Minimal Criteria for Lung Ultrasonography in Internal Medicine

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Abstract
Background
Point-of-care lung ultrasound (LUS) examination is increasingly utilized in Internal Medicine. To improve the standardization of LUS education and clinical use, explicit minimal criteria for defining what is an acceptable and clinically useful image are needed.

Methods
A 97-item online survey of potential minimal criteria for common uses of LUS in Internal Medicine was developed and sent to 10 international point-of-care ultrasound experts. Their opinion on the inclusion of each item was sought and items not achieving consensus (defined as agreement by at least 70% of the experts) were reassessed in subsequent rounds. A total of three rounds were conducted.

Results
Seventy-four minimal criteria were agreed upon for inclusion, 24 were agreed upon for exclusion, and two did not reach consensus.

Conclusions
Experts agreed on 74 minimal criteria for Internal Medicine LUS. The use of these minimal criteria during teaching and clinical use is strongly recommended.

Résumé
Contexte
L'échographie pulmonaire au point d'intervention est de plus en plus utilisée en médecine interne. Pour améliorer l'uniformisation de la formation sur l'échographie pulmonaire et de

son utilisation clinique, il faut des critères minimaux explicites pour définir ce qu'est une image acceptable et utile sur le plan clinique.

Méthodologie

Un sondage en ligne de 97 éléments portant sur des critères minimaux possibles dans l'utilisation courante de l'échographie pulmonaire en médecine interne a été élaboré et soumis à 10 experts internationaux en échographie au point d'intervention. Leur avis sur l'inclusion de chaque élément a été sondé, et les éléments pour lesquels il n'y avait pas de consensus (défini par l'accord d'au moins 70 % des experts) ont été réévalués lors de tours suivants. Au total, trois tours ont été effectués.

Résultats

Soixante-quatorze critères minimaux ont été acceptés, 24 ont été exclus et deux n'ont pas fait consensus.

Conclusions

Les experts se sont entendus sur 74 critères minimaux relatifs à l'échographie pulmonaire en médecine interne. L'utilisation de ces critères minimaux au cours de l'enseignement et de l'utilisation clinique est fortement recommandée.

Background

The role of point-of-care ultrasound (POCUS) in the care of medical patients is being increasingly recognized.[1–3] Of the recommended Canadian Internal Medicine POCUS applications,[3] lung ultrasound (LUS) is one of the easiest to learn and has high clinical utility.[4] Its use in medical patients with dyspnea, for example, is associated with increased diagnostic accuracy at the bedside.[5–7] Its use may also be gaining importance in the assessment of patients with coronavirus-19.[8] Despite it being relatively easy to learn, to support the use of LUS clinically, appropriate training in image acquisition and interpretation is required. It is generally accepted by POCUS experts that images not meeting minimal criteria, such as those that have insufficient depth or inadequate optimization of the pleural line, should not be used to support clinical decision-making,[9] as they may introduce serious diagnostic errors. Both achieving minimal criteria during image acquisition and the recognition of when these criteria have not been met are fundamental to POCUS competency.[9] In addition, the use of minimal criteria in POCUS training programs is considered a key indicator of high-quality education.[10]

Despite the critical importance of minimal criteria, existing resources on learning LUS, while useful, focus primarily on image acquisition and interpretation,[4,11,12] without an explicit list of minimal criteria that an image must meet. As POCUS education expands across the country, articulation of such criteria

becomes increasingly important if high-quality education is to be standardized. Given that trained POCUS experts agree on the importance of minimal criteria,[9] through consensus methods, this study seeks to encapsulate this codex of expert knowledge into an explicit list of minimal criteria for LUS. These minimal criteria can then be used to guide clinical use as well as LUS education for residency training programs.

