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HEALTHCARE ASSOCIATED COVID-19 TRANSMISSION: STRATEGIES TO PREVENT

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Abstract

Coronavirus disease 2019 (COVID-19) can cause another problem for healthcare facilities, which is nosocomial transmission. Clinicians performed nosocomial pneumonia prevention vigilantly during the COVID-19 pandemic. To date, the magnitude and risk factors for infection in healthcare environments are unknown in severe acute respiratory syndrome coronavirus 2 transmission. An overwhelming number of COVID-19 infections not only could paralyze the health system but could contribute, above all, to the occasional epidemic of hospital patients and the healthcare workers, along with elevated morbidity and mortality. The COVID-19 increasing case may limit the availability of occupancy rooms in hospitals, so doctors need tools to assess the likelihood of COVID-19 at the initial examination by triage based on epidemiological risks, routine investigations and bedside observation for safe isolation. The specific challenges of COVID-19 exist because this is a new disease with clinical, radiological, and laboratory features that can be variable

We review nosocomial transmission of COVID-19. The data indicate that the prevalence of hospital-acquired COVID-19 infection varies. While reports regarding nosocomial transmission or healthcare-associated COVID-19 infection are still growing, several hospitals claim there were none or minimal nosocomial transmission. Infection prevention and control techniques were initially aimed at prompt patient identification, separation and monitoring in compliance with case descriptions. Engineering controls provide proper and efficient ventilation, likely augmented by filtration of pollutants and air disinfection, air recirculation protection, and overcrowding protection. Administrative assistance to reduce the risk of nosocomial severe acute respiratory syndrome coronavirus 2 is introduced with the reduction of choice healthcare services, decanting centers, deployment of isolation facilities, appropriate personal security facilities, coordination of the rapid molecular diagnostic laboratory network, constructive monitoring, and organization of the personnel forum and training. These principal strategies can suppress intra-hospital transmission of COVID-19 if strictly implemented during a pandemic era.

Keywords: *healthcare associated COVID-19, nosocomial COVID-19, healthcare workers, intra-hospital transmission.*

Introduction

Coronavirus disease 2019 (COVID-19) may bring risk of nosocomial transmission and cause healthcare-associated outbreaks. Healthcare staff are at the greatest risk of transferring employment in contrast with other industries and may have a role in transmission into hospitals. To date, the magnitude and risk factors for infection in healthcare environments are unknown in Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) transmission [*Lan F et al., 2020; Sikkema R et al., 2020*]. Growing population spread of COVID-19 makes it impossible to see whether diseases are contracted by healthcare workers (HCW) in the workplace or in the environment [*Heinzerling A et*

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al., 2020]. An overwhelming number of COVID-19 infections not only could paralyze the health system but could contribute, above all, to the occasional epidemic of hospital patients and the HCWs, along with elevated morbidity and mortality [*Cheng V et al., 2020*]. Nevertheless, after thorough infection prevention and control behavior, nosocomial infection levels can decrease [*Rickman H et al., 2020*].

The infection prevention and control (IPC) strategy focuses on fast patient diagnosis, separation and monitoring through case descriptions [*Rickman H et al., 2020*]. An aspect of the IPC standard is to place patients with suspected transmissible infections separately from the others to protect patients and staff from possible transmission. The COVID-19 increasing case may limit the availability of occupancy rooms in hospitals, so doctors need tools to assess the likelihood of COVID-19 at the initial examination by triage based on epidemiological risks, routine investigations and bedside observation for safe isolation. The specific challenges of COVID-19 exist because this is a new disease with clinical, radiological, and laboratory features that can be variable [*Patterson B et al., 2020*]. Here, we review nosocomial transmission of COVID-19.

MATERIAL AND METHODS

A review of literature was performed using PubMed, DOAJ, ScienceDirect, and Google Scholar database. Up to the date of analysis of 23 September 2020, all papers have been searched. Searches were made using keywords: “healthcare-associated” or “nosocomial transmission” or “hospital transmission” and COVID-19. Abstracts and article relevant materials have been reviewed, and associated articles were searched, which were eventually checked, for their importance and bibliographies. To identify more research not published in scientific journals and health reports, Google search engine was used.

