Nigerian Journal of Medical Imaging and Radiation Therapy

THE ROLE OF ULTRASONOGRAPHY IN THE DIAGNOSIS OF COVID-19 PNEUMONIA IN THE EMERGENCY SETTING: A REVIEW

[1]Ugochukwu-Ogbonna I.T., [2]Gloria M.L., [3]Joseph D.Z., [3]Itopa R.E., [2]Umar A., [4]Shem S.L, [5]Ameh O.P

[1]Department of Medical Radiography and Radiological Sciences, Faculty of Health Sciences and Technology, College of Medicine, University of Nigeria, Enugu Campus, Nigeria.
[2]Department of Nursing Abubakar Tafawa Balewa University Teaching Hospital Bauchi, Bauchi State, Nigeria
[3]Department of Radiography, Bayero University Kano, Kano State, Nigeria
[4]Department of Radiography, Ahmadu Bello University Zaria. Kaduna State, Nigeria
[5]Imperial Diagnostic Center, Bauchi, Bauchi State, Nigeria.

Corresponding Author: Ugochukwu-Ogbonna I.T,
Email: itheodorah@yahoo.com
Phone Number : +2348064014058

ARTICLE INFO

Keywords: [COVID-19, Pneumonia, Ultrasonography, Computed Tomography, Chest x-ray]

ABSTRACT

Introduction: COVID-19 patients present with signs and symptoms which can be categorized into mild, moderate and severe symptoms. Important in the line of care is the diagnosis of viral pneumonia in these patients. Ultrasonography plays a critical and imperative role in this assessment and gives a clear and definitive diagnosis.
Objective: To determine the role of Ultrasonography in the diagnosis of patients with COVID-19 Pneumonia in the emergency setting.
Method: A systematic review of research works conducted by field researchers who directly observed COVID-19 patients were carefully studied. Relevant and related literature in reputable indexed journals and good impact factor journals were appraised and analysed. Search terms were COVID 19 Pneumonia, Diagnosis and Management of COVID 19 and Imaging of COVID 19 Pneumonia. The findings were synthesized from appraisal and analysis of literature.
Results: Ultrasonography is important in the triaging of COVID-19 patients suspected with pneumonia because it reveals findings such as bilateral B-lines and sub-pleural consolidations. These findings were also confirmed by Computed tomography and chest X-ray in all the patients diagnosed with pneumonia by Ultrasonography.
Conclusion: Ultrasonography plays a key role in the evaluation of viral pneumonia in emergency settings. It can be used as a triaging tool in which patients with identified lesions are prioritized for CT scans thereby reducing the number of contagious patients using the CT scanner, the cost and extent of radiation use.

INTRODUCTION

The novel coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-Cov2), is known to cause mild to severe lower respiratory disease (coronavirus disease 2019 (COVID-19)) that extends bilaterally with basal and peripheral involvement of the lung [1]. Computed tomography (CT) has been the most widely recommended and used imaging modality for screening thus far. However, it has significant downsides, including the need for extensive sterilization of equipment after use with highly contagious COVID-19 virus, along with cost and excessive radiation. Lung ultrasonography has been previously established as an excellent method of diagnosing and monitoring pneumonia and acute respiratory distress syndrome, particularly when compared with chest radiograph [3, 4], and thus has potential as an inexpensive and effective imaging modality in the early diagnosis and monitoring of patients with COVID-19.

