Diagnostic Ultrasound Services During the Coronavirus Disease (COVID-19) Pandemic

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OBJECTIVE. Nosocomial transmission of coronavirus disease (COVID-19) to frontline health care workers is well known, and health care workers may inadvertently become vectors for onward transmission. Ultrasound (US) service providers are at significant risk because scanning usually requires prolonged close patient contact. The bulky US equipment may also facilitate fomite transmission of disease. With increasing use of point-of-care and portable diagnostic US services, the risk is substantial.

CONCLUSION. Our experience and protocols may help service providers with their own effective response against COVID-19.

The coronavirus disease (COVID-19) pandemic has affected almost all countries around the world and has brought some medical facilities to the brink of collapse [1]. Because of high viral transmissibility, there is considerable risk to frontline health care workers who may become infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and inadvertently become vectors for onward transmission [2–4]. Imaging equipment, particularly ultrasound (US), is at high risk for surface transmission as a result of frequent direct contact with large numbers of patients. US services are frequently required for the diagnosis of comorbid conditions that are and that are not related to COVID-19 (e.g., pleural effusion, renal obstruction, cholecystitis, and deep venous thrombosis [DVT]) [5].

Ultrasound is easily portable, cost effective, and relatively fast in experienced hands. By providing real-time visualization directly at the patient's bedside, US is a powerful tool for diagnosis and efficient treatment and is an excellent modality to complement the overall quality of the traditional physical examination. Use of portable US can limit the number of staff exposed to a confirmed or suspected case, in comparison with scans performed in the US department or use of other modalities like radiography or CT. In addition, US is an invaluable guide for several safe bedside interventions like fluid drainage and vascular access. More recently, point-of-care ultrasound in the management of patients with COVID-19 has been reported to minimize the use of medical devices and health care worker–patient interactions to only the necessary procedures. Some authors report high diagnostic accuracy compared with auscultation or radiography when assessing lung abnormalities like pneumonia and acute respiratory distress syndrome [6]. It has also been suggested that lung ultrasound may allow clinicians to determine when a patient is on the clinical spectrum of COVID-19–associated pulmonary injury [7, 8]. With expertise and optimal resources made available, point-of-care US with handheld or palm-size devices can prove invaluable.

This article serves to share our institutional diagnostic US protocol for effective service provision, staff protection, and business continuity planning [9]. The protocols and guidelines detailed were developed in consultation with our colleagues specializing in infectious diseases and specifically for the COVID-19 pandemic, with reference to our experience with the 2003 severe acute respiratory syndrome (SARS) epidemic and expertise from other institutions [10–14].

Mitigation of risk to health care workers includes service segregation; COVID-19 testing and case definitions; screening measures; inpatient US workflow for suspected or confirmed COVID-19 cases; personal protection, equipment protection, and decontamination; surveillance after the procedure; awareness of psychologic impact on health care workers; and public education.

Keywords: coronavirus disease, COVID-19, pandemic, personal protection equipment, pneumonia, ultrasound

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Service Segregation

In our institution, US services are segregated into three broad sections: inpatient, outpatient, and community clinics, according to the unique characteristics of each.

Inpatient services are segregated into the tertiary hospital and a colocated community hospital. Dedicated negative air pressure rooms are available for scanning of isolation cases [10]. Outpatient services are physically segregated into two locations: general US and subspecialty US (e.g., musculoskeletal, breast). Community clinics are government-funded primary care facilities located outside the main hospital campus, and diagnostic US services for these are provided by our staff.

Staff are mainly segregated by location (e.g., separate teams manage general and musculoskeletal US, with minimal movement of personnel between assigned teams) or by time (i.e., staff assigned to cover the same physical location work nonoverlapping shifts). Standby teams are identified to cover personnel shortages (e.g., staff illness or mandatory quarantine because of potential staff exposure). Segregating manpower into redundant functional teams allows continued provision of essential services in the unfortunate event of intrahospital transmission that could require coworkers to be quarantined [10, 12]. Segregation does significantly affect department workload. To address this, we reduced elective case listing, and nonessential staff leave was restricted as part of overall national policy [10].

