PATHOGENS AND GLOBAL HEALTH
2020, VOL. 114, NO. 7, 349–359
https://doi.org/10.1080/20477724.2020.1807177

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REVIEW

Viricidal treatments for prevention of coronavirus infection

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ABSTRACT

Coronavirus disease 2019 (COVID-19), which causes severe acute respiratory syndrome and lung failure, is caused by the novel coronavirus, also known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Due to high transmission rates from individual to individual, it has progressed to a pandemic. However, indirect transmission from inanimate objects or surfaces that have come in contact with a patient poses an even more significant threat as it is difficult to trace the source of infection in these cases. Therefore, these surfaces and objects require disinfection with chemicals having potent viricidal activity. These include alcohols, aldehydes, quaternary ammonium compounds, chlorhexidine, and chlorine-based disinfectants, among others. They vary in their viricidal activity depending on their structure, concentrations, and mechanism of action. Several studies have looked into these agents and the transmission of the virus related to it. Moreover, certain viricides, if used as constituents of commercially available oral disinfectants, can further aid in preventing ventilator-associated pneumonia and maintain oral hygiene. However, these chemicals are not entirely free of potential hazards. In this review, we have compiled and critically appraised some commonly used viricidal agents in healthcare settings and the role they can play in the prevention of SARS-CoV-2 transmission.

KEYWORDS

COVID-19; SARS-CoV-2; viricidal; disinfectant; chlorhexidine; ethanol

1. Introduction

Human Coronavirus (HCoV) is a significant public health problem worldwide, and a substantial number of reports on nosocomial outbreaks of CoVs infections have been communicated. Coronaviruses (CoVs) are single-stranded (ss) positive-sense RNA viruses, characteristic of rapid mutation and recombination. They cause respiratory or intestinal infections in humans and animals [1]. Currently, there are 39 species in five genera and two subfamilies belonging to the family Coronaviridae, according to the Coronaviridae Study Group (CSG) [2,3]. The severe acute respiratory syndrome coronavirus (SARS-CoV) comes under the genus beta-coronavirus under the subfamily ortho-coronavirinae [2]. Comparative genomic analysis has revealed that the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), responsible for the coronavirus disease 2019 (COVID-19) pandemic, clusters in trees with the species SARS-CoV and genus beta-coronavirus, thus being assigned to the same species as mentioned earlier [4,5].

Indirect CoV transmission by contaminated objects can only be prevented through stringent infection-control measures, including the use of chemical viricides or biocides, which render the virus noninfectious. Currently, many viricidal agents are being explored for the infection control of SARS-CoV-2; however, there lacks a comprehensive review giving an update on the most potent viricidal agents that may be effective against this deadly virus. This review is a focused review of the currently available viricidal agents and their efficacy against SARS-CoV-2 infection.

1. Coronaviruses

CoVs are mainly classified by crown-like spikes on their surfaces and belong to the Coronavirinae subfamily, classified by phylogenetic clustering into four groups: the α, β, γ, and δ CoVs, of which α and β CoVs cause human infections [6]. CoVs contain four major types of structural proteins namely, the spike protein (S) (attaches to the host receptor and causes subsequent fusion of the virus and the cell membrane), nucleocapsid protein (N), membrane protein (M), and the envelope protein (E) [7]. The first HCoV was identified in the mid-1960s in human embryonic tracheal organ cultures, and until 2003, two HCoV species, HCoV-229E and HCoV-OC43 were recognized. Currently, seven different CoV strains are known to infect humans, including the important HCoV-229E, HCoV-NL63, HCoV-OC43, and HCoV-HKU1, which generally causes mild self-resolving infection. The other viruses from this group are SARS-CoV, Middle East Respiratory Syndrome coronavirus (MERS-CoV), and the novel SARS-CoV-2, which cause lethal respiratory infections in humans [8,9].

Transmissible gastroenteritis virus (TGEV), a member of the Coronaviridae family, causes severe gastroenteritis and leads to alterations of many cellular processes [10, 11].

According to current evidence, the SARS-CoV-2 virus is transmitted through respiratory droplets and contact routes. Droplet transmission occurs when a person is in close contact with a patient with respiratory symptoms and thus, is at risk of being exposed to infective respiratory

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droplets. It can also occur by indirect contact with surfaces infected by the patient [12]. Airborne transmission may also be possible under certain circumstances.

