Is there a role for lung ultrasound during the COVID-19 pandemic?

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Short title: Lung Ultrasound (LUS) findings in Covid-19

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Lung Ultrasound (LUS) has significantly evolved over the last years with respect to its theoretical and operative aspects. Consequentially, its clinical application has become to be sufficiently known and widespread.

One of the characteristic aspects of LUS is the ability to define the alterations affecting the ratio between tissue and air in the superficial lung [1].

Normally, the lung surface mainly consists of air. Incident ultrasound waves are thus generally completely back-reflected by the visceral pleural plane, especially when healthy. In this context, the scattering of ultrasound waves produces artefactual images characterized by horizontal reverberations of the pleural line (A lines) and mirror effects.

When the ratio between air, tissue, fluid, or other biological components is reduced, the lung no longer presents itself as an almost complete specular reflector. Hence, various types of localized vertical artifacts appear on the ultrasound images in relation to the alterations of the subpleural tissue [2,3].

These artifacts have generally been called B lines [4] but recently it has become clear that B lines are very heterogeneous in their appearance. Moreover, their heterogeneity may be exploited as a mean to characterize the alterations of the lung surface [5].

Another well known phenomenon linked to the increase in subpleural lung density (in the absence of consolidated tissue) is the coalescence of many vertical artifacts in more extended echogenic patterns, in which the individual artifacts are still recognizable or fused in a single homogeneous subpleural echogenic area (white lung).

When the subpleural density goes towards the value of 1 g / ml (about that of the solid tissue), then consolidations appear.

Therefore the clinician, through the visual inspection of LUS images, can detect, at the subpleural level, non-consolidative increases in the ratio between full (tissue) and empty (air), and asses them in a range between normal and consolidative. Topographical pictures of the lesions can also be acquired. Finally, the extent of these lesions on the lung surface, as well as their evolution or regression over time, can also be evaluated.

The study of these patterns shows a very high sensitivity in cases of interstitial and alveolar-interstitial lung diseases, wich have a peripheral distribution. Numerous studies on ARDS [6] confirm this. Other studies related to the 2009 H1N1 [7] epidemic confirm these hypotheses even in a viral-infectious setting.

The recent pneumonia outbreak spreading from Wuhan, China, in December 2019, is caused by the 2019 novel coronavirus (2019-nCoV) infection, defined as new coronavirus disease (COVID-19) [8]. This epidemic currently involves many areas of the world, with particular incidence in Italy, representing a serious challenge to public health and efficiency of the healthcare structures.

The histopathology of initial COVID-19 pneumonia is characterized by alveolar damage, which includes alveolar edema, while the inflammatory component is patchy and mild. Reparative processes with pneumocyte hyperplasia and interstitial thickening can occur. The advanced phases show gravitational consolidations similar to those of the ARDS. There are hemorrhagic necrosis, alveolar congestion, edema, flaking and fibrosis [9].

The analysis of the available CT data from patients with Covid 19 pneumonia [10] shows largely bilateral lesions, patchy, also confluent, appearing as ground glass or with the mixed consolidative and ground glass pattern. 10% of lesions with a crazy paving appearance are reported. The lesions often have a wedge-like appearance with a pleural base. Major consolidations may show air bronchograms. Pleural effusion is absent. Patchy or confluent lesions tend to be distributed along the pleura. The lobe most frequently affected is the lower right lobe, followed by the upper and lower left lobes. The posterior lung is involved in 67% of cases [11].

Given that LUS can identify changes in the physical state of superficial lung tissue, which correlate with histopathology and that can be identified in CT, but remain hidden in a large percentage of chest radiographs, the role of LUS can be relevant in the context of the Covid 19 epidemic. It should also not be underestimated that, in experimental models of ARDS, LUS has proved capable of detecting lung lesions before the development of hypoxemia.

