Review / Обзор
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Lung ultrasound in COVID-19 pregnancies: a literature review

Francesca Moro[1], Giuliana Beneduce[1,✉], Danilo Buonsenso[1], Chiara Landolfo[1], Floriana Mascilini[1], Giovanni Scambia[1,2], Antonia C. Testa[1,2]
[1] Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica Largo Agostino Gemelli 8, Rome, Italy
[2] Università Cattolica del Sacro Cuore, Istituto di Clinica Ostetrica e Ginecologica Largo Francesco Vito, 1-00168 Rome, Italy

Abstract

Lung ultrasound has been recognized as a valid imaging method for diagnosing and monitoring COVID-19 pneumonia in pregnant women. The present review aimed to summarize the main findings reported in the literature and international guidelines on the role of lung ultrasound in the care of pregnant women affected by COVID-19. A search strategy was developed and applied to PubMed, Scopus, Web of Science and EMBASE to identify previous papers reporting the utility of ultrasound in diagnosing and monitoring COVID-19 pneumonia. The search retrieved 369 articles and 23 of these were selected for analysis. The articles mainly focused on the definition of the procedure, development of training programs for obstetricians managing pregnant women with suspicion of COVID-19 and definition of scoring systems. The clinical applications of lung ultrasound in this setting have also been described. This review could encourage obstetricians to learn lung ultrasound to use during critical events like a pandemic.

Keywords: pregnancy; lung ultrasound; COVID-19; obstetrics; pulmonary; pneumonia
MeSH terms:
PREGNANCY COMPLICATIONS, INFECTIOUS – DIAGNOSIS
COVID-19 – DIAGNOSIS
COVID-19 – COMPLICATIONS
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CONTACT INFORMATION:
Giuliana Beneduce, MD, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica.
Address: Via San Melchiade Papa 11, Rome, Italy
Tel.: +39 339 8193699
E-mail: giulyanaben@gmail.com

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Ультразвуковое исследование легких у беременных с COVID-19: обзор литературы

Ф. Моро[1], Дж. Бенедуче[1,✉], Д. Буонсенсо[1], К. Ландольфо[1], Ф. Масцилини[1], Дж. Скамбиа[1,2], А.К. Теста[1,2]

[1] Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья Ларго Агостино Джемелли, 8, Рим, Италия

[2] Католический университет Святого Сердца, Институт акушерства и гинекологии Ларго Франческо Вито, 1-00168, Рим, Италия

Аннотация

Ультразвуковое исследование (УЗИ) легких признано обоснованным методом исследования для диагностики и мониторинга пневмонии при COVID-19 у беременных женщин. Целью настоящего обзора является обобщение основных результатов исследований, представленных в литературе и международных руководствах о роли УЗИ легких в наблюдении беременных женщин с COVID-19. Для отбора опубликованных статей об использовании УЗИ для диагностики и мониторинга пневмонии при COVID-19 была разработана стратегия поиска, которая применена в PubMed, Scopus, Web of Science и EMBASE. В результате поиска найдено 369 статей, 23 из которых выбраны для анализа. В основном статьи посвящены описанию техники проведения УЗИ легких, разработке программ обучения акушеров, ведущих наблюдение за беременными с подозрением на COVID-19, и разработке балльных систем оценки результатов исследования. Также описана клиническая применимость УЗИ легких в этих условиях. Представленный обзор может побудить акушеров изучать методику проведения и интерпретации УЗИ легких – методику, которая может использоваться в таких критических условиях, как пандемия.

