

Expert Consensus Framework for Standardizing Lung Ultrasound Training for Neonatologists Issued by ESPNIC Neonatal Critical Care Section and Point-of-Care Ultrasound Working Group



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PURPOSE: To provide an expert consensus framework for standardizing lung ultrasound training for neonatologists.

METHODS: We selected an international panel of 15 neonatologist experts in lung ultrasound, based on clinical and research expertise criteria. Ten questions were proposed by the chairs to the expert panel, who assessed their priority (using a 1-9 Likert-type scale). Five subgroups of 2 to 3 experts were identified to develop the statements for each clinical question; each expert contributed to developing 2 statements with their scientific rationale. All expert panelists, including the chairs, voted on all statements using a 1 to 9 Likert-type scale. A maximum of 2 rounds of voting was agreed as part of the modified Delphi process, although consensus on all the statements was reached after the first round. The statements were classified as agreement (range 7-9), uncertainty (4-6), or disagreement (1-3) when the median score and $\geq 75\%$ of votes laid within the specific range.

RESULTS: All 10 statements reached an agreement with a median score of 9 for 9 statements and of 8.5 for 1 statement. The percentage of level of agreement ranged between 80% and 100%.

CONCLUSION: This consensus provides a framework for the development of neonatal lung ultrasound training program dedicated to neonatologists. CHEST 2026; 170(1):200-211

KEY WORDS: education; lung; neonates; training; ultrasonography

The clinical use of lung ultrasound (LUS) in neonatal ICUs has increased substantially over the last decade,¹ together with the research output regarding this technique.² LUS is an easily available, quick,

noninvasive, radiation-free bedside diagnostic tool, which can be used as an integrated part of the clinical evaluation for diagnostic and therapeutic purposes. LUS has been demonstrated to have an excellent diagnostic

ABBREVIATIONS: ESICM = European Society of Intensive Care Medicine; ESPNIC = European Society of Paediatric and Neonatal Intensive Care; LMIC = low- and middle-income country; LUS = lung ultrasound; OSCE = Objective Structured Clinical Examination; OSAUS = Objective Structured Assessment of Ultrasound Skills; PICO = Patient-Intervention-Comparator-Outcome

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accuracy for the most common causes of neonatal respiratory failure, including respiratory distress syndrome, transient tachypnea, neonatal ARDS, pneumothorax, pleural effusion, and congestive pulmonary edema.³ For these indications, LUS has been recommended by the European Society of Paediatric and Neonatal Intensive Care (ESPNIC) guidelines.³ Among the many possible functional applications, LUS can be used to guide diuretic therapy in the presence of pulmonary edema⁴ and chest tube insertion to drain pleural effusions.³ Through the calculation of LUS aeration scores, quantitative LUS is a widely used tool to assess the severity of respiratory distress syndrome and guide surfactant therapy⁵ but also to assess the alveolar

recruitment in relation to oxygenation^{6,7} and predict the development of bronchopulmonary dysplasia.⁸ These applications have been recently recommended by the ESPNIC-European Society of Intensive Care Medicine (ESICM) joint consensus on quantitative LUS.⁹

Despite the benefit of LUS and the exponential diffusion, there remains a lack of structured training specifically designed for neonatal intensivists. ESPNIC aimed to develop an expert consensus to develop a framework for standardizing LUS training. This framework is intended to guide educators in designing training courses and tools and promoting future research in this field.

Methods

General Data

Throughout this project, we adhered to the Accurate Consensus Reporting Document and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines.^{10,11} Given the anticipated low quality of available evidence to inform the development of a LUS training framework, a consensus approach was chosen over a formal clinical practice guideline methodology. This study is exempted from IRB application.

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A scoping review was performed (e-Appendix 1) and literature search was summarized as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart in e-Figure 1.

Panel Composition

The project was led by 2 co-chairs (Y. S. and D. D. L., who also served as methodologists), who determined the methodology, drafted the protocol, established the criteria for experts' selection, identified the questions (using the Patient-Intervention-Comparator-Outcome [PICO] framework), managed the voting process, and led the whole project. Panelists were required to demonstrate: (1) well-established clinical expertise; and (2) relevant research activity both involving the application of LUS to critically ill neonates. The clinical expertise was defined as > 5 years of work in neonatal ICUs using LUS. The research activity criterion consisted of at least 1 original last/first author peer-reviewed publication on LUS in the last 10 years. Experts were initially chosen from among the members of 2 ESPNIC internal structures: the neonatal critical care section and the point-of-care ultrasound working group. The search was then expanded to have some experts representing North America and Asia, and at least 1 from low- and middle-income countries (LMICs). A fair gender balance was ensured. Research and clinical competencies were considered as overriding criteria.

