Turk J Intensive Care 2021;19(Suppl 1):1-7
DOI: 10.4274/tybd.galenos.2021.41736

ORIGINAL RESEARCH / *ÖZGÜN ARAŞTIRMA*

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Evaluating the Correlation Between Thoracic Ultrasound and Thoracic Computed Tomography Scores of Patients with Severe COVID-19 Pneumonia Receiving Intensive Care

Yoğun Bakımda Şiddetli COVID-19 Pnömonili Hastalarda, Toraks Ultrason ve Toraks Bilgisayarlı Tomografi Skorlamaları Arasındaki Korelasyonun Değerlendirilmesi

Received/Geliş Tarihi : 19.10.2020
Accepted/Kabul Tarihi : 20.01.2021

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Turkish Journal of Intensive Care published by Galenos Publishing House.

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ABSTRACT *Objective:* The coronavirus disease-2019 (COVID-19) pandemic has turned into a global health issue in a short time because of its increasing mortality and high infection rate. Since thoracic computed tomography (CT) cannot be performed and it is not possible to transfer COVID-19 patients followed-up in the intensive care unit (ICU), follow-up, and diagnosis using lung ultrasound (LUS) has been highly advantageous nowadays. The aim of this study was to assess the correlation between the thoracic CT score and LUS score and to determine their association with mortality.

Materials and Methods: Patients admitted to the ICU, diagnosed to have COVID-19 pneumonia, underwent an initial thoracic CT examination and who underwent LUS during admission to the ICU were included in the study. The clinical parameters, demographic characteristics, prognosis, LUS, and thoracic CT scores of the patients were recorded prospectively. The survivors and deceased patients' demographic characteristics were compared.

Results: The mean age of the 29 patients included in this study was 61.93±14.21 years, and the male-to-female ratio was 18/11 (62.1%/37.9%). A strong positive correlation was between the thoracic CT score and LUS score (r=0.964; p<0.001). The thoracic CT and LUS scores of the survivors were 15.5±2.7 and 27.3±4.9, respectively, while those of the deceased patients were 14.1±3.4 and 25.6±5.8, respectively, and the two groups found no significant difference.

Conclusion: A strong positive correlation was found between the thoracic CT score and LUS score of COVID-19 patients admitted to the ICU. This result shows that LUS is easily preferred for patients who require imaging for diagnosis and follow-up under intensive care conditions. The mortality rates of COVID-19 patients could not be predicted by either thoracic CT score or LUS score.
Keywords: Critical care, COVID-19 pneumonia, computed tomography, lung ultrasound

ÖZ *Amaç:* Koronavirüs hastalığı-2019 (COVID-19) pandemisi, artan mortalite ve yüksek enfeksiyon oranı nedeniyle hızlı bir şekilde küresel bir sağlık sorununa dönüşmüştür. Bilgisayarlı tomografisi (BT) yapılamadığı ve yoğun bakımda takip edilen COVID-19 hastalarının transferinin mümkün olmadığı için akciğer ultrasonu (LUS) ile takip ve tanı günümüzde oldukça avantajlı hale gelmiştir. Bu çalışmanın amacı torasik BT skoru ile LUS skoru arasındaki ilişkiyi değerlendirmek ve mortalite ile ilişkisini tespit etmektir.

Gereç ve Yöntem: Yoğun bakım ünitesine (YBÜ) kabul edilen, COVID-19 pnömonisi tanısı alan, ön toraks BT incelemesi yapılan ve YBÜ'ye kabul sırasında LUS yapılan hastalar çalışmaya dahil edilmiştir. Hastaların klinik parametreleri, demografik özellikleri, prognozu, LUS ve toraks BT skorları prospektif olarak kaydedilmiştir. Hayatta kalanlar ve ölen hastaların demografik özellikleri karşılaştırılmıştır.

