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Review Article

A review of the effectiveness of fever tent setup in COVID-19 pandemic from a radiology perspective

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ABSTRACT

Introduction: This paper describes our experience in setting up a dedicated imaging facility within a temporary fever tentage in an acute tertiary hospital in Singapore during the coronavirus disease 2019 (COVID-19) pandemic. We review the effectiveness of the setup and its role from the radiological perspective in detail.

Methods: The dedicated imaging facility within the temporary fever tentage was equipped with a computer-on-wheels (COWs) to access patients' medical records and a portable x-ray machine to allow for a smooth workflow. Radiation dose measurements were acquired around the imaging facility using phantoms and dosimeters to ensure radiation safety.

Results: Due to its rapid nature and availability as a screening tool, chest x-ray (CXR) is the most widely used imaging modality during the COVID-19 pandemic. Our dedicated fever tent setup minimizes possible in-hospital transmission between both patients and staff and provides a more streamlined workflow to tackle the high workload. It allowed us to reduce the time required for each radiograph, providing timely imaging services and radiological reports for expedient clinical screening.

Discussion: The close collaboration between Radiology and Emergency Departments in setting up the fever tentage is a crucial tool in managing the COVID-19 pandemic. The fever tentage imaging facility is a highly effective tool, providing the means to handle the increased patient load in a streamlined and safe manner during a pandemic.

Conclusion: This paper provides insights and guidelines in setting up a dedicated imaging service within the fever tent for future infectious disease outbreak contingency plans.

Keywords: Chest X-ray; COVID-19; Fever tent; Effectiveness; Radiology

RÉSUMÉ

Introduction: Cet article décrit notre expérience dans la mise en place d'une installation d'imagerie dédiée dans une tente temporaire pour la fièvre dans un hôpital tertiaire de Singapour pendant la pandémie de coronavirus 2019 (COVID-19). Nous examinons en détail l'efficacité de cette installation et son rôle du point de vue radiologique.

Méthodologie: L'installation d'imagerie dédiée dans la tente temporaire pour la fièvre comprenait un ordinateur sur roues pour accéder aux dossiers médicaux des patients et une machine à rayons X portable pour permettre un flux de travail fluide. Des mesures de la dose de rayonnement ont été effectuées autour de l'installation d'imagerie en utilisant des fantômes et des dosimètres pour garantir la sécurité radiologique.

Résultats: En raison de sa rapidité et de sa disponibilité en tant qu'outil de dépistage, la radiographie pulmonaire est la modalité d'imagerie la plus utilisée pendant la pandémie de COVID-19. Notre installation de tente réservée à la fièvre minimise les risques de transmission à l'hôpital entre les patients et le personnel, et permet un flux de travail plus rationnel pour faire face à la charge de travail élevée. Elle nous a permis de réduire le temps nécessaire à chaque radiographie, en fournissant des services d'imagerie et des rapports radiologiques opportuns pour un dépistage clinique rapide.

Discussion: L'étroite collaboration entre la radiologie et le service des urgences pour la mise en place de la tente pour la fièvre est un outil crucial pour nous permettre de gérer la pandémie de COVID-19. L'installation d'imagerie de la tente pour la fièvre est un outil très efficace, fournissant les moyens de gérer l'augmentation du nombre de patients d'une manière rationnelle et sûre pendant une pandémie.

Conclusion: Cet article fournit des indications et des lignes directrices pour la mise en place d'un service d'imagerie dédié dans la tente pour la fièvre pour les futurs plans d'urgence en cas d'épidémie de maladie infectieuse.