The current clinical evidence (although not yet represented in the literature), the theoretical bases of LUS in the areated lung, and LUS findings of similar aspects in other pathologies (ARDS, flu virus pneumonia) strongly suggest a potential diagnostic accuracy of LUS that may be useful for

- triage (pneumonia / non-pneumonia) of symptomatic patients at home as well as in the pre-hospital phase
- diagnostic suspicion and awareness in the Emergency Room setting
- prognostic stratification and monitoring of subjects with pneumonia on the basis of the extension of specific patterns and their evolution towards the consolidation phase in the Emergency Room setting
- management of ICU patients with regard to ventilation and weaning
- monitoring the effect of therapeutic measures (antiviral or others)
- reducing the number of healthcare professionals exposed during patient stratification (a single clinician would be necessary to perform an objective medical examination and imaging investigation directly at the patient's bed)

From the current clinical evidence, we consider the LUS patterns of subjects with COVID-19 pneumonia quite characteristic. The first pulmonary manifestations are represented by a patchy distribution of interstitial artifactual signs (single and/or confluent vertical artifacts, small white lung regions). Subsequently these patterns extend to multiple areas of the lung surface. The further evolution is represented by the appearance, still patchy, of small subpleural consolidation with associated areas of white lung. The evolution in consolidations, especially in a gravitational position, with or without air bronchograms, and their increasing extension along the lung surface indicate the evolution towards the phase of respiratory insufficiency that requires invasive ventilatory support.

Fig. 1 and Fig 2 show the characteristics of the sonographic interstitial syndrome present in intermediate COVID-19 pneumonia. Early viral pneumonia shows few, usually bilateral, pulmonary lung areas characterized by single or bundled, pneumogenic-type vertical artifacts, or small areas of white lung. Advanced COVID-19 pneumonia exhibits evident consolidation, especially in the posterobasal regions, and widespread pathched artifactual changes. This pattern is similar to ARDS.

In this context, it is of great interested the development of algorithms able to aid the clinicitan with a real time detection and localization system [12].

Studies aimed at clarifying the diagnostic and prognostic role of LUS in COVID-19 are urgently needed. The well-known advantages of LUS in terms of portability, bedside evaluation, safety and possibility of repeating the examination during follow-up cannot be overlooked and should be exploited and implemented. Moreover, the possibility of performing LUS at the bedside minimize the need of tranferring the patient, with a potential risk of further infection spreading withing the healthcare personnel. Comparison with chest X-ray and/or lung CT scan might help designing a proper diagnostic workup according to the general and local technological and human resources.

A suggested acquisition protocol is described below:

- Use convex or linear probes. The latter are preferrable to study the detail of the pleural and subpleural alterations.
- Use single focal point modality (no multifocusing) and set the focal point on the pleura line.
- Preferabbly scans need to be intercostal (not hortogonal to the ribs), as to cover the widest surface possible with one scan.
- Evaluate the presence of the artifactual patterns in multiple areas and bilaterally, as to study the extent of the lung surface affected. Ideally 16 areas in total: Anterior Midclavicular (Apical, Medial, Basal) right and left, Posterior Paraspinal (Apical, Medial, Basal) right and left, and Lateral Axillary (Apical and Basal) medial right and left.

Figure 1: Top. Two images from a patient confirmed with COVID-19 pneumonia. Typical vertical pneumogenic large artifacts originate from the pleural line or from small, blurred subpleural consolidations. Their origin is not point-like. Below. The pleural line is interrupted by more visible yet small consolidations. Large vertical artifacts are seen arising from the consolidations and they are superimposed on areas of white lung. Convex probe, intercostal scans.