3. Persistence of coronavirus in different environmental conditions

HCoV (strain 229E) can remain infectious on different types of materials from two (2) hours up to nine (9) days [13,14]. High temperatures (30–40°C) have shown to decrease the time of persistence of different pathogenic viruses namely, MHV, MERS-CoV, and TGEV. However, at low temperatures, the stability of TGEV and MHV may be increased for longer durations (28 days) (Figure 1). SARS-CoV-2 may remain infectious on surfaces or objects for up to 72 hours [15], Five different experimental conditions (aerosols, plastic, stainless steel, copper, and cardboard) involving two viruses (SARS-CoV-2 and SARS-CoV) revealed that SARS-CoV-2 remained viable in aerosols for 3 hours, the infectious titer being reduced from 103.5 to 102.7 Median Tissue Culture Infectious Dose (TCID50) per milliliter of air, similar to that observed with SARS-CoV, which reduced from 104.3 to 103.5 TCID50 per milliliter. The viability of the virus was higher for plastic and stainless steel than on copper and cardboard. Viable SARS-CoV-2 was not detected after 4 hours on copper and after 24 hours on cardboard, whereas for SARS-CoV, the inactivity was detected after 8 hours on both copper and cardboard [16].

Positive toilet bowl and sink samples were suggestive of viral shedding in the stool [17] and could be a potential route of transmission for SARS-CoV. Post-cleaning of the bowl and sink revealed samples were negative, suggesting that current decontamination measures were sufficient. Air samples from the