Coronavirus Disease Testing and Case Definitions

Singapore's epidemic response uses a nationally defined color-coded protocol called disease outbreak response system condition (DORSCON) [15–17]. The protocol shows what needs to be done to prevent and reduce the impact of infections (Table 1). DORSCON takes into account the current disease situation overseas, how transmissible the disease is, how likely it is to arrive into the country, and the impact it may have on the local community.

National and hospital policies are calibrated according to the DORSCON level, and further granularity can be achieved within levels if required. The hospital's COVID-19 suspected and confirmed case definitions were aligned with the national policy developed by the Ministry of Health of Singapore. During the initial weeks of the outbreak, definitions of suspected cases of COVID-19 in the hospital were set according to travel to certain affected areas (e.g., Hubei province in China and later including Italy, Iran, and other countries), close contact with confirmed cases, and symptoms of upper respiratory illness. These definitions were expanded as the outbreak progressed with increased community transmission.

Currently, the definition of a suspected case of COVID-19 is any person with clinical signs and symptoms suggestive of community-acquired pneumonia or community-acquired severe respiratory infection with breathlessness or acute respiratory illness of any degree (including cough, sore throat, coryza, anosmia) with travel outside Singapore or close contact with a confirmed case of COVID-19 or exposure to a known local cluster [18]. Nosocomial or aspiration pneumonia without link to confirmed cases are excluded.

Suspected cases are admitted to designated isolation wards and undergo polymerase chain reaction testing for SARS-CoV-2 virus using nasopharyngeal swabs. Test results are available 4–6 hours after swabbing. An initial negative swab test is confirmed with a second swab performed 24 hours later. Patients who are suspected to have COVID-19 or who have a confirmed case are managed in the same way in our US protocol.

Screening Measures

Screening measures were stepped up gradually as the outbreak progressed. Initially, patients coming for outpatient US scans underwent screening at the registration counter consisting of a body temperature check and a questionnaire for symptoms, travel, and contact history. A patient identified as a potential case was immediately brought to a designated room and interviewed by the on-duty radiologist to ascertain symptoms and obtain detailed contact and travel history. The patient's case was then discussed with the infectious diseases team on duty. If the patient was deemed safe to proceed with an US scan, the scan would only be performed in dedicated US rooms with negative pressure ventilation as an added precaution. Patients meeting the suspected-case definition were immediately admitted to isolation wards and tested for SARS-CoV-2.

At the current DORSCON orange level, which reflects a disease that spreads easily but is contained in Singapore, perimeter screening is performed for all persons entering hospital premises [15]. Measures include registration, health declaration, and temperature screening of all hospital visitors including patients, companions, product vendors, product delivery persons, maintenance workers, and so forth. Health declarations include

TABLE 1: Nationally Defined Color-Coded Disease Outbreak Response System Condition (DORSCON) Framework

Alert Level	Nature of Disease	Geographic Extent of Infection Spread	Advice to Public				Disruption of Daily Life
			Be Socially Responsible	Maintain Good Personal Hygiene	Comply With Control Measures	Practice Social Distancing	
Green[a]	Mild or, if severe, not easily spread		Required	Required	Not required	Not required	Minimal
Yellow[b]	Severe and easily spread	Outside of Singapore or, if spreading in Singapore, mild and contained	Required	Required	Not required	Not required	Minimal
Orange[c]	Severe and easily spread	Spreading in Singapore, but not widely (contained)	Required	Required	Required	Not required	Moderate
Red	Severe	Widespread	Required	Required	Required	Required	Major

Note—Contents derived from [15].

[a]Middle East respiratory syndrome and avian influenza A (H7N9) virus are examples of diseases that would warrant an alert level of green.