Bulgular: Bu çalışmaya dahil edilen 29 hastanın yaş ortalaması 61,93±14,21 yıl ve erkek-kadın oranı 18/11 (%62,1/37,9) idi. Torasik BT skoru ile LUS skoru arasında güçlü bir pozitif korelasyon vardı

(r=0,964; p<0,001). Sağ kalanların torasik BT ve LUS skorları sırasıyla 15,5±2,7 ve 27,3±4,9 iken, ölen hastalarınki sırasıyla 14,1±3,4 ve 25,6±5,8 idi ve iki grup arasında anlamlı bir fark bulunmamıştır.
Sonuç: YBÜ'ye yatırılan COVID-19 hastalarının torasik BT skoru ile LUS skoru arasında güçlü pozitif korelasyon bulunmuştur. Bu sonuç, yoğun bakım koşullarında tanı ve takip için görüntüleme gerektiren hastalarda LUS'nin rahatlıkla tercih edildiğini göstermektedir. COVID-19 hastalarının ölüm oranları ne torasik BT skoru ne de LUS skoru ile tahmin edilememiştir.
Anahtar Kelimeler: Yoğun bakım, COVID-19 pnömoni, bilgisayarlı tomografi, akciğer ultrasonu

Introduction

The world currently faces a pandemic that is rapidly spreading due to complications in the respiratory system that results in pneumonia, caused by a new coronavirus (severe acute respiratory syndrome coronavirus 2) and called coronavirus disease-2019 (COVID-19) in 2019 (1). It is estimated that 5 to 10% of the infected cases need critical care 15 to 20% of them have severe pneumonia (2).

Imaging modalities mainly help diagnos and manage COVID-19 suspected patients (3). Chest radiograph displays low-density pneumonia foci (viral pneumonia), most of which involve bilateral mid-lower zones in this disease. However, chest X-ray shows low the sensitivity (30-60%) (4), and pneumonia is not excluded by normal chest radiograph (1). It has been proven that computed tomography (CT) findings can diagnose most of the cases with screening test of an initial false-negative reverse transcriptase-polymerase chain reaction (RT-PCR) (5-7). COVID-19 patients present with bilateral multilobar ground-glass opacification, crazy-paving pattern and consolidation etc. with a peripheral distribution (8). Although CT is a highly sensitive and specific imaging technique, it has some disadvantages, especially for critically ill patients who are monitored in intensive care. The transfer of a COVID-19 patient from the intensive care unit (ICU) for CT, who is monitored in invasive mechanical ventilation (IMV), has drawbacks both in terms of the spread of infection and the patients' exposure to ionized radiation due to the patient's critical condition. The CT scanner needs to be thoroughly cleaned after each suspected case of COVID-19, to prevent the spread of the infection to other patients and healthcare staff (9).

Lung ultrasound (LUS), which is currently used as a diagnostic tool in emergency departments (1), is a promising imaging tool for COVID-19, considering both the peripheral involvement of the lung and the disadvantages of CT and plain radiograph (8). This imaging modality is quick, portable, easy to learn, repeatable, with high inter-rater and intra-rater reproducibility (10). Due to its ease of use at the bedside (11), it can also be guiding in the management of the disease and follow-up in patients having a high mortality risk who are monitored with IMV (12) in the intensive care unit. Although COVID-19 patients receiving invasive ventilation will often have non-recruitable lung lesions early on, recruitable lesions may develop later in the disease course (9). LUS could titrate ventilator settings in positive end-expiratory pressure (PEEP) -induced lung recruitment, and also facilitates successful weaning from mechanical ventilation (12). Its easy repeatable can also be useful in the early diagnosis of complications. this study evaluated the correlation between the baseline LUS score and CT score of severe COVID-19 patients who were followed up in the ICU was determined as the primary end point and its correlation with mortality was determined as the secondary end point.