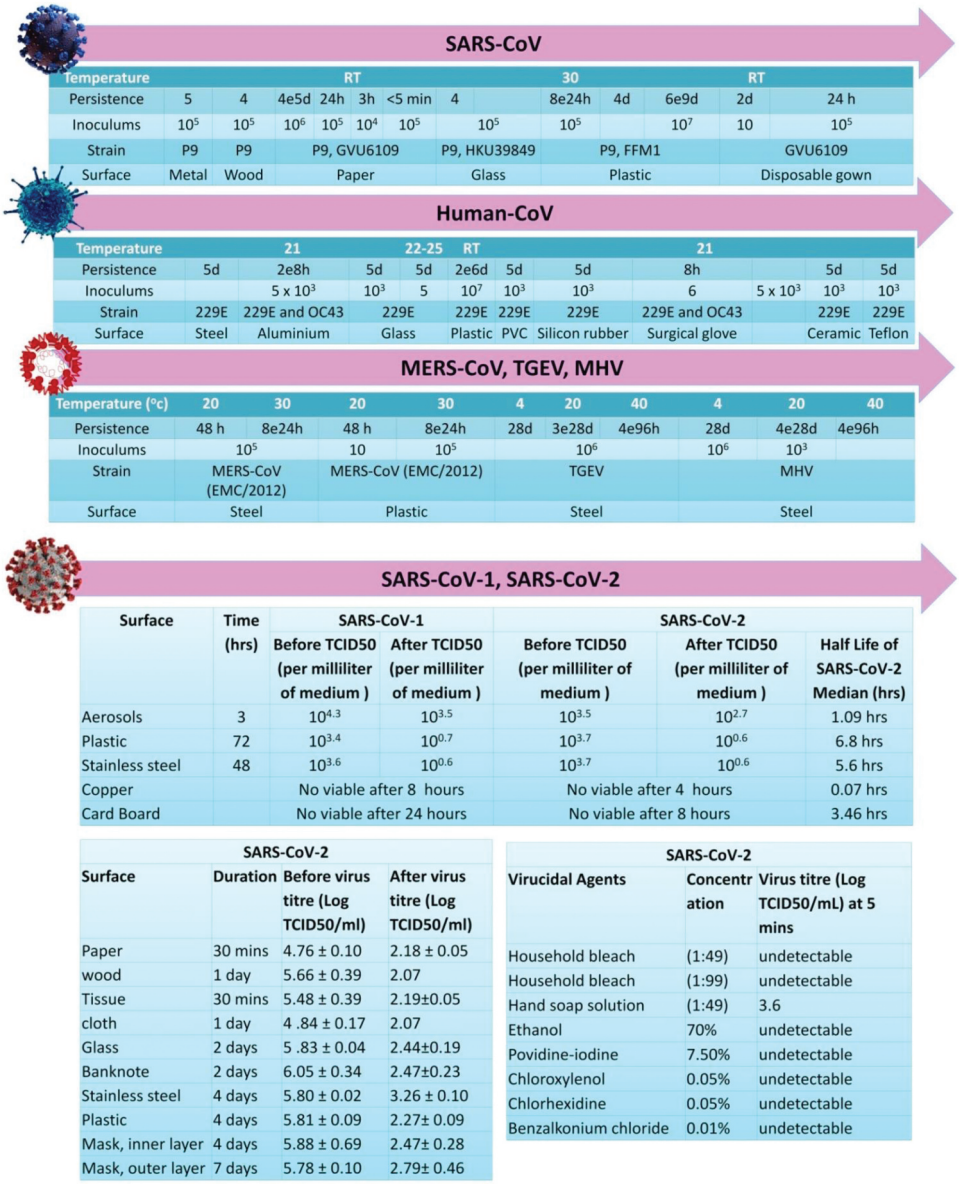


Figure 1. Persistence of different species of coronaviruses on various types of inanimate surfaces and viricidal agents activity against SARS-CoV-2. Reference: [16,21,34,70–76].

patients' room were negative, despite the extent and persistence of other environmental contamination. However, swabs taken from the air exhaust outlets tested positive, suggesting that small virus-laden droplets may be displaced by airflows and deposited on equipment such as vents. Another study [18] has shown that air-conditioned ventilation prompted droplet transmission due to recirculation of the contaminated air. The Personal Protective Equipment (PPE) samples unsurprisingly tested positive. Further, shoe covers were not part of PPE recommendations, and negative results in an anteroom and clean corridor hinted at low risk of transmission from contaminated footwear [12].

Chin et al. reported the stability of SARS-CoV-2 in different environmental conditions, including different temperatures. It is highly stable at 4°C and sensitive to heat. On increasing the incubation temperature to 70°C, the time for virus inactivation was reduced to 5 minutes. The stability of the virus on different surfaces was determined by using a 5-µL droplet of virus culture pipetted on a surface at room temperature. In contrast, no infectious virus could be recovered from tissue papers after a 3-hour incubation, and it was detected from treated wood and cloth until day 2, suggesting the enhanced viability of infectious virus for 24 hours on treated wood and cloth. SARS-CoV-2, is more stable on smooth surfaces and it was not detected from treated smooth surfaces on Day 4 (glass and banknote) or Day 7 (stainless steel and plastic). Strikingly, a significant level of the infectious virus could still be detected on the outer surface of a surgical mask, even on Day 7.

These observations show that SARS CoV-2 is a highly infectious virus that can persist in the environment and various unanimated surfaces for long durations. Nevertheless, using common household disinfectants like 0.05% triclosan, 0.12% chloroxylenol, or 79.0% ethanol provided a 3log10 reduction in viral titers with a 30-second contact time for SARS-CoV surrogate [19,20].

5. Disinfection of coronaviruses by viricidal agents

The viricidal effects of various disinfectants at different concentrations were evident, as no infectious virus could be detected after a 5-minute incubation at room temperature in SARS-CoV-2 culture [21] (Table 1 and Table 2, Figure 2). There are multiple favored disinfectants including alcohols, glutaraldehyde and ortho-phthaldehyde, chlorhexidine, hydrogen peroxide, iodine and iodophor, sodium hypochlorite and quarternary ammonium compounds.