Pneumonia is a form of acute respiratory infection that affects the lungs. When a person has pneumonia the alveoli are filled with fluids and pus instead of air which makes breathing painful and limits oxygen intake (WHO,2019). Based on the latest European Respiratory Society Guidelines [5, 6], pneumonia is defined as an acute illness with signs or symptoms compatible with a respiratory tract infection supported by radiological evidence of lung infiltrates.There is a strong consensus that chest X-ray (CXR) should be performed in all patients admitted with suspected pneumonia [6] because medical history and physical examination cannot provide sufficient evidence [7]. In emergency settings, however, the use of CXR may have major limitations due to patient conditions, waste of time, and interobserver variability [8]. Therefore, in critically ill patients with suspected pneumonia, the use of computed tomography (CT) scan is recommended [9, 10]. But CT is not always easily available in all emergency departments and is limited by exposure risks and costs [11, 12]. Lung ultrasonography (LUS) has also been proposed for detection of pneumonia [13–17], but it is still not widely accepted in clinical practice [18, 19]. This is because LUS has been generally validated by comparison with CXR, which is recognized to have low specificity, whereas CT was only sporadically used as comparator. Although there is agreement that LUS is suitable for detecting consolidations directly or via related artefact, the diagnosis of pneumonia may be missed in about 8% of cases [14, 17], possibly due to limitations of visual analysis. Indeed, reflection artifacts may be weak or even absent and thus not detectable by eye when consolidation is small or far from pleural line. Quantitative analysis of ultrasonography is an objective method that has been clinically applied to different organs but not yet to lungs [20]. In a recent study [21], quantitative lung ultrasonography (QLUS) proved to be an accurate method to evaluate extravascular lung water in a model of pulmonary edema. It can be hypothesized that QLUS may also be useful for detection of pulmonary consolidations of different origins.

With the outbreak of COVID-19 pandemic, the world is left in doubt when it will come to a halt or if a permanent solution will ever be discovered. There is however a rapid and positive response from the health sectors around the world to end the spread and treat those already infected by the virus. Before medically treating COVID-19 patients, accurate diagnosis of presenting clinical ailments is an important process in the line of care.

It is still debatable which imaging modality best captures the early signs and evidence of pneumonia in a COVID-19 suspected case. The question of which imaging modality is best erupts from the various qualities of images, cost and ease of access (availability of both equipment and skilled personnel) of the various modalities especially in emergency situations.

For the purpose of this research work, the role of Ultrasonography in diagnosing pneumonia in emergency cases of COVID-19 will be compared with the results of other imaging modalities such as Computed Tomography (CT) and Chest X-ray (CXR) as observed by frontline health professionals. These other imaging modalities are widely used and have presented various images of typical pneumonia-affected lungs.

Moreover, some challenges still pose themselves at the early stage of the pneumonic diagnosis using Ultrasonography which includes difficulty in operating effectively the ultrasound machines for lung Ultrasonography, due to little experience and readiness especially in the face of emergency of the COVID-19 rapid case upsurge. It is discovered that most sonographers haven't had much exposure to this imaging modality, and may need time to get familiar with it. Many healthcare facilities are yet to incorporate the use of Ultrasound technology in diagnosing COVID-19 pneumonia patients especially in emergency departments. This may be as a result of unavailability of much research data

to encourage its utilisation thus necessitating the use of other available clinical imaging modalities.It is a general belief that other imaging modalities, such as the Computed Tomography (CT) perform better in clear image capture and make diagnosis of pneumonia and other image-related diagnosis easier.

The objective of the study is to determine the role of Ultrasonography in the diagnosis of patients with COVID-19 related pneumonia in an emergency setting.

LITERATURE REVIEW

The medical research field has been much busier since the outbreak of the COVID-19 than usual, in the hope of finding a lasting solution to the disease. Despite the considerable efforts of governments and the health sectors of various nations to end the COVID-19 and death spread, new cases of infected individuals and related-deaths are on the increase daily. Overtime, researchers and authors have published some findings through employing several techniques while on the job of treating infected patients and during case-oriented experiments. A summary of the published papers will be reviewed below using their abstract excerpts to stay abreast the works and progress of major researchers so far in speculating the role of Ultrasonography in diagnosing emergency cases of pneumonia in COVID-19 patients.