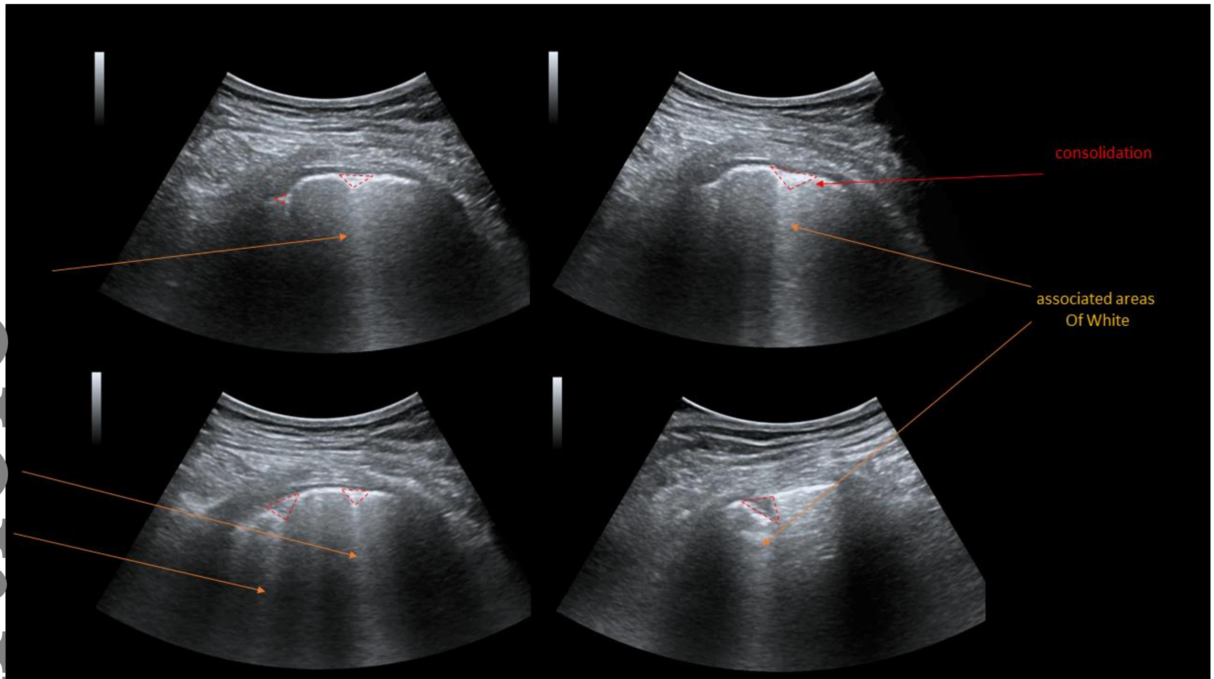
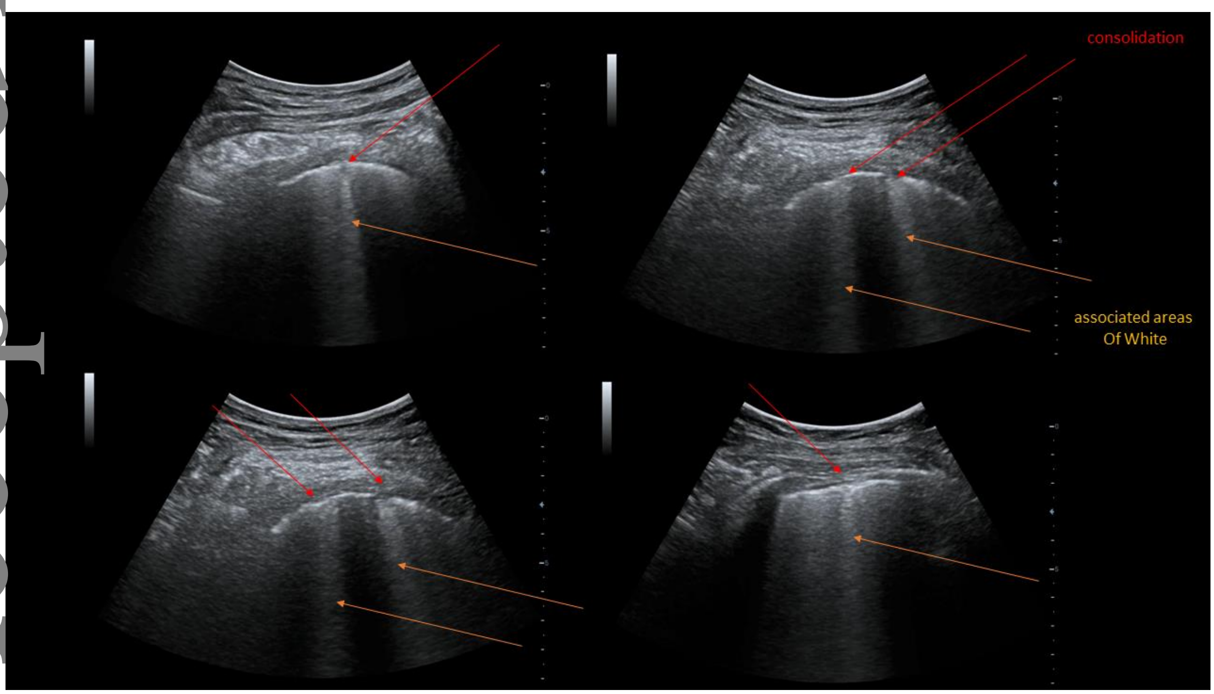


Figure 2: Similar findings on a second patient confirmed with COVID-19 pneumonia.



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