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Contents

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OPINION REVIEW

- 56 Implementation of lung ultrasound in the triage of pregnant women during the SARS-CoV-2 pandemics
Tekin AB, Yassa M

MINIREVIEWS

- 64 Application of radiomics in hepatocellular carcinoma: A review
Jin ZC, Zhong BY
- 73 Artificial intelligence in coronary computed tomography angiography
Zhang ZZ, Guo Y, Hou Y

Contents

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Implementation of lung ultrasound in the triage of pregnant women during the SARS-CoV-2 pandemics

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Abstract

Lung ultrasound (US) has been shown that it is able to detect interstitial lung disease, subpleural consolidations and acute respiratory distress syndrome in clinical and physical studies that assess its role in upper respiratory infections. It is used worldwide in the coronavirus disease 2019 (COVID-19) outbreak and the effectiveness has been assessed in several studies. Fast diagnosis of COVID-19 is essential in deciding for patient isolation, clinical care and reducing transmission. Imaging the lung and pleura by ultrasound is efficient, cost-effective, and safe and it is recognized as rapid, repeatable, and reliable. Obstetricians are already using the US and are quite proficient in doing so. During the pandemic, performing lung US (LUS) right after the fetal assessment until reverse transcription polymerase chain reaction results are obtained, particularly in settings that have a centralized testing center, was found feasible for the prediction of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. The use of LUS is efficient in the triage and monitoring of pregnant women. Clinicians dealing with pregnant women should consider LUS as the first-line diagnostic tool in pregnant women during the SARS-CoV-2 pandemic.

Key Words: COVID-19 pandemics; Lung; Ultrasound imaging; Pregnancy; SARS-CoV-2; Triage

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Core Tip: Lung ultrasound (US) is based on specific pattern recognition and does not require complex measurements, therefore obstetricians can easily learn and use lung ultrasound (LUS) in the pandemic. LUS examination can be a routine after a routine obstetric US examination. Fast diagnosis of coronavirus disease 2019 is essential in

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deciding for patient isolation, clinical care, and reducing transmission. Clinicians dealing with pregnant women should consider LUS as the first-line diagnostic tool in pregnant women during the severe acute respiratory syndrome coronavirus 2 pandemic.

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INTRODUCTION

Lung ultrasound (US) use has been discussed for years in emergency medicine, intensive care units, and cardiovascular diseases. The use of lung US (LUS) has increased in the last 15-20 years upon advancements in the visualization of pleural effusions, lung masses, and afterward evolved to be able to evaluate lung parenchyma mainly as a point-of-care technique[1]. Pulmonologists, emergency medicine physicians, thoracic and cardiac surgeons often benefit from LUS in the management of traumatic conditions and intraoperative situations[2]. Coronavirus disease 2019 (COVID-19) pneumonia mainly involves the lung periphery and causes interstitial pneumonia. Therefore, LUS is highly suitable for the management of this disease[3]. The obstetricians are already familiar with the US and they are at the frontline in the fight against the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic for infected pregnant women treatment[4]. LUS is based on specific pattern recognition and does not require complex measurements, therefore the obstetricians can easily learn and use LUS in the pandemic[1,5].

