Ultrasound News

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Imaging Essay
Pulmonary Imaging

Lung Ultrasound: The Essentials

Thomas J. Marini, Deborah J. Rubens, Yu T. Zhao, Justin Weis, Timothy P. O'Connor, William H. Novak, Katherine A. Kaproth-Joslin

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Abstract

Compared with chest radiography, lung US may have higher sensitivity for detection of pleural effusion, pneumonia, pneumothorax, and pulmonary edema. It is increasingly used in the intensive care unit to detect these conditions.

Although US of the lungs is increasingly used clinically, diagnostic radiologists are not routinely trained in its use and interpretation. Lung US is a highly sensitive and specific modality that aids in the evaluation of the lungs for many different abnormalities, including pneumonia, pleural effusion, pulmonary edema, and pneumothorax. This review provides an overview of lung US to equip the diagnostic radiologist with knowledge needed to interpret this increasingly used modality.

Supplemental material is available for this article.

Keywords: Adults and Pediatrics, Pulmonary, Ultrasound

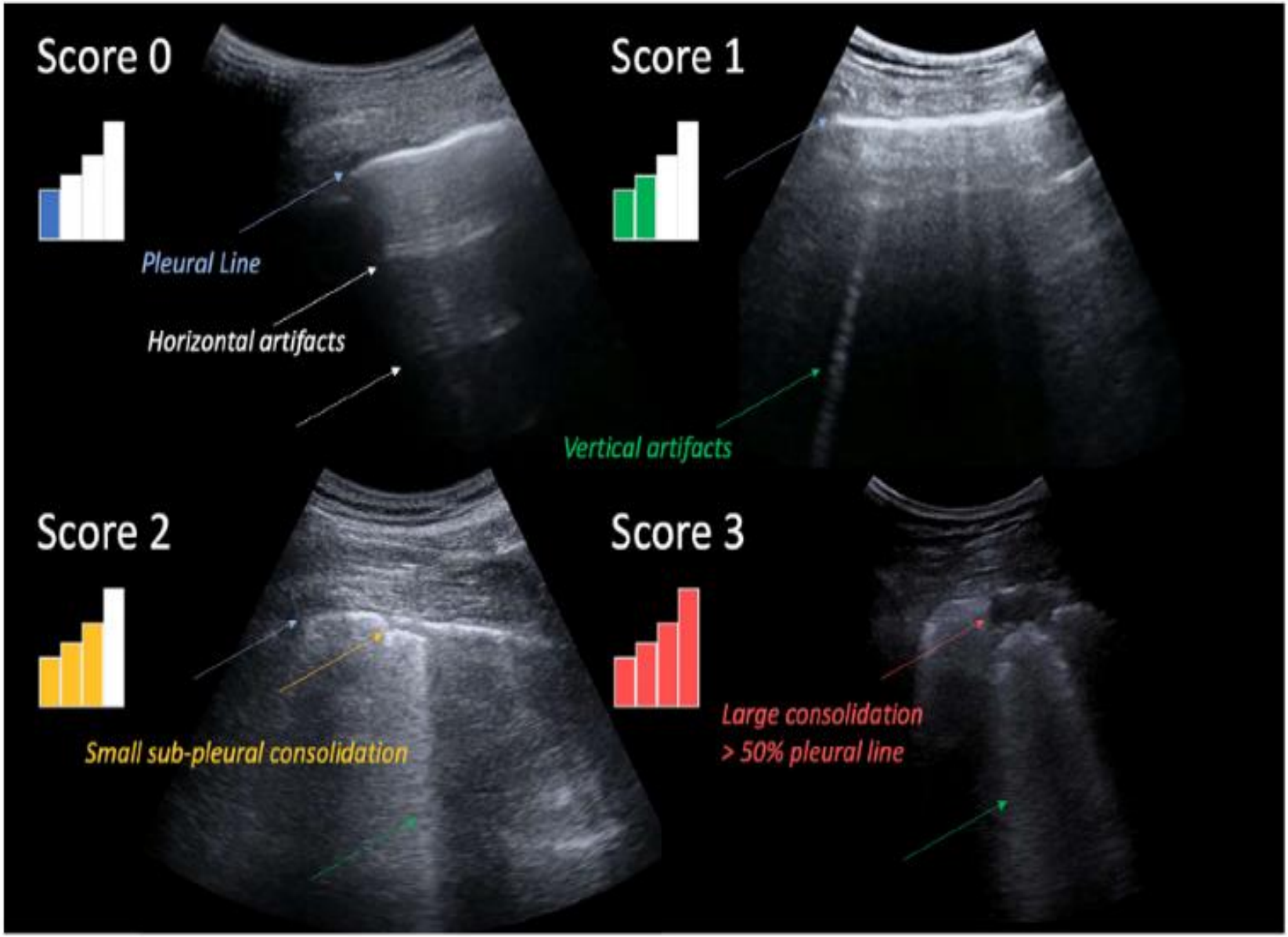
Lung Ultrasound in COVID-19 and Post-COVID-19 Patients, an Evidence-Based Approach

Libertario Demi, PhD, Federico Mento, MSc, Antonio Di Sabatino, MD, Anna Fiengo, MD, Umberto Sabatini, MD, Veronica Narvena Macioce, Marco Robol, PhD, Francesco Tursi, MD, Carmelo Sofia, MD, Chiara Di Cienzo, MD, Andrea Smargiassi, MD, PhD, Riccardo Inchingolo, MD, PhD, Tiziano Perrone, MD, PhD

