Disaster Medicine and Public Health Preparedness

www.cambridge.org/dmp

Concepts in Disaster Medicine

Cite this article: Ahmad IA and Osei E. Occupational health and safety measures in healthcare settings during COVID-19: Strategies for protecting staff, patients and visitors. *Disaster Med Public Health Prep*. doi: https://doi.org/10.1017/dmp.2021.294.

Keywords:
covid-19; sars-cov-2; infection control measures; nosocomial transmission; healthcare settings

Corresponding author:
Ernest Osei,
Email: ernest.osei@grhosp.on.ca.

SDMPH
SOCIETY FOR DISASTER MEDICINE & PUBLIC HEALTH

Occupational Health and Safety Measures in Healthcare Settings during COVID-19: Strategies for Protecting Staff, Patients and Visitors

Isra Asma Ahmad[1] and Ernest Osei[2,3,4,5]

[1]Department of Public Health and Health Systems, University of Waterloo, Waterloo, ON, Canada; [2]Department of Medical Physics, Grand River Regional Cancer Centre, Kitchener, ON, Canada; [3]Department of Physics and Astronomy, University of Waterloo, Waterloo, ON, Canada; [4]Department of Systems Design Engineering, University of Waterloo, Waterloo, ON, Canada and [5]Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON Canada

Abstract

The COVID-19 (SARS-CoV-2) pandemic has profoundly impacted almost every aspect of healthcare systems worldwide, placing the health and safety of frontline healthcare workers at risk, and it still continues to remain an important public health challenge. Several hospitals have put in place strategies to manage space, staff, and supplies in order to continue to deliver optimum care to patients while at the same time protecting the health and safety of staff and patients. However, the emergence of the second and third waves of the virus with the influx of new cases continue to add an additional level of complexity to the already challenging situation of containing the spread and lowering the rate of transmission, thus pushing healthcare systems to the limit. In this narrative review paper, we describe various strategies including administrative controls, environmental controls, and use of personal protective equipment, implemented by occupational health and safety departments for the protection of healthcare workers, patients, and visitors from SARS-CoV-2 virus infection. The protection and safeguard of the health and safety of healthcare workers and patients through the implementation of effective infection control measures, adequate management of possible outbreaks and minimization of the risk of nosocomial transmission is an important and effective strategy of SARS-CoV-2 pandemic management in any healthcare facility. High quality patient care hinges on ensuring that the care providers are well protected and supported so they can provide the best quality of care to their patients.

Introduction

The coronavirus disease (COVID-19) caused by the SARS-CoV-2 virus was declared a Public Health Emergency of International Concern on January 30, 2020 and a pandemic on March 11, 2020 by the World Health Organization (WHO).[1] Numerous studies have since reported that SARS-CoV-2 is primarily transmitted through respiratory particles (such as droplets) falling directly on individuals when an infected person who is unmasked, sneezes, coughs, or talks and the infected secretions enter the mucous membranes of another person either through the mouth, nose or eye.[2–13] Furthermore, several studies have also reported that airborne transmission of the virus can occur when particles float in the air for a prolonged period of time (which is likely to occur during aerosol-generating procedures),[2,6–9] and a person remains in the environment for at least 15 minutes. According to Public Health Ontario,[2] secondary transmission of the virus can also occur if a person touches a contaminated surface and then proceeds to touch the mouth, nose or eye. The Center for Systems Science and Engineering (CSSE) at Johns Hopkins University,[14] reported that there are currently over 191 million cases of COVID-19 and over 4.1 million COVID-19 related deaths worldwide as at July 20, 2021. The continual emergence of new SARS-CoV-2 variants has added an additional level of complexity to the already challenging situation of containing the spread and lowering the rate of transmissions.

The SARS-CoV-2 pandemic still remains a significant public health challenge as most healthcare systems worldwide have limited capacity and resources to handle the influx of new cases each day.[15–17] Consequently, public health officials and policy makers worldwide are constantly developing new strategies based on continuously changing evidence-based guidelines to manage the spread of the virus in order to help alleviate its burden on healthcare systems and to save the lives of thousands of people. Furthermore, occupational health and safety departments and administrators in hospitals have been working closely with public health offices to develop policies providing optimal protection for healthcare workers, patients, and visitors via elimination of all possible transmission pathways to prevent nosocomial transmissions. One of

the important tenets of effective pandemic management has been the protection and safeguard of the health and safety of healthcare workers and patients through implementation of effective safety measures at hospitals to avoid or minimize potential nosocomial transmissions.[20,25,26,38,41] Numerous studies have reported that the establishment and implementation of robust infection prevention management policies in hospital settings are vital in minimizing the spread of SARS-CoV-2.[18–21] Moreover, high quality patient care hinges on ensuring that the care providers are very well protected and supported so they can provide the best quality of care to their patients. Therefore, the goal of this narrative review paper is to describe various infection control strategies implemented by occupational health and safety departments in healthcare settings and played paramount roles in reducing nosocomial spread for the protection of healthcare staff, patients and visitors against the COVID-19 and prevent healthcare facilities from becoming the epicenters of SARS-CoV-2 virus transmission.

Protection of healthcare workers

The public health and hospital-based Occupational Health and Safety departments in several countries have collaborated using the best available evidence-based guidelines to provide protection for frontline healthcare workers, patients and visitors against SARS-CoV-2, and COVID-19. The protection of healthcare professionals is paramount to the sustainability of healthcare systems in any pandemic since they play a pivotal role in the delivery of safe and effective treatment for patients while maintaining their safety.[22–24] Healthcare professionals bear the brunt of the current pandemic with the management of various surges of new cases each day, working longer hours, frequent shifts, and possibly fewer breaks while potentially compromising their own health to support COVID-19 patients. According to Abbas *et al.*,[25] healthcare workers are at greater risk of contracting the virus since they work in environments with active transmission and a myriad number of exposure pathways through both indirect and direct contact with patients who may be infected with the virus. Moreover, lessons learnt from past epidemics such as the Severe Acute Respiratory Syndrome (SARS) show that inadequate protection of healthcare staff could potentially lead to staff shortage as absenteeism may increase, and the few remaining staff may be required to complete additional care duties and work longer hours which could potentially lead to occupational burnout.[26–31] According to Temsah *et al.*,[26] added work pressure on healthcare workers could take a toll on their mental well-being and potentially increase their susceptibility to depression and post-traumatic stress disorder. Furthermore, inadequate protection and management of the health of healthcare workers can have a ripple effect on patients and their families.[26] Consequently, the design and effective implementation of stringent and vigilant infection control policies and procedures aimed at the protection and care of healthcare workers, is an important cornerstone for the prevention of nosocomial SARS-CoV-2 infection and the sustainability of patient care.[26] High quality patient care hinges on ensuring that the care providers are very well protected and adequately supported so that they can provide the best quality of care to their patients.

