



Operation of ultrasonography services in a dedicated paediatric hospital and a university hospital in Greece under the COVID-19 pandemic

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Abstract

Ultrasonography (US) is one of the most common diagnostic imaging tests in children. During the coronavirus disease 2019 (COVID-19) pandemic, it is important to operate with a plan designed to protect health care workers, to prevent transmission of infection from child and parents to another child or an accompanying person in the US suite, and to save valuable protective material and resources. Measures during routine US in children can be challenging both in general hospitals with paediatric units and in dedicated paediatric hospitals. Special considerations include: a) cancellation or rescheduling of unnecessary imaging tests, b) a relevant questionnaire on the request form informing about patient and accompanying person's symptoms and likely exposure in addition to general triage, c) appropriate patient and parent protective measures, d) recruitment and selection of US machines in different protected areas depending on the possibility or certainty for the infection, e) regular personnel protective measures and personal hand hygiene, f) routine disinfection of probes and adjacent surfaces and g) machine/room deep disinfection, if required. Our purpose is to present the modified US services in children during the COVID-19 pandemic in two hospitals based on the instructions of the national organization of public health in Greece and what is known about the mode of transmission of the virus.

Keywords Children · Coronavirus · COVID-19 · Infection control · Safety · Ultrasonography

Introduction

The coronavirus 2019 (COVID-19) pandemic presented in Wuhan, China, and has so far affected more than 4 million people worldwide (May 9, 2020), with a mortality range of almost 7% [1]. Interestingly, the majority of people infected

by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) have mild disease that does not require hospitalization [2]. COVID-19 appears to be transmitted human-to-human via droplets, i.e. when a person coughs, sneezes or talks loudly, or via direct contact, i.e. contact of a contaminated hand with the mouth, nose or eye conjunctiva [3]. Infection has been estimated to have an incubation period of 2–14 days (mean: 6.4 days) [3]. Asymptomatic patients in the incubation period may potentially transmit the virus [4]. Moreover, children with COVID-19 may have mild symptoms or may be asymptomatic [3]. For these two reasons, the temporary closure of schools and daycare facilities has been employed as a containment measure.

Ultrasonography (US) is widely used in children and can be performed in radiology departments of general or dedicated paediatric hospitals, in private hospitals or practices, in intensive care units, in emergency departments, in clinics or even in ambulances, where available. Disinfecting US transducers is important because of the risks of cross infection from dirty probes, which is mostly relevant when probes touch infectious material [5].

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In the paediatric setting during the COVID-19 pandemic, it is important to operate with a plan designed not only to protect health care workers and thus ensure continuity of care, but also to prevent transmission of infection among patients and their accompanying carers. It is also important to use personal protective measures prudently so resources remain available. For this reason, there were discussions among radiologists, trained nurses and infectious diseases specialists in two Greek hospitals to formulate feasible protective measures for US in a general hospital with paediatric units and in a dedicated paediatric hospital.

We present our modified conditions of US service during the COVID-19 pandemic. We understand that epidemiology, policies and health care conditions may vary from country to country and from hospital to hospital. Our modifications were based on the instructions of the national organization of public health in Greece and considered protection of staff, protection of the general population, local settings and protection of resources. We describe scenarios of US scanning not only for COVID-19 patients, but for all possible current settings.

National containment measures

As of March 11, 2020, containment measures to protect the general population in Greece have been increasingly strict and follow the European Centre for Disease Prevention and Control social distancing measures [6].

These comprised closure of schools and universities, closure of all stores except supermarkets and pharmacies, no indoor gathering of people or outdoor activities with the exception of limited solitary exercise keeping distance (>2 m) from other citizens, an intense “stay at home” campaign, encouragement of work and education from home whenever possible and restrictions on transportation. Travellers from abroad were strictly introduced into a 14-day quarantine and expected to soon be denied entry into the country. On March 23, people were told to stay home (enforced lockdown).

Regarding patient care, outpatient appointments have been cancelled or postponed to reduce potential exposure to asymptomatic carriers. As a result, the number of US tests of outpatients has dramatically decreased. To date, the incidence of COVID-19 in Greece is less compared to other European countries.

