



CASE REPORT

REVISED Case Report: Pulmonary hemorrhage as a rare cause of lung ultrasound A/B-profile [version 2; peer review: 2 approved]

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v2 First published: 05 Jun 2019, 8:788 (<https://doi.org/10.12688/f1000research.19329.1>)
 Latest published: 08 Aug 2019, 8:788 (<https://doi.org/10.12688/f1000research.19329.2>)

Abstract

When using lung ultrasound to determine the cause of acute respiratory failure, the BLUE protocol is often used. In a 65-year old patient, an A/B-profile was found, suggesting pneumonia, following the flowchart of this protocol. In this case, however, pulmonary hemorrhage confirmed by bronchoscopy was the final diagnosis. This case report outlines the importance of understanding the limitations of the BLUE protocol and that lung ultrasound findings should always be used in the context of the patient's history and physical exam. In addition, pulmonary hemorrhage should be considered in patients with no clinical signs of pneumonia and/or presence of risk factors for lung bleeding as a rare cause of lung ultrasound A/B-profile.

Keywords

Lung Ultrasound, BLUE-Protocol, Pulmonary Hemorrhage

Open Peer Review

Reviewer Status

	Invited Reviewers	
	1	2
REVISED		
version 2 published 08 Aug 2019	report	
version 1 published 05 Jun 2019	? report	 report

- 1 **Belaid Bouhemad**, CHU de Dijon, Dijon, France
- 2 **Daniel A. Lichtenstein** , Paris-West University, Boulogne, France

Any reports and responses or comments on the article can be found at the end of the article.

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Author roles: **Haaksma ME:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation; **Nossent EJ:** Supervision, Visualization, Writing – Review & Editing; **Elbers P:** Supervision, Visualization, Writing – Review & Editing; **Tuinman PR** : Conceptualization, Methodology, Supervision, Visualization, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

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How to cite this article: Haaksma ME, Nossent EJ, Elbers P and Tuinman PR. **Case Report: Pulmonary hemorrhage as a rare cause of lung ultrasound A/B-profile [version 2; peer review: 2 approved]** F1000Research 2019, 8:788 (<https://doi.org/10.12688/f1000research.19329.2>)

First published: 05 Jun 2019, 8:788 (<https://doi.org/10.12688/f1000research.19329.1>)

REVISED Amendments from Version 1

In this version we addressed the comments of our reviewers Dr. Bouhemad and Dr. Lichtenstein. These included minor changes such as the addition of 2 references to cite expert reviews in the field of lung ultrasound and rephrasing nomenclature in accordance to the BLUE-protocol.

See referee reports

Introduction

Over the last few years, lung ultrasound has found routine use in critical care, even outperforming chest X-ray in detecting lung pathology^{1,2}. Systematic approaches for its application are advised and have already been developed. For example, the BLUE protocol, developed by Lichtenstein *et al.*, is often used to rapidly identify the cause of acute respiratory failure, with a claimed accuracy of 90.5%¹. It uses interpretation of artifacts visible in the presence of pleural and/or pulmonary pathology on three distinct places. These include the upper BLUE-point on the midclavicular line, the lower BLUE-point more caudally and lateral and the PLAPS-point (posterolateral alveolar and/or pleural syndrome point) on the dorsal side of the patient, continuing horizontally from the lower BLUE-point. The most frequently seen artifacts are lung-sliding and A-lines. The first being movement of the visceral pleura sliding against the parietal pleura and the second being a reverberation artifact of the pleural line. Their presence indicates unaffected lung surface.

B-lines are vertical hyperechogenic artifacts and are linked to fluid buildup in lung tissue. The presence of more than two B-lines indicates interstitial syndrome. Combining these artifacts on every point and following the schema, the physician is led to five distinct diagnoses, which are cardiogenic pulmonary edema, pulmonary embolism, pneumothorax, obstructive disease or pneumonia. The latter being characterized by unilateral lung rockets resulting in an A/B-profile.

In the following article we present a case of pulmonary hemorrhage as a rare cause of lung ultrasound A/B-profile.

