



Usefulness of Mobile Computed Tomography in Patients with Coronavirus Disease 2019 Pneumonia: A Case Series

Ji Young Rho, MD, PhD¹, Kwon-Ha Yoon, MD, PhD¹, Sooyeon Jeong, MD¹, Jae-Hoon Lee, MD, PhD², Chul Park, MD, PhD², Hye-Won Kim, MD, PhD¹

Departments of ¹Radiology and ²Internal Medicine, Wonkwang University School of Medicine Hospital, Iksan, Korea

The coronavirus disease (COVID-19) outbreak has reached global pandemic status as announced by the World Health Organization, which currently recommends reverse transcription polymerase chain reaction (RT-PCR) as the standard diagnostic tool. However, although the RT-PCR test results may be found negative, there are cases that are found positive for COVID-19 pneumonia on computed tomography (CT) scan. CT is also useful in assessing the severity of COVID-19 pneumonia. When clinicians desire a CT scan of a patient with COVID-19 to monitor treatment response, a safe method for patient transport is necessary. To address the engagement of medical resources necessary to transport a patient with COVID-19, our institution has implemented the use of mobile CT. Therefore, we report two cases of COVID-19 pneumonia evaluated by using mobile cone-beam CT. Although mobile cone-beam CT had some limitations regarding its image quality such as scatter noise, motion and streak artifacts, and limited field of view compared with conventional multi-detector CT, both cases had acceptable image quality to establish the diagnosis of COVID-19 pneumonia. We report the usefulness of mobile cone-beam CT in patients with COVID-19 pneumonia.

Keywords: Coronavirus; Pneumonia; COVID-19; Computed tomography; Mobile

INTRODUCTION

In December 2019, coronavirus disease (COVID-19) was first reported in China. The disease is now a global health emergency, with pandemic status declared by the World Health Organization (WHO). As of April 27, 2020, at time of publication, there were 2810325 confirmed cases, including 193825 deaths, in 213 countries according to WHO data (1). In the current situation of pandemic spread, the early diagnosis in epidemic areas is of significant importance. Reverse transcription polymerase chain reaction (RT-PCR) is the standard method for confirming COVID-19 infection as

recommended by the WHO. RT-PCR often produces negative test results in patients with mild symptoms, while chest computed tomography (CT) might identify pneumonia (2-5). This is consistent with reports that chest CT is more sensitive than RT-PCR (6, 7). However, chest CT has limited specificity. In a meta-analysis study on the diagnostic performance of RT-PCR and CT, the pooled sensitivity and specificity were 94% and 37%, respectively, for chest CT (8). In other reports, chest CT was considered beneficial in the treatment management of COVID-19 because it could determine the severity and extent of COVID-19 pneumonia (9-11). Thus, when clinicians desire a CT scan of a patient with COVID-19 to monitor treatment response, a safe method for patient transport is necessary. To address the engagement of medical resources necessary to transport a patient with COVID-19, our institution has implemented the use of mobile cone-beam CT. Therefore, we report two cases of COVID-19 pneumonia using mobile cone-beam CT. Mobile cone-beam CT can allow a rapid diagnosis of COVID-19 while minimizing the risk of infection spread in a negative pressure isolation room compared with conventional multi-detector CT. Additionally, we report the usefulness of mobile

Received: April 13, 2020 **Revised:** May 11, 2020

Accepted: May 13, 2020

This study was supported by Wonkwang University 2018.

Corresponding author: Kwon-Ha Yoon, MD, PhD, Department of Radiology, Wonkwang University School of Medicine Hospital, 895 Muwang-ro, Iksan 54538, Korea.

• E-mail: khy1646@wku.ac.kr

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

cone-beam CT in patients with COVID-19 pneumonia.

CASE REPORT

This retrospective study was approved by the Institutional Review Board of the Wonkwang University School of Medicine Hospital, and the requirement for informed consent was waived.