Evidence of nosocomial transmission

There is currently evidence that SARS-CoV-2 transmission occurs mainly between individuals, through direct, indirect or near contact with infected individuals through infected secretions such as saliva and respiratory secretions or their respiratory droplets, which are released by the infected person as they cough, sneeze, speak or sing. In health environments, airborne virus transmission can occur when some medical procedures, called aerosol-generating technique, emit very small droplets called aerosols [*WHO, 2020*].

Clinicians have carefully conducted nosocomial pneumonia prevention during COVID-19 pandemic. For example, many hospitals in the USA were taking their own precautions as a result of the current COVID-19 pandemic before voluntary mask use was recommended by US Centers for Disease Control and Prevention (CDC). While these increased precautionary measures have overwhelmingly impacted health workers, 9282 of COVID-19 confirmed incidents, resulting in 27 deaths, with 55% reported contracting the virus during their work, based on a CDC study on April 9, 2020 [*Burrer S et al., 2020*]. The threat of COVID-19 impacts health staff not only in the frontline, but also raises their family exposure [*Hu L et al., 2020*].

The prevalence of healthcare-associated COVID-19 infection is reported to be 16.2%. Patients who were infected with COVID-19 during hospital stay had a longer length of stay, but this did not affect mortality [*Marago I, Minen I, 2020*]. Between 315,531 United States COVID-19 cases, CDC reported on February 12 to April 9, the HCW employment status data was valid for 49,370 (16%), of which 9,282 (19%) were HCW cases. Healthcare-workers accounted for 11% (1,689 of 15,194) of all reported cases [*Huff H, Singh A, 2020; Burrer S et al., 2020*]. Fifty-seven (41.3 percent) of patients in a single center sequence of 138 COVID-19 patients from Wuhan, China, were suspected of having been contaminated in the hospitals. The population consisted of 17 (12.3%) patients who had been admitted for other reasons in addition to 40 (29%) HCWs [*Wang D et al., 2020*]. In a certified healthcare center in the State of Washington, 76 residents of SARS-CoV-2 were screened for polymerase chain reaction (PCR) after a positive employee checked, and 48 (63 percent) of 76 tested were positive. Of the 48 citizens, 27 (56 percent) were asymptomatic on the day of the examination, followed by 24 of those with symptoms [*Arons M et al., 2020*]. In a major London teaching hospital, 66/435 (15%) of COVID-19 inpatient cases between 2 March and 12 April 2020 were definitely or probably hospital-acquired, through varied transmission routes. The case fatality was 36% [*Rickman H et al., 2020*].

The COVID-19 in Older People study was formulated as a prognostic instrument for COVID 19 patients for the measurement of a variety of clinical parameters and biomarkers. This secondary research aimed at examin-

To overcome it is possible, due to the uniting the knowledge and will of all doctors in the world

ing the burden of nosocomial COVID-19 (NC) infection and determining whether patients who witnessed community-acquired COVID-19 in the population had worse performance. As many as 12.5% of all COVID-19 cases were due to patient transmission in hospital. The average mortality rate for NC infections decreased by 27.2%. NC affected patients have had a longer hospital stay. This NC category was older and more fragile for non-COVID-19 prior admission factors, both leading to a median stay for more than one month in hospital [*Carter B et al., 2020*].

While reports regarding nosocomial transmission or healthcare-associated COVID-19 infection is still growing, several hospitals claim there were none or minimal nosocomial transmission. In the Department of Respiratory and Critical Care of Zhongnan Hospital in Wuhan University, China, 33 cases of 2019 coronavirus (COVID-19) were found from December 25, 2019 to January 31, 2020, but there was no infected affiliated HCW [*Zhang G et al., 2020*]. No medical care provider had been afflicted with COVID-19 in Nanjing, China, before 4 March. There was also no case of COVID-19 infection in hospitals with those undergoing both outpatient and inpatient and hospital treatment [*Shen Y et al., 2020*]. There have been 1,080 health care personnel (HCP) infections in Wuhan City. However, no one was contaminated between February 5 and July 2020 in the hospitals with >5,000 HCP [*Yang Y et al., 2020*]. Until March 1, Shenzhen Hospital admitted 418 cases of COVID-19 and discharged 163 cases. None of the 1,264 health employees have been affected, meanwhile. In comparison, 1,870 people treated over the same time were not cross-infected [*Huang T et al., 2020*].