Methods
Survey Development

This study received approval from the Conjoint Health Research Ethics Board at the University of Calgary (#REB16-2452). Using existing key reference resources for LUS,[11,13–22] two independent investigators (J.D. and I.M.) drafted a list of minimal criteria for all intended applications of LUS, to be as inclusive as possible. Disagreements were resolved by discussion and if necessary consensus from additional investigators. This 78-item list was formatted into an online survey (www.surveymonkey.com, SurveyMonkey Inc., San Mateo, CA, USA).

This draft online survey was piloted in May 2019 on 14 Internal Medicine and Family Medicine physicians with at least 1 month of formal ultrasound training for feedback on survey length, clarity, response options, missing or redundant items, and flow. Feedback was reviewed by both J.D. and I.M. and incorporated into the final 97-item survey.

Table 1. Baseline Characteristics of the 10 Participants on the Expert Panel

Characteristic	N (%)
Country of Practice	
Canada	5 (50)
USA	5 (50)
Specialty	
Emergency medicine	3 (30)
Critical care medicine	1 (10)
General internal medicine	6 (60)
Gender	
Male	4 (40)
Female	6 (60)
Years of experience using POCUS*	
3–4	1 (10)
5–6	3 (30)
7–8	1 (10)
9–10	1 (10)
>10	4 (40)
Years of experience teaching POCUS*	
1–2	1 (10)
3–4	2 (20)
5–6	1 (10)
7–8	2 (20)
9–10	1 (10
>10	3 (30)
Years of experience assessing POCUS*	
1–2	2 (20)
3–4	1 (10)
5–6	2 (20)
7–8	2 (20)
9–10	1 (10)
>10	2 (20)
Number of peer-reviewed publications related to POCUS	
1–2	1 (10)
3–4	5 (50)
>10	4 (40)
Completion of POCUS fellowship of 1-year duration or more	
Yes	6 (60)
No	4 (40)

* POCUS denotes point-of-care ultrasound.

Expert Panel

Our expert panel included 10 international POCUS experts who had at least 1 year of fellowship training in ultrasonography OR a 3-year track record of teaching and assessing POCUS AND a minimum of three peer-reviewed POCUS-related publications. The experts completed three rounds of the online survey between June 2019 and September 2019, where they were asked regarding specific minimal criteria and if a given item must or must not be present to meet minimal criteria. We defined consensus as agreement by at least 70% of the experts.[23] Open-ended response options were also provided to capture missing items and additional comments. Items that did not reach consensus were included in subsequent rounds, which included new or revised items based on expert feedback from the previous round. Results from survey responses from prior rounds were provided to the participants in the form of the percentages of those who chose each option, as well as relevant comments that led to any item revisions.

Results

All 10 experts completed all rounds of the survey. Table 1 outlines the baseline characteristics of the experts.

Round 1

In round 1, of the 97 items considered, consensus was reached to include 50 items. For 18 items, consensus was reached for being NOT mandatory (Table 2). No consensus was reached for the remaining 29 items.

Round 2

Based on feedback from experts in round 1, two new questions were added to the 29 items that were without consensus from Round 1. The new questions were: (i) For a lung scan to be considered acceptable, one of the following lung patterns/findings MUST be present deep to the pleural line: A-lines, B lines, consolidation, or pleural effusion and (ii) To rule out pneumothorax, the least gravitationally dependent areas of the chest MUST be scanned (e.g., anterior chest in a supine patient).

Of the 31 items considered in this round, 16 items reached consensus to be included, 4 reached consensus for NOT being mandatory, and 11 items did not reach consensus (Table 2).

Round 3

Round 3 included the 11 items from round 2 that did not meet consensus as well as one new item on the need to scan the posterolateral regions of the lungs for evidence of pneumonia/consolidation. Of the 12 items considered, 8 reached consensus