The 2 co-chairs invited the selected panelists by email on January 9, 2025, and all accepted the first invitation. The invited panelists were neither requested nor allowed to suggest other panel members. No fees or incentives were proposed for participation. Finally, the panel included 15 experts (9 from the European

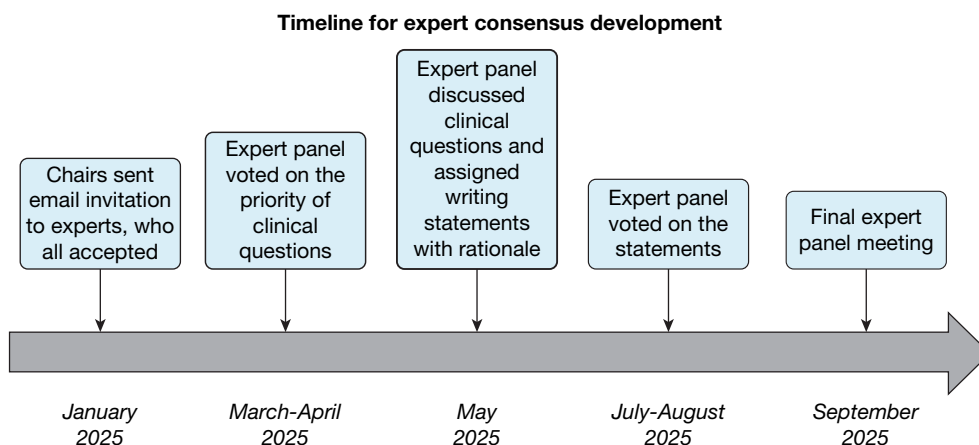


Figure 1 – Workflow for developing the expert consensus on neonatal lung ultrasound training. This figure illustrates the structured methodology used to develop the the European Society of Pediatric and Neonatal Research expert consensus, including expert panel selection, prioritization of Patient-Intervention-Comparator-Outcome questions, subgroup assignments, statement drafting, Delphi voting rounds, and final consensus approval.

Union, 2 from the United States, 2 from the United Kingdom, 1 from the United Arab Emirates, and 1 from India), 40% women, and 1 expert from an LMIC (P. S.). No patient or family representatives were invited due to the highly technical nature of the work, which focused on specialized professional medical training.

PICO Questions

An initial list of 10 PICO questions was drafted by the chairs and anonymously voted for priority by the panel using a 1 to 9 Likert-type scale with a customized online Google module (1st round of vote email sent on March 19, 2025); an open text section was also available for each question to comment, as well as an extra question for suggestions. Two weeks were given to vote (questionnaire and results are reported in [e-Table 1](#) and [e-Appendix 2](#)). We followed the model developed by UCLA-RAND Corporation and classified the results into 3 categories: low (1-3 mean score = dismissed), intermediate (4-6 = modified to be revoted or reconsidered), and high priority (“critical”) (7-9 = retained in original format).^{5,12}

All statements and the rationales were voted by all panelists using the aforementioned Likert-type scale, and a space for free comments was provided.⁹ The Likert-type scale results were analyzed with the following criteria: a

score of 1 to 3 indicated rejection or disagreement (“not appropriate”); 4 to 6 -indicated (“uncertainty”); and 7 to 9 indicated agreement/support (“appropriate”).¹¹ Consensus was reached when both the following criteria were met: (1) at least 75% of the respondents assigned a score within the 1 to 3 or 7 to 9 ranges, which rejected or accepted the statements/rationales, respectively; and 2) the median score was within these ranges.⁹⁻¹² We used medians because we anticipated that the response distribution would not be normal, and we did not want to make any statistical assumptions.

[Figure 1](#) shows the project workflow. The type of consensus achieved was determined by the median score: “agreement” was defined for a median score ≥ 7 , and “disagreement” for a median score ≤ 3 . A median score within the 4 to 6 range meant that most of the group had scored the items as “uncertain.”