ABSTRACT

- Objectives—Worldwide, lung ultrasound (LUS) was utilized to assess coronavirus disease 2019 (COVID-19) patients. Often, imaging protocols were however defined arbitrarily and not following an evidence-based approach. Moreover, extensive studies on LUS in post-COVID-19 patients are currently lacking. This study analyses the impact of different LUS imaging protocols on the evaluation of COVID-19 and post-COVID-19 LUS data.
- Methods—LUS data from 220 patients were collected, 100 COVID-19 positive and 120 post-COVID-19. A validated and standardized imaging protocol based on 14 scanning areas and a 4-level scoring system was implemented. We utilized this dataset to compare the capability of 5 imaging protocols, respectively based on 4, 8, 10, 12, and 14 scanning areas, to intercept the most important LUS findings. This to evaluate the optimal trade-off between a time-efficient imaging protocol and an accurate LUS examination. We also performed a longitudinal study, aimed at investigating how to eventually simplify the protocol during follow-up.
- Additionally, we present results on the agreement between AI models and LUS experts with respect to LUS data evaluation.
- Results—A 12-areas protocol emerges as the optimal trade-off, for bothCOVID-19 and post-COVID-19 patients. For what concerns follow-up studies, it appears not to be possible to reduce the number of scanning areas. Finally, COVID-19 and post-COVID-19 LUS data seem to show differences capable to confuse AI models that were not trained on post-COVID-19 data, supporting the hypothesis of the existence of LUS patterns specific to post-COVID-19.
- Conclusions—A 12-areas acquisition protocol is recommended for both COVID-19 and post-COVID-19 patients, also during follow-up.

- Key Words —artificial intelligence; COVID-19; lung ultrasound; post-COVID-19; SARS-CoV-2


Score 0
Pleural Line
Horizontal artifacts
Score 1
Vertical artifacts
Score 2
Small sub-pleural consolidation
Score 3
Large consolidation
> 50% pleural line

Conclusion

In conclusion, the proposed scoring system is applicable to assess COVID-19 and post-COVID-19 patients. For both COVID-19 and post-COVID-19 patients, a 12-areas acquisition protocol is confirmed as the optimal trade-off between a time-efficient and accurate LUS examination procedure. Moreover, the worst scores are confirmed to be found in the basal posterior areas for both patients' populations. As for what concerns follow-up studies, it appears not to be possible to simplify the acquisition process, as no clear correlation was found among the score evolution across different areas. Finally, LUS data obtained from COVID-19 and post-COVID-19 seem to display differences which are capable of confusing AI models that were not trained on post-COVID-19 data. This opens interesting questions on the existence of specific patterns associated to post-COVID-19 patients. Research in this direction will be the focus of future studies.

Original Article | Published: 04 September 2019

Evaluation of a novel curriculum on point-of-care ultrasound competency and confidence

Levi Filler, Daniel Orosco, Daniel Rigdon, Carl Mitchell, James Price, Scott Lotz & Jeffrey R. Stowell

Emergency Radiology **27**, 37–40 (2020) | Cite this article

Abstract

- Introduction
- Point-of-care ultrasound (POCUS) education is a requirement of graduate medical education in EM. Milestones have been established to assess resident US competency. However, the delivery of POCUS education has not been standardized. This study aims to evaluate the impact of implementing a longitudinal, structured POCUS curriculum during EM residency on trainee competency and confidence.
- Methods
- A prospective study of PGY-3 trainees before and after implementation of a novel POCUS curriculum was performed over an 18-month period at an EM residency training program. Curriculum design included longitudinal POCUS application–based monthly electronic content, bi-monthly residency conference sessions, and hands-on rotations. PGY-3 resident's POCUS knowledge was assessed with a 38-question multiple-choice and image-based exam. Further, PGY-3 residents were surveyed regarding POCUS confidence. Survey results evaluated provider confidence, satisfaction with the novel curriculum, and overall perception of POCUS utility scored on a 1 (low) to 5 (high) scale. Results were evaluated using an unpaired *t* test for data analysis.
- Results
- Mean quiz scores of 8 pre-curriculum PGY-3 residents (84%; 95%CI 78.46–89.54) were not significantly different when compared with 13 post-curriculum PGY-3 residents (82%; 95%CI 77.11–86.89) ($p = 0.6126$). Survey results for pre-curriculum trainees across each section were 4.13 (95%CI 3.91–4.35), 3.68 (95%CI 3.32–4.04), and 4.33 (95%CI 4.06–4.6). Results for post-curriculum trainees trended higher for each section at 4.22 (95%CI 4.04–4.40) ($p = 0.4738$), 3.84 (95%CI 3.52–4.16) ($p = 0.5279$), and 4.49 (95%CI 4.21–4.77) ($p = 0.4534$).
- Conclusions
- Implementation of a structured, longitudinal POCUS curriculum resulted in a trend towards improved trainee confidence, satisfaction, and perception of POCUS. Future studies are needed to identify the optimal structure for POCUS educational content delivery and competency assessment for EM resident providers.

Original Article

Point-of-Care Ultrasound Needs Assessment, Curriculum Design, and Curriculum Assessment in a Large Academic Internal Medicine Residency Program

Authors: James E. Anstey, MD, Trevor P. Jensen, MD, Nima Afshar, MD

Abstract

Objectives: Internal medicine (IM) residency point-of-care ultrasound (POCUS) curricula are being developed but often are limited in scope or components. In this article, we discuss the demonstration of a need for POCUS training in our large academic IM residency program; the development of a longitudinal curriculum; and the impact of the curriculum on POCUS knowledge, use, and confidence.

