

REVIEW

Indirect consequences of coronavirus disease 2019: Skin lesions caused by the frequent hand sanitation and use of personal protective equipment and strategies for their prevention

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) enforced the use of hand sanitation and of personal protective equipment, such as masks and visors, especially by health-care professionals, but also by the general public. However, frequent hand sanitation and the prolonged and continuous use of personal protective equipment are responsible for constant frictional and pressure forces on skin causing lesions, the most reported being acne, facial itching, dryness, and rash. Thus, it is important to find measures to prevent skin lesions, in order to improve the quality of life of health-care professionals and of the general public. This article gathers the current information regarding measures to prevent human to human transmission of COVID-19, reviews the most common skin lesions caused by the use of hand sanitizers and different types of personal protective equipment, and the possible preventive measures that can be used on a daily basis to minimize the risk of developing skin-related pathologies. Daily skin care routines and the incorporation of a dressing between the skin and the personal protective equipment to serve as a protective barrier are some of the applied measures. Moisturizers and dressings improve the skin's ability to respond to constant aggressions. Lastly, the need for additional studies to evaluate the lubrication properties of different types of dressings is discussed. The understanding of what kind of dressing is more suitable to prevent pressure injuries is crucial to promote healthy skin and wellbeing during pandemic times.

KEYWORDS

coronavirus disease 2019, dressings, hand sanitation, personal protective equipment, skin care, skin lesions

1 | INTRODUCTION: INDIRECT CONSEQUENCES OF THE COVID-19 PANDEMIC FOR THE SKIN

The coronavirus disease 2019 (COVID-19) disease, caused by the novel coronavirus (CoV), severe acute respiratory syndrome

coronavirus 2 (SARS-CoV-2), was first reported by the end of 2019 and was declared a global pandemic by the World Health Organization (WHO) in March 2020.¹⁻³

Coronavirus disease 2019 is highly infectious in terms of human-to-human transmission, which is evident by the high number of reported cases and deaths during this pandemic.⁴⁻⁶ This disease

can be transmitted directly, through contact or aerosols, commonly by cough, sneeze, droplet inhalation, and contact with oral, nasal, and eye mucous membranes.⁷⁻⁹ Touching a contaminated surface followed by touching the facial area may also be a form of transmission.¹⁰

To minimize the spread of COVID-19, countries have adopted measures such as air disinfection of cities and communities, spraying disinfectant and alcohol on surfaces, use of personal protective equipment (PPE), lockdown of cities and increasing scientific evidence-based public health education to reduce anxiety and misinformation, and mass testing.^{11,12}

The last update of the COVID-19 Treatment Guidelines from the National Institutes of Health (NIH) states that currently there is no known agent that can prevent or treat the infection, thus vaccination is the hopeful solution to control the pandemic.¹³⁻¹⁶ However, the current vaccines might not be effective against new viral variants.¹⁷⁻¹⁹ When quarantine and isolation are not possible, personal protective actions must be strictly followed. Frequent hand sanitation and the use of PPE, however effective protective measures, may have a negative impact on the skin, causing lesions.²⁰

To adapt to changing environmental conditions and restore damaged skin, keratinocytes in the stratum corneum (SC) are constantly renewed.²¹ When the restoration is compromised due to aggressive conditions, the barrier integrity is compromised and transepidermal water loss (TEWL) increases, causing inflamed and dry skin.^{20,22} Detergents and other chemicals in sanitizers, hot water rinse, and drying procedures are extremely aggressive to the skin.²⁰ Also, several of these products often contain antimicrobial drugs which alter the skin bacterial community, critical for cutaneous host defense.^{23,24} Skin lesions may also arise after prolonged and continuous use of PPE due to sustained pressure, tension, friction, and increased humidity and temperature. Health-care professionals (HCP) with long shifts are more prone to such lesions.²⁵ Frequently reported symptoms are acne, facial itching, skin flaking, dryness, burning sensation, rash, and in more severe cases ulceration, ischemia, and infections.²⁶⁻²⁸

To prevent skin lesions in HCP, a dressing can be incorporated between the skin and the PPE, serving as a protective barrier, reducing the impact on tissues, and improving the skin's ability to respond to constant aggressions. Nowadays, HCP adapt dressings available in health-care facilities and apply them underneath the PPE to prevent injuries.²⁹ Another important measure to prevent skin lesions is a daily skin care routine of the hands and face using creams or other moisturizers to reinforce the barrier, increasing its ability to respond to constant aggressions.^{26,30}

This review focuses on skin damage due to frequent hand sanitation and PPE use, one of the indirect impacts of COVID-19, which affects both HCP and the general public (GP). Different environments require different types of PPE, each type responsible for specific skin lesions. Therefore, the most suitable solution to minimize the impact caused by the PPE must be chosen wisely, with moisturizers and dressings often being the most efficient form to prevent skin lesions, improving the quality of life of the HCP but also of the GP.

2 | HAND HYGIENE: WHICH IS THE BEST ROUTINE?