4.1. Alcohols

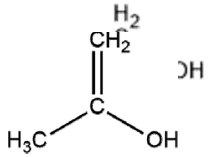
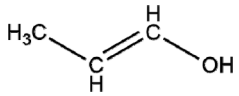
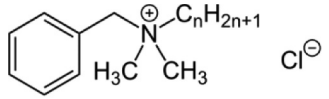
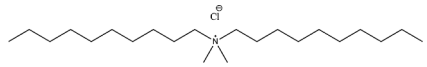
Alcohols have been widely used for disinfection of both skin and inanimate surfaces [22]. The primary mode of action of alcohol-based disinfectants is coagulation or denaturation of proteins and solubility of the lipids in alcohols, which is achieved by increased membrane permeability and subsequently, membrane-disruption, as shown by Kamm and Rutala in two separate studies [23,24]. At concentrations of 75% to 95%, methanol inactivated enveloped viruses like SARS-CoV (Isolate FFM-1) and MERS-CoV (Strain EMC) (24, 25), while at 70% concentrations, it inactivated MHV (Strains MHV-2 and MHV-N) in 30 seconds. The propanols were more active for SARS-CoV (Isolate FFM-1), MERS-CoV (Strain EMC) and at concentrations of 70% to 100%, they inactivated the viruses in 30 seconds. Hence, propanols required lower concentrations to have the same effect with similar exposure times (14 seconds and 28 seconds, respectively). Similarly, Kariwa et al. and Rabenau et al. showed that the combination of 2-propanol (45%) and 1-propanol (30%) was found to be effective for SARS-CoV (isolate FFM-1) [25, 26] (Table 3). Kratzel et al. showed that both ethanol and propanol were efficient in virus inactivation at >30% (v/v) concentration in 30 seconds. It is worth mentioning that this is the recommended time for practical purposes but not usually followed. Hence, following these WHO-recommended formulations can be crucial in minimizing the transmission and maximizing the viral inactivation of SARS-CoV-2 [27]. Varied types and concentrations of alcohols thus enable effective disinfection. However, alcohols being flammable substances should be used with caution. It is also worth noting that anionic additives in hand disinfectants containing alcohol may negate the efficacy of chlorhexidine gluconate persistence [28].

4.2. Glutaraldehyde and ortho-phthalaldehyde

The biocidal activity of aldehydes is based on the reactivity of the aldehyde group [29] and its ability to undergo alkylation reactions. Formaldehyde and glutaraldehyde have been in use for sterilization and disinfection of medical devices for a long time. Formaldehyde is an excellent biocide, but high toxicity limits its use. Glutaraldehyde is widely used for routine disinfection of medical devices, like flexible fiber optic endoscopes and heat-sensitive medical devices. Ortho-Phthalaldehyde (OPA) is a high-level disinfectant.

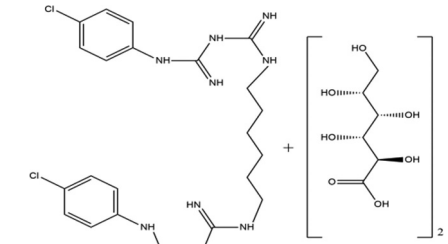
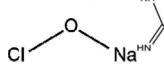
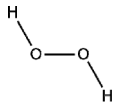
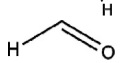
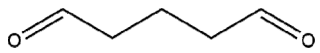
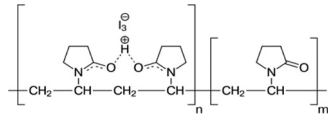
Glutaraldehyde is a monomeric-free aldehyde molecule. Reactivity of glutaraldehyde with protein, being a condensation reaction, increases as the pH rises from 4 to 9 [30]. It interacts with sulfhydryl moieties of membrane proteins and compromises cellular function by disrupting DNA and RNA [31]. A 1997 study on

Table 1. Disinfection of coronaviruses by different types of viricidal agents, including their chemical structure and mechanism of action.

Viricidal agents	Chemical Structure	Different Species of Corona Virus	Mechanism of Action	Reference
Ethanol		MERS-CoV TGEV MHV SARS-CoV-2	Membrane damage leads to coagulation and denaturation of protein.	[23,24 26 27]
2-Propanol		SARS-CoV MARS-CoV MHV CCV HCoV SARS-CoV-2	Membrane damage leads to coagulation and denaturation of protein.	
1-propanol		SARS-CoV	Membrane damage leads to coagulation and denaturation of protein.	
Benzalkonium chloride	 n = 8, 10, 12, 14, 16, 18	MHV CCV HCoV	Damage outer membrane and envelope and leading to damage of phospholipids bi layers cause the membrane or envelop destruction leakage of genetic content (DNA or RNA)	[36]
Didecyldimethyl ammonium chloride		CCV SARS-CoV-2	Membrane damage, precipitation of protein	[A. 64, 62] [65]

(*Continued*)

Table 1. (Continued).

