

SHORT COMMUNICATION

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Pleura-ABCDE - a structured expert-based protocol for neonatal lung ultrasound documentation and interpretation

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Abstract

Background Neonatal lung ultrasound is a rapidly emerging imaging modality with increasing impact, but lacks standardized protocols and curricula, resulting in inconsistent dissemination and quality assurance.

Results We present a structured protocol for documentation and interpretation of lung ultrasound. For each lung region, the acronym Pleura-ABCDE is used to analyze the pleura (sliding, morphology), A-Lines, B-Lines, Consolidation, Dynamics (lung point, double lung point) and Effusion. The structured documentation and interpretation could provide clues to differentiate respiratory diseases in newborns.

Conclusion The Pleura-ABCDE protocol provides structured documentation and interpretation support for lung ultrasound in neonates. In contrast to flowchart-based protocols, a pattern-based approach and link to clinical presentation allows an integrative perspective on the use of neonatal lung ultrasound. Therefore, with this expert-based proposal, we aim to improve documentation and thereby support diagnostic quality and reproducibility, as recommended by international ultrasound societies.

Keywords Point-of-care ultrasound, Lung ultrasound, Ultrasound, Pleura-ABCDE, Neonate

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Background

Lung ultrasound is a rapidly growing methodology that enables the clinician to gain bedside real-time information and compare the results to clinical findings. The neonatal lung ultrasound examination is a unique technique with specific features, indications and diseases. The small size of the diagnostic surface results in a fast examination time and the utilization of high-resolution ultrasound probes. Therefore, lung ultrasound has the potential to speed up diagnostics, enable follow-up examinations and reduce the risk of radiation exposure for our vulnerable neonatal patients [1].

Although a promising steep learning curve in beginners [2, 3] and a high interobserver agreement [4], the disadvantages (as for all ultrasound examinations) of lung

ultrasound are the dependency on the experience and level of training of the investigators as well as the physical constraints of the ultrasound technique. In light of these challenges, international ultrasound societies have advocated for the necessity of standardization, training programs, and Point-of-Care Ultrasound Stewardship initiatives [5]. Recent progress in lung ultrasound publications try to set up a standardization for examination protocols, result interpretation and terminology [5–9]. Furthermore, significant advances have been made in the differentiation of unique ultrasound patterns, which hold the potential to guide clinicians in differentiating respiratory pathologies [8, 10] and offer a decision-making tool, particularly in the emergency setting [11, 12].

Despite the growing body of evidence, there remains a paucity of standardized report forms and educational curricula specifically designed for the ultrasound examination of the neonatal lung [13].

We introduce a pragmatic, hands-on approach to neonatal lung ultrasound, which includes a standardized documentation protocol (the Pleura-ABCDE protocol) to establish a benchmark for quality assurance and improve the comparability and communication of lung ultrasound examinations. This approach could also guide clinicians in the interpretation of ultrasound findings, facilitating the differentiation of respiratory diseases in newborns.

This protocol reflects the shared expert opinion of a group of 8 clinicians, representing five hospitals in two countries (4 clinicians from Austria, 4 clinicians from Germany) each with more than five years of experience in neonatal lung ultrasound. While no formal consensus methodology (e.g., Delphi or anonymized voting) was applied, the recommendations were developed through collaborative online discussions. These discussions aimed to integrate available evidence with practical insights from clinical experience to formulate a pragmatic and consistent approach to neonatal lung ultrasound in addition to a targeted literature search by five author group members [14]. The consensus, reached through online conferences, synthesized evidence and expert insights to ensure a standardized and reliable approach. Artificial intelligence (DeepL Write, ChatGPT) was used for text editing and proofreading. The final content has been created following a critical revision and approval by all authors, to ensure the scientific integrity and prevent ethical ambiguity.

Results

Pleura-ABCDE protocol

The Pleura-ABCDE protocol is presented in Fig. 1. Prior to the examination, patient data such as name, date of birth, gestational age and corrected gestational age are documented. Furthermore, the indication for the

examination, the breathing support and the fraction of inspiratory oxygen are noted.

In line with international guidelines, we recommend a 10-zones approach to separate the lungs into five parts for each lung for the documentation and assessment of lung artefacts [9, 15].

In a complete lung examination, all lung areas are thoroughly scanned in the sagittal plane during a minimum of three breathing cycles, moreover a transversal / intercostal scan could be added and the transdiaphragmatic view could be used for the detection of pleural effusions. As a standard form of minimum documentation, it is recommended that a video clip (duration of at least three seconds) of every lung area is saved in the sagittal plane. During the examination, every lung area should be analyzed, and the artefacts are documented using the following Pleura-ABCDE protocol.

In critically ill or unstable neonates, Point-of-Care ultrasound should be used as a targeted Point-of-Care toolkit. Rather than completing a full protocol in all cases, the examination should prioritize relevant findings while minimizing stress for the patient.

To complete the Pleura-ABCDE protocol, a brief overview of the key ultrasound findings included is provided.

Pleura

The pleura appears as an echogenic horizontal line beneath the ribs and intercostal muscles. Two aspects of the pleural line are significant for diagnostic assessment:

1. Lung sliding: Visualization of a respiratory-synchronous movement of the visceral and parietal pleura. Lung sliding can be made visible in M-Mode by documenting the so-called Seashore sign. No lung sliding visualizes the Stratosphere sign:
 - The *Seashore sign* appears as horizontal echogenic lines (waves) representing muscle and fat tissue above a homogeneous artifact structure (beach) due to the moment of the lung and the creation of artifacts (Fig. 2). This finding indicates regular ventilation of the lungs [16].
 - The *Stratosphere sign* indicates the disappearance of motion artefacts and the creation of a barcode-like appearance due to the emergence of constant horizontal A-Lines (Fig. 2). The presence of the Stratosphere sign may suggest the possibility of a pneumothorax [16].
2. Pleural line: The pleural line can appear regular (thin and well-defined) or irregular (often mentioned as rough or thickened), with a blurred and partially interrupted appearance (Fig. 3). The thickening of the pleural line changes within the respiratory cycle