Mitigation strategies to control the spread of sars-cov-2/covid-19

Several studies have reported on effective strategies required to control the spread of SARS-CoV-2 within healthcare settings such as staff vaccination,[32–47] the implementation of administrative control measures (i.e. triaging procedures, limiting the number of people into the hospital, cohorting of patients and staff), environmental control measures (i.e. effective surface cleaning, adequate ventilation, and air filtration), engineering control measures, the proper use of personal protective equipment (PPE) such as face masks and respiratory hygiene, and the elimination of the hazard.

Administrative controls

Administrative controls are modifications in work procedures including timing of work, policies, rules and regulations, work practices (including training, supervision, housekeeping, personal hygiene practices, equipment maintenance, and schedules) that are instituted to prevent or eliminate exposure of staff, patients, and visitors to any hazards that may be present within the healthcare settings.[32,35,36] Administrative controls are very effective in reducing or limiting the transmission of infectious diseases in healthcare settings through the identification of all the potential exposure pathways and the implementation of practices and policies required to prevent or eliminate the source of spread of exposures. The primary objective of administrative control measures implemented in hospitals is to ensure that patients, visitors, and healthcare staff who may be infected with any infectious disease such as COVID-19 could be promptly identified, diagnosed, isolated, and treated in an effort to prevent the spread of the infection to others within the hospital.[32,37,38] Several studies have reported that the success of any administrative control measures instituted within healthcare settings is heavily dependent on the careful guidance and directions provided by the occupational health and safety departments and any infection prevention disease committees that may have been established to manage and prevent the spread of the infection.[32,35,48] The occupational health and safety departments within healthcare facilities serve to ensure that the organization has the resource capacity, knowledge, training, policies and procedures to adequately implement any established infection control measures. According to Su *et al.*,[35] administrative control measures can be effective in reducing the transmission of infections if they are well implemented, adequately enforced, and continually monitored to better facilitate staff, patient, and visitor compliance. Several studies have reported that administrative control measures such as triage procedures at main entrances of the facility, limiting the number of patients and visitors to the facility, cohorting of patients and healthcare workers, and physical distancing practices are all effective measures of preventing or limiting the spread of SARS-CoV-2 infection in hospitals.[32,35–40,43–47,49–59,61] According to Lu *et al.*,[40] the establishment of infection control strategies such as material preparation and distribution, training on infection prevention measures, a triage strategy, limiting traffic into the hospital, reorganization of hospital departments to minimize the number of people present at any particular time, and keeping the environment sanitized are very effective strategies to contain the spread of the SARS-CoV-2.

Triaging procedures

Triaging is a systematic process used to control patient flow in a clinic or a facility to ensure that those with urgent healthcare needs are prioritized to receive immediate care.[62] Studies have reported that the implementation of triaging processes within the healthcare system has significant potential to prevent the spread of nosocomial infection through prompt identification of patients, staff, and visitors who may be infected with SARS-CoV-2. Furthermore, ensuring the triaging procedures are tailored towards prompt

identification and detection of SARS-CoV-2 affected individuals is very critical in reducing exposure by staff, patients, and visitors.[36,39,63–67] Lee *et al.*,[68] reported that the implementation of proper triage procedures is an important factor in helping to prevent the spread of SARS-CoV-2. According to Wong *et al.*,[36] Wang *et al.*,[39] and Lee *et al.*,[68] an effective triaging process can be established for early identification of patients, staff, and visitors who may be infected with SARS-CoV-2, and should be set up only at the main entrances of the healthcare facility to ensure that all patients, staff, and visitors entering the facility are screened using the same standard questionnaire. However, in order to minimize congestion at the facilities' entrances, it is suggested that different triage stations should be established at 2 different main entrances; 1 to be used by staff and the other by patients and visitors. Furthermore, it is important that all other access to the healthcare facility is inaccessible to all staff, patients, and visitors. Lee *et al.*,[68] reported that performing temperature checks, asking about patients travel history, close contacts, and new symptoms, are very important information to gather as part of the triage process. They reported the installation of infrared thermal cameras within hospitals in Taiwan as part of the triaging process for prompt detection of patients, visitors, or staff with elevated body temperatures (fever) as an effective approach for temperature checks in hospitals. Numerous studies have reported that the most common screening criteria questions used in most healthcare facilities at triaging stations include the following: asking patients/ staff/ visitors if (i) they are experiencing any symptoms of upper respiratory infection, (ii) travelled outside the country within the past 14 days, (iii) if they have visited any facility with known outbreak, and (iv) if they have been in contact with any individual who has been diagnosed with COVID-19.[36,39,69–72] If a patient, staff or visitor responds yes to any of the questions, it is recommended that they be immediately placed in an airborne isolation room and tested for SARS-CoV-2. According to Wang *et al.*,[39] the implementation of the triage procedures in various hospitals have been very effective in prompt identification of patients, staff, and visitors with infection and thus has significantly reduced the risk of transmissions in several hospitals.

Limiting traffic in healthcare facilities

Studies have reported that limiting the number of people present in the healthcare facility at any given time is an effective strategy for the prevention and minimization of potential exposure and spread of SARS-CoV-2 in the facility.[32,40,41,73–76] Consequently, a number of hospitals worldwide cancelled, postponed, or severely reduced several healthcare services including elective surgeries, patient follow-up, face-to-face patient consults, cancer screening/prevention services, and certain diagnostic and treatment services. Furthermore, several hospitals shifted to telemedicine, restricted in-hospital visitations, and implemented strategies for some staff to work from home in an effort to minimize potential pathways of exposure to SARS-CoV-2.[32,36,41,77] Although these measures may potentially reduce the spread of SARS-COV-2, it is recommended that 1 should carefully weigh the benefits of patient care with both the risk of patients contracting SARS-COV-2, and the downstream consequences of delaying, modifying, or cancelling diagnostic and treatment activities.[77] A study conducted by The Lancet Digital Health reported that the use of telemedicine increased from 10% to 75% in the UK during the height of the COVID-19 lockdown.[78] According to Lai *et al.*,[41] the postponement of elective surgeries will also ensure that healthcare facilities have adequate resources (beds, ventilators etc.) and staff for possible surge in COVID-19 cases. Liu *et al.*,[42] also reported that adding restrictions to the number of visitors, maintaining a visitor log, and limiting the number of entrances to the hospital are important access control strategies to limit the number of people in the hospital, thereby reducing nosocomial spread of SARS-CoV-2.