General guidelines for health care workers that apply to ultrasonography

National guidelines are written in Greek and comprise (among others) general information, recommendations on patient triage, basic precautions, risk assessment for health care workers

and protection measures during manipulations around patients with suspected coronavirus infection [7]. They are in line with the World Health Organization (WHO) and European Centre for Disease Prevention and Control guidelines [8, 9]. There are also detailed instructions about donning (wearing personal protective equipment, which includes mask, glasses or goggles, waterproof gowns, long gloves) and doffing (undress in an ordered “inside out” technique to avoid droplets/contaminated material). Explicit instructions with photographs and sketches are mounted on the walls of all examination rooms in radiology departments [10]. Similar instructions in English are also available from European organizations [11, 12] (Fig. 1).

Health care workers who provide care to COVID-19 patients should be fully protected while those caring for non-COVID-19 patients without respiratory symptoms should wear protective equipment according to standard precautions and risk assessment [8].

Health care practitioners should also be aware of and apply the general preventive measures both during duty and in everyday life [7, 8]:

- a. Perform hand hygiene frequently with an alcohol-based hand rub if hands are not visibly dirty or with soap and water if hands are dirty.
- b. Avoid touching eyes, nose and mouth.
- c. Practice respiratory hygiene by coughing or sneezing into a bent elbow or tissue and then immediately dispose the tissue.
- d. Wear a medical mask if you have respiratory symptoms and perform hand hygiene after disposing of the mask.
- e. Maintain social distance (suggestion of 1–2 m depending on the country) from individuals with respiratory symptoms and socialize as little as possible (<10 min).

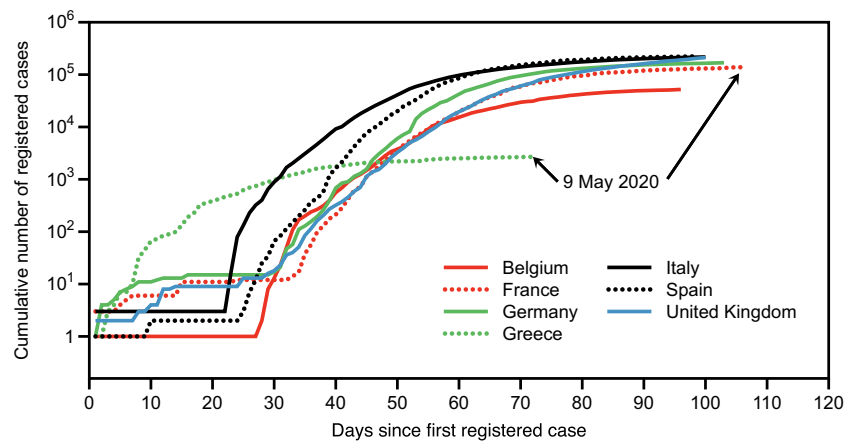
Organization of a local plan

Based on the mode of transmission of COVID-19, a plan on a local level is mandatory [13]. Ideal personnel protection during US scanning would involve routine personal protection equipment for contact, droplet and airborne transmission [8]. However, this is unrealistic and would cause an unnecessary and a potentially harmful waste of resources [8, 12]. Considerations for a logical, feasible plan are listed in Table 1.

Hospital settings, dedicated COVID-19 areas and recruited US machines

Characteristics of our hospitals with emphasis on paediatric services, available US machines and modifications for

Fig. 1 Cumulative number (log scale) of registered people infected with COVID-19 by the number of days since the first registered case for Belgium, France, Germany, Greece, Italy, Spain and the United Kingdom. Data extracted from the European Centre for Disease Prevention and Control: <https://data.europa.eu/euodp/en/data/dataset/covid-19-coronavirus-data>. Accessed 9 May 2020



dedicated COVID-19 areas and machine recruitment are summarized in Table 2. Locating all of the US machines in large hospitals can be challenging, as they may be moved, be uncatalogued or may be unknown to personnel [14]. Leaving US machines in designated COVID-19 areas is a measure in line with efforts to move COVID-19 patients inside the hospital as little as possible [7]. US is not expected to be performed routinely in patients with COVID-19. However, it may be requested for emergencies, hospitalized patients and selected outpatients who are all potential carriers. To date, the authors’ collective experience involves US in 27 suspected COVID-19 patients, 12 adults and 15 children of whom 3 (all adults) were eventually confirmed to have COVID-19. It should be pointed out that one additional adult tested positive following the US scan, and personnel were quarantined

because they scanned the patient as per routine, wearing only a surgical mask and gloves while the patient was not wearing any protection. No US personnel have developed symptoms suggestive of COVID-19.