All statements reached an agreement after the first round of completely anonymous voting performed on a dedicated ESPNIC online platform. Meetings between panelists were virtual and supported by the ESPNIC secretariat. No industry was involved in any phase of the project. [e-Table 2](#) classifies all the articles that panelists used during the preparation of statements and rationales.

Results

All 10 clinical questions were given high priority with a median score of 9 (interquartile range, 7-9). The consensus was achieved on all 10 statements

following the first round of voting. Each statement is accompanied by a rationale, supporting evidence, and practical considerations for implementation. The median scores, range, and percentage of

TABLE 1] Summary of Final Expert Consensus Statements With Their Relative Scores and Percentage of Agreement

Expert Consensus Statement	Median (Range)	% of Agreement
STATEMENT 1: In a neonatal LUS course, theoretical knowledge can be delivered by in-person, online, or hybrid formats, but in-person and hybrid courses have the additional benefit of real-time hands-on training over online only courses.	9 (7-9)	100
STATEMENT 2: In a neonatal LUS course, it is recommended to test the knowledge of neonatologists using a multiple-choice question test before and after attending.	9 (6-9)	80
STATEMENT 3: Hands-on courses can be useful for neonatologists to develop technical skills in LUS, enhancing diagnostic accuracy and confidence through practical, supervised training.	9 (4-9)	86.6
STATEMENT 4: Supervised hands-on training for neonatologists performing LUS can be associated with improved technical skills, diagnostic accuracy, and confidence in image acquisition. Evidence from the literature suggests that direct supervision accelerates skill development and enhances competency compared to theoretical training or unsupervised practice. A structured, supervised hands-on period may therefore be useful for achieving proficiency in neonatal LUS.	9 (1-9)	86.6
STATEMENT 5: There are no data available to recommend a specific number of scans required to acquire sufficient LUS proficiency in neonates. However, data from adult critical care suggest that 25-30 scans would grant over 80% of proficiency and there are no reasons to believe that this would be very different in neonates.	9 (5-9)	93.3
STATEMENT 6: Assessment of neonatologists' ability to interpret and integrate LUS findings with medical history, clinical evaluation, and biological data may be incorporated into LUS training programs. Objective methods such as written tests and imaging review with expert concordance on diagnosis and clinical case evaluations may be used.	9 (7-9)	100
STATEMENT 7: Neonatologists performing LUS less than monthly may need to demonstrate sustained competency through periodic image review by qualified experts or colleagues.	9 (4-9)	80
STATEMENT 8: LUS education programs for neonatologists can follow a tiered structure, with complex or nuanced findings requiring more extensive training.	9 (3-9)	93.3
STATEMENT 9: Linear probes are well suited for visualizing the pleural line and lung artifacts in neonates (and particularly micro-linear high-frequency probes for preterm infants). They should also be preferred over nonlinear probes for teaching purposes, particularly for beginners, when available. However, there is currently little evidence to favor one type of probe over another for teaching purposes. If linear probes are unavailable, others may be used to teach LUS.	9 (5-9)	93.3
STATEMENT 10: Specifically dedicated LUS courses tailored to LMIC are effective in achieving sufficient context-relevant proficiency. Evidence supports that localized or hybrid educational models, even with limited resources, can lead to satisfactory context-adapted skill acquisition comparable to standard training offered in high-income countries.	9 (7-9)	100

LMIC = low- and middle-income country; LUS = lung ultrasound.

agreement of each statement are summarized in [Table 1](#).

PICO QUESTION 1: For neonatologists willing to learn and perform LUS, which educational tool is more effective to gain the necessary theoretical knowledge?

STATEMENT 1: In a neonatal LUS course, theoretical knowledge can be delivered by in-person, online, or hybrid formats, but in-person and hybrid courses have the additional benefit of real-time hands-on training over online only courses.

RATIONALE: Lectures can be provided via live in-person sessions, virtual lectures, or self-directed web-based modules. In-person training offers the advantage of immediate feedback, real-time interaction.¹³⁻¹⁵ However, it requires travel and dedicated resources and lacks flexibility. An effective learning can also be achieved virtually through web-based software, e-learning packages, online simulations, or lectures.^{16,17} Online training allows access from any location, facilitates the delivery of theoretical concepts and image interpretation, and is more time-efficient for knowledge

dissemination. Hybrid methods were described in 12 studies, typically blending online lectures or videos with in-person practical sessions.¹⁸⁻²⁹

Several studies have compared delivery methods. Florescu et al²⁹ randomized medical students into 3 learning groups and showed no differences among trainees attending courses characterized by hands-on + lectures, hands-on alone, or a webcast. Similarly, other studies reported that web-based learning was noninferior to traditional methods.³⁰⁻³² Therefore, overall, no clear superiority of 1 educational modality has been demonstrated. While in-person learning continues to provide valuable interaction, online and hybrid approaches expand accessibility and scalability, suggesting that flexible, blended models may optimize LUS training.