[b]The influenza A (H1N1) pandemic would warrant an alert level of yellow.

[c]The experience of the severe acute respiratory syndrome outbreak in Singapore is an example of a situation that would warrant an alert level of orange. As of June 2, 2020, the coronavirus disease (COVID-19) outbreak warranted an alert level of orange.

travel history, contact history, and relevant symptoms, whereas temperature screening is performed using thermal scanners at entry points with verification of scanner-targeted individuals using tympanic thermal scanners. False declarations are subject to severe penalties under the nation's Infectious Diseases Act. Visitors meeting criteria (fever, cough, significant contact history) are denied entry.

All outpatient US requests are vetted and prioritized according to clinical urgency. Initially only certain groups of patients were required to wear face masks (those who were immunocompromised, outpatients who showed no symptoms but were returning from affected areas, and outpatients who showed no symptoms but had a history of contact with a confirmed case). However, as of June 2020, all patients and visitors are required to wear face masks. Current policy also restricts each patient to one accompanying person.

All inpatient scans are vetted for clinical urgency and patient COVID-19 status. Patients who are not suspected to have COVID-19 come to a dedicated inpatient US imaging center via predefined routes. Patients who cannot physically be moved to the department (e.g., those in intensive care or who are in reverse isolation for an immunocompromised state) receive portable bedside US by a dedicated team of a radiologist and a sonographer. The primary clinical team is responsible for checking and updating the current isolation status of patients under their care. To prevent cross contamination, inpatients are not allowed to move to the outpatient scan area.

Inpatient Ultrasound Workflow for Coronavirus Disease Cases

US scans for all suspected and confirmed COVID-19 cases are done at the patient's bedside to minimize patient movement within the hospital. For patients who are suspected or confirmed to have COVID-19, direct discussions between attending physicians on the primary clinical team and the on-duty attending radiologist are mandated. These conversations help to clearly define the urgency and validity of a scan and specific clinical question to be answered.

Nonurgent inpatient scans for patients suspected or confirmed to have COVID-19 are deferred until patients are de-isolated as required by national protocol [19]. Urgent scans for this group of patients follows the dedicated institutional workflow detailed in this section. Furthermore, we try to consolidate all US scan requests to prevent multiple separate isolation ward visits.

The sonographer on duty prepares the equipment required. The sonographer and attending radiologist proceed to the ward together and perform the scan using hospital-recommended personal protective equipment (PPE). Trainees are not allowed to participate in these procedures to mitigate risk. The detailed workflow for each step of this process is shown in Figure 1. The roles of each staff member are predefined and rehearsed.

Scan protocols have been adjusted to balance speed and clinical relevance: abbreviated protocols are accepted as long as they provide the necessary clinical information to aid clinical management. For example, scans to rule out DVT are performed for the iliac and femoral segments only, priority is given to gray-scale and dynamic compression whereas color and pulsed Doppler sequences are used only for problem solving, and scans are terminated once thrombosis is detected. This abbreviated approach allows initiation of appropriate management (e.g., anticoagulation) while reducing overall scan time (and hence staff exposure). Image labeling, measurements, and uploading are only done on return to the department.

For added insurance, cine sequences of areas of concern are captured for later review. The radiologist and sonographer proceed together to perform each scan. This is in contrast to our regular inpatient portable US workflow in which a trained sonographer performs the scan alone and uploads the images (usually for several patients consecutively), and the images are then sent to a dedicated radiologist for reporting. Although a radiologist and sonographer unit working in tandem substantially reduces throughput, it is a necessary sacrifice to ensure that there will be no need to repeat the scan or obtain extra images.