Triage

Triage of patients is essential [7]. Recognizing a symptomatic possible COVID-19 patient before they enter the hospital ensures quarantine and the performance of necessary imaging tests under appropriate precautions [15]. According to WHO and radiology expert panels, trained personnel should ask about fever, signs/symptoms of respiratory tract infection or close contact with someone with confirmed or suspected COVID-19 [15, 16]. These inquiries are routinely asked at the entrances of both hospitals and also by radiology personnel (Fig. 2). Information either on the request form/electronic system or via phone about the child, family and accompanying person’s symptoms and epidemiological history provides an index of COVID-19 likelihood before the patient’s arrival at the radiology department. Cancellation of US examinations that are not deemed urgent are considered on a case-by case basis and preferably following discussion with the referring physician. However, definitively excluding the disease cannot be achieved on the basis of history and clinical examination, or even by a chest radiograph [17]. This is why we apply protection measures during routine scanning and not exclusively for suspected/confirmed COVID-19 patients.

Table 1 Questions and considerations relevant to management of US services

1. How many entrances are there in the hospital and how many designated COVID-19 areas exist?
2. How is triage of possible COVID-19 patients performed, where and by whom?
3. How many US machines are there and what are the possibilities for portable machines in secluded areas?
4. How is performance of tests restricted to absolutely necessary ones without the danger of missed data in lockdown circumstances?
5. How many different scenarios are there when performing US in the hospital?
6. How should we protect staff as a priority inside the hospital?
7. Who performs the tests and under what personal protection measures in known COVID-19 patients?
8. What should patients wear or do before or during the examination?
9. How do we address special considerations in children like accompanying person and lack of cooperation?
10. How do we ensure appropriate disinfection of probes, machines and rooms in all scenarios?
11. How do we save resources and ensure they are not wasted on non-COVID-19 patients?

Modifications of US operation

Standard of practice in both hospitals has changed according to the probability of scanning a COVID-19 patient. We could identify three main scenarios: a) children and adults arriving at the emergency department with respiratory symptoms or a history of contact and also with

Table 2 Hospital characteristics, modifications of areas and machine recruitment due to the COVID-19 pandemic