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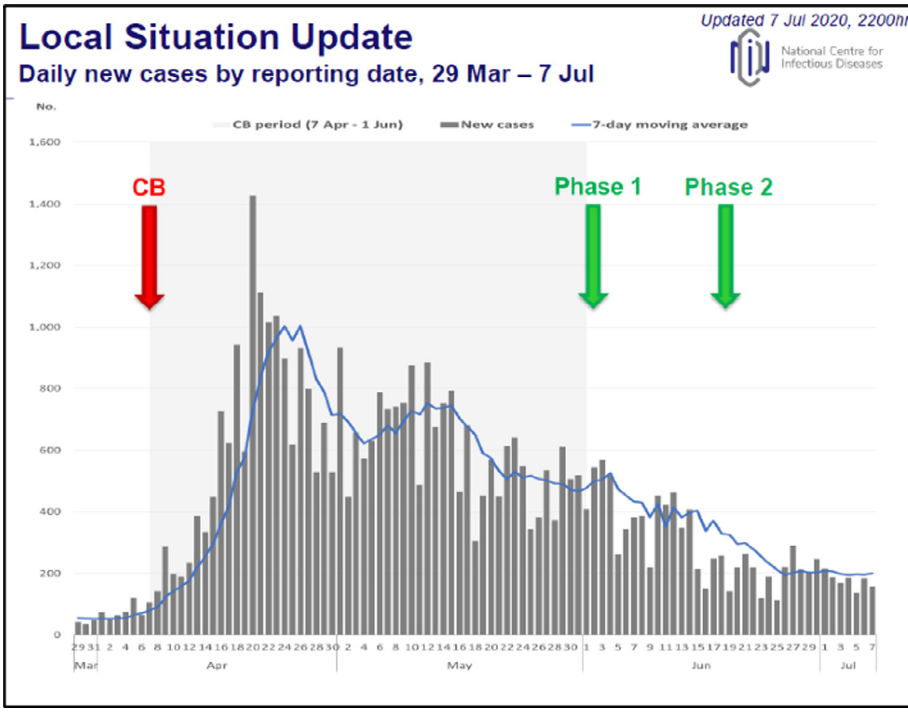

Fig. 1. The situational update in Singapore from 29 March 2020 to 7 July 2020. Circuit Breaker (CB) started on 7 Apr 2020 shown by the red arrow, followed by Phase 1 and Phase 2 shown by the green arrows. During CB period, an elevated set of safe distancing measures were implemented to pre-empt the trend of increasing local transmission of COVID-19. Phases of reopening were implemented, phase 1 (Safe reopening) and phase 2 (Safe transition) with measures progressively lifted. The daily new cases gradually iincreased from the end of March and spiked in mid-April. After that, the graph shows a decreasing trend of daily new cases.

Introduction

The rapid onset of the COVID-19 pandemic has brought about much apprehension and has threatened to overwhelm healthcare systems globally. Since the first reported case in Wuhan, China, on December 2019,[1] the virus's rapid spread prompted the WHO to declare it a pandemic in March 2020.[2] As of August 2020, the cumulative cases stand at 18.4 million with 700 000 deaths globally.[3] Prevention and containment of virus transmission is deemed the surest way to reduce morbidity and mortality[4] even with vaccination.[5]

Highly infectious, the COVID-19 virus manifests itself in patients with symptoms ranging from mild to severe respiratory illness.[6] Medical imaging techniques, such as the Chest X-Ray (CXR), chest computed tomography (CT) and even ultrasound (of lungs), in conjunction with RT-PCR (reverse transcription polymerase chain reaction) testing[7,8] was used in its diagnosis.

In Singapore, there are nine public and eight private hospitals[9] island-wide to serve a population of 5.7 million.[10] Singapore confirmed its first imported case on the 23rd January 2020 and to date (31st August 2020) has seen 56812 confirmed COVID-19 cases.[11] At its peak during April 2020, the highest recorded daily number of cases was 1425[12] and a total of 5390 suspected cases were reviewed in our institution. Given the rapid spread in both community and foreign worker dormitories, the Singapore government has implemented two months of heightened safe distancing measures (Circuit Breaker period) on the 7th April 2020.[13] Tighter measures were implemented to curb the transmission of COVID-19. Figure 1 shows the situational update in Singapore from March to July 2020.

In this paper, we review on the effectiveness of the fever tent setup during the pandemic in "the institution" from the radiological perspective. Being an acute tertiary institution in close proximity to a number of foreign worker dormitories, we received a total of 2450 confirmed COVID-19 patients as of August 2020.

Due to the longer turnaround time of the serological RT-PCR (Reverse transcription polymerase chain reaction) testing,[2] as well as the highly variable and non-specific nature of COVID-19 symptomology, CXRs are still widely used for screening suspect cases internationally.[14,15] During the months of February to August, there was a sharp increase in screening chest radiographs. For example, there was a threefold increase in CXR cases from February (1904 CXRs) to March (6100 CXRs).

The COVID-19 virus is highly contagious. It is transmissible by airborne droplets and close contact with secretions. To handle both the increased demand and highly contagious nature of the cases, the Radiology Department collaborated with the Emergency Department to set up a fever tent. We will discuss the benefits and challenges Radiology faced with this setup.