SCORING SYSTEM FOR LUS

LUS has been shown that it is able to detect interstitial lung disease, subpleural consolidations and acute respiratory distress syndrome in clinical and physical studies that assess its role in upper respiratory infections[6-8]. It is widely used worldwide in the COVID-19 outbreak and the effectiveness has been assessed in several studies[9-14]. LUS evaluation covers 14 anatomical regions, 3 posterior, 2 lateral, 2 anterior, in both hemithorax and intercostal spaces in supine, right lateral, left lateral positions during at least 10 s[6]. In different scoring systems, the target regions were varied between 4 to 7 regions for each hemithorax[15]. Pleural thickness, pleural continuity, pleural drift (with inspiration and expiration), presence of subpleural consolidated areas, parenchymal artifacts (vertical, horizontal), and the presence of a white lung pattern should be focused in every region. The results of 14 anatomical regions are scored between 0 and 3; LUS 0 is defined as normal LUS findings, LUS score of 1 is defined as mild involvement, LUS score of 2 is defined as moderate involvement and LUS score of 3 is defined as severe lung involvement[6]. Normal US findings (LUS 0) represent thin, continuous, and regular pleural lines, presence of respiratory pleural shift and parenchymal horizontal artifacts due to normally aerated lung surface reflectivity (A lines) in LUS. Mild involvement (LUS 1) is defined with an indented pleural line (irregularities in the pleural line, continuity is not broken), the sporadic vertical white area under the pleura (B line). Moderate involvement (LUS 2) is defined with broken pleura (continuity disorder in the pleural line), small to the large white area of consolidation under pleura, and multiple white vertical lines (B lines) that progress to the end of the viewed area. Severe lung involvement (LUS 3) is defined as a severe broken pleura pattern in addition to a dense and wide "white lung" pattern with or without consolidated area in LUS[6]. B lines, small consolidated areas and broken pleural lines are suggestive of COVID-19[16]. Bacterial pneumonia is mainly represented with isolated large lobar consolidation with or without pleural effusion and dynamic air bronchograms[17].

ADVANTAGES OF LUS

Fast diagnosis of COVID-19 is essential in deciding for patient isolation, clinical care and reducing transmission. For diagnosis of COVID-19, symptoms are leading us and mainly reverse transcription polymerase chain reaction (RT-PCR) testing is the first choice for definitive diagnosis. However, the sensitivity of the SARS-CoV-2 RT-PCR which is the gold standard for diagnosis is estimated as 75% [18]. Furthermore, RT-PCR results may need several days and cannot be sufficient in places with high patient density [18]. Concerning radiologic diagnosis of COVID-19 is based on chest computed tomography (CT) with typical ground-glass opacities and patchy infiltrates in chest radiography, or both [10]. The main advantage of LUS is not only reducing the exposure to ionizing radiation but also reducing the risk of contamination and decrease the burden on the health system. Moreover, it enables monitoring (repetitive measurements) [4,9-11]. However, CT has disadvantages of ionizing radiation exposure, the need for extensive decontamination and is unobtainable in resource-limited situations. Owing to these facts, CT is not an optimal screening tool and not feasible in monitoring the patient's clinical situation [18]. Especially when we think of a special population such as pregnant women or pediatric patients, CT is not an attractive choice for the diagnosis of lung involvement. A low level of ionizing radiation exposure by chest imaging during pregnancy is considered relatively safe, but this can cause anxiety for many pregnant women and health care providers [10]. More than half of the pregnant women refused to have the chest CT in our center (unpublished data).

Imaging the lung and pleura by the US is efficient, cost-effective, and safe, and it is recognized as rapid, repeatable, and reliable [8]. LUS is convenient for bedside evaluation of patients and suitable for vulnerable populations such as pregnant women and children [11,19]. It is already well-known that LUS has the advantages of being a non-ionizer, rapid and easy to perform, and provides dynamic imaging. In addition, LUS has a value and an advantage of applicability to a variety of practice environments, when the other diagnostic tools are unavailable [18].

Obstetricians are already using the US and quite proficient in the use of it. During the pandemic, it was proposed that LUS may be performed by obstetricians and therefore, LUS examination can be a routine after a routine obstetric US examination [4]. This approach might have an impact on reducing the workload of radiologists and the need for chest CT, thereby minimizing the risk of transmission. Pregnant and non-pregnant women have previously been reported to be similar with regard to radiologic findings of COVID-19 [10,20]. Performing LUS right after the fetal assessment until RT-PCR results are obtained, particularly in settings that have a centralized testing center, was found feasible for the prediction of the SARS-CoV-2 infection. This approach is successful in reducing the use of chest CT or X-rays for pregnant women.