Mobile CT Scanners and Imaging Interpretation

Mobile cone-beam CT scans were obtained using the MX-CBT1240 (Phion 2.0™, NanoFocusRay Co., Ltd., Iksan, Korea) (Fig. 1). Components of the MX-CBT1240 system included a high-frequency generator, a rotating anode X-ray tube, and an amorphous silicon thin-film transistor flat panel detector. The system had the following specifications: scan time, 7–13 seconds; bore size, 650 mm; single scan, 360 degree rotation; field of view (FOV), transaxial 260 mm and length 165 mm; reconstruction time, less than 41 seconds; alternating current (AC) power, 200–230 V-/13 A and 50/60 Hz; and weight, 400 kg. Typical scanning parameters included the following: 95 kV, 15 mA, 1 pitch, 3-mm slice thickness, and a rotation time of 20 milliseconds (ms). According to the accreditation support module, the volume CT dose index (CTDI_{vol}) had a reference value of 21 mGy in adult chest CT and no reference value in adult high resolution CT (12). With scanning parameters of 95 kV, 15 mAs, and 20 ms rotation time, the CTDI_{vol} of the mobile cone-beam



Fig. 1. Photograph of mobile CT scanner. Mobile CT scan was performed on patient with coronavirus disease 2019 pneumonia in negative pressure isolation room. CT = computed tomography

chest CT was calculated at 3.0 mGy. Regarding the problem of short scanning distance, we stitched the image by shooting twice with a mobile CT scanner. Subsequently, the mobile CT images were able to cover the whole thorax in the Z-axis. An iterative reconstruction algorithm was used for image reconstruction and for preprocessed sinogram generation. The obtained images were preprocessed into two-dimensional projection images in parallel to decrease image processing time. The final CT images were displayed using a three-dimensional image viewer (Xelis, INFINTT, Healthcare Co., Ltd., Seoul, Korea). The mobile cone-beam CT obtained pass certification in the image quality inspection results according to the guideline of the Korean Institute for Accreditation of Medical Image (13). Two chest radiologists with more than 20 years of experience retrospectively reviewed the CT images on a picture archiving and communication system (PACS, INFINTT Healthcare Co., Ltd.). All images were viewed on both lung and mediastinal window settings. The radiologists documented by consensus each significant finding that was detected on CT. Severity of COVID-19 pneumonia was classified according to the chest CT severity score method suggested by Yang et al. (9). Initial cone-beam mobile CT images from two patients showed typical CT findings of COVID-19 pneumonia and high chest CT severity scores that could reflect severe COVID-19 pneumonia.

Patient 1

A 50-year-old male patient with COVID-19 pneumonia diagnosed by RT-PCR was admitted to our hospital. He presented with a mild fever, myalgia, and chest discomfort for 3 days. On admission into a negative pressure isolation room, a chest anteroposterior (AP) radiograph showed peripherally distributed patchy opacities in the right lung. Serial chest AP radiographs showed persistence of the right lung opacities. To evaluate the severity of COVID-19 pneumonia, we performed mobile chest CT 5 days after admission. The CT images revealed multifocal ground-glass opacities and mixed consolidations, with most appearing at the peripheral or subpleural areas of both lungs and predominantly involving both lower lobes (Fig. 2).

Patient 2

A 65-year-old female patient with COVID-19 pneumonia diagnosed by RT-PCR was referred for further evaluation. She presented with dyspnea, cough, nausea, and vomiting for 4 days. On admission into a negative pressure isolation

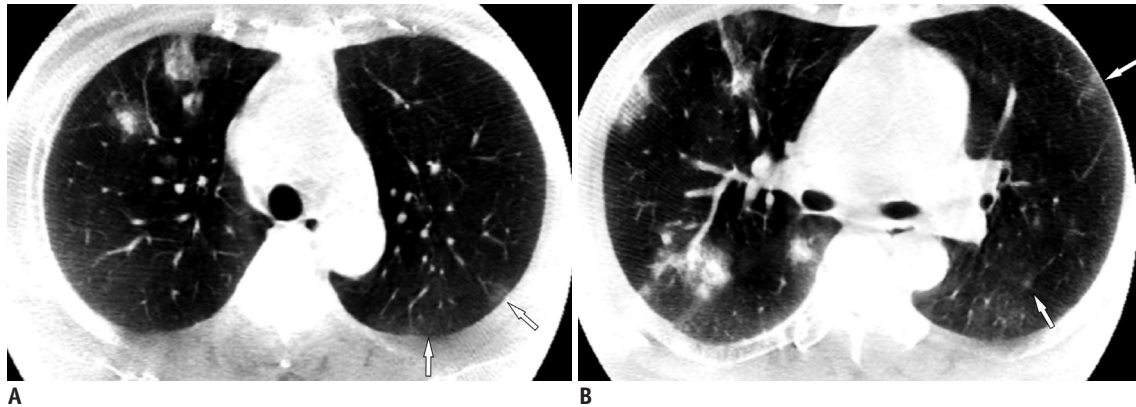


Fig. 2. Mobile CT scan of 50-year-old male patient with coronavirus disease 2019 pneumonia.