Despite abbreviated protocols, the scanning time may not be significantly shortened because patients who are unwell may not be able to fully cooperate with the examination. In addition, increased care and awareness are needed to ensure no inadvertent breaks in staff protection. On average, a bilateral lower limb DVT scan requires approximately 30

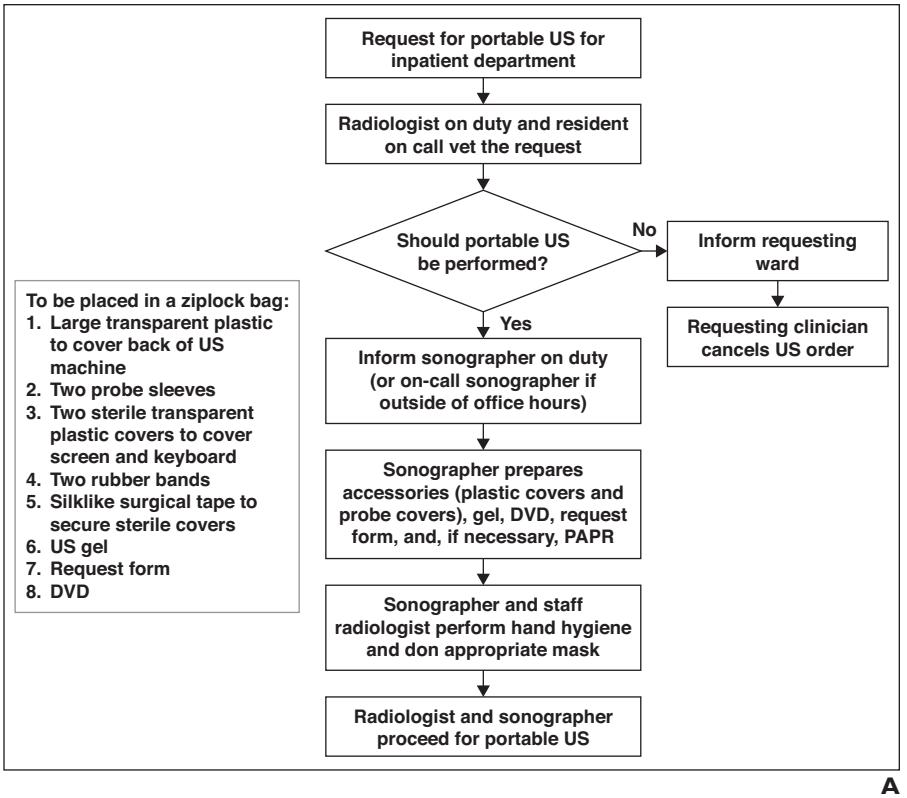
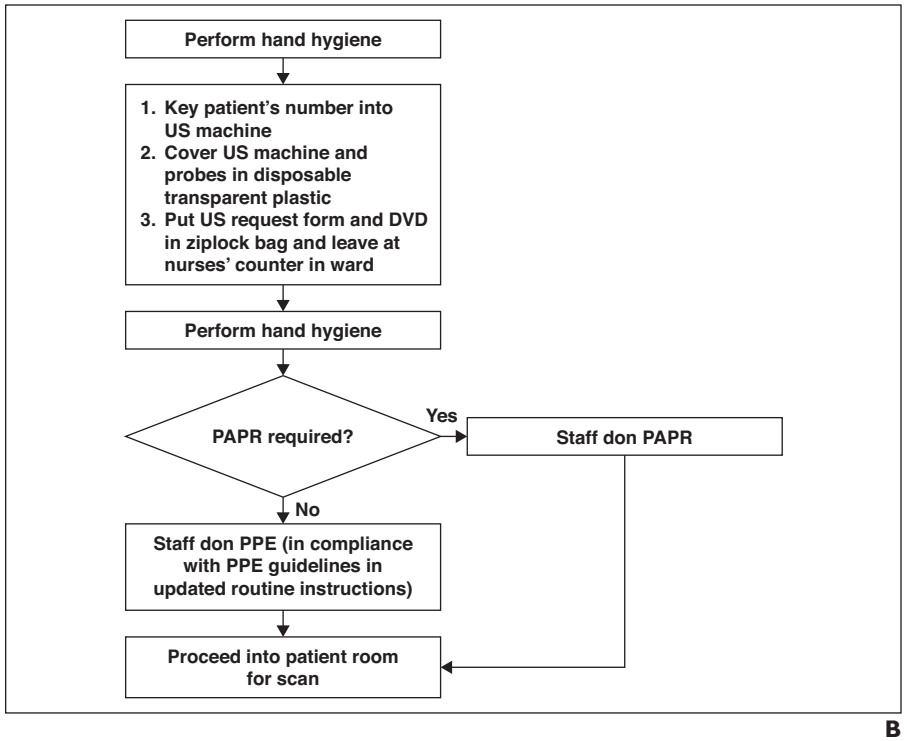
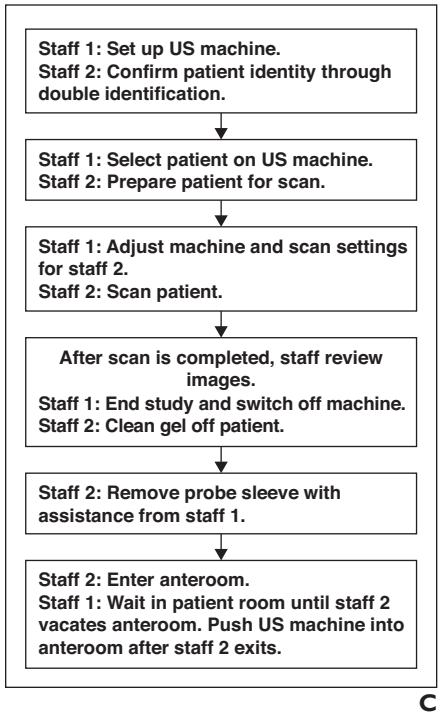
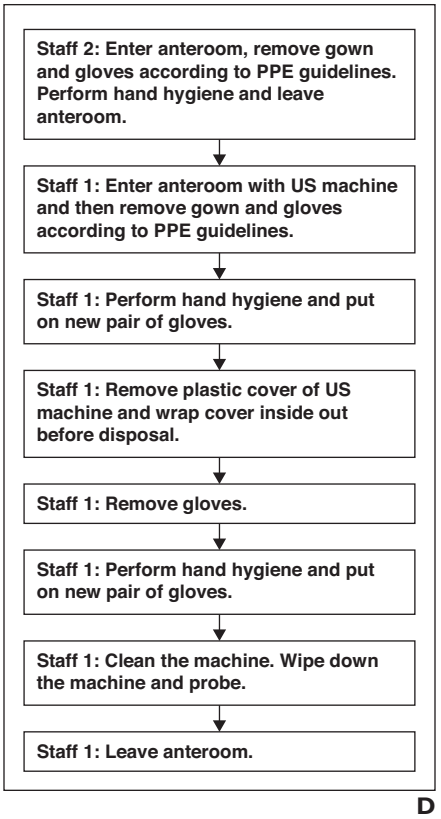