Materials and Methods

Patients

The study was approved by the Clinical Research Ethics Committee of Gaziosmanpaşa Training and Research Hospital (decision no: 87, date: 28.05.2020). Written informed consent was obtained from the patients to be included in the study and/or their relatives. The study was conducted prospectively between June 2020 and July 2020. The inclusion criteria were as follows: among patients and/or their relatives those who gave written consent, who were over 18 years of age, hospitalized in intensive care with a diagnosis of COVID-19 pneumonia, had a definite diagnosis by PCR, had an initial thorax CT examination, and underwent LUS at admission to intensive care. The exclusion criteria were as follows: patients under 18 years of age who did not give written consent, had no definitive diagnosis by PCR, previous lung resection, no thorax CT and LUS at admission to intensive care. Thorax CT scoring was performed by an experienced radiologist, while LUS scoring was performed an experienced anesthesia and reanimation specialist. The demographic characteristics, clinical parameters, prognosis, thorax CT and LUS scores of the patients were recorded

prospectively. The correlation between thorax CT score and LUS score was evaluated.

Radiological Evaluation

LUS Score

An intensive care specialist experienced in this field performed LUS using a 2- to 5-MHz transducer (Esaote MyLabSeven, Getz Healthcare Malaysia). A probe cover was used to cover the transducer, and disinfectant wipes were used to clean the ultrasound device and transducer after each use. LUS examinations were performed in the supine position at the bedside, and twelve-zone examinations were performed. Each hemithorax is separated into 6 quadrants: lateral, posterior, and anterior zones (separated by the anterior and posterior axillary lines) each divided in lower and upper portion (Figure 1). the LUS pattern was used to score each zone as follows: the presence of lung sliding with A-lines or below two isolated B-lines, scored 0; when multiple well-defined B-lines presented, scored 1; the presence of multiple coalescent B-lines, scored 2; the presence of a tissue pattern characterized by dynamic air bronchograms (lung consolidation), scored 3. The sum of the scores was calculated by recording and using the worst ultrasound pattern found in each zone (total score =36).

CT Technique and Image Interpretation

The low dose protocol of our hospital with a 128-slice multi-detector CT scanner (Optima; General Electric Healthcare, Wisconsin, USA) was used to obtain the thorax CT scans in the study. All CT scans were performed during a single breath-hold without contrast administration. A radiologist with 9-year experience in interpreting thorax CT imaging (FC), on a PACS imaging workstation reviewed all CT images (Infinitt PACS; Infinitt Healthcare, Seoul, Korea).

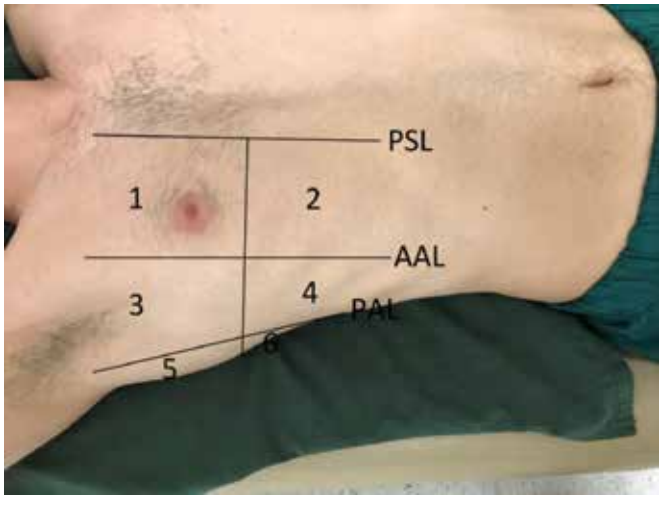

Figure 1. Chest segments in lung ultrasound
AAL: Anterior axillary line, PAL: posterior axillary line, PSL: parasternal line

As in the ultrasound evaluation, we divided each lung into lateral, anterior, and posterior quadrants based on the posterior and anterior axillary lines, and then each quadrant was divided into lower and upper sections. Each quadrant was scored 0-3. Score 0 indicated no parenchymal involvement, score 1 indicated parenchymal involvement rate between 0 and 33%, score 2 indicated parenchymal involvement rate between 33% and 66%, and score 3 indicated parenchymal involvement rate above 66%.