Abstract

Objectives: Internal medicine (IM) residency point-of-care ultrasound (POCUS) curricula are being developed but often are limited in scope or components. In this article, we discuss the demonstration of a need for POCUS training in our large academic IM residency program; the development of a longitudinal curriculum; and the impact of the curriculum on POCUS knowledge, use, and confidence.

Methods: In 2014, we designed a cross-sectional POCUS survey and knowledge test for all IM residents at the University of California, San Francisco. The results of this assessment drove the design of a longitudinal POCUS curriculum that included a 2-hour workshop for all IM interns and a 1-month elective offered to all IM residents. Residents were tested on their POCUS knowledge and image interpretation before the elective and were given the same test 6 months after the elective. The posttest included a survey of self-reported POCUS use and confidence.

Results: In the needs assessment, residents scored a mean of 27% on the knowledge test, and across all applications the percentage of residents reporting confidence in their POCUS skills was lower than the percentage reporting use of the application in clinical practice. Residents scored a mean of 37% on the elective pretest and 74% on the posttest, an increase of 37% (95% confidence interval 31.6–42.8, $P < 0.001$), with improvements seen across all applications. After the elective, self-reported use of POCUS and confidence in POCUS skills were increased for the applications, using the needs assessment as an approximate baseline. For core cardiac and pulmonary applications, 76% to 95% of residents, depending on application, reported “high” or “very high” use and 79% to 100% reported “high” or “very high” confidence in their POCUS skills.

J Gen Intern Med. 2017 Sep;32(9):1052-1057. doi: 10.1007/s11606-017-4071-5. Epub 2017 May 11.

Internal Medicine Point-of-Care Ultrasound Curriculum: Consensus Recommendations from the Canadian Internal Medicine Ultrasound (CIMUS) Group

Irene W Y Ma [1 2], Shane Arishenkoff [3], Jeffrey Wiseman [4], Janeve Desy [5], Jonathan Ailon [6], Leslie Martin [7], Mirek Otremba [6], Samantha Halman [8], Patrick Willemot [4], Marcus Blouw [9], Canadian Internal Medicine Ultrasound (CIMUS) Group*

Collaborators, Affiliations + expand

PMID: 28497416 PMCID: PMC5570740 DOI: 10.1007/s11606-017-4071-5

Abstract

Bedside point-of-care ultrasound (POCUS) is increasingly used to assess medical patients. At present, no consensus exists for what POCUS curriculum is appropriate for internal medicine residency training programs. This document details the consensus-based recommendations by the Canadian Internal Medicine Ultrasound (CIMUS) group, comprising 39 members, representing 14 institutions across Canada. Guiding principles for selecting curricular content were determined a priori. Consensus was defined as agreement by at least 80% of the members on POCUS applications deemed appropriate for teaching and assessment of trainees in the core (internal medicine postgraduate years [PGY] 1-3) and expanded (general internal medicine PGY 4-5) training programs. We recommend four POCUS applications for the core PGY 1-3 curriculum (inferior vena cava, lung B lines, pleural effusion, and abdominal free fluid) and three ultrasound-guided procedures (central venous catheterization, thoracentesis, and paracentesis). For the expanded PGY 4-5 curriculum, we recommend an additional seven applications (internal jugular vein, lung consolidation, pneumothorax, knee effusion, gross left ventricular systolic function, pericardial effusion, and right ventricular strain) and four ultrasound-guided procedures (knee arthrocentesis, arterial line insertion, arterial blood gas sampling, and peripheral venous catheterization). These recommendations will provide a framework for training programs at a national level.

Keywords: curriculum; internal medicine; point-of-care ultrasound.

Watson *et al. BMC Medical Education* (2018) 18:217
https://doi.org/10.1186/s12909-018-1326-8

BMC Medical Education

RESEARCH ARTICLE Open Access

Point of care ultrasound training for internal medicine: a Canadian multi-centre learner needs assessment study

Kathryn Watson[1], Ada Lam[2], Shane Arishenkoff[3], Samantha Halman[4], Neil E. Gibson[2], Jeffrey Yu[5], Kathryn Myers[5], Marcy Mintz[1] and Irene W. Y. Ma[1,6*]

Conclusions

Our multi-center survey results from Canadian internal medicine residents suggest that learners found POCUS highly applicable to the practice of internal medicine, especially for identifying ascites and cardiac findings and for guiding central line insertion, paracentesis, and thoracentesis. Significant gaps were reported in skills and knowledge. Development of POCUS education should take these results into consideration when deciding where to focus curriculum efforts.

> Mil Med. 2019 Dec 1;184(11-12):901-906. doi: 10.1093/milmed/usz124.

Not Just Hocus POCUS: Implementation of a Point of Care Ultrasound Curriculum for Internal Medicine Trainees at a Large Residency Program

Thomas E Mellor [1], Zachary Junga [1], Sarah Ordway [1], Timothy Hunter [1], William T Shimeall [1], Sarah Krajnik [2], Lisa Tibbs [2], Jeffrey Mikita [2], Joseph Zeman [1], Paul Clark [1]

Affiliations + expand

PMID: 31125075 DOI: 10.1093/milmed/usz124

Abstract

Introduction: In 2018, the American College of Physicians formally acknowledged the importance of Point of Care Ultrasound (POCUS) to the practice of internal medicine (IM). For the military internist, POCUS training is critical for care of the trauma patient in austere environments, mass casualty events and natural disasters. While emergency medicine and critical care training programs have adopted POCUS education, few IM programs have integrated POCUS into their core curricula. We designed and implemented an iterative POCUS curriculum for trainees at a large military IM residency program over a two-year period.