Fig. 1—Flowcharts of processes and protocols for portable ultrasound (US).
A, Flowchart shows process for vetting US requests and scan preparations in inpatient imaging center. All requests are consolidated to minimize visits. PAPR = powered air purifying respirator.

(Fig. 1 continues on next page)







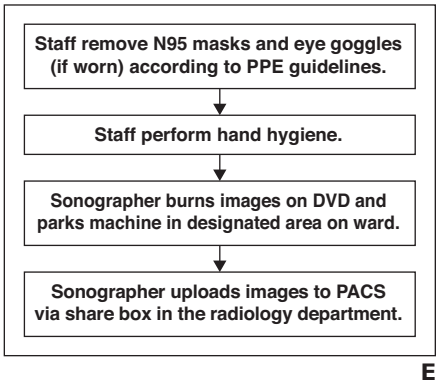


Fig. 1 (continued)—Flowcharts of processes and protocols for portable ultrasound (US).
B, Flowchart shows protocol in corridor of requesting ward, before entry into patient isolation room. PPE = personal protective equipment.
C, Flowchart shows protocol within inpatient isolation room including duties of two staff. Staff 1 maintains no patient contact; staff 2 performs all patient contact.
D, Flowchart shows protocol after scan completion within anteroom outside patient area.
E, Flowchart shows final process in corridor of requesting ward and postprocessing in clean work space area.

minutes for transfer to patient location and preparation, 20–30 minutes scan time, and 30–45 minutes after the scan for PPE doffing, decontamination, and return to department. Essentially, a minimum 1.5-hour time block must be dedicated for each case.

Personal Protection, Equipment Protection, and Decontamination

General Protection Measures

Because of the nation's previous encounter with SARS, general infection control measures have become ingrained in the psyche of all staff, and compliance rates are usually maintained at well over 90% [11]. All hospital staff undergo yearly refresher training on basic infection control measures such as the World Health Organization–defined "five moments of hand hygiene" [20]. Bottles of approved alcohol-based hand sanitizers and moisturizers are widely available around the hospital campus at strategic locations and high-touch areas (e.g., elevator lobbies, stairwells, department entrances, and scanning and reporting areas).

All health care workers undergo annual influenza vaccination, which in the current situation serves to reduce potential additional cases of seasonal influenza. All frontline staff also undergo N95 particulate respirator fit testing and refresher courses for the powered air purifying respirator (PAPR), and this information is logged in the hospital records of each individual [21].

In outpatient scanning locations, all patient contact surfaces and US machine probes are cleaned thoroughly at the end of each examination. The sonographer wears a surgical mask throughout the procedure and practices hand hygiene before and after patient contact.

A

B

Fig. 2—Photographs of protective draping.
A and **B,** Ultrasound equipment including appropriate ultrasound probe is draped with transparent plastic and secured with general surgical tape (*arrow,* **B**).

In the present situation, hospital staff are required to wear surgical masks in all clinical and patient fronting areas.

Social distancing is encouraged within the hospital system to reduce the likelihood that an infected health care worker may pass on the disease to multiple colleagues or vulnerable patients. Close grouping (e.g., during meetings or lectures, mealtimes, and multidisciplinary treatment meetings) is discouraged. Multidisciplinary meetings and continuing medical education activities have increasingly moved online using web-based medical confidentiality–compliant systems (e.g., Webex [Cisco]).

Specific Protection Measures

Droplet and contact precautions are recommended for most instances of patient contact. Transmission capability may increase during aerosol-generating procedures, but there is controversy regarding both the definition of aerosol-generating procedures and the appropriate PPE to be used, with some but not all authorities recommending the use of the PAPR [22]. The use of PAPRs potentially adds to the technical challenge of performing US and other procedures and may not be necessary for routine use in the absence of aerosol-generating procedures for COVID-19.

In our institution, the staff radiologist and sonographer wear full PPE comprising a single-use N95 mask, single-use eye protection, a disposable gown, two layers of disposable gloves, and a single-use head cap to attend to the patient. All personnel don a dedicated isolation ward uniform and recommended PPE before patient contact. If possible, scan timing should be scheduled to avoid concomitant aerosol-generating procedures such as intubation or extubation, oral or tracheostomy suctioning, nebulizer therapy, and positive pressure noninvasive ventilation.

Equipment (e.g., battery, probe, gel) is checked before entry into patient areas to prevent cases of inadvertent failure during scanning. US equipment is covered with disposable plastic covers (Fig. 2) before entering the patient's room. In the room, the two staff are divided into the nonpatient contact (staff 1) and the direct patient contact (staff 2), and the specific duties of the two are as detailed in Figure 1C.