PICO QUESTION 2: Should the knowledge of neonatologists be tested before and after attending a neonatal LUS course?

STATEMENT 2: In a neonatal LUS course, it is recommended to test the knowledge of neonatologists using a multiple-choice question test before and after attending.

RATIONALE: Conducting both a pre- and a post-course knowledge test is recommended when designing LUS educational activities. A pre-test provides essential baseline information, helping the teachers to address identified gaps, and to establish a reference point for measuring learning gains.³³ A post-course test assesses whether learning objectives have been met, evaluates the effectiveness of teaching methods and materials, and provides a basis for issuing a certificate to participants who demonstrate adequate knowledge. Taken together, pre- and post-tests not only provide objective evidence of progress but also help motivate participants by highlighting their achievements at the end of the course.^{20,32,34-37} Although it is not mandatory to use both forms of evaluation, their combination can be recommended.³⁸ If only 1 test is conducted, a final (post-course) assessment should be preferred; however, without a pre-course test, it is impossible to determine the magnitude of knowledge acquisition by individual participants.³⁹

PICO QUESTION 3: Should neonatologists attend a hands-on course to learn LUS technical skills?

STATEMENT 3: Hands-on courses can be useful for neonatologists to develop technical skills in LUS,

enhancing diagnostic accuracy and confidence through practical, supervised training.

RATIONALE: Hands-on courses are common and may be beneficial to improve the technical skills. Participants can practice image acquisition while receiving immediate feedback from experienced instructors, to correct errors, refine probe handling, and optimize image quality. Multiple studies have demonstrated that physicians and medical students who participate in point-of-care ultrasound courses that include hands-on training achieve good diagnostic accuracy and technical skills.¹³⁻¹⁵ High-fidelity simulators may offer interesting alternatives.^{14,40-43} Hand motion analysis method can track probe movements and may be helpful for developing LUS technical skills.⁴⁴ In resource-limited areas, alternative or adjunctive methods (eg, simulation) might also contribute to skill acquisition if hands-on training is not available.

PICO QUESTION 4: Should neonatologists follow a supervised in-person hands-on training period to develop sufficient technical skills after attending a dedicated LUS course?

STATEMENT 4: Supervised hands-on training for neonatologists performing LUS can be associated with improved technical skills, diagnostic accuracy, and confidence in image acquisition. Evidence from the literature suggests that direct supervision accelerates skill development and enhances competency compared to theoretical training or unsupervised practice. A structured, supervised hands-on period may therefore be useful for achieving proficiency in neonatal LUS.

RATIONALE: Expert supervision and hands-on training not only help to accelerate learners' image acquisition skills but may also be helpful for the image interpretation and its integration in clinical decision-making algorithms.^{15,45-47} Longitudinal checks during the training period can provide a more accurate evaluation of decision-making skills.²⁶ In settings where access to experts is limited, virtual courses and artificial intelligence tools may facilitate real-time guidance and feedback, but it is unknown if this can completely eliminate the need for an actual training period.^{14,26,37,48}

PICO QUESTION 5: For neonatologists, how many supervised scans are required to acquire sufficient LUS proficiency (in terms of both technical skills and image interpretation)?

STATEMENT 5: There are no data available to recommend a specific number of scans required to

acquire sufficient LUS proficiency in neonates. However, data from adult critical care suggest that 25-30 scans would grant over 80% of proficiency, and there are no reasons to believe that this would be very different in neonates.

