Technical Note

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Pediatric lung ultrasound: Tips and tricks for better scanning and interpretation

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ABSTRACT

In recent decades lung ultrasound (LUS) has emerged as an invaluable bedside imaging tool for the evaluation of respiratory conditions such as pneumonia, bronchiolitis, pneumothorax, and pleural effusion in pediatric age, thanks to the thin chest wall and absence of rib ossification. Despite its growing application, optimizing technique and interpretation remains crucial for reliable diagnostic performance. The present educational paper provides practical tips and tricks to enhance the accuracy, efficiency, and clinical value of LUS in pediatric patients, focusing on probe selection, patient positioning, scanning technique, common artifacts, and interpretation pitfalls.

Key words: pediatric lung ultrasound, chest sonography, children, point-of-care ultrasound

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Why is lung ultrasound important in pediatric age?

Accurate and timely diagnosis of respiratory diseases in children is extremely important, as they are the leading morbid condition in this age group [1]. In the past, the diagnosis of respiratory diseases was performed through chest ray (CXR) and/or chest computed tomography (CT), involving exposure to ionizing radiation. Over the past twenty years, knowledge of lung ultrasound (LUS) has demonstrated that the lung could be studied also by US and abnormalities in the lung parenchyma cause artifacts. The interpretation of artifacts is the basis for the clinical application of LUS [2,3]. Initially, LUS was predominantly used in adults and in emergency settings [4,5]. In the last years, its applications have changed and its use has enormously increased in the pediatric population, especially in the emergency room, and after the COVID-19 pandemic, being portable and repeatable at the patient's bedside, free from ionizing radiations, relatively easy-to-perform and highly specific for the majority of respiratory diseases in children [6-9]. Nevertheless, numerous barriers still hinder the routine use of this diagnostic tool in various pediatric settings, such as non-intensive pediatric units or outpatient clinics [10,11]. Gaps to be filled for further LUS widespread development in children include lack/inadequate diagnostic imaging equipment, scarce collaboration with specialists (i.e., cardiology, radiology), liability concerns and structured educational programs [12].

In the present practice article, the Pediatric Ultrasound Study Group of Italian Society of Pediatrics (SIP) report the basic principles, clinical uses, technique and reporting of LUS in pediatric patients. The paper has been drafted in collaboration with a panel of expert pediatricians, pediatric radiologists and pulmonologists, members of Thoracic Ultrasound Academy (AdET), Italian Society of Medical and Interventional Radiology (SIRM) and Italian Society of Ultrasound in Medicine and Biology (SIUMB). This article provides a basic approach to LUS procedures, and offers practical tips that can be applied in various pediatric clinical scenarios.

Technical considerations regarding ultrasound transducer selection, sonographic technique as well as common indications are presented. Additionally, a variety of clinical considerations are discussed.

The present article does not address possible neonatal respiratory patterns, except for pneumonia and bronchiolitis.

Technical and clinical considerations on LUS

1. The technical tricks that make a difference

Being non-invasive and painless, LUS is suitable both for neonatal and pediatric age, with a wide range of applications supported by research literature [12-19]. Lung ultrasound approach in children, as well as in adults, should be guided by clinically driven suspicion of a specific pathological condition, especially if performed in restless infants or life-threatening situations. However, a comprehensive examination of all intercostal spaces is recommended in order to avoid misdiagnosis. Preparation tips are summarized in Table 1.

2. Scanning technique pearls

The thorax should be explored in the craniocaudal (head-to-toe) axis, positioning the probe both perpendicular and parallel to the ribs, along all intercostal spaces. When the probe is placed longitudinally on the chest wall the "bat sign" may be appreciated: it identifies the upper and lower ribs (bat's wings) with

Table 1. Practical preparation tips for scanning pediatric patients.

LUS Preparation Tips	
Choose the right probe	• A high frequency linear probe (7-12 MHz) should be used due to its better resolution • Other probes (convex, microconvex or sector) can be used depending on body surface and age or if linear probes are not available
Machine settings	• Turn off image enhancement filters (e.g., harmonics, compounding): artifacts are diagnostic! • Depth: focus on pleura with adequate margin below (usually 3–4 cm in neonates, 5–6 cm in older children). • Gain: Too bright/too dark hides artifacts
Patient positioning	• Supine for anterior and lateral views • Sitting for posterior views (if possible)
Little tricks for big success in Pediatrics	• Warm the gel avoiding cold probes • Engage child-friendly distractions (toys, cartoons) • Scan quickly but thoroughly when the child is calm

the pleural line lying about half centimeter below the ribs (bat's body). The pleural line appears as a horizontal hyperechoic line a half centimeter below the rib line. Normally it is regular, thin, smooth and it shows synchronous movement with breathing called lung-sliding. Another indicator of a normally air-filled lung, is the so called "Curtain sign" which appears when aerated lung tissue in the costophrenic recess moves like a curtain over the diaphragm during breathing.