2.1 | Hand sanitizers versus handwashing

Hand hygiene is one of the most effective ways to reduce the spread of microorganisms, and with COVID-19 it is no different.³¹⁻³³

Alcohol-based hand sanitizers (ABHS), alcohol-free hand sanitizers (AFHS) and soaps efficiently inactivate microorganisms by dissolving their lipid membranes. Alcohol gel solutions have gained popularity as they are a simple alternative to the traditional method of soap and water to wash hands.³¹ Sanitizer dispensers commonly used in hospitals are nowadays usual in places where people gather, such as shopping malls, restaurants, schools, and workplaces.^{31,33,34} However, the use of hand sanitizer is only effective if the hands are not visibly soiled, dirty, or greasy; in these cases, hands must be washed. To remove resident pathogens, handwashing is more effective if the formulation contains antimicrobial agents, but hand sanitizers with at least 60% alcohol are even more effective.

2.1.1 | Soaps: Simple, yet efficient

Soaps are a mixture of surfactants, emulsifying agents, polymers, humectants and, often, perfumes. The cleaning action of soaps is mainly due to the surfactant, chemically sodium or potassium salts of saturated or unsaturated long-chain fatty acids. When the surfactant monomers are above their critical micelle concentration, they self-associate to form micellar aggregates, which act as emulsifiers that solubilize hydrophobic substances such as oil, grease, dirt, and virus particles.³⁵

The soap must be chosen according to type and format. Antibacterial soaps, usually containing triclosan, chlorhexidine gluconate, iodophor, or povidone, are not more effective than normal soaps in reducing the risk of viral infections, at least in healthy individuals.^{35,36} In fact, the addition of antibacterial compounds to hand soaps may contribute to antibiotic resistance and allergic reactions in skin.³⁶ The soap format, which is more relevant in terms of compliance, does not influence efficacy, but many public places and hospitals provide liquid soap as it is easier and cleaner to share with others.³⁷

2.1.2 | Hand sanitizers: Several options with several purposes

Alcohol-based hand sanitizers have disinfectant and biocidal properties, granted by the strength, type, and antiviral activity of the alcohol used in the formulation, usually ethanol, isopropanol, and/or n-propanol.³⁸ Several ABHS are commercially available, with one or more types of alcohol present in different dosage forms, namely spray, liquid, wipes, gel, and foam, with the last two being preferable to the liquid.

The WHO suggested two hand rub formulations to reduce the infectivity and spread of enveloped viruses,²⁰ the efficacy of

which was evaluated by Kratzel *et al.*³⁹ Formulation I contained 80% (v/v) ethanol, 1.45% (v/v) glycerol, and 0.125% (v/v) hydrogen peroxide, while formulation II used 75% (v/v) isopropyl alcohol instead of ethanol. The study showed that both formulations were efficient in inactivating SARS-CoV-2, supporting their use in health-care systems during viral pandemics. **Table 1** shows examples of ABHS used by the GP and by HCP, available in the European and US markets.^{20,33,40,41}

The AFHS do not contain alcohol but instead use very low concentrations of non-flammable antiseptic chemicals, being safer for children and people with atopic skin. One example is benzalkonium chloride, a quaternary ammonium compound, which has been recommended for use against SARS-CoV-2 by both the US Environmental Protection Agency and Health Canada. Other chemical groups with potent viricidal agents capable of inactivating all lipophilic and some hydrophilic viruses are summarized in **Table 2**. These sanitizers are mainly used by the GP, except for benzalkonium chloride which is also used by HCP due to its proven efficacy in viral inactivation.^{33,45}

2.2 | Reported hand skin lesions: unpleasant consequences of one's protection

During the SARS-CoV-2 pandemic, HCP report that they sanitize their hands more than 10 times daily.⁵⁵ This increases skin dryness, cracking, flaking, fissuring, itchiness, and even bleeding, symptoms often associated with dermatitis.^{34,38} Due to these disadvantages, regular soap and water may be an alternative, with some users washing their hands immediately before or after using an ABHS. However, the repeated cycle of wet-and-dry further dehydrates skin, leading to dermatitis.^{20,34,38,55} The most reported skin problem caused by hand sanitation is dermatitis, the most common being contact dermatitis (~80% of cases) and the less common is allergic dermatitis.^{34,38}

Irritant contact dermatitis symptoms include burning, stinging, and skin soreness. The discomfort occurs within a short time, usually reaching its peak minutes or hours after exposure. The symptoms are more commonly reported for iodophor products, but products

TABLE 1 Specifications of alcohol-based hand sanitizers available in the European and US markets used by the general public and HCP