Viricidal agents	Chemical Structure	Different Species of Corona Virus	Mechanism of Action	Reference
Chlorhexidine digluconate		MHV CCV	Membrane damage, precipitation of protein and genetic content (DNA or RNA)	[38]
Sodium hypochlorite		MHV CCV		[19,24,36]
Hydrogen peroxide		CCV MARS-CoV MHV	Causes genetic content (DNA or RNA) breakage	[42,43]
Formaldehyde		SARS-CoV CCV HCoV	Damage the outer cell membrane or envelop.	[34,36]
Glutardialdehyde		SARS-CoV	Damage the outer cell membrane or envelop	[30,32,33]
Povidone iodine		SARS-CoV MARS-CoV SARS-CoV-2	Oxidized the cell membrane and degrade the Genetic Material (RNA or DNA)	[50,52,25 54]

CCV: Canine Coronavirus; HCoV: Human Coronavirus; MERS-CoV: Middle East Respiratory Syndrome coronavirus; MHV: Mouse Hepatitis Virus; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2

Table 2. Disinfection of coronaviruses by various types of viricidal agents in suspension tests.

Virus	Strain/isolate	Exposure time	Virucidal agent	Concentration	Reduction of viral infectivity (log10)	Reference
SARS-CoV-2	München1.1/2020/929	30 s	Ethanol	≥30%	≥5.9	[27, 54 66]
			2-Propanol	≥30%	4.8 and ≥5.9	
	USA-WA1/2020	1 min	ethanol	61%	≥4.2	
		1 min	Salicylic Acid	0.10%	≥3.1	
		30 s	Iodine	90%	3.0 ± 4	
		2 min		50%	1.1 ± 0.3	
		5 min	Parachloro-metaxylenol	0.094%	≥4.7	
		1 min		0.018%	≥3.0	
		5 min	Quaternary ammonium compound	0.19%	≥4.1	
		2 min			≥3.5	
SARS-CoV/SARS-CoV-1	Isolate FFM-1	30 s	Ethanol	95%	5.5	[34 26 25 53 67]
				85%	5.5	
				80%	4.3	
				78%	5	
			2-Propanol	100%	3.3	
				75%	4	
				70%	3.3	
			1-& 2-Propanol	45% and 30%	4.3	
					2.8	
		2 min	Formaldehyde	1%	> 3.0	
				0.70%	> 3.0	
	Hanoi strain	5 min	Glutaraldehyde	2.50%	> 4.0	
	Isolate FFM-1	2 min		0.50%	> 4.0	
	Hanoi strain	1 min		1%	> 4.0	
				0.47%	3.8	
				0.25%	> 4.0	
				0.23%	> 4.0	
	Isolate FFM-1	15 s		0.23%	4.4	
MERS-CoV	Strain EMC	30 s	Ethanol	80%	> 4.0	[67 52 53]
			2-Propanol	75%	4	
	Isolate HCoV-EMC/2012	15 s	Povidone iodine	7.50%	4.6	
				4%	5	
				1%	4.3	
				0.23%	4.4	
CCV	Strain I-71	10 min	Ethanol	70%	> 3.3	[36]
			2-Propanol	50%	> 3.7	[64]
			Benzalkonium chloride	0.05%	> 3.7	[38]
	Strain S378	3 d		0.00%	3	
			Didecyldimethyl ammonium chloride	0.00%	> 4.0	
	Strain I-71	10 min	Chlorhexidine digluconate	0.02%	0.3	
			Sodium hypochlorite	0.01%	1.1	
				0.00%	0.9	
			Formaldehyde	0.70%	> 3.7	
		24 h		0.01%	> 4.0	
MHV	Strains MHV-2 and MHV-N	10 min	Ethanol	70%	> 3.9	[36,19]
			2-Propanol	50%	> 3.7	
			Benzalkonium chloride	0.05%	> 3.7	
			Chlorhexidine digluconate	0.02%	0.7e0.8	
	Strain MHV-1	30 s	Sodium hypochlorite	0.21%	4	
	Strains MHV-2 and MHV-N	10 min		0.01%	2.3e2.8	
				0.00%	0.3e0.6	
		10 min	Formaldehyde	0.70%	> 3.5	

CCV: Canine Coronavirus; HCoV: Human Coronavirus; MERS-CoV: Middle East Respiratory Syndrome coronavirus; MHV: Mouse Hepatitis Virus; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2