A, B. Axial CT scans showed multifocal patchy ground-glass opacities and mixed consolidations in peripheral to subpleural areas of right upper lobe and superior segment of right lower lobe. Subtle subpleural ground-glass opacities (arrows) in left upper lobe were observed.

room, a chest AP radiograph showed multifocal patchy opacities in the right middle and both lower lung zones. The bilateral lung opacities appeared aggravated on follow-up chest AP radiographs. To evaluate the severity of COVID-19 pneumonia, we performed mobile chest CT 2 days after admission. The CT images revealed multifocal peripheral to subpleural ground-glass opacities and mixed consolidations in both lungs, predominantly in both lower lobes (Fig. 3A, B). Follow-up mobile chest CT images showed significant improvement in both lungs (Fig. 3C, D). A repeat RT-PCR produced negative test result, and the patient was discharged.

DISCUSSION

In December 2019, COVID-19 was first reported in China. It has now been declared a global health emergency, and a pandemic status was determined by the WHO.

RT-PCR is the standard method performed to establish the diagnosis of COVID-19 infection as recommended by the WHO. However, in patients with mild symptoms, RT-PCR often produces negative test results (2-5). In a study comprising 1014 patients with COVID-19 pneumonia who underwent both chest CT and RT-PCR, the sensitivity of CT was 97% relative to RT-PCR (6). Additionally, in a study comprising 51 patients both undergoing initial CT and RT-PCR, the sensitivity of chest CT was greater than that of RT-PCR (98% vs. 71%, respectively) (7). However, chest CT had limited specificity. In a meta-analysis study assessing the diagnostic performance of CT and RT-PCR, the pooled sensitivity and specificity were 94% and 37% for chest CT and the pooled sensitivity was 89% for RT-PCR, respectively (8). They concluded that the use of chest CT scans in a low-

prevalence region could induce a large number of false-positive results.

Typical CT findings of COVID-19 pneumonia have been reported as multifocal patchy ground-glass opacities located subpleurally or peripherally and/or consolidations in both lungs, predominantly in both lower lobes (14-18). Some reports found that CT-determined severity in COVID-19 pneumonia is considered consistent and can reflect the clinical classification of COVID-19 (9-11). In a study by Yang et al. (9), the CT severity score was defined by summing up individual scores of 0, 1, and 2 from 20 lung regions. The CT severity scores were higher in patients with severe COVID-19 compared with those of patients experiencing mild symptoms of COVID-19.

Chest CT scan is usually not recommended as a screening diagnosis of patients with COVID-19. Both the American College of Radiology and the Korean Society of Radiology clarified that CT should not be used to screen for or as the first-line test to diagnose COVID-19 (19, 20). The Fleischner Society also published a similar position statement that chest imaging with chest radiography and CT is not indicated in patients with suspected COVID-19 and mild clinical features unless they are at risk for disease progression (21). Imaging is indicated for patients with moderate to severe features of COVID-19 or worsening respiratory status. Thus, when clinicians desire a CT scan of a patient with COVID-19 to monitor treatment response and assess if patients are eligible for discharge, they request assistance from the infection control department to determine the safe method for patient transport. To address the engagement of medical resources necessary to transport a patient with COVID-19, our institution has implemented the use of mobile CT. For patients with COVID-19,