Table 2. Minimal Criteria For Internal Medicine Lung Ultrasound

	Minimal Criteria	% agreement
	General Criteria	
1	For a lung scan to be considered acceptable, one of the following lung patterns/findings MUST be present deep to the pleural line: A-lines, B-lines, consolidation, or pleural effusion	90[2]
2	Whenever possible, we recommend recording a minimum of a 6-s cineloop	80[3]
3	Using a lung preset is NOT mandatory if abnormalities can be visualized	70[1]
4	Turning off tissue harmonic imaging is NOT mandatory if abnormalities can be visualized	70[1]
	Assessing for Pleural Sliding	
	Acceptable transducer(s)	
5	Linear	100[1]
6	Curvilinear	90[1]
7	Phased array	80[2]
8	Microconvex	70[1]
	Minimal criteria for pleural sliding	
9	Pleural line MUST be clearly visible	100[1]
10	Pleural line MUST be clearly centered	80[1]
11	Pleural line MUST be as echogenic as possible (by fanning)	80[1]
12	To state that lung sliding is ABSENT, at least one rib MUST be visible	100[3]
13	Showing two consecutive ribs is NOT mandatory	80[1]
14	Lung zones MUST be labeled	80[2]
15	If pleural sliding not seen, MUST use at least 1 maneuver	100[1]
	Acceptable maneuvers to improve pleural sliding visualization	
16	Decrease depth	80[1]
17	Change to a linear transducer	100[1]
18	Adjust gain	70[1]
19	Use M-mode	80[1]
	Maneuvers deemed not mandatory	
20	Increasing frequency is NOT a mandatory maneuver	80[1]
21	Moving the focus is NOT a mandatory maneuver	90[3]
22	Using Doppler is NOT a mandatory maneuver	100[1]
	Still image archive for pleural sliding if cineloops not available	
23	A still image of M-mode is acceptable to show the presence or absence of lung sliding	90[1]
24	A B-mode still image is NOT acceptable to show the presence of lung sliding	90[1]
25	A B-mode still image is NOT acceptable to show the absence of lung sliding	90[1]
	Assessing for Pleural Irregularities	
	Acceptable transducer(s)	
26	Linear	100[1]
27	Curvilinear	80[1]
28	Microconvex	100[2]
29	Phased array LEAST preferred	70[2]
	Minimal criteria for pleural irregularities	
30	Pleural line MUST be clearly visible	100[1]

	Minimal Criteria	% agreement
	General Criteria	
31	Pleural line MUST be clearly centered	80[1]
32	Pleural line MUST be as echogenic as possible (by fanning)	100[1]
33	Lung zones MUST be labeled	80[2]
34	Showing two consecutive ribs is NOT mandatory	90[1]
	No consensus: At least one rib must be visible 50	
	Assessing for Lung Point/Pneumothorax Assessment	
	Acceptable transducer(s)	
35	Linear	100[1]
36	Curvilinear	100[1]
37	Phased array	70[1]
38	Microconvex	70[1]
	Minimal criteria for lung point/pneumothorax assessment	
39	Pleural line MUST be clearly visible	100[1]
40	Pleural line MUST be clearly centered	70[1]
41	Pleural line MUST be as echogenic as possible (by fanning)	70[1]
42	Lung zones MUST be labeled	80[2]
43	Must scan bilaterally to rule out a pneumothorax unless clinically not indicated (e.g., post-procedure)	80[1]
44	To rule out pneumothorax, the least gravitationally dependent areas of the chest MUST be scanned (e.g., anterior chest in a supine patient)	90[3]
45	Lung point is NOT mandatory to diagnose pneumothorax	90[2]
47	Showing two consecutive ribs is NOT mandatory	80[1]
	No consensus: At least one rib must be visible	50
	Still image archive for lung point/pneumothorax if cineloops not available	
47	A still image of M-mode is acceptable to show lung point	80[2]
48	A B-mode still image is NOT acceptable to show lung point	100[1]
	Assessing for B-Lines	
	Acceptable transducer(s)	
49	Curvilinear	100[1]
50	Phased array	100[1]
51	Microconvex	70[1]
52	Linear NOT acceptable*	89[1]
	Minimal criteria for B-lines assessment	
53	Pleural line MUST be clearly visible	90[1]
54	Pleural line MUST be clearly centered	100[2]
55	Pleural line MUST be as echogenic as possible (by fanning)	90[1]
56	At least one rib must be visible	70[1]
57	Lung zones MUST be labeled	90[2]
58	Must scan bilaterally to rule OUT pulmonary edema	100[1]
59	To rule OUT pulmonary edema, we encourage learners to scan a minimum of eight lung areas (four on each side) whenever possible	80[2]
60	For the diagnosis of B-lines, we recommend a minimum depth of 10 cm below the pleural line be imaged	70[3]
61	Showing two consecutive ribs is NOT mandatory	70[1]