In-hospital COVID-19 transmission can be carried out on many possible routes. HCWs may have been contaminated by international travel, social connections, or nosocomial transition. Super-spreading activities became probable at mass gatherings, such as carnivals, at which many HCWs became interested at positive tests for SARS-CoV-2. Healthcare workers are at greater risk of being exposed to infections in laboratories that may also spread to their hospitals via the introduction of a virus [*Sikkema R et al., 2020*].

A research in the field of healthcare workers and patients in the same hospitals using epidemiological and whole-genome sequencing (WGS) of SARS-CoV-2 to explain origins and mechanism of transmission of SRAS-CoV-2 shows that genomic diversity is associated with multiple introductions by population infections and some local amplifications linked to particular group social activities, instead of the widespread within-hospital transmission. Direct hospital transmission cannot be reliably excluded. However, this evidence does not favor large nosocomial transmission as a cause of infection in healthcare settings [*Sikkema R et al., 2020*].

How to reduce viral exposure in hospital setting

Airborne transmission of the virus may arise in healthcare settings, especially during aerosol generating procedures. Any indoor crowded room outbreak studies have indicated the ability to spread aerosol [*WHO, 2020*]. In hospital buildings where there could be a lot of people gathering in one place, virus contamination in room air is very likely to occur. Building engineering controls, which include appropriate and efficient ventilation for particulate filtration and disinfection of air, are necessary in order to reduce viral air pollution. Proper distribution of ventilation (i.e., placement of supply and exhaust ventilation) is also necessary as a method to replace contaminated air with clean air [*Morawska L et al., 2020*]. Airborne infection isolation rooms may not be available in every hospital, hence to reduce the risk of airborne transmission, using natural ventilation in isolated wards can be done by opening windows open 30 minutes twice a day and electronic fans over windows in inpatient wards [*Lee I et al., 2020*]. In addition, hospitals must have an innovative use to reduce HCW exposure to SARS-CoV-2, for examples, using camera technology to observe patients in isolation rooms for 24 hours monitored by doctors and nurses. Staff only perform face-to-face care if necessary to prevent contamination [*Tan T et al., 2020*].

Isolate suspected patient from the others

Separation of patients COVID-19 is an important way to reduce infection and hospital spread. Potential interventions include: 1) monitoring and exclusion of visitors from visiting for respiratory symptoms that could contribute to virus like influenza, myalgia, pheasants, rhinorrhea, and coughing; 2) prohibiting health workers from operating with the symptoms of upper respiratory tract even without influenza; and 3) checking all visitors for respiratory symptoms associated with virus. Both respiratory viruses (including SARS-CoV-2) are checked on positive visitors regardless of disease seriousness and measures for the care of respiratory syndrome patients regardless of virus symptoms are implemented (single room, contact measures, drip precautions and eye protection) [*Michael K, 2020*].

In Taiwan, visitors who develop a fever regardless of respiratory illness, and who have a history of traveling to China or Hong Kong/Macau within 14 days before the onset of symptoms, or close contact with a

confirmed case of COVID-19, are prohibited from entering the hospital, and directed to the emergency department to be isolated. Access control to avoid overcrowding in hospitals is carried out by limiting visitors [*Lee I et al., 2020*].

The application of a patient triaging system at the University College London Hospital is based on the clinical features of COVID-19, including age and comorbidities. All patients treated were allocated to four categories in the Emergency Department namely category A (low probability; high risk), B (high probability; high risk), C (high probability; low risk) and D (low probability; low risk). Category A includes low COVID-19 patients but significant comorbidity and is prioritized for single occupancy rooms. Categories B and C include high COVID-19 patients, with significant comorbidities in Category B. Category C includes patients with minimal comorbidity so they are grouped in multiple beds with low occupancy rates. Meanwhile, category C is low COVID-19 patients without significant comorbidities. This approach is carried out with a combination of innovative IPC measures to reduce bed pressure without increasing the risk of transmission [*Patterson B et al., 2020*].

The method of fever screening plays an essential part in hospital infection prevention and management. Patients with fever are split into 3 stages of a triage: a pre-examination and triage pass, a special triage pass and, after asking the patient about their medical background, the doctor signs the "Notification of epidemiological background" [*Huang T et al., 2020*].