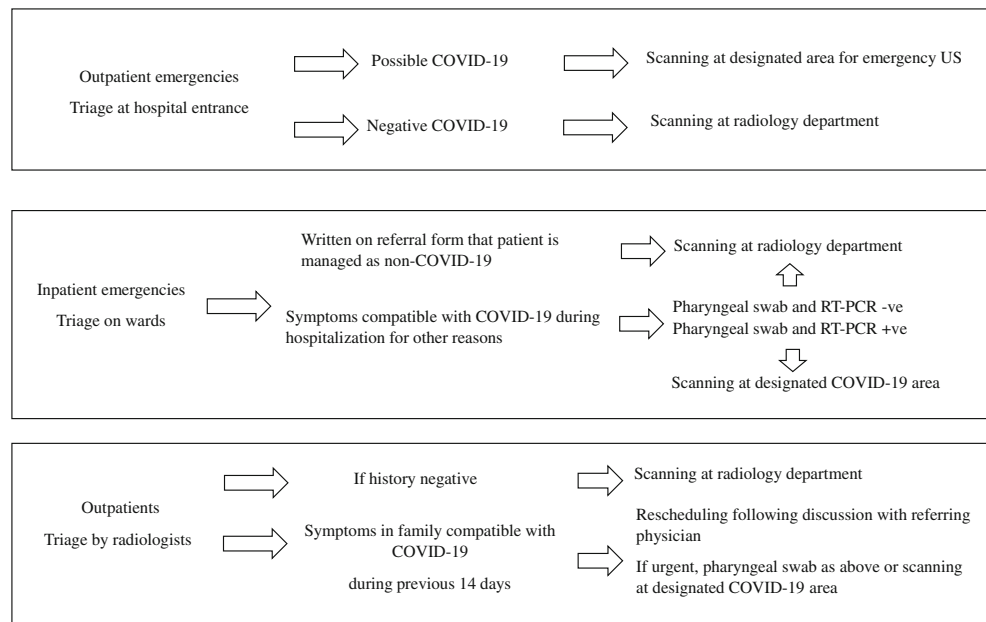
	Hospital 1	Hospital 2
Setting	700-bed general university hospital	420-bed paediatric hospital with one university clinic
Patients	adults and children	children only
Accident and emergency department	yes	yes
PICU	1	1
NICU	1	1
Adult ICU	1	0
Inpatient clinics	one academic general paediatric clinic, one paediatric surgery, one paediatric haematology oncology, several adult clinics	one academic paediatric, two additional paediatric clinics, two paediatric surgery clinics, two paediatric orthopaedic clinics, one paediatric ear, nose and throat clinic, one paediatric haematology-oncology clinic
Outpatient clinics	Cancelled. Selected patients (adults and children) are scanned following discussion consultant-to-consultant with regular exceptions of oncology, trauma and pregnant patients.	All outpatient appointments cancelled except: a) those that will impact patient management according to the referring physician, b) those ordered by the paediatric surgeon to evaluate possible postsurgical complications, and c) those requested following hospitalization of a child if their follow-up is necessary.
Designated/restricted negative-pressure COVID-19 areas for suspected or confirmed COVID-19 patients	Area with 3 negative-pressure chambers and two isolated rooms at the emergency department, 1 negative-pressure and one isolation room at PICU, 1 isolated area at NICU, several beds and negative pressure chambers at ICU, a newly introduced “Coronavirus-19” ward with 8 negative-pressure rooms and 16 isolated beds	Designated area in the emergency department, two paediatric COVID-19 wards with 4 negative-pressure rooms, 2 isolation rooms, 11 more rooms, 2 negative-pressure rooms and 13 isolated beds in PICU
US machines available in the hospital	Two non-mobile US machines at US suite, one machine at PICU, one machine at NICU, one machine at ICU, several machines at adult wards (cardiology, urology, gynecology) and two machines at the accident and emergency department	Four state-of-the art US machines in the ultrasound unit, two of them are used as portable also, one more US machine permanently at PICU and one at NICU
Recruitment of US machines in designated COVID-19 areas	The US machines at PICU, at NICU and at ICU have been assigned as “COVID-19 equipment,” when required. One machine at the emergency department and one at the “Coronavirus-19” ward have been recruited exclusively for suspected/confirmed COVID-19 patients.	One of the two portable US machines of the ultrasound unit has been transferred in the dedicated COVID-19 radiology area (next to the x-ray room where only radiographs of suspected COVID-19 patients are performed) and is dedicated to confirmed/suspected COVID-19 children referred from the emergency department. It is also transported to COVID-19 wards, PICU and NICU for suspected/confirmed COVID-19 patients. The second portable US machine (bedside examinations, surgery room) and the US machines at PICU and NICU are used only for non-COVID-19 patients.
US operators	radiologists	radiologists

ICU intensive care unit, NICU neonatal intensive care unit, PICU paediatric intensive care unit

suspected diagnoses that may require US (for example, febrile children with possible intussusception or appendicitis) are scanned as COVID-19 patients, b) likely not COVID-19 children and adults referred for routine US scanning, and c) suspected/confirmed COVID-19 patients are hospitalized in a COVID-19 ward or in a neonatal, paediatric or intensive care unit, requiring an US scan during hospitalization (Table 3). One should bear in mind that in highly endemic areas, all patients could potentially be asymptomatic COVID-19 carriers in the incubation

period. Consequently, modifications comprised the use of portable machines as much as possible, use of protective equipment by patients and accompanying people, use of protective equipment by personnel depending on the level of suspicion for COVID-19 as prudently as possible, the reduction of scan duration based on the choice of the more confident/experienced operator, the reduction of the number of individuals in the scanning room, and a more meticulous selection of patients and disinfection procedures (Table 3) [7, 8, 15, 16, 18–20].

Fig. 2 Decision tree for scanning based on referrals, patient triage and swab test, when available. -ve negative, +ve positive, *RT-PCR* reverse transcription polymerase chain reaction



Patients at the neonatal or paediatric intensive care units, regardless of the probability of COVID-19, are examined at bedside by regularly disinfected machines, especially in the event of previous COVID-19 patient scanning, as per standard operation in these settings. Protection with a simple disposable gown, hygiene of probes with soap water or nonalcoholic solution, followed by hand hygiene, use of mask and gloves and finally cleaning of used probes with disinfectant containing hydrogen peroxide ensures the protection of neonates and children from cross-contamination and are not meant to protect the radiologists.