RATIONALE: According to some studies on adults, the number of scans required to achieve LUS competency range from 3 to 87 scans.⁴⁹⁻⁵² Selame et al⁵³ reported no correlation between scan volume and accuracy in emergency medicine residents, suggesting that the number of scans alone may not be a highly reliable measure for proficiency. Nevertheless, the wide variation in reported thresholds is linked to the relevant heterogeneity in study end points (eg, some studies focused on image acquisition and others on interpretation). The number of ultrasound examinations needed to achieve proficiency shall be individualized based on learner progression. This is exactly what has been done in critical care medicine, where 25 to 30 scans are allowed to reach 80% proficiency as suggested by some high-quality multicenter studies.^{22,41}

Thus, several medical societies recommend a minimum of 25 to 30 scans (with various supervision schedules) as the number needed to achieve proficiency. For instance, the UK Intensive Care Society and the Australian Society of Ultrasound in Medicine endorsed curriculums that require 30 scans, of which at least 10 must be supervised and no more than 10 should be normal cases.⁵⁴⁻⁵⁶ The British Thoracic Society and an Italian expert consensus recommend tiered training, with a defined number of scans and summative assessments tailored to the level of experience.⁵³⁻⁵⁵

PICO QUESTION 6: Should the ability of neonatologists to interpret and integrate LUS findings with medical history, as well as clinical and biological data, be specifically assessed?

STATEMENT 6: Assessment of neonatologists' ability to interpret and integrate LUS findings with medical history, clinical evaluation, and biological data may be incorporated into LUS training programs. Objective methods such as written tests and imaging review with expert concordance on diagnosis and clinical case evaluations may be used.

RATIONALE: Integration of imaging findings with clinical and biological information is an important principle of medical imaging interpretation and may be

particularly relevant to LUS as the technique is performed and interpreted in real time at the bedside. Because clinicians may use LUS findings to inform immediate clinical decisions, training programs might benefit from incorporating interpretive and integrative decision-making skills. Several teaching approaches includes:

- *Scenario-Based Learning:* Learners engage in simulated clinical scenarios where they use ultrasound findings to make real-time decisions.¹⁷
- *Problem-Based Learning:* Group discussions and case-based problem-solving sessions help learners integrate LUS findings in clinical contexts.²⁵
- *Mentorship Programs:* Experienced clinicians guide learners on applying LUS findings effectively in real-world practice.²⁶
- *Continuous Assessment:* Experts provide regular evaluation and feedback on learners' clinical reasoning and interpretation.⁵³

All 4 methods have their pros and cons, and there is no evidence to prefer 1 method over the other. Thus, the choice should be based on the available resources and learners' needs. The baseline clinical experience of learners may influence how readily LUS findings are integrated into clinical decision-making, and differing levels of supervision may be needed for junior vs more experienced clinicians.^{26,47,57-59} These methods have used inter-rater reliability between trainees and experts to confirm competency.⁵⁸⁻⁶¹

PICO QUESTION 7: For neonatologists who do not perform LUS regularly, should there be a requirement to document the maintenance of their skills?

STATEMENT 7: Neonatologists performing LUS less than monthly may need to demonstrate sustained competency through periodic image review by qualified experts or colleagues.

RATIONALE: Like other procedural skills, LUS proficiency could decline without regular practice, compromising diagnostic accuracy in critical neonatal conditions. Although long-term data on skill decay are limited, existing evidence suggests that retention varies depending on context. Selame et al⁵³ found that performing just 1 to 2 scans per month was sufficient to maintain 98.1% diagnostic accuracy, indicating that regular practice supports skill maintenance, although long-term data remain limited. This raises concerns about skill decay among neonatologists performing LUS less than once or twice per month, which represents a

very low level of activity and requires continued assessment. Mazmany et al⁶² demonstrated high inter-rater reliability through remote image review, and Grubic et al²⁶ confirmed that remote feedback can sustain LUS skills in LMIC and rural settings, respectively. Together, these findings support the incorporation of periodic image review to ensure maintenance of competency.

PICO QUESTION 8: Which neonatal LUS sign/finding is more difficult to recognize and requires more training?

STATEMENT 8: LUS educational program for neonatologists can follow a tiered structure, with complex or nuanced findings requiring more extensive training.

RATIONALE: LUS findings vary in complexity, supporting the need for a tiered educational approach that emphasizes supervised practice for nuanced interpretations. Some studies demonstrated that brief training sessions (1-4 hours of formal and hands-on training) enabled trainees to accurately detect simple binary findings such as pleural effusion.^{33,63} Similarly, Rodríguez-Fanjul et al²⁴ reported near-perfect inter-rater agreement for pleural effusion after 6 hours of lectures and just 2 hours of hands-on training (Cohen's kappa = 0.87; 95% CI, 0.83-0.89). More nuanced findings, such as distinguishing apnea from absent lung sliding, may require real-time scanning rather than review of pre-recorded clips⁶⁴ and, most likely, longer training.⁵⁵ Furthermore, integrating findings into clinical decision-making algorithms, such as those to guide surfactant administration, alveolar recruitment, or other critical care interventions, demands a deeper understanding of pathophysiology.^{6,63,65} A tiered program allows for a progressive acquisition of technical and interpretive skills.