Ключевые слова: беременность; ультразвуковое исследование легких; COVID-19; акушерство; легочный; пневмония

Рубрики MeSH:
БЕРЕМЕННОСТИ ОСЛОЖНЕНИЯ ИНФЕКЦИОННЫЕ – ДИАГНОСТИКА
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COVID-19 – ОСЛОЖНЕНИЯ
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КОНТАКТНАЯ ИНФОРМАЦИЯ:
Джулиана Бенедуче, MD, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья.
Адрес: Виа Сан Мелчиади Папа 11, Рим, Италия
Tel.: +39 339 8193699
E-mail: giulyanaben@gmail.com

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List of abbreviation

COVID-19 – COrona VIrus Disease 2019
CT – computed tomography
LUS – lung ultrasound
SIS – sonographic interstitial syndrome

HIGHLIGHTS	КЛЮЧЕВЫЕ ПОЛОЖЕНИЯ
Lung ultrasound could play an essential role in the management of COVID-19 pneumonia in pregnant women.	Ультразвуковое исследование легких может играть важную роль в лечении пневмонии при COVID-19 у беременных.
Pneumologists use lung ultrasound to detect pulmonary consolidations with high sensitivity and specificity.	Пульмонологи применяют ультразвуковое исследование легких для обнаружения уплотнения легочной ткани с высокой чувствительностью и специфичностью.
There are few data in the literature about the use of lung ultrasound in COVID-19 pregnant women.	В литературе мало данных об использовании ультразвукового исследования легких у беременных с COVID-19.
With the patient in a supine position, the ultrasound examiner can simply move the probe from the abdomen to the chest, scanning the anterior and lateral areas of the thorax.	В положении пациента лежа на спине специалист по ультразвуковому исследованию может просто переместить датчик с брюшной полости на грудную клетку, сканируя ее переднюю и боковую области.
Lung ultrasound is a rapid, low-cost, safe and bed-side method for pregnant women.	Ультразвуковое исследование легких – это быстрый, недорогой и безопасный метод для беременных женщин, который может использоваться у постели пациента.
Lung ultrasound is an easily learnable method that could be taught all over the world.	Ультразвуковое исследование легких – это метод легкого обучения, которому можно научить во всем мире.
To identify a standardized approach, different image scoring systems have been proposed.	Для определения стандартизированного подхода предложены различные балльные системы оценки изображений.
In developing areas like low- and middle-income countries, ultrasound may be the only useful radiological service.	В странах с низким и средним уровнем дохода ультразвуковое исследование может быть единственным полезным методом диагностики.

At the outbreak of the COrona VIrus Disease 2019 (COVID-19) pandemic, the scientific community needed to evaluate the severity of lung involvement rapidly and in a standardized way. Even if chest computed tomography (CT) is the best imaging method in the diagnosis of COVID-19 infection, lung ultrasound (LUS) was quickly recognized as a tool for the diagnosis and monitoring of pneumonia [1]. In recent years, LUS has gained a diagnostic role in acutely dyspneic patients [2].

Pneumologists use LUS to detect pulmonary consolidations with high sensitivity and specificity, to study chronic obstructive disease, asthma, pulmonary embolism and pneumothorax, with a positive predictive value ranging from 83 to 100% [3, 4]. In the pediatric fields, LUS is also used to detect typical acute respiratory distress syndrome patterns of bilateral diffuse loss of aeration, as well as several other respiratory conditions, including the commonest disorders like pneumonia and bronchiolitis [5, 6]. LUS examination represents a substitute for chest radiography or CT since it is practical, reliable, cost-effective, and safe.

Ultrasound examination can be carried out at the bedside avoiding unnecessary movement and risks for clinicians. These advantages are more important for vulnerable patients, such as pregnant women. Physiological changes during pregnancy have a significant impact on the immune system, respiratory system, cardiovascular function, and coagulation: these may have effects on COVID-19 disease progression and lung involvement.

In the literature, there are few reviews and case reports about the role of LUS in evaluating COVID-19 disease in pregnant women. The current review aims to summarize the main findings reported in both literature and international guidelines on this role.

METHODS

Review of the literature

A search strategy was developed and applied to PubMed, Scopus, Web of Science and EMBASE to identify previous studies reporting LUS as a tool for diagnosis of pregnant women with COVID-19. We used the following words for selection “covid” and “pregnancy” and “lung ultrasound”, “lung ultrasound” and “pregnancy”, “lung ultrasound” and “pregnant women”.

