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Experience in the use of lung ultrasound in patients of the respiratory hospital of Siberian State Medical University with COVID-19 pneumonia

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ABSTRACT

Aim. To evaluate the possibility of using lung ultrasound for diagnosing COVID-19 pneumonia in patients of the respiratory hospital of Siberian State Medical University (SSMU).

Materials and methods. An analysis of lung ultrasound data was carried out in 39 patients (17 men and 22 women aged 33–78 years) with COVID-19 pneumonia. Lung ultrasound was performed in all patients in addition to radiography performed at the prehospital stage and in 15 patients who underwent computed tomography (CT) of the lungs.

Results. In the majority (61.6%) of cases, during the ultrasound examination, COVID-19 pneumonia manifested itself as interstitial lung disease. The white lung phenomenon and a combination of the aforementioned interstitial changes were recorded with the same frequency (5.1%), while pulmonary consolidation in addition to interstitial changes was visualized in 10.2% of cases. Interstitial lung disease was bilateral in 83.3% of patients and unilateral in 16.7% of cases. The inferior lobes of the lungs were affected in 60.0% of cases, middle lobe – in 30.0% of cases, and superior lobes – in 15.0% of patients. The ultrasound examination detected changes in the lungs in 32 patients, while radiographic changes were present in 35 cases. Bilateral inflammation was more often detected by radiography than by ultrasound. When comparing the data of lung ultrasound and CT, the agreement between the methods was found in 66.7% of cases, and the discrepancy between the findings of the two methods was observed mainly in patients with a large number of affected segments of the lungs and localization of the disease in the superior lobes according to CT.

Conclusion. Lung ultrasound is a valuable tool that can be used to stratify risk in patients at any stage of diagnosis and treatment in the context of the COVID-19 pandemic due to availability, speed of implementation, and the absence of a need for patient transportation.

Keywords: COVID-19 pneumonia, lung ultrasound, radiology

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Conformity with the principles of ethics. All patients signed an informed consent to examination. The study was approved by the local Ethics Committee at SSMU.

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Опыт применения ультразвукового исследования легких у пациентов респираторного госпиталя СибГМУ с коронавирусн пневмонией

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РЕЗЮМЕ

Цель. Изучить возможность использования ультразвукового исследования (УЗИ) легких в диагностике пневмонии COVID-19 у пациентов респираторного госпиталя СибГМУ.

Материалы и методы. Проведен анализ данных УЗИ легких у 39 пациентов (17 мужчин и 22 женщины в возрасте 33–78 лет) с пневмонией, вызванной SARS-CoV-2. УЗИ легких выполнено всем пациентам дополнительно к рентгенографии (РГ), проведенной на догоспитальном этапе, и 15 пациентам с компьютерной томографией (КТ) легких.

Результаты. В большинстве случаев (61,6%) при УЗИ пневмония проявлялась интерстициальным синдромом, с одинаковой частотой (5,1%) регистрировались феномен «белого легкого» и сочетание перечисленных интерстициальных изменений, в 10,2% визуализировалась консолидация легочной ткани дополнительно к интерстициальным изменениям. Интерстициальный синдром в 83,3% носил двусторонний характер, в 16,7% – односторонний. Поражение нижних отделов легких выявлено в 60,0% случаев, средних – в 30,0%, верхних – в 15,0%. При УЗИ изменения в легких были диагностированы у 32 пациентов и 35 пациентов методом РГ. Двусторонний воспалительный процесс чаще выявлялся при РГ, чем при УЗИ. При сравнении данных УЗИ и КТ легких совпадение установлено в 66,7% случаев, а расхождение результатов двух методов наблюдалось у пациентов с большим числом пораженных сегментов легких и локализацией процесса в верхних долях легких по КТ.

Заключение. Проведенное УЗИ легких показало, что этот метод визуализации должен быть применен для стратификации риска у пациентов на любом этапе диагностики и лечения в условиях пандемии COVID-19 в силу доступности, быстроты выполнения, отсутствия необходимости в транспортировке больных.

Ключевые слова: пневмония, COVID-19, ультразвуковое исследование легких, лучевая диагностика

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Источник финансирования. Авторы заявляют об отсутствии финансирования при проведении исследования.

Соответствие принципам этики. Все пациенты подписали информированное согласие на проведение исследования. Исследование одобрено локальным этическим комитетом СибГМУ.