Stepwise removal of PPE is done after exiting the patient's room. A controller (e.g., an infection control nurse) is recruited whenever possible to provide independent critique and guidance of PPE donning and doffing technique to ensure quality. The anteroom is included in purpose-built isolation rooms and serves to separate the contaminated patient area from noncontaminated work spaces [23]. The step-by-step processes in the anteroom and outside the anteroom (ward corridor) are as shown in Figures 1D and 1E. Finally, staff are required to shower and change into a new set of hospital scrubs before leaving the isolation ward area.

It is important to ensure that items do not inadvertently travel unprotected between patient and work space areas; for example, case paperwork and request forms must always remain outside in the clean work space and must not be brought into the anteroom or patient area. Care should be taken to prevent contamination of the hand sanitizer bottles in the anteroom and clean work space areas during the steps mentioned. No-touch door activators allow staff movement without contact with door handles.

The steps for donning and doffing of PPE can be complex, and our staff undergo dedicated training before treating patients with COVID-19. Online training modules are also available for review.

Surveillance After the Procedure

All staff are required to self-report their body temperature twice daily via a nation-

Fig. 3—Photograph shows seating rearrangement in outpatient area to ensure social distancing of patients and caregivers from other patients during wait for ultrasound scans.

al online reporting system. Those with fever or respiratory symptoms are required to visit the staff clinic for appropriate investigation or home medical leave. Those meeting the suspected case definition undergo in-hospital quarantine until results of definitive testing are available.

Psychologic Impact

The psychologic impact on health care employees can be significant during epidemics and can persist or manifest many years later. Studies during the SARS epidemic have shown a persistence rate of posttraumatic stress disorders as high as 40% among hospital employees 3 years after the outbreak [24]. A proactive, supportive hospital environment is paramount to combat the psychologic stress during these trying times. At our institution, we have well-established committees at both the hospital and department levels. At the department level, the Radiological Science Office of Staff Experience plays a vital role in looking after the welfare of the entire radiology team. The team members actively engage the frontline radiology staff with simple but meaningful gestures like providing adequate pantry supplies, providing regular staff counseling for emotional health on a case-by-case basis, and facilitating the tokens of appreciation and kind gestures coming from the community to the staff.

Public Education

Our staff at outpatient US services take every opportunity to educate patients and their accompanying visitors on the importance of social responsibility and to reinforce proper hand hygiene techniques. US departments can reinforce social distancing guidelines by taking simple steps such as rearranging patient seating in outpatient waiting areas (Fig. 3). These additional measures can be invaluable in preventing the spread of serious communicable pathogens.

Conclusion

US personnel are frontline staff who may be frequently exposed to patients with COVID-19 in the current pandemic. The screening of patients and visitors, segregation and monitoring of staff, vetting of scans, adherence to strict protocols, and teamwork are all important for the safety of health care workers and to prevent nosocomial transmission.

