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# Lung ultrasound for home monitoring of a COVID-19 positive patient

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# Keywords

Covid19

Lung ultrasound

Telemedicine

## Abstract

Not since WWII have novel solutions for medical resource allocation and implementation been in such dire need. A subset of patients with COVID-19 and lung involvement pose a disposition challenge, particularly when hospital resources are constrained. Those not in respiratory failure are sent home, often with phone monitoring and/ respiratory rate and oxygen saturation monitoring. Hypoxemia may be a late presentation and is often preceded by abnormal lung findings on ultrasound. Early identification of pulmonary progression may preempt emergency hospitalization for respiratory decompensation and facilitate more timely admission. With the goal of safely isolating infected patients while providing advanced monitoring, we present a first report of patient self-performed lung ultrasound in the home with a hand-held device under the guidance of a physician using a novel TeleGuidance platform.

## Introduction

In late March, the Piedmont region, Italy, reported more than 7,000 diagnosed cases of COVID-19 with 3,000 of these cases discharged to home quarantine [1,2]. The rapid increase of infected patients creates an unmanageable situation for hospitals and emergency medical service (EMS) providers [3].

Lung ultrasound (LUS) imaging for pneumonia and acute respiratory distress syndrome has been documented for years [4-6] and recent evidence supports the role of LUS for the management of COVID-19 patients [7,8]. LUS has been demonstrated in the home setting [9,10], but never by the patient him/herself. This case report details the integration of LUS into the home management plan of a COVID-19 patient using a novel TeleGuidance approach.

## Case Report

On March 2nd, a 26 year-old female nurse had occupational exposure to COVID-19 while working at the emergency department (ED). The patient went into home isolation with no symptoms and monitored her vitals twice daily (Table 1), receiving confirmation of positive RT-qPCR on March 10th. From March 13-21, she performed daily unsupervised LUS examinations (iQ, Butterfly Network) and uploaded these to the cloud for review by an expert operator (E.P., with 12 years experience). The patient had prior point-of-care ultrasound (POCUS) training, including a single-day didactic course and 40 supervised bedside evaluations for peripheral intravenous access and bladder examinations.

Beginning March 21st, a TeleGuidance feature became available on the device that allowed real-time remote support by the expert operator, who could use two-way audio and video to guide the novice to obtain optimized views. The expert operator could adjust the ultrasound

settings (preset, depth, gain) and capture cines. The subject obtained images under TeleGuidance supervision from March 21-28.

Daily LUS examinations were saved and scored for image quality by a second expert (M.S.) blinded to the acquisition and interpretation. The scoring convention used was: 0, no lung visualized; 1, image poorly informative, pleural line partially visualized; 2, image interpretable, pleural line partially visualized but sufficient for evaluation; 3, image easily interpreted, pleural line well visualized. Images scoring 0 or 1 were considered non-diagnostic. Image quality was compared between the self-guided and remote expert-guided approach (using the Kruskal Wallis test).

Table 2 describes the number of zones imaged, the diagnostic quality, and the daily sonographic findings. Over time, bilateral B-lines and small subpleural consolidations developed. Bilateral lung sliding was present and no pleural effusions were found for the entire period. Overall, 114 images were acquired. The median quality score for unsupervised scans (n=35) was significantly lower than for supervised teleguidance scans (n=79) (2 vs 3 respectively,  $p < .001$ ), but only 3 images were reviewed as non-diagnostic (2.6%). For the initial, unsupervised scans, cines were recorded for three zones (anterior, lateral, and posterior) per hemithorax. During teleguidance sessions, a 12-zone protocol was followed (superior and inferior, anterior, lateral, and posterior). An example teleguidance session is shown in Figure 1.

Based on the patient's symptoms, a focused cardiac ultrasound was also performed due to the presence of bilateral chest pain using parasternal short and long axis views. This exam excluded a pericardial effusion, dilatation of the right ventricle and abnormal left ventricular contractility.