Similarly, interventional procedures that are performed under US guidance, including contrast-enhanced voiding urosonography (ceVUS), US-guided pneumatic or saline reduction of intussusception, US-guided core needle biopsy and percutaneous drainage of various fluid collections, are being performed with advanced measures of staff and patient protection, probe protection with covering and subsequent disinfection (due to the probe’s vicinity with body fluids and because they could be considered aerosol-generating procedures when children are not sedated). These measures are routine in both suspected/confirmed COVID-19 children and elective outpatients, due to the probability of infection by asymptomatic children, as per local guidelines.

Patient conduct during ultrasound scanning

The routine use of a simple mask by patients who are asymptomatic is controversial. In environments with restricted resources or low incidence for COVID-19, such a measure is considered unnecessary for routine US scanning [21]. However, in centers with available recourses, personal hand

hygiene and a simple mask or facial coverage on patients, especially on those with respiratory symptoms, are strongly advised by local authorities [16, 18]. Moreover, correct application of a mask on a child for the duration of stay in the US suite is not always feasible. We have been surprised by how well children can wear masks. We have had children as young as 4 years old who tolerated the mask, probably because everybody including their parents was wearing one as well. In this context, children ages 5 years or older may adhere, while nontolerant children include mainly toddlers and uncooperative children of any age.

Personal protective equipment for ultrasound operators

Personal protective equipment accompanied by appropriate donning and doffing is an indispensable measure in confirmed COVID-19 cases [8]. The ultimate goal is to prevent infected hands from touching the face, mouth, nose and eye conjunctiva of US operators [17]. Instructions about personnel protection are continuously being revised, depending on the area of the examination, patient risk profile and nature of the personnel-patient contact [21]. There is a consensus for protection with fitted respirator masks (N95 respirators, FFP2 or the equivalent), eye goggles, robe and appropriate shoes for aerosol-producing procedures like intubation, suction, turning the patient into a prone position, etc., in confirmed COVID-19 patients [22]. This is the best practice for US, provided there is no shortage of respirator masks. However, in procedures that do not produce aerosol, instructions vary, and simple face masks instead of respirator masks are acceptable in the event of shortages [22].

Table 3 Summary of the differences of standards of practice between regular operation and different scenarios with relevant supporting literature, regarding parameters before, during and after scanning

Parameter	Previous standard of practice	Scenario suspected/confirmed COVID-19 patient referred from emergency department ^a	Scenario non-COVID-19 patient, routine scanning	Scenario suspected/confirmed COVID-19 patient in a COVID-19 ward or ICU or PICU	Referenced recommendations
Upon referral	Performed or scheduled as soon as possible when indicated	Discuss necessity to perform US before serological results between consultants	Screen for symptoms and risk factors of both child and family, reschedule when appropriate	Discuss necessity to perform US or postpone	Perform scans that will alter patient management [7, 15]
Patient appointment	Every 10–20 min	Hospital 2: allow 1-h downtime for passive air exchange	Every 30 min		Avoid crowding and allow passive air exchange and disinfection [15]
Place and machines	Patients scanned at ultrasound units	Patients scanned at designated area Hospital 1: at the emergency department by a dedicated portable machine Hospital 2: at designated area of the radiology department by a dedicated machine	Patient scanned at ultrasound units	Patient scanned at designated ward or unit by a dedicated portable machine. In hospital 2 this is transported from the radiology department	Use portable machines as much as possible [15]
Patient conduct	No protective equipment, toys allowed/-mandatory	Mask, hand hygiene	Mask only if respiratory symptoms, revised recently into mask for all patients ^b , personal hand hygiene, toys and unnecessary equipment avoided	Mask, hand hygiene	Address all patients as possible COVID-19, recourses allowing [7, 8, 16, 18]
Accompanying persons	1 or 2	None or 1, on a case-by case basis ^c , mask, hand hygiene	None or 1, on a case-by case basis, mask	None or 1, on a case-by case basis, mask, hand hygiene	Keep as few people in room as possible [18]
Protection of personnel	Hand hygiene, gloves optional	Full PPE	Simple mask, gloves optional if available, regular hand hygiene from elbows down, short-sleeved uniform	Full PPE in Hospital 1, full PPE, covered probe and keyboard as per availability in interventional procedures	Local guidelines, revised depending on local risk, recourses [8]
Who performs the test	The registrar, under supervision, teaching possible during scanning	The most confident and experienced operator	The most confident and experienced operator	The most confident and experienced operator	Fewer people and the shortest time with the patient as possible [18]
Upon completion of test	Wipe the gel off the transducer, use different wipe for patient	Wipe the gel off the transducer, use different wipe for patient and invariably disinfect probe, machine	Wipe the gel off the transducer, use different wipe for patient and invariably disinfect probe	Wipe the gel off the transducer, use different wipe for patient and invariably disinfect probe, machine	Local and International guidelines [19, 20]