RESULTS

The search retrieved 369 articles, a selection from abstracts and full texts, yielded 23 publications. We found one prospective study, one retrospective study, three reviews, two case series, five case reports, nine letters, and one guideline. We divided the selected papers into three main subgroups: definition of the procedure, training program, score systems and clinical applications.

Definition of the procedure

Many authors described how to perform LUS in different settings (i.e. obstetrics, emergency, paediatrics). For example, at Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Rome, Italy, a practical approach has been proposed for obstetricians and gynaecologists to manage pregnant women during the COVID-19 pandemic. Obstetricians and gynaecologists represent a category of clinicians who use ultrasound during their routine practice, and it would be easy for them to extend the examination to the lungs. Therefore, LUS can be considered as an ‘extension’ of the obstetric abdominal ultrasound evaluation. Both linear and convex probes can be used, but linear ones are better for evaluating details of the pleural line and subpleural

space due to their high frequencies and resolution. With the patient in a supine position, the ultrasound examiner can simply move the probe from the abdomen to the chest, scanning the anterior and lateral areas of the thorax [6].

The examination of the lung should include the whole pulmonary area, from basal to upper zones of the thorax. Four vertical lines (right mid-axillary line, right parasternal line, left parasternal line, left mid-axillary line) can be followed to perform a systematic examination. The next step is to scan the posterior paravertebral surface of the thorax with the patient in a sitting or lateral position [7].

M. Yassa et al. also described how to perform the LUS on pregnant women: for each patient fourteen areas (3 posterior, 2 lateral, and 2 anterior) were scanned for at least 10 seconds [8].

The exam was performed in supine, right-sided and left-sided positions. Where applicable, scanning from the intercostal space is preferred.

G. Soldati et al. proposed the same standard sequence of evaluations of fourteen areas (3 posterior, 2 lateral, and 2 anterior), using landmarks on chest anatomic lines [9].

For a patient able to maintain the sitting position the sequence includes: right basal on the paravertebral line above the curtain sign; right middle on the paravertebral line at the inferior angle of the shoulder blade; right upper on the paravertebral line at the spine of the shoulder blade; left basal on the paravertebral line above the curtain sign; left middle on the paravertebral line at the inferior angle of the shoulder blade; left upper on the paravertebral line at the spine of the shoulder blade; right basal on the midaxillary line below the internipple line; right upper on the midaxillary line above the internipple line; left basal on the midaxillary line below the internipple line; left upper on the midaxillary line above the internipple line; right basal on the midclavicular line below the internipple line; right upper on the midclavicular line above the internipple line; left basal on the midclavicular line below the internipple line; and left upper on the midclavicular line above the internipple line.

Development of training program. One single experience

To date, only one standardized training experience has been reported. a research team in Rome, Italy, developed a specific single day training program to provide gynaecologists and obstetricians, already skilled in ultrasound examination, with the theoretical background for the recognition of the main LUS patterns. The program design was presented to the COVID-19 Research Ethical Committee who evaluated and approved the project [10]. The teachers were two pneumologists and one paediatrician skilled in LUS. They all have more than 10 years of experience in LUS practice, research and teaching. The teaching program is available on a dedicated website[1].

The training program consisted of three phases: a phase 1 of 15 minutes pre-test, including 10 ultrasound video clips submitted to 11 learners. Each video showed normal (pattern = 1) or typical pathological (patterns = 2–6) lung ultrasound patterns; phase 2 consisted of a theoretical lesson on LUS findings both normal and pathological; phase 3 consisted of 15 minutes post-test to verify the knowledge acquired. During post-test analysis, the ultrasound patterns were divided into two groups (pattern 1 = normal and patterns 2–6 = abnormal), 8/10 participants correctly discriminated normal from pathological patterns in all cases, 2/10 in 90% of cases, and 1/10 in 80% of cases. This experience is a useful preliminary step for teaching theoretical LUS skills [10].