Pleura-ABCDE protocol

Neonatal Lung Ultrasound Examination

Name			Gestational age																				
Date of birth			Corrected gestational age																				
Breathing support	no		HFNC	CPAP	nHFO	CMV																	
Mean airway pressure																							
FIO2																							
Indication																							
<table border="1"> <tr> <td colspan="5">Right Lung</td> <td colspan="2">Left Lung</td> </tr> <tr> <td>R1</td> <td>R2</td> <td>R3</td> <td>R4</td> <td>R5</td> <td>L1</td> <td>L2</td> <td>L3</td> <td>L4</td> <td>L5</td> </tr> </table>							Right Lung					Left Lung		R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Right Lung					Left Lung																		
R1	R2	R3	R4	R5	L1	L2	L3	L4	L5														
Pleura																							
Sliding																							
M-Mode	Seashore																						
	Stratosphere																						
Morphology	Thin																						
	Irregular																						
A	A-Lines																						
B	B-Lines																						
Spared																							
Confluent																							
C	Consolidation																						
Size																							
Air Bronchogram																							
D	Dynamics																						
Lung Point																							
Double Lung Point																							
E	Effusion																						
Size																							
Score																							
Interpretation							Score Σ																

Fig. 1 Pleura-ABCDE protocol, FIO2– fraction of inspired oxygen, HFNC– High flow nasal cannula, CPAP– Continuous positive airway pressure, nHFO– non-invasive high-frequency oscillation, CV– Conventional mechanical ventilation, iHFO– invasive high-frequency oscillation, LUA– left upper anterior region, LLA– left lower anterior region, LL– left lateral region, LUP– left upper posterior region, LLP– left lower posterior region, RUA– right upper anterior region, RLA– right lower anterior region, RL– right lateral region, RUP– right upper posterior region, RLP– right lower posterior region