The literature of lung ultrasonography in COVID-19 patients is scarce but promising. Huang et al [22] showed in a small preliminary study that 75% of observed patients with COVID-19 had identifiable lesions in the bilateral lower lobes. This study examined 20 patients with noncritical illness, using a 3 to 17-MHz high-frequency linear array to characterize lung lesions, and found a few identifying characteristics: numerous bilateral B lines, subpleural pulmonary consolidations, and poor blood flow. These findings were highly consistent with findings on CT. In addition, they determined that COVID-19 subpleural lesions differed significantly from similar ones observed in bacterial pneumonia, pulmonary abscess, tuberculosis, atelectasis, and cardiogenic pulmonary edema, [22] an example of which is that B lines in COVID-19 appear to be more fixed, fused, and obtuse compared with those in cardiogenic pulmonary edema.[22]

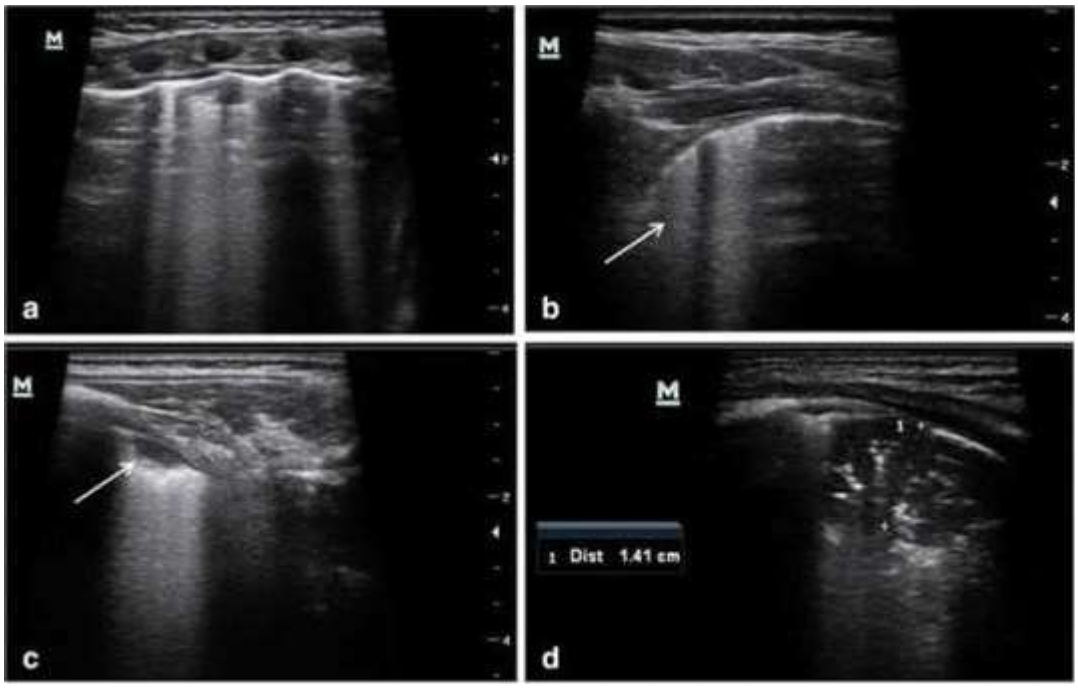
Peng et al [23] also examined 20 patients with COVID-19, using lung ultrasonography, and described similar characteristic findings that typically appeared in a multilobar distribution: focal B lines were the main early features, followed by alveolar interstitial syndrome in progressive stages, and then A lines during convalescence. Pleural effusions were rarely observed at any stage.

A third preliminary study performed by Poggiali et al, [24] using ultrasonography and CT, evaluated 12 patients who presented with symptomatic COVID-19. They reported good consistency between B lines on ultrasonography and ground-glass opacities on CT in all 12 patients with both modalities identifying organizing pneumonia in 4 of them.