PICO QUESTION 9: For neonatologists willing to perform LUS, which probe or frequency is most appropriate to teach the technique effectively?

STATEMENT 9: Linear probes are well suited for visualizing the pleural line and lung artifacts in neonates (and particularly micro-linear high-frequency probes for preterm infants). They should also be preferred over nonlinear probes for teaching purposes, particularly for beginners, when available. However, there is currently little evidence to favor one type of probe over another for teaching purposes. If linear probes are unavailable, others may be used to teach LUS.

RATIONALE: High-frequency linear probes must be preferred for the best visualization and the integration of LUS findings in neonatal and pediatric critical care practice, as recently recommended.⁸ When it comes to teaching purposes, the data seem less clear. Gomond-Le Goff et al⁶⁶ reported good inter-rater reliability for the main LUS findings with both linear and non-linear probes, except that beginners may be more proficient with the linear probe. Given the small size of newborn lungs, clinicians have always preferred to use linear probes in clinical practice, with micro-linear high-frequency probes preferred for preterm infants.^{23,59,65} Logically, aeration scores may be higher with linear than non-linear probes as the former have a higher superficial resolution.⁶⁶ Caution is warranted, as most literature has been produced with linear probes between 10 and 18 MHz, while ultra-high frequency micro-linear probes with frequencies beyond 20 MHz are now available and their use significantly increases the B-line density.⁶⁶ These findings suggest that most probes might be suitable for training, at least initially, if a linear probe is unavailable, provided that trainees remain aware of their potential differences and are well tutored. Then, once proficiency is reached, linear and micro-linear probes should be used, bearing in mind their technical characteristics and possible influence on quantitative LUS findings. In addition to probe selection, we acknowledge that ultrasound system settings might influence the image quality and therefore the training; these aspects will deserve dedicated studies.

PICO QUESTION 10: For neonatologists working in LMIC, how should dedicated training courses and periods be organized?

STATEMENT 10: Specifically dedicated LUS courses tailored to LMIC are effective in achieving sufficient context-relevant proficiency. Evidence supports that localized or hybrid educational models, even with limited resources, can lead to satisfactory context-adapted skill acquisition comparable to standard training offered in high-income countries.

RATIONALE: Research has shown that LUS training programs are effective in LMICs when customized to the local context.^{41,60,62,67-69} Dedicated courses that combine theoretical instruction with supervised hands-on scanning, as well as hybrid models adapted to local needs, have proven effective in Ghana, Bangladesh, Rwanda, Armenia, Peru, Sri Lanka, United Arab Emirates, India, and Bahrain, across both adult and pediatric populations.^{41,58,62,67-69} In an expert-limited