During the COVID-19 emergency the University Centre for International Solidarity of Università Cattolica, in Rome, (CESI) and Fondazione Policlinico Universitario A. Gemelli, IRCCS, in Rome, promoted a distance learning project called “Fast lung ultrasound teaching program beyond Europe during COVID-19 pandemic: Africa’s reality”. Ten doctors, together with physicists and engineers from the University of Trento, prepared a training protocol to support doctors and health care workers in Africa in the use of LUS. The ultrasound equipment, available in many African hospitals to monitor pregnant women, can be converted into a COVID-19 detector[2].

Interpretation of the images. Score systems

To identify a standardized approach, different image scoring systems have been proposed. In a normal lung, at ultrasound examination, the pleura appears as a highly hyperechoic horizontal line (pleural line) and hyperechoic, parallel, horizontal artifacts (‘A-lines’) are visible [11]. A-lines indicate normal inflated peripheral lungs if combined with the ‘sliding’ of the pleural line [12].

In the cases of viral pneumonia, interstitial lung disease, pulmonary fibrosis, pulmonary oedema, lung deflation, or lung contusion, different shapes and lengths of vertical artifacts, called B-lines, are generated [13]. Another typical pattern of viral pneumonia is the “white lung”, where white is visible, and the pleural line is irregular and thickened. The distribution of the white area can be monofocal or multifocal, patchy, surrounded by spared areas and with no gravitational distribution. This pattern is common during the early stage of COVID-19 when no A or B-lines are visible [12]. If any consolidation (hypoechoic areas) appears, there is loss of lung aeration and a transition of these areas towards acoustic properties like soft tissue. Below these irregular hypoechoic areas, vertical artifacts are generally found [14].

A standardized approach to optimize the use of LUS in patients with COVID-19 has been proposed. In the setting of COVID-19, wireless transducers and tablets represent the most appropriate ultrasound

[1] https://covid19.disi.unitn.it/iclusdb/login

[2] https://centridiateneo.unicatt.it/solidarieta-internazionale-studi-e-ricerche-fast-lung-ultrasound-teaching-program