Lu *et al.*,[40] described infection control measures that were established in a West China Hospital in an Ear-Nose-and-Throat (ENT) department to protect healthcare workers and patients from potential SARS-CoV-2 infection. They reported that in order to decrease the number of patients present at the ENT clinic, they separated the waiting area from the treatment area, reduced the number of appointments, re-scheduled appointments at different times, restricted visitation to a single visitor, increased online consulting services, and initially suspended elective surgeries. They concluded that the infection control measures that were implemented significantly reduced the number of people in the clinic and were very effective in preventing nosocomial SARS-CoV-2 infection in the ENT department. Wang *et al.*,[59] investigated the impact of implementing recommendations that were outlined by the National Cancer Center and Chinese Academy of Sciences for the protection of patients and staff from contracting SARS-CoV-2. They reported suspending elective surgeries, reducing inpatient and outpatient visits in the oncology department, suspending chemotherapy treatments where possible, and using oral administration of anti-cancer drugs for patients. They observed that the precautions employed were very successful in preventing the spread of cross infection since no COVID-19 cases were reported among staff or patients in the department during the time of the study. They concluded that during the COVID-19 era, it is possible to continue to provide treatment to patients with cancer who urgently require it, without compromising patients' health, by implementing appropriate safety measures that can prevent cross infection. Al-Shamsi *et al.*,[48] investigated some practical approaches to manage cancer treatment during the SARS-CoV-2 pandemic. They recommended that deferring elective surgeries and outpatient visits, postponing chemotherapy and radiation treatment on a case-by-case basis, using alternative treatments such as oral anti-cancer therapy where possible, and utilizing telemedicine for patient follow-up and support, are imperative measures that can help reduce the number of people in the facility and help curb the spread of infection and prevent potential risk of exposure to SARS-CoV-2. They concluded that these measures have the potential to minimize the spread of COVID-19 in healthcare facilities and protect patients who are immunocompromised from contracting the infection. Jindal *et al.*,[53] also investigated the management practices of cancer patients during this pandemic and suggested similar approaches in order to provide safe cancer care. They suggested the deferment of cancer patients' regimes if they are tested positive for COVID-19/SARS-CoV-2 and acknowledged that treatment centers pose a great risk of exposure to the infection. They concluded that although deferring treatment could minimize the spread of SARS-CoV-2, it can potentially compromise the health of patients and their condition could progress from potentially curable (with near-normal life expectancy) to likely incurable (with much reduced life expectancy).

Cohorting of patients

The World Health Organization characterized cohorting patients as the concept of separating patients who have been infected by the same laboratory confirmed pathogen into 1 ward.[33] There is sufficient evidence that suggests that cohorting patients is an effective

measure in containing and preventing the spread of infections such as gastroenteritis in hospital settings,[50,55,79,80] and has been reported to be potentially effective to reduce the risk of transmission and exposure to SARS-CoV-2.[43,44,56] The World Health Organization and the US Centre for Disease Control and Prevention guidelines recommended the cohorting of COVID-19 patients as it can potentially limit the number of patients and healthcare workers who could be exposed to the virus and will help contain its spread in the healthcare settings. Cohorting of patients has been a common practice in infection control strategies that are utilized to manage outbreaks and the prevention of the spread of nosocomial infection.[43,44,56,68]

According to Lee *et al.*,[68] cohorting patients is an effective strategy to reduce nosocomial SARS-CoV-2 infection when coupled with other measures such as triaging procedures and the use of personal protective equipment. Patterson *et al.*,[44] investigated measures needed to protect patients with comorbidities who have been admitted to the hospital to prevent them from being exposed to SARS-CoV-2. They reported using clinical, laboratory, and radiological markers to promptly identify and cohort patients with COVID-19 in order to minimize the risk of exposure to staff and other patients. The implementation of the cohorting strategy ensured that patients who tested negative for COVID-19/SARS-CoV-2 did not acquire the infection during their hospital visit, as they were housed in single occupancy rooms distanced from patients who were COVID-19 positive. Furthermore, they reported that cohorting patients helped alleviate the demand for single occupancy rooms, as patients who are infected were grouped together in the same space. As a result, single rooms were then utilized for patients with comorbidities or at greater risk for complications due to COVID-19. They concluded that cohorting patients, is an effective measure in preventing healthcare-associated COVID-19 infection among patients with comorbidities.

Congregate care settings such as long-term care homes or nursing homes are also highly susceptible to COVID-19 outbreaks. Cohorting residents, can often be a mitigation strategy that is utilized in congregate care settings as an outbreak management strategy. Montoya *et al.*,[56] examined some of the interventions implemented to manage COVID-19 outbreaks at 3 different nursing homes in Michigan to avert further transmission to other residents and staff. They reported using cohorting residents with COVID-19 as 1 of the many reduction and control strategies implemented to manage the outbreaks at each of the nursing homes. They found that cohorting residents who were SARS-CoV-2 positive through prompt testing decreased asymptomatic transmission to other staff and residents. They concluded that cohorting the residents is an effective method for outbreak management and lowering the prevalence of COVID-19 in nursing home settings.

Cohorting of healthcare workers

Cohorting of healthcare workers is also considered an effective administrative control measure that can be employed to minimize the exposure and reduce the risk of transmission of SARS-CoV-2 since the approach could significantly limit the number of staffs who interact with potentially infected patients.[32,34,45,46,52,58,61] In this approach, a group of healthcare workers are assigned to be responsible for the care of only patients who are diagnosed to be SARS-CoV-2 positive, thus limiting the number of other healthcare workers to any potential exposure to the virus.[32,34,45,46,52,58] According to the Centers for Disease Control and Prevention (CDC),[34] minimizing the number of patient-staff interactions is an effective control measure for reducing SARS-CoV-2 transmission in healthcare facilities. The CDC has recommended that healthcare workers should minimize the number of patient encounters by simultaneously performing some medical procedures or examinations where possible.[34] Additionally,[52,58,61] other studies have reported that developing healthcare teams is an effective measure in minimizing the risk of hospital-acquired infections. There is sufficient evidence suggesting that the cohorting of healthcare workers is effective in minimizing cross-transmission of infectious agents,[51,57,59] and could potentially reduce cross transmission of SARS-CoV-2. Chandy *et al.*,[45] examined evidence-based measures needed to reduce the transmission of SARS-CoV-2 among patients and staff in healthcare-settings. They reported that cross-covering staff who have been caring for patients with COVID-19 in other units, can lead to intra-hospital transmission, thus, cohorting COVID-19 healthcare teams is imperative. Furthermore, they suggested that multiple teams should be developed as COVID-19 is highly contiguous and if members of 1 team need to go into isolation, the alternative staff members can fill in. They concluded that there are multiple pathways of transmission and formulating healthcare teams can potentially prevent the transfer of SARS-CoV-2 to non-COVID-19 patients and staff. In a systematic review by Abad *et al.*,[46] they reported that cohorting patients and healthcare workers is an effective strategy to reduce intra-hospital transmission of infectious diseases. They observed that about 88.5% of studies have reported a significant reduction in the spread of infection when cohorting healthcare workers was implemented with other infectious disease measures such as cohorting patients, and good hand hygiene practices. They concluded that although determining the effectiveness of cohorting healthcare staff can be challenging as typically, other mitigation measures are usually implemented simultaneously, they reported that cohorting staff strengthens the overall infection control strategy.