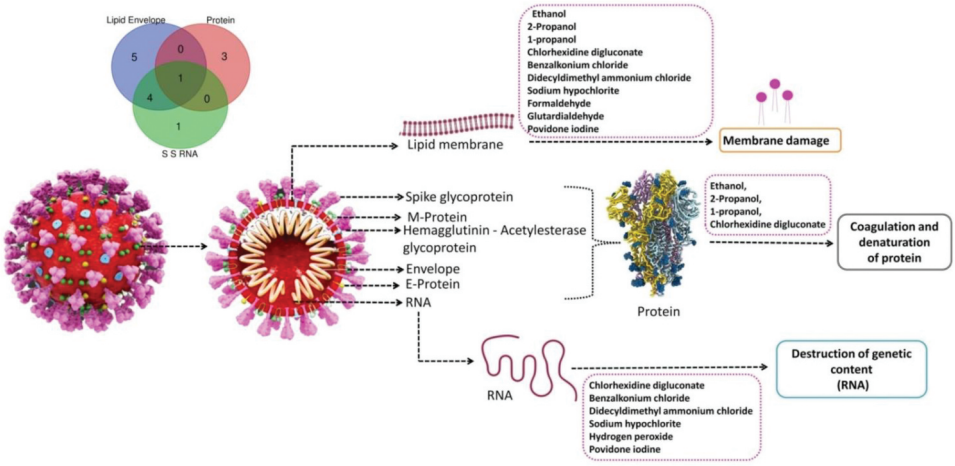


Figure 2. Mechanism of disinfection of coronaviruses by various types of viricidal agents.

Table 3. Action of active viricidal agents on different species of coronaviruses.

Viricidal agent	SARS CoV-2	SARS CoV-1	MERS CoV	MHV	CCV	HCoV	Reference
Ethanol	+	+	+	+	+	+	[34, 26, 36, 67] [27]
2-Propanol	+	+	+	+	+	-	[27,34,36,67]
1-Propanol	-	+	-	-	-	-	[34]
Benzalkonium chloride	-	-	-	+	+	+	[60, 36, 68]
Didecyldimethyl ammonium chloride	+	-	-	-	+	-	[60][59,66]
Chlorhexidine digluconate	-	-	+	+	+	-	[36]
Sodium hypochlorite	+	-	+	+	+	-	[19,21,36]
Hydrogen peroxide	+	-	+	-	-	-	[46,69]
Formaldehyde	-	+	-	+	+	-	[35, 34, 36]
Glutaraldehyde	-	+	-	-	-	-	[25,34]
Povidone iodine	+	+	+	-	-	-	[28,54,55,56]

CCV: Canine Coronavirus; HCoV: Human Coronavirus; MERS-CoV: Middle East Respiratory Syndrome coronavirus; MHV: Mouse Hepatitis Virus; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2; SARS-CoV-1: Severe Acute Respiratory Syndrome Coronavirus-1. '+' denotes that the viricidal agent is effective against the respective virus. '-' studies have not been carried out on the efficacy of these agents yet

poliovirus type 1 and echovirus type 25 showed that glutaraldehyde disrupts the protein capsid by reacting with the lysine residues, disrupting the viral integrity [32]. When the virus was exposed to glutaraldehyde, enzymatic function via DNA polymerase was also affected [33]. Further, glutaraldehyde has proven viricidal activity against SARS-CoV (Hanoi strain) at 2.5% concentration, and SARS-CoV (Isolate FFM-1) at 0.5% concentration, as it inactivated the respective viruses in 5 and 2 minutes [25,34]. Other studies have demonstrated the viricidal activity of formaldehyde against SARS-CoV (Hanoi strain), CCV (I-71), and MHV [38, 37, 39]. The European Center for Disease Prevention and Control has reported in an interim document released in February 2020, that 2% glutaraldehyde is effective against HCoV-229E. Thus, the viricidal activity of glutaraldehyde and phthalaldehyde is proven in SARS-CoV strains, but its effect on SARS-CoV-2 is explicitly lacking and seems an attractive area to be explored further [37].