Table II. Comparison of Survey Results after Intervention #2

Question	Pre-
How confident are you in your knowledge of ultrasound? [a]	2.48
How beneficial do you believe ultrasound skills will be for the health of your patients? [a]	4.7
How confident do you feel performing procedures under the guidance of ultrasound? [a]	2.62
How often do you currently/intend to incorporate the use of ultrasound into your practice? [b]	2.63

[a] 1 = Not at all 2 = Slightly 3 = Moderately 4 = Quite 5 = Extremely.

[b] 1 = Never 2 = Rarely 3 = Sometimes 4 = Frequently.

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Demonstration of a portable, smart-phone compatible ultrasound transducer in performing the focused cardiac examination on a healthy model.

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Letter

Point-of-Care Ultrasound Training and Credentialing for mid-late Career Emergency Physicians: Is it worth it?

Courtney M. Smalley, MD, FACEP[1]; Erin L. Simon, DO[2]; McKinsey R. Muir, MHSA[1]; Fernando Delgado, MSIE[1]; Baruch S. Fertel, MD, MPA[1]

(1) Cleveland Clinic Health System
(2) Akron General Medical Center

if only one patient had a shorter length of stay or was transferred to definitive care for trauma or aortic catastrophe based on POCUS training, then the training of mid to late career EM physicians in Basic POCUS may be worth the time and resource investment.

Table 1. Basic Point-of-Care Ultrasound Privileges

Credentialing Tier	**Applications**	**Number of Scans Required**
Basic Ultrasound (all scan types required for completion)	General applications: focused assessment with sonography in trauma (FAST), US guided venous access placement, abdominal aorta aneurysm (AAA)	FAST: 25 scans AAA: 25 scans Central Line: 10 scans
Requirements for Point-of-Care Ultrasound Study 1.Adequate image acquisition 2.Adequate image interpretation 3.Appropriate labeling of each image		

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Ultrasound Imaging of Quadriceps Tendon in a Recreational Golfer

Shawn D. Felton, EdD, LAT, ATC; Arie J. van Duijn, PT, MScPT, EdD

Florida Gulf Coast University, Fort Myers, FL 33965-6565, USA

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DOI: https://doi.org/10.24908/pocus.v6i2.14626

Abstract

The patient was a 69-year-old recreational golfer who injured his right . While walking between the 9th and 18th holes, he slipped on pine straw. Ultrasound images of the quadriceps tendon post-injury revealed a full-thickness tear of the Quadriceps tendon, Rectus Femoris and Vastus intermedius. The diagnosis was confirmed through MRI arthrogram imaging. The hypoechoic finding in the ultrasound exam demonstrated the imaging to be as precise in diagnosing a full thickness tear as the MRI. The patient underwent surgical repair of the Quadriceps Tendon and is currently progressing in rehabilitation.

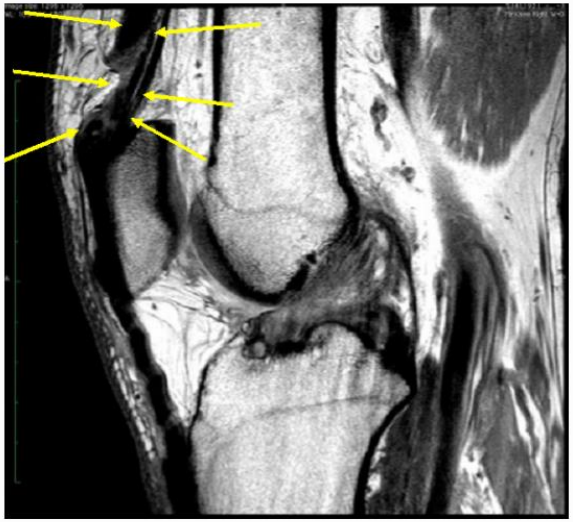

Figure 3. Post-injury MRI w/o contrast showing a portion of the quadriceps complex completely torn. The superficial aspect of the rectus femoris is avulsed from its patellar attachment and retracted proximally. Thinner smaller components of the vastus lateralis, vastus intermedius and vastus medialis remain intact. Arrowheads denote the torn quadriceps complex.