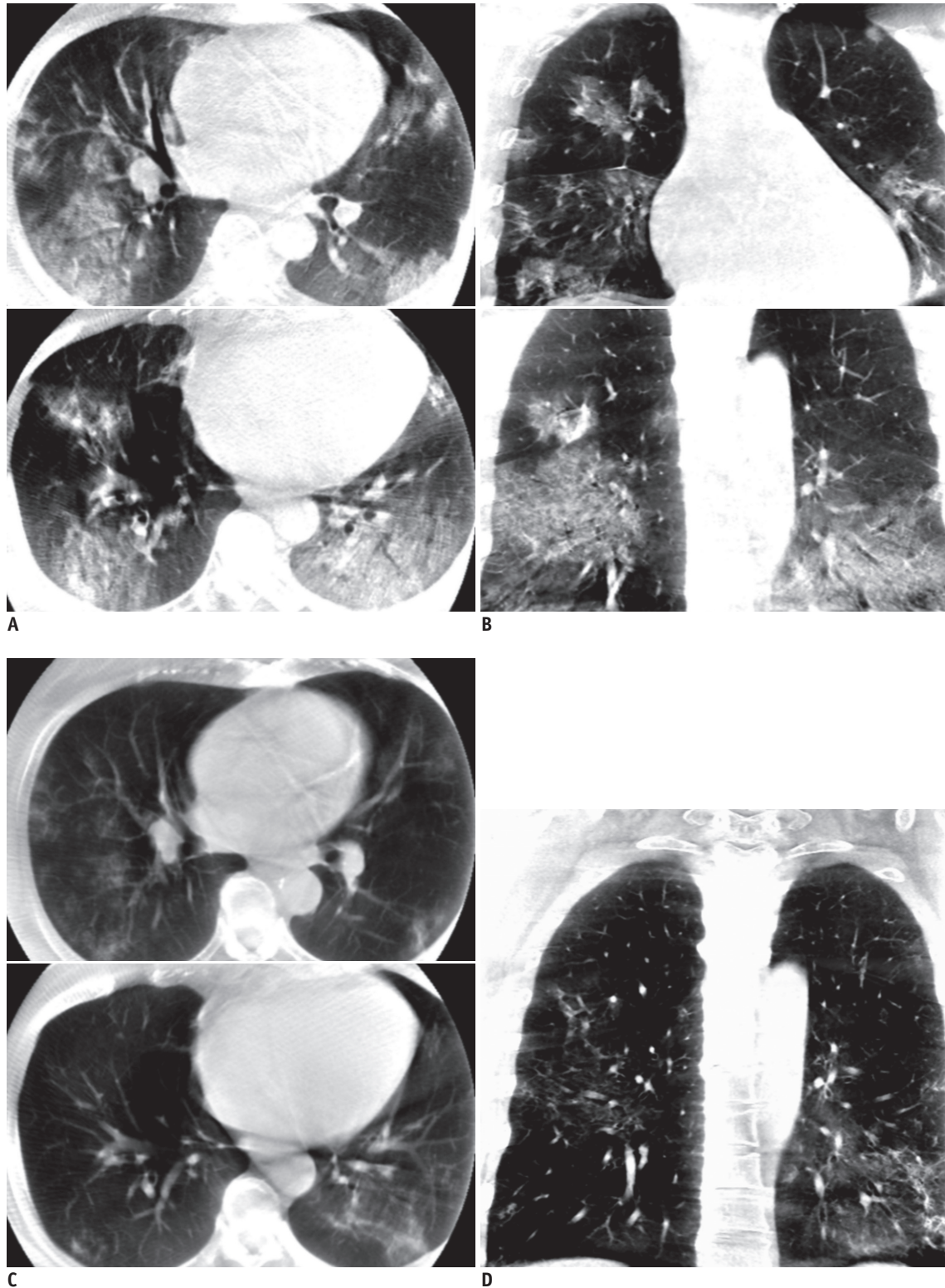


Fig. 3. Mobile CT scan of 65-year-old female patient with coronavirus disease 2019 pneumonia. Coronal reconstruction images obtained by automatic stitching covered whole lung. Initial axial (A) and coronal (B) CT scans revealed multifocal ground-glass opacities and mixed consolidations distributed peripherally to subpleurally in both lungs, predominantly in both lower lobes. Evidence of progressive resolution of parenchymal lesions was observed in follow-up axial (C) and coronal (D) CT scans obtained on day 9.

conventional fixed CT has the following limitations: it results in transportation difficulties outside of a negative pressure isolation room, it needs cleaning and downtime in the radiology room, and increases healthcare expenses and radiation doses (21). In particular, in severe patients, the risks of transport increase. The risks include compromised of monitoring devices, intubation tubes, intravenous lines, hypotension, and hypoxia (22, 23). On the contrary, if a mobile CT scanner is available, only two radiology technicians are taken to the negative pressure isolation room with the scanner. Hence, the area of quarantine is minimized, and the risk of transport is significantly low. Additionally, the amount of time required for imaging is reduced by eliminating the transport for patients (23). According to the Radiology Department Preparedness for COVID-19 suggested by the Radiology Scientific Expert Panel, when possible, portable imaging, including portable chest radiography and portable CT, is performed in the patients' rooms to limit equipment, room, and hallway decontamination requirements (24). Besides the negative pressure isolation room, mobile CT allows for critically ill patients in the intensive care unit (ICU) or operating room to remain in one place without risking transportation-related morbidity and provides fast access to information when establishing emergent patient care decisions (22).