The examiner should fan the probe slightly to catch subtle sliding or artifacts. Both sides scanning, starting anteriorly (second–fourth intercostal spaces, midclavicular line) is preferable for comparison. The use of a systematic approach dividing the chest into zones may prevent missing findings. Literature reports several proposals for the division of the lung in pediatric and neonatology fields [20-23]. In children and infants each hemitorax can be divided in six regions per hemithorax: anterior, lateral, and posterior fields are identified by sternum, anterior and posterior axillary lines; each field is divided into superior and inferior regions. For neonates, it is possible to reduce the number of scanned areas from six to three per hemithorax, creating a single lateral zone on each side without investigating posterior fields [21]. In case of bronchiolitis eight pulmonary fields can be identified: one anterior region, one lateral region and two posterior regions. Posterior lung fields are divided into paravertebral and basal [22].

3. Image interpretation tips

Lung artifacts arise from the characteristic acoustic limitation of ultrasound through air. In the case of LUS, their combination and integration with the patient's clinical data may help healthcare professionals to exclude or confirm a clinical suspicion. Lung ultrasound artifacts and main patterns are listed below and illustrated in Figure 1 [22].

a. A-lines are hyperechoic lines horizontally orientated across the ultrasound screen as reverberations of the pleural line. Taken together, A-lines and lung sliding ensure the absence of pathology reaching the pleura in that area.
b. The Short Vertical Artifacts (SVA) are vertical artifacts that rapidly fade before reaching the bottom of the screen [16]. They are not considered a pathological sign.
c. B-lines are vertical hyperechoic artifacts, originating from the pleural line and lying approximately perpendicular to the latter. The presence of B-line is related to the expansion of the interlobular septae and the accumulation of fluid in the lung [24]. Isolated B-lines are not considered pathological findings.
d. Multiple B-lines are many B-lines in each scan. They are considered the sonographic sign of lung involvement, and their number increases along with decreasing air content and increasing lung density. Multiple B-lines are considered pathological findings (interstitial syndrome).
e. The white lung is a completely white subpleural field without distinguishing horizontal reverberation. It is considered an independent pathological finding of interstitial syndrome.
f. Consolidations: their sonographic sign is a subpleural echo-poor region or one with