TRIAGE WITH LUS

Despite the extensive use of LUS in clinical studies, the use of LUS in the triage of pregnant women during the COVID-19 pandemic is still scarce in the literature.

One of the main problems in the management of the population during the SARS-CoV-2 pandemic is to determine the asymptomatic carriers [21]. This issue becomes prominent in pregnant women due to the mixed symptoms that can naturally be interpreted as common complaints of pregnancy. In a recent study by Sutton *et al* [21], the asymptomatic carrier rate in the labor ward was found as 13.7%. Another milestone study from Vintzileos *et al* [22] showed that two-thirds of all pregnant women infected with SARS-CoV-2 were asymptomatic during admission to the labor ward unit. Those results have raised concerns about the high rate of asymptomatic carriers during intensely progressing pandemic.

In our clinic, patients with symptoms are isolated in the hospital until SARS-CoV-2 RT-PCR results are obtained. Asymptomatic pregnant women are initially triaged using LUS and their clinic management is adjusted according to the obtained LUS score. Asymptomatic patients with mild lung involvement were closely followed up until RT-PCR results with home isolation and further close monitoring with LUS is planned. Pregnant women with moderate or severe lung involvement in US receive medical treatment regardless of being symptomatic or asymptomatic. Possible false-negative cases, that are symptomatic with initial normal LUS findings are scheduled for a repeat US in 3 d and offered for Chest CT. This algorithm is schematized in Figure 1.