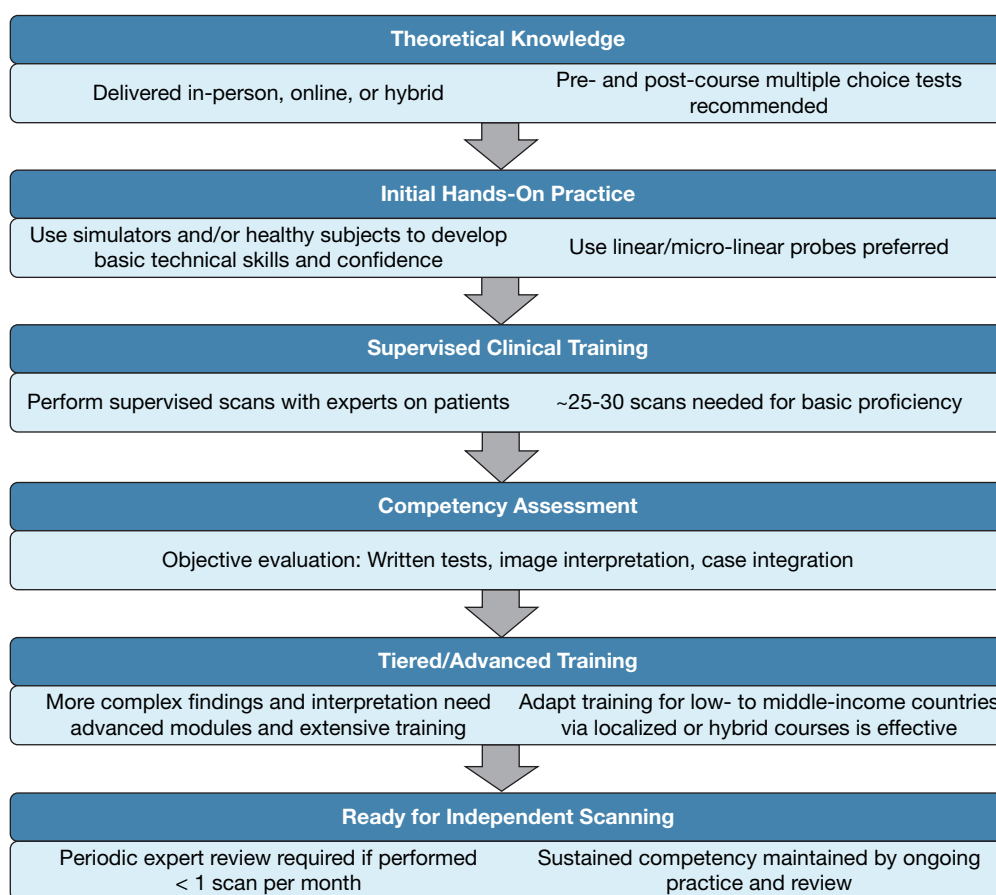


Figure 2 – Structured framework for neonatal lung ultrasound training and maintenance of skills. This flow diagram summarizes the proposed tiered training model for neonatologists, outlining the sequential stages of theoretical education, hands-on supervised practice, competency assessment, certification, and ongoing skill maintenance through periodic image review or re-evaluation.

area, remote supervision with tele-ultrasound could be helpful in ensuring sustainable skill development.²⁵ Where a formal LUS certification is unavailable, suitability to teach LUS may be based on demonstrable expertise. Indicators may include sustained neonatal LUS practice, experience in neonatal respiratory care, and concordance with expert interpretation. Integration of LUS findings into clinical decision-making is also particularly important.

Discussion

ESPNIC is continuously engaged to provide clinicians with the necessary training tools to improve their skills. This is particularly useful for a relatively new technique with several potential applications, such as LUS. In fact, ESPNIC has been organizing an online LUS training course since 2021.⁷⁰ Therefore, the present consensus was perfectly coherent with the ESPNIC mission and current activities.

We have developed 10 consensus statements (Table 1) that provide overarching principles to inform the development of a training framework (Fig 2). These principles are easy to follow and based on the practical experience; therefore, they reflect the actual needs of clinicians. Despite that there should not be any insurmountable barrier to their implementation, some problems exist such as limited protected teaching time and shortages of formal recognition, as highlighted by recent surveys in Australia and New Zealand.⁷¹ Furthermore, certain adaptations can be considered in some cases. In fact, our principles should guide the design of local programs, supporting adjustment across diverse educational settings and needs worldwide. For example, in some settings (eg, during wars or international crisis) an in-person training may not be possible and online or hybrid tools might be preferred. Also, the time required to achieve proficiency and integration of LUS findings with clinical data may vary

TABLE 2] Summary of Key Differences Between Neonatal, Pediatric, and Adult LUS Training Frameworks