Materials and methods

Due to the retrospective nature of the study with no patient or patient data involvement, ethics approval was not required.

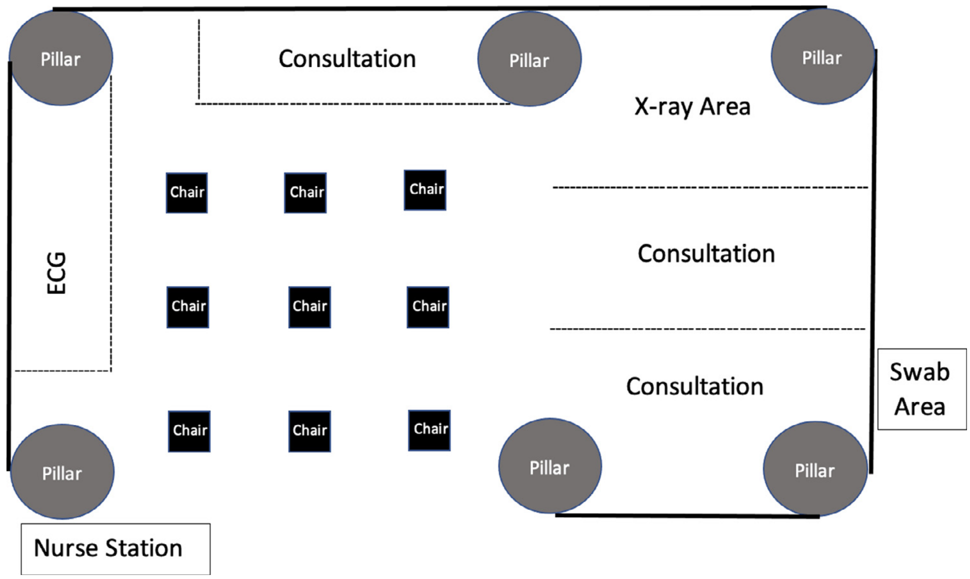

Fig. 2. Shows the overall layout of the fever tent with dedicated x-ray area, consultation rooms, nurse station, swab area, ECG station and patient holding area. The perimeter of the fever tent area is demarcated by wooden planks.

Table 1
The various fever imaging facilities.

Fever Imaging Facilities	Patient population
1. Fever Tent X-ray	Ambulant patients for COVD-19 screening chest radiograph only.
2. Fixed X-ray Room	Ambulant patients for COVID-19 screening chest radiograph and suspected COVID-19 patients with miscellaneous X-ray requests
3. Portable X-ray Machine (Fever Facilities)	CXR and/or miscellaneous X-ray requests

In our hospital, all COVID-19 related X-rays were imaged within the dedicated fever imaging areas as detailed below. Screening and triaging was conducted at the entrance of the Emergency Department, where patients with respiratory symptoms and/or close contacts with COVID-19 patients were triaged into the fever zone. In the fever zone, there are various fever imaging facilities (Table 1).

A temporary sheltered outdoor fever tent was set up at the Emergency Department (ED) on 10th February 2020 to minimise in-hospital contamination and to cope with the surge of patients during Covid-19 pandemic. An X-ray facility was constructed within the fever tent itself utilising a digital radiography (DR) portable X-ray machine. A retrospective review of the average time taken for a CXR in fever tent X-ray and fixed X-ray Room for the month of May 2020 was conducted.

Fever tent setup

The structure of the fever tent erected with wooden planks was segregated into areas for doctor consultations, patient waiting areas, Covid-19 swab areas and an imaging facility for CXRs (Fig. 2).

The portable X-ray machine was parked at a fixed location while maintaining the standard of source to image distance (SID) of 180 cm. The direction of the primary beam was distanced away from the patient waiting area. In order to cater to patients of various heights, a motorised, remote-operated adjustable stand was used to hold the imaging detector. With all the main components of the X-ray unit fixed, the radiographers, who are already limited by their comprehensive personal protective equipment (PPE), had fewer variables to deal with and this helped to reduce physical fatigue and examination time.