Brand ^{42,43}	Manufacturer ⁴³	Active components ³³	Dosage Form ⁴³	Users ³³	Mechanism of action ^{20,33}	Interference with the skin barrier ⁴⁴
Alcogel H®	Prodene Klint (division of Mediprop)	Isopropanol	Gel	GP	Denaturation of proteins and lipids in membranes of microorganisms;	Removes significant amounts of lipids from the stratum corneum, which may impair the skin barrier function
Assanis Pro Gel®	Blue Skin	Ethanol, Isopropanol, Quaternary ammonium	Gel	GP	reduction of the surface tension of the cell membrane	
Clinogel®	Viatrix	Isopropanol, Triclosan	Gel	HCP/GP		
Dermalcool®	Deb Arma (division of Neoderma)	Ethanol, Isopropanol, Triclosan	Gel	GP		
Manugel Plus®	Anios	Ethanol, Isopropanol, Phenoxyethanol	Gel	HCP/GP		
Manugel Plus NPC®	Anios	Ethanol, Isopropanol, Phenoxyethanol	Gel	HCP/GP		
Manurub®	Stéridine (division of Hydenet)	Phenoxyethanol, n-propanol, Isopropanol, Ethanol	Liquid	HCP		
Manurub Gel	Stéridine (division of Hydenet)	Phenoxyethanol, Amino-methylpropanol, Ethanol	Gel	HCP/GP		
Purell®	Gojo	Ethanol, Isopropanol	Gel	GP		
Purell 85®	Gojo	Ethanol, Isopropanol	Gel	HCP/GP		
Spitacid®	Ecolab Health Care (supplied by Paragerm)	Ethanol, Isopropanol, Benzyl alcohol	Liquid	HCP/GP		
Spitagel®	Ecolab Health Care (supplied by Paragerm)	Ethanol, Isopropanol, Hydrogen peroxide	Gel	GP		
Sterillium®	Bode Chemie (supplied by Rivadis)	Isopropanol, n-propanol, Mecetronium ethylsulphate	Liquid	GP		
Sterillium Gel®	Bode Chemie (supplied by Rivadis)	Ethanol	Gel	HCP/GP		

Abbreviations: GP, general public; HCP, health-care professional.

TABLE 2 Chemical groups of commonly used alcohol-free hand sanitizers

Chemical group ³³	Examples of active ingredients ³³	Users ³³	Action mechanism ⁴⁵⁻⁴⁸	Concentration (%) ^{33,46,47,49}	Interference with the skin barrier ⁴⁸⁻⁵⁴
Chlorine compounds	Sodium hypochlorite	GP	Halogenation/oxidation of cellular proteins; cytotoxic mechanism: cellular energy metabolism impairment, DNA synthesis reduction, progressive mitochondrial dehydrogenase dysfunction, and subsequent cell death	0.01-4	Cytotoxic to keratocytes, compromise skin barrier integrity; oxidizing agents damage healthy tissue and its components (e.g., human SC, collagen, fibroblasts, immunological cells such as macrophages)
	Chlorine dioxide	GP			
	Chloramine-t-trihydrate	GP			
	Calcium hypochlorite	GP			
	Sodium dichloroisocyanurate	GP			
Iodine compounds	Povidone-iodine (polyvinylpyrrolidone with iodine)	GP	Penetrate the pathogen cell membrane, irreversibly binds tyrosine residues in proteins, interfere with hydrogen bonds in some amino acids residues and nucleic acids, oxidize sulfhydryl groups, react with unsaturated bonds in lipids; oxidizing agents that cause the precipitation of bacterial proteins and nucleic acids; block the respiratory electron transport chain through electrolytic reactions with enzymes	5-10	Corrosive; inhibits fibroblast aggregation, delaying wound healing, induction of epithelial cell death, and inhibition of leukocyte migration; high concentrations may cause necrosis, low concentrations cause apoptosis
QAC	Benzalkonium chlorides	HCP/ GP	Lower surface tension; enzymatic inactivation; denaturation of essential microbial cytoplasmic proteins	0.02-0.04	Promote keratinization due to keratinocytes death in the epidermis; strongly hydrophilic QAC bind to the negatively charged extracellular matrix on the cell surface, inducing strong subacute cytotoxicity
	Benzyl dimethyl octyl ammonium chloride	GP			
	Didecyl dimethyl ammonium chloride	GP			
Peroxygens	Hydrogen peroxide	GP	Inactivate contaminating spores; produce hydroxyl radicals (OH·) that damage cell components, leading to the breakdown of biofilms, cell membranes, and cell walls	0.5-3	Diffuses through the SC into the epidermis, breaking down into oxygen and water and converted to OH·, which can overwhelm the skin's antioxidant system and drive oxidative stress-triggered apoptosis or necrosis of sensitive cells; corrosive damage, lipid peroxidation, cytotoxicity in fibroblasts and keratinocytes
	Peracetic acid	GP			

TABLE 2 (Continued)

Chemical group ³³	Examples of active ingredients ³³	Users ³³	Action mechanism ⁴⁵⁻⁴⁸	Concentration (%) ^{33,46,47,49}	Interference with the skin barrier ⁴⁸⁻⁵⁴
Phenols	Triclosan	GP	Penetrate cytoplasmic membrane bilayer; alter the cell membrane and the synthesis of RNA, fatty acids and proteins	0.2–0.5	Topical application of triclosan damages the skin barrier, inducing cellular and immune responses, including modulation of cytokines expression by keratinocytes
Biguanide	Chlorhexidine	GP	Ionic interaction; passively diffuses through bacterial cell membranes altering their permeability; inhibits the enzymes of the periplasmic space; high concentrations cause precipitation of proteins and nucleic acids	0.5–4	Increases cell permeability contributing to cell components leakage; decreases cell proliferation by suppressing DNA synthesis; alters cytoskeletal organization, changing cellular configuration; disrupts protein synthesis

Abbreviations: GP, general public; HCP, health-care professional; QAC, Quaternary ammonium compounds; SC, stratum corneum.