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References

1. Johns Hopkins University & Medicine website. COVID-19 dashboard by the Center for Systems Science and Engineering at Johns Hopkins University. coronavirus.jhu.edu/map.html. Accessed May 4, 2020
2. Zou L, Ruan F, Huang M, et al. SARS-CoV-2 viral load in upper respiratory specimens of infected patients. *N Engl J Med* 2020; 382:1177–1179
3. Wang W, Xu Y, Gao R, et al. Detection of SARS-CoV-2 in different types of clinical specimens. *JAMA* 2020; 323:1843–1844
4. Ong SWX, Tan YK, Chia PY, et al. Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. *JAMA* 2020; 323:1610–1612
5. Li XY, Du B, Wang YS, et al. The key points in treatment of the critical coronavirus disease 2019 patient [in Chinese]. *Zhonghua Jie He Hu Xi Za Zhi* 2020; 43:277–281
6. Lichtenstein DA, Malbrain MLNG. Lung ultrasound in the critically ill (LUCI): a translational discipline. *Anaesthesiol Intensive Ther* 2017; 49:430–436
7. Gargani L. Ultrasound of the lungs: more than a room with a view. *Heart Fail Clin* 2019; 15:297–303
8. Smith MJ, Hayward SA, Innes SM, Miller ASC. Point-of-care lung ultrasound in patients with COVID-19: a narrative review. *Anaesthesia* 2020 Apr 10 [Epub ahead of print]
9. Mossa-Basha M, Meltzer CC, Kim DC, Tuite MJ, Kolli KP, Tan BS. Radiology department preparedness for COVID-19: *Radiology* Scientific Expert Panel. *Radiology* 2020 Mar 16 [Epub ahead of print]
10. Cheng LTE, Chan LP, Tan BH, et al. Déjà vu or jamais vu? How the severe acute respiratory syndrome experience influenced a Singapore radiology department's response to the coronavirus disease (COVID-19) epidemic. *AJR* 2020; 214:1206–1210
11. Gogna A, Tay KH, Tan BS. Severe acute respiratory syndrome: 11 years later—a radiology perspective. *AJR* 2014; 203:746–748
12. Da Zhuang K, Tan BS, Tan BH, Too CW, Tay KH. Old threat, new enemy: is your interventional radiology service ready for the coronavirus disease 2019? *Cardiovasc Intervent Radiol* 2020; 43:665–666
13. Lau TN, Teo N, Tay KH, et al. Is your interventional radiology service ready for SARS? The Singapore experience. *Cardiovasc Intervent Radiol* 2003; 26:421–427
14. Moreno CC, Kraft CS, Vanairsdale S, et al. Performance of bedside diagnostic ultrasound in an Ebola isolation unit: the Emory University Hospital experience. *AJR* 2015; 204:1157–1159
15. Singapore Ministry of Health website. What do the different DORSCON levels mean. www.gov.sg/article/what-do-the-different-dorscon-levels-mean. Accessed March 7, 2020
16. Wee LE, Conceicao EP, Sim XYJ, et al. Minimising intra-hospital transmission of COVID-19: the role of social distancing. *J Hosp Infect* 2020 Apr 12 [Epub ahead of print]
17. Gogna A, Punamiya S, Gopinathan A, et al. Preparing IR for COVID-19: the Singapore experience. *J Vasc Interv Radiol* 2020; 31:869–875
18. Singapore Ministry of Health (MOH) website. MOH circular 123/2020. www.healthprofessionals.gov.sg/docs/librariesprovider12/default-document-library/moh-cir-no-123_2020_11may20_revision-of-suspect-case-definition-for-covid-19.pdf. Published May 11, 2020. Accessed June 5, 2020
19. Tay JY, Lim PL, Marimuthu K, et al. De-isolating COVID-19 suspect cases: a continuing challenge. *Clin Infect Dis* 2020 Feb 26 [Epub ahead of print]
20. World Health Organization website. My 5 moments of hand hygiene. www.who.int/gpsc/5may/background/5moments/en/. Accessed March 1, 2020
21. Mirza SK, Tragon TR, Fukui MB, Hartman MS, Hartman AL. Microbiology for radiologists: how to minimize infection transmission in the radiology department. *RadioGraphics* 2015; 35:1231–1244
22. Health Protection Scotland website. Aerosol generating procedures (AGPs). hpspubsrepo.blob.core.windows.net/hps-website/nss/2893/documents/1_tbp-lr-agp-v1.pdf. Accessed June 5, 2020
23. Bluemke DA, Meltzer CC. Ebola virus disease: radiology preparedness. *Radiology* 2015; 274:527–531
24. Wu P, Fang Y, Guan Z, et al. The psychological impact of the SARS epidemic on hospital employees in China: exposure, risk perception, and altruistic acceptance of risk. *Can J Psychiatry* 2009; 54:302–311