^a Hospital 1: mixed adult and paediatric hospital; Hospital 2: dedicated paediatric hospital

^b We require a mask on both children and accompanying people following scanning of a COVID-19 patient who did not wear a mask

^c We are scanning older (>7 years) children alone in the room only when they state they are comfortable and allow one carer in the room in all other circumstances and in scans requiring nudity (for example, testicular US)

ICU intensive care unit, PICU pediatric intensive care unit, PPE personal protective equipment

In an attempt to save materials, our staff dealing with non-COVID-19 patients wear short-sleeved uniforms, avoid touching the face with hands, avoid close contact with the patient as much as possible, reduce scanning time as much as possible to 14 min in the room per patient and perform personal hand hygiene from the elbows down regularly (local guideline). Masks may remain on the examiner's face for 2 h provided that they are not touched by bare hands or used gloves and they are not moved over or under the face. This is in accordance with measures suggested in case of a shortage of materials [9]. Our teams decided to adopt these measures from the start to save protective equipment for confirmed hospitalized COVID-19 cases and aerosol-generating procedures and we will potentially revise them depending on risk during the pandemic (Table 3) [17].

Disinfection

US equipment is a possible transmitter of infectious diseases, as shown in tests of probes used in emergency departments and intensive care units, especially concerning interventional procedures or contact with body fluids [23, 24]. To date, there is no consensus regarding best practice for probe disinfection, even during routine US procedures [5, 24]. Few facilities adhere to a regular disinfection plan [5]. The virus SARS-CoV-2 is detectable in aerosols for up to 3 h and in other materials for 4–24 h depending on the composition of the material, with simultaneous great reduction of virus titer [25]. This stability likely contributes to transmission in health care settings [25]. Consequently, probes in our hospitals are disinfected after each scan with an antiviral agent like sodium hypochlorite that is left on the probes until dry, while soap is also an acceptable option in restricted resources [9]. Surface disinfection with 0.1% sodium hypochlorite or 62–71% ethanol significantly reduces coronavirus infectivity on surfaces within a minimum 1 min exposure time [26]. The use of sheaths does not change the type of processing recommended for the transducer, due to the potential for breakage of the probe covers and we consider them in confirmed COVID-19 children, especially in the event of an interventional procedure [26]. The decontamination of the imaging room after caring for a suspected COVID-19 patient includes a 1-h downtime for passive air exchange [15].

Disinfecting portable machines can be the responsibility of the personnel who work in the room that hosts the machines and/or the responsibility of the personnel who use the machines, depending on local protocols, staff availability and workload. Ideally, a trained cleaning team is responsible for all machinery in dedicated COVID-19 areas according to the local operation plan and a logbook that mentions the exact time and names of the personnel who

performed each scan and disinfected the machine afterward ensures appropriate procedures. We understand this may not be available in all hospitals and that trained personnel should disinfect machines and surfaces, depending on local instructions.

Conclusion

We have modified our US services following the probability of different COVID-19 scenarios. We hope that increased training of staff and regular simulations on the use of personal protective equipment and meticulous hand hygiene may prevent personnel infection and US-related patient contamination. Extra challenges for children include the necessity to triage parents/accompanying people together with patients, the appropriate application of hand hygiene and masks on symptomatic children. Triaged US machines in designated areas, regular but selective personnel protective measures, routine hand hygiene, and the wiping and disinfection of probes and adjacent surfaces may prove to be successful protective measures. In conclusion, we tried to provide lines for action or confirmation of preparedness that readers may find relevant to their own health care systems [15].

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Compliance with ethical standards

Conflicts of interest None

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