containing chlorhexidine, chloroxylenol, triclosan, quaternary ammonium compounds, detergents, alcohol-based products and other additives used in hand cleaning products, have also been reported to cause contact dermatitis.^{20,38,56}

Allergic dermatitis, characterized by a sensibility to a specific allergen followed by an inflammatory response, is not commonly caused by hand sanitizers, occurring only in 20% of reported cases. The main symptom is pruritus, which usually occurs 24–48 h after exposure to the causative agent, reaching a peak 72–96 h post-contact. Various compounds present in hand hygiene products can cause allergic reactions, namely fragrance and preservatives such as benzyl alcohol, stearyl or isostearyl alcohol, phenoxyethanol, myristyl alcohol, propylene glycol, parabens, or benzalkonium chloride. Studies have shown changes in the SC and keratinocytes in skin exposed to ABHS with isopropanol and n-propanol and concluded that ethanol-based sanitizers are better tolerated by the skin.^{20,38,56}

2.3 | Prevention of hand skin lesions

The WHO suggested three primary strategies to minimize hand hygiene-related dermatitis: selection of less irritating products, avoidance of practices that increase skin irritation, and application of moisturizing skin care products following hand cleansing.

Moisturizing increases skin hydration and replenishes lipids. Hand lotions and creams containing humectants, fats, and oils are absorbed by the epidermis, creating a moisture environment. The oil content replenishes sebum, which forms a film on the skin surface to prevent water loss.^{38,56} This strategy is mainly used by the

GP. To compensate, it is recommended that HCP switch from soaps and detergents to ABHS rubs containing humectants. Frequent handwashing is not only aggressive to the skin due to detergent action but hot water rinse and towel drying also contribute for the increase of skin irritation, in extreme cases.⁵⁶ The WHO recommends formulations containing 1.45% (v/v) glycerol, which better condition the skin when compared with soap handwash.²⁰ Additionally, ABHS with humectants are well tolerated and often associated with better acceptability over other hand hygiene products. It is also recommended to select less irritant hand hygiene products.^{20,38} In this aspect, ABHS are in advantage compared with AFHS, since triclosan, chlorhexidine, and quaternary ammonium compounds are considered dermatitis enhancers. In case of allergic dermatitis, it is preferable to use a fragrance-free product with less harmful preservatives; for example, weak acids.^{20,31,38,55,56} Table 3 summarizes the characteristics of both types of dermatitis, their causes, and preventive actions to avoid skin lesions.

3 | PERSONAL PROTECTIVE EQUIPMENT: THE MODERN “SKIN SHIELDS”

Personal protective equipment such as masks, gowns, or gloves, are considered one of the most used strategies for protecting both HCP and patients.⁵⁹ Face masks, especially surgical masks, are the most popular PPE used by both HCP and the GP.⁶⁰

When dealing with COVID-19 patients, HCP must follow a strict protocol to correctly place PPE. First, an adequate hand hygiene must be performed. Then, the boots are put on, followed by the

TABLE 3 Summary of the main skin lesions caused by hand sanitizers, their causes and prevention

Skin pathology ^{38,56}		
	Contact dermatitis	Allergic dermatitis
Clinical features ^{31,38}	Burning, redness, stinging, soreness	Pruritus, redness
Pathogenesis ^{57,58}	Direct toxic effect by chemicals or physical agents on the epidermal keratinocytes, resulting in SC disruption and repair impairment, triggers the innate immune system	Delayed T-cell-mediated hypersensitivity reaction to external chemicals or physical agents occurring in susceptible individuals
Causes ^{20,56}	Detergents, hot water rinse, iodophors, chlorhexidine; chloroxylenol, triclosan, quaternary ammonium compounds; alcohol-based products	Fragrance, preservatives, isopropanol, n-propanol
Solution ^{20,56}	Application of moisturizing skin care products; alcohol-based hand sanitizers containing humectants	Use fragrance-free products, less harmful preservatives
Affected population ⁵⁵	HCP/GP	HCP/GP

Abbreviations: GP, general public; HCP, health-care professional; SC, stratum corneum.

TABLE 4 Reported skin lesions resulting from the use of PPE and respective treatments and preventions

Personal protective equipment ^{30,59,66}	Users ⁵⁹	Protection mechanisms ⁵⁹	Skin lesions ^{56,65,66,69}	Interference with skin barrier ^{29,30,89-91}	Treatment/Prevention ^{20,26,28,29,67}
Masks and respirators	GP/HCP	Prevention of inhalation of infectious particles	Nasal bridge scarring, cheeks facial itching, dry skin and rash, discoloration and ulceration on the nose bridge, jaw, cheeks and ears, tissue ischemia and hypoxia, "maskne"	Differences in the skin temperature, transepidermal water loss, sebum content, skin pH, skin pores size and elasticity within hours. Tissue deformation, cell damage and death, inflammation, edema, interstitial pressure and ischemia	Mild cases: Skin care with moisturizers. Severe cases: Antibacterial cleansers; creams with bacterial/fungal/ anti-inflammatory agents; glucocorticoid creams; dressings as an interface between the PPE and skin
Medical gloves	GP/HCP	Protection against anticipated contact with blood, infectious materials	Contact and allergic dermatitis	Shearing forces and physical pressure associated with recurrent application and removal of gloves, compromising blood supply, possibly leading to ischemia, cellular death and tissue necrosis	Moisturization before donning occlusive gloves with hand cream or mild steroid cream; nonfractional drying
Gowns, coveralls and aprons	HCP	Protection against the transmission of microorganisms in blood and fluids of potentially infected patients.	Acne in the chest and back, allergic dermatitis	Device-related pressure injuries due to friction between the clothing edge and the skin. Temperature increase altering skin pH levels	Skin care with moisturizers
Goggles and face shields	HCP	Protection of eyes from exposure to splashes, sprays, splatter and respiratory secretions	Indentations, ecchymosis, maceration, abrasion, erosion	Mechanical damage to the skin trough pressure forces leading to ischemia ³⁰	Cream with bacterial/ fungal/ anti-inflammatory agents; glucocorticoid creams; dressings as an interface between the PPE and skin