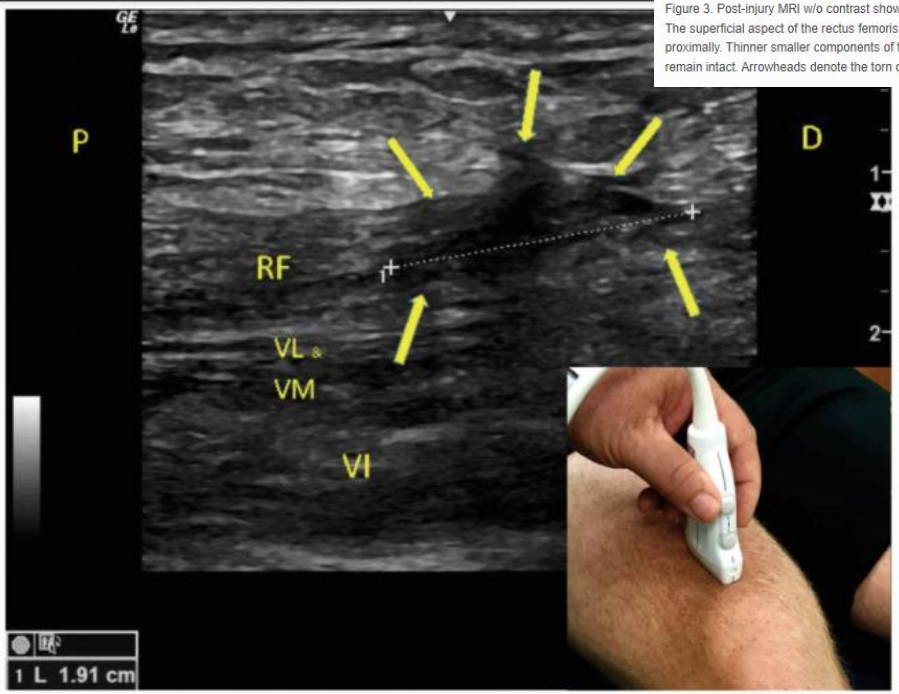

Figure 1. Post-injury long-axis ultrasound image of the Rectus Femoris (RF) (5-12 MHz linear transducer). The proximal and distal aspect of the rectus femoris exhibits a normal hyperechoic appearance, but a substantial hypoechoic area is noted (arrowheads), 1.9 cm which is suggestive of fluid and a full thickness mid-tendon tear of the rectus femoris. Also, mild hypoechoic signaling indicating fluid in the medial and lateral muscles indicating a strain with mild hypoechoic signaling deep indicating strain of vastus intermedius. Positioning of the ultrasound probe is seen in the bottom right-hand corner of the image. Abbreviations: P: proximal; D: distal; RF: rectus femoris; VL: vastus lateralis; VM: vastus medialis; VI vastus intermedius.

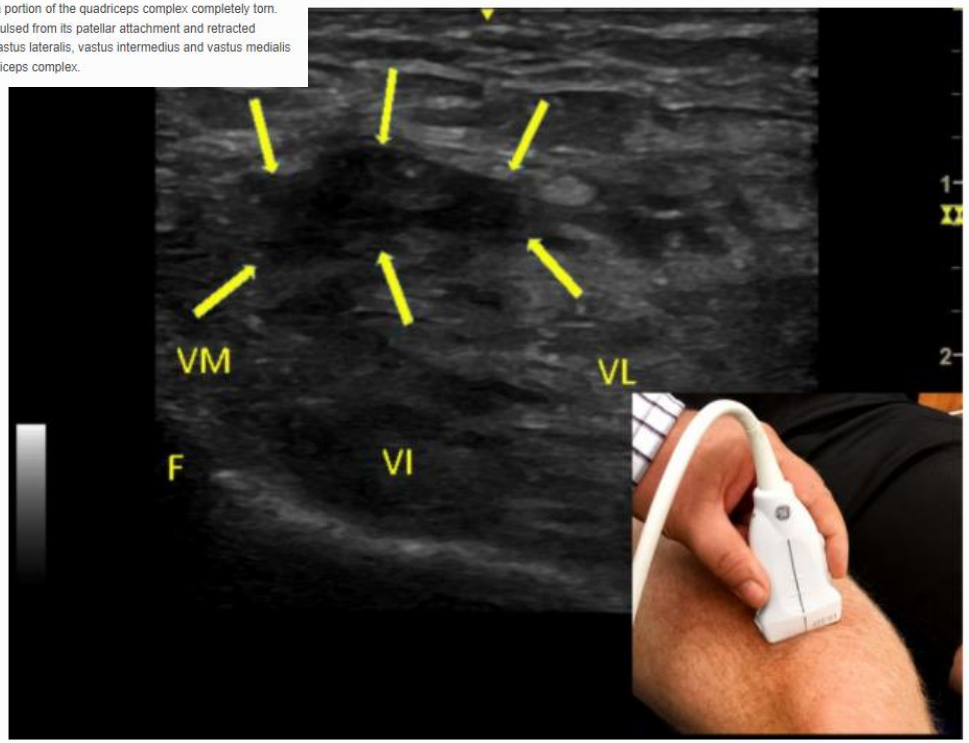

Figure 2. Post-injury short-axis ultrasound image of the Rectus Femoris. Disruption of the musculotendinous fibers of the rectus femoris can be visualized. A large hypoechoic gap in the rectus femoris is present, denoting the presence of significant fluid (arrows). Deeper areas of hypoechoic signaling indicating straining of the vastus medialis and lateralis and intermedius. Positioning of the ultrasound probe is seen in the bottom right-hand corner of the image. Abbreviations: F: femur; VL: vastus lateralis; VM: vastus medialis; VI vastus intermedius.

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Lung Ultrasound to Monitor Disease Severity and Aid Prognostication in COVID-19 Pneumonia: A Retrospective Analysis of Serial Lung Ultrasound Assessments

Matthew Llewelyn Gibbins, MBChB DTMH FRCA FFICM[1]; Quentin Otto, MA MB BChir DiMM[2]; Paul Adrian Clarke, BM BSc MRCP FRCA FFICM[1]; Stefan Gurney MB BS MD (Res) FRCA FFICM[1]

(1) Anaesthetic and Intensive Care Medicine Consultant, Bristol Royal Infirmary (BRI), Bristol, BS2 8HW
(2) Acute Care Common Stem trainee, BRI, Bristol, BS2 8HW