According to Pascal et al in their paper titled "COVID-19 pneumonia manifestations at the admission on chest ultrasound, radiographs, and CT: single-center study and comprehensive radiologic literature review" published in the journal titled "European Journal of Radiology Open", in 2020, they investigated the imaging features of emerging COVID-19 pneumonia on chest ultrasound (US), radiographs (CXR) and computed tomography (CT) examinations performed at admission and to provide a comprehensive radiological literature review on ongoing radiological data from recent publications. Their study enrolled consecutive patients from February 15, 2020, to March 15, 2020, with laboratory-confirmed SARS-CoV-2 hospitalized in Valduce Hospital (Como, Italy). Multi-modality imaging findings were evaluated and compared. Literature research was conducted through a methodical search on Pubmed and Embase databases. Fifty-eight patients (36 men, 22 women; age range, 18–98 years) were included in the study. Among these, chest US, CXR, and CT were performed respectively in twenty-two, thirty-two and forty-two patients. Lung US findings were consistent with diffuse B lines (100%) and subpleural consolidations (27.3%). CXR showed prevalent manifestations of consolidations (46.9%) and hazy increased opacities (37.5%). Typical CT features included bilateral and multilobar ground-glass opacities (GGO) with (59.5%) and without (35.7%) consolidations having a predominantly peripheral distribution (64.3%). Other imaging features included crazy paving pattern (57.1%), fibrous stripes (50%), subpleural lines (35.7%), architectural distortion (28.6%), air bronchogram sign (26.2%), vascular thickening (23.8%) and nodules (2.4%). Also, enlarged lymph nodes (14.3 %) and pleural effusion (7.1%) were observed. The literature review identified twenty-six original studies supporting our imaging chest findings. The

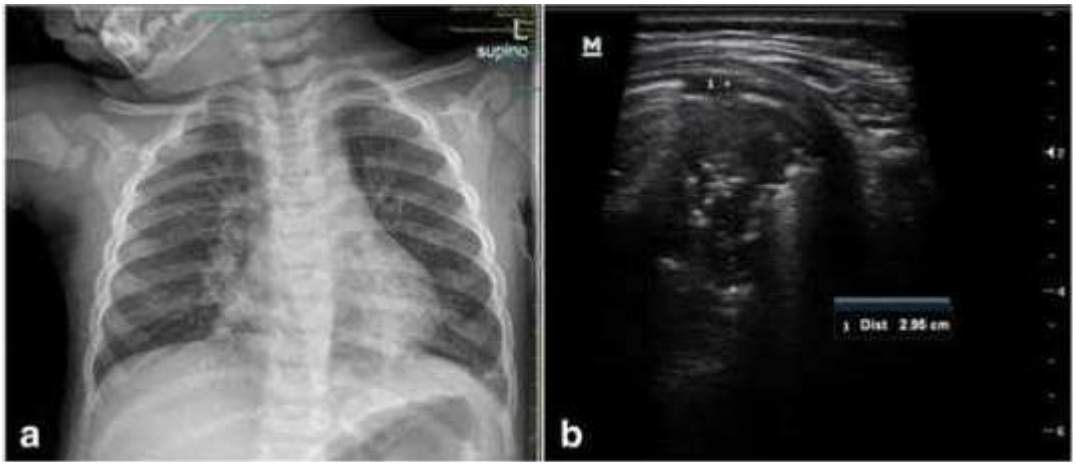
spectrum of chest imaging manifestations of COVID-19 pneumonia upon admission includes B lines and consolidations on US, consolidations and hazy increased opacities on CXR, and multifocal GGO with consolidations on CT.

According to [26] Giovanni and Luna, in their study titled "Sonographic signs and patterns of COVID-19 pneumonia, They made the following findings; This novel corona virus SARS-CoV-2 has a specific tropism for the low respiratory airways, but causes severe pneumonia in a low percentage of patients. Pneumonia in COVID-19 has peculiar features and can be studied by lung ultrasound in the early approach to suspected patients. COVID-19 typically induces an interstitial diffuse bilateral pneumonia with lesions in asymmetric and patchy distribution involving mainly the lung periphery, which makes it particularly suitable for an ultrasound investigation. The sonographic signs of interest in COVID-19 include all those which are well known in ARDS. These are the B-lines in various forms, both separate and coalescent, irregular or fragmented aspect of the pleural line, and small peripheral consolidations. Alternation of Ground Glass Opacification with crazy paving and consolidations can be well depicted by lung ultrasound (LUS). All the LUS signs of COVID-19 pneumonia can be observed in a variety of different lung conditions. However, what gives specificity to LUS is the distribution of the pattern and the current epidemiological milieu. Finally, LUS imaging is also useful to observe the regional distribution of these patterns and describe the patchy bilateral spread of lesions. The Correlation with timing of the onset of symptoms should be always considered. When the LUS pattern is the result of several days of disease, it is potentially less evolutive than similar patterns observed at a very early phase. Also, the combination of sonographic signs/patterns and their correlation with blood exams in different phenotypes of the disease may allow for a reliable characterization at presentation in the ED and be of help in triaging and admitting patients.