This was especially important because, although sheltered, the tent was located outdoors. The high ambient temperature and humidity of our climate made it physically taxing on the radiographers and staff. The PPE required to be worn by the radiographers included a hair net, disposable isolation gown, gloves and eye goggles. These conditions were also unfavourable to the portable X-ray machine. This required the implementation of larger industrial sized air coolers to achieve feasible working conditions for our staff and equipment.

Within the x-ray imaging area (Fig. 3), privacy curtains were used to partition the changing and imaging areas. Multiple electrical points essential for supplying the portable X-ray machine, cooler, and COWs were mounted at accessible locations in the fever tent. Electronic signature pads were connected to the computers to document pregnancy declaration for female patients of child bearing age. Waste bins, contaminated linen bins, and consumables storage were also made available.

Infection control

In terms of infection control, proper infection control guidelines and standards were adhered to in the fever tent. Machines and equipment that came into contact with patients were disinfected with disinfectant wipes after every examination. X-ray examinations were also performed with a 5-minute interval to

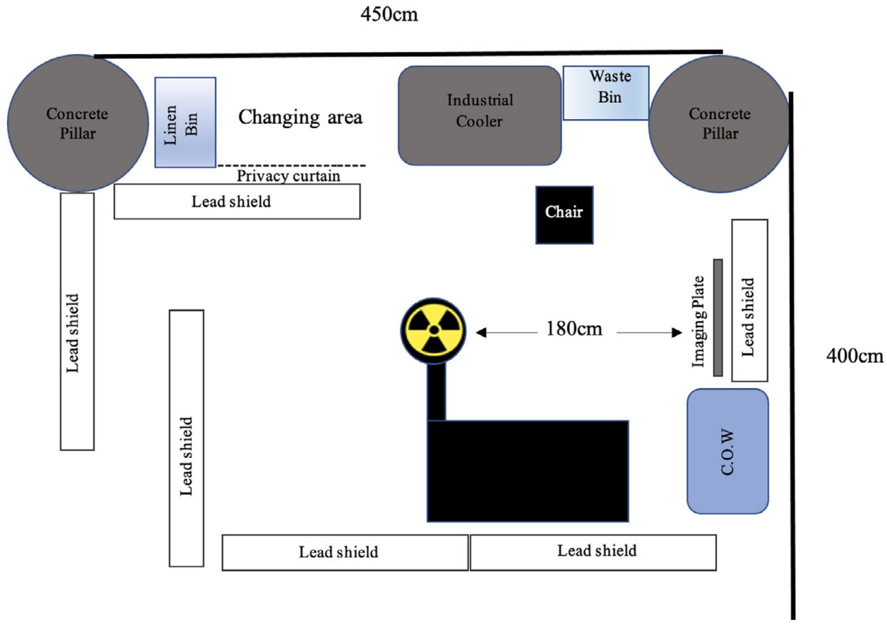

Fig. 3. The layout of the fully functional fever tent x-ray area, with portable machine (radiation sign), computer-on-wheels (C.O.W). changing area, changing area and industrial cooler. The x-ray area was lined with multiple lead shields in an overlay fashion for radiation protection. The x-ray tube was positioned 180cm away from the imaging plate for consistency of chest x-rays.

allow the disinfectant solution to dry fully before the next examination. Additionally, single-use disposable plastic bags were used to cover the detector plate to prevent cross-contamination between patients. All patients were required to wear facemasks and advised to sanitise their hands upon entering the ED facility.

Radiation safety

Located in a relatively small makeshift area, radiation safety was our immediate concern. Multiple portable X-ray shields (of 0.2 mm Pb thickness) were placed in an overlay fashion to allay concerns with scatter radiation To further confirm this, radiation readings (Fig 4) were measured at various locations. Multiple chest x-ray exposures (66kVp, 6mAs) were made on phantoms and dosimeters were used to document exposure readings. The readings were taken at least three times at four sides of the fever tent x-ray facility to ensure accuracy. The results showed that the areas behind lead shields and not in line with the direct beam were comparable to background radiation, not exceeding 10μSv/hr.[16] This was in accordance with guidelines from the National Environment Agency (NEA) – Radiation Protection and Nuclear Science Division (RPNSD) who was consulted, and approved the licence to perform radiographs at the premise. Radiation signs and barricades were put up to warn and restrict human traffic from entering these unsafe zones (primary beam area).

