than half a million COVID-19 patients in low and middle income countries need 1.1 million cylinders of oxygen per day and that the insufficient supply has resulted in unnecessary loss of lives [66]. Recently, India faced a severe lack of oxygen supply which claimed the lives of 524 COVID-19 patients [67].

The only solution for this crisis is increasing the production of oxygen in the chemical plants. Oxygen is commercially produced using a modification of the cryogenic distillation process which was originally developed in 1895 [68]. As an extremely cold cryogenic section is used in the cryogenic distillation process to separate air, all the impurities that might solidify such as water vapor, carbon dioxide and certain heavy hydrocarbons are removed to prevent the freezing and clogging of the cryogenic piping. After pre-treatment, the air is submitted to fractional distillation, where the components are gradually separated in various stages. Since all distillation processes work by boiling a liquid to separate one or more of the components, a cryogenic section is needed to provide the very low temperatures needed to liquefy the gas components. When the liquid oxygen is separated, it is purified and stored or distributed after the necessary quality control checks are done [68].

Development of vaccines

Vaccines are an important tool to stop the pandemic. In the context of taking precautions to prevent the spread of the virus, the development of a vaccine that is both safe and effective is the most needed thing in this hour of crisis. Vaccines prepare the immune system to fight against the pathogen. Vaccine development involves the combined effort of Biochemistry, Organic chemistry, Physical chemistry and, of course, Biology.

Figure 14: Schematic diagram of the production unit in a liquid oxygen plant.

The antigen, which is the primary component of the vaccine, can be a protein or any other part of the pathogen or even the entire pathogen itself in either live or dead form. Apart from the antigen, vaccines contain other chemical components such as adjuvants, stabilizers, diluents and preservatives [69].

Figure 15: The chemical components of a vaccine.

The vaccines for COVID-19 can be of different types, such as a live weakened vaccine, DNA vaccine, RNA vaccine, subunit vaccine, vector-based vaccine and inactivated SARS-COV-2 vaccine [70]. The live weakened vaccines are designed basically to inactivate exonuclease effects of protein 14 (nsp14) and to remove the protein which acts as the envelope protein in the virus. The DNA vaccine can be used in producing the DNA corona spike protein to develop synthetic DNA based SARS-CoV-2 candidate vaccines. RNA vaccine is developed with the use of mRNA-1273, which encodes for the SARS-CoV-2 protein. In vector-based vaccines, the antigen of a virus is transmitted by the genome of another virus. Inactivated SARS-CoV-2 vaccine, contains the virus in the inactivated form and stimulates the production of antibodies. These are vaccine development techniques that have been used so far. Among these RNA-based vaccines and vector-based vaccines seem more favourable [70].

Figure 16: List of Candidate vaccines in phase III trials for COVID-19.

Source: WHO (2020). Update on COVID-19 vaccine development. https://www.who.int/docs/default-source/coronaviruse/risk-comms- updates/update45-vaccines-developement.pdf?sfvrsn=13098bfc_5

Challenges of covid-19

The enormous scale of the COVID-19 crisis and its impact causes a lot of fear, uncertainty and anxiety all over the world. The rapid transmission of SARS-CoV-2 has devastated the economy, politics and public health of all countries. The main challenges are treatment and vaccines for COVID-19. Without effective antiviral drugs to treat SARS-CoV-2 infection, the mortality rate is very high. As lockdown measurements alone cannot slow down the spread of COVID-19, more effort is being invested in the development of vaccines but their efficacy still remains a question. Since the economy of poor countries is hit hard by COVID-19, it is a challenging task to get their entire population vaccinated. The issue of how to ensure equal access to vaccines worldwide continues unanswered. According to new projections, the vast majority of adults in emerging economies would have been immunized by mid-2022. This timeline may be extended for middle-income countries until late 2022 or early 2023, although for poorer countries, mass immunization may not occur until 2024 [71].

The sudden increase in the number of cases and death rate of COVID-19 due to the emergence of new strains of SARS-CoV-2 is another issue in most countries. The shortage of medical devices and other safety equipment has affected the quality of healthcare and caused many deaths. Some countries are also facing a shortage of ICU beds.

The world's economy has been severely shaken and the developing countries are the ones to suffer a lot. Some countries are solely based on tourism which has been hit hard due to the pandemic. The unemployment rate has increased manifold. As a result of the low status of the economy, political conflicts and power struggle has become more rampant.

The pandemic has also created an educational crisis. In order to enforce social distancing to prevent the spread of the virus, most governments have temporarily shut down schools and other educational institutions. The UN Educational, Scientific and Cultural Organisation (UNESCO) estimates that 60% of the world's student population has been affected, with 1.19 billion students out of school across 150 countries. Loss of access to education not only diminishes learning in the short term but also increases long-term dropout rates and reduces future socioeconomic opportunities [72].