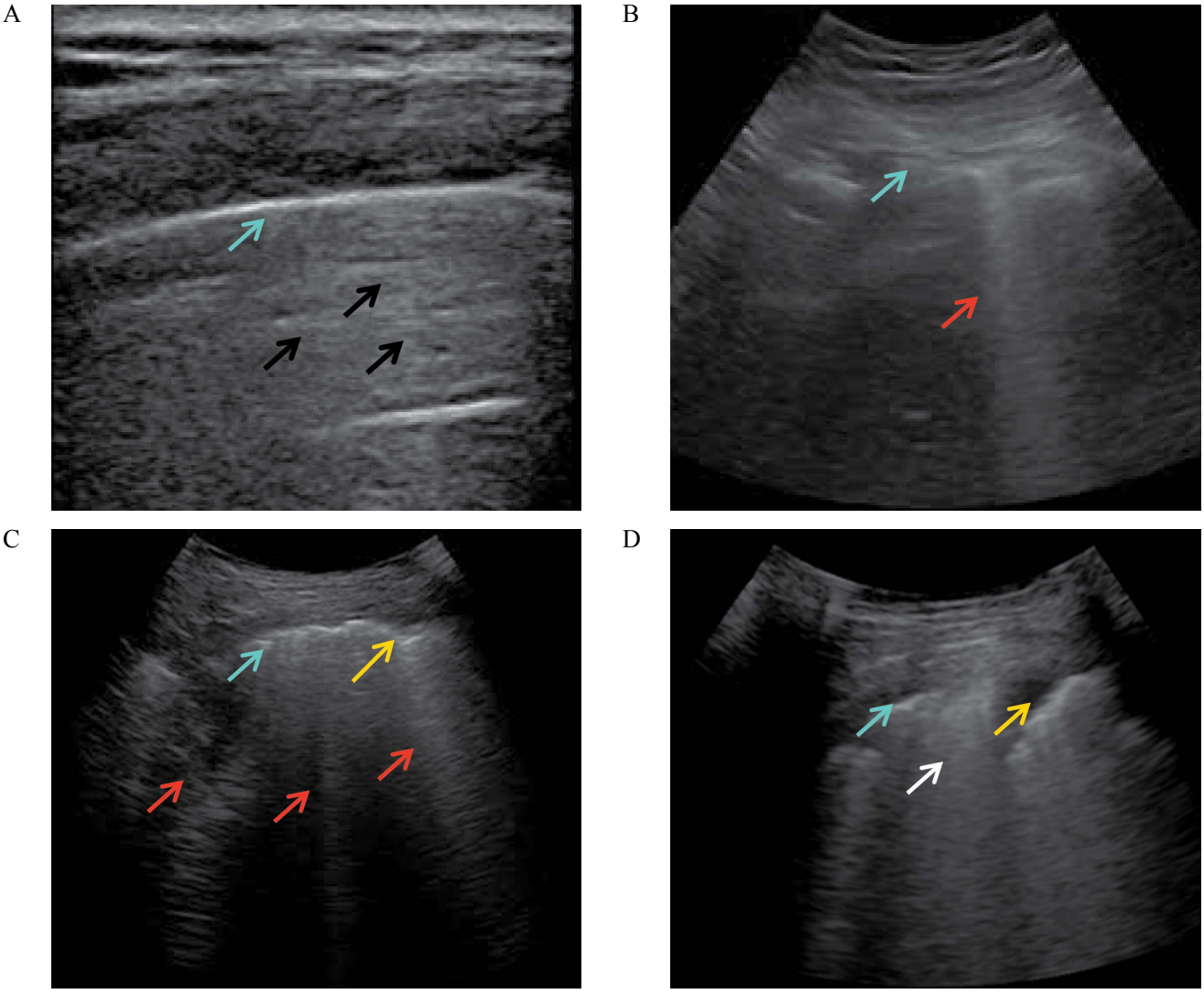

FIG. Lung ultrasound imaging and the scoring system (A–D). (A) Score 0: a regular pleural line (blue arrow) and A-lines (black arrows); (B) Score 1: an irregular pleural line (blue arrow) and an isolated B-line (red arrow); (C) Score 2: an irregular pleural line (blue arrow), multiple B-lines (red arrows), and consolidations (yellow arrow); (D) Score 3: an irregular pleural line (blue arrow), large area of white lung (white arrow) and subpleural consolidations (yellow arrow).

РИС. Ультразвуковое исследование легких и балльная система (A–D). (A) 0 баллов: непрерывная плевральная линия (голубая стрелка) и А-линии (черные стрелки); (B) 1 балл: прерывистая плевральная линия (синяя стрелка) и единичная В-линия (красная стрелка); (C) 2 балла: прерывистая плевральная линия (синяя стрелка), множество В-линий (красные стрелки) и консолидация (желтая стрелка); (D) 3 балла: прерывистая плевральная линия (синяя стрелка), большой участок белого легкого (белая стрелка) и субплевральная консолидация (желтая стрелка).

equipment because they can be wrapped in single-use plastic covers, reducing the risk of contamination. If these devices are unavailable, portable ones can be used, although maximum care for sterilization is necessary. The authors realized an easy score system to evaluate lung involvement of COVID-19 patients: for each of the 14 areas evaluated the ultrasound examiner writes the highest score obtained [9]:

- Score 0: If you can see a continuous and regular pleural line with horizontal artifacts, referred to as A-lines (Figure A).
- Score 1: If the pleural line is indented and there are visible vertical areas (linked to local changes) referred to as B-lines. Vertical artifacts, resulting in the so-called sonographic interstitial syndrome (SIS) are indicative of a hyperdense pre-consolidated lung state (Figure B).
- Score 2: If the pleural line is broken and there are consolidated areas due to the loss of aeration, with associated areas of white, and with air still present; this condition is called white lung (Figure C).
- Score 3: If there are largely extended parts of white lung (Figure D) [9].