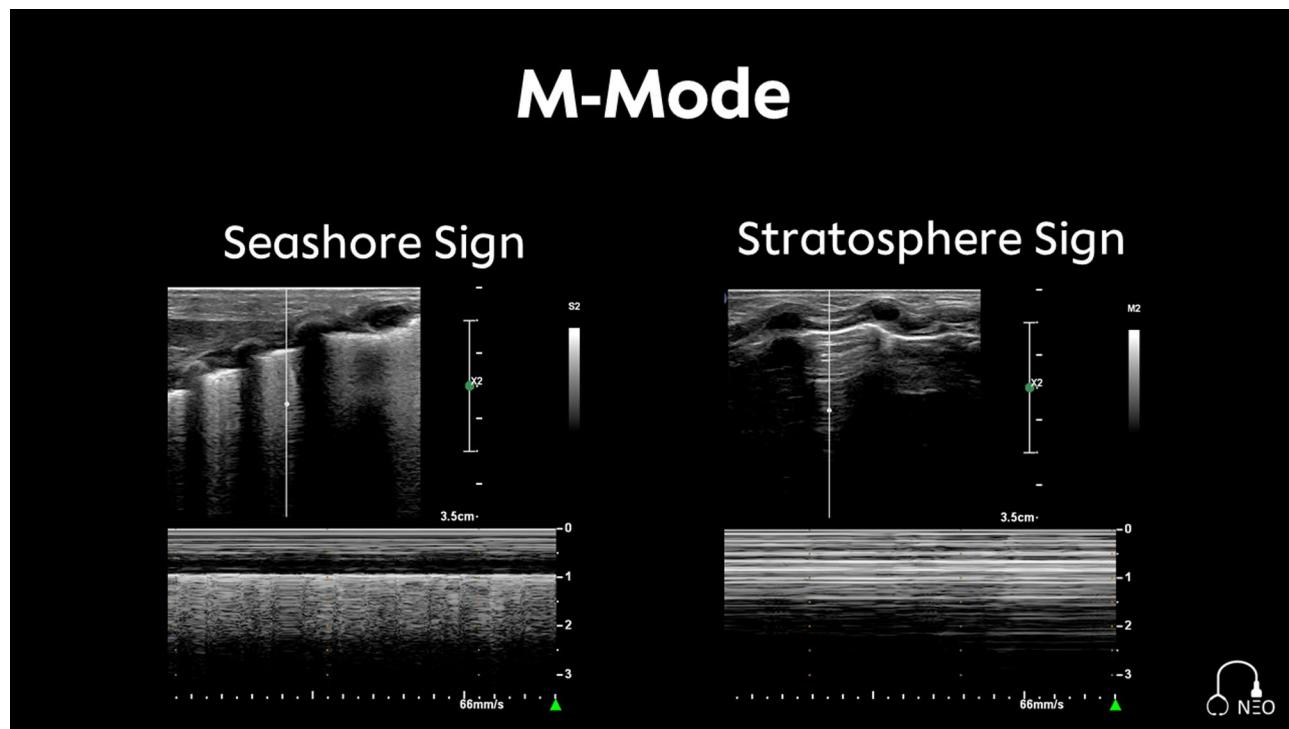


Fig. 2 M-Mode Seashore sign and Stratosphere sign

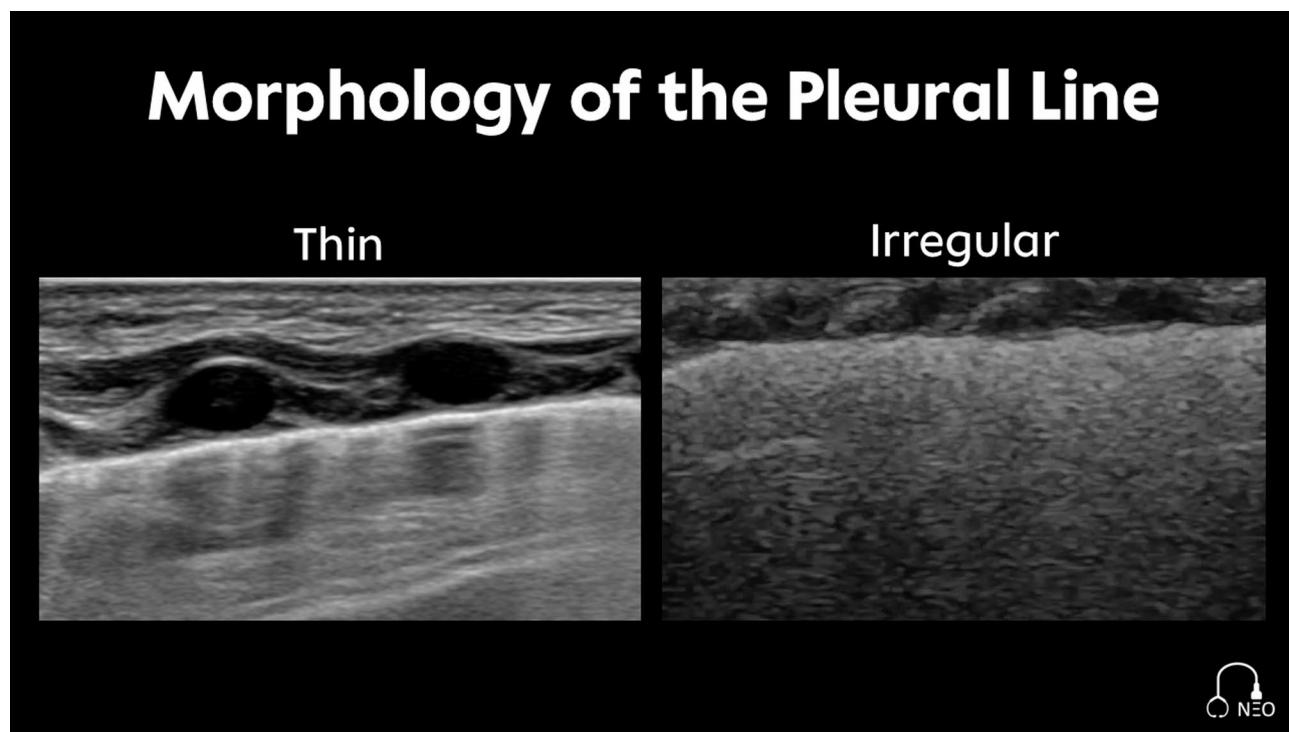


Fig. 3 Morphology of the pleural line

and is increased in respiratory distress syndrome and neonatal acute respiratory distress syndrome compared to patients without lung pathologies [17].

A-Lines

Echogenic horizontal reverberation artifacts, which extend repeatedly into the depth of the image at equal distances between the transducer and the pleura (Fig. 4).

B-Lines

B-Lines are vertical echogenic “laser-like” ring-down artefacts that originate from the visceral pleura and exhibit a respiratory-synchronous horizontal movement [18]. B-Lines partially erase A-Lines. Literature distinguishes several different types of B-Lines. For reasons of simplicity, we differentiate between two forms:

1. *Spared B-Lines*: Isolated B-Lines in the intercostal space [19] (Fig. 5).
2. *Confluent B-Lines*: Filling the entire intercostal space; “white lung” [19] (Fig. 6).

Consolidation

Consolidations are characterized as hypoechoic tissue-like structures, originating from the pleura (Fig. 7) [20]. Their extent is typically quantified by measuring the vertical distance from the pleural surface to the deepest edge of the lesion (consolidation index) as described in the UNION International multicenter study on neonatal

respiratory failure [21]. To distinguish true consolidations from subpleural consolidations, a threshold depth of ≥ 0.5 cm/kg or > 1 cm is applied. Lesions below this threshold are generally considered pleural irregularities or part of an interstitial pattern and are not classified as consolidations.

Within the consolidation echogenic artefacts might be visualized as air bronchogram (Fig. 8) [22]. It is caused by air trapping in a structure devoid of air.

Dynamics

Lung point

The Lung point is the pathognomonic sign for the presence of a pneumothorax [23]. The term is used to describe the point at which the visceral and parietal pleura are in direct contact on one side (pleural sliding is visible, B-Lines are present) and on the other side, the two pleural layers are separated by air/pneumothorax (pleural sliding is not visible, B-Lines are absent, Fig. 9A). In the supine position of the neonate, air is usually accumulated at the anterior region of the thorax. The documentation of the anatomical region (mid clavicular line, anterior axillary line, mid axillary line, posterior axillary line) and the dynamic change could support the estimation of the size of a pneumothorax [24]. In case of an increasing pneumothorax, the lung point is shifted to the lateral thoracic wall. (Fig. 9B).