On March 28th, during a telephone follow-up with the Hygiene and Public Health Service (SISP) the patient reported dyspnea at mild exertion. Per protocol, EMS brought her to the ED, where chest radiography (CXR), arterial blood gas analysis, and laboratory tests were performed (Table S1 and Figure S1). The laboratory tests were all normal and the CXR was negative for pneumonia, which was different from the bilateral basal B-lines found on POCUS the same day (Table 2). The patient was not admitted and was followed at home until symptom resolution on April 6th.

## Discussion

We highlight three key findings within this case: first, daily LUS allowed the attending physician to correlate the reported symptoms of shortness of breath with radiographic findings. Second, when the subject reported bilateral chest pain, cardiac involvement was ruled out. Third, despite a normal CXR in the ED, lung involvement was still present as documented by the presence of B-lines, suggesting that LUS could provide additional information that isn't seen on CXR for COVID-19 patients.

In conclusion, we present a new mechanism for monitoring COVID-19 in the home using a novel TeleGuidance system for LUS that can be performed by the patient (or by EMS). Integrating LUS into home management could decrease the need for patients to be transported to a hospital or imaging center, avoiding unnecessary disease transmission through patient movement [11].

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**Table 1. Subjects's daily vitals and symptoms**

March	mean temperature	oxygen saturation at rest	oxygen saturation at mild exertion	respiratory rate	symptoms
2	likely day of contact with a positive case during a night shift				
3	N/A	N/A	N/A	N/A	no
4	N/A	N/A	N/A	N/A	no
5	N/A	N/A	N/A	N/A	no
6	N/A	N/A	N/A	N/A	no - first day of quarantine
7	N/A	N/A	N/A	N/A	myalgia
8	N/A	N/A	N/A	N/A	myalgia and headache
9	36.5	N/A	N/A	18-20	myalgia, headache, diarrhea, nasal congestion
10	36.5	N/A	N/A	18-20	myalgia, diarrhea, nasal congestion
11	36.5	N/A	N/A	18-20	myalgia, nasal congestion
12	36.5	97	N/A	18-20	mild shortness of breath
13	36.5	97	N/A	22	shortness of breath
14	36.5	97-99	N/A	24	shortness of breath
15	36.5	97-99	91-93	22	diarrhea, shortness of breath on mild exertion

16	36.5	98-99	91-93	22	shortness of breath on mild exertion and episodic left localized chest pain
17	36.5	98-99	91-93	20	shortness of breath on mild exertion
18	36.5	98-99	91-93	20	shortness of breath on mild exertion
19	36.5	98-99	NA	18	sore throat
20	36.5	98-99	NA	16	sore throat, epigastric, left midclavicular and anterior axillary pain
21	36.5	98-99	NA	16	sore throat
22	36.5	98-99	91-93	16	shortness of breath on mild-moderate exertion and bibasal chest pain
23	36.5	98-99	NA	16	headache and bibasal chest pain
24	36.5	98-99	91	16	shortness of breath on mild-moderate exertion and bibasal chest pain
25	36.5	98-99	93-94	16	left basal chest pain
26	36.5	98-99	93-94	16	left basal chest pain and shortness of breath on mild-moderate exertion
27	36.5	98-99	93-94	16	left basal chest pain and shortness of breath on mild-moderate exertion
28	36.5	98-99	95	16	left basal chest pain and shortness of breath on mild-moderate exertion (ED evaluation)

Legend: N/A, not available



**Table 2**

Daily lung ultrasound report including the number of images, image quality, and ultrasound findings. The last day reported corresponds to the day the subject was assessed in the hospital (highlight).