Environmental controls

Environmental controls, both primary and secondary, are measures that are usually instituted with the intent to reduce the amount of droplet nuclei containing infectious pathogens that may be present in the air.[32,34,41] The primary environmental controls involve the utilization of mechanical ventilation systems such as hoods, to remove or reduce infectious microorganisms that may be present in the air, whereas the secondary environmental controls involve the use of either the HEPA filtration or/and ultraviolet germicidal irradiation systems to remove aerosol causing diseases agents from the air.[81–90] According to Lee,[81] controlling the direction of airflow in enclosed spaces can potentially reduce the presence of aerosol causing diseases and thus minimize the likely spread of diseases to adjoining spaces. Evidence suggests that SARS-CoV-2 can be transmitted from an infected person to others through respiratory droplets and aerosols, created when an infected person coughs/sneezes, sings, shouts, or talks.[11,13,32] Thus incorporating environmental control measures that are capable of removing SARS-CoV-2 from the air, into infectious disease control strategies, is important to reduce its spread in healthcare facilities.[32,34,82] Several studies have demonstrated that the implementation of environmental control measures such as adequate ventilation, installation of air dampers and HEPA filtration systems, the redistribution of airflow in facilities, and regular maintenance of the heating, ventilation and air-conditioning systems are effective mitigation strategies to minimize the spread of nosocomial SARS-CoV-2,[41,82,89,91–95] Evidence suggests that adequate utilization of

the heating, ventilation, and air conditioning systems in healthcare facilities is imperative to help minimize airborne transmission of SARS-CoV-2.[41,82–91,95] Somsen *et al.*,[82] investigated how ventilation levels impact the amount of airborne droplets present at a given time in various spaces, to gain a better insight of airborne transmission in order to suggest appropriate mitigation strategies needed to prevent the spread of SARS-CoV-2. They observed that in spaces with adequate ventilation, the quantity of aerosols present in the air decreased by about 50% within 30 seconds of adequate ventilation, whereas a greater amount of aerosols persist in the air for a prolonged period of time in poorly ventilated spaces. They concluded that poorly ventilated areas could lead to the spread of SARS-CoV-2 via aerosol droplets as they remain suspended in the air for a prolonged period. Consequently, proper ventilation plays a vital role in preventing airborne transmission of SARS-CoV-2 by removing aerosol particles in the air. Lai *et al.*,[41] examined different infection control measures implemented at an ophthalmology clinic to minimize the spread of SARS-CoV-2. They reported that adding fresh air dampers to the ventilation system and using high efficiency particulate air filters to purify the air and to remove the infectious droplets, could potentially reduce infectious droplets present in the air, thus lowering the concentration of droplets by redistributing airflow. They concluded that the implementation of this environmental control measure is imperative in preventing the spread of SARS-CoV-2. Saran *et al.*,[91] also reviewed several heating, ventilation, and air conditioning system guidelines for information on how healthcare facilities could improve or maintain high indoor air quality to prevent the spread of nosocomial transmission. They suggested that, for optimal safety and protection of staff, any suspected or confirmed COVID-19 patient should be admitted in an airborne isolation room with an air exchange rate of at least 6 air exchanges per hour for older facilities, and at least 12 air exchanges per hour for newly built facilities. They reported that guidelines from several professional bodies suggest that all aerosol generating procedures relating to COVID-19 should be performed in well ventilated negative pressure rooms to mitigate airborne transmission. Adjusting the air distribution, air flow rate, and air exchange rates of the heating ventilation and air condition systems in such spaces would potentially minimize infectious particles from reaching non-contaminated spaces. They concluded that the heating ventilation and air condition systems in healthcare facilities could play an integral role to prevent the spread of airborne nosocomial transmission of SARS-CoV-2 and proper utilization and maintenance of such systems should be incorporated in any pandemic management program.

Personal protective equipment (PPE)

Personal protective equipment (PPE) serves as a barrier between the wearer and the environment, to prevent pathogens from entering the body, and has been proven to effectively protect healthcare workers from exposure to various pathogens.[32,34,36,96] Some examples of PPE include surgical masks, N95 respirators, medical gloves, gowns, goggles, and face shields.[96] According to Barratt *et al.*,[97] it is imperative that every healthcare setting has a well-established PPE program which clearly outlines any hazards that pose illness within the working environment, ensures adequate selection and use of PPE, clearly outlines donning on and off practices, regular testing of PPE for staff, regular inventory check of PPE to determine if they have an adequate amount of supply in case of any emergency, and regular staff training on the use of PPE. The proper use of PPE can potentially prevent self-contamination as well as transfer of infection from person to person, and several studies have established the importance of PPE in protecting healthcare workers and in prevention of the spread of nosocomial SARS-CoV-2 in health care settings.[98–107] However, according to Hoernke *et al.*,[101] it is important for hospital administrators and occupational health and safety departments to understand some of the challenges that frontline workers experience when using PPE, so that when developing pandemic preparedness strategies, they could help implement tailored approaches to address some of staff concerns.

Kalantary *et al.*,[98] conducted a narrative review to identify the different pathways of exposure to COVID-19 among healthcare workers and on the use of PPE to prevent SARS-CoV-2 transmission. They indicated that healthcare workers are more susceptible to the acquisition of SARS-CoV-2 since they are more likely to be in close contact with infected patients, and reported that aerosol generating procedures such as tracheal intubation, tracheotomy, and manual ventilation, are activities that pose the greatest risk of transmission to healthcare workers. Consequently, they recommended that to ensure adequate protection of staff, healthcare workers should always wear full PPE, including N95 respirators, eye protection, gown, gloves, and aprons during aerosol generating procedures, although regular surgical masks could be used during non-aerosol generating procedures. They concluded that the use of PPE is imperative in protecting healthcare workers from acquiring SARS-CoV-2 and is an effective infection control measure in lowering viral transmission. Tan *et al.*,[99] reviewed the inconsistencies that are reported in the literature pertaining to the recommended PPE use among surgical staff. They reported that all patients with COVID-19 pose a significant risk to healthcare workers, thus proper use of PPE is deemed necessary in all procedures for optimal protection. They suggested the use of surgical mask, disposable gown, gloves, eye protection, and a head covering during non-aerosol generating procedures and the use of N95 respirators, disposable long-sleeved gown, apron, gloves, eye protection, head covering, and shoe covering for aerosol generating procedures. Furthermore, they suggested that in order to ensure optimal protection and minimize the risk of cross-contamination, all healthcare workers should receive proper training on the donning on and off of PPE and if possible, should appoint a staff member who ensures that all members are donning on and off the PPE in the proper sequence. They concluded that PPE is an important line of defense against SARS-CoV-2 and should be readily available to all healthcare workers. Jamieson *et al.*,[100] reviewed the recommended practices on the use of PPE to minimize the risk of SARS-CoV-2 exposure and ensure optimal protection for obstetricians. The main purpose of their study was to inform and guide healthcare workers on selecting the appropriate PPE based on the pathway of exposure. They reported the odds of contracting a respiratory infection (0.09%) with proper and consistent use of gloves, gown, mask, and eye protection, coupled with other infection-control measures such as appropriate donning on and doffing off practices, adherence to proper hand hygiene practices and continual cleaning of high touch surfaces. They concluded that consistent and proper use of PPE in conjunction with adhering to adequate hand hygiene practices are important and effective in reducing the risk of acquiring SARS-CoV-2 infection. Hoernke *et al.*,[101] investigated some of the challenges healthcare workers in the UK experienced regarding the use of PPE during the SARS-CoV-2 pandemic. They observed that several healthcare