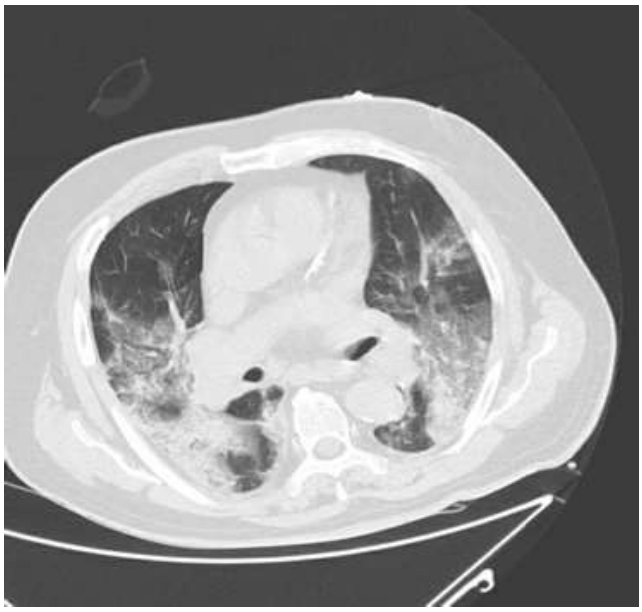
Carlotta et al. BMC Pulmonary Medicine (2018) [27]
Fig. 1: Lung Ultrasound Images

Lung ultrasound images in a patient with bronchiolitis complicated by pneumonia. a Transversal intercostals approach showed multiple B lines, consistent with bronchiolitis. b Longitudinal thoracic scan, revealed irregular pleural surface and confluent B lines (arrow). c The left posterior lung field showed a small subpleural consolidation without sonographic air bronchograms (arrow) - a typical finding in infants with bronchiolitis – associated with focally confluent B lines arising from the margin of the consolidation. d The scan of the posterior region of the right lung revealed a consolidation with hyperechoic air bronchograms suggestive of pneumonia



Carlotta et al. BMC Pulmonary Medicine (2018) [27]
Fig.2: Chest X-ray and Lung Ultrasound Images

Comparison of CXR and LUS in a patient with bronchiolitis complicated by pneumonia in the right lung. a CXR showed a right lung consolidation consistent with pneumonia, associated with hyperinflation and a mediastinal herniation of the left lung. b LUS revealed a large hypoechoic consolidated area with sonographic air bronchograms with branching pattern, compatible with pneumonia.



Fabio Macori. Radiopaedia.org [28]
Fig. 3: Computer Tomography Image

There are bilateral large areas of ground-glass opacities with crazy paving and, more evident at both bases, areas of consolidation with enlarged mediastinal lymph nodes.

DISCUSSION

Literature on the role of Ultrasonography in diagnosing viral pneumonia in COVID-19 patients are limited. Nonetheless, from the few literature available it can be deduced that it is a promising venture to delve into.