Case presentation

A 65-year old Caucasian male presented to the emergency ward with hemoptysis and respiratory distress. The patient's history contained multiple pulmonary embolisms and subsequent chronic thromboembolic pulmonary hypertension, for which he was using acenocoumarol. Additionally, a non-specified form of pulmonary vasculitis was suspected, with concomitant treatment of prednisone. Bronchoscopy revealed pulmonary hemorrhage originating from the right pulmonary artery, which was coiled, and ICU admission followed. Two days after admission the patient was stable and extubated but showed signs of respiratory distress within the same day. Non-invasive ventilatory assistance failed and the patient was reintubated, while tranexamic acid (intravenous single dose, 1000 mg) was started as the cause was suspected to be a rebleed. Ultrasound examination according to the BLUE-protocol showed an A/B-profile (Figure 1a, b)

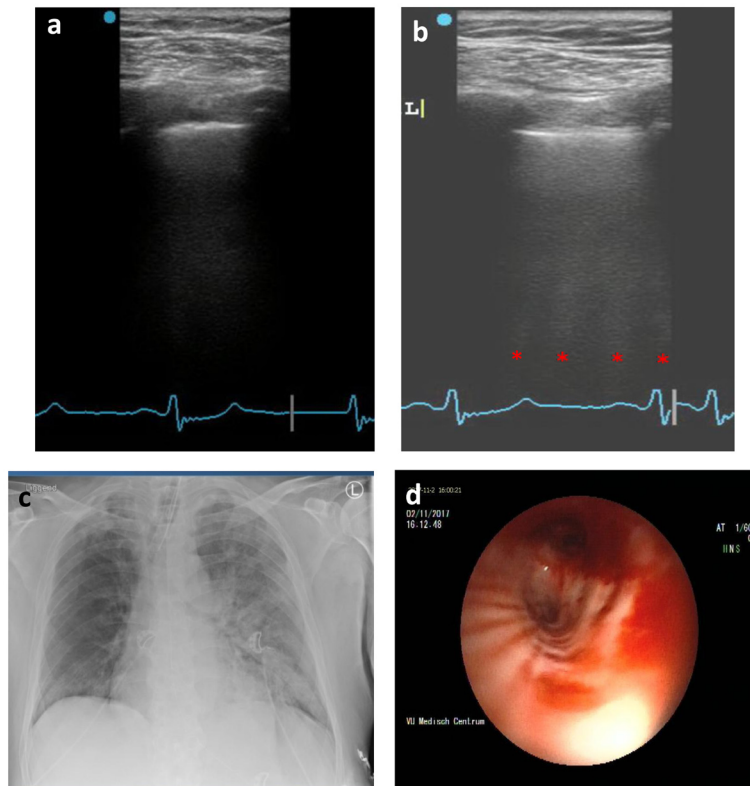


Figure 1. Images taken of the patient's lungs. (a) A-profile (right lung). **(b)** B-profile with four distinguishable B-lines (left lung). Red dots, B-lines. **(c)** Chest X-ray with marked consolidation in the left lung. **(d)** Bronchoscopy of left main bronchus displaying bleeding from the upper lobe.

and chest X-ray showed left-sided consolidation (Figure 1c). Subsequent bronchoscopy revealed a bleed originating from the left upper lobe (Figure 1d) which was successfully coiled.

The following days were marked by respiratory instability and tracheal tube occlusion due to blood clots. One week after admission the patient developed atrial fibrillation, which was only temporarily relieved by cardiac resynchronization and amiodarone (300 mg intravenous loading dose in addition to 1200 mg/24 h intravenous for 1 day). This caused a further decline in cardiopulmonary function. A day later CT-angiography was performed and showed a fully occluded right bronchial artery and widespread occlusions in the left lung because of thrombosis. Due to the lack of additional therapeutic options, palliative care was started in line with the patient's wishes, after which he passed away.

Discussion

Lung ultrasound has been demonstrated to be of high value in patients with respiratory symptoms. The BLUE-protocol is probably one of the most well-used protocols in these patients due to its ease of use and high accuracy. However, with all the enthusiasm around it, it is of vital importance to be aware of its limitations.