frontline workers reported inadequate supply of PPE, did not receive proper training in the use of PPE, and there was lack of guidance and protocols on the prolonged use of PPE. Furthermore, staff reported some inherent restrictions with the use of PPE such as difficulties communicating with patients, developing skin reactions, and the discomfort of feeling too hot. They suggested that as a good practice to help minimize PPE fatigue, staff should be encouraged to take breaks. They concluded that the use of PPE is very instrumental to help protect frontline workers from acquiring SARS-CoV-2 infection and in prevention of transmission to colleagues and patients. Furthermore, they emphasized the importance of ensuring adequate supply of PPE, training staff on its proper use, and approaches to combat PPE fatigue.[101]

Conclusion

The SARS-CoV-2/COVID-19 pandemic has significantly impacted almost every aspect of healthcare systems worldwide, placing the health and safety of frontline workers at risk and still remains an important public health challenge. Furthermore, healthcare facilities could be a potential source of the spread of infection as patients with active SARS-CoV-2 infection may visit such facilities for treatment or consultation. Consequently, the establishment, implementation and enforcement of robust infection prevention management controls and policies in hospital settings are paramount to reduce the risk of nosocomial infection, decrease the likelihood of healthcare workers contracting the infection, and thus minimize the spread of SARS-CoV-2. The protection and safeguard of the health and safety of frontline healthcare workers and patients through the implementation of effective safety measures, adequate management of possible outbreaks and minimization of nosocomial transmission is an important and effective strategy of pandemic management used by occupational health and safety departments in healthcare settings.

Search Strategy

The following databases; PubMed (National Library of Medicine Bethesda, MD), PMC (U.S. National Institutes of Health's National Library of Medicine, Bethesda, MD), NCBI (National Center for Biotechnology Information, U.S. National Library of Medicine), PNAS (National Academy of Science, Washington, DC), Springer Link (Springer Nature, London, U.K.), Wiley Online Library (John Wiley & Sons Inc., Hoboken, NJ), The Lacent, Science Direct (Elsevier, Amsterdam, The Netherlands), Medline (National Library of Medicine, Bethesda, MD) were searched from December 2019 to March 2021, for relevant studies published in English between 2010 and 2021, reporting on strategies for protection of healthcare workers, patients, and staff from nosocomial COVID-19 infections. The literature search used the following keywords: 'COVID-19,' 'nosocomial transmission,' 'pandemic management,' 'COVID-19 infection in hospitals,' 'Protection against COVID-19,' 'Healthcare staff management in COVID-19,' 'Infection control during COVID-19,' 'COVID-19 outbreak in hospital,' 'Strategies to control COVID-19,' 'Triage and COVID-19,' 'Cohorting patients and COVID-19,' 'Cohorting staff and COVID-19.' The searches were not limited by study design and included conference abstracts, full research articles, and reviews.

Conflict of interest. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. **Ohannessian R, Duong TA, Odone A.** Global telemedicine implementation and integration within health systems to fight the covid-19 pandemic: A call to action. *JMIR Public Health Surveill.* 2020;6(2):e18810.
2. Ontario Agency for Health Protection and Promotion (Public Health Ontario). *COVID-19 routes of transmission- what we know so far;* 2020. Toronto, ON: Queen's Printer for Ontario. [Internet]. www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/2020/12/routes-transmission-covid-19.pdf?la=en.
3. **World Health Organization (WHO).** *Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations: scientific brief, 27 March 2020*. No. WHO/2019-nCoV/Sci_Brief/Transmission_modes/2020.1.
4. **Endersby RVW, Ho ECY, Spencer AO, Goldstein DH, Schubert E.** Barrier devices for reducing aerosol and droplet transmission in covid-19 patients: advantages, disadvantages, and alternative solutions. *Anesth Analg.* 2020;131(2):e121-e123.
5. **Morawska L, Tang JW, Bahnfleth W, *et al.*** How can airborne transmission of COVID-19 indoors be minimized?. *Environ Int.* 2020;142:105832.
6. **Howard BE.** High-Risk aerosol-generating procedures in covid-19: Respiratory protective equipment considerations. *Otolaryngol Head Neck Surg.* 2020;163(1):98-103.
7. **Klompas M, Baker M, Rhee C.** What is an aerosol-generating procedure?. *JAMA Surg.* 2021;156(2):113-114.
8. **Hamilton GS.** Aerosol-generating procedures in the COVID era. *Respirology.* 2021;26(5):416-418.
9. **Bolton L, Mills C, Wallace S, Brady MC**; Royal College of Speech and Language Therapists (RCSLT) COVID-19 Advisory Group. Aerosol generating procedures, dysphagia assessment and COVID-19: A rapid review. *Int J Lang Commun Disord.* 2020;55(4):629-636.
10. **Larsen JR, Martin MR, Martin JD, Kuhn P, Hicks JB.** Modeling the onset of symptoms of covid-19. *Front Public Health.* 2020;8:473.
11. **Wan S, Xiang Y, Fang W, *et al.*** Clinical features and treatment of COVID-19 patients in northeast Chongqing. *J Med Virol.* 2020;92(7):797-806.
12. **Filatov A, Sharma P, Hindi F, Espinosa PS.** Neurological complications of coronavirus disease (covid-19): Encephalopathy. *Cureus.* 2020;12(3):e7352.
13. **Krajewska J, Krajewski W, Zub K, Zatoński T.** covid-19 in otolaryngologist practice: a review of current knowledge. *Eur Arch Otorhinolaryngol.* 2020;277(7):1885-1897.
14. Johns Hopkins Coronavirus Resource Center, The Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU). Covid-19 dashboard. https://coronavirus.jhu.edu/map.html. Accessed 20 July 2021.
15. **Shen X, Zou X, Zhong X, Yan J, Li L.** Psychological stress of ICU nurses in the time of COVID-19. *Crit Care.* 2020;24(1):200.
16. **Iyengar K, Mabrouk A, Jain VK, Venkatesan A, Vaishya R.** Learning opportunities from COVID-19 and future effects on health care system. *Diabetes Metab Syndr.* 2020;14(5):943-946.
17. **Blumenthal D, Fowler EJ, Abrams M, Collins SR.** Covid-19 - Implications for the health care system [published correction appears in *N Engl J Med.* 2020 Jul 23;:]. *N Engl J Med.* 2020;383(15):1483-1488.
18. **Reeves JJ, Hollandsworth HM, Torriani FJ, *et al.*** Rapid response to COVID-19: Health informatics support for outbreak management in an academic health system. *J Am Med Inform Assoc.* 2020;27(6):853-859.
19. **Chang CM, Tan TW, Ho TC, Chen CC, Su TH, Lin CY.** COVID-19: Taiwan's epidemiological characteristics and public and hospital responses. *PeerJ.* 2020;8:e9360.
20. **Liang XH, Tang X, Luo YT, Zhang M, Feng ZP.** Effects of policies and containment measures on control of COVID-19 epidemic in Chongqing. *World J Clin Cases.* 2020;8(14):2959-2976.

