Cite as: Buda N, Kosiak W, Radzikowska E, Olszewski R, Jassem E, Grabczak EM, et al.; Polish Committee on Lung Ultrasound (PC-LUS) for POLLUS-IM. Polish recommendations for lung ultrasound in internal medicine (POLLUS-IM). J Ultrason 2018; 18: 198–206.

Submitted: 23.05.2018
Accepted: 08.08.2018
Published: 06.09.2018

Polish recommendations for lung ultrasound in internal medicine (POLLUS-IM)

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DOI: 10.15557/JoU.2018.0030

Keywords
lung ultrasound, chest sonography, internal medicine, recommendation

Abstract

Objective: The aim of this study was to establish recommendations for the use of lung ultrasound in internal medicine, based on reliable data and expert opinions. Methods: The bibliography from the databases (Pubmed, Medline, OVID, Embase) has been fully reviewed up to August 2017. Members of the expert group assessed the credibility of the literature data. Then, in three rounds, a discussion was held on individual recommendations (in accordance with the Delphi procedure) followed by secret voting. **Results:** Thirty-eight recommendations for the use of lung ultrasound in internal medicine were established as well as discussed and subjected to secret voting in three rounds. The first 31 recommendations concerned the use of ultrasound in the diagnosis of the following conditions: pneumothorax, pulmonary consolidation, pneumonia, atelectasis, pulmonary embolism, malignant neoplastic lesions, interstitial lung lesions, cardiogenic pulmonary edema, interstitial lung diseases with fibrosis, dyspnea, pleural pain and acute cough. Furthermore, seven additional statements were made regarding the technical conditions of lung ultrasound examination and the need for training in the basics of lung ultrasound in a group of doctors during their specialization programs and medical students. The panel of experts established a consensus on all 38 recommendations.

Introduction

In the past 40 years, a significant increase in knowledge about lung ultrasound has been observed. There are more and more publications and meta-analyses in this area. In 2012, the first recommendations were created by the EFSUMB expert group[1]. Currently in Poland, lung ultrasound is performed by several thousand physicians, over 95% of whom are clinicians (non-radiologists) of various specialties, primarily in internal medicine, pediatrics, anesthesiology as well as intensive therapy and thoracic surgery.

In light of numerous new reports and growing popularity of lung ultrasound, there is a need to create national recommendations for the use of lung ultrasound in internal diseases[2–10]. In order to develop such a document, invitations were sent to representatives of all Medical Universities in Poland. Fifteen people responded to the invitation and created a multidisciplinary team of experts consisting of specialists in internal medicine, pneumonology, cardiology, radiology and pediatrics. Additionally, specialists in statistics and methodology also joined the team.

Methodology

The stages of preparing the recommendations included respectively: (a) reviewing and selecting the literature, (b) creating a database, (c) specifying statements, (d) analyzing literature data credibility, (e) discussions using the Delphi procedure, and (f) secret ballot of experts in three rounds.

Review and selection of the literature and creation of a database for analysis

The literature review was carried out independently by four people. Publications were searched for in the following databases: PubMed, OVID, Embase, MEDLINE. Searches were carried out using the following terms (Medical Subject Heading): "ultrasonography," "chest sonography," "lung ultrasound," „diagnostic imaging," "respiratory tract diseases," "pneumonia," "pulmonary embolism," "pneumothorax," "cardiogenic pulmonary edema," "non-cardiogenic pulmonary edema," "lung tumor," "atelectasis," "interstitial lung disease," "pulmonary fibrosis," "pleural effusion," "diaphragm" and excluding such terms as "endoscopy," "mammary ultrasonography," "prenatal ultrasonography," "endoscopic

ultrasound-guided fine needle aspiration." The analysis included prospective, retrospective and observational studies as well as meta-analyses with their full texts or summaries published in English before August 2017. In addition, two English-language books were included in the database. The initial selection of publications was based on the verification of titles and abstracts, followed by an analysis of the full texts of selected articles. In the absence of a full-text English version, the data contained in the summary were evaluated.