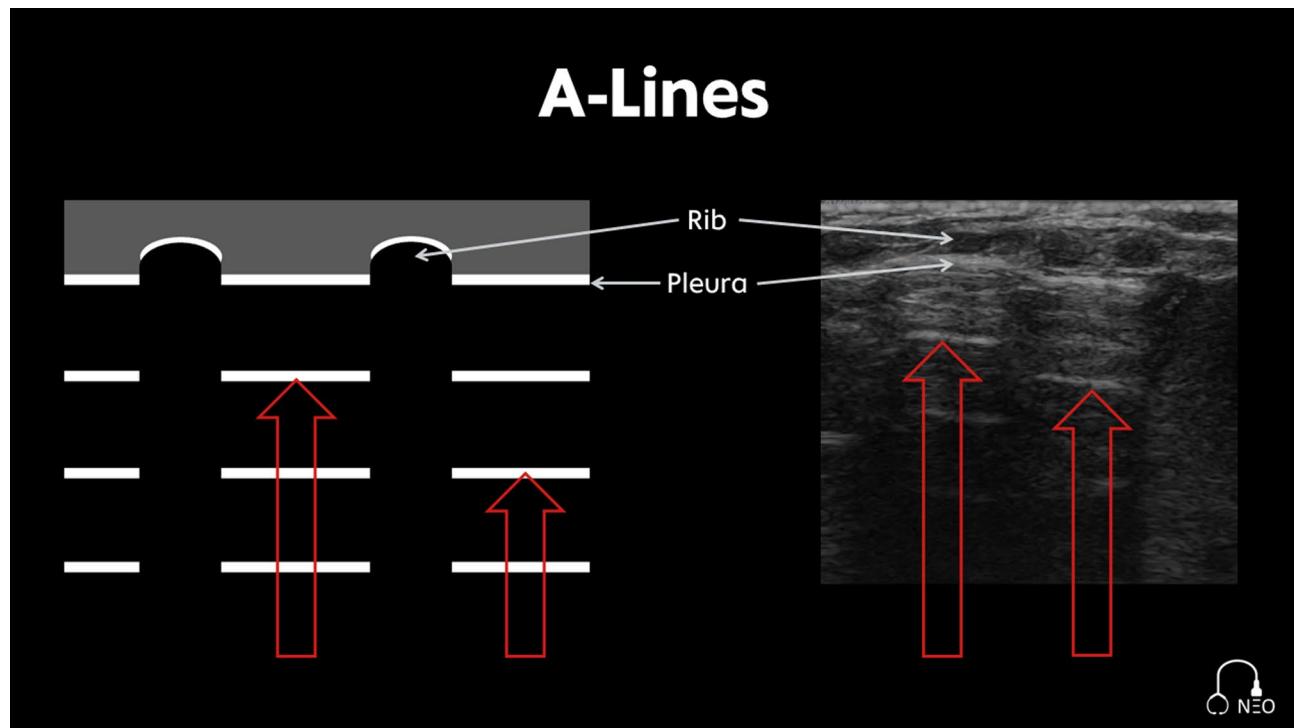


Fig. 4 A-Lines

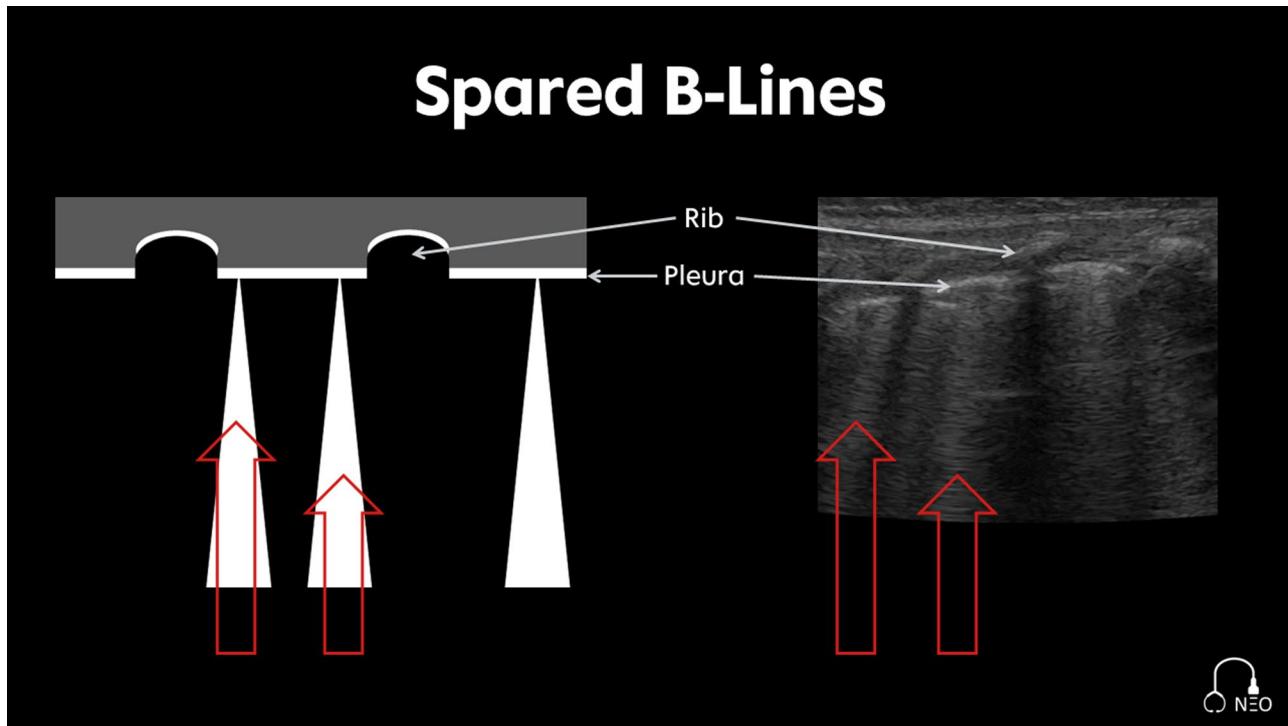


Fig. 5 Spared B-Lines

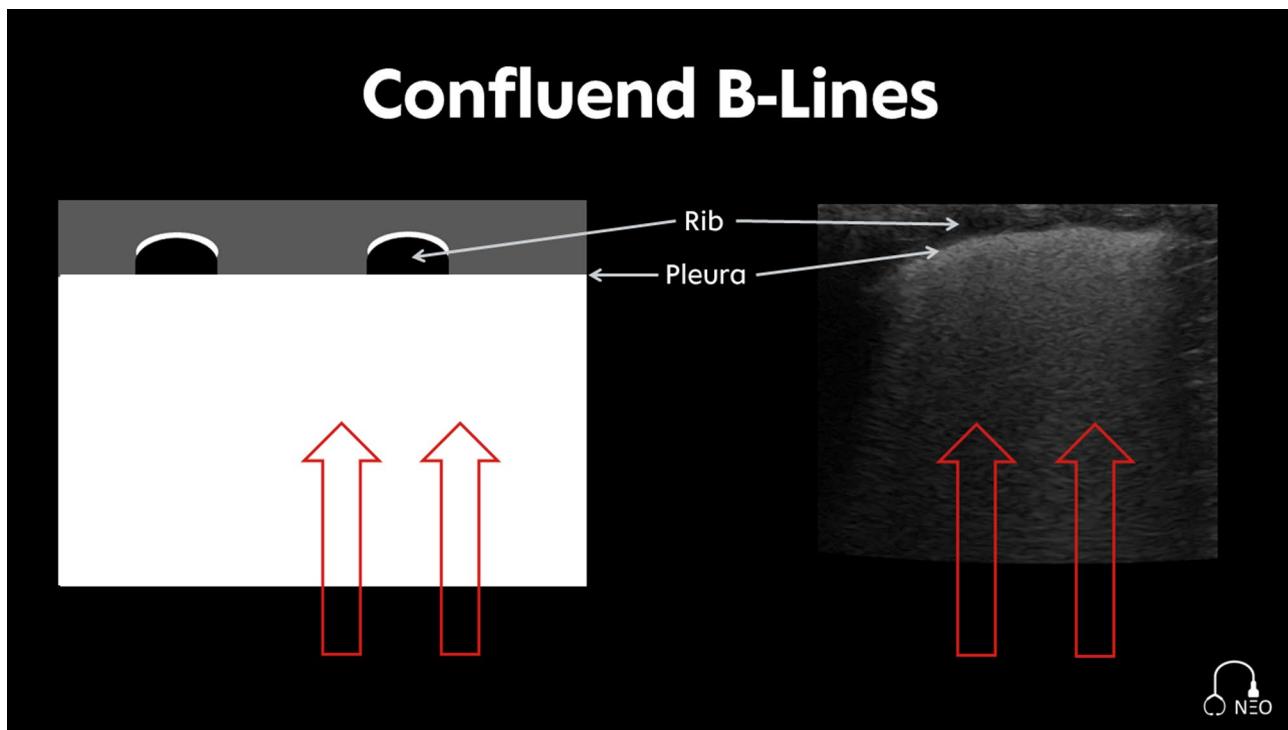