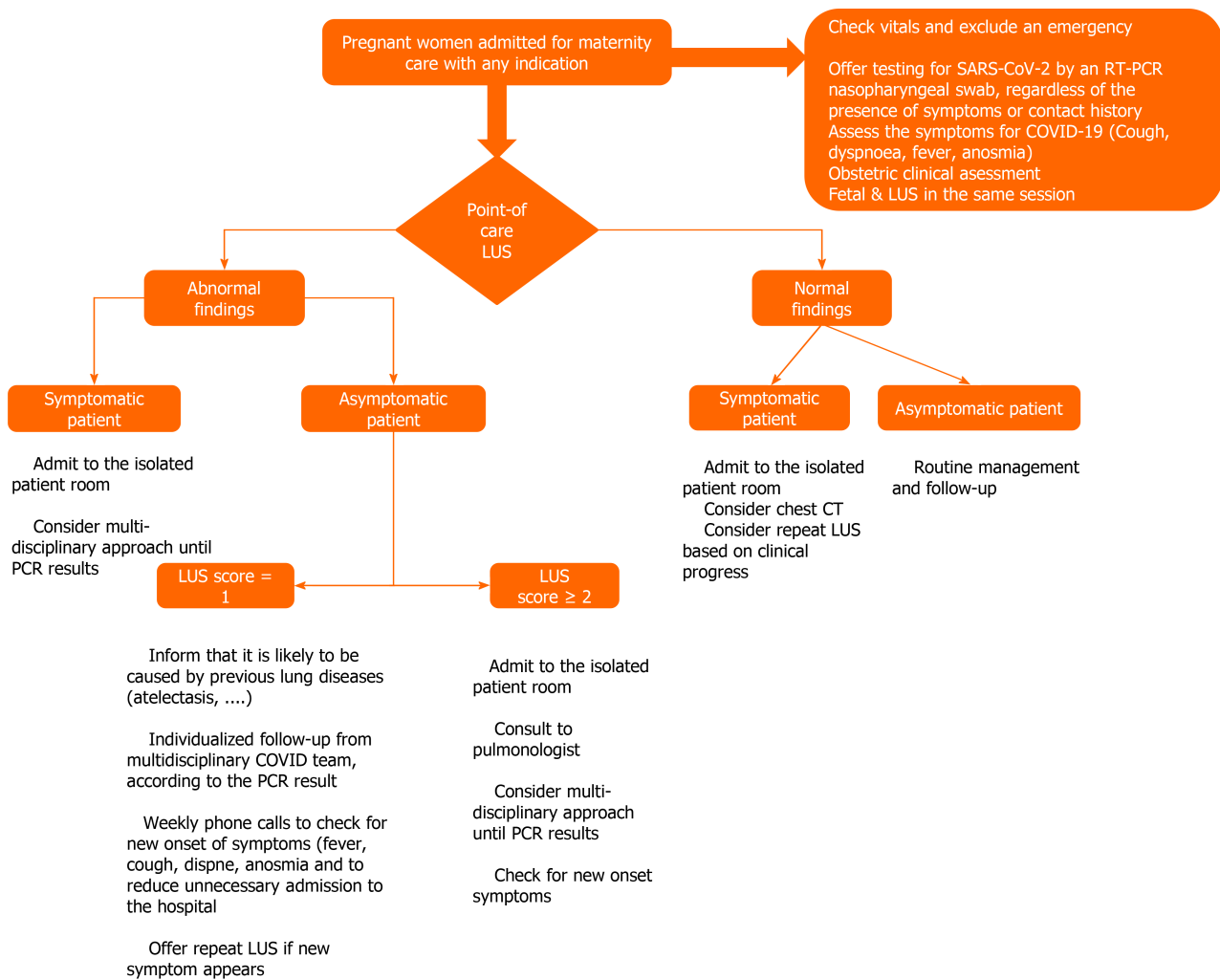


Figure 1 Main triage algorithm of pregnant women based on lung ultrasound. COVID: Coronavirus disease; COVID-19: Coronavirus disease 2019; CT: Computed tomography; LUS: Lung ultrasound; PCR: Polymerase chain reaction; SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2.

Pregnant women are vulnerable population that possess medical and social burdens. In the COVID-19 pandemic, they require several encounters with the healthcare staff, and most of them are hospitalized for birth[23]. The common physiological changes of pregnancy may coincide with the symptoms of COVID-19 infection and undetected cases of COVID-19 were 4-9 cases to 1 detected case in a study in the labor ward[24]. The undetected infection has been thought to contribute to the transmission of the virus[25]. Due to the excess of undetected cases and transmission of infection from asymptomatic carriers, the need for universal screening of pregnant women is emphasized[21,22]. All pregnant women should be offered RT-PCR testing for SARS-CoV-2 infection regardless of the maternal symptoms on admission to the hospital according to the Royal College of Obstetricians & Gynecologists statement[26]. Our study investigating the universal testing strategy for SARS-CoV-2 infection with RT-PCR in pregnant women who were admitted to the hospital showed an overall and asymptomatic infection diagnosis rate of 7.77% and 4.05%, respectively[27]. The false positivity of LUS was due to previous benign lung diseases where the main maternal symptom status comes forward in the interpretation of LUS findings[27]. In our routine approach, LUS comes prior to the maternal symptomatology because mild COVID-19 symptoms can interfere with the natural pregnancy-related symptoms, moreover, we observed that LUS signs can alert the clinician before bothersome symptoms occur. In our algorithm for the interpretation of LUS findings that combines the lung imaging and the maternal symptomatology; a LUS score of 1 was accepted as a normal finding in asymptomatic pregnant women with aiming to reduce the false positivity of LUS imaging. LUS scores of 2 and 3 were adopted as abnormal regardless of the symptom status. In addition, using LUS in the triage of pregnant women was found more predictive in detecting the infection than the use of symptomatology solely with a positive predictive value and sensitivity of

82.3% and 60.9%, respectively[27].