The fever clinic in Nanjing, China, was intended as an outpatient first-line treatment and the ventilation system was modified to prevent backflow of air in the fever clinic. Contaminated blocks (meeting patient), buffer corridors (wearing and removing PPE), and hygiene blocks (resting) are separated. The triage center is fully responsible for collecting the epidemiological history of each visitor prior to entering the clinic. Online consultation and prescription systems are recommended for non-emergencies and sterilization of air by ultraviolet light is carried out for 10 minutes [*Shen Y et al., 2020*].

The application of Traffic Control Bundling (TCB) in Taiwan during SARS 2003, proved effective in decreasing nosocomial infections of health workers, patients and hospital visitors [*Yen M et al., 2011; 2014*]. Traffic Control Bundling is a multimodal version of maintenance that Taiwan has successfully implemented in the past [*Lai C et al., 2018; Kao C et al., 2019*]. An integrated infection control strategy that includes triage before entering the hospital, separation of risk zones, and the use of personal protective equipment (PPE) with checkpoints [*Yen M et al., 2011*]. The risk zone in the TCB protocol is divided into three categories: contamination, transition, and clean zones. A strategy of 100% hand hygiene compliance among healthcare workers coupled with the use of strict PPE and standard infection control procedures in hospitals during the SARS outbreak in Taiwan, droplet contact and transmission were efficiently controlled. Hence, the decrease in SARS infection in the community is evidenced by the fact that no new cases were diagnosed during the two incubation periods one week after the application of TCB [*Yen M et al., 2011; 2014; 2020*].

There are differences between COVID-19 and SARS which has unique characteristics such as asymptomatic infection, hyper-affinity to the ACE2 receptor which causes high transmission, false negativity, and incubation of up to 22 days [*Wrapp D et al., 2020; Lai C et al., 2020*]. These characteristics require the TCB protocol to ensure effective transmission control in isolation wards and transition zones. Community treatment is required in hospitals by disinfection of hands at checkpoints and applying face masks for all hospital visitors to contain COVID-19 [*Yen M et al., 2020*].

The COVID-19 strategy in Singapore is to treat and handle all COVID-19 cases in hospitals and conduct contact tracing to identify, isolate and monitor all exposed contacts. The Systems Engineering Initiative for Patient Safety is a human-based model used in medical care frequently to examine fundamental causes of patient safety accidents. This model is used to describe measures being taken to prevent transmission of COVID-19 in acute tertiary hospitals in Singapore [*Gan W et al., 2020*].

Modify the habits of work

Administrative support for infection control can minimize the risk of SARS-CoV-2 nosocomial transmission. This strategy can be done by reducing elective clinical services, decanting wards, mobilizing isolation facilities, providing PPE, coordinating laboratory networks in active surveillance for inpatients and outpatients with the aim of zero nosocomial transmission [*Cheng V et al., 2020*]. Administrative responses are also carried out by establishing an Emergency Leadership Committee [*Michael K, 2020*].

Social distancing is equally important in reducing the spread of nosocomial in hospitals. The problems of social distancing and limited physical space such as in elevators and clinical rooms in hospitals require additional guidelines to protect healthcare workers [*Hu L et al., 2020; Wee L et al., 2020a*]. Infrastructure modifications are instituted to facilitate social

distancing by adding partitions. Health workers are required to wear surgical masks and patients are directed to maintain a distance of 1 meter from each other supported by visual signs (for example floor markings and chair markings) to wait and queue in the sitting and standing areas [*Wee L et al., 2020a*]. Nosocomial transmission may occur during meetings between doctors and nurses who are infected but have not shown clear symptoms. Transmission of SARS-CoV-2 is very possible anywhere with anyone so it is necessary to reduce gatherings of people and maintain social distance among health workers [*Zhang G et al., 2020*].

Healthcare workers have the potential to infect others during the pre-symptomatic phase so it is essential to limit or prohibit frontline health workers from taking turns across units. Nurses, orders, and cleaning staff are prohibited from rotating to work in different units to reduce transmission acquired in the hospital. Personnel rotation may be done at least a monthly schedule to prevent the spread of the virus. Every healthcare worker requires monitoring for symptoms of upper respiratory tract infection every 8 hours with a higher temperature of 37.5°*C* and to follow up with a PCR test [*Tan T et al., 2020*].