Fig. 6 Confluent B-Lines

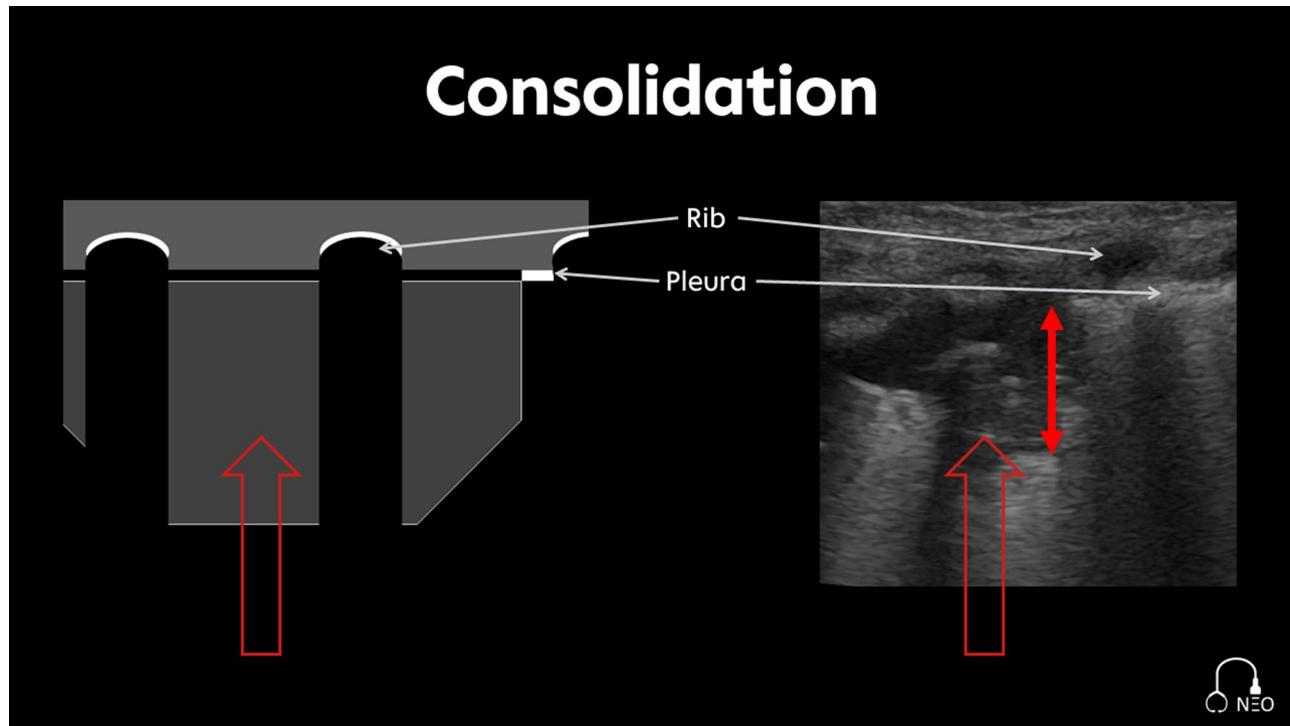


Fig. 7 Consolidation, the double-headed red arrow indicates the measurement of the consolidation size (consolidation index)