21. **Ho HJ, Zhang ZX, Huang Z, Aung AH, Lim WY, Chow A.** Use of a real-time locating system for contact tracing of health care workers during the covid-19 pandemic at an infectious disease center in Singapore: Validation study. *J Med Internet Res.* 2020;22(5):e19437.
22. **Malik JS, Jenner C, Ward PA.** Maximizing application of the aerosol box in protecting healthcare workers during the COVID-19 pandemic. *Anaesthesia.* 2020;75(7):974-975.
23. **Chan PS, Berg RA, Nadkarni VM.** Code blue during the COVID-19 pandemic. *Circulation: Cardiovascular Quality and Outcomes.* 2020;13(5): e006779.
24. **Nayna Schwerdtle P, Connell CJ, Lee S, *et al.*** Nurse expertise: A critical resource in the covid-19 pandemic response. *Ann Glob Health.* 2020;86(1):49.
25. **Abbas M, Nunes TR, Martischang R, *et al.*** Nosocomial transmission and outbreaks of coronavirus disease 2019: The need to protect both patients and healthcare workers. *Antimicrobial Resistance & Infection Control.* 2021;10(1):1-13.
26. **Temsah MH, Al-Sohime F, Alamro N, *et al.*** The psychological impact of COVID-19 pandemic on health care workers in a MERS-CoV endemic country [published correction appears in J Infect Public Health. 2020 Oct;13(10):1599]. *J Infect Public Health. 2020*;13(6):877-882.
27. **Cai H, Tu B, Ma J, *et al.*** Psychological impact and coping strategies of frontline medical staff in Hunan between January and March 2020 during the outbreak of coronavirus disease 2019 (COVID-19) in Hubei, China. *Med Sci Monit.* 2020;26:e924171.
28. **Walton M, Murray E, Christian MD.** Mental health care for medical staff and affiliated healthcare workers during the COVID-19 pandemic. *Eur Heart J Acute Cardiovasc Care.* 2020;9(3):241-247.
29. **Billings J, Ching BCF, Gkofa V, Greene T, Bloomfield M.** Experiences of frontline healthcare workers and their views about support during COVID-19 and previous pandemics: A systematic review and qualitative meta-synthesis. *BMC Health Serv Res.* 2021;21(1):923.
30. **Heath C, Sommerfield A, von Ungern-Sternberg BS.** Resilience strategies to manage psychological distress among healthcare workers during the COVID-19 pandemic: A narrative review. *Anaesthesia.* 2020; 75(10):1364-1371.
31. **Mesa Vieira C, Franco OH, Gómez Restrepo C, Abel T.** COVID-19: The forgotten priorities of the pandemic. *Maturitas.* 2020;136:38-41.
32. **de Perio MA, Dowell CH, Delaney LJ, *et al.*** Strategies for optimizing the supply of N95 filtering face piece respirators during the coronavirus disease 2019 (COVID-19) pandemic. *Disaster Med Public Health Prep.* 2020;14(5):658-669.
33. **World Health Organization (WHO)**. *Infection prevention and control during health care when COVID-19 is suspected: Interim guidance;* 19 March 2020 (No. WHO/2019-nCoV/IPC/2020.3).
34. **Centers for Disease Control and Prevention**. *Infection Control: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2); 2020.* Infection Control Guidance.
35. **Su CP, de Perio MA, Cummings KJ, McCague AB, Luckhaupt SE, Sweeney MH.** Case investigations of infectious diseases occurring in workplaces, United States, 2006-2015. *Emerg Infect Dis.* 2019;25(3):397-405.
36. **Wong J, Goh QY, Tan Z, *et al.*** Preparing for a COVID-19 pandemic: A review of operating room outbreak response measures in a large tertiary hospital in Singapore. Se préparer pour la pandémie de COVID-19: revue des moyens déployés dans un bloc opératoire d'un grand hôpital tertiaire au Singapour. *Can J Anaesth.* 2020;67(6):732-745.
37. **Chang YT, Lin CY, Tsai MJ, *et al.*** Infection control measures of a Taiwanese hospital to confront the COVID-19 pandemic. *Kaohsiung J Med Sci.* 2020;36(5):296-304.
38. **Sydnor ER, Perl TM.** Hospital epidemiology and infection control in acute-care settings. *Clin Microbiol Rev.* 2011;24(1):141-173.
39. **Wang Q, Wang X, Lin H.** The role of triage in the prevention and control of COVID-19. *Infect Control Hosp Epidemiol.* 2020;41(7):772-776.
40. **Lu D, Wang H, Yu R, Yang H, Zhao Y.** Integrated infection control strategy to minimize nosocomial infection of coronavirus disease 2019 among ENT healthcare workers. *J Hosp Infect.* 2020;104(4):454-455.
41. **Lai TH, Tang EW, Chau SK, Fung KS, Li KK.** Stepping up infection control measures in ophthalmology during the novel coronavirus outbreak: An experience from Hong Kong. *Graefes Arch Clin Exp Ophthalmol.* 2020;258(5):1049-1055. doi: 10.1007/s00417-020-04641-8.
42. **Liu SY, Kang XL, Wang CH, *et al.*** Protection procedures and preventions against the spread of coronavirus disease 2019 in healthcare settings for nursing personnel: Lessons from Taiwan. *Aust Crit Care.* 2021; 34(2):182-190.
43. **Cho JH, Kang SH, Park HC, *et al.*** Hemodialysis with cohort isolation to prevent secondary transmission during a covid-19 outbreak in Korea. *J Am Soc Nephrol.* 2020;31(7):1398-1408.
44. **Patterson B, Marks M, Martinez-Garcia G, *et al.*** A novel cohorting and isolation strategy for suspected COVID-19 cases during a pandemic. *J Hosp Infect.* 2020;105(4):632-637.
45. **Chandy PE, Nasir MU, Srinivasan S, Klass D, Nicolaou S, B Babu S**. Interventional radiology and COVID-19: Evidence-based measures to limit transmission. *Diagn Interv Radiol.* 2020;26(3):236-240.
46. **Abad CL, Barker AK, Safdar N.** A systematic review of the effectiveness of cohorting to reduce transmission of healthcare-associated *C. difficile* and multidrug-resistant organisms. *Infect Control Hosp Epidemiol.* 2020; 41(6):691-709.
47. **Palmore TN, Henderson DK.** Managing transmission of carbapenem-resistant enterobacteriaceae in healthcare settings: a view from the trenches. *Clin Infect Dis.* 2013;57(11):1593-1599.
48. **World Health Organization**. *Infection prevention and control of epidemic- and pandemic-prone acute respiratory infections in health care*; 2014.
49. **Al-Shamsi HO, Alhazzani W, Alhuraiji A, *et al.*** A practical approach to the management of cancer patients during the novel coronavirus disease 2019 (covid-19) pandemic: An international collaborative group. *Oncologist.* 2020;25(6):e936-e945.
50. **Barclay L, Park GW, Vega E, *et al.*** Infection control for norovirus. *Clin Microbiol Infect.* 2014;20(8):731-740.
51. **Cooper BS, Stone SP, Kibbler CC, *et al.*** Isolation measures in the hospital management of methicillin resistant Staphylococcus aureus (MRSA): Systematic review of the literature. *BMJ.* 2004;329(7465):533.
52. **French CE, McKenzie BC, Coope C, *et al.*** Risk of nosocomial respiratory syncytial virus infection and effectiveness of control measures to prevent transmission events: A systematic review. *Influenza Other Respir Viruses.* 2016;10(4):268-290.
53. **Jindal V, Sahu KK, Gaikazian S, Siddiqui AD, Jaiyesimi I.** Cancer treatment during COVID-19 pandemic. *Medical Oncology.* 2020;37:1-3.
54. **Greig JD, Lee MB.** A review of nosocomial norovirus outbreaks: Infection control interventions found effective. *Epidemiol Infect.* 2012;140(7): 1151-1160.
55. **MacCannell T, Umscheid CA, Agarwal RK, *et al.*** Guideline for the prevention and control of norovirus gastroenteritis outbreaks in healthcare settings. *Infect Control Hosp Epidemiol.* 2011;32(10):939-969.
56. **Montoya A, Jenq G, Mills JP, *et al.*** Partnering with local hospitals and public health to manage COVID-19 outbreaks in nursing homes. *J Am Geriatr Soc.* 2021;69(1):30-36.
57. **Nijssen S, Bonten MJ, Weinstein RA.** Are active microbiological surveillance and subsequent isolation needed to prevent the spread of methicillin-resistant Staphylococcus aureus?. *Clin Infect Dis.* 2005;40(3):405-409.
58. **Bonten MJ, Austin DJ, Lipsitch M.** Understanding the spread of antibiotic resistant pathogens in hospitals: Mathematical models as tools for control. *Clin Infect Dis.* 2001;33(10):1739-1746.
59. **Said MA, Perl TM, Sears CL.** Healthcare epidemiology: Gastrointestinal flu: norovirus in health care and long-term care facilities. *Clin Infect Dis.* 2008;47(9):1202-1208.
60. **Wang Z, Wang J, He J.** Active and effective measures for the care of patients with cancer during the covid-19 spread in China. *JAMA Oncol.* 2020;6(5):631-632.
61. **Zhang Y, Sun Z, Latour JM, Hu B, Qian J.** Hospital response to the COVID-19 outbreak: The experience in Shanghai, China. *J Adv Nurs.* 2020;76(7):1483-1485.
62. **FitzGerald G, Jelinek GA, Scott D, Gerdtz MF.** Emergency department triage revisited. *Emerg Med J.* 2010;27(2):86-92.
63. **Chung HS, Lee DE, Kim JK, *et al.*** Revised triage and surveillance protocols for temporary emergency department closures in tertiary hospitals