Abbreviations: GP, general public; HCP, health-care professional; PPE, personal protective equipment.

gown or overall, then the face protection (masks, goggles, and/or face shields) and, finally the gloves, after another hand sanitation.³⁰

The prolonged daily use of PPE may cause skin lesions, due to poor air permeability, friction, and pressure. Additionally, the fear of further discomfort and pain can affect the willingness to work long shifts and the psychological wellbeing. To avoid this, prevention and treatment measures should be followed, particularly by HCP.^{29,30,59} Table 4 summarizes the reported skin lesions due to PPE use by the GP and HCP, their treatment and prevention.

3.1 | Types of PPE: Each area with its own protection

3.1.1 | Mask and respirators

Surgical face masks and N95 respirators are the most commonly used by both HCP and the GP, for facial protection.⁴⁰ Their main function is to prevent inhalation of infectious particles since SARS-CoV-2 is mainly transmitted via aerosol. Masks are loose-fitting, single-use, disposable devices with different thicknesses that create a physical barrier between the mouth and nose of the user and the contaminated environment. The proper use of surgical masks blocks large-particle droplets, splashes, or sprays that may contain viruses and bacteria, preventing their entrance through the mouth and nose and/or protecting those around a contaminated user.^{59,60} Respirators are protective devices designed to ensure a close facial fit, with edges that seal around the nose and mouth, and with an efficient filtration system.^{27,59,60} Due to the enhanced protection properties, respirators can be used for up to 8 h, while surgical masks should only be used 4–6 h.^{27,59–61}

3.1.2 | Medical gloves

The second most used PPE are medical gloves, which are mainly used by HCP.⁶¹ Regarding the GP, there is no evidence that gloves provide additional protection compared to bare hands, if the hands do not touch the face.^{61,62} Despite the physical barrier gloves offer, prolonged use and reuse may create small imperfections on their surface, allowing the entry of pathogenic microorganisms.⁵⁹ Transmission of SARS-CoV-2 may occur if the hands are bare or gloved; thus, it is imperative to minimize contact with the face and increase the frequency of handwashing or sanitization.⁶² When in direct contact with COVID-19 patients, HCP use double gloving which decreases the potential risk of transmission through glove holes or damage due to disinfectants. It also reduces the risk of hand contamination when removing gloves, since the external pair, which may be contaminated, is removed before the inner one.⁵⁹ Three types of gloves are available in hospital environment – latex, nitrile, and vinyl – differing in their composition, which reflects on their durability, resistance, elasticity, and comfort.⁵⁶

3.1.3 | Body protection: Gowns, coveralls, and aprons

Gowns and coveralls are mainly used by HCP, with the main function of protecting against the transmission of pathogenic microorganisms in blood and fluids. These PPE may also be used to help prevent the gown wearer from transmitting microorganisms to patients with weakened immune systems. There are different types of gowns and coveralls with variable protection levels, which depend on the physical and chemical properties of the fabric, the type of pathogen, the carrier characteristics, and external factors. The WHO recommends long-sleeved, non-sterile, impermeable, fluid-resistant gowns, or coveralls as the most suitable PPE for high-risk settings. Although coveralls cover a large part of the body surface area for enhanced protection, gowns are easier to put and remove, cause less heat stress, and are more easily available in a hospital environment. It has been suggested to use aprons over gowns as an additional measure to protect from contamination during aerosol-generating procedures.^{59,63}

3.1.4 | Goggles and face shields

Eye protection is used by HCP to protect eyes from exposure to splashes, sprays, splatter, and respiratory secretions of infected patients. Disposable eye protection should be removed and discarded or, if reusable, should be cleaned and disinfected after patient encounter. Goggles are used mainly by HCP but face shields have gained some popularity among the GP, who find these more comfortable than masks. Shields also have the advantage of covering the sides and length of the face but should not replace masks, and instead should be used as an additional protection measure. In the case of HCP, shields may be preferred to goggles, which frequently fog, affecting visibility, and do not provide full-face coverage.^{59,64,65}