Possible sources of infectious diseases in the hospital environment are visitors and outpatients. To reduce risk, filling out a travel survey and contact history and thermal fever scans before admission to the hospital are performed. Whereas for outpatient companions, only 1 person is allowed. This is done to reduce the possibility of COVID-19 entering the community into the hospital environment [*Gan W et al., 2020*].

Removing the bug from hospital environment

The standard of environmental sanitation will minimize disease transmission in hospitals and also avoid outbreaks of hospital infection. The extent of SARS-CoV-2 contamination and the possible relation to its transmission are, however, poorly known. In the designated COVID-19 hospital, most touchable surfaces were highly polluted, indicating that the atmosphere is a possible medium for transmission of the disease [*Wu S et al., 2020*].

Environmental surface hygiene and improved hand hygiene to prevent the spread of the virus during a pandemic are mandatory to ensure safety and quality of medical care [*Wang J et al., 2020; Wu S et al., 2020*]. The decontamination method can be carried with disinfection 4 times a day. Air disinfection can be conducted using 3 methods: (1) Opening the windows if available and ventilate the area for minimal 30 minutes 2-3 times a day; (2) Ultraviolet irradiation for 30 minutes (twice a day); (3) Spray the area with a disinfectant containing 500 *mg/L* chlorine. For discharged patients, all personal belonging should be sprayed with disinfectant and any remaining clothing is disinfected and disposed of as medical waste [*Yang Y et al., 2020*].

Contaminant products visible on the surfaces of care facilities and appliances, including bed rails, bedside tables, furniture, door handles, computer screens, keyboards, monitor computers, desks, chairs and controls, must be cleaned in full before disinfection in the nursing and break room and every other household objects. In the case of alleged or confirmed COVID-19 incidents, hospital cleaning workers shall disinfect all regions that have been approached, and have worn full PPE during cleaning. Fluorescent marker method and adenosine triphosphate (ATP) bioluminescence can be used to evaluate environment sanitation [*Wang J et al., 2020; Tan T et al., 2020*].

With this implementation, Taiwanese health facilities have reported "Zero" infected cases to frontline healthcare workers through their COVID-19 confirmed case treatment. Environmental cleaning is strictly carried out to maintain hospital cleanliness, especially those related to COVID-19 cases. Hospitals also should assemble mobile medical equipment into Central Sterilization Service Department (CSSD) after use by patients, to ensure installation in a perfect environment and follow cleaning and disinfecting protocols for cleaning equipment [*Wang J et al., 2020; Tan T et al., 2020*].

Optimizing personal protective equipment (PPE) use as the final defense

Health workers are required to use personal protective equipment to handle patients suspected of COVID-19. Several guidelines regarding using the standards PPE already generally available. These guidelines should be implemented to prevent overuse and underuse of PPE. All healthcare personnel that handle COVID-19 patients should wear protective equipment as such white coat, N95 mask, surgical mask, surgical cap, goggles, shoe covers, isolation gown, gloves, protective clothing, pair of gloves other, protective hoods, and boot covers [*Yang Y et al., 2020*]. The PPE that must be used for handling samples and specimens to the laboratory is surgical gloves and medical masks with a suitable leak-proof container to prevent contamination. CSSD operators should wear disposable face shields, medical masks, headgear, waterproof gloves, and waterproof gowns to clean medical equipment and surgical instruments [*Yang Y et al., 2020; Tan T et al., 2020*].

It is recommended that HCPs enter the anteroom in pairs so that they can monitor and assist each other

while donning PPE. Clear instructions for the sequence of PPE removal, as well as a reminder of disinfecting the doorknob when opening the door can be installed in this anteroom [*Lee I et al., 2020*]. Supervision regarding donning and doffing of the PPE should be done as a method to ensure a proper using of PPE. The effect of implementing the 24-hour Supervise-Correct-Improvement supervision model was investigated in the COVID-19 isolation ward in the process of wearing and removing personal protective equipment. The result suggest that continuous supervision and protection is needed to correct mistakes during PPE using and to confirm that HCW is fully protected with their PPE [*Li S et al., 2020*].