Key Differences	Neonatal LUS Curriculum (Singh et al, 2026) Current Study	Pediatric LUS Curriculum (Musolino et al, ⁵⁴ 2025)	Adult/Multispecialty LUS (Musolino et al, ⁵⁴ 2025)
Target learners	Neonatal/pediatric residents, fellows and attending neonatologists	Pediatric residents, fellows, and practicing pediatricians	Physicians from multiple specialties (respiratory, emergency, anesthesia, radiology)
Structure of learning	Tiered training: Identifying and interpreting complex or nuanced findings requiring more extensive training	Four progressive levels: Foundational → Secondary → Advanced → Masterclass. Each with defined competencies, supervised scans, and certification validity (4 years)	Three competence levels implicitly assessed (Novice, Intermediate, Expert), based on performance using the LUS-OSAUS tool
Curricular components	Theoretical knowledge (online, in person or hybrid courses) and practical sessions under direct supervision. Review of clinical cases and integration with clinical aspects	Twenty 1-hour didactic sessions (physics, modes, artifacts, lung semiotics, focused cardiac US), hands-on practice, tutor validation, OSCE examinations	Objective evaluation tool with 17 assessment items across 6 domains (indication, systematic exam, technical skills, findings, documentation, conclusion)
Assessment tools	Multiple-choice questions test before and after the course and supervised clinical observation	Combination of written examination, OSCE, and SDOT	LUS-OSAUS scoring rubric (1-5 per item, maximum score 85) used to objectively measure technical and interpretative performance
Competence validation	Certification after the course, requiring re-evaluation if < 1 examination per month by experts or qualified colleagues	Certification after each level, valid for 4 years, requiring re-evaluation. National commission for advanced level testing	Construct validity proven: differentiated novice, intermediate, and expert levels statistically. Good interrater reliability
Practical training requirements	Minimum of 25-30 supervised scans; tutor supervision required for progression	Minimum of 30 (foundational), 60 (secondary), and 60 (advanced) supervised scans; tutor supervision required for progression	Training quantified by competence level, not fixed scan number—emphasizes individualized learning rate over procedure counts

LUS = lung ultrasound; OSAUS = Objective Structured Assessment of Technical Skills; OSCE = Objective Structured Clinical Examination; SDOT = Standardized Direct Observational Tool; US = ultrasound.

based on the basic clinical knowledge (which differs between young and senior clinicians) and the previous expertise accumulated in ultrasonography of other organs. Particular issues may exist in LMICs, where adjustments should consider the availability of adequate materials (eg, probes, tools to save LUS images and clips), as research has shown that LMIC-tailored ultrasound training is generally effective.^{41,60,62,67-69}

Moreover, our work is also useful because it establishes the foundations of training frameworks. These foundations are currently based on expert consensus but may be improved by adequate trials or high-quality observational studies in the future. For instance, identifying which neonatal LUS finding requires more training has been recognized as a key issue (eg, PICO question 8), and our consensus may be confirmed or modified by future dedicated studies. These studies should use as outcomes the improvement of diagnostic accuracy after the introduction of LUS training but also the trainees' satisfaction. Moreover, LUS training should be integrated with the other neonatal competencies. Nonetheless, neonatology is a specific field, not yet recognized as independent medical specialty, and there is no curriculum shared across the countries to train neonatologists.⁷² Discussions are undergoing in the United States and European Union to finally promote the creation of a residency in "neonatal critical care" which would share training with intensive care medicine and thus also include LUS.^{73,74}

Several LUS training frameworks have been previously defined for older populations.^{55,75} Given the unique pathophysiology and size of critically ill neonates, extrapolation from pediatric or adult training models may introduce imprecision. Table 2 summarizes the key differences between the proposed neonatal training and the existing pediatric and adult frameworks. The table allows one to contextualize the structure, assessment strategies, and other details of training for patients of different ages and to highlight why a neonatal-specific training is necessary. Therefore, we proposed that neonatologists follow a neonatal-specific training program, including approaches tailored to local needs.

Despite our efforts to apply the most rigorous methodology, we acknowledge some limitations. First, ours is a mainly experts' opinion-based consensus, given the lack of high-quality evidence on neonatal LUS

training. This does not decrease its importance, given the clinical interest and the similar work that has been done for ultrasound training in adult critical care, where more evidence-based data are available.⁷⁶ Our panel included a relatively small number of experts, but this reflects the size of a small specialty such as ours. We did not include nurses or physiotherapists, since the consensus was exclusively focused on LUS training for neonatologists. The use of LUS by allied health care professionals is variable depending on the setting, country, and the national regulations, and thus it would require locally customized works to successfully improve their training. Our expert panel also does not equally represent all countries because the expertise was considered an overriding criterion and ours was an ESPNIC project, therefore a mainly European initiative. We acknowledge that the lack of Australian or South American panelists might have decreased the representiveness. However, to be as more inclusive as possible, we created an international panel with at least some non-European colleagues, based on strict pre-defined criteria to minimize the selection bias. As we did not identify any study on virtual reality-based training, this method was not addressed by our work; these emerging tools will likely be the object of future update of our consensus.

In conclusion, our expert consensus provides a framework to standardize neonatal LUS teaching and guides future educational development.

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