Prior to making any x-ray exposures, the radiographer ensured that only the patient undergoing the x-ray examination was present in the examination room. An oral warning was given before making any x-ray exposures. Sufficient time was given to the other healthcare personnel nearby so they could move away from the examination room and be at a safe distance away from the radiation source and standing behind the lead shield. The portable x-ray machine sounded an audible warning when a radiation exposure was made. Radiographers working in the fever tent were to wear a Thermo-Luminescence Dosimeter (TLD) personal radiation monitoring device for monitoring of individual radiation dose received while performing the chest X-ray at fever tent.

Image quality

The CXRs in the fever tent were performed using digital radiography (DR) technology, with the patient positioned Posterior-Anterior (PA) erect. CXRs done bedside in the fever facility were performed with the patient positioned Anterior-Posterior (AP) sitting or supine. PA erect CXRs are preferred because of image quality consistency. The set-up for PA erect CXRs is as follows: source-to-image distance (SID) of 180cm, and the patient is positioned upright with their chest against the erect Bucky with shoulders rolled forwards and head extended slightly.[17] This standardised radiographic technique allows for accurate comparison between repeated PA CXR examinations.[18]

In addition, PA erect CXRs allows for accurate assessment of the cardiothoracic ratio. When compared to AP CXRs, PA erect have minimal magnification of the heart and mediastinal structures. Magnification of these structures on the AP CXRs are mainly caused by two reasons. First, a shorter SID is used for AP CXRs which results in a greater divergence of the X-ray beam on the chest structures, leading to its magnification. Furthermore, the CXR position causes the chest structures to be further from the image detector. Such errors can lead to false impressions of cardiomegaly, mediastinal enlargement and aortic enlargement.[19] Therefore, CXR standardised techniques

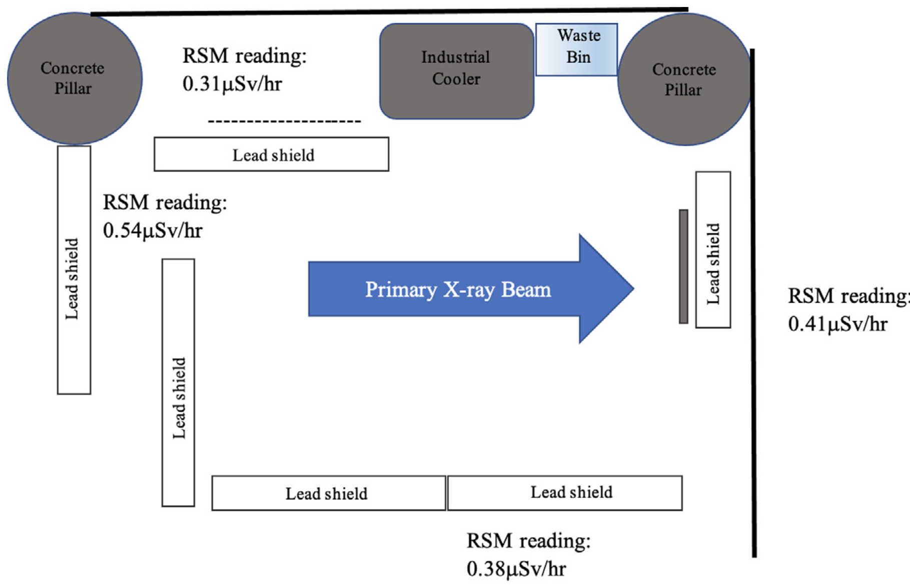

Fig. 4. The average radiation survey meter (RSM) readings, 0.31μSv/hr, 0.41μSv/hr, 0.38μSv/hr and 0.54μSv/hr at four regions. The readings were taken with the primary x-ray beam (blue arrow) directed at a phantom with chest x-ray exposures (66kVp, 6mAs).

performed for COVID-19 screening at the fever tent is preferred.

DR technology has an inherent wide dynamic range and post-processing capability which reduce the number of retakes due to exposure errors.[20] Safe radiologic practices ensure that patient dose is kept as low as reasonably achievable (ALARA) while ensuring diagnostic image quality.[21]

Electronic work flow

Our institution is fully equipped with electronic medical record (EMR) and electronic devices such as COWs and laptops which were used to access imaging orders. Electronic signature pad was connected to the computers to document pregnancy declaration for female patients within child bearing age. By eliminating the hardcopy forms, it reduced cross infection for healthcare workers. On the other hand, electronic devices can be easily cleaned with alcohol based wipes.