In recent years, other authors have proposed similar scores. According to Q. Deng et al each zone was scored as follows: a normal lung pattern with normal

lung sliding with A-lines or fewer than two isolated B-lines was scored as 0; the presence of 3 or more well-spaced B-lines presented in a single intercostal space was scored as 1; the presence of crowded B-lines (more than 50% range in a view) with or without consolidation limited to the subpleural space was scored as 2; the presence of confluent B-lines (approaching 100% range in a view) or a tissue pattern with dynamic air bronchogram, defined as lung consolidation, was scored as 3 [15]. The most severe ultrasound finding can be considered representative of the entire zone. In the same way, L. Ji et al. used the following scores in line with previous studies: score 0: well-spaced B-lines < 3; score 1: well-spaced B-lines ≥ 3; score 2: multiple coalescent B-lines; score 3: lung consolidation [16]. The pleural line was quantitatively scored as follows: score 0: normal; score 1: irregular pleural line; score 2: blurred pleural line [16] (table).

According to available evidence, suspicious ultrasound findings, even not specific, for COVID-19 pneumonia are the presence of alterations of pleural line and SIS with patchy, bilateral distribution in symptomatic patients; white lung with patchy, bilateral distribution associated or not with small subpleural consolidations. SIS with homogeneous bilateral distribution without spared areas and regular, bright, vertical artifacts with gravitational distribution, is suggestive of cardiogenic pulmonary oedema. Moreover, large, unilateral consolidations, as well as large pleural effusions, are patterns usually not compatible with COVID-19 pneumonia [17, 18].

Clinical applications

No prospective studies have been published describing the impact of LUS in the management of pregnant women affected by COVID-19. In a small series of patients, LUS has been used in this management. The authors assessed lung involvement of four pregnant patients on admission to hospital and during disease. The advantage of LUS is that it is radiation-free, and therefore can be used as the first diagnostic step before chest X-ray or CT scan [19].

Last year, M.G. Porpora et al. evaluated the role of LUS in the decision-making process, studying the correlation between LUS score and CT score carried out after delivery, which strengthens the reliability of LUS as an alternative diagnostic method to CT in pregnant women [20]. Chest CT was performed after delivery in patients with high LUS score or persistent respiratory symptoms and showed a score up to 4 with an involvement <10% in five cases, a score between 5 and 8 with involvement of 10–25% in three women, while in the patients with a LUS score of 23, CT showed 60–70% lung involvement with a score of 16. Even if the CT findings were more precise than LUS in defining pulmonary impairment, these results suggest a positive correlation between LUS and CT [20].

Table. **Score systems for evaluating ultrasound of the lungs**

Таблица. **Системы балльной оценки ультразвукового исследования легких**

Author, ref. / Автор, № источника	N° of areas explored / Количество исследуемых зон	Score 0 / 0 баллов	Score 1 / 1 балл	Score 2 / 2 балла	Score 3 / 3 балла	Total score / Сумма баллов
Soldati G. [9]	12	Continuous and regular pleural line with horizontal artifacts, referred to as A-lines / Непрерывная и ровная плевральная линия с горизонтальными артефактами – А-линиями	Pleural line is indented with vertical areas referred to as B-lines / Плевральная линия прерывается вертикально расположенными В-линиями	Pleural line is broken with consolidated areas, and areas of white / Плевральная линия прерывается консолидированными участками и участками белого цвета	Largely extended part of white lung / Значительная часть легкого представлена белым цветом	36
Deng Q. [21]	8	Normal lung sliding with A-lines or <2 isolated B-lines / Нормальное движение легких с А-линиями или <2 изолированными В-линиями	≥3 well- spaced B-lines presented in a single intercostal space / ≥3 четко разделенных В-линий, представленных в одном межреберье	Crowded B-lines (> 50% range in a view) with or without consolidation limited to the subpleural space / Множество В-линий (>50% в зоне исследования) с консолидацией, ограниченной субплевральным пространством или без нее	Confluent B-lines or a tissue pattern with dynamic air bronchogram, defined as lung consolidation / Сливающиеся В-линии или рисунок ткани с динамической воздушной бронхограммой – консолидация	24
Ji L. [16]	12	Well-spaced B-lines <3 / Четко отделенные друг от друга В-линии <3	Well-spaced B-lines ≥3 / Четко отделенные друг от друга В-линии ≥3	Multiple coalescent B-lines / Несколько сливающихся В-линий	Lung consolidation / Консолидация	36