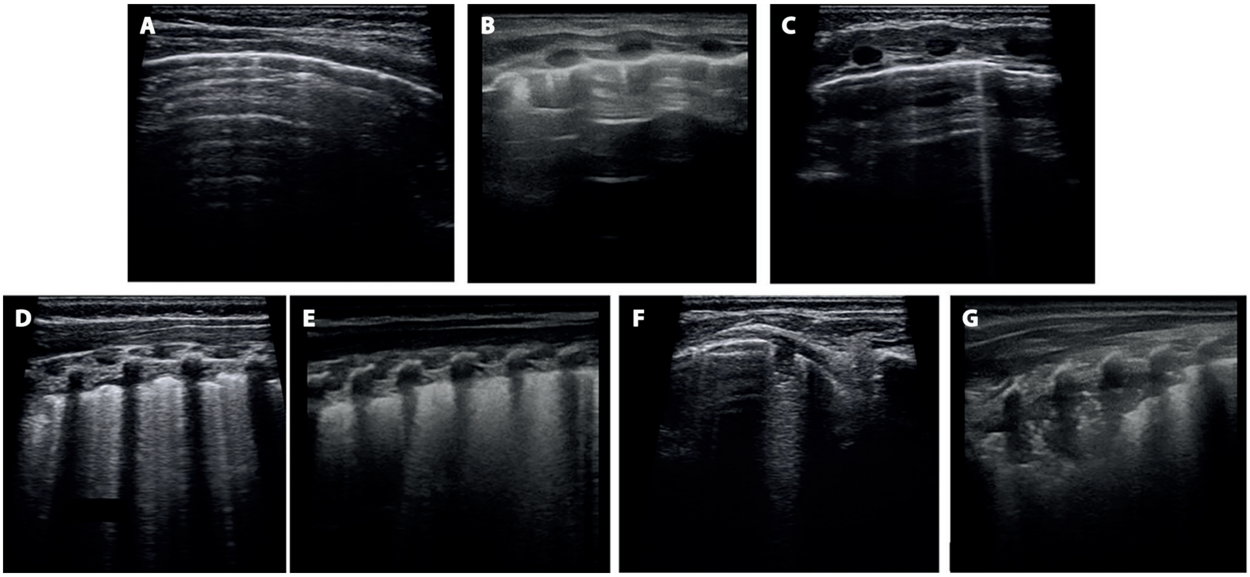

Figure 1. Image Interpretation Tips: Artifacts and Patterns [22].

tissue-like echotexture. Consolidations are classified according to their linear size (greater superficial extension consolidation < 1 cm or > 1 cm) [22,25-26]. Consolidations and atelectasis may appear with the same echotexture as the liver, termed hepatization.

Simple and practical mnemonic "ABCDE" for LUS may help remembering the key steps and findings during the exam (Table 2).

Possibile pitfalls and solutions to be considered while interpreting LUS are reported in Table 3.

4. Clinical integration tips

Complementing but not replacing patient's history, exams and labs, LUS should be used in support of the differential diagnosis of children with respiratory distress, chest pain and any chest symptoms. The current clinical indications for LUS in children are: diagnosis and follow-up of pneumonia, pleural effusion, bronchiolitis and diagnosis of pneumothorax (PNX), hemothorax and pulmonary contusions [6,14-15, 27-28]. Lung ultrasound is ideal for serial assessments in intensive care settings for determining pneumothorax evolution, fluid overload (also combined with cardiac ultrasound) or pneumonia treatment response.

4.1. Pneumonia and pleural effusion

Lung ultrasound has a number of strengths and limitations for detecting community-acquired pneumonia (CAP) in children (Table 4).

Consolidation is the most reported finding in children with pneumonia, even if LUS does not rule out lesions that do not reach the pleura [14, 28-33]. Consolidation appears as hypoechogenic area of the lung and it should be measured in longitudinal, transverse and sagittal axis in the largest lesion dimensions (Figure 2). Literature data report that small subpleural consolidations with dimensions < 1 cm represented in the middle upper quadrants suggest a viral aetiology [26-34], whereas extensive consolidations with lobar involvement, evidence of fissuritis (hyperechoic line within the consolidation) and extensive air bronchograms may be indicative of bacterial etiology (for example pneumococcal). The integration of clinical, laboratory and ultrasound data will allow for greater diagnostic precision. Lung ultrasound could also be a valuable method for monitoring of pneumonia in children since a significant correlation between the decreasing consolidation's size over the days of treatment has been reported [35]. Other sonographic signs of pneumonia are dynamic air bronchograms (hyperechoic spots within the hypoechoic consolidated lung

Table 2. Quick Mnemonic “A-B-C-D-E” for interpreting LUS artifacts in paediatric age.

ABCDE Mnemonic for LUS in Children			
A	A-lines	Air	Normally aerated lung
B	B-lines	Water increase/air reduction (interstitial syndrome)	Useful for diagnosing interstitial lung disease which can be mild, moderate or severe, depending on the number of lung fields involved and the number/consistency of the B lines within the single field.
C	Consolidation	Lung infection or atelectasis (Collapse)	Small consolidations <1 cm suggest viral infections. Extensive consolidations with dynamic air bronchograms suggest bacterial pneumonia. Extensive consolidations with static air bronchograms suggest atelectatic areas.
D	Diaphragm/dynamics	Curtain sign, pleural effusion	Useful for pleural effusion diagnosis and evaluation of its extent.
E	Edges	Pleural sliding or irregularities, effusion, lung point	In case of absence of pleural sliding, especially if the lung point is highlighted, the clinician can diagnose pneumothorax.

Table 3. Possibile pitfalls and solutions in interpreting LUS.