3.2 | The “side effects” of PPE: Reported skin lesions

3.2.1 | Lesions caused by masks

The main face protections used by HCP and the GP, surgical masks and N95 respirators, exert different physical pressures on the skin. Because surgical masks are loose-fitted, they exert less pressure and friction than N95 respirators, nevertheless slight tensions can cause skin damage. N95 respirators seal around the nose and mouth leading to nasal bridge scarring, cheeks itching, dry skin, and rash, among others (Figure 1d). The friction and pressure forces are also responsible for poor local blood circulation, causing tissue ischemia and hypoxia. Skin transpiration and water vapor exhaled from the mouth and nose create a moist and hot environment, which softens the skin, reducing the SC ability to resist external pressure and shear forces, and resulting in rashes, redness, and acne, also known as “maskne” (Figure 1c).^{29,66,67}



FIGURE 1 Examples of the most reported skin lesions caused the use of masks, gloves, goggles/face shields, gowns and coveralls by health-care professionals. (a) Redness and irritation caused by alcohol-based hand sanitizers; (b) dry skin caused by glove usage; (c) “maskne”; (d) scarring on the nose bridge due to N95 masks; (e) indentation on the forehead caused by face shield usage; (f) indentation under the eye from goggles usage; (g) ulceration behind the ear caused by mask elastic ear loops; (h,i) acne on the chest and back, respectively, caused by coverall usage

“Maskne” is a type of skin lesion which seems to result from follicular occlusion, mechanical stresses between the textile of the mask and the skin, and skin microbiome changes related to external factors such as temperature and humidity increase, and changes in pH balance. The moist environment increases sebum secretion, causing occlusion, irritation, and inflammation of the epidermis, contributing to the visual appearance of acne. “Maskne” is more frequent in women than in men, possibly because facial hair confers some protection. Additionally, women may use makeup, which contain comedogenic ingredients that may cause pore clogging, leading to skin breakouts.^{65,68}

The elastic loops that stretch around the ears also exert pressure and shear forces on the ear’s skin causing pain and discomfort and leading to allergic contact dermatitis and ulceration with continuous use (Figure 1g).⁶⁹ Not only the frictions between the ear and the loop strap, trapping of sweat, use of disinfectant to “clean” the mask are frequent causes of dermatitis, but the strap material including thermoelastic polymer, rubber, and latex are also responsible to promote skin disruption.

3.2.2 | Lesions caused by gloves

Contact and allergic dermatitis are the most reported hand skin lesions, due to frequent hand sanitation, and due to the use of gloves. Long-term use of gloves has been reported to cause overhydration of the SC, leading to maceration and erosion.⁷⁰ Latex gloves are popular among

users for their comfort, cost, and touch sensitivity characteristics. However, several cases of allergic reactions have been reported, particularly among HCP. These include skin pathologies such as urticaria and angioedema but also rhinitis, conjunctivitis, bronchospasm and, in severe cases, anaphylaxis.⁷¹ As a solution to avoid latex-related allergic reactions, most health-care facilities have switched to nitrile gloves. These, however, contain several chemicals used during the manufacture process including pigments, fillers, vulcanizing agents, and rubber accelerators. Vinyl gloves are another option, considered to be safer because they are rubber acceleration-free, with rare reports of allergic dermatitis. Apart from allergic reactions, long-term use of gloves causes occlusive effects in skin and also moisture imbalance which, coupled with excessive hand cleansing, may cause irritation, maceration, erosion, desquamation, and dermatitis (Figure 1a,b).^{56,72} Shear forces associated with wearing or removing gloves may also contribute to hand dermatitis in HCP. Additionally, donning gloves with wet hands from either washing or applying alcohol increases the risk of skin irritation due to the constant humid environment.²⁰

3.2.3 | Lesions caused by other PPE

Gowns and coveralls have requirements for tightness, covering the skin all over the body, creating a humid and hot environment. Acne in the chest and back (Figure 1h,i) is likely to occur since skin in these

locations is rich in sebaceous glands, producing sweat and sebum responsible for pore clogging. Allergic skin reactions may result from irritation due to excessive sweating and from constant contact between the skin and the PPE. When this hostile humid environment lasts for more than 10 h, it is inevitable that skin reactions occur. Other symptoms reported by HCP include dry skin, itching, rash, and inflammation.^{29,73}

Face and eye protection such as goggles and face shields can squeeze and rub the cheeks, forehead, and nasal bridge. These areas are exposed to constant pressure and friction for long periods of time, causing skin indentations (Figure 1e,f) and, in some extreme and rare cases, ecchymosis, maceration, abrasion, and erosion.³⁰

3.3 | Prevention of PPE-caused skin lesions: Good skin care and alternative solutions

Skin damage caused by PPE may be reduced by decreasing adhesion, pressure, and friction in the areas of use, as well as adequate skin care.⁷² The first step is to decrease the use of PPE through 15-min breaks every 4 h, alleviating the pressure and attenuate the hostile environment caused by PPE use. When breaks are not possible, other options to minimize skin damage include a careful daily skin care routine and incorporation of dressings between the skin and the PPE (Figure 2).