CT and LUS images of 39 pregnant patients were retrospectively collected and compared by Q. Deng et al. [21]. Quantitative LUS scores correlated highly with chest CT findings and could effectively evaluate lung lesions in pregnant women. Pearson correlation analysis revealed high correlation on admission (r = 0.793, $p < 0.01$) between LUS and CT. Some authors proposed an approach to manage admission of pregnant women to hospital when COVID-19 is suspected (fever, dry cough, and dyspnea) [22].

Patients should undergo LUS to define subsequent diagnostic/therapeutic steps. In most cases, pregnant women have a normal LUS pattern, while, in advanced pregnancy, a mild, posterior, bilateral, basal, homogenous SIS could be detectable for volume reduction of inferior lung lobes.

If LUS findings show patchy, bilateral SIS with or without small patchy, bilateral, subpleural consolidations, patients must isolate until the results of microbiological tests (both nasal/throat swab and rapid serologic tests). If LUS does not indicate COVID-19 lung involvement, arterial blood gases (ABG) must be evaluated. When PaO2/FiO2 ratio is < 400, patients should be isolated, until microbiological test results (both nasal/throat swab and rapid serologic tests) are obtained. a positive result of these tests requires hospitalization and isolation. If microbiological tests are both negative, a chest X-ray is necessary. In case of both LUS with no signs of COVID-19 pneumonia and normal gas exchanges with PaO2/FiO2 > 400, pregnant women undergo maternal and fetal monitoring until microbiological test results. If both microbiological tests are negative, the patient should be isolated at home, maintaining contact either in the case of worsening symptoms requiring hospital admission or in the case of mild and stable symptoms, waiting for the results of the second Sars-CoV-2 swab test.

In the literature there are other non-systematic pictorial reviews whose authors postulated that LUS should be the first-choice imaging method in pregnant women suspected of having COVID-19 infection [8]. A. Giannini et al. used LUS to evaluate the progression of disease in pregnant women affected by COVID-19 pneumonia and they suggested the additional use of LUS in routine lung ultrasonography aimed at tracking the evolution of the disease [23]. In contrast, M. Sperandeo et al. considered the use of LUS in COVID-19 pneumonia restricted and confusing, because of the nonspecific findings that may be misleading [24].

DISCUSSION

LUS has been demonstrated to be an accurate imaging method to detect pulmonary and pleural conditions and evaluate lung involvement and its evolution in pregnant women affected by COVID-19. During pregnancy, there is a need for rapid, low-cost, safe, and bed-side assessment of the maternal lung in patients with suspected coronavirus disease. Chest CT may be reserved for cases where LUS is insufficient to answer the clinical question. In addition, LUS results are immediately available to the clinician, allowing decisions about the initial empirical treatment and it is also an easily learnable tool.

In developing areas like low- and middle-income countries, ultrasound may be the only useful radiological service. During a pandemic, training is also fundamental for the sustainability, quality, and reliability of this method. LUS can be learned by a variety of medical professionals, not just radiologists, to permit rapid assessment and treatment in a variety of settings [25].

This narrative review demonstrated that LUS can be used in a standardized way to detect lung involvement. Little data is available in the literature on this topic. We recognize that our study is a narrative review and not a systematic review or metaanalysis, lacking important requirements for quality control such as risk of bias, quality assessment, and statistical analysis. However, our goal was to provide an overview of the literature on the new role of LUS in diagnosing pregnant women affected by COVID-19 and to offer a strategy to manage these patients.