Abstract

Background: The aim of this retrospective analysis was to assess if serial lung ultrasound assessments in patients with COVID-19 pneumonia, including a novel simplified scoring system, correlate with PaO_2:FiO_2 ratio, as a marker of disease severity, and patient outcomes. **Methods**: Patients treated for COVID-19 pneumonia in a tertiary intensive care unit who had a lung ultrasound assessment were included. Standardised assessments of anterior and lateral lung regions were prospectively recorded. A validated lung ultrasound score-of-aeration and a simplified scoring system based on the number of disease-free lung regions were correlated with: PaO_2:FiO_2 ratio, successful weaning from mechanical ventilation, and status (alive or dead) at discharge. MedCalc© statistical software was used for statistical analysis. **Results**: 28 patients (109 assessments) were included. Correlation was seen between score-of-aeration and PaO_2:FiO_2 ratio ($r = -0.61$, $p<0.0001$) and between the simplified scoring system and PaO_2:FiO_2 ratio ($r = 0.52$ $p<0.0001$). Achieving a score-of-aeration of ≤9/24 or ≥2 disease-free regions was associated with successful weaning from mechanical ventilation and survival to ICU discharge (accuracy of 94% and 97% respectively). **Conclusion**: Retrospective analysis from this small cohort of patients demonstrates that scores-of-aeration and a simplified scoring system based on the number of disease-free antero-lateral regions from serial LUS assessments correlate with PaO_2:FiO_2 ratio as a marker of disease severity in patients with COVID-19 pneumonia. In addition, lung ultrasound may help identify patients who will have favourable outcomes.

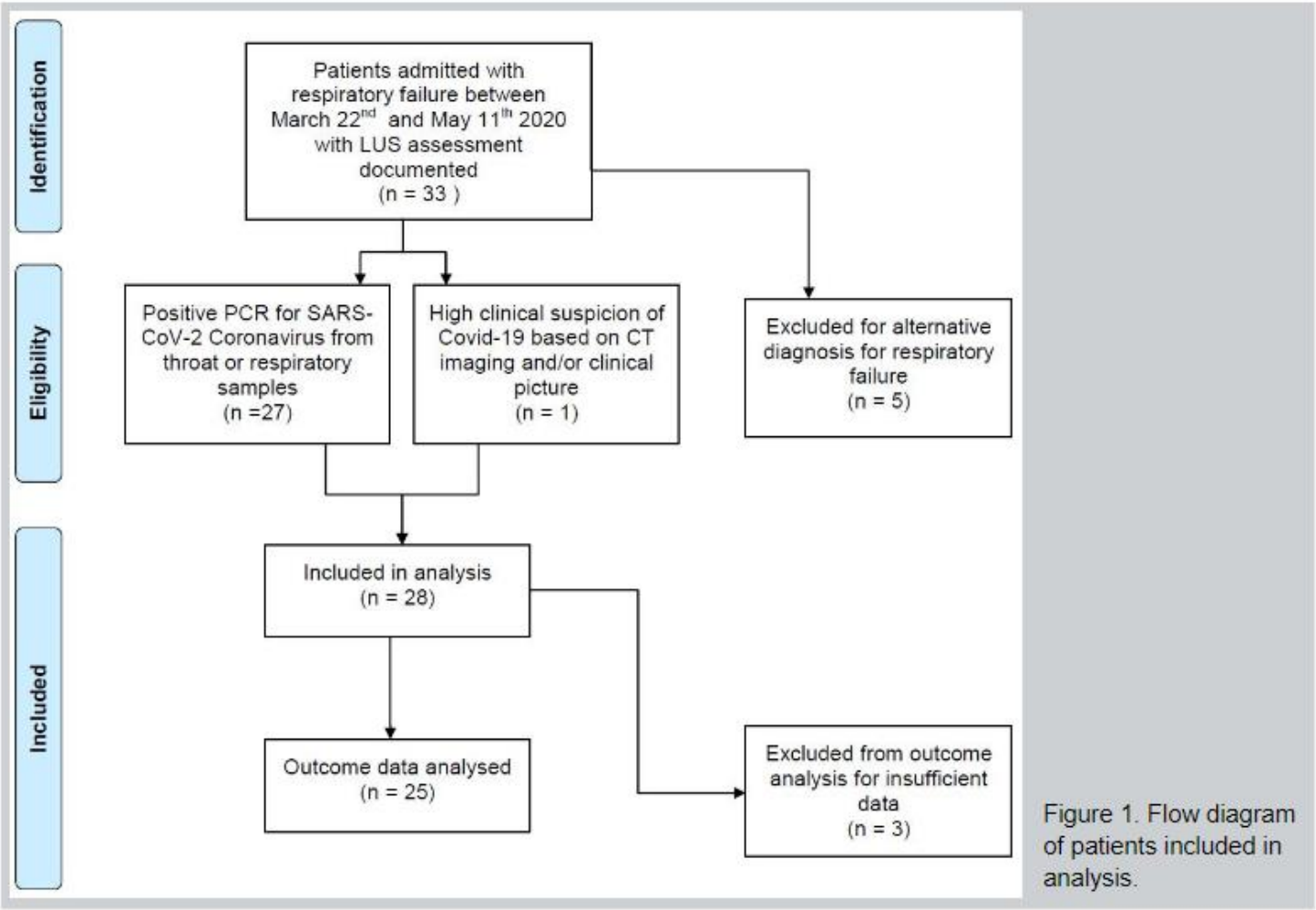

Figure 1. Flow diagram of patients included in analysis.