3.3.1 | Facial skin care

A daily skin care routine is crucial to reinforce the skin, increasing its strength against external forces. Moisturizer formulations, such as ointments, creams, lotions, and gels (in decreasing order of moisturizing ability), contain occlusive, humectant, and emollient components, which can prevent and treat dermatitis caused by PPE use.^{30,56,65} The ingredients present on the moisturizer formulation should help restore the SC structure: occlusives create a physical barrier on the skin, decreasing TEWL, thus reestablishing the skin water content; humectants also decrease TEWL by attracting water to the skin; and emollients consisting primarily of lipids, restore the disrupted lipid in the SC preventing skin dehydration. A daily direct application of moisturizers on the regions in direct contact with the PPE, such as ears, forehead, nose bridge, cheeks, and chin, may prevent dermatitis.^{26,30,65} The application of hyperoxygenated fatty acids for the prevention of ulcers is well documented and may be a good option as well. Compounds containing essential oils have presented beneficial results regarding wound healing, providing optimal skin hydration and reverse non-blanching erythema. These advantages are possible due to the capability of increasing the cohesiveness of the cells in the SC, decreasing TEWL and skin desquamation, and also facilitating anti-radical activity in oxidative stress process of cells.⁷⁴

However, simple moisturization is not enough to treat “maskne”, which may require antibacterial cleansers and anti-inflammatories and/or antibiotic topical medicines.^{30,65} Excessive pressure exerted

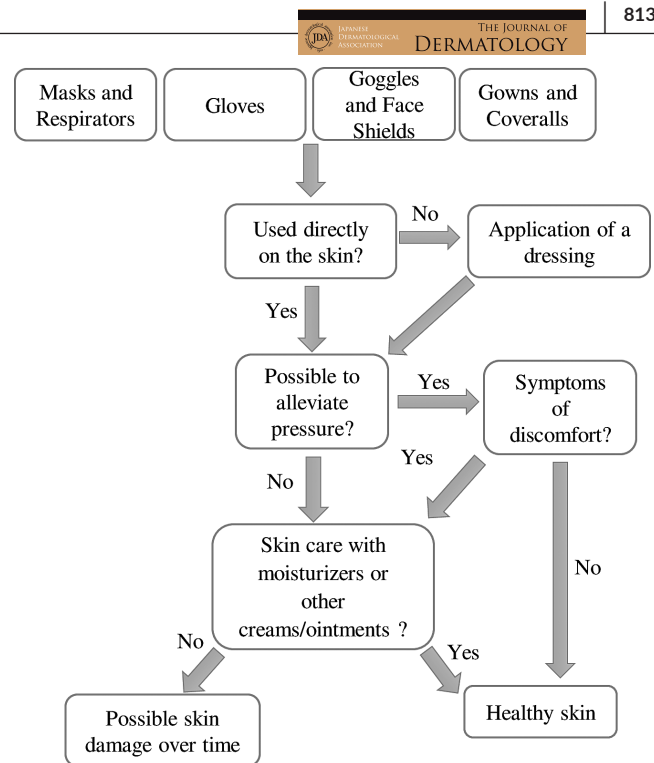


FIGURE 2 Summary of possible outcomes of personal protective equipment (PPE) use in terms of skin health. The arrows represent hypothetical decisions one might make when using a PPE, which may or may not result in skin damage

by N95 respirators, face shields, and goggles, may originate eczema-like lesions and ulcers followed by secondary bacterial or fungal infections. In these cases, glucocorticoid creams/ointments or antibiotic/antifungal ointments can be applied topically.³⁰

Facial cleansing prior to moisturizing is also an essential step: washing the face can prevent multiple skin problems by rinsing external impurities and preventing pore clog. The American Academy of Dermatology Association recommends six steps for an efficient facial cleanse: (i) the use of a non-abrasive and non-alcoholic cleanser; (ii) fingertips spreading with lukewarm water; (iii) scrubbing avoidance; (iv) pat dry with a soft towel; (v) moisturizer application; and limit washing to twice a day and after sweating. These steps aim at decreasing or avoiding skin irritability, with gentle and delicate movements being preferred over harsh scrubbing.⁷⁵ Harsh cleansing products such as chemical peels, exfoliants, and treatments with retinoids should be avoided since these products may enhance sensitive skin problems. Additionally, as previous mentioned, some makeup products contain comedogenic ingredients which promotes pore clog. Thus, makeup should be avoided or, if needed, non-comedogenic products should be chosen.⁷⁶

3.3.2 | Hand skin care

Similarly to facial skin care, hand skin care should also include gentle washing and moisturization. Nonfractional drying method should all be applied in hands, as well moisturization with cream or, in severe

cases, with a mild topical steroid cream before donning occlusive gloves. The moisturization process should be repeated every 3 to 4 h after hand washing.^{20,56} In scenarios where alternatives to latex gloves are not available, another suggestion is to use cotton gloves inside latex gloves to protect against allergic reactions.⁷⁷

A study by Stutz *et al.*⁷⁸ reported that 69.5% of nurses considered ABHS more damaging than handwashing using mild soap and water. However, two other studies^{79,80} suggested that the use of ABHS caused less dryness and irritation than regular hand soap, possibly due to the presence of strong surfactants in soap formulations. Another study showed that the use of ABHS after washing removed the detergent left in the SC, the main cause of skin irritation, thus having a protective advantage compared with washing alone. However, no increased protection against viruses was observed.⁸¹