The protocol was originally developed for and tested in an emergency room population, although it is now frequently used in ICU patients, relying on a 90% diagnostic accuracy¹. We don't know, however, whether the same accuracy can be achieved in such a radically different patient population. ICU patients are frequently ventilated and could potentially be diagnosed with multiple pulmonary problems at the same time. In addition, pathology might be more subtle or different pathologies are present at the same time. To our knowledge, it is not clear how the BLUE-protocol performs in a setting with more than one underlying disease. Equally, the prevalence of included diagnoses differs between the ICU and the emergency room. This could potentially also influence its accuracy.

Furthermore, the BLUE-protocol relies on simplification of reality by categorizing the etiology of dyspnea into five groups. This is also demonstrated by our case report, in which A/B profile was not caused by pneumonia but pulmonary hemorrhage. In line with this and the findings of our case report, we want to highlight how important it is to interpret the artifacts in the context of the patient's history and physical exam. AB profile would normally suggest pneumonia as the underlying cause, but in the absence of infectious symptoms and parameters this

seems unlikely. Pairing the profile with the patient's recent history of pulmonary hemorrhage, this diagnosis also fits the picture. While this is only one example, it is not unlikely that other scenarios in which the seen artifact could be paired with more than one diagnosis can present itself.

Aside from ambiguity of profiles, another problem is the lack of certain diagnoses, such as ARDS (adult respiratory distress syndrome). In the ICU it is a frequently encountered problem, but has currently no place in the BLUE-protocol. Including more complex problems like these or even more rare diagnoses could presumably also impact its accuracy.

Lastly, we do not know what the optimal approach is, given that different available protocols have not been compared. Assessing only three points per hemithorax might not be sufficient and perhaps more comprehensive imaging with more areas investigated are necessary^{3,4}. The optimal balance of areas screened vs. time spent on an exam is yet to be determined. While expert reviews are available, strict protocols in regards to choice of probe and their settings during examination are not available^{5,6}. This also might influence the quality of images and hence the interpretation of artifacts. In the future, we therefore hope to see more elaborate guidelines that encompass detailed information for image acquisition. Inclusion of more diagnoses perhaps with more advanced lung ultrasound modalities, such as Doppler or 3D imaging, would help to develop lung ultrasound to an even more sophisticated diagnostic tool.

Conclusion

This case report outlines the importance of understanding the limitations of the BLUE-protocol and that lung ultrasound, like other imaging modalities, should always be used in the context of the patient's history and physical exam. Also, pulmonary hemorrhage should be considered in patients with no clinical signs of pneumonia and/or presence of risk factors for lung bleeding as a rare cause of lung ultrasound A/B-profile.

Data availability

No data are associated with this article.

Consent

Written informed consent for publication of clinical details and clinical images was obtained from the patient's family.

Grant information

The author(s) declare that no grants were involved in supporting this work.

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[PubMed Abstract](#) | [Publisher Full Text](#)

Open Peer Review

Current Peer Review Status:  

Version 2

Reviewer Report 28 August 2019

<https://doi.org/10.5256/f1000research.22077.r52233>

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Ok for me. All asked modifications were done. Good work, nothing to add.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 27 June 2019

<https://doi.org/10.5256/f1000research.21188.r49575>

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Daniel A. Lichtenstein 

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Reviewing this interesting case report was a fine opportunity to make basic reminders on the BLUE-protocol. We hope this will allow the readers to better understand how to use it.

We briefly correct minor details. The authors speak of *BLUE-1* and *BLUE-2*. Following the lung ultrasound nomenclature, they should speak of upper and lower BLUE-points¹. Four lines before Conclusions, minor typo (*with perhaps with*).

This being said, the good point is the illustration of a rare cause of dyspnea (pulmonary hemorrhage) seen through the BLUE-protocol (and generating an A/B-profile). This is important to know for future uses. We now have to comment numerous other points (focusing on the most important for shortening our analysis).

The article begins softly by a simple case report of a rare situation, and then increasingly challenges several areas of the BLUE-protocol, not specifically related to the topic on focus (the non infectious A/B-profile). While respecting and understanding the approach of the authors, our review will explain again what is the BLUE-protocol - a precious reminder for those who did not read this article.

This case report is presented as a limitation of the BLUE-protocol. It should, on the contrary, be understood as a perfect illustration of its spirit. May we remind that the BLUE-protocol is a *clinical* protocol. First of all (this is specified in its title), it includes the critical notion that the patient is in respiratory failure. If the BLUE-protocol was independent from this detail, we would all have severe asthma or exacerbated COPD, that is, the nude profile. Second, the BLUE-protocol is only the ultrasound part of a clinical approach to the patient. The BLUE-protocol is always performed after having received simple data of a simple history and a simple physical examination (see below for this case report).