The need to monitor healthcare workers

Integrated control, risk prevention and personal liability management techniques can effectively diagnose COVID-19 infection clusters in healthcare professionals. Monitoring symptoms of infection among health workers may be a means of surveillance supported by a comprehensive outbreak management strategy, which focuses on monitoring symptoms of acute respiratory infections for early case detection, outbreak management, and encouraging adherence at the individual level [*Wee Liang E et al., 2020b*].

The global approach to the studies for SARS-CoV-2 differs across countries, such as South Korea in which persons with respiratory disorders and exposures are identified. Meanwhile, in Spain and Indonesia, tests are carried out on individuals with severe symptoms or those at high risk. A shortage of staff in health care is a condition of concern in this era of pandemics and a lack of effective testing has led health workers to isolate themselves due to history of contact [*Black J et al., 2020*].

Doctors and non-medical services carry an increased risk of getting infected during their work. Healthcare workers who have contact with suspected or confirmed cases of COVID-19 should undergo a surveillance including socio-demographic information, aspects of event exposure (date, place, length and distance of exposure, use of PPE) and contact person details (if known). Health care workers who show at least one main symptom (fever, cough and dyspnea) are categorized as a high risk. Moderate risk is assigned in cases of exposure for more than 15 minutes or at a distance of less than 2 meters without proper, undamaged PPE use, while low risk is assigned to HCWs exposed to less than 15 minutes and more than 2 meters or using appropriate PPE and not broken. Health care workers at high risk are required to immediately stop their work activities, undergo testing for COVID-19 and remain under home quarantine until testing results indicate action needs to be taken. All healthcare workers need to be cured microbiologically (two tests negative within 48-72 hours) to return to work [*Garzaro G et al., 2020*].

Perpetual training and education to healthcare workers

Training and education should be dedicated to health care providers and to non-medical personnel. All medical and non-medical personnel must understand clinical practice guidelines, the National guidelines for the management of COVID-19, and local guidelines in each hospital. This was done to carry out an emergency response that was supervised by the IPC team [*Shen Y et al., 2020*]. During the beginning of the pandemic, each nursing unit was provided with adequate online education and training in handling the COVID-19 pandemic from installing PPE to transferring suspected and confirmed COVID-19 cases. For examples in Taiwan, all frontline healthcare providers are set to learn from online courses at least 80% of the completion rate as set by infectious disease specialists in hospitals, which helps health care providers to gain a better understanding of COVID-19. Provide emotional support to health workers [*Tan T et al., 2020*].

Conclusion

The overwhelming growth of COVID-19 cases and super-spreading capability of SARS-CoV-2 virus can cause hospitals to experience a significant new problem, which is nosocomial transmission of COVID-19. Some hospitals or health facilities have their own strategies to prevent intra-hospital transmission and proven to be successful in reducing the nosocomial COVID-19 transmission. The principles of preventing nosocomial transmission conducted in these hospitals include the strict implementation of infection prevention and control practices, engineering control such as air ventilation re-arrangements, separation of high risk cases or triage system, workflow arrangements, decontamination processes, regulation of PPE donning and doffing, HCW surveillance and also training and education to the healthcare workers.