3.3.3 | Body skin care

Skin from other body areas such as ears, chest, and back may also be affected by the prolonged use of PPE, although less than that of face and hands.^{29,30,73}

The use of masks usually causes ear soreness; thus, different types of masks with different types of ties and ear loops should be used on different days, to ensure that the pressure is not always exerted in the same areas. Some users even wear an ear loop adapter to alleviate the pressure.⁷⁶ Goggles are used by HCP in hospitals and complaints include foggy lenses and general discomfort. Goggle tightness should be adjusted to avoid intense pressure on the skin.⁷⁷

The prolonged use of gowns and coveralls causes excessive sweating and a hot and humid environment. The sodium present in sweat can dehydrate, sting, and irritate the skin leading to dermatitis. After leaving the contaminated area, a quick shower with lukewarm water is recommended. Over-showering removes the lipids from the skin surface, disrupting the SC due to the presence of surfactants in shampoos and soaps; thus, post-shower moisturization is an important step to recover the skin lipids and avoid scaling and dryness.^{77,82}

3.3.4 | The use of dressings: An alternative approach

Dressings are frequently used to prevent skin lesions such as pressure ulcers in patients.^{28,83} These same dressings can be adapted by HCP to be used underneath the PPE in areas of higher pressure and/or repeated rubbing. The goal of the dressing application is to prevent injuries by redistributing and reducing pressure and avoid the friction triggered by PPE displacement, without interfering with the PPE efficacy.^{29,72}

Three commercial dressings are used by HCP as an interface between the PPE and the skin: hydrogel, hydrocolloid, and foam dressings. Hydrogel alleviates skin damage resulting by lowering the indentation, pain, and itching caused by compression.⁶⁷ This dressing is biocompatible, has good compliance as it is breathable, and absorbs/releases moisture to

guarantee skin moisturization. The hydrocolloid dressing is a gel-like material, commonly used for wound healing, with good compliance from patients, and which can be placed on irregularly shaped body parts without changing the tightness of the PPE. Both dressings are easy to apply and remove without damaging the skin. Foam dressings are optimal for preventing ulcers due to their high resistance to pressure and shear forces. However, these are much thicker than hydrogel and hydrocolloid dressings, which may compromise the PPE tightness and efficacy.^{28,29}

Although dressings as an interface between the PPE and the skin are well documented, studies concerning the efficacy of dressings containing excipients with wound-healing or anti-inflammatory properties are scarce. There are several commercially available dressings with different excipients, with different properties and applications. For example, hydrogel dressings containing a combination of retinoids and antibiotic can be used to treat acne.⁶⁵ Hydrocolloid dressings with silver nitrate, with antimicrobial properties, are also commercially available.⁸⁴ Another option is the silicone dressing, which is indicated to prevent trauma to wounds and surrounding skin, alleviating patients' pain. It has good compliance, it is easily removed, does not traumatize the wound or the surrounding skin, and therefore does not interfere with the healing process.⁸⁵ When ulcers are present, a viable choice is the alginate dressing containing extract of natural brown algae, mainly polysaccharides, which provides a moist healing environment, promotes cell proliferation, reduces pain, protects the tissue from injuries, and accelerates wound healing.⁸⁶ One of the most recent advances has been the introduction of hydrofiber technology, a soft, sterile, non-woven pad dressing, composed of sodium carboxymethylcellulose, which is incorporated in the form of a fleece held together by a needle-bonding process. When in contact with exudates, it transforms into a soft gel, creating a moist environment to support the healing process.⁸⁷

Recently, Massen *et al.*⁸⁸ reported the use of tribology methods to evaluate the lubricating properties of zinc oxide and titanium dioxide, excipients with known cicatrization properties. The study showed low friction values and concluded that the incorporation of excipients is a simple and efficient method to reduce the shear loading on the skin, therefore relieving skin injuries caused by PPE. Dressings with healing and moisture properties capable of reducing pressure and shear forces can dramatically change the quality of life of HCP. However, there are still uncertainties pertaining the protective effect of these devices and they have a high cost for health institutions.²⁸

4 | CONCLUSION AND FUTURE DIRECTIONS

The COVID-19 pandemic is responsible for new daily measures aiming to minimize human-to-human transmission; these include physical distancing, remote work, frequent hand sanitation, and the use of PPE.⁹² An important drawback is the increase of skin lesions due to the continuous use of PPE and frequent hand sanitation; thus, research on the prevention or treatment of such lesions is timely.

This review focuses on skin injuries resulting from the frequent hand hygiene and use of PPE during the COVID-19 pandemic, and how to possibly prevent them. The most frequent skin lesions reported by both the GP and HCP are acne, facial itching, rash, and dryness, which cause physical and psychological discomfort. Prevention includes the use of preservative- and fragrance-free ABHS rubs containing humectants, daily skin care routine with moisturizers, and using dressing placement between the skin and the PPE as a protective barrier. To the best of our knowledge, published results concerning the lubrication properties of dressings with healing properties are scarce. Thus, additional tribological studies with different types of dressings are needed, to understand which is more suitable to reduce pressure and shear forces exerted by PPE, promoting comfort, and improving quality of life for all during pandemic times.

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CONFLICT OF INTEREST

None declared.

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