(continued)

	Minimal Criteria	% agreement
	General Criteria	
	Still image archive for B-lines if cineloops not available	
62	A B-mode still image is acceptable to show positive B-lines	70[1]
63	A B-mode still image is NOT acceptable to rule out presence of B-lines 90[2]	
	Assessing for Consolidation	
	Acceptable transducer(s)	
64	Curvilinear	100[1]
65	Phased array	90[1]
66	Microconvex	100[2]
67	Linear acceptable if consolidation can be visualized	90[3]
	Minimal criteria for consolidation	
68	Pleural line MUST be clearly visible	100[2]
69	Lung zones MUST be labeled	90[2]
70	Must scan bilaterally to rule out a pneumonia	100[1]
71	To look for pneumonia/consolidation, we encourage learners scan a minimum of eight lung areas (four on each side)	70[3]
72	To look for pneumonia/consolidation, posterolateral regions MUST be scanned	70[3]
73	Pleural line being clearly centered is NOT mandatory	70[1]
74	Pleural line being as echogenic as possible is NOT mandatory	70[1]
75	If consolidation is visualized, having at least one rib visible is NOT mandatory	90[3]
76	Showing two consecutive ribs is NOT mandatory	100[1]
	Minimal criteria for basal zone consolidation	
77	MUST attempt to visualize the spine	70[1]
78	Diaphragm MUST be visualized	90[1]
79	Spleen or liver MUST be visualized	70[1]
80	Lung zones MUST be labeled	70[2]
81	Consolidation must show air bronchograms	70[1]
82	Demonstrating the spleen/kidney or liver/kidney interface is NOT mandatory	80[2]
83	Air bronchograms do NOT need to be dynamic	80[1]
	Still image archive for consolidation if cineloops not available	
84	A B-mode still image is acceptable to show consolidation	100[1]
	Assessing for Pleural Effusion	
	Acceptable transducer(s)	
85	Curvilinear	100[1]
86	Phased array	100[1]
87	Microconvex	70[1]
88	Linear NOT acceptable*	100[1]
	Minimal criteria for pleural effusion	
89	MUST attempt to visualize the spine	80[1]
90	Diaphragm MUST be visualized	100[1]
91	Spleen or liver MUST be visualized	80[1]
92	Lung zones MUST be labeled	70[2]
93	MUST scan bilaterally to rule out a pleural effusion	100[1]
94	MUST scan a minimum of two zones to rule out pleural effusion	70[1]

	Minimal Criteria	% agreement
	General Criteria	
95	To diagnose a pleural effusion, at least 25% of the diaphragm MUST be visualized	90[3]
96	Demonstrating the spleen/kidney or liver/kidney interface is NOT mandatory	80[2]
97	Sinusoid sign is NOT mandatory	70[1]
	Still image archive for pleural effusion if cineloops not available	
98	A B-mode still image is acceptable to show presence of pleural effusion	100[1]

* Only nine experts responded to these questions.

Expert responses to items and the round in which the items achieved consensus are shown as superscript numbers

to be included, 2 reached consensus for NOT being mandatory, and 2 items remained without consensus (Table 2).

The final list of items is listed in Table 2 and included 74 mandatory items, 24 items that were considered NOT mandatory and 2 items that never reached consensus.