As the healthcare system is burdened with the management of COVID-19, people who need treatment for other health conditions have been neglected. Difficulties are faced by many parts of the healthcare industry including long-term care, skilled nursing facilities, and assisted living facilities [73].

Common myths and misconceptions about the transmission, treatment and preventive measures of covid-19

Misconceptions about the SARS-CoV-2 virus began spreading across the world since the beginning of the pandemic. While some people refused to believe that the virus was real, others pointed fingers at powerful countries and big organizations, accusing them of creating the virus for the purpose of genocide and bioterrorism [74]. Protests advanced to the point that led to the emergence of 'anti-maskers', mostly in the USA, who refused to take the threat of the virus seriously and eventually led to a drastically high death toll [75]. The most common misconception about coronavirus is about it being a man-made virus, created in a lab as a bio-weapon [76]. However, studies have found out that the genome sequence of the SARS-CoV-2 shows no characteristics of it being artificially created in the lab, rather shows that its origin was through a natural process when its genome was compared to other naturally occurring viruses [76]. In Australia, people started believing that various kinds of antibiotics were effective in treating COVID-19 which was a complete myth when WHO confirmed that antibiotics does not work against viruses and is only effective against bacteria [77].

A cross-sectional study conducted in Saudi to study the misconceptions and key to those misconceptions found out that people of Saudi believed that women are more vulnerable to the infection and that rinsing the nose with saline and drinking water every 15 minutes protects one from getting infected [78]. Similarly in Iran, people believed that coronavirus can be prevented by washing hands with salt and hot water solution and that it is transmitted by air or by animals. 15.1% of the total sample of the study believed that coronavirus can only be treated fully by traditional healers [79]. A study conducted in Nigeria to assess the misconceptions about COVID-19 showed that Nigerians believed that COVID-19 can be prevented by exposing oneself to the sun or temperatures higher than 25 degree Celsius, some even hold on to the belief that being able to hold one's breathe for more than 10 seconds without coughing or feeling discomfort meant that one is free from coronavirus [80]. People also began drinking alcohol in Nigeria in order to kill the virus inside them along with holding onto the belief that the virus cannot transmit in hot and humid places [80].

Few other common misconceptions included beliefs such as people thinking being young and energetic will make them less or not susceptible to the virus and that being religious and chanting prayers can kill the virus. People in some parts of Nigeria were not even sure if the COVID-19 pandemic was real and few others thought that they are safe as long as they do not travel across borders calling the virus a "rich man's virus" and that consuming gins, garlic, ginger, herbal mixtures and African foods/soups work as preventive measures against COVID-19 pandemic. All of these are some common myths and misconceptions in different parts of the globe regarding COVID-19 transmission, treatment and prevention which are mainly spread through social media due to lack of awareness and proper knowledge about COVID-19. Erroneous information about the proper treatment of the coronavirus in Iran led to the death of approximately 700 individuals in the year 2020. This was a consequence of the consumption of alcohol contaminated with methanol, which is extremely toxic for consumption, due to the belief that it would kill the virus.

In early 2021, a traditional healer residing in a rural village in Sri Lanka formulated a fake "Covid syrup" which he claimed to be a miracle recipe obtained from a Hindu Goddess. Thousands of villagers fell victim to his fabrications and ignored the lockdown regulations set by the government to obtain and drink the syrup [81]. The failure of this feigned cure was proved when the Sri Lankan health minister, who also consumed the syrup, tested positive for COVID-19, followed by many other cases in the country [81]. Lack of knowledge and the spread of misinformation is prevalent even in the USA. Former president of America, Donald Trump, encouraged ingestion or injection of disinfectants to treat viral infection. He also recommended exposure to the UV rays of the sun as treatment methods [82]. These proclamations received outrageous protests mainly from medical professionals and can only be debunked by scientific evidence.

Conclusion

Since the outbreak of the coronavirus disease in 2019, chemistry has been playing a very significant role in studying the disease in depth. Due to the advancement in chemistry and other fields of science, the structure and molecular mechanisms of the newly discovered coronavirus was unraveled within a very short time. Studies on various diagnostic methods, treatment modes and prevention strategies were also enhanced. As discussed earlier in the paper, there are also various vaccines, some already in use, some still under clinical trials which are backed up strongly by chemistry. In conclusion, chemistry has played a very significant role in the battle against this newly discovered virus and helped researchers in discovering ways to diagnose, treat and prevent the effects caused by the new coronavirus.

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