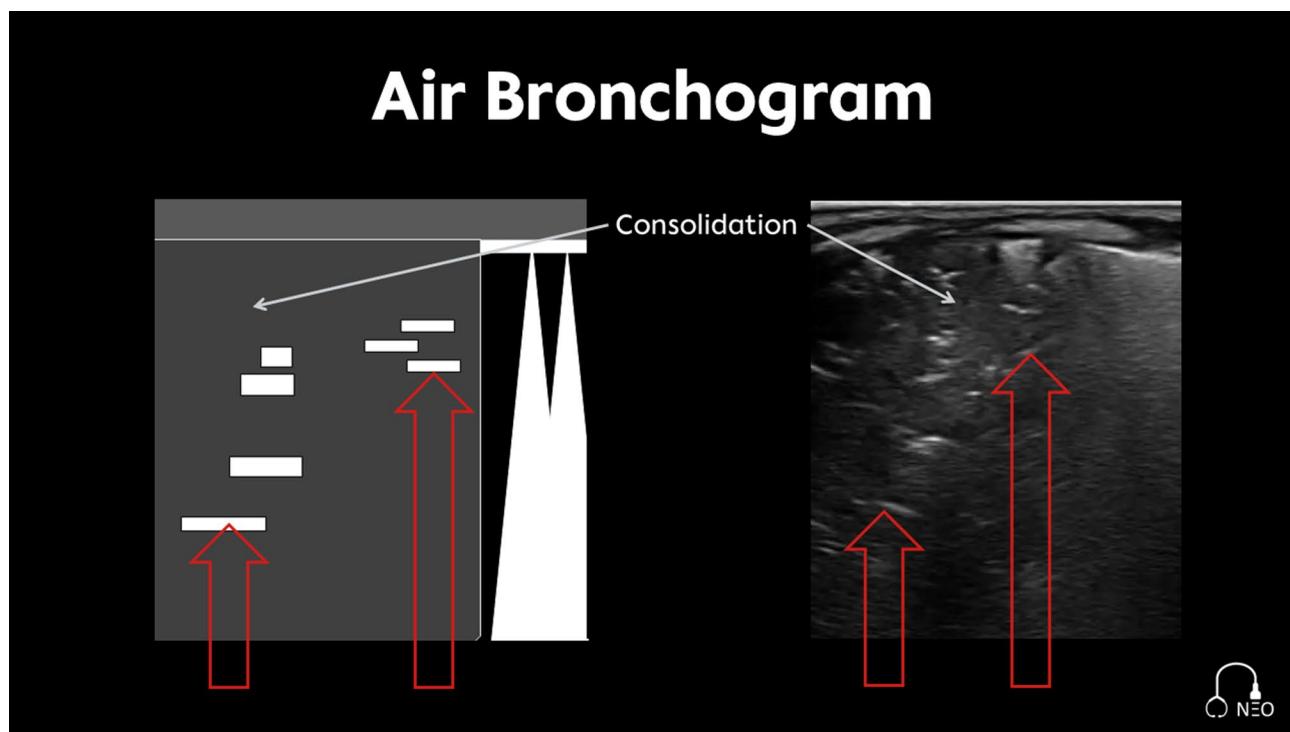


Fig. 8 Air bronchogram

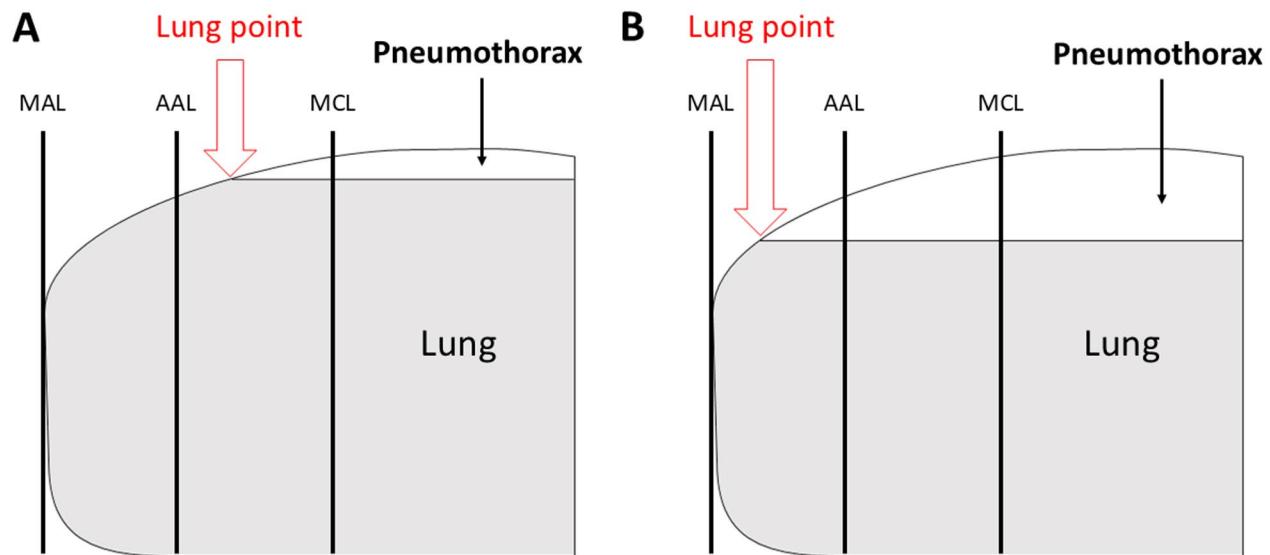


Fig. 9 Lung point, MAL - Mid axillary line, AAL - Anterior axillary line, MCL - Mid clavicular line