During the literature review, the Zotero program was used (*Center for History and New Media at George Mason University*). The next stage involved the combination of the results of the data search done by all four people, and the duplicate papers were removed. Finally, 275 publications were included in the process of creating the recommendations.

Establishing statements

The statements were created on the basis of available data, most frequently appearing in selected references. They concerned the following conditions: pneumothorax, lung consolidations, pneumonia, atelectasis, pulmonary embolism, malignant neoplastic lesions, interstitial lung lesions, cardiogenic pulmonary edema, interstitial lung diseases with fibrosis, diagnosis of dyspnea, pleural pains and acute cough. The established statements were first used to verify the credibility of the literature data, and then they were subjected to expert opinions.

Moreover, additional statements were developed regarding technical conditions for lung ultrasound examination as well as the need for training in the basics of lung ultrasonography in a group of doctors in training and students. These additional statements were analyzed and reviewed by experts, without a credibility analysis of the literature data.

Data credibility analysis

When analyzing the credibility of the literature data, the following parameters were taken into account: age, sex, number of examined patients, homogeneity of patient groups participating in a study, inclusion and exclusion criteria, type of work (prospective, retrospective, meta-analysis), sensitivity and specificity of an employed method, true positive (TP), false positive (FP), true negative (TN) and false negative (FN) results, and imaging method recognized as the gold diagnostic standard. In addition, *the Tool for the Quality Assessment of Diagnostic Accuracy Studies* (QUADAS *score* and QUADAS *score-2*), recommended by the Cochrane Diagnostic Test Accuracy Working Group, was used to estimate the methodological quality of the work[11–13] (Tab. 1).

A – data come from many meta-analyses, and/or it is unlikely that further research will change the credibility of effectiveness or accuracy of the method
B – data come from individual large non-randomized trials (meta-analysis, prospective cohort study), and/or further testing may have a significant impact on the credibility of effectiveness or accuracy of the method
C – agreed expert opinion and/or data from small studies, retrospective studies, registers, case series, or case reports, and/or it is very likely that further testing will have an important impact on the credibility of effectiveness or accuracy of the method. Any estimation of the effects or accuracy of the method is very uncertain (very low)

Tab. 1. *Level of evidence*

Experts' opinion

The experts' final opinion was a result of a three-step procedure involving discussions with the application of the Delphi procedure[14] in groups of 4 people with two supervisors, and three rounds of secret voting.

The first round of voting took place in November 2017 at the Medical University of Gdansk. At this stage of the meeting, a discussion was held in small groups according to the Delphi system, followed by anonymous ballot. The voted-out statements received ≥ 80% of positive votes. More than 50% of votes against a given statement was considered to be synonymous with the negation of the statement. Statements with 50–80% of positive votes were discussed again and underwent voting in the second round.

The second round of voting was also held in November 2017. An online discussion in accordance with the modified Delphi system was conducted via the Internet website, and then, after anonymous distribution of all opinions to the participants, a secret voting was held. As a result of the second round of voting, a consensus was reached on the ambiguous results from the first round.

In December 2017, the third and final round of voting was held, which ended with unambiguous results and consensus (Tab. 2 and Tab. 4).

I Recommendations

Pneumothorax

1. Sonographic indicators of pneumothorax are: no *"lung sliding,"* no vertical artifacts of reverberation, no *"lung pulse,"* and the presence of *"lung point"*. (A1)
2. The presence of *"lung sliding"*, vertical artifacts of reverberation originating from the pleural line and *"lung pulse"* excludes pneumothorax. (A1)
3. In a patient with acute respiratory failure with a significant suspicion of pneumothorax, it is not necessary to search for *"lung point"*. (A1)

1	For	≥ 80%
2	Against	≤ 50%
0	Undecided	51–79%

Tab. 2. *Experts' opinion*

4. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in patients with suspected pneumothorax. (A1)
5. In the diagnosis of pneumothorax, convex and linear probes are recommended. (A1)