as a response to covid-19 crisis in Daegu Metropolitan City. *J Korean Med Sci.* 2020;35(19):e189.
64. **Fasola G, Pelizzari G, Zara D, *et al.*** Feasibility and predictive performance of a triage system for patients with cancer during the covid-19 pandemic. *Oncologist.* 2021;26(4):e694-e703.
65. **Oh J, Lee JK, Schwarz D, Ratcliffe HL, Markuns JF, Hirschhorn LR.** National response to covid-19 in the republic of Korea and lessons learned for other countries. *Health Syst Reform.* 2020;6(1):e1753464.
66. **Schaye VE, Reich JA, Bosworth BP, *et al.*** Collaborating across private, public, community, and federal hospital systems: Lessons learned from the covid-19 pandemic response in NYC. *NEJM Catalyst Innovations in Care Delivery.* 2020;1(6).
67. **Wake RM, Morgan M, Choi J, Winn S.** Reducing nosocomial transmission of COVID-19: implementation of a COVID-19 triage system. *Clin Med (Lond).* 2020;20(5):e141-e145.
68. **Lee IK, Wang CC, Lin MC, Kung CT, Lan KC, Lee CT.** Effective strategies to prevent coronavirus disease-2019 (COVID-19) outbreak in hospital. *J Hosp Infect.* 2020;105(1):102-103.
69. **Ornaghi S, Callegari C, Milazzo R, *et al.*** Performance of an extended triage questionnaire to detect suspected cases of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection in obstetric patients: Experience from 2 large teaching hospitals in Lombardy, Northern Italy. *PloS One.* 2020;15(9):e0239173.
70. **Judson TJ, Odisho AY, Neinstein AB, *et al.*** Rapid design and implementation of an integrated patient self-triage and self-scheduling tool for COVID-19. *J Am Med Inform Assoc.* 2020;27(6):860-866.
71. **Silvery A, Nizami MI, Sharma A, Bhaskar L.** Three tier screening tool and second triage to minimize the spread of covid-19 in the emergency department of a tertiary hospital in India. *Frontiers in Emergency Medicine.* 2020;4(2s):e50-e50.
72. **Quah LJJ, Tan BKK, Fua TP, *et al.*** Reorganising the emergency department to manage the COVID-19 outbreak. *Int J Emerg Med.* 2020; 13(1):32.
73. **Falvey JR, Krafft C, Kornetti D.** The essential role of home- and community-based physical therapists during the covid-19 pandemic. *Phys Ther.* 2020;100(7):1058-1061.
74. **Jones MS, Goley AL, Alexander BE, Keller SB, Caldwell MM, Buse JB.** Inpatient transition to virtual care during covid-19 pandemic. *Diabetes Technol Ther.* 2020;22(6):444-448.
75. **De Simone V, Guarise P, Guardalben S, *et al.*** Telecardiology during the Covid-19 pandemic: Past mistakes and future hopes. *Am J Cardiovasc Dis.* 2020;10(2):34-47.
76. **Singh J, Green MB, Lindblom S, Reif MS, Thakkar NP, Papali A.** Telecritical care clinical and operational strategies in response to covid-19. *Telemed J E Health.* 2021;27(3):261-268.
77. **Osei E, Francis R, Mohamed A, Sheraz L, Soltani-Mayvan F.** Impact of COVID-19 pandemic on the oncologic care continuum: Urgent need to restore patients care to pre-COVID-19 era. *J Radiother Pract.* 2021:1-11.
78. **McCall B.** Could telemedicine solve the cancer backlog?. *The Lancet Digital Health.* 2020;2(9):e456-e457.
79. **Rajagopalan S, Yoshikawa TT.** Norovirus infections in long-term care facilities. *J Am Geriatr Soc.* 2016;64(5):1097-1103.
80. **Lopman BA, Andrews N, Sarangi J, Vipond IB, Brown DW, Reacher MH.** Institutional risk factors for outbreaks of nosocomial gastroenteritis: Survival analysis of a cohort of hospital units in South-west England, 2002-2003. *J Hosp Infect.* 2005;60(2):135-143.
81. **Lee JY.** Tuberculosis infection control in health-care facilities: environmental control and personal protection. *Tuberc Respir Dis (Seoul).* 2016;79(4):234-240.
82. **Somsen GA, van Rijn C, Kooij S, Bem RA, Bonn D.** Small droplet aerosols in poorly ventilated spaces and SARS-CoV-2 transmission. *Lancet Respir Med.* 2020;8(7):658-659.
83. **Capolongo S, Gola M, Brambilla A, Morganti A, Mosca EI, Barach P.** COVID-19 and healthcare facilities: A decalogue of design strategies for resilient hospitals. *Acta Biomed.* 2020;91(9-S):50-60.
84. **Choi H, Chatterjee P, Lichtfouse E, *et al.*** Classical and alternative disinfection strategies to control the COVID-19 virus in healthcare facilities: A review [published online ahead of print, 2021 Jan 22]. *Environ Chem Lett.* 2021;1-7.
85. **Dietz L, Horve PF, Coil DA, Fretz M, Eisen JA, Van Den Wymelenberg K.** 2019 novel coronavirus (covid-19) pandemic: Built environment considerations to reduce transmission [published correction appears in mSystems. 2020 May 5;5(3):]. *mSystems.* 2020;5(2):e00245-20.