4.3. Chlorhexidine

Chlorhexidine is a substituted biguanide, which contains the C2H5N7 component, and has highly potent antimicrobial activity, low toxicity, and binds to the stratum corneum of the skin and mucous membranes [38]. It is one of the most common components of alcohol-based sanitizers, as the addition of chlorhexidine in low concentrations (0.5–1.0%) to alcohol-based preparations has higher residual activity than alcohol alone [39]. Antiviral effects of chlorhexidine are due to its interaction with the viral membrane lipids in enveloped viruses. Due to higher solubility of the lipids in chlorhexidine, it is more active against enveloped viruses with a lipid membrane, such as HIV [40,41]. Also, its antimicrobial activity is minimally affected by the presence of organic material, including blood. Coronaviruses, MHV (MHV-2 and MHV-N) and CCV (I-71), were inactivated within 10 min by 0.02% chlorhexidine. Aqueous formulations (0.50–0.75%) were found to be more effective than plain soap.

As a common side-effect to chlorhexidine, concentration-dependent skin irritation can occur. Chlorhexidine in >1% concentration can cause conjunctivitis and corneal damage, so care must be taken to avoid such exposure. Further, it should not be used in middle and inner ear surgery as it is ototoxic.

4.4. Hydrogen peroxide (H2O2)

Hydrogen peroxide has been used for its antiseptic properties since the 1800s [42]. Initially, H2O2 was

used as a disinfectant, and it is used at various concentrations to disinfect materials such as drinking water, medical equipment, and septic tank waste. Free hydroxyl radicals react with lipids, proteins, and nucleic acids, cleavage of the RNA and DNA backbone, oxidation, causing denaturation of proteins, disruption of biological membranes and sulfhydryl bonds in proteins and enzymes [43]. High concentrations of H2O2 can counter the decrease in efficacy when it gets degraded in water and oxygen with the presence of catalase. High temperatures are also needed as a crucial factor with increased H2O2 concentrations [44,45]. Recently, in a study conducted on 73 N95 masks from five different models, Cramer et al. have shown that ionized H2O2 technology Stera-Mist is effective in sterilizing N95 masks [46].

4.5. Iodine and iodophor

Iodine in the form of a tincture has been used since the early 1900s as preoperative skin preparation, and iodophors are classified as low- or intermediate-level disinfectants [24] because they are not sufficiently sporicidal in a short application time. The destructive effect of iodine and iodophors is related to the concentration of the free molecular iodine, which correlates with its antimicrobial activity [47,48]. N-iodo compounds act by destroying the protein structure by reacting with the -NH group of amino acids and irreversible oxidation of -SH (thiol) groups of cysteine, ultimately leading to loss of protein disulfide linkages [24,31].

Iodination of phenolic and imidazole groups of the amino-acids tyrosine and histidine and pyrimidine derivatives of cytosine and uracil lead to steric hindrances in hydrogen bonds and denaturation of DNA. Iodine binding to unsaturated fatty acids has been shown to alter the physical properties of lipids and hence lipid-containing membranes [49].

Iodine and iodophors have been effective against a wide range of viruses, including CoVs and enteroviruses, polio, herpes, vaccinia, rabies, and tobacco mosaic viruses [49–51]. Povidone-iodine, a complex of polyvinylpyrrolidone and iodine, is routinely used in surgical procedures, and numerous studies have validated its safety. It showed rapid and effective viricidal activity against different types of HCoVs like SARS-CoVs (Isolate FFM-1 & Hanoi strain), and MERS-CoV (HCoV-EMC/2012), at concentrations of 0.23% to 7.5% with 15- and 60-second exposures, respectively [25,52,53]. Liang et al. characterized the viricidal activity of long-acting povidone-iodine gel formulations in the inactivation of SARS-CoV-2 in VERO76 cells in a time- and dose-dependent manner. Further, no toxicity was observed [54]. Povidone-iodine has also been recommended by UK investigators as nasal spray and mouthwash in health workers to prevent infection of the airways [55].

Due to increased free iodine concentrations, lower concentration iodophor preparations have better antimicrobial activity but are more prone to cause skin irritation and contact dermatitis, therefore must be used with caution.

4.6. Sodium hypochlorite

Sodium hypochlorite in solution shows a broad-spectrum antimicrobial activity and is generally used in sterilization of healthcare facilities [24]. 'Strong chlorine solution' is a 0.5% solution of hypochlorite (containing approximately 5000 ppm free chlorine) used for disinfecting areas contaminated with body fluids, including large blood spills [24,56].