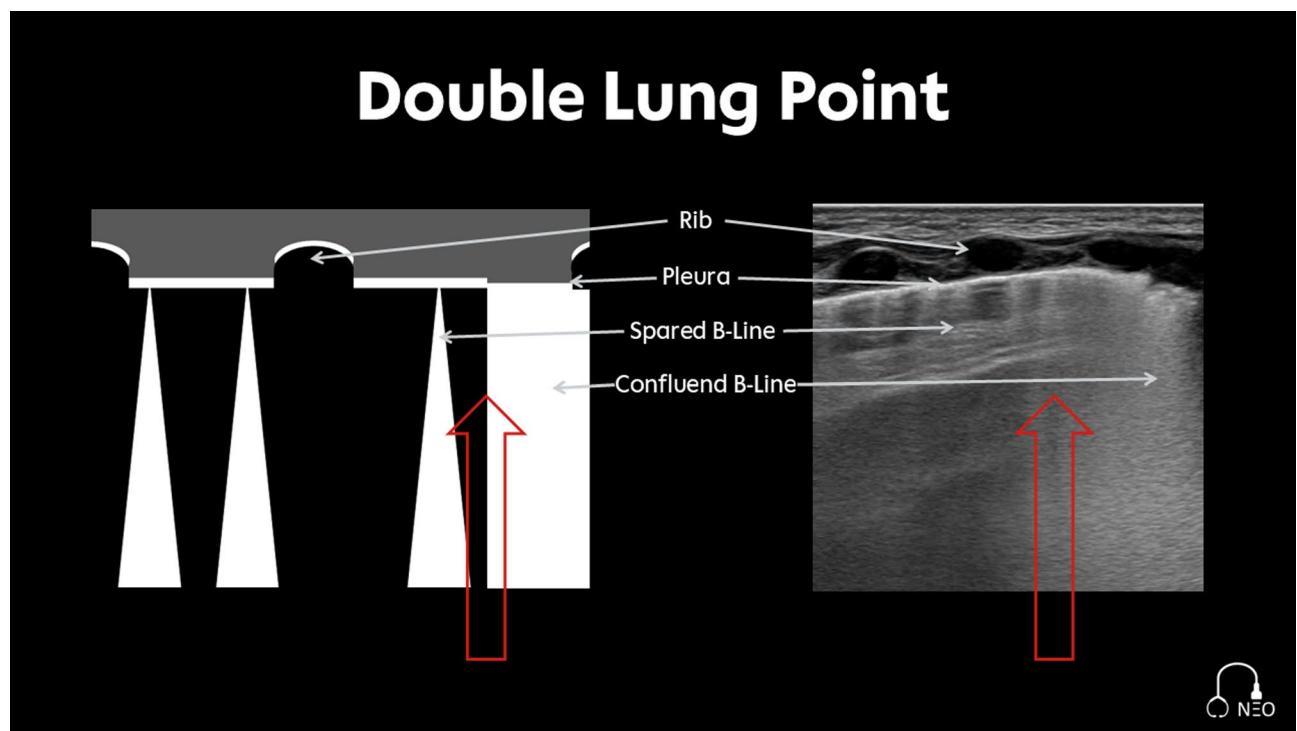


Fig. 10 Double lung point

Double lung point

The Double lung point (Fig. 10) is used to denote a discernible discrepancy in the sonographic image, manifesting as confluent B-Lines in the inferior lung regions and spared B-Lines or A-Lines in the superior lung regions [25]. This finding may be indicative of an inhomogeneous water clearing process, which is more pronounced in the superior or ventral lung regions. This phenomenon has been observed in transient tachypnoea of the newborn [25].

Effusion

Pleural effusion refers to an accumulation of fluid in the pleural space. Following the force of gravity, the largest amount of fluid in newborns positioned in the supine position can therefore be detected in the costodiaphragmatic recess, approximately at the level of the posterior axillary line in the sagittal plane.

The measurement of pleural effusion should be performed at the site of a possible puncture and documented accordingly to allow for repeated measurements and comparability. We suggest measuring the effusion in the 4th intercostal space in the transversal (intercostal) plane measuring the maximum size between the lung surface and thoracic wall (Fig. 11).

Score

There are numerous pulmonary scoring systems utilized for the guidance of clinical decision-making, e.g.

surfactant therapy [10, 26, 27], the assessment of respiratory weaning [28] or the evaluation of the severity of a respiratory illness [29]. Each scoring system is based on the sum of individual lung area scores, which could be added, based on the documentation of the Pleura-ABCDE protocol.

Interpretation

Lung ultrasound is a useful diagnostic technology that can be used as a bedside tool by the treating physician. To improve the clinical impact of the Pleura-ABCDE protocol an interpretation guideline is demonstrated (Table 1). The authors wish to highlight that Table 1 offers a practical overview of typical lung ultrasound findings observed in defined thoracic regions and may support clinical reasoning in the context of neonatal respiratory distress. Nonetheless, it is essential to note that this table is neither comprehensive nor definitive. Considerable overlap between different pathologies is common, and distinguishing features are often indistinct or lacking. For this reason, isolated interpretation of sonographic findings should be avoided. A reliable diagnosis requires integration of additional modalities, including laboratory results, clinical features (e.g., timing of symptom onset, evidence of pulmonary hemorrhage), and relevant perinatal history such as gestational age or prolonged rupture of membranes.

For a detailed description of the specific ultrasound findings associated with respiratory diseases, we refer to