Later, the authors consider that “the BLUE-protocol relies on [over] simplification”, with only five groups of diseases. May we remind that it has considered 97% of the patients (adults, seen in the ER, all admitted to the ICU)? We also remind that the majority of diagnostic mistakes (and dramas) include these frequent causes of dyspnea, this is why the BLUE-protocol focuses on the real, daily life. By the way, the 3% of other patients had countless causes (including this interesting case report). Creating a decision tree with all causes of dyspnea would generate a decision tree beyond any description in terms of complexity. Anyway, an answer to the concern of the authors can be consulted in our latest textbook, the E-BLUE-protocol, that is, an extended BLUE-protocol². They will find more developments of each profile by using tools from simple (echocardiography e.g.) to complex and invasive procedures.

For each of the usual diseases, the reader benefits from various values of accuracies, which indicates that the BLUE-protocol is not designed for giving but suggesting (more or less highly) diagnoses.

Therefore, we are here in a caricatural situation where the doctor has immediately detected a particular setting and is therefore invited to promptly use additional tests (as the authors rightly did in this case report). Here for instance, the history immediately points on a very particular situation (a long history of pulmonary embolism), and the physical examination immediately detects a major sign (hemoptysis) (and, we guess, absence of fever). The BLUE-protocol can of course be performed, but for building a diagnosis, such patients are immediately excluded from its thought process, and managed independently.

This being said, we will comment on several points through the article:

1. Lung sliding and A-lines are “unaffected lung tissue”. We rather speak of unaffected lung *surface*. We remind that the A-profile (anterior bilateral lung sliding plus predominant A-lines) can be seen in pulmonary embolism (generating the A-DVT-profile), pure posterior pneumoniae (A-V-PLAPS-profile) and COPD and/or asthma (nude profile).
2. The authors consider that three points are too limited. Yet they cautiously use the word “perhaps”, and we invite them to test the BLUE-protocol with more points. We have done this comparison since three decades and did not find a significant change in the accuracies. We never found time

for submitting our data, and strongly encourage the authors to making this comparison, and publish it.

3. B-lines are “linked” to fluid buildup. This is one of four possibilities only. *Stricto sensu*, the B-line indicates fluid surrounded by air (in a ratio of 1%-99% roughly). This fluid can be interstitial; it can be transudative in the case of hydrostatic pulmonary edema (B-profile usually), or exudative in the case of pneumonia/ARDS (B'-profile in many cases). The fluid can be intra-cellular; normal in the case of a simple lung fissure (isolated B-line), or pathologic on the case of chronic interstitial disease (usually lung rockets).
4. “The presence of more than two B-lines” is not sufficient. The diagnosis of interstitial syndrome is based, not on a number, but on a concentration of B-lines. The problem is (very simply) solved if you add “between two ribs”, that is a distance of roughly 2 cm, that is, 3 B-lines every 2 cm.
5. “Unilateral B-lines resulting in an A/B-profile”. Please replace “B-lines” by “lung rockets” and it will be correct. The B-line is not a disease, we almost all have B-lines. Reminder, more than two B-lines between 2 ribs are called lung rockets.
6. The authors write: “it is not clear how the BLUE-protocol performs in a setting with more than one underlying disease”. If they raise the issue of mixt diseases, these cases are integrated in the E-BLUE-protocol. In the native article, such patients were excluded for obvious methodological reasons (this affected roughly 1% of the patients). If a patient has two conditions potentially generating dyspnea, which gold standard will be able to determine the respective part of both diseases? It can be 50-50%, it can also be 51-49%, up to, potentially, 99-1%.
7. The authors write that ARDS has “currently no place in the BLUE-protocol”. This is wrong. The lecture of the native article shows that ARDS is considered as a pneumonia (severe, extensive, deadly, but just a pneumonia), which makes sense in the large majority of cases, again for simplifying a daily situation. The four profiles of pneumonia (B', AB, C and AVPLAPS-profile) are found in the majority of cases of ARDS.
8. The authors “don't know whether the same accuracy can be achieved in such a radically different patient population” (emergency room versus ICU). First, some diagnoses can perfectly be achieved in ICU patients. A pneumothorax still is a pneumothorax. A major pleural effusion is still a pleural effusion. An increase of lung rockets (from septal rockets to glass rockets, e.g.) indicates a worsening (and many other examples). Yet the authors are partially right, these are two different groups. The answer is simple. The BLUE-protocol is reserved for the initial diagnosis (usually in the ER). For ICU patients, submitted to mechanical ventilation and severe diseases with fast changes, the CEURF (our academic teaching centre) has designed a specific approach, the Pink-protocol. These patients have no dyspnea and no cyanosis (hence this label), but they have no more lung function. The technique is more comprehensive than the BLUE-protocol (more points of investigation), and the interpretation is, obviously, more complex. Obstructive atelectases, e.g., much more frequent in this group, are integrated within the Pink-protocol.
9. According to the authors, there is “no strict guidelines in regard to choice of probe”. We just recall the probe which we have used through all our publications on whole body ultrasound since our first success, submitted since 1991³. We use it for assessing abdominal disorders, deep venous thromboses, and all our procedures (including subclavian cannulation). We do not prevent the community to use classical probes, we just see the drawbacks of this approach: cost (buying

