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● *Clinical Note*

LUNG ULTRASOUND IN PATIENTS WITH ACUTE RESPIRATORY FAILURE REDUCES CONVENTIONAL IMAGING AND HEALTH CARE PROVIDER EXPOSURE TO COVID-19

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Abstract—Lung ultrasound gained a leading position in the last year as an imaging technique for the assessment and management of patients with acute respiratory failure. In coronavirus disease 2019 (COVID-19), its role may be of further importance because it is performed bedside and may limit chest X-ray and the need for transport to radiology for computed tomography (CT) scan. Since February 21, we progressively turned into a coronavirus-dedicated intensive care unit and applied an ultrasound-based approach to avoid traditional imaging and limit contamination as much as possible. We performed a complete daily examination with lung ultrasound score computation and systematic search of complications (pneumothorax, ventilator-associated pneumonia); on-duty physicians were free to perform CT or chest X-ray when deemed indicated. We compared conventional imaging exams performed in the first 4 wk of the COVID-19 epidemic with those in the same time frame in 2019: there were 84 patients in 2020 and 112 in 2019; 64 and 22 (76.2% vs. 19.6%, $p < 0.001$) had acute respiratory failure, respectively, of which 55 (85.9%) were COVID-19 in 2020. When COVID-19 patients in 2020 were compared with acute respiratory failure patients in 2019, the median number of chest X-rays was 1.0 (1.0−2.0) versus 3.0 (1.0−4.0) ($p = 0.0098$); 2 patients 2 (3.6%) versus 7 patients (31.8%) had undergone at least one thoracic CT scan ($p = 0.001$). A self-imposed ultrasound-based approach reduces the number of chest X-rays and thoracic CT scans in COVID-19 patients compared with patients with standard acute respiratory failure, thus reducing the number of health care providers exposed to possible contamination and sparing personal protective equipment. (E-mail: silvia.mongodi@libero.it) © 2020 World Federation for Ultrasound in Medicine & Biology. All rights reserved.

Key Words: Lung ultrasound, Lung monitoring, COVID-19, Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), ARDS.

INTRODUCTION

On March 11, 2020, the World Health Organization declared the new coronavirus disease 2019 (COVID-19) as an ongoing pandemic emergency. The first reported case had been identified in Wuhan, China, on December 8, 2019. Since then, the disease has rapidly spread worldwide. Around 5%−10% of COVID-19 patients require mechanical ventilation for acute respiratory failure (ARF), of whom 65%−85% are classified as having acute respiratory distress syndrome (Wu and McGoogan, 2020; Yang et al. 2020). The typical radiologic findings are consolidations and ground glass opacities with a peripheral distribution. Frequently, lung involvement is bilateral, with destruction of pulmonary parenchyma

caused by consolidations and interstitial inflammation (Chung et al. 2020).

As in all acutely ill respiratory patients, lung imaging is mandatory for assessment of disease severity and to guide clinical management. However, radiology societies have advised against the systematic use of computed tomography (CT) and have suggested reducing the number of chest X-rays (CXRs) in COVID-19, to minimize the exposure of health care providers to this highly infective disease (Simpson et al. 2020). In this context, lung ultrasound (LUS) could be the ideal imaging technique as it is available at the bedside, it is performed directly by the in-charge physicians and it provides reliable information for diagnosis and monitoring of ARF (Chiumello et al. 2018; Mojoli et al. 2019; Pescarissi et al. 2020). The aim of our study was to test whether the systematic use of a LUS-based approach could reduce the number of conventional radiologic exams during the COVID-19 epidemic.