Discussion

In this study, we defined 74 consensus-based minimal criteria for key findings in Internal Medicine LUS. These criteria are both explicit and practical, taking into consideration potential equipment limitations such as commonly available transducers and machine functions (e.g., options for focus and transducer frequency modulation). It also takes into consideration the LUS findings in question. For example, while experts generally agreed that for most findings the pleural line should be visible, centered, made as echogenic as possible by fanning, and with at least one rib visible, in the presence of certain findings, such as an obvious consolidation, centering of the pleural line was not deemed mandatory (#73) nor was it necessary that the pleural line itself be optimized (#74). In another example (#12), experts made it clear that if pleural sliding is visible, the presence of at least one rib may not be necessary. However, to state that lung sliding is ABSENT, at least one rib MUST be visible, so that the pleural line can be properly identified in such cases. Also, the group explicitly outlines image storage requirements. For example, while the presence of B-lines can be confirmed and documented with a still image (#62), their absence cannot be so confirmed (#63) due to the respiratory movement of B lines, making it possible to miss a positive finding with a still image. Such key information, while inherently known to LUS experts, has not been previously outlined and is vitally important for all learners and training programs to recognize.

There are some limitations to our study. First, a few of our items required significant revisions. For example, while 100% of our experts agreed that a minimal depth must be achieved for the assessment of B-lines, (to avoid mistaking these for z-lines),[24] it was challenging to derive consensus on what this minimal depth should be, as it is partially dependent on the patient's body habitus (e.g., the more subcutaneous tissue depth present, the deeper the distance required). Ultimately, only by the third round were our experts able to achieve consensus once our revisions reflected this variability in subcutaneous tissue depth (#60: a minimum of 10 cm required, starting from below the pleural line, rather than at the skin surface). We encountered similar wording issues when describing the amount of diaphragm required to be imaged in the assessment for pleural effusions. Rather than describing exactly which portions of the diaphragm were required to be visualized (medial vs lateral), experts were ultimately able to agree on the overall percentage of a diaphragm that must be visualized (#95). Second, the online survey design did not allow for rich discussion amongst experts, and comments were limited to open text boxes only. However, despite this limitation, our experts were very engaged, and key comments from them led to significant wording revisions and additional items. Third, our minimal criteria are intended to be exactly that—minimal criteria. While using a lung preset and turning off tissue harmonic imaging should be performed whenever possible, if findings are seen, our group was willing to forego these settings (#3, #4). However, from a learner's perspective, it may still be prudent to be consistent in the use of an optimal preset or demonstrate the presence of both ribs using a curvilinear transducer whenever possible, even though these are not considered mandatory. Fourth, we did not perform a systematic review. However, our experts are true experts of LUS, including a number who participated in national and international consensus statements that did include an extensive literature strategy.[8,11] Lastly, although not every expert answered every question in our survey, only two questions in all three rounds of the survey had missing responses.

In conclusion, our experts agreed upon 74 items required for meeting minimal criteria for LUS uses relevant to internal

medicine, and 24 items were NOT required. In the teaching of LUS, adherence to these criteria is recommended.

Statement of Contributions

JD, VEN, ASL, and IWYM contributed to conception and design, and procurement of data; JD and IWYM contributed to the analysis of data, to the initial draft of the manuscript, and critical review and drafting of the manuscript.

Conflict of Interest Statement for All Authors

Dr. Ma is funded by the John A. Buchanan Chair of General Internal Medicine, University of Calgary.

Dr. Liteplo had received a grant from GE/EMF to perform ultrasound research, has consulted for Philips Healthcare, and is involved in ultrasound-related research sponsored by Fujifilm/Sonosite unrelated to this research.

Dr. Buchanan is a clinical advisor for MEDO.Ai, in developing artificial-intelligence-based software for common point-of-care ultrasound applications.

Dr. Dversdal is employed part-time by Vave Health in the Chief Medical Officer's role. Primary contributions to this manuscript were all prior to this role.

Drs. Arishenkoff, Dumoulin, Desy, Noble, Liu, and Olszynski have no conflicts of interest to report.

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