Conclusions

Our retrospective analysis of 95 serial LUS assessments in a cohort of 28 patients with COVID-19 pneumonia demonstrates that findings correlate with PaO2:FiO2 ratio as a marker of disease severity and could provide useful information regarding prognostication. We believe this simple, safe, and inexpensive bedside investigation can contribute to the wider patient assessment and aid decision making during the global COVID-19 pandemic. The easily learnt simplified scoring system warrants validating in a larger cohort

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The Use of Thoracic Ultrasound to Predict Transudative and Exudative Pleural Effusion

Peter T. Evans MD[1†]; Robert S. Zhang MD[1†]; Yulei Cao MS[2]; Sean Breslin MD[1]; Nova Panebianco MD, MPH[3]; Cameron M. Baston MD, MSCE[1,4]; David M. DiBardino, MD[1,4]

(1) Department of Medicine, University of Pennsylvania, Philadelphia, PA
(2) Drexel University College of Medicine, Philadelphia, PA
(3) Department of Emergency Medicine, University of Pennsylvania, Philadelphia, PA
(4) Section of Interventional Pulmonology and Thoracic Oncology, Division of Pulmonary, Allergy and Critical Care, University of Pennsylvania, Philadelphia, PA

[†]PE and RSZ contributed equally to this work

Abstract

Objectives: Pleural effusion is a common reason for hospital admission with thoracentesis often required to diagnose an underlying cause. This study aimed to determine if the imaging characteristics of TUS effectively differentiates between transudative and exudative pleural fluid. **Methods:** Patients undergoing TUS with pleural fluid analysis were retrospectively identified at a single center between July 2016 and March 2018. TUS images were interpreted and characterized by established criteria. We determined diagnostic performance characteristics of image criteria to distinguish transudative from exudative pleural effusions. **Results:** 166 patients underwent thoracentesis for fluid analysis of which 48% had a known malignancy. 74% of the pleural effusions were characterized as exudative by Light's Criteria. TUS demonstrated anechoic effusions in 118 (71%) of samples. The presences of septations on TUS was highly specific in for exudative effusions (95.2%) with high positive predictive values (89.5%) and likelihood ratio (2.85). No TUS characteristics, even when adjusting for patient characteristics such as heart failure or malignancy, were sensitive for exudative effusions. **Conclusions:** Among our cohort, anechoic images did not allow reliable differentiation between transudative and exudative fluid. Presence of complex septated or complex homogenous appearance was high specific and predictive of exudative fluid.

Table 3. Diagnostic Performance of Ultrasound Score to Predict Exudative Effusions.

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Positive LR (95% CI)
Nonzero sonographic score (%)	29 (21-38)	71 (55-84)	74 (60-86)	25 (18-34)	1.0 (0.6-1.7)
Presence of Septations (%)	13(8-21)	95 (84-99)	89 (67-98)	27 (20-35)	2.9 (0.7-12)
Anechoic Effusion Resulting in Transudate	71 (55-84)	29 (21-38)	25 (18-34)	75 (60-86)	1.0 (0.8-1.2)

Table 4. Diagnostic Performance of Ultrasound Score to Predict Exudative Effusions (Video Only)

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Positive LR (95% CI)
Nonzero sonographic score (%)	37 (27-48)	68 (46-85)	80 (65-91)	23 (14-36)	1.1 (0.6-2.2)
Presence of Septations (%)	19 (11-28)	96 (80-99)	94 (73-99)	24 (16-34)	4.7 (0.66-33.8)
Anechoic Effusion Resulting in Transudate	68 (46-85)	37 (27-85)	23 (14-34)	80 (56-91)	1.1 (0.8-1.5)