METHODS

We admitted the first COVID-19 patient on February 21 and progressively transformed our intensive care unit (ICU) into a coronavirus unit, reaching 100% of patients with COVID-19 on March 6, 2020 (Mojoli et al. 2020). Because our health care providers have high skills and experience in LUS and habitually use ultrasound in daily management of ARF patients, although in general integrated with traditional imaging, from the beginning we decided to use an LUS-based approach. The aim of this self-imposed limitation was to minimize transport of COVID-19 patients to the radiology department, reduce the number of bedside CXRs and therefore reduce the exposure of health care professionals. A complete 12-area examination, with computation of the LUS score (Mongodi et al. 2017), is performed daily with a Vivid iq ultrasound machine (GE Healthcare, Chicago, IL, USA). A 9-MHz linear probe is used if the pleural line is visualized with one focus on the pleural line, artifact-erasing software and harmonics are abolished, and depth is adjusted to be at least twice the depth of the pleural line (Mongodi et al. 2019); a phased-array probe is used in case of consolidations or pleural effusions. The complete LUS examination is finalized to monitor lung aeration; guide the respiratory strategy, that is, positive end-expiratory pressure titration, pronation (Bouhemad et al. 2011; Mojoli et al. 2019); and identify complications (*i.e.,* pneumothorax and ventilator-associated pneumonia [Mongodi et al. 2016; Mojoli et al. 2019]). On-duty physicians are free to perform CT or CXR when deemed necessary. Operators were either recognized experts in the field or trainees who had completed 25 supervised examinations (Rouby et al. 2018).

We computed the number of traditional imaging exams performed in all ICU patients, including those previously admitted, from February 22 to March 22, 2020, and compared it with the number for the same time frame in 2019. We focused on CXRs and chest CTs per patient and per patient-bed days, in particular for patients with ARF. Informed consent was collected according to the *ad hoc* procedures defined by the ethics committee for the COVID-19 pandemic. The treating physicians had the responsibility for the patients' data management and protection aiming at the improvement in treatment and safety.

Quantitative and categorical variables are expressed as the median and number (percentage), respectively. Normally distributed data were assessed with the Shapiro−Wilk test. Comparisons between time frames were performed with the unpaired Wilcoxon−Mann Whitney U-test for quantitative variables and the Fisher exact/χ^2-test for categorical variables. Comparisons were performed between the following pairs: overall ICU population in 2020 versus 2019; ARF patients in 2020 versus those in 2019; COVID-19 patients in 2020 versus ARF patients in 2019. A p value <0.05 was considered to indicate significance. Statistical analysis was performed using STATA14 for Macintosh.

RESULTS

Over the time frames analyzed, we had 84 patients in 2020 and 112 in 2019 in our 23-bed ICU, for a total of 969 and 1070 and patient-bed days, respectively (Table 1); we had an increased number of ARF patients in 2020 (76.2% vs. 19.6%, $p < 0.001$), mainly because of COVID-19 (85.9%). Comparison of ARF patients revealed that male sex was more frequent (53 [82.8%] vs. 12 (54.6%), $p = 0.008$) and body mass index was higher (27.5 [24.6−30.9] vs. 23.5 [20.1−27.6], $p = 0.0132$) in 2020 than 2019.

Results concerning the use of traditional imaging are outlined in Table 2. No significant difference was observed when comparing the overall ICU population in 2020 versus that in 2019. When comparing COVID-19 ARF in 2020 with ARF in 2019, the percentages of patients having undergone at least one CXR were similar (85.5% vs. 86.4%, $p = 1.000$), but the median number of CXRs per patient was significantly lower in COVID-19 (1.0 [1.0−2.0] vs. 3.0 [1.0−4.0], $p = 0.0098$). Similar results were obtained when considering the number of exams performed per patient-bed day. The percentage of patients who underwent at least one thoracic CT scan was lower in COVID-19 versus ARF in 2019 (3.6% vs. 31.8%, $p = 0.001$). Only 2 COVID-19 patients underwent CT, one twice. Similar results are obtained when considering the median number of CT scans per patient and per patient-bed day.

Table 1. Clinical features in the ICU populations during COVID-2019 in 2020 and during the same time frame in 2019*

Characteristic	2019 (112 patients)	2020 (84 patients)	p Value
Males	63 (56.3)	65 (77.4)	**0.002**
Age, y	64.0 [53.0−74.0]	63.5 [50.5−70.0]	0.2726
BMI, kg/m^2	25.8 [22.8−30.0]	26.3 [23.5−30.7]	0.1774
ICU stay, h	74.0 [23.0−239.0]	221.5 [111.5−341.5]	**<0.0001**
Provenience			
Emergency department	46 (41.1)	19 (22.6)	**<0.001**
Subacute care	10 (8.9)	32 (38.1)	**<0.001**
Surgical ward	39 (34.8)	9 (10.7)	**<0.001**
Medical ward	17 (15.2)	24 (28.6)	**<0.001**
Post-surgical patients	36 (32.1)	11 (13.1)	**0.002**
Acute respiratory failure	22 (19.6)	64 (76.2)	**<0.001**
COVID-19	0.0 (0.0)	55 (65.5)	
Males	12 (54.6)	53 (82.8)	**0.008**
Age, y	63.0 [50.0−73.0]	62.5 [51.5−70.5]	1.0000
BMI, kg/m^2	23.5 [20.1−27.6]	27.5 [24.6−30.9]	**0.0132**
ICU stay, h	210.0 [105.0−522.0]	238.0 [151.0−378.5]	0.9882