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INTRODUCTION

In March 2020, the World Health Organization declared COVID-19 (COrona VIrus Disease 2019) caused by the SARS-CoV-2 virus a pandemic [1]. Rapid spread of the virus required significant restructuring of the healthcare system, changes in the working conditions for doctors, and obligatory widespread implementation of the most essential methods for examining a patient's condition, such as measuring arterial blood oxygen saturation and diagnostic radiology methods for detecting COVID-19 pneumonia [2], mostly computed tomography (CT) of the lungs, which has the greatest sensitivity in its diagnosis [3–5].

Lung ultrasound (US) for diagnosing pneumonia and viral infections in the lungs previously occupied a

modest place in clinical practice and was more often used in situations when plain radiography and CT of the lungs were not available (pregnant women, lack of technical capabilities) [6, 7].

To date, the theoretical foundations of lung US have been significantly enriched, and, therefore, clinical application of the method has become more objective for use in the context of the COVID-19 pandemic [8]. Studies [9–11] indicate a significant role of lung US for the diagnosis of interstitial lung disease [12], acute respiratory distress syndrome (ARDS) [13], pleural disorder, and lung inflammation of any etiology [14], i.e. the main manifestations of lung damage in COVID-19. Currently, domestic evidence base for lung US in patients with COVID-19 is being compiled in the context of a growing number of COVID-19 cases among the population and forced restriction on the use of classical methods of lung examination (palpation, percussion, auscultation) by therapists due to a high risk of viral contamination.

The aim of the study was to evaluate the possibility of using lung US for diagnosing COVID-19 pneumonia in patients of the respiratory hospital of Siberian State Medical University (SSMU).

MATERIALS AND METHODS

To implement the program on combating the novel coronavirus infection at Siberian State Medical University, from May 16 to September 30, 2020, a separate building of Advanced Therapy Clinics was allocated and converted into a respiratory hospital for treating COVID-19 patients. Lung US was included in examination of patients at the respiratory hospital, in contrast to other hospitals in the Tomsk region providing similar medical care.

To investigate the capabilities of lung US and the potential for applying the method in the diagnosis of COVID-19 pneumonia, 39 patients (17 men and 22 women) aged 33–78 years (average age 59.4 ± 15.4 years) were included in the study; they were admitted to the respiratory hospital of Siberian State Medical University.

Inclusion criteria were a verified diagnosis of novel coronavirus infection in oropharyngeal swabs, diagnostically significant blood concentration of IgM and IgG to the viral antigen, the presence of clinical signs of respiratory infection, and a signed informed consent to participate in the study.

Exclusion criteria included concomitant lung pathology (neoplasms, tuberculosis, pneumoconiosis) and somatic symptom disorders (diffuse connective tissue diseases, severe heart failure), which could affect the radiographic lung pattern.

The severity of the patient's condition was assessed using the National Early Warning Score (NEWS), a protocol for assessing the severity of a patient's condition [15]. It included assessment of the respiratory rate, blood oxygen saturation level, body temperature, systolic blood pressure, heart rate, and changes in the level of consciousness.

In 4 patients, the NEWS score was equal to or more than 7, the condition of these patients was assessed as severe, requiring mechanical ventilation (MV). In 12 patients, the NEWS score ranged from 5 to 6, their condition corresponded to moderate severity. In 23 patients with the score of 4 or less, the condition was considered mild.

Lung US was performed on a Mindray M 7 ultrasound machine in a sitting position. In order to reduce the time spent in the red zone of the hospital, the protocol of lung US was simplified. The following anatomical approaches were sequentially used: posterior surface of the chest: 1) right and left lower zones: paravertebrally at the level of IX – X ribs; 2) right and left upper zones: paravertebrally at the level of the scapular spine. Lateral sections of the chest: 1) right and left lower zones (along the midaxillary line to the intersection with the horizontal line drawn through the epigastric angle); 2) right and left upper zones (along the midaxillary line at the entrance to the armpit). Anterior sections of the chest: 1) right and left lower zones (along the right midclavicular line at the horizontal line drawn through the epigastric angle); 2) right and left upper zones (along the right midclavicular line at the level of II – III ribs).

To assess the identified radiographic changes in the examined patients, we used the terminology and descriptive characteristics presented by the Consensus Statement of the RASUDM (Russian Association of Ultrasound Diagnostic Specialists in Medicine) [7]. The following parameters were analyzed: the state of the pleural line, registration of B-lines in various variants, and the presence of signs of pulmonary consolidation and pleural effusion.