Troubleshooting common pitfalls in interpreting artifacts	
Mistake	**How to avoid**
Mistaking absence of sliding for pneumothorax	Confirm with M-mode or lung point (consider breath-holding or fibrosis)
Misinterpreting B-lines	True B-lines originate from the pleural line and reach the bottom, erase A-lines, move with respiration
Overlooking probe pressure artifact	Keep light, steady pressure
Too many artifacts?	Adjust gain and depth, reduce gel
Confusing intestinal content with consolidation	Identify the diaphragm
Over-reliance on a single ultrasound feature	Combine ultrasound findings with clinical signs and other diagnostics

Table 4. Strengths and limitations of LUS for pneumonia.

LUS for Pneumonia	
Strengths	**Limitations**
Fast and repeatable at the patient’s bedside	Operator-dependent
High sensitivity for peripheral and subpleural lesions	Central or deep lesions covered by aerated lung may not be visualized easily, cannot indicate the aetiologic factor
Equal to or higher diagnostic accuracy and sensitivity compared with CXR	Does not fully replace CT in complex cases
Useful for monitoring over time	May not clearly distinguish pneumonia from other conditions (atelectasis, tumors)
Valuable tool in resource-limited settings	Requires standardized protocols for reliability
Helps guide procedures safely in complicated pneumonia (e.g., thoracentesis)	

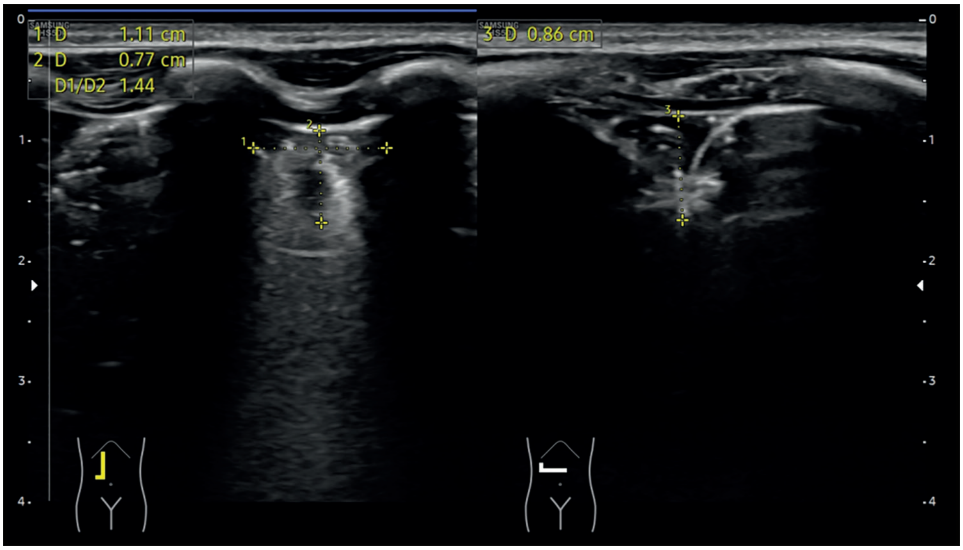

Figure 2. LUS image of the pneumonic lung consolidation measured in longitudinal, transverse and sagittal axis.

tissue, branching with respiration), B-lines and pleural effusion.

Regarding pleural effusion, it typically appears as an anechoic (black) or hypoechoic (dark gray) area located between the visceral and parietal pleura, above the diaphragm. Lung ultrasound plays a pivotal role in pediatric age for detection, quantification, and organisation of pleural effusion. Indeed, LUS is more sensitive than CXR in diagnosis and monitoring effusion [28,33,36] and it is as accurate as CT for the detection of effusion [28,33]. Lung ultrasound evaluation in an upright (sitting or standing) position allows quantification even for small fluid's amounts since effusion collects at lung bases due to gravity-dependency. In supine or semi-recumbent position effusion tracks posteriorly [6]. The visualization of the spine above diaphragm ("spine sign") and a sinusoidal pattern of dynamic changes during respiration in Motion Mode (M mode) ("sinusoid sign") confirm fluid presence. For large pleural effusions, the lung may be trapped within effusion, appearing as if it is floating or emerging from the fluid ("jellyfish sign") [37]. Lung ultrasound can also differentiate between various fluid's composition of pleural effusion: anechoic and homogeneous in simple trasudative effusion; hypoechoic with fibrin strands or septations in complex/septated effusion; echogenic debris and loculations in empyema/exudate; mixed echogenicity, swirling echoes ("plankton sign") in hemothorax. Lung ultrasound can estimate the volume of pleural fluid [6,38] (Table 5).