Statistical Analysis

SPSS statistical software package (SPSS, version 17.0 for windows) was used for the statistical analyses and G-power 3 for MacOs program was used for power analysis. Intergroup power analysis between more than two independent groups was performed priori based on the Pearson correlation one tail test, (q: 0.8; power: 0.8; alpha error: 0.05). In order for the total sample size to generate 0.8 power, a total of 46 data [thorax ultrasonography (USG) and thorax CT] of 23 patients were planned to be included in the study, the distribution of parameters is homogeneous or not was checked with the Kolmogorov-Smirnov test. Parametric tests were used for the data with homogeneous distribution, while nonparametric tests were used for the data with non-normally distribution. Pearson's correlation test was used to determine whether there is a significant relationship between CT score and LUS score. Results were given as mean ± standard deviation. We considered A p-value of below 0.05 as statistically significant.

Results

The study included 29 patients with thorax CT and LUS at intensive care admission. The mean age of the patients was 61.93±14.21 years, 37% of them were female. The patients' demographic characteristics are given in Table 1. Of the 29 patients, 13 died in intensive care. There was no significant difference between the mean age of survived and dead patients (57.6±12.8 vs. 67.3±14.4; p=0.065). Regarding the gender distribution, the ratio of males was higher among the survived patients, and the ratio of females was higher among the patients who died (0.018). The two groups showed no difference in terms of length of stay in the ICU, body mass index, and co-morbidities (Table 1).

Of the survived patients, 5 were followed up with high flow nasal oxygen (HFNO), 8 with non-invasive mechanical ventilation (NIMV) and 3 with IMV. Of the patients who died, 3 were followed with HFNO, 8 with NIMV and 2 with IMV. A strong positive correlation was found between thorax CT score and LUS score (r=0.964; p<0.001) (Figure 2). The thorax CT score of the survivors was 15.5±2.7, and the LUS score was 27.3±4.9. The thorax CT score of those who died was 14.1±3.4, and the LUS score was 25.6±5.8. No significant difference was found between the two groups in terms of thorax CT score and LUS score (Table 2).

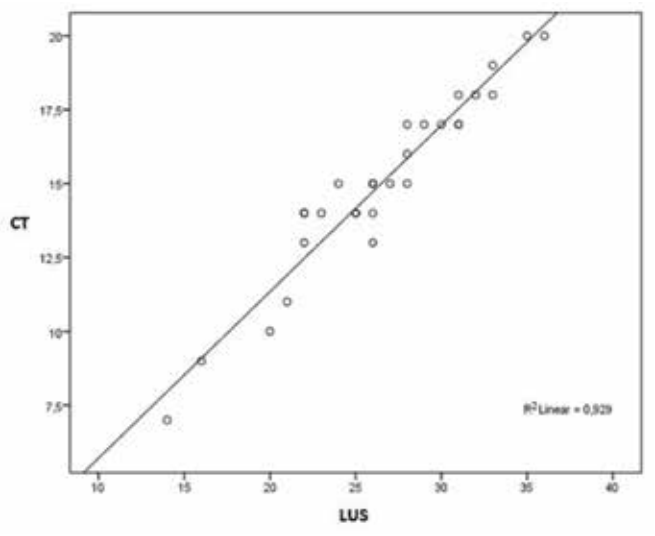

Figure 2. Correlation of thorax CT and LUS scores. There is a strong positive correlation between CT and LUS scorings (r=0.964; p=0.001)
CT: Computed tomography, LUS: lung ultrasound

Discussion

In the study, the correlation of LUS with CT score and its role in determining mortality was evaluated in patients requiring intensive care follow-up due to COVID-19 pneumonia. As a result of the study, a strong positive correlation was found between thorax CT score and LUS score, but it was found that the thorax CT score and LUS score were not effective in determining mortality.