Experts' comments[15–18]

a) The lack of the *"lung point"* sign with simultaneous appearance of pneumothorax occurs in cases of critical or "mantle-like" pneumothorax.
b) The status post pleurodesis affects the occurrence of "*lung sliding*" (the sign will be absent/limited) and the presence of vertical artifacts of reverberation, which exclude the presence of pneumothorax.
c) Encapsulated pneumothorax. Pneumothorax may be localized and the air position in the pleural cavity does not have to change with the patient's position in this case.
d) *"Lung point"* is the border between pneumothorax and the normal pleural cavity; this symptom can be observed in B- or M-mode.
e) *"Lung pulse"* is the pulse of the lung resulting from the movements of the heart transferred to the lung. This sign is observed in patients with hyperkinetic circulation and is an early sign of atelectasis. The *"lung pulse"* sign is well visible in M-mode and/or power Doppler examinations.
f) The recommended position of the examination is the supine position (except for patients presenting with orthopnea).

Consolidations

6. Sonographic features of consolidations are: the presence of a subpleural hypoechoic area with echostructure resembling that of the liver. (A1)
7. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in confirming the presence of subpleural consolidations. (A1)
8. Subpleural consolidations may have various causes, most commonly: pneumonia, atelectasis (compression- or resorption-related), pulmonary embolism, subpleural neoplastic lesions (primary or metastatic), and lung contusions. (A1)

Experts' comments[19–20]

a) Experts emphasize the multiple morbidities within the respiratory system. The coexistence of more than one respiratory disease, which is encountered in clinical practice, results in the overlap of several pathological changes in lung ultrasound. It should also be remembered that the reference test in the assessment of pulmonary lesions is computed tomography performed according to a protocol suitable for an initial diagnosis.

Pneumonia

9. Sonographic features of pneumonia are: consolidation, irregular marginal contour, air bronchogram, "air trap" sign, comet tail artifacts (B lines), normal vasculature in CD and PD (*color Doppler and power Doppler*), and fluid in the pleural cavity. (A1)
10. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in confirming the presence of pneumonia. (A1)

Experts' comments[19,21–24]

a) To point 9: The criteria for inflammatory lesions are divided into: parenchymatous (consolidation with irregular marginal outline, dynamic air bronchogram visible within the consolidation or/and the air trap sign), vascular (normal flow pattern in CD and PD) and pleural (fluid in the pleural cavity);
b) Consolidation means airless area of the lung;
c) Air bronchogram is air visible in the bronchial tree within consolidation;
d) The dynamic air bronchogram is visible on inspiration and disappears on expiration;
e) A correct vascular pattern, i.e. compatible with the anatomical standard, is observed in CD and/or PD.
f) Experts point out that inflammatory changes in the course of tuberculosis, mycosis, pneumocystosis, viral infection, as well as atypical pneumonia may have a different sonomorphology than described in point 9. It is also important to remember about the possibility of overlap of typical inflammatory changes and those caused by less common pathogens.
g) To point 10: The description does not apply to bronchopneumonia.

Atelectasis

11. Sonographic features of compression atelectasis are: fluid in the pleural cavity, consolidation of homogeneous echogenicity and echostructure, static air bronchogram, the "air trap" sign, and normal vasculature in CD and PD. (A1)
12. Sonographic features of resorption atelectasis are: consolidation of homogeneous echogenicity and echostructure, fluid bronchogram, static air bronchogram, normal vasculature in CD and PD, possible visualization of a pathological mass at the top of the consolidation. (A1)
13. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in confirming compression atelectasis. (A1)
14. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in confirming resorption atelectasis. (A1)

Experts' comments[25–26]

a) Blood flows in CD and PD are normal only in the area of compression atelectasis or in the consolidation area constituting resorption atelectasis, and not in a pathological mass associated with cancer.
b) Static air bronchogram represents the presence of air in the bronchial tree and is visible through all breathing phases.