All imaging requests were filtered according to patient location and examination type. They were performed either within the fever tent itself, the fixed X-ray room or performed portably at the fever facility. Upon performing the examination, all COVID-19 suspect cases had 'COVID' remarked in the EMR system by the radiographers to alert the radiologist for STAT reporting, within 1 hour. Suspect case definition for Covid-19 as follows: a) A person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness AND travel within 14 days before onset of illness had travelled abroad b) A person with an acute respiratory illness of any degree of severity who, within 14 days before onset of illness had been to any of the areas requiring heightened vigilance as listed on Healthcare Professional Portals or had close contact with a case of COVID-19 infection

The labelling of COVID suspects in the system allows easy and consistent shunting into a new worklist folder. This independent list was to be regularly checked by the radiologist and allowed for a quick turn-around-time from completion of the study to finalization of the report within approximately one hour. This service was provided around the clock, extending up to two hours overnight.

Results

In May 2020, a total of 2035 CXR were done at the fixed x-ray room and fever tent. The average time taken to complete the CXR from the request initiation to completion were 19.92mins and 12.78mins at the fixed x-ray room and fever tent respectively. The implementation of the temporary X-ray facility within the fever tent has allowed us to improve our efficiency of COVID screening radiographs.

Between 11th February 2020 to 31st July 2020, a total of 14234 chest radiographs were performed in our temporary fever tent, with a total of 1693 hours saved with the implementation of the fever tent x-ray facility.

Discussion

The CXR workflow and process in the fever tent area was greatly accelerated by designated placements of the lead shields, portable Digital Radiography (DR) machine and DR X-ray detector placed within the area. With this essential equipment in position, the radiographers required minimal adjustments during the image acquisition process, resulting in uninterrupted workflow. With the faster rate of acquisition in the fever tent coupled with the ability to accommodate a large number of patients, it translated to shorter procedural time and ability to decant patients better. With the implementation of the fever tent, a larger number of patients can be accommodated. The maximum capacity of the fever tent is 109 patients (66 ambulant patients and 43 non-ambulant patients).

The infrastructure designated for use in the fever tent X-ray area also helped increase the efficiency in performing X-ray procedures. The wireless compatible portable DR machine was used in the fever tent X-ray area. With the wireless capabilities, it allowed the radiographer to retrieve the worklist and send acquired images seamlessly. The wireless nature of the DR set-up also obviated the need for processing of cassettes by the reader, as compared to the Computed Radiography (CR) in the fixed X-ray room. This minimised movement and improved efficiency in this otherwise cramped space. Using DR would also omit the need to process cassettes. Having fewer touch points could lead to better infection control.

The placement of a portable workstation in the fever tent X-ray facility enabled radiographers wireless access to the EMR easily to view X-ray orders as well as to check patent's identity during the examination. The workstation also allowed female patients of child bearing age (12-55 years old) to sign on the electronic pregnancy declaration form prior to X-ray. This saved time as radiographers did not have to print the hardcopy forms to scan into EMR after the procedure.

Initial radiation safety concern of the fever tent was alleviated. The X-ray area within the tent was enclosed by several overlapping lead shields that were specifically arranged to minimize leakage of scatter radiation. This helped to eradicate any unnecessary radiation exposure to staff who are nearby. Radiation dose measurements taken across multiple tent locations showed no significant increase in radiation dose. This is in keeping with National Environmental Agency (NEA)'s licensing for radiation facilities, not exceeding 10μSv/hr.[16]

In order to build capacity to support the surge in the number of COVID-19 cases, countries around the world have adopted different methods. In China, a community hospital was repurposed and designated as COVID-19 hospital.[22] An exhibition centre was transformed into a COVID-19 hospital in Spain.[23] A military hospital run by military staff was also used to manage COVID-19 patients in France.[24] Similarly, we have followed World Health Organization (WHO) recommendation by having the fever tent setup to augment COVID-19 patient care and essential health services.[25] We had a similar setup as the accelerated care units (ACU)s in San Francisco, with portable X-ray services. However, there was no specific mention of the X-ray setup and how radiation safety measures were adhered to in these ACUs.[26] In other sites with tent, there were no dedicated x-ray service within the temporary facility, patients who required imaging were escorted through a separate exit and a dedicated pathway directly into the main ED.[27,28] However, this approach would result in the lack of seamless experience for the patients.