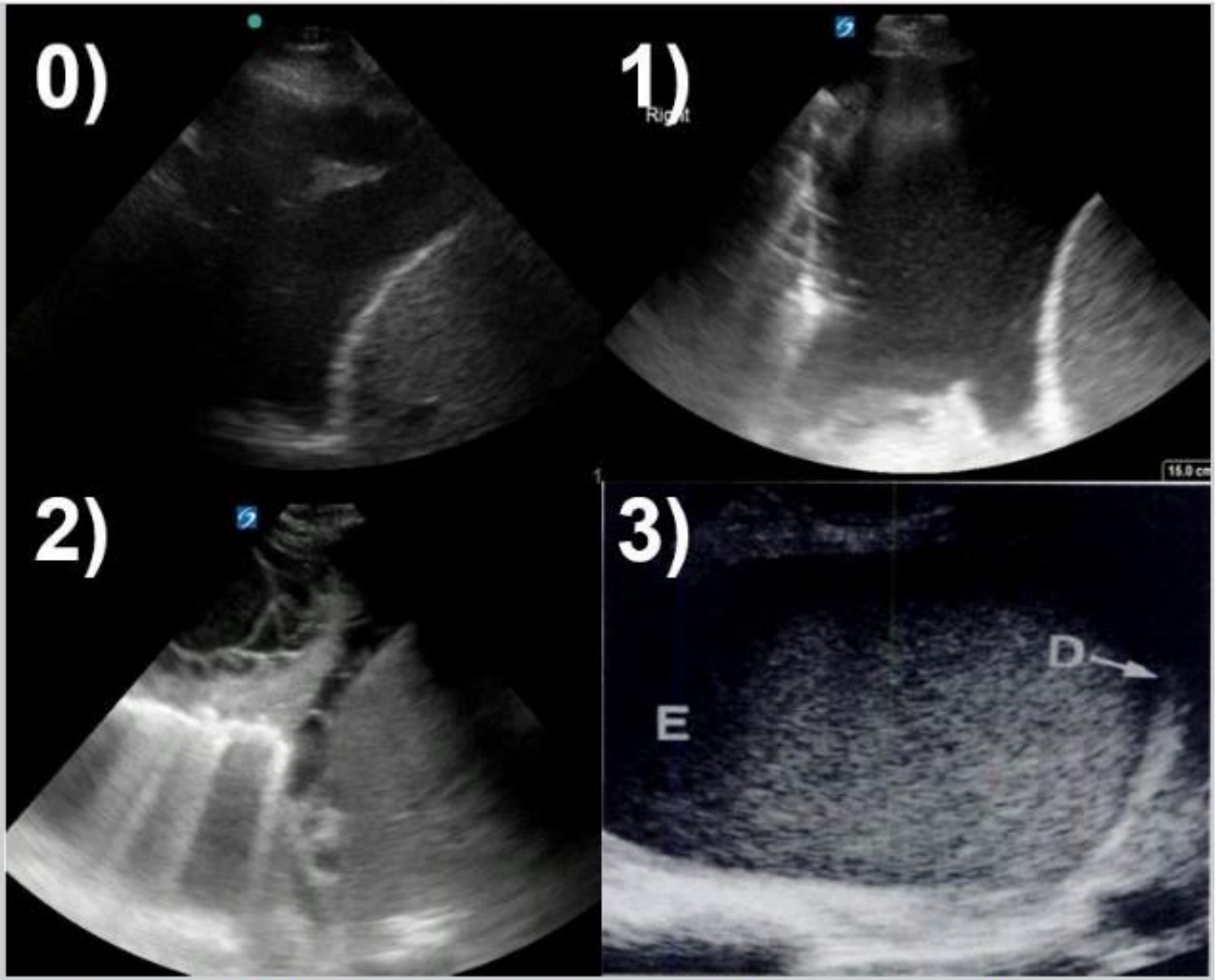

Figure 1. Sample pleural fluid images. 0, anechoic – no echoes present between the pleura and diaphragm; 1, complex, non-septated – increased echogenicity of the space between the pleura and diaphragm, without clear hyperechoic linear findings to suggest septation; 2, complex, septated – echogenic linear structures present in the space between the pleura and diaphragm; 3, homogenously echogenic – echogenic material filling the entire space between the pleura and diaphragm.

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Letter to the Editor | Free Access

A New Type of Outpatient: Lung Ultrasound after COVID-19 Infection

Andrea Boccatonda MD, Giulio Cocco MD, Soccorsa Sofia MD, Esterita Accogli MD, Susanna Vicari MD, Cosima Schiavone PhD

First published: 08 November 2021 | https://doi.org/10.1002/jum.15871

To the Editor:

We have seen the spotlight of lung ultrasound, which has found its definitive (finally!) consecration in the SARS-CoV-2 pandemic as a first-level method for the evaluation of signs of pneumonia and in its monitoring.[1] It is known that the detection of B lines or vertical artifacts with nonhomogeneous distribution and an irregularity of the pleural line are the main signs of COVID-19 pneumonia especially in the early phase.[2] As the disease progresses, the bilateral interstitial disease pattern worsens, by involving more and more lung areas in an increasingly severe manner (up to pulmonary edema visible as white lung areas on ultrasound) and up to induce consolidation areas, as evidence of complete pulmonary deaeration.[3] Almost a year and a half after the onset of the pandemic, many patients have more or less completely recovered. We have poor evidences about the chronic evolution of COVID-19 infection and residual lung damage. Nowadays, there is an increasing number of requests for lung ultrasound in outpatients to evaluate lung damage after COVID-19 infection/pneumonia.

Figure 1. Lung ultrasound on a 42-year-old outpatient 3 months after the acute phase of the COVID-19 infection. The patient had a mild form of pneumonia that did not require hospitalization. The image shows an irregularity of the pleural line which is thickened or interrupted in some segments, more evident in the basal dorsal lung fields.

Figure 2. Lung ultrasound on a 54-year-old outpatient 1 month after the acute phase of the COVID-19 infection. The patient presented with a severe form of pneumonia that required admission to intensive care for invasive ventilation. The image shows a residual hypoechoic sub-pleural consolidation, a sign of residual de-aeration of the evaluated lung field.

a widespread irregularity of the pleural line.

seems to be the most frequently residual sign from COVID-19 pneumonia, also visible in patients who developed mild pneumonia (Figure 1). In our series, patients who had been treated for a mild form of pneumonia showed a clear irregularity of the pleural line at 3 months (similar to initial pictures of chronic fibrosing interstitial disease) in the dorsal basal fields, often in the absence of other pathological signs. The optimal situation is to perform an ultrasound follow-up of the patient during and after the COVID-19 infection, by using the same method and the same reporting scheme. In the few cases examined, we used the LUS score, thus showing a decrease in score number, but whether this score gradually decreases to zero or settles on a severity score over time is not known yet.

A first question to answer is whether lung ultrasound is relevant enough to be considered as a screen/control method for an accurate assessment of residual lung damage; we should point out that lung ultrasound can evaluate only changes that reach the

pulmonary pleura. Notably, the association of ultrasound with clinical and laboratory/spirometric data can strengthen subsequent clinical choices. Secondly, it is relevant to establish the timing of control both from the acute phase of the infection, according to the clinical history and phenotypes of the patients, and over time (we suggest 3, 6 and 12 months). Thirdly, it is important to understand the evolution of lung damage over time from a pathophysiological and pathological point of view; indeed, some patients had a complete *restitutio ad integrum* on the one hand and others who will develop chronic interstitial disease on the other. In the latter case, the ultrasound findings could be similar to that known for chronic lung diseases with pleural line irregularities, irregular B lines, and small subpleural consolidations.

We hope that future controlled comparative studies can answer those questions. Furthermore, the publication of specific guidelines, with a clear definition of the study and reporting methods, will allow a comparison of patients between different physicians.