Pulmonary embolism

15. Sonographic features of pulmonary embolism may include: consolidation, mostly wedged or oval/round in shape, central echo, flow amputation in CD: the so-called *"vascular sign"*, local fluid right above the subpleural lesion, and local interstitial lesions. (A1)
16. If pulmonary embolism is suspected, lung ultrasound may be a good diagnostic strategy to confirm the diagnosis. (A1)

Experts' comments[27–29]

a) Changes described in point 15 may indicate "not-high-risk" pulmonary embolism, because ultrasound examination in this case highlights lesions typical of pulmonary embolism located at the periphery of the lung.
b) To identify pulmonary embolism with lung ultrasound (LUS) in patients with acute respiratory failure, BLUE *Protocol* is recommended[30].
c) LUS can be an alternative diagnostic method in pulmonary embolism if angio-CT cannot be performed or is contraindicated: e.g. in pregnant women, patients with acute kidney injury, or patients with allergic reactions to contrast agents.
d) In the diagnosis of non-high risk pulmonary embolism (no hypotension or shock), when the clinical probability is low/intermediate or unlikely, LUS is a good additional option to be used in the presence of negative angio-CT and positive D-dimer test, alongside echocardiography and venous compression test.
e) The use of LUS is a good complementary examination (next to echocardiography and venous compression test) in the diagnosis of pulmonary embolism when there is a high clinical probability of pulmonary embolism or when pulmonary embolism is probable and the result of angio-CT is negative.
f) Pulmonary embolism cannot be ruled out based on a negative LUS result.

Subpleural malignant neoplastic lesions

17. Sonographic features of subpleural malignant lesions are: infiltration of adjacent structures, varied sonomorphology of consolidations, chaotic vasculature in CD and PD, concomitant resorption atelectasis and/or fluid in the pleural cavity. (A1)
18. Lung ultrasonography is a good diagnostic strategy to be used in invasive procedures (transthoracic lung biopsy) in the diagnosis of subpleural masses that are suspicious of malignancy. (A1)

Experts' comments[31–32]

a) To point 17: Subpleural malignant neoplastic lesions may be accompanied by additional vascularization from the intercostal vessels. They can be observed in CD and PD.
b) To point 18: The use of ultrasound guidance during a biopsy concerns both subpleural lesions and biopsies through the acoustic window formed by fluid or atelectasis.

Interstitial pulmonary lesions

19. Sonographic features of interstitial syndrome are: the presence of *"lung sliding"* and ≥3 B line artifacts in one intercostal space in the longitudinal scan (in relation to the body axis). (A1)
20. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in revealing interstitial lesions. (A1)
21. Interstitial syndromes may have various causes including: cardiogenic pulmonary edema, non-cardiogenic pulmonary edema, interstitial lung diseases, infections, and status post broncho-alveolar lavage. (A1)
22. In the differential diagnosis of the causes of interstitial syndromes, it is recommended to use a convex/microconvex or sector probe, and, in some cases, a linear probe. (A1)

Experts' comments[33–34]

a) B line artifacts are vertical artifacts of reverberation. They originate from the pleural line, reach the lower edge of the screen and move with the movements of the pleural lines. They resemble a laser beam.
b) To point 19: The exception is status post pleurodesis or so-called: stiff lung.
c) To point 22: A linear probe should be used in the differential diagnosis of the causes of interstitial syndromes when there are asymmetric interstitial lesions in both lungs, in the presence of the so-called spared areas, and also in the case of suspected respiratory tract infections, as well as in any clinically unclear cause of interstitial lesions in the lungs.