COVID-19 = coronavirus disease 2019; ICU = intensive care unit; BMI = body mass index; IQR = interquartile range.
* Values are expressed as the number (%) or median [interquartile range]. Significant p values < 0.05 are in boldface.

DISCUSSION

The main result of the present work is that a self-imposed LUS-based approach reduces the number of CXRs and thoracic CT scans in COVID-19 patients compared with standard ARF patients; this implies that LUS helps to reduce the need for transport of infectious patients to the radiology department and for bedside CXRs, thus reducing the number of health care providers exposed to possible contamination and sparing personal protective equipment.

Interestingly, in our center, not all patients with ARF underwent at least one CXR and fewer than 1 in 3 underwent chest CT in the examined time frame in 2019. For many years, LUS has been used in our center for the assessment and management of ARF patients. Even in the context where the use of conventional chest imaging had already been optimized by the daily practice of LUS, a self-imposed LUS-based approach could further reduce the number of conventional exams. The two COVID-19 patients who underwent CT for lung assessment both had a condition preventing LUS examination (i.e., subcutaneous emphysema and pneumomediastinum).

As for limitations, first we analyzed only thoracic CT scans and CXRs, as no COVID-19 patient required imaging other than thoracic, so far. Second, the integration of LUS findings in the management of ARF requires well-trained physicians (Rouby et al. 2018). Automation may be of help in the future to overcome this limitation

Table 2. Use of traditional radiology in the ICU populations during COVID-19 epidemic in 2020 and in the same time frame in 2019*

	Chest X-ray			Thoracic CT scan		
	2019	2020	p	2019	2020	p
Patients who underwent traditional imaging						
Overall	78 (69.6)	68 (81.0)	0.072	18 (16.1)	14 (16.7)	0.911
With ARF	19 (86.4)	53 (82.8)	1.000	7 (31.8)	8 (12.5)	**0.039**
COVID-19		47 (85.5)	1.000[†]		2 (3.6)	**0.001**[†]
No. of imaging exams per patient						
Overall	1.0 [0.0−3.0]	1.0 [1.0−2.0]	0.6672	0.0 [0.0−0.0]	0.0 [0.0−0.0]	0.8928
	1.8 ± 2.1	1.6 ± 1.4		0.2 ± 0.5	0.2 ± 0.5	
With ARF	3.0 [1.0−4.0]	1.0 [1.0−2.0]	**0.0079**	0.0 [0.0−0.1]	0.0 [0.0−0.0]	**0.0372**
	3.1 ± 2.7	1.5 ± 1.1		0.4 ± 0.6	0.2 ± 0.5	
COVID-19[†]		1.0 [1.0−2.0]	**0.0098**[†]		0.0 [0.0−0.0]	**0.0006**[†]
		1.5 ± 1.1			0.06 ± 0.3	
Exams per patient-bed day						
Overall	204 (19.1)	133 (13.7)	**0.001**	23 (2.2)	18 (1.9)	0.639
With ARF	69 (19.1)	98 (12.4)	**0.003**	11 (3.0)	11 (1.4)	0.058
COVID-19[†]		85 (13.8)	**0.028**[†]		3 (0.5)	**0.001**[†]

ARF = acute respiratory failure; COVID-19 = coronavirus disease 2019; ICU = intensive care unit.
* Values are expressed as the number (%), median [interquartile range] or mean ± standard deviation. Significant p values < 0.05 are in boldface.
† COVID-19 patients in 2020 are compared with ARF patients in 2019.

for lung aeration quantification (Brusasco et al. 2019; Piculjan et al. 2019).

CONCLUSIONS

A LUS-based approach for the management of COVID-19 ARF reduces the number of conventional thoracic imaging exams and reduces exposure of health care professionals.

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