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REFERENCES

1. *Arons MM, Hatfield KM, Reddy SC, Kimball A, James A., et al.* Presymptomatic SARS-CoV-2 Infections and Transmission in a Skilled Nursing Facility. N Engl J Med. 2020; 382(22): 2081-2090
2. *Black JRM, Chris Bailey C, Przewrocka J, Dijkstra KK, Swanton C.* COVID-19: the case for health-care worker screening to prevent hospital transmission. Lancet. 2020; 395(10234): 1418-1420
3. *Burrer SL, de Perio MA, Hughes MM, Kuhar DT., et al.* (CDC COVID-19 Response Team), Characteristics of Health Care Personnel with COVID-19, Morbidity and Mortality Weekly Report (MMWR) – United States, February 12-April 9. 2020; 69(15): 477-481
4. *Carter B, Collins JT, Barlow-Pay F, Rickard F, Bruce E., et al.* Nosocomial COVID-19 Infection: Examining the Risk of Mortality. The COPE-Nosocomial Study (COVID in Older People). J Hosp Infect. 2020; 106(2): 376-384
5. *Cheng VCC, Wong SC, Chuang VWM, So SYC, Chen JHK., et al.* Absence of Nosocomial Transmission of Coronavirus Disease 2019 (COVID-19) Due to SARS-CoV-2 in the Prepandemic phase in Hong Kong. Am J Infect Control. 2020; 48(8): 890-896
6. *Gan WH, Lim JW, Koh D* Preventing Intra-Hospital Infection and Transmission of Coronavirus Disease 2019 in Health-care Workers. Saf Health Work. 2020; 11(2): 241-243
7. *Garzaro G, Clari M, Ciocan C, Grillo E, Mansour I., et al.* (Group, UniTo and CSSTo COVID-19 Occupational Health Working), COVID-19 Infection and Diffusion Among the Healthcare Workforce in a Large University-Hospital in Northwest Italy (4/15/2020). Med Lav. 2020; 111(3): 184-194
8. *Heinzerling A, Stuckey MJ, Scheuer T, Xu K, Perkins KM., et al.* Transmission of COVID-19 to Health Care Personnel During Exposures to a Hospitalized Patient – Solano County, California, February 2020. Morbidity and Mortality Weekly Report (MMWR). Morb Mortal Wkly Rep. 2020; 69(15): 472-476
9. *Hu LQ, Wang J, Huang A, Wang D, Wang J.* COVID-19 and Improved Prevention of Hospital-Acquired Infection. Br J Anaesth. 2020; 5(37): 5-6
10. *Huang T, Guo Y, Li S, Zheng Y, Lei L., et al.* Application and Effects of Fever Screening System in the Prevention of Nosocomial Infection in the Only Designated Hospital of Coronavirus Disease 2019 (COVID-19) in Shenzhen, China. Infect Control Hosp Epidemiol. 2020; 41: 1-10
11. *Huff HV, Singh A.* Asymptomatic Transmission During the COVID-19 Pandemic and Implications for Public Health Strategies. Clin Infect Dis. 2020; ciaa654
12. *Kao, CC, Chiang HT, Chen CY, Hung CT, Chen YC., et al.* National bundle care program implementation to reduce ventilator-associated pneumonia in intensive care units in Taiwan. J Microbiol Immunol Infect. 2019; 52(4): 592-597
13. *Klompas M.* Coronavirus Disease 2019 (COVID-19): Protecting Hospitals from the Invisible. Ann Intern Med. 2020; 172(9): 19-21
14. *Lai CC, Cia CT, Chiang HT, Kung YC, Shi ZY., et al.,* Implementation of a national bundle care program to reduce central line-associated bloodstream infections in intensive care units in Taiwan. J Microbiol Immunol Infect. 2018; 51(5): 666-671
15. *Lai CC, Liu YH, Wang CYi, Wang YH, Hsueh SC., et al.* Asymptomatic carrier state, acute respiratory disease, and pneumonia due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): Facts and myths. J Microbiol Immunol Infect. 2020. Elsevier Ltd. doi: 10.1016/j.jmii.2020.02.012
16. *Lan FY, Wei CF, Hsu YT, Christiani DC, Kales SN.* Work-related COVID-19 Transmission in Six Asian Countries/Areas: A Follow-Up Study. PLoS One. 2020; 15(5): 1-11
17. *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
18. *Li S, Guo Y, Zheng Y, Lei L, Zeng X., et al.* Practice and Exploration of 24h "SCI" Model in Personal Protection Supervision in COVID-19 Isolation Ward. Infect. Control Hosp. Epidemiol. 2020; 1-7
19. *Marago I, Minen I.* Hospital-Acquired COVID-19 Infection – The Magnitude of the Problem. (6/4/2020), Lancet Infect Dis. 2020. SSRN: https://ssrn.com/abstract=3622387 or http://dx.doi.org/10.2139/ssrn.3622387

20. *Morawska L, Tang JW, Bahnfleth W, Bluyssen PM, Boerstra A., et al.* How Can Airborne Transmission of COVID-19 Indoors be Minimised? Environ Int. 2020; 142: https://doi.org/10.1016/j.envint.2020.105832

21. *Patterson B, Marks M, Martinez-Garcia G, Bidwell G, Luintel A., et al.* A novel cohorting and isolation strategy for suspected COVID-19 cases during a pandemic. J Hosp Infect. 2020; 105(4): 632-637