Cardiogenic pulmonary edema

23. Sonographic features of cardiogenic pulmonary edema are most frequently bilateral, gravitational and symmetrical interstitial syndromes and/or interstitial-alveolar syndromes and/or the *"white lung"* sign. (A1)
24. The use of lung ultrasound in the diagnosis of cardiogenic pulmonary edema is a good diagnostic strategy. (A1)
25. The use of lung ultrasound in patients diagnosed with heart failure is an important method of monitoring during periods of clinical stabilization and during periods of exacerbation. (A1)

Experts' comments[35–38]

a) Interstitial syndrome, interstitial-alveolar syndrome and the white lung sign are defined as successively occurring stages of interstitial lesions in the course of cardiogenic pulmonary edema. In their definition, all three of these signs have at least 3 B line artifacts occurring in one intercostal space in the longitudinal scan (relative to the

body axis), however, the distance between individual B line artifacts decreases with an increasing fluid volume in the interstitial space and in the alveoli.
b) To point 23: Additionally, one can observe fluid in the pleural cavity, which is the result of heart failure.
c) To point 25: The sum of B lines correlates with the symptoms of heart failure and the level of natriuretic peptides. It is also a prognostic factor for the occurrence of serious cardiovascular events.
d) To monitor fluid therapy, it is also recommended to use the FALLS protocols (*Fluid Administration Limited by Lung Sonography*), an IVC collapse assessment[39].

Interstitial lung diseases with pulmonary fibrosis

26. Sonographic features of interstitial lung diseases with fibrosis are: "*lung sliding,*" presence of ≥3 B line artifacts in one intercostal space (longitudinal scan in relation to the body axis), and abnormalities in the pleural line. (A1)
27. The use of lung ultrasound may be a better diagnostic strategy than chest X-ray in the diagnosis of interstitial lung diseases with fibrosis. (A1)
28. The use of lung ultrasound in the monitoring of interstitial lung diseases with pulmonary fibrosis may be useful in patient monitoring. (C1)

Experts' comments[40–41]

a) To point 26: Abnormalities in the pleural line are described as: irregular, tightened fragmented or blurred.
b) To point 28: The use of LUS in the diagnosis of interstitial pulmonary diseases in the active phase is based on case reports and relates to: pulmonary vasculitis, sarcoidosis, hypersensitivity pneumonitis, diffuse alveolar hemorrhage in the course of systemic connective tissue diseases, pulmonary alveolar proteinosis, interstitial pneumonias in the course of systemic connective tissue diseases presenting as ground glass opacities in HRCT.

Other recommendations

29. The use of lung ultrasonography may be a good diagnostic strategy in the diagnosis of causes of dyspnea. (A1)
30. The use of lung ultrasonography may be a good diagnostic strategy in the differential diagnosis of pleural pain. (A1)
31. The use of lung ultrasonography may be a good diagnostic strategy in the differential diagnosis of acute cough. (A1)
32. A lung ultrasound performed by a trained clinician is at a similar level to a lung ultrasound performed by a radiologist. (A1)

Experts' comments[23,28,35,42]

a) To point 32: The publications show clearly that bedsite lung ultrasound performed by trained clinicians is a better solution than transporting the patient to the radiology department for LUS. The clinician has data from the patient's medical history, physical examination, as well as the current condition, which affects the accuracy of the final diagnosis.

II. Additional Experts' opinions

33. In the case of an unstable patient with dyspnea, bedsite examination is recommended.

Opinion of the authors on the balance of beneficial and adverse effects of the intervention	Level of evidence	Strength of recommendation	Strength of recommendation – practical implications
1	A	1A	strong recommendation; a given procedure should be widely used as long as there are no strong contraindications
1	B	1B	strong recommendation, but with less degree of certainty; probably right in most individual cases
1	C	1C	the average strength of recommendation; the recommendation may change after obtaining more reliable data; probably right
2	A	2A	the average strength of recommendation; the decision on its adoption is a matter of choice and may depend on local and individual conditions; intervention does not have to be used
2	B	2B	weak recommendation; alternative conduct can be just as good or better
2	C	2C	weak recommendation; alternative treatment is probably equally acceptable