Imaging findings of COVID-19 on the chest radiograph are often subtle, particularly in early-mild disease, with only 69% of admitted patients presenting with an abnormal chest radiograph. When reporting radiographs from this COVID-19 specific folder, the radiologist is made aware of the clinical context and can thus tailor his sensitivity for COVID-19 specific findings. For example, the most frequently encountered findings of "dry" air space opacities.[14,29] which can be subtle and non-specific in a different clinical context. The label of the radiograph into the "COVID folder", much like any good clinical history, would cue the radiologist into increasing his sensitivity and clinical suspicion for subtle pulmonary consolidations. This would be in addition to the usually reported abnormalities such as pulmonary masses, rib fractures, pneumothoraxes etc. On the ground, we did not find an increase in other overlooked findings during this period.

With a system and mindset to answer specific clinical question, the fever tent helped to facilitate clearer communication between the emergency physicians and the radiologists and minimizes secondary calls or questions which might delay the patient's isolation or de-isolation status. Made aware of the clinical suspicion and appropriate context for COVID-19 pneumonia, the radiologist would tend to make a specific mention to include COVID-19 related findings, tailoring his or her report to address the explicit purpose of the study - to assess for possible COVID pneumonia. It is important to note that this occured in a period before rapid test kits were available, thus chest radiographs were an essential screening tool, playing a large role in triaging potential COVID patients.

Lastly, the flexible nature of the fever tent setup meant that hospital staff were always able to adapt the setup to accommodate the current situation. This allows the effective channelling of available resources to ensure maximisation of manpower, space and machines. For example, during the surge of COVID-19 patients from the foreign worker dormitories, more chairs were added and the fever tent was expanded to a bigger area to put up with the increased number of patients. This also extended to the imaging facility within the tent where more machines could be brought in or equipment could be moved around to suit the situation.

The unprecedented COVID-19 pandemic has drastically changed the lives of people all around the world. Within the radiology department, we were challenged to reconfigure our setup and work processes in response to the needs of frontline imaging services to aid in timely diagnosis for the patients who presented to our hospital. Lessons learnt from the COVID-19 pandemic should be incorporated into the design and planning of future radiology departments and facilities. This will enable our future healthcare facilities to be equipped with imaging services that are integrated with the hospital's outbreak containment and infection control strategies.

Challenges

With the change to the environment and workflow, working in the fever tent raised inevitable challenges. The most pertinent issues such as the portable machine experiencing intermittent Wireless-Fidelity (Wi-Fi) connection issues due to the instability of Wi-Fi connection, detector artefacts, space constraints and warm environment as discussed below.

Connection issues

The portable X-ray machine is connected to the patient's worklist wirelessly while the imaging detector is connected to the portable machine via WI-FI. This allows acquired images to be sent to the facility's picture archiving and communication system (PACS) in a few seconds.

However, instability of the hospital's Wi-Fi network connection at the fever tent would disrupt this workflow, as the fever tent is not within range of the Wi-Fi coverage. Patients would then have to be brought to the fixed X-ray room for their procedure, potentially delaying diagnosis.

Also, it was noted by the engineer that signal emitting devices would disrupt the connection between the detector and the machine. To resolve this, the position of the detector on the erect stand was adjusted to receive a better signal and to increase the distance of the patients' mobile device from the detector.

In addition, a transmission cable was also available as a backup to mitigate the intermittent connection issues. However, it was used only as a contingency plan with infection control considerations and would be cleaned with disinfectant wipes after usage.

Heating of machine

Singapore has a typically tropical coastal climate; it is warm and humid throughout the year. There is little variation in temperature and its daily temperature ranges from between 23°C to 33°C.[30] The outdoor fever tent has no air-conditioning and the temperature can fluctuate between 28-36°Celsius (C) in the day and 24-28°C at night. When the detector absorbs high energy from the X-ray photons, heat is also naturally produced. Coupled with that, the detector's temperature can increase by a magnitude of 7°C above the calibrated optimal working temperature (26°C) causing intermittent overheating of the detector. This overheating may result in intermittent degradation of image quality with artefacts (Fig. 5). Cooling industrial fans and a laptop cooler were installed in the facility to reduce the ambient temperature and cool the detector respectively.