The general identifiable sonographic findings in viral pneumonia cases in COVID-19 patients are bilateral lower lobes lesions which includes mainly B-lines and subpleural consolidations. Huang at al, indicated that 75% of the 20 patients examined showed bilateral B-lines, subpleural pulmonary consolidation and poor blood flow [22]. Likewise Peng at al noted that in all 20 patients examined, multilobar distribution of focal B-lines were seen as early feature of pneumonia in these patients. Poggiali at al, identified B-lines in all 12 cases of symptomatic COVID-19 patients with organizing pneumonia in 4 of them [24]. Pascal et al [25] identified B-lines (100%) and subpleural consolidation (27.3%) in patients diagnosed with pneumonia due to COVID-19. Giovanni et al, concurred to this by stating that COVID-19 typically induces an interstitial diffuse bilateral pneumonia with lesions in asymmetric and patchy distribution involving mainly the lung periphery [26]. This implies that features of pneumonia in COVID-19 patients are identifiable using Ultrasonography. Therefore, the use of Ultrasonography in the diagnosis of pneumonia in COVID-19 patients should be encouraged.

There are relative differences in the presentations of COVID-19 pneumonia from those of other aetiologies. This is supported by Huang et al [22] who established that COVID-19 subpleural lesions differed significantly from those observed in bacterial pneumonia, Tuberculosis, Pulmonary abscess,atelectasis, and cardiogenic pulmonary edema, an example of which is that B lines in COVID-19 appear to be more fixed, fused, and obtuse compared with those in cardiogenic

pulmonary edema. This is also in agreement with Giovanni et al [26] who stated that all the LUS signs of COVID-19 pneumonia can be observed in a variety of different lung conditions, however, what gives specificity to LUS is the distribution of the pattern and the current epidemiological milieu. This implies that COVID-19 pneumonia can be differentiated from pneumonia due to other disease processes using Ultrasonography. Thus Ultrasonography can be relied on for the diagnosis of COVID-19 pneumonia if these distinguishing patterns are noted and well documented.

The stage of the COVID-19 disease (determined by the duration of onset of symptoms) can affect the sonographic patterns observed. This is in line with Peng et al [23] who explained that focal B lines were the main early features, followed by alveolar interstitial syndrome in progressive stages, and then A lines during convalescence. Pleural effusions were rarely observed at any stage. This is also similar to the description by Giovanni et al [26] that Correlation with timing of the onset of symptoms should be always considered. When the LUS pattern is the result of several days of disease, it is potentially less evolutive than similar patterns observed at a very early phase. The implication of this is that sonographic finding alone may not be highly specific. Therefore, Clinical information that can guide COVID-19 pneumonia staging should be available for proper correlation with observed features. Also a sonographer trained to handle COVID-19 patients may be in a better position to add up presenting features and make a good diagnosis.

There is high consistency of the ultrasound findings with those of either Chest CT scan or chest X-ray for the same cases of pneumonia in COVID-19 patients. This is seen in the work by Poggiali et al [24] where they reported good consistency between B lines on ultrasonography and ground-glass opacities (GGO) on CT in all 12 patients with both modalities identifying organizing pneumonia in 4 of them. Pascal et al [25] reported similar findings noting that the spectrum of chest imaging manifestations of COVID-19 pneumonia upon admission includes B lines and consolidations on US, consolidations and hazy increased opacities on CXR, and multifocal GGO with consolidations on CT. This implies that the sensitivity and specificity of Ultrasonography in diagnosing COVID-19 pneumonia is consistently high. Therefore, in limited resource and emergency settings where Ultrasonography is the only available imaging modality, it can be of significant aid especially with the skills of a trained sonographer in diagnosing COVID-19 pneumonia.

CONCLUSION

Through the process of careful studies and research with the early clinical evidence, lung ultrasonography in COVID-19 patients was able to identify characteristic lesions that were highly consistent with findings on CT. Computed Tomography is still considered the preferred imaging modality, ultrasonography may be useful in evaluating for early lung changes in patients with suspected COVID-19 in emergency department or in monitoring the progression of confirmed cases. In resource limited settings, ultrasonography can be applied as a triaging tool. In this case, patients with identified lesions are prioritized for CT imaging, with the hope of reducing the number of contagious patients entering the scanner, minimizing unnecessary exposure to radiation and the cost of their management. There is still an obvious need for more clinical evidence before definitive conclusions can be made; however, that should not stop clinicians from using ultrasonography during this pandemic since it has more benefits than risks.