A prerequisite for including the results of lung US of patients in the analysis was performance of radiography (RG) and, in some cases, CT of the lungs. Chest X-ray at the prehospital stage was performed in all 39 patients and repeated in 4 individuals; CT of the lungs was performed in 15 cases additionally after radiography.

Chest X-ray included plain radiography of the lungs and lateral chest views. For the period of functioning of the respiratory hospital at Siberian State Medical University, this method was the most accessible and often primary, and sometimes it was the only technique for visualizing changes in the lungs of patients with suspected COVID-19 pneumonia. In case of an ambiguous X-ray pattern or when the condition of the patients aggravated, they additionally underwent multi-slice computed tomography (MSCT). MSCT of the chest was performed with 1.25 mm reformatted slice thickness and subsequent image analysis in the maximum intensity projection (MIP) and volume rendering technique (VRT). In 2 cases, MSCT was supplemented with lung densitometry for greater objectivity in assessing the density of the lung parenchyma.

Quantitative data were presented as $X \pm \sigma$, where X is the mean, and σ is the standard deviation. Qualitative data were presented as absolute and relative frequencies, *n* (%).

RESULTS AND DISCUSSION

Following lung US, normal lung tissue was visualized in 7 patients in the form of typical reverberation artefacts – thin lines located parallel to the pleura (A-lines). In this case, the entire complex of images (pleural line, A-lines) shifted in rhythm with respiration (the phenomenon of lung sliding).

Signs of interstitial lung disease ("I") were detected in 24 (61.6%) patients, that is, in the majority of the studied individuals. In this case, more than 3 B-lines were detected in 2 scanning areas. The formation of B-lines (hyperechoic bands) that originated from the pleural line and gradually expanded due to the entry of exudate into the interalveolar space is pathognomonic for interstitial lung disease. In 2 (5.1%) cases, with progression of interstitial lung disease, the B-lines became coalescent, up to a continuous hyperechoic area ("E", the white lung phenomenon). In the same number of cases, a combination of the listed interstitial changes was noted (Table 1).

The progressive course of the disease was characterized by transition from purely interstitial pneumonia to mixed interstitial – parenchymal disease with the appearance of pulmonary consolidation ("C") – airless lung tissue with signs of inflammatory exudate. In this case, the US pattern was characterized by the disappearance of the pleural line and the presence of a hypoechoic area of irregular shape, along the border with which lung tissue with characteristic B-lines was visualized. In 4 cases, different combinations of signs of interstitial lung disease, white lung, and pulmonary consolidation were visualized. A small volume of pleural effusion in addition to the major pulmonary changes was detected in 9 patients.

Table 1

US signs characteristic of lung damage in COVID-19

Parameter	*n* (%)
Visualization of normal lung tissue (N)	7 (18.0)
Signs of interstitial lung disease (I)	24 (61.6)
White lung phenomenon (E)	2 (5.1)
Combination of the white» lung phenomenon and interstitial lung disease	2 (5.1)
Combination of the white lung phenomenon interstitial lung disease, and pulmonary consolidation (C)	4 (10.2)

In 20 patients (83.3%), the US pattern of interstitial lung disease was bilateral, in 4 (16.7%) – unilateral. The inferior lobes of the lungs were affected in 11 cases (60.0%), middle lobe – in 6 cases (30.0%), and superior lobes – in 3 cases (15.0%).

The previous results of the authors' study showed high sensitivity of similar identified radiographic changes for interstitial and alveolar – interstitial lung diseases in acute respiratory distress syndrome (ARDS) [16] and lung damage in the influenza A (H1N1) pandemic in 2009 [17].

The use of US for the diagnosis of lung damage in the COVID-19 pandemic is described in the studies by foreign authors who demonstrated high sensitivity of the method combined with moderate specificity for the diagnosis of coronavirus infection [18, 19]. In addition, a number of researchers assessed the predictive accuracy of scales based on lung US findings in relation to the outcome of the disease [20], the effectiveness of specific treatment methods [21], the length of stay in the intensive care unit, and the need for respiratory support in COVID-19 [22].

Chest X-ray detected changes in the lung tissue in 35 patients, and US – in 32 patients. The architecture of the lungs in most patients was described as local or diffuse increased attenuation in the pulmonary interstitial stroma, less often – as a ground glass opacity. In the US protocol, the most typical changes included manifestations of interstitial lung disease and the white lung phenomenon in the corresponding anatomical zones. According to the RG data, the development of viral and bacterial pneumonia, in addition to the described interstitial changes, was characterized by

the appearance of areas of pulmonary consolidation, which complied with the US findings.