MONITORING WITH LUS AND OTHER AREAS OF USE

In monitoring the clinical progress of pregnant women, LUS is a harmless choice and valuable in terms of deciding either delivery or upgrade the medical treatment[10]. LUS is a very practical alternative in the respiratory system propaedeutic as it allows for repetition of exams, can be portable and performed at the patient's bedside[15]. The recent study suggested the integration of LUS into the routine clinical management of COVID-19[28]. In addition, this recent study emphasized in the emergency department that LUS may correctly triage patients according to their degree of lung involvement[28]. Abnormal LUS findings were reported as relevant with early admission into emergency units or intensive care units[27]. It is reasonable to offer LUS for the triage and monitoring of the clinical progress of patients with leaving the indication of chest CT scan as reserved only for the more complex cases, such as unexpected deterioration in clinical progress and patients with previous lung diseases[28]. Moreover, the detection power for the presence of consolidations there was found in a good agreement between the chest CT and LUS[29]. The studies regarding LUS usage in pregnant women are summarized in Table 1[10,27,30-36].

Considering the patients who are receiving respiratory support is recommended that they should be monitored closely for clinical deterioration[37]. In this regard, serial LUS is suitable for efficient monitoring[37]. The decision to proceed with invasive mechanical ventilation and intubation can be a challenging choice and LUS might be an accurate indicator of the ideal moment of intubation[37]. In intubated patients, LUS could evaluate the pulmonary aeration loss and ventilation condition dynamically thus, enabling the prediction of the healing process[37]. In intensive care units, chest CT scan is risky for transporting critically unwell patients, and decontamination is a time-consuming process[37]. The use of portable chest radiographs is not suitable due to the poor correlation with clinical picture[37].

LIMITATIONS OF LUS

Despite the several advantages of LUS in the COVID-19 pandemic setting, the diagnostic accuracy of LUS may be affected by the patient's characteristics and comorbidities including elevated body-mass index and pre-existing interstitial lung diseases[38,39]. The findings of preexisting interstitial inflammation, scarring, and pleural thickening can mimic the initial COVID-19 imaging. In addition, heart failure causing pulmonary edema or end-stage renal disease may lead to diagnostic confusion with the interstitial inflammation caused by COVID-19. Approximately 70% of the lung surface can be visualized with a systematic LUS examination, however, lesions located in the blind area of the US can be missed[31].

The studies investigating the use of LUS in the COVID-19 pandemic have included small sample sizes and much effort is needed to increase the quality of those studies to promote the LUS scanning in the triage of COVID-19[15]. The specific protocols for triage should be formed and the effects of the clinicians' experience and the inter-operator agreement should be further studied[40-42].

User-related limitations can be challenging in the management of the patient that depends on the LUS scores. It is postulated that less-experienced users are tended to label the mild abnormalities in a single lung field as compatible with COVID-19. The US settings of the LUS can affect the interpretation of LUS images such as undergained or overgained images may lead to false-negative or positive assessments[18].

CONCLUSION

LUS is promising in the management of pregnant women with COVID-19 with considering the advantages of being non-ionizer, dynamic, rapid, reliable, and reproducible. The use of LUS seems efficient in the triage and monitoring of pregnant women. LUS scanning can be combined with initial maternal symptom status in order to reduce the false positivity of LUS. Clinicians dealing with pregnant women may consider LUS as the first-line diagnostic tool in pregnant women during the SARS-CoV-2 pandemic.

Table 1 Studies reported the use of lung ultrasound in pregnant women with coronavirus disease 2019