RECOMMENDATIONS

Following the challenges faced by health workers in the use of the Ultrasonography as stated above, the problems can be addressed thus;

1. The government and relevant Authorities should ensure that more hands (sonographers) are employed and well remunerated. Sonographers should be encouraged to carry out CPDs and equipped with periodic and effective workshops on the global best ultrasound imaging practices.
2. The government should support the health sector by making available more ultrasound machines in hospitals especially in emergency departments. More research works should be funded in the field of lung Ultrasonography and standard operating protocols should be established for the diagnosis of pneumonia in COVID-19 patients in the emergency setting.
3. Radiographers (Sonographers) and radiologists (Sonologist) should be ready and willing to expand their scope; and to harness the underlying benefits of lung Ultrasonography.
4. The Association of Radiographers Nigeria (ARN) and Association of Radiologist in Nigeria (ARIN) should engage their members with sufficient and adequate training and CPD's in LUS in order to build competence and capacity in LUS.

Acknowledgement: To all Radiographers who assisted us with relevant and related literature.

Conflict of Interest: Nil

REFERENCES

[1] Kanne P, Little B, Chung J, et al. Essentials for radiologists on COVID-19: an update—Radiology Scientific Expert Panel. Available at: https://doi.org.1148/radiol.2020200527. Accessed May 8, 2020.

[2] National Health Commission of the People's Republic of China. Diagnosistment of novel coronavirus pneumonia (trial, the fifth version). Available at: http://www.nhc.gov.cn/yzygj/s7653p/20200 2 / 3b09b894ac9b4204a79db5b8912d4440.html.

[3] Mayo PH, Copetti R, Feller-Kopman D, et al. Thoracic ultrasonography: a narrative review. Intensive Care Med. 2019;45:1200-1211.

[4] Pagano A, Numis FG, Visone G, et al. Lung ultrasound for diagnosis of pneumonia in emergency department. Intern Emerg Med. 2015;10:851-854.

[5] M. Woodhead, F. Blasi, S. Ewig et al., "Guidelines for the management of adult lower respiratory tract infections—summary," Clinical Microbiology and Infection, vol. 17, supplement 6, pp. 1–24, 2011.

[6] L. A. Mandell, R. G. Wunderink, A. Anzueto et al., "Infectious Diseases Society of America/American Thoracic Society consensus guidelines on the management of community-acquired pneumonia in adults," Clinical Infectious Diseases, vol. 44, supplement 2, pp. S27–S72, 2007.

[7] J. P. Metlay and M. J. Fine, "Testing strategies in the initial management of patients with community-acquired pneumonia,"Annals of Internal Medicine, vol. 138, no. 2, pp. 109–118, 2003.

[8] M. N. Albaum, L. C. Hill, M. Murphy et al., "Interobserver reliability of the chest radiograph in community-acquired pneumonia," Chest, vol. 110, no. 2, pp. 343–350, 1996.

[9] D. L. A. Wyncoll and T. W. Evans, "Acute respiratory distress syndrome," The Lancet, vol. 354, no. 9177, pp. 497–501, 1999.

[10] G. J. Moran, R. E. Rothman, and G. A. Volturo, "Emergency management of community-acquired bacterial pneumonia:what is new since the 2007 Infectious Diseases Society of America/American Thoracic Society guidelines," American Journal of Emergency Medicine, vol. 31, no. 3, pp. 602–612, 2013.

[11] H. Syrjal¨ a, M. Broas, I. Suramo, A. Ojala, and S. L ¨ ahde, "High- ¨resolution computed tomography for the diagnosis of community-acquired pneumonia," Clinical Infectious Diseases, vol. 27, no. 2, pp. 358–363, 1998.

[12] D. Garg, L. B. Johnson, S. Szpunar, and J. T. Fishbain, "Clinical value of chest computerized tomography scans in patients admitted with pneumonia," Journal of Hospital Medicine, vol. 9, no. 7, pp. 447–450, 2014.