Sodium hypochlorite damages membrane envelopes by the oxidation of proteins and lipids and nucleic acid degradation [31]. Sakjnimit et al. showed its viricidal activity against MHV (MHV-2 and MHV-N) and CCV (I-71) at 0.001% to 0.01% concentrations, respectively, and the viruses were inactivated in 10 minutes [36], while MHV (MHV-1) was inactivated in 30 seconds at 0.21% concentration [19].

4.7. Quaternary ammonium compounds

Quaternary ammonium compounds (QACs) are widely used as disinfectants, and alkyl benzalkonium chlorides are one of the most familiar examples [39,57]. The antimicrobial activity of these compounds can be attributed to the adsorption to cytoplasmic membrane and leakage of cellular constituents. Chemically, the quaternaries are organically substituted ammonium compounds in which the nitrogen atom has a valence of five. Four of the substituted radicals (R1–R4) are alkyl or heterocyclic radicals of a given size or chain length, and the fifth (X–) is a halide, sulfate, or similar radical. The chemical names of QACs used in hospitals include alkyl dimethyl benzyl ammonium chloride, alkyl di-decyl dimethyl ammonium chloride, and di-alkyl dimethyl ammonium chloride. The mechanisms by which these chemicals act are denaturation of essential cell proteins, disruption of the lipid membrane, and damage to proteins and nucleic acid [58]. Known QAC having anti-coronaviral activity are ammonium chloride, cetylpyridinium chloride, and miramistin. Among these, cetylpyridinium chloride has demonstrated its antiviral activity against an array of coronaviruses and is cheap and widely accessible to be used in hospital settings [59]. Di-decyl dimethyl ammonium chloride has proven viricidal activity against CCV (Strain S378) at 0.0025% concentration and inactivates viruses in 3 days [60]. Hence, this compound may potentially be useful in disinfecting surgical masks and N95 masks.

However, having weak activity against gram-negative bacteria, these compounds are prone to

contamination, and have been traced to outbreaks in the past. Therefore, they must be used judiciously.

5. SARS-CoV-2 and oral hygiene

High viral loads in the oropharynx of infected patients of COVID-19, as well as an increased risk of ventilator-associated pneumonia in critically ill patients, beg the consideration of proper oral hygiene. Ingredients such as chlorhexidine are part of mouth rinses available on the market, and hence can be used to reduce oral transmission of SARS-CoV-2. It is indicated in gingivitis and post-surgery periodontal disease and has been reported to be able to penetrate oral biofilms [61,62]. Flavonoids have also shown anti-coronaviral activity due to the inhibitory effect of 3 C protease type [63]. Compounds such as herbacetin and 3-β-d-glucoside can inhibit the enzyme activity of MERS-CoV/3 CLpro [63]. Citrox, a combination of natural bioflavonoids, which has a broad spectrum of antimicrobial effects, is also useful. It is an oxidizing agent, making it potentially useful in reducing the salivary viral load, including that of SARS-CoV-2 [64]. Cyclodextrins, modified with mercapto-undecane sulfonic acids, are capable of destroying outer shells of the virus. Hence, these agents, alone or in combinations, can also be used to reduce oral viral load [64], which can prove to be extremely beneficial in containing and reducing any viral spread through speech or coughing.

7. Conclusion

Coronaviruses are highly infectious, and novel coronavirus SARS CoV-2 has the menacing feature of longer persistence in the environment and various inanimate surfaces. Additionally, persistent lack of specific antiviral treatments makes it a challenging entity for the development of efficacious means of prevention. Under such alarming conditions, disinfection for personal hygiene as well as disinfection of various hospital areas, medical devices, and medical personnel protection is a primary modality of controlling the spread of this virus. Available antiseptic-disinfectants should be fundamentally and rigorously evaluated in this health crisis. However, few chemicals are efficient enough within a specific contact time and without toxicity. Formulations having the presence of multiple disinfectants may be considered. Among the major chemical formulations that can be useful, alcohol and chlorhexidine-based disinfectants and sodium hypochlorite and benzalkonium chloride solutions are primary choices. These are tried and tested in various hospital settings and medical personnel use have shown robustness in viricidal action. An effective disinfection strategy used by healthcare service providers and by individuals has the potential to go a long way in fighting this global pandemic.

Disclosure statement

No potential conflict of interest was reported by the authors.

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