Ref.	Country	Type of study	Cohort	Diagnosis	LUS technic	Conclusion
Buonsenso <i>et al</i> [31], 2020	Italy	Case report	4 pregnant women at 24, 38, 17, and 35 wk gestational age	LUS was carried out before the positive RT-PCR result. Nasopharyngeal swab RT-PCR confirmation	14 regions evaluation with the convex probe.	LUS was correlated with CT findings, this tool should be considered in clinical deterioration to check the lung status for COVID-19 pneumonia and LUS might be preferred to chest X-ray in pregnant women
Deng <i>et al</i> [31], 2021	China	Retrospective study	27 of pregnant women at the third trimester, 8 of them at the second trimester, and 4 of them at the first trimester	29 of them with pharynx RT-PCR testing and 10 with epidemiologic history, symptoms, and imaging results	12 zones: 2 anterior zones, 2 lateral zones, and 2 posterior zones <i>per</i> side. Each zone was scored 0 to 3 and total LUS scores were used in the clinical assessment of patients	Quantitative LUS can be considered a reliable follow-up tool for dynamic lung monitoring in pregnant women with COVID-19 and can reduce the use of chest CT
Gil-Rodrigo <i>et al</i> [32], 2021	Spain	Letter to the editor	4 women at gestational weeks 6, 9, 19 and 25, 2 of them confirmed as COVID-19	Symptoms and LUS were used as initial assessment and nasopharyngeal swab RTPCR was used for confirmation	With convex transducer, 8 posterior lung areas	With regard to potential disease transmission during a pandemic, LUS in pregnant women enables safe diagnosis and early treatment. One of the limitations is the absence of standardized training, the learning curve is relatively
Inchingolo <i>et al</i> [33], 2020	Italy	Case report	1 pregnant woman at 23 wk gestational age	Oropharyngeal swab RT-PCR	14 regions with Convex wireless transducer (3.5 MHz)	Point-of-care LUS examination could play a key role in the assessment of pregnant women with suspected COVID-19
Kalafat E <i>et al</i> [34], 2020	Turkey	Case report	32-yr-old woman at 35 + 3 wk gestational age	Symptoms and lung ultrasound findings first and confirmed by nasopharyngeal RT-PCR after	Thick and bilateral B-lines in the basal posterior lungs area (during the first assessment), diffuse B-lines (2 d later)	Report of positive lung ultrasound findings consistent with COVID-19 in a pregnant woman with an initially negative RT-PCR result
Porpora <i>et al</i> [35], 2021	Italy	Prospective observational study	30 pregnant women at 36 wk of median gestational age (range between 28-38 wk)	Nasopharyngeal swab RT-PCR	Linear or convex probes, the LUS investigation was carried out with the 12-zone method, both in the supine and lateral positions	LUS is proven to be safe, reliable, sensitive, easily repeatable, and could be a guide to define the most appropriate strategy for improving clinical and pregnancy outcomes
Yassa <i>et al</i> [10], 2021	Turkey	Case series	8 Pregnant women (9-38 wk) who underwent LUS examinations after obstetric US examinations	Symptoms and LUS first and confirmed by nasopharyngeal RT-PCR testing later	Fourteen areas (3 posterior, 2 lateral, and 2 anterior) were scanned <i>per</i> patient for 10 seconds along the indicated lines	After an obstetric US assessment, the routine use of LUS can substantially influence the clinical treatment of pregnant women with COVID-19
Yassa <i>et al</i> [27], 2020	Turkey	Prospective Cohort	296 pregnant women (23 with a positive result for COVID-19) at 5 to 42 wk gestational ages (mean = 35.18 wk)	LUS first and confirmed by nasopharyngeal RT-PCR later	12 areas, with the posterior ones in the posterior axillary line	Using lung ultrasound was found more predictive in detecting the infection than the use of symptomatology solely
Youssef <i>et al</i> [36], 2020	Italy	Case report	1 pregnant woman, 33 yr old at 26 wk of gestational age	LUS findings were former, positive nasopharyngeal swab RTPCR confirmation later	6 regions in each hemithorax (2 anterior, 2 lateral, and 2 posterior). Linear or convex probes	We believe that extensive training of physicians may be considerably helpful in terms of the ongoing pandemic of COVID-19

COVID-19: Coronavirus disease 2019; CT: Computed tomography; LUS: Lung ultrasound; RT-PCR: Reverse transcription polymerase chain reaction; US: Ultrasound.

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