[13] O. Gehmacher, G. Mathis, A. Kopf, and M. Scheier, "Ultrasound imaging of pneumonia," Ultrasound in Medicine and Biology, vol. 21, no. 9, pp. 1119–1122, 1995.

[14] A. Reissig and C. Kroegel, "Sonographic diagnosis and followup of pneumonia: a prospective study," Respiration, vol. 74, no. 5, pp. 537–547, 2007.

[15] S. Parlamento, R. Copetti, and S. di Bartolomeo, "Evaluation of lung ultrasound for the diagnosis of pneumonia in the ED," American Journal of Emergency Medicine, vol. 27, no. 4, pp. 379–384, 2009.

[16] M. Sperandeo, V. Carnevale, S. Muscarella et al., "Clinical application of transthoracic ultrasonography in inpatients with pneumonia," European Journal of Clinical Investigation, vol. 41, no. 1, pp. 1–7, 2011.

[17] A. Reissig, R. Copetti, G. Mathis et al., "Lung ultrasound in the diagnosis and follow-up of community-acquired pneumonia: a prospective, multicenter, diagnostic accuracy study," Chest, vol. 142, no. 4, pp. 965–972, 2012.

[18] G. Volpicelli, M. Elbarbary, M. Blaivas et al., "International evidence-based recommendations for point-of-care lung ultrasound," Intensive Care Medicine, vol. 38, no. 4, pp. 577–591, 2012.

[19] M. A. Chavez, N. Shams, L. E. Ellington et al., "Lung ultrasound for the diagnosis of pneumonia in adults: a systematic review

and meta-analysis," Respiratory Research, vol. 15, no. 1, article 50, 2014.

[20] K. Doi, "Computer-aided diagnosis in medical imaging: historical review, current status and future potential," Computerized Medical Imaging and Graphics, vol. 31, no. 4-5, pp. 198–211, 2007.

[21] F. Corradi, L. Ball, C. Brusasco et al., "Assessment of extravascular lung water by quantitative ultrasound and CT in isolated bovine lung," Respiratory Physiology and Neurobiology, vol. 187, no. 3, pp. 244–249, 2013.

[22] Huang Y, Wang S, Liu Y, et al. A preliminary study on the ultrasonic manifestations of peripulmonary lesions of non-critical novel coronavirus pneumonia (COVID-19) (February 26, 2020). Available at: https://doi.org/10.2139/ssrn.3544750. Accessed May 8, 2020.

[23] Peng Q, Wang X, Zhang L. Findings of lung ultrasonography of novel corona virus pneumonia during the 2019-2020 epidemic. Intensive Care Med. https://doi.org/10.1007/s00134-020-05996-6.

[24] Poggiali E, Dacrema A, Bastoni D, et al. Can lung US help critical care clinicians in the early diagnosis of novel coronavirus (COVID-19) pneumonia? Radiology. https://doi.org/10.1148/radiol.2020200847. Volume. - : - 2020 Annals of Emergency

[25] Pascal L, Francesco V, Filipino Z, et al., (COVID-19) Pneumonia manifestation at the admission of chest ultrasound, radiographs, and CT: single-center study and comprehensive radiologic literature review. "European Journal of Radiology Open", in 2020.

[26] Giovanni V & Luna G, "Sonographic signs and patterns of COVID-19 pneumonia", The Ultrasound Journal". (2020) 12:22 https://doi.org/10.1186/s13089-020-00171-w-Pubmed

[27] Carlotta B, Luca Pi, Michelangelo Bi, Laura G, Ada D, Arianna D, Giacomo F and Marcello L. Lung ultrasound for the diagnosis of pneumonia in children with acute bronchiolitis; Biagi et al. BMC Pulmonary Medicine (2018) 18:191 https://doi.org/10.1186/s12890-018-0750-1

[28] Fabio Macori. COVID-19 pneumonia. Radiopaedia.org. (Last edited 19th April, 2020). Available at https://radiopaedia.org/cases/covid-19-pneumonia-12?lang=gb Retrieved May 22, 2020.