probes), time (changing probes), infectious issues (cleaning probes - we are unable to avoid asepsis errors when using more than one probe) and last, a more complicated approach to the subtle science of lung ultrasound. Our probe is unique because of its logical ergonomics (allowing all accesses), its range allowing to detect both superficial and deep details (using the criteria 2 and 4 of the B-line), and its clear ability to visualise B-lines (using criteria 5 and 7) (Fig. 1).

10. In the Figure 1B, we do not see any B-line. Or, we just guess some, ill-defined, in the fog - and our 3-decade experience helped us a lot. How about novice users? The criterion N°5 of the B-line: "well-defined" (laser like), and the criterion N°7: "hyperechoic" (that is, white like the pleural line) are missing. This is a severe concern. Look our world (available since at least 1982), and please compare (Fig. 1). The result is a hindrance to an optimal development of lung ultrasound, and the need for complicated solutions. With a simple machine and probe, B-lines need no sophistication, no artificial intelligence, no automatic detection, no 3-D nor Doppler imaging.

Suggested solutions:

Please try to deactivate *all* filters of your modern machine, maybe you will succeed to have a convincing image. The manufacturer must not only sell you the unit, they must also find where are all those filter which, to our opinion, have no utility in critical ultrasound but just resulting in such images.

The authors argue for Doppler and 3D imaging. Here, our answer is simple. Since three decades, we promise to use these sophisticated techniques as soon as we will feel limited by the simple and standardized approach provided by CEURF. This time has still not come. When we see the provided image quality, we understand why people develop sophisticated solutions. The physicians who use suitable equipment will, likely, not need these sophistication's. On purpose, we insist on this point.

We take the advantage of this providential tribune for pointing out that the value of "100%" likely does not exist in medicine (apart from privileged exceptions, such as the lung point). In the native article, the A/B-profile was 100% specific to pneumonia. This beautiful performance was of course due to a weak number (12 of 300 studied patients had the A/B-profile). It is completely intuitive that multiplying the numbers will make appear exceptional situations. If we make a study of 1000 cases of AB-profile, rare diseases will be seen sometimes. We will see maybe 10 or 20 noninfectious causes, not a lot more we guess. Therefore, the specificity of the A/B-profile would become 99%, maybe 98%, not less. This is the basic statistical art.

We are of course sorry about the outcome of this patient. Some academicians may argue that if a tool is used in an exceptional setting, makes anyway a diagnosis, but does not help the patient from a sad outcome, this tool was eventually of limited value here. We respect life too much for just thinking this.

Conclusions:

This review was a nice opportunity for a pedagogic exercise: reminding what is the BLUE-protocol. If we were asked to summarize our review in a few words, we would write: "Please pilot the BLUE-protocol. Be a doctor... and it will give its best". We congratulate the authors to use this attractive part of lung ultrasound, and we encourage them for any further investigations.