Poggiali et al. (13) reported that there was a strong harmony between thorax CT and simultaneous LUS in COVID-19 patients presenting with flu-like symptoms. The authors of this study suggested the use of LUS as an alternative to thorax CT for early diagnosis of COVID-19 infection. Yin et al. (14) showed that there was a significant correlation between higher LUS score and 28-day increase in mortality in 175 patients admitted to the ICU in their study. In our study, no significant correlation was found between thorax CT score and LUS score and the severe COVID-19 patients' mortality. We thought it might be depending on our less number of patients.

LUS is increasingly used as a reliable tool for evaluating lung diseases, especially in intensive care. Since COVID-19 pneumonia lesions are predominantly peripheral and subpleural, the use of LUS is more appropriate (5). Typical patterns detected by LUS are characterized by both split (Figure 3) and combined B-lines of different shapes (Figure 4), irregular and/or split pleural line, peripheral small consolidations (Figure 5), and large consolidations with dynamic air bronchograms (15,16). These patterns are often interleaved with "protected areas" (A-lines) (17). A large pleural effusion is not a common finding (15). Yasukawa

Table 1. Comparation of demographic and clinical data

	Group 1 (survivors) (n=16)	Group 2 (non-survivors) (n=13)	p-value
Age	57.6±12.8	67.3±14.4	0.065
Gender (M/F)	13/3	5/8	0.018
BMI	29.7±7.3	33.5±6.8	0.164
Duration of ICU stay (days)	13.2±8.5	11.5±8.9	0.602
Co-morbidite (exist/not exist)	12/4	11/2	0.525
Ventilation (n)			
HFNO	5	3	0.689
NIMV	8	8	
IMV	3	2	

HFNO: High flow nasal oxygen, NIMV: Non-invasive mechanical ventilation, IMV: invasive mechanical ventilation, BMI: body mass index, ICU: intensive care unit

Table 2. Comparison of survivors and non-survivors CT and LUS scorings			
	Group 1 (survivors) (n=16)	Group 2 (non-survivors) (n=13)	p-value
CT score	15.5±2.7	14.1±3.4	0.244
LUS score	27.3±4.9	25.6±5.8	0.401
CT: Computed tomography, LUS: lung ultrasound			

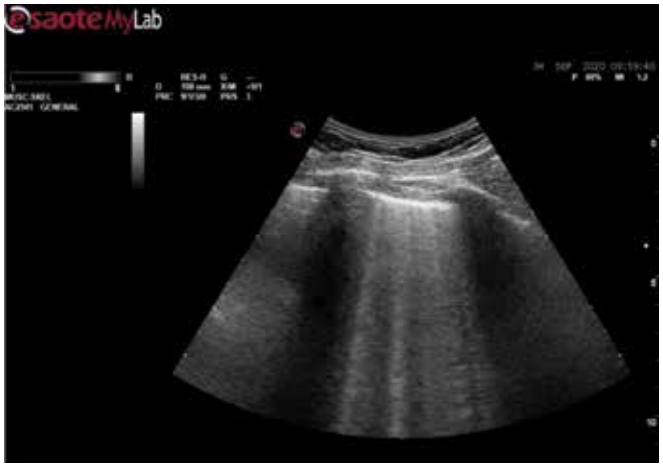

Figure 3. Lung ultrasound shows multiple B-lines

Figure 4. Lung ultrasound shows confluent B-lines

and Minami (8) evaluated the LUS findings of 10 patients who presented to the Internal Medicine Department with COVID-19, and all patients had thick irregular pleural lines and converging B lines. They reported small subpleural consolidations in five of 10 patients. Peng et al. (15) reported the recurrence of A lines following treatment. They recommended the use of ultrasound to assess critical treatment response and prognosis prior to the COVID-19 outbreak, that their recurrence indicates a reduction in interstitial infiltration. In our study, abnormal LUS findings,

Figure 5. Lung ultrasound shows small subpleural consolidation

pleural line abnormalities, mainly B-lines, and consolidation were found in COVID-19 patients. Bilateral involvement was found with a dominant distribution in the posterior segment of the lungs. The composition of the different B-lines density and areas of consolidation varied in parallel with clinical severity.