Head CT has remained the standard diagnostic CT imaging tool for portable scanning since the introduction of mobile units (23, 25, 26). Additionally, mobile chest or abdominal CT scans can be performed at the bedside, without the need to transport the patient from the ICU (27, 28). Several reports demonstrated that although less preferred, portable CT images are considered to be of adequate diagnostic quality when compared with fixed scanners (23, 25, 27, 28). Specifically in the study of portable CT to evaluate thoracic disease in ICU, scan quality was considered comparable with that of fixed CT for mediastinal windows and relatively inferior for lung windows, but portable CT provides images of diagnostic quality (27). The mobile cone-beam CT in our institution has several benefits. It is compact and mobile, with an easy installation, low radiation dose, and fast scan time. On the contrary, the size of the FOV and the scanning distance for most machines including the mobile cone-beam CT are small and will result in increased noise, thereby degrading imaging quality (25). To overcome the limited Z-axis of short scanning distance, the images were stitched by shooting twice with a mobile CT scanner. Additionally, mobile cone-beam CT has the

following intrinsic limitations: it has low-photon flux from X-ray source, and its image quality is more degraded due to scatter noise by flat field detector and motion and streak artifacts compared with conventional multi-detector CT. Our institution has a few cases of mobile cone-beam CT clinical experiences. Three mobile CT scans were performed on the reported two patients, and conventional multi-detector CT was not performed. Thus, image comparison was not possible. Further studies on mobile cone-beam CT image quality evaluation including fixed CT comparisons are required in a larger number of patient populations.

In conclusion, mobile cone-beam CT plays a critical role in COVID-19 in a negative pressure isolation room, serious illness, or emergency centers.

Conflicts of Interest

KH Yoon is CEO of Nanofocusray, Ltd.

ORCID iDs

Kwon-Ha Yoon

<https://orcid.org/0000-0002-2634-8510>

Ji Young Rho

<https://orcid.org/0000-0001-6645-3983>

Sooyeon Jeong

<https://orcid.org/0000-0003-2630-2245>

Hye-Won Kim

<https://orcid.org/0000-0002-8969-3047>

REFERENCES

1. Coronavirus disease (COVID-19) pandemic. World Health Organization Web site. <https://www.who.int/emergencies/diseases/novel-coronavirus-2019>. Published 2020. Accessed April 27, 2020
2. Xie X, Zhong Z, Zhao W, Zheng C, Wang F, Liu J. Chest CT for typical 2019-nCoV pneumonia: relationship to negative RT-PCR testing. *Radiology* 2020 Feb 12 [Epub]. <https://doi.org/10.1148/radiol.2020200343>
3. Huang P, Liu T, Huang L, Liu H, Lei M, Xu W, et al. Use of chest CT in combination with negative RT-PCR assay for the 2019 novel coronavirus but high clinical suspicion. *Radiology* 2020;295:22-23
4. Li D, Wang D, Dong J, Wang N, Huang H, Xu H, et al. False-negative results of real-time reverse-transcriptase polymerase chain reaction for severe acute respiratory syndrome coronavirus 2: role of deep-learning-based CT diagnosis and insights from two cases. *Korean J Radiol* 2020;21:505-508
5. Hao W, Li M. Clinical diagnostic value of CT imaging in COVID-19 with multiple negative RT-PCR testing. *Travel Med*