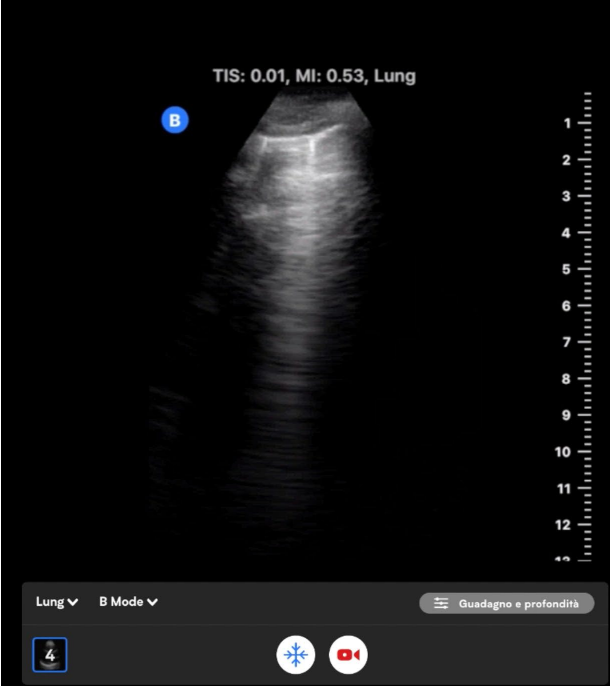
Day (March)	Number of lung zones imaged	% diagnostic quality	POCUS findings	
			Left	Right
13	7	100	<b>Anterior:</b> few vertical artifacts, thin pleural line; <b>Lateral:</b> few no confluent b-lines <b>Posterior:</b> few no confluent b-lines	<b>Anterior:</b> multiple non-confluent B-lines (inferior) <b>Lateral:</b> few no confluent b-lines; single B-lines and some small vertical artifacts (inferior) <b>Posterior:</b> multiple non-confluent B-lines
14	6	100	<b>Anterior:</b> few small vertical artifacts <b>Lateral:</b> few no confluent vertical artifacts (inferior) <b>Posterior:</b> multiple vertical artifacts, rare, no b-lines.	<b>Anterior:</b> few vertical artifact <b>Lateral:</b> some not confluent b-lines (inferior) <b>Posterior:</b> few b-lines (inferior)
15	7	86	<b>Anterior:</b> some no confluent B-lines. <b>Lateral:</b> some no confluent B-lines. <b>Posterior:</b> some isolated B-lines (left>right)	<b>Anterior:</b> some B-lines, not confluent (inferior) <b>Lateral:</b> isolate B-lines (superior), diffuse B-lines, not confluent (inferior) <b>Posterior:</b> some isolated B-lines (left>right)
16	6	100	<b>Anterior:</b> some small vertical artifacts <b>Lateral:</b> some no confluent B-lines <b>Posterior:</b> some small vertical artifacts	<b>Anterior:</b> Some vertical artifacts <b>Lateral:</b> few no confluent B-lines <b>Posterior:</b> few no confluent B-lines
17	9	100	<b>Anterior:</b> few vertical artifacts and a single B-line in the inferior area; <b>Lateral:</b> few vertical artifacts <b>Posterior:</b> some small vertical artifacts	<b>Anterior:</b> some vertical artifacts, a single B-line between superior and inferior zones <b>Lateral:</b> some B-lines in inferior area <b>Posterior:</b> some B-lines
18	9	100	<b>Anterior:</b> normal	<b>Anterior:</b> A single B-lines