NIMV, HFNO, continuous positive airway pressure devices and IMV were used for the intensive care treatment of COVID-19 pneumonia (18,19). In our study, 16 of 29 patients were followed with NIMV, 8 with HFNO and 5 with IMV, daily lung examinations were performed with USG and treatment was planned. LUS is used for PEEP titration, changing ventilation parameters, and extubation planning (12,20). In their study, Schultz et al. (9) stated that the follow-up of COVID-19 patients under IMV could be performed with LUS as an easy bedside tool. Bouhemad et al. (20) demonstrated the significance of LUS in determining ventilator settings by recruitment with PEEP. With the repeated LUS and scoring system, it made it possible to follow up the lung pathology.

The significance of lung imaging in areas affected by the COVID-19 outbreak was reported by Ai et al. (21) stating that 60-93% of patients had positive thorax CT findings consistent with COVID-19 before RT-PCR results turn positive. In a study by Kalafat et al. (22), they found positive LUS findings consistent with COVID-19 pneumonia

in a woman who initially had a negative RT-PCR result. They reported that the patient, whose RT-PCR tests were negative and positive in the repeated follow-up, correlated with the LUS score and CT score. The study by Yasukawa and Minami (8) showed that LUS was a promising additional lung imaging tool in COVID-19 pneumonia, especially in environments with limited resources. LUS was easy to perform in our study, and therefore it guided us in the triage of the patient suspected of having COVID-19 pneumonia.

In their study, Pan et al. (23) followed up lung involvement by performing multiple thorax CT scans at different times (at least three). Ai et al. (21) concluded in their study that multiple RT-PCR assays and serial thorax CT scans had high sensitivity for the diagnosis of COVID-19. CT has been used predominantly for the diagnosis of COVID-19; however, limitations such as radiation exposure, limited mobility, and expensive devices may limit its usefulness, especially during emergencies with insufficient medical resources. Vetrugno et al. (24) stated in their study that they achieved a significant reduction using chest X-rays and CT scans during this pandemic with LUS, which helped them perform the care and management of their patients a little more efficient.

Considering its sensitivity, portability, and safety, LUS is the preferred imaging modality to aid in the early diagnosis and evaluation of COVID-19 pneumonia. In addition, ultrasound is the only imaging technique accessible near patients' beds for timely diagnosis of pulmonary complications and follow-up of disease changes (25).

Considering that approximately 9 to 12% of healthcare workers are infected in light of data from Italy and Spain, the two countries with the highest rate of COVID-19, this is a very important point (1). In our study, the same physician responsible for the patient obtained pulmonary images with with LUS at the bedside, so that the number of healthcare professionals who could be exposed to the virus could be minimized.

Conclusion

Thorax CT is an effective imaging technique used to diagnose and follow up COVID-19 patients. LUS can help diagnose COVID-19 in environments with limited resources where chest X-ray, CT, and RT-PCR are not readily available or have a long turnaround time. The strong correlation between LUS score and CT score in COVID-19 patients shows that LUS can be preferred when CT is required. This may provide early detection and intervention for complications, especially during follow-up. The mortality of COVID-19 patients cannot be predicted with thorax CT score and LUS score. Future studies including more patients will shed light on this issue.

Ethics

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee of Gaziosmanpaşa Training and Research Hospital (decision no: 87, date: 28.05.2020).

Informed Consent: Written informed consent was obtained from the patients to be included in the study and/or their relatives.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: A.V., F.Ç., Design: D.G.M., F.Ç., Data Collection and Process: A.V., F.Ç., Analysis or Interpretation: D.G.M., Ü.A.T., Literature Search: D.G.M., Z.Ç., Writing: A.V.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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