Repeated lung US in the studied group of patients was performed in single cases. Thus, with a combined pattern of interstitial lung disease, the white lung phenomenon, and pulmonary consolidation diagnosed by US, repeated US performed 5 days later typically demonstrated positive changes – the presence of only interstitial lung disease. This was confirmed by RG carried out at runtime, indicating resolution of pulmonary consolidation with persisting signs of viral lesions. On the contrary, in 2 cases, with negative dynamics of the radiographic lung pattern (in the context of probable ARDS) manifested through a significant increase in the attenuation of the pulmonary pattern due to the interstitial component, repeated US revealed signs of diffuse bilateral interstitial lung disease in all scanning areas and in all lung segments.

Bilateral localization of the process was more often detected by X-ray than by ultrasound – in 34 and 29 patients, respectively. However, in two cases, interstitial lung disease was present according to lung US in patients with ambiguous X-ray data. Probably, these discrepancies are associated with the dynamics of the pathological process, the study of patients at different time intervals, better diagnostic capabilities of US in subpleural localization of changes, and the presence of a respiratory artifact in patients with dyspnea.

Using CT, changes in the lungs were additionally diagnosed in 4 patients with negative X-ray presentation. The agreement between the data of CT and lung US was observed in 10 (66.7%) cases out of 15 patients who underwent CT. Similar changes in the lungs were identified by CT and US with lower lobe localization of the process, and the discrepancy between the two methods was observed mainly in patients with a large number of affected lung segments and localization of the inflammation in the superior lobes of the lungs according to CT. It is worth noting that the results of CT were in line with lung densitometry data and US findings, which confirmed the absence of areas of pulmonary consolidation in 2 patients.

A priori, clinical observations indicate that in diseases that cause drastic morphological changes in the lung tissue (pneumonia, tuberculosis), repeated use of radiology techniques for providing real-time, visual control over the state of the affected tissue is not relevant, since the dynamics of pathological changes during treatment is determined by a combination of physical research methods.

On the contrary, COVID-19 pneumonia often develops rapidly, with short survival for patients, therefore, even minimal changes in the lung tissue detected during follow-up are important for patient routing and determining further treatment strategy. Evaluation of the dynamics in US signs allows to make a right decision on prescription of antibiotic and glucocorticoid therapy. It is possible that in the future, the accumulated experience in US in patients with different clinical courses of COVID-19 (phenotypes L and H) will contribute to the diagnosis of lung recruitment maneuvers and earlier and justified transition to the prone position, as well as to the use of oxygen therapy and high positive end-expiratory pressure (PEEP) during mechanical ventilation, i.e. to preservation of the only possibility of prolonging life in some patients.

CONCLUSION

The analysis of US changes in the lungs in patients with verified coronavirus infection SARS-CoV-2 and their comparison with the data of RG and CT of the lungs indicate the possibility of using the method in the diagnosis of COVID-19 pneumonia in a tense epidemiological situation.

In the vast majority of cases, in patients with COVID-19 pneumonia, the ultrasound pattern of the lungs was characterized by interstitial lung disease. Less frequently, diffuse lesions of the lung tissue (the white lung phenomenon) and a combination of interstitial changes (interstitial lung disease and the white lung phenomenon) with pulmonary consolidation were recorded. The obtained and presented data of lung US will help doctors to improve their understanding of radiographic changes in COVID-19 pneumonia. The use of this lung imaging technique should be expanded and brought closer to the patient at any stage of diagnosis and treatment in the context of the COVID-19 pandemic due to the information content, availability, speed of implementation, and the absence of a need for patient transportation.

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Authors contribution

Porovskiy Ya.V. – conception and design, substantiation of the manuscript, analysis and interpretation of data, critical revision of the article for important intellectual content, drafting of the article. Bespalova I.D. – analysis and interpretation of data, critical revision of the article for important intellectual content, drafting of the article, editing of the article, final approval of the manuscript for publication. Sorokina T.V., Dish A.Ju. – analysis of data, editing of the article. Kanev A.F., Koshchavtseva Yu.I. – data search and analytics, interpretation of data. Chuyashenko E.V., Shoulga O.S., Balabanova A.A. – carrying out of the research, analysis of data.

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