86. **Ren C, Xi C, Wang J, *et al.*** Mitigating Covid-19 infection disease transmission in indoor environment using physical barriers. *Sustain Cities Soc.* 2021;74:103175.
87. **Kohanski MA, Lo LJ, Waring MS.** Review of indoor aerosol generation, transport, and control in the context of COVID-19. *Int Forum Allergy Rhinol.* 2020;10(10):1173-1179.
88. **Rezaei N, Jafari M, Nazari A, *et al.*** A novel methodology and new concept of SARS-CoV-2 elimination in heating and ventilating air conditioning systems using waste heat recovery. *AIP Adv.* 2020;10(8): 085308.
89. **Shajahan A, Culp CH, Williamson B.** Effects of indoor environmental parameters related to building heating, ventilation, and air conditioning systems on patients' medical outcomes: A review of scientific research on hospital buildings. *Indoor Air.* 2019;29(2):161-176.
90. **Morawska L, Milton DK.** It is time to address airborne transmission of coronavirus disease 2019 (COVID-19). *Clin Infect Dis.* 2020;71(9): 2311-2313.
91. **Saran S, Gurjar M, Baronia A, *et al.*** Heating, ventilation and air conditioning (HVAC) in intensive care unit. *Crit Care.* 2020;24:194.
92. **Bhagat RK, Linden PF.** Displacement ventilation: A viable ventilation strategy for makeshift hospitals and public buildings to contain COVID-19 and other airborne diseases. *R Soc Open Sci.* 2020;7(9):200680.
93. **Gu D, Zheng Z, Zhao P, Xie L, Xu Z, Lu X.** High-efficiency simulation framework to analyze the impact of exhaust air from covid-19 temporary hospitals and its typical applications. *Applied Sciences.* 2020;10(11): 3949.
94. **Chirico F, Sacco A, Bragazzi NL, Magnavita N.** Can air-conditioning systems contribute to the spread of sars/mers/covid-19 infection? Insights from a rapid review of the literature. *Int J Environ Res Public Health.* 2020;17(17):6052.
95. **Mousavi ES, Kananizadeh N, Martinello RA, Sherman JD.** COVID-19 Outbreak and hospital air quality: A systematic review of evidence on air filtration and recirculation. *Environ Sci Technol.* 2021; 55(7):4134-4147.
96. **Tomas ME, Kundrapu S, Thota P, *et al.*** Contamination of health care personnel during removal of personal protective equipment. *JAMA Intern Med.* 2015;175(12):1904-1910.
97. **Barratt R, Shaban RZ, Gilbert GL.** Characteristics of personal protective equipment training programs in Australia and New Zealand hospitals: A survey. *Infect Dis Health.* 2020;25(4):253-261.
98. **Kalantary S, Khadem M, Golbabaei F.** Personal protective equipment for protecting healthcare staff during covid-19 outbreak: A narrative review. *Front Emerg Med.* 2020;4(2s):e61.
99. **Tan L, Kovoor JG, Williamson P, *et al.*** Personal protective equipment and evidence-based advice for surgical departments during COVID-19. *ANZ Journal of Surgery.* 2020;90(9):1566-1572.
100. **Jamieson DJ, Steinberg JP, Martinello RA, Perl TM, Rasmussen SA.** Obstetricians on the coronavirus disease 2019 (COVID-19) front lines and the confusing world of personal protective equipment. *Obstet Gynecol.* 2020;135(6):1257-1263.
101. **Hoernke K, Djellouli N, Andrews L, *et al.*** Frontline healthcare workers' experiences with personal protective equipment during the COVID-19 pandemic in the UK: A rapid qualitative appraisal. *BMJ Open.* 2021; 11(1):e046199.
102. **Mick P, Murphy R.** Aerosol-generating otolaryngology procedures and the need for enhanced PPE during the COVID-19 pandemic: a literature review. *J Otolaryngol Head Neck Surg.* 2020;49(1):29.
103. **Kim H, Hegde S, LaFiura C, *et al.*** Access to personal protective equipment in exposed healthcare workers and COVID-19 illness, severity, symptoms and duration: A population-based case-control study in six countries. *BMJ Glob Health.* 2021;6(1):e004611.

104. **Newby JC, Mabry MC, Carlisle BA, Olson DM, Lane BE.** Reflections on nursing ingenuity during the COVID-19 pandemic. *J Neurosci Nurs.* 2020;52(5):E13-E16.
105. **Muñoz-Leyva F, Niazi AU.** Common breaches in biosafety during donning and doffing of protective personal equipment used in the care of COVID-19 patients. *Can J Anaesth.* 2020;67(7):900-901.
106. **Torjesen I.** Covid-19: Appropriate PPE prevents infections in doctors in frontline roles, study shows. *BMJ.* 2020;369:m2330.
107. **Suzuki T, Hayakawa K, Ainai A, *et al.*** Effectiveness of personal protective equipment in preventing severe acute respiratory syndrome coronavirus 2 infection among healthcare workers. *J Infect Chemother.* 2021;27(1): 120-122.