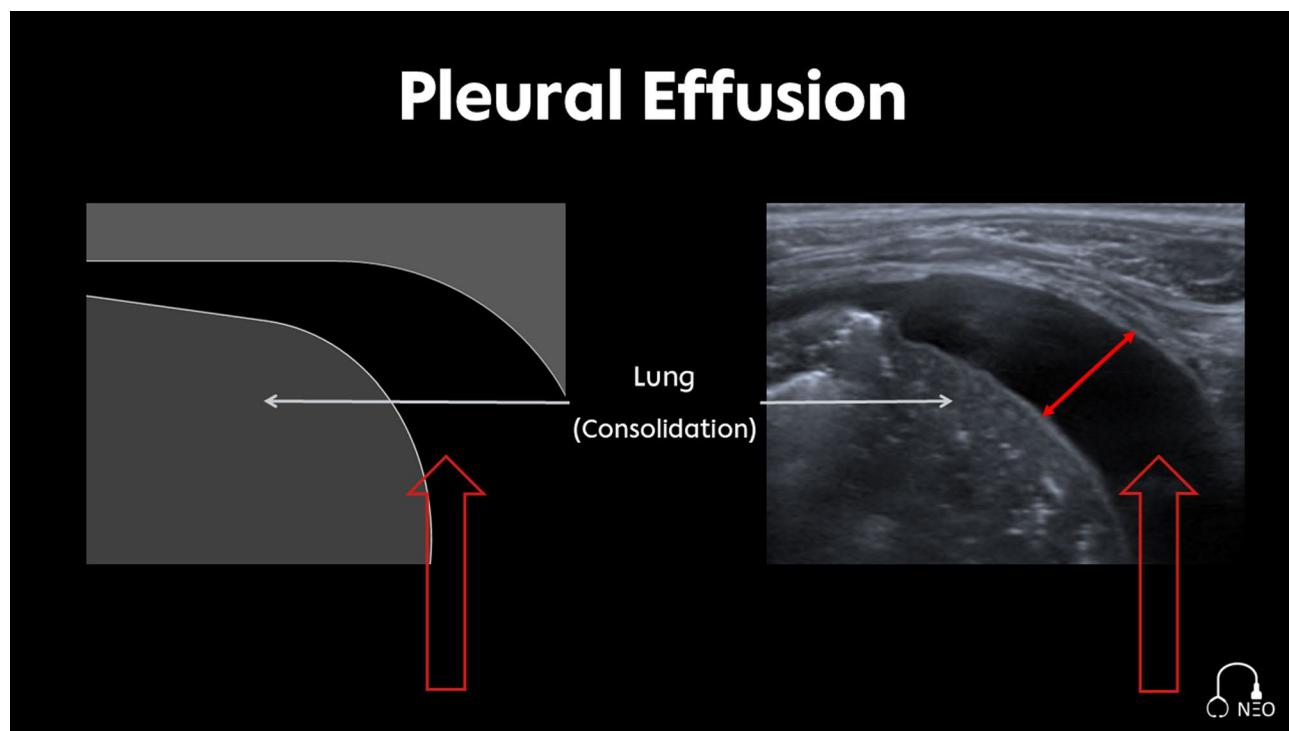


Fig. 11 Pleural effusion, the double-headed red arrow indicates the measurement of the pleural effusion in the transversal plane

Table 1 Pleura-ABCDE interpretation of respiratory pathologies of the newborn. *TTN*– Transient tachypnoea of the newborn, *RDS*– Respiratory distress syndrome, *MAS*– Meconium aspiration syndrome, *PH*– Pulmonary hemorrhage, *ARDS*– Acute respiratory distress syndrome, *BPD*– Bronchopulmonary dysplasia

Respiratory Pathologies												
	Normal	Pneumothorax	TTN	RDS	Pneumonia	Atelectasis	MAS	PH	Lung edema	Neonatal ARDS	BPD	
Pleura												
Sliding	+	-	+	+	+	+	+	+	+	+	+	+
M-Mode	Seashore	+	-	+	+	+	+	+	+	+	+	+
	Stratosphere	-	+	-	-	-	-	-	-	-	-	-
Morphology	Thin	+	+	+	-	(+)	+	-	+	+	-	-
	Irregular	-	-	-	++	(+)	-	+	-	-	+	+
A	A-Lines											
		+	+	+	+	(+)	(+)	(+)	(+)	+	+	(+)
B	B-Lines											
Spared		-	-	++	++	+	+	+	+	++	+	+
Confluent		-	-	+	++	+	+	+	+	++	+	+
C	Consolidation											
		-	-	-	-	+	+	+	+	-	+	+
	Air bronchogram	-	-	-	-	+	(+)	(+)	(+)	-	(+)	(+)
D	Dynamics											
Lung Point		-	(+)	-	-	-	-	-	-	-	-	-
Double Lung Point		-	-	(+)	-	-	-	-	-	-	-	-
E	Effusion											
		-	-	-	(+)	(+)	(+)	(+)	(+)	-	(+)	(+)
+/-		normal findings										
(+)		possible finding										
		+ pathological finding										
		++ pathological finding, high quantity										

previous publications and international expert consensus statements [30–32].

Conclusion

The Pleura-ABCDE protocol represents an expert-based structured approach that proposes a standardized reporting and interpretation framework for clinicians. It is intended to support examination quality and reproducibility, aligning with goals expressed by international ultrasound societies [5, 33].

To address the absence of standardization guidelines, international groups dedicated to the field of ultrasound have proposed a series of standards for neonatal lung ultrasound examinations. The proposal involves the utilization of a documentation system based on an ABCDE framework [8]. The authors strongly support this approach, particularly its application as an extended lung ultrasound protocol. It is vital to highlight its user-friendliness and its practical usage. Consequently, an even more pragmatic approach has been adopted.

Through this structured guideline, all lung regions are systematically examined and classified to ensure a high level of reproducibility and quality assurance. The protocol is intended for the use as a universal tool of all neonatal patients without a difference in gestational age. This method contrasts with flow-chart-based approaches [12], where the clinician follows a pathway to rule-in or rule-out different diagnoses and could be used for all clinical scenarios (e.g. Emergencies or Follow-ups).

Lung ultrasound represents a significant advancement in modern neonatology, with the highest impact being achieved by integrating it with bedside examination tools, as opposed to traditional clinical examinations, laboratory diagnostics and bedside monitoring [34]. Ensuring the quality of ultrasound examinations necessitates that treating clinicians possess a comprehensive understanding of the indications and limitations of the examination, in addition to ensure a sufficient level of training. Based on our shared clinical and educational experience, we suggest that the Pleura-ABCDE protocol may serve as a useful component in training curricula, providing a structured approach to neonatal lung ultrasound.

Despite its primary clinical aim of supporting clinicians, the Pleura-ABCDE protocol could also be adapted and used as a standardized reporting tool in future research projects. To achieve this, the implementation of a multicenter prospective validation study could be implemented to assess reproducibility and diagnostic impact.

In conclusion, the Pleura-ABCDE protocol could enhance the systematic evaluation of lung ultrasound, facilitating rapid diagnosis and management of various pulmonary conditions. We believe this structured method may support clinical decision-making and promote the integration of ultrasound into routine neonatal care.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13089-025-00442-4>.

Supplementary Material 1

Supplementary Material 2

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Dedicated to all ultrasound knights of the world.

Author contributions

JS wrote the protocol draft. JS, FS, EK, LA, MK, NP and BS participated in the expert group meetings and contributed to the manuscript. CB contributed to the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data availability

The Pleura-ABCDE protocol and interpretation guideline is available in the supplement area. No data analysis was used to create the manuscript.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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