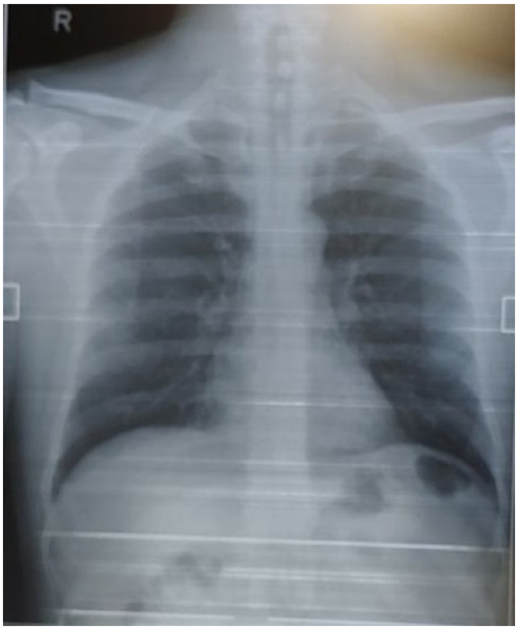

Fig. 5. Shows an chest x-ray with multiple horizontal linear artefacts which were caused by overheating of x-ray detector.

Detector wear and tear artefacts

Radiographers performed daily quality check on hardware and warning signs. Daily test exposures were also made to ensure optimal image quality. Due to the pandemic, the portable machine in the tent has been heavily utilised to screen the surge of patients. Wear and tear artefacts inevitably ensued as seen by the radiopaque speckled appearance on the image (Fig 6). To resolve the issue of recurrent artefacts, regular detector calibration by the engineer is required. However, due to Covid-19 safety measures, staff contact within the fever tent had to be minimised, and radiographers had to learn to troubleshoot and resolve the issue. There were also times where calibration-trained radiographers were not rostered on duty when an incident occurred. This problem was overcome by training more radiographers to be proficient in performing detector calibration and to have more regular detector calibration sessions conducted. In addition, regular updates and communication between supervisors and the pandemic team ensured that everyone knew how to handle the problem when encountered. Regular online continual professional development (CPD) sessions with examples of digital radiographic artifacts were also carried out. This helped to educate the radiographers on how to identify these artefacts and thereafter know how to resolve the artefact or prevent the artefacts on subsequent CXR images.

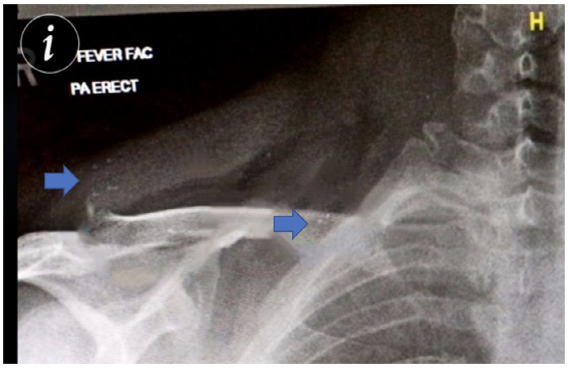

Fig. 6. It is a chest x-ray image with radiopaque speckled appearance as shown by the blue arrows.

Space constraints

Multiple lead shields were used to demarcate the X-ray area. This limited the space and thus could only accommodate ambulant patients. Hence, all X-rays for non-ambulant patients, bedbound or requiring wheelchair assistance would have to be done in the fixed X-ray room.

Staff condition

Heat exhaustion was another challenge faced by the radiographers working in the fever tent. In line with hospital's infection control requirements, it was mandated that they had to don full PPE despite the warm and humid weather. However, this was overcome with the increase in manpower to allow for more regular breaks to rest and rehydrate during the pandemic shift.

Radiographers were segregated into 2 main teams, clean and pandemic with rotations of 2–3-week cycles. Radiographers on shift worked minimum 40 hours per week, averaged over one or 2-week shift roster. At the start, the pandemic team consisted of 8 radiographers per week, with 2 radiographers per shift. To cope with the extra demand, an addition of 4 radiographers per week were allocated to the pandemic team, totalling up to 3 radiographers per shift.

Conclusion

Despite the challenges faced, the many advantages of the fever tent have clearly shown that it has been an effective strategy to manage the pandemic in terms of patient segregation in imaging. This collaboration between Radiology and ED to set up the tent was crucial and contributed much towards the hospital's needs to cope with the surge in the number of patients in this emergency.

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