CONCLUSION

The pandemic has taught us to reallocate our resources, and to make the best use of our talents. LUS is a promising imaging tool that can be used for pregnant women with suspected COVID-19 pneumonia following an initial fetal assessment. This review can encourage obstetricians to learn LUS to be used during pandemics and to provide more knowledge in this field. Other prospective studies should be explored.

AUTHOR CONTRIBUTIONS

Francesca Moro is responsible for study design, drafting of the manuscript and data interpretations. Giuliana Beneduce researched and analyzed the literature on the review topic and drafted the manuscript. Danilo Buonsenso, Chiara Landolfo, and Floriana Mascilini, participated in writing the text of the manuscript and its interpretation. Giovanni Scambia and Antonia Carla Testa are responsible for the critical revision of the manuscript and for the important intellectual content and developed the general concept of the article and supervised its writing. All authors participated in the discussion and editing of the work. All authors approved the final version of the publication.

ВКЛАД АВТОРОВ

Ф. Моро разработала дизайн исследования, участвовала в интерпретации данных и написании рукописи. Дж. Бенедуче проводила поиск и анализ источников по теме обзора и подготовила текст рукописи к публикации. Д. Буонсенсо, К. Ландольфо и Ф. Масцилини участвовали в интерпретации данных и написании текста. Дж. Скамбиа и А.К. Теста разработали общую концепцию статьи, руководили ее написанием и несут ответственность за критический пересмотр рукописи на предмет основного интеллектуального содержания. Все авторы участвовали в обсуждении и редактировании работы. Все авторы одобрили окончательную версию публикации.

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INFORMATION ABOUT THE AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

Francesca Moro, MD, PhD, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica.
ORCID: https://orcid.org/0000-0002-5070-7245

Моро Франческа, MD, PhD, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья.
ORCID: https://orcid.org/0000-0002-5070-7245

Giuliana Beneduce✉**,** MD, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica.
ORCID: https://orcid.org/0000-0003-3866-2109

Danilo Buonsenso, MD, PhD, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica.
ORCID: https://orcid.org/0000-0001-8567-2639

Chiara Landolfo, MD, PhD, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica.
ORCID: https://orcid.org/0000-0001-9808-7957

Floriana Mascilini, MD, PhD, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica.
ORCID: https://orcid.org/0000-0003-0736-3114

Giovanni Scambia, MD, PhD, Prof., Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica; Università Cattolica del Sacro Cuore, Istituto di Clinica Ostetrica e Ginecologica.
ORCID: https://orcid.org/0000-0003-2758-1063

Antonia Carla Testa, MD, PhD, Prof., Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Dipartimento Scienze della Salute della Donna, del Bambino e di Sanità Pubblica; Università Cattolica del Sacro Cuore, Istituto di Clinica Ostetrica e Ginecologica.
ORCID: https://orcid.org/0000-0003-2217-8726

Бенедуче Джулиана✉**,** MD, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья.
ORCID: https://orcid.org/0000-0003-3866-2109

Буонсенсо Данило, MD, PhD, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья.
ORCID: https://orcid.org/0000-0001-8567-2639

Ландольфо Кьяра, MD, PhD, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья.
ORCID: https://orcid.org/0000-0001-9808-7957

Масцилини Флориана, MD, PhD, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья.
ORCID: https://orcid.org/0000-0003-0736-3114

Скамбия Джованни, MD, PhD, профессор, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья; Католический университет Святого Сердца, Институт акушерства и гинекологии.
ORCID: https://orcid.org/0000-0003-2758-1063

Теста Антония Карла, MD, PhD, профессор, Больница Университета Агостино Джемелли, Научный институт исследований, госпитализации и здравоохранения (IRCCS), Департамент женского, детского и общественного здоровья; Католический университет Святого Сердца, Институт акушерства и гинекологии.
ORCID: https://orcid.org/0000-0003-2217-8726

✉ Автор, ответственный за переписку / Corresponding author