Tab. 3. *Strength of recommendations*

The number of the statement	Level of evidence	Expert opinion			Strength of recommendations
	A, B, C	I round	II round	III round	
1	A	> 80%	> 80%	> 80%	A1
2	A	>80%	>80%	>80%	A1
3	A	>80%	>80%	>80%	A1
4	A	>80%	>80%	>80%	A1
5	A	>80%	>80%	>80%	A1
6	A	>80%	>80%	>80%	A1
7	A	>80%	>80%	>80%	A1
8	A	>80%	>80%	>80%	A1
9	A	>80%	>80%	>80%	A1
10	A	>80%	>80%	>80%	A1
11	A	>80%	>80%	>80%	A1
12	A	>80%	>80%	>80%	A1
13	A	>80%	>80%	>80%	A1
14	A	>80%	>80%	>80%	A1
15	A	>80%	>80%	>80%	A1
16	A	>80%	>80%	>80%	A1
17	A	>80%	>80%	>80%	A1
18	A	>80%	>80%	>80%	A1
19	A	>80%	>80%	>80%	A1
20	A	>80%	>80%	>80%	A1
21	A	>80%	>80%	>80%	A1
22	A	>80%	>80%	>80%	A1
23	A	>80%	>80%	>80%	A1
24	A	>80%	>80%	>80%	A1
25	A	>80%	>80%	>80%	A1
26	A	>80%	>80%	>80%	A1
27	A	>80%	>80%	>80%	A1
28	C	>80%	>80%	>80%	C1
29	A	>80%	>80%	>80%	A1
30	A	>80%	>80%	>80%	A1
31	A	>50% and <80%	>80%	>80%	A1
32	N/A	>80%	>80%	>80%	N/A
33	N/A	>80%	>80%	>80%	N/A
34	N/A	>80%	>80%	>80%	N/A
35	N/A	>80%	>80%	>80%	N/A
36	N/A	>80%	>80%	>80%	N/A
37	N/A	>80%	>80%	>80%	N/A
38	N/A	>80%	>80%	>80%	N/A

Tab. 4. *Results of data credibility (level of evidence) and expert opinions for individual statements. N/A – not applicable*

34. The scanning technique depends on the clinical condition of the patient and should cover the largest possible area of the lungs.
35. Lung ultrasound in a patient with respiratory failure conducted by a trained clinician is a good and safe element of the differential diagnosis of lung diseases.
36. Basic training in the theoretical and practical use of lung ultrasound is recommended for doctors during their specialization programs, including internists, cardiologists, pneumonologists and nephrologists.
37. The recommended basic course for clinicians during their specialization programs should include in its curriculum the diagnosis of: pleural fluid, pneumothorax, cardiogenic and non-cardiogenic pulmonary edema, interstitial lung diseases with fibrosis, pneumonia, atelectasis, pulmonary embolism, subpleural neoplastic lesions, rib fracture as well as learning to assist in diagnostic procedures and invasive therapy.
38. It is recommended to incorporate basic lung ultrasound training into the curriculum of medical students.

Experts' comments

a) To point 34: When testing a patient in a stable clinical condition, it is recommended to use convex probes (possibly the microconvex or sector probes) and linear probes. The patient can be examined in a sitting and lying position (except for patients with a forced position or orthopnea, in whom the examination is carried out only in a sitting or semi-sitting position).

Conclusion

Lung ultrasound is becoming more and more popular among clinicians. These recommendations (POLLUS-IM) have been developed for internists (of various sub-specialties), trained and performing lung ultrasound on a daily basis, as well as for those who do not perform ultrasound examinations. However, it should be remembered that the use of lung ultrasound by internists results from their interest and additional training; it usually does not fall within the scope of their specialization program. Therefore, it is done voluntarily, usually as an additional tool to aid in the clinician's work. This results in the lack of agreement between people who perform and who do not perform ultrasound examinations. The expanding scope of reliable literature indicates an increase in the possibility of using lung ultrasound at the patient's bedside. Accelerating the diagnostic process and establishing the differential and final diagnosis using the "sono-stethoscope" is the key element of appropriate patient management and offers a greater chance for patient's survival.

The POLLUS recommendations will be updated every few years, along with emerging new, relevant reports in the literature.

Conflicts of interest

The authors declare that they have no conflicts of interests.

The content of the recommendations has been approved by the Polish Ultrasound Society.

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