			<p><b>Lateral:</b> some small vertical artifacts and 2-3 in the basal area</p> <p><b>Posterior:</b> some B-lines with a likely subpleural consolidation</p>	<p>between superior and inferior areas and a few small vertical artifacts</p> <p><b>Lateral:</b> 2-3 B-lines</p> <p><b>Posterior:</b> 2-3 B-lines</p>
19	11	100	<p><b>Anterior:</b> normal</p> <p><b>Lateral:</b> some vertical artifacts and 2-3 B-lines in the inferior, lateral area</p> <p><b>Posterior:</b> some B-lines with a likely subpleural consolidation</p>	<p><b>Anterior:</b> A single B-line between superior and inferior anterior areas, a few small vertical artifacts</p> <p><b>Lateral:</b> 2-3 basal B-lines</p> <p><b>Posterior:</b> 2-3 basal B-lines</p>
20	8	100	<p><b>Anterior:</b> few vertical artifacts with irregular pleural line</p> <p><b>Lateral:</b> irregular and thickened pleural line with some B-lines</p> <p><b>Posterior:</b> some B-lines with a subpleural consolidation.</p>	<p><b>Anterior:</b> few small vertical artifacts</p> <p><b>Lateral:</b> 2-3 B-lines between superior and inferior areas with a small subpleural consolidation</p> <p><b>Posterior:</b> 2-3 basal B-lines</p>
21	10	100	<p><b>Anterior:</b> few vertical artifacts with irregular pleural line</p> <p><b>Lateral:</b> irregular and thickened pleural line with some B-lines</p> <p><b>Posterior:</b> some B-lines in with a subpleural consolidation.</p>	<p><b>Anterior:</b> few vertical artifacts</p> <p><b>Lateral:</b> some B-lines in the inferior area</p> <p><b>Posterior:</b> 2-3 basal B-lines</p>
22	7	100	<p><b>Anterior:</b> few vertical artifacts</p> <p><b>Lateral:</b> some vertical artifacts with some B-lines</p> <p><b>Posterior:</b> some B-lines in with a subpleural consolidation.</p>	<p><b>Anterior:</b> few vertical artifacts</p> <p><b>Lateral:</b> Some vertical artifacts in the inferior area with an irregular pleural line</p> <p><b>Posterior:</b> some basal B-lines</p>
23	11	100	<p><b>Anterior:</b> few vertical artifacts</p> <p><b>Lateral:</b> few vertical artifacts</p> <p><b>Posterior:</b> some B-lines in the basal zone with a subpleural consolidation.</p>	<p><b>Anterior:</b> Some small vertical artifacts</p> <p><b>Lateral:</b> Some small vertical artifacts</p> <p><b>Posterior:</b> 2-3 basal B-lines</p>
24	11	91	<p><b>Anterior:</b> few vertical artifacts</p>	<p><b>Anterior:</b> Some small vertical artifacts</p>

			<b>Lateral:</b> 2-3 B-lines in the basal area <b>Posterior:</b> 2-3 B-lines in the basal area with a small subpleural consolidation.	<b>Lateral:</b> a single B-lines <b>Posterior:</b> an irregular pleural line with a small subpleural consolidation in the inferior area
25	12	92	<b>Anterior:</b> irregular pleural line <b>Lateral:</b> 2 B-lines in the basal area <b>Posterior:</b> 2 B-lines in the basal area	<b>Anterior:</b> irregular pleural line with a few vertical artifacts <b>Lateral:</b> few B-lines <b>Posterior:</b> vertical artifacts with a small subpleural consolidation in the inferior area
26	12	100	<b>Anterior:</b> irregular pleural line <b>Lateral:</b> irregular pleural line with some B-lines in the basal area <b>Posterior:</b> some B-lines in the basal area	<b>Anterior:</b> irregular pleural line with 1 B-line in the superior area <b>Lateral:</b> 2-3 non confluent B-lines in the basal lateral area <b>Posterior:</b> 2 B-lines in the basal area.
27	12	100	<b>Anterior:</b> irregular pleural line <b>Lateral:</b> some vertical artifacts between superior and inferior anterior areas with a single B-line <b>Posterior:</b> few B-lines in the basal area	<b>Anterior:</b> Irregular pleural line <b>Lateral:</b> some diffuse small vertical artifacts and a single B-line in the basal area. <b>Posterior:</b> few B-lines in the basal area.
28	12	100	<b>Anterior:</b> irregular pleural line <b>Lateral:</b> some vertical artifacts with 2-3 basal B-lines <b>Posterior:</b> few B-lines in the basal area	<b>Anterior:</b> minimally irregular pleural line <b>Lateral:</b> 1-2 B-lines in the basal area <b>Posterior:</b> 1-2 B-lines in the basal area

**Figure 1**

The expert's view of a teleguidance session with the lung image shown on the left and the two-way video features on the right. The expert can change modes, adjust depth and gain, and save clips. Directions can be given through augmented reality buttons and/or auditory feedback.



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Fai scorrere il dito sul video o scegli un'istruzione per guidare l'IQ dell'utente.