- Infect Dis* 2020;34:101627
6. Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. *Radiology* 2020 Feb 26 [Epub]. <https://doi.org/10.1148/radiol.2020200642>
 7. Fang Y, Zhang H, Xie J, Lin M, Ying L, Pang P, et al. Sensitivity of chest CT for COVID-19: comparison to RT-PCR. *Radiology* 2020 Feb 19 [Epub]. <https://doi.org/10.1148/radiol.2020200432>
 8. Kim H, Hong H, Yoon SH. Diagnostic performance of CT and reverse transcriptase-polymerase chain reaction for coronavirus disease 2019: a meta-analysis. *Radiology* 2020 Apr 17 [Epub]. <https://doi.org/10.1148/radiol.2020201343>
 9. Yang R, Li X, Liu H, Zhen Y, Zhang X, Xiong Q, et al. Chest CT severity score: an imaging tool for assessing severe COVID-19. *Radiology: Cardiothoracic Imaging* 2020 Mar 30 [Epub]. <https://doi.org/10.1148/ryct.2020200047>
 10. Li K, Fang Y, Li W, Pan C, Qin P, Zhong Y, et al. CT image visual quantitative evaluation and clinical classification of coronavirus disease (COVID-19). *Eur Radiol* 2020 Mar 25 [Epub]. <https://doi.org/10.1007/s00330-020-06817-6>
 11. Zhao W, Zhong Z, Xie X, Yu Q, Liu J. Relation between chest CT findings and clinical conditions of coronavirus disease (COVID-19) pneumonia: a multicenter study. *AJR Am J Roentgenol* 2020;214:1072-1077
 12. Technique parameters and anatomic coverage: CT-adult chest module (revised 12-12-19). Accreditation Support Web site. <https://accreditationsupport.acr.org/support/solutions/articles/11000049637-technique-parameters-and-anatomic-coverage-ct-adult-chest-module-revised-12-12-19->. Published December 13, 2019. Accessed March 11, 2020
 13. The CT accreditation program. Korean Institute for Accreditation of Medical Image Web site. <http://www.kiami.or.kr/Kiami/Default.aspx?lm=3&rp=38>. Published 2004. Accessed March 11, 2020
 14. Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, et al. CT imaging features of 2019 novel coronavirus (2019-nCoV). *Radiology* 2020;295:202-207
 15. Yoon SH, Lee KH, Kim JY, Lee YK, Ko H, Kim KH, et al. Chest radiographic and CT findings of the 2019 novel coronavirus disease (COVID-19): analysis of nine patients treated in Korea. *Korean J Radiol* 2020;21:494-500
 16. Kong W, Agarwal PP. Chest imaging appearance of COVID-19 infection. *Radiology: Cardiothoracic Imaging* 2020 Feb 13 [Epub]. <https://doi.org/10.1148/ryct.2020200028>
 17. Han R, Huang L, Jiang H, Dong J, Peng H, Zhang D. Early clinical and CT manifestations of coronavirus disease 2019 (COVID-19) pneumonia. *AJR Am J Roentgenol* 2020 Mar 17 [Epub]. <https://doi.org/10.2214/AJR.20.22961>
 18. Li Y, Xia L. Coronavirus disease 2019 (COVID-19): role of chest CT in diagnosis and management. *AJR Am J Roentgenol* 2020;214:1280-1286
 19. ACR recommendations for the use of chest radiography and computed tomography (CT) for suspected COVID-19 infection. American College of Radiology Web site. <https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-and-CT-for-Suspected-COVID19-Infection>. Published March 11, 2020. Accessed March 30, 2020
 20. KSR/KSTR guidelines for the use of diagnostic imaging for COVID-19 guideline. The Korean Society of Radiology Web site. <http://www.radiology.or.kr/member/question.html?mode=view&uid=42>. Published March 8, 2020. Accessed March 11, 2020
 21. Rubin GD, Ryerson CJ, Haramati LB, Sverzellati N, Kanne JP, Raouf S, et al. The role of chest imaging in patient management during the COVID-19 pandemic: a multinational consensus statement from the Fleischner Society. *Chest* 2020 Apr 7 [Epub]. <https://doi.org/10.1016/j.chest.2020.04.003>
 22. Carlson AP. The benefits of a portable head CT scanner. *interhospi.com*, 2011. Available at: <https://www.interhospi.com/enews/20111115/editors-choice.pdf>. Accessed March 30, 2020
 23. Abdullah AC, Adnan JS, Rahman NA, Palur R. Limited evaluation of image quality produced by a portable head CT scanner (CereTom) in a neurosurgery centre. *Malays J Med Sci* 2017;24:104-112
 24. 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]. <https://doi.org/10.1148/radiol.2020200988>
 25. Rumboldt Z, Huda W, All JW. Review of portable CT with assessment of a dedicated head CT scanner. *AJNR Am J Neuroradiol* 2009;30:1630-1636
 26. Carlson AP, Yonas H. Portable head computed tomography scanner--technology and applications: experience with 3421 scans. *J Neuroimaging* 2012;22:408-415
 27. White CS, Meyer CA, Wu J, Mirvis SE. Portable CT: assessing thoracic disease in the intensive care unit. *AJR Am J Roentgenol* 1999;173:1351-1356
 28. Maher MM, Hahn PF, Gervais DA, Seoighe B, Ravenscroft JB, Mueller PR. Portable abdominal CT: analysis of quality and clinical impact in more than 100 consecutive cases. *AJR Am J Roentgenol* 2004;183:663-670