4.2. Pneumothorax

The diagnostic accuracy of LUS for PNX has been largely confirmed, reaching 100% in sensitivity, specificity, positive and negative predictive value [14,39]. The diagnosis of PNX is reliable not only in pediatric but also in neonatal age [40-41]. The advantages of LUS for PNX are multiple: it is faster than CXR, especially in trauma, intensive and emergency settings, it may be helpful in drainage and it reduces the use of CXR in follow-up of diagnosed PNX.

The patient should be evaluated in the supine semi-upright position, starting from anterior chest at second–fourth intercostal spaces, mid-clavicular line. Suggestive signs of PNX could be: absent pleural sliding, absent B-lines and lung point. The latter represents the transition between sliding and non-sliding lung and it is 100% specific for PNX. A further possibility to confirm PNX is selecting M mode, which can be useful in complicated situations (patients on mechanical ventilation, unstable patients, numerous movement artifacts) [42]. Normally, the lung shows a "sandy" or "seashore" appearance on M Mode since the two layers of the pleura move against each other. In case of PNX, a pattern of parallel horizontal A lines on

Table 5. Pleural effusion assessment and volume estimation on LUS modified Soldati [33].

Quantification	Description	Ultrasound Visualization	Volume estimation (ml)
Minimal	Limited to costophrenic sinus	Effusion limited to Costophrenic sinus	< 100
Small	Lower lung lobe partially involved	1 intercostal space	100 – 500
Moderate	Lower lung lobe partially/completely collapsed	2 -3 intercostal spaces	500 -1500
Large or Massime	Upper lung lobe partially involed/ fully collapsed lung	4 or more intercostal spaces	> 1500

Table 6. Bronchiolitis Ultrasound Score and clinical management modified Gori et al. [22].

Score	Type of bronchiolitis	Management	Diagnostic and therapeutic choices
Ultrasound score <9	Mild	If clinical findings are reassuring, home management possible with respiratory monitoring by the caregiver	Follow-up by the attending physician.
Ultrasound score > 9	Moderate-severe	Hospitalization in pediatric ward and clinical/ultrasound monitoring	Repeat ultrasound after 24 hours: • if the score decreases, discharge possible if the clinical findings are reassuring • if the score increases, consider ventilator support at high flow rates

M Mode ("Barcode or stratosphere sign"), indicating the absence of lung sliding, can be appreciated.

4.3. Bronchiolitis

Diagnostic criteria for bronchiolitis are based on clinical history and examination. Current guidelines do not suggest to routinely perform laboratory tests while CXR should be reserved for the most severe cases [22]. During the last decade, LUS has been proven to be a useful diagnostic method in the diagnosis and management of bronchiolitis [22]. From the first studies on bronchiolitis [43-47], it is now established in the literature that LUS is not only able to diagnose this pathological condition but it has equal to or greater diagnostic value than CXR in bronchiolitis diagnosis [20,25,48-52] and it is also useful in finding out complications, monitoring patients over time and assessing management and severity of bronchiolitis [28]. Moreover, recent papers highlighted how LUS score may be helpful in stratifying the severity of bronchiolitis [22-23,48,53-56], accurately predicting the need for pediatric intensive care admission, continuous positive airway pressure (CPAP) respiratory support in children [23] and identifying patients at increased risk of requiring respiratory support within 24 hours of initial emergency department assessment [57-59].

Therefore, from a practical standpoint, performing a lung ultrasound can guide the clinician in patient management (Table 6) [22].

The LUS scanning pills for bronchiolitis include: setting the depth to visualize pleura about 3-4 cm below; positioning the infant patient supine, in lateral decubitus, or being held by caregiver if crying, sitting position if cooperative older child; evaluating the posterior apical areas and paravertebral fields, where air trapping phenomenon is more pronounced, especially in supine infants. Typical bronchiolitis artifacts range from interstitial syndrome (focal or confluent B lines, white lung) to subpleural consolidations <1 cm, to extensive areas of atelectasis in severe bronchiolitis. Pleural line is often irregular, thickened, and small pleural effusion might be occasionally present [22,28].