Figure 1: (Figure 2⁴ (middle image))

B-lines, as they were described in the CEURF nomenclature with their seven criteria. Three are constant (comet-tail artifact, arising from the pleural line, moving in sync with lung sliding). Four are almost constant (long, well-defined, erasing A-lines, hyperechoic). Here, typical lung rockets. From a 1992

Hitachi 405 and its microconvex probe.

Note that in the figure under link, the terms *B7 and B3 lines* were long replaced by the much more speaking *septal rockets and glass rockets*, respectively.

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Is the background of the case's history and progression described in sufficient detail?

Yes

Are enough details provided of any physical examination and diagnostic tests, treatment given and outcomes?

Yes

Is sufficient discussion included of the importance of the findings and their relevance to future understanding of disease processes, diagnosis or treatment?

Yes

Is the case presented with sufficient detail to be useful for other practitioners?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Critical care medicine, critical ultrasound, lung ultrasound.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 26 Jul 2019

Mark Haaksma, VU University Medical Center, Amsterdam, Amsterdam, The Netherlands

Dear Dr. Lichtenstein,

Thank you for your time and expertise. We have adjusted the manuscript according to you feedback and would also like to respond to your comment.

We would like to point out that this article was in no way meant to directly critique the BLUE-protocol. We ourselves are avid users of said protocol and ultrasound in general. The enthusiasm around it is, rightfully so, rapidly spreading. With it however, we have noticed that eagerness to quickly implement LUS in daily ICU practice comes with a lack of caution. Therefore,

this article is meant as a reminder of certain caveats, which do not necessarily stem from the protocol but its implementation.

We agree that in this instance the cause for respiratory failure was relatively clear and that application of the BLUE protocol was not called for. However, we believe with this clear-cut situation we underline our points given in the discussion and above. Point being that the high accuracy of the protocol should not lead physicians to a misplaced sense of security in more dubious cases. This again, is more as consequence of its implementation and not the protocol itself.

In regard to image and probes we agree that the presented microconvex probe probably has various benefits over other probes that are frequently used. However, exactly the fact that various probes are being used is of great importance. Physicians should, yet sometimes might not be, aware of this. In our daily practice, we also see that there are differences in image quality depending on probes used.

While we agree that “simple” LUS is sufficient for B-line assessment, we still believe that in the spirit of scientific curiosity we are obliged to research whether arising modalities such as 3D and doppler imaging might contribute to it. Perhaps new possibilities will present itself in this regard.

Nevertheless, we want to thank you for your elaborate comment. It is without a doubt a good reminder and lesson of the BLUE-protocol for all readers.

Competing Interests: No competing interests were disclosed.

Reviewer Report 21 June 2019

<https://doi.org/10.5256/f1000research.21188.r49573>

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Belaid Bouhemad

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Authors described limitations of the «BLUE protocol» about one case of hemoptysis. The authors should be commended for this task. The case report is well written, “English” seems to me very good. I have only 2 comments to add to the discussion part:

1. Blue protocol is not for ICU, we agree, and Lung US ICU protocols or guidelines are not available. But review written by experts are available. Please quote Bouhemad *Anesthesiology*, 2015 Feb;122(2):437-47¹, and Mojoli, *Am J Respir Crit Care Med*, 2019 Mar 15;199(6):701-714². Moreover, in these papers, the issues of the needed “examinations points” (at least 6 X right/left) and probe are discussed.
2. In the conclusion, authors should precise that lung ultrasound "as all imaging technique should be considered in the patient's....etc".

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Is the background of the case's history and progression described in sufficient detail?

Yes

Are enough details provided of any physical examination and diagnostic tests, treatment given and outcomes?

Yes

Is sufficient discussion included of the importance of the findings and their relevance to future understanding of disease processes, diagnosis or treatment?

Partly

Is the case presented with sufficient detail to be useful for other practitioners?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Ultrasound, ICU

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 26 Jul 2019

Mark Haaksma, VU University Medical Center, Amsterdam, Amsterdam, The Netherlands

Dear Dr. Bouhemad,

Thank you for your time and expertise. We have adjusted the manuscript according to your feedback. The mentioned reviews are indeed an excellent addition to this article. We also agree that all imaging modalities have to be seen in the context of the patient.

Competing Interests: No competing interests were disclosed.

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