22. *Rickman HM, Rampling T, Shaw K, Martinez-Garcia G, Hail L., et al.* Nosocomial Transmission of COVID-19: A Restrospective Study of 66 Hospital-acquired Cases in London Teaching Hospital. Clin Infect Dis. 2020; 40: 1-30

23. *Shen Y, Cui Y, Li N, Tian C, Chen M., et al.* Emergency Responses to Covid-19 Outbreak: Experiences and Lessons from a General Hospital in Nanjing, China. Cardiovasc Intervent Radiol. 2020; 43(6): 810-819

24. *Sikkema RS, Pas SD, Nieuwenhuijse DF, O'Toole Á, Verweij JJ., et al.* COVID-19 in health-care workers in three hospitals in the south of the Netherlands: a cross-sectional study. Lancet Infect Dis. 2020; 3099(20): 1-8

25. *Tan TW, Chang CM, Chang MN.* Intra-hospital preventive principles to protect frontline healthcare workers to overcome pandemic COVID-19 in Taiwan. Critical Care. 2020; 24(328). https://doi.org/10.1186/s13054-020-02983-7

26. *Wang D, Hu B, Hu C, Zhu F, Liu X., et al.* Clinical Characteristics of 138 Hospitalized Patients with 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. JAMA. 2020; 323(11): 1061-1069

27. *Wang J, Feng H, Zhang S, Ni Z, Ni L., et al.* SARS-CoV-2 RNA Detection of Hospital Isolation Wards Hygiene Monitoring During the Coronavirus Disease 2019 Outbreak in a Chinese Hospital. Int J Infect Dis. 2020; 94: 103-106

28. *Wee LE, Conceicao EP, Sim XYJ, Aung MK, Tan KY., et al.* Minimizing Intra-Hospital Transmission of COVID-19: The Role of Social Distancing. J Hosp Infect. 2020a; 105(2): 113-115

29. *Wee LE, Sim JX, Conceicao EP, Aung MK, Goh JQ., et al.* Containment of COVID-19 cases Among Healthcare Workers: The Role of Surveillance, Early Detection, and Outbreak Management. Infect. Control Hosp. Epidemiol. 2020b; 41(7): 765-771

30. *WHO*. Transmission of SARS-CoV-2: Implications for Infection Prevention Precautions. 2020; 1-10p. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

31. *Wrapp D, Wang N, Corbett KS, Goldsmith JA, Hsieh CL., et al.* Cryo-EM structure of the 2019-nCoV spike in the perfusion conformation. Science. 2020; 367(6483): 1260-1263

32. *Wu S, Wang Y, Jin X, Tian J, Liu J, Mao Y.* Environmental Contamination by SARS-CoV-2 in a Designated Hospital for Coronavirus Disease 2019. Am J Infect Control. 2020; 48(8): 910-914

33. *Yang Y, Wang H, Chen K, Zhou J, Deng S, Wang Y.* Shelter hospital mode: How do we prevent COVID-19 hospital-acquired infection? Infect. Control Hosp. Epidemiol. 2020; 41(7): 872-873

34. *Yen MY, Chiu AWH, Schwartz J, King CC, Lin YE., et al.* From SARS in 2003 to H1N1 in 2009: lessons learned from Taiwan in preparation for the next pandemic. Journal of Hospital Infection. 2014; 87(4): 185-193

35. *Yen MY, Lin YE, Lee CH, Ho MS, Huang FY., et al.* Taiwan's traffic control bundle and the elimination of nosocomial severe acute respiratory syndrome among healthcare workers. J Hosp Infect. 2011; 77(4): 332-337

36. *Yen MY, Schwartz J, Chen SY, King CC, Yang GY, Hsueh PR.* Interrupting COVID-19 transmission by implementing enhanced traffic control bundling: Implications for global prevention and control efforts. J Microbiol Immunol Infect. 2020; 53: 377-380

37. *Zhang GQ, Pan HQ, Hu XX, He SJ, Chen YF., et al.* The role of isolation rooms, facemasks and intensified hand hygiene in the prevention of nosocomial COVID-19 transmission in a pulmonary clinical setting. Infect Dis Poverty. 2020; 9(1): 104