5. How I do it: Reporting

Despite the increase in the use of LUS, literature regarding the report is limited [19,60,61]. Using a structured format may improves readability and consistency; hence the suggestion is to organize the report into clear sections, pointing out: personal patient's data (name, surname, date of birth), indication for examination, technique and probe used, findings (by region) and conclusion with possible indication of subsequent check, if necessary. The proposal of a reporting model from the Academy of Thoracic Ultrasound [19] with the checklist method, can be easily applied in all settings and supports the homogeneity among operators, creating a common language among practitioners (Figure 3). Reporting tips are summarized in Table 7.

Date …/…/….
Place…..

First name:
Last name:
Date of birth:

Reason for the examination:

Ultrasound machine:

Probe:

SIGN	FIND	RIGHT				LEFT			
		Front	Lateral	Para-vertebral	Basal	Front	Lateral	Para-vertebral	Basal
SLIDING SING	ABSENT								
PLEURAL LINE	IRREGULAR								
	INTERRUPTED								
COURTAIN SIGN	REDUCED								
	ABSENT								
B LINES	ISOLATED								
	MULTIPLE								
WHITE LUNG									
CONSOLIDATION	< 1 cm								
CONSOLIDATION	> 1 cm								
PLEURAL EFFUSION									

NORMAL FINDING	
PATHOLOGICAL FINDING	

DESCRIPTION	
CONCLUSIONS	

DR. …………………..

NB: Thoracic ultrasound has no diagnostic validity for lung lesions that do not emerge from the pleura at the level of the explored and explorable chest wall. Interstitial pathology that does not emerge on the explorable visceral pleura is not detected by ultrasound. Large regions of the mediastinum cannot be explored with transparietal ultrasound.

Figure 3. Checklist reporting method for LUS [19].

Table 7. Reporting tips for LUS.

LUS Reporting Tips
Describe the Examination Clearly • Probe type (e.g., linear, curvilinear, phased array) • Areas scanned (anterior, lateral, posterior; right vs. left) • Patient position (supine, seated, lateral decubitus)
Use Standardized, Recognized Terminology Examples of precise and accepted terms: • A-lines present / absent • B-lines: focal / diffuse / confluent • Pleural sliding: present / reduced / absent • Consolidation: location, size, air bronchograms present • Pleural effusion: small / moderate / large, free / loculated • Lung point: identified / not identified (if pneumothorax suspected) Avoid vague phrases like “some B-lines” or “maybe effusion.”
Report by Lung Regions Consider breaking findings down per side and zone: Example: • Right Anterior: Normal A-lines, sliding present • Left Lateral: Multiple B-lines, reduced sliding • Right Posterior: Subpleural consolidation with air bronchograms
Common Phrases to Simplify Reporting • Normal exam: “Normal lung ultrasound with preserved pleural sliding and A-lines throughout. No B-lines, consolidation, or effusion detected.” • Pulmonary edema: “Bilateral diffuse B-lines consistent with interstitial syndrome suggestive of pulmonary edema.” • Pneumonia: “Focal subpleural consolidation with dynamic air bronchograms in posterior lower zone, consistent with pneumonia.” • Pneumothorax ruled out: “Pleural sliding and lung pulse present bilaterally; no lung point identified; no evidence of pneumothorax.”
Final Reporting Tips • Keep it clear and concise • Avoid jargon not universally understood • Ensure consistency between findings and impression • Document uncertainties (e.g., “Limited views due to body habitus e.g. obese child”)

Conclusions

Lung ultrasound is a powerful, portable tool, suitable for diagnosing many pediatric respiratory conditions. The greatest potential of LUS belongs to the dynamic follow-up of pulmonary conditions, making everyday decisions easier for clinicians and enabling a higher quality of treatment and faster recovery [6]. Mastery requires regular practice (also on normals) to develop pattern recognition and clinical correlation proficiency. Recording short clips for later learning and reviewing abnormal cases with mentors may be useful for further increasing the operator's expertise. A standardized reporting method can reduce the dependency operator make it easier to perform multicenter international studies.

List of abbreviations:

CXR: Chest X-ray
CT: Chest computed tomography
LUS: Lung ultrasound
SIP: Italian Society of Pediatrics
AdET: Thoracic Ultrasound Academy
SIRM: Italian Society of Medical and Interventional Radiology
SIUMB: Italian Society of Ultrasound in Medicine and Biology
SVA: Short Vertical Artifacts
PNX: Pneumothorax

CAP: Community-acquired pneumonia
M mode: Motion Mode
CPAP: Continuous positive airway pressure

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