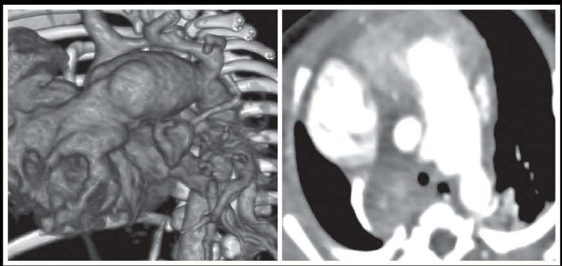
Imaging of PEDIATRIC CHEST



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CHAPTER 2

Ultrasound Chest: Basics and Role

Amit Gupta, Priyanka Naranje

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INTRODUCTION

Traditionally, lung has always been considered as an unsuitable organ to be evaluated by ultrasonography (USG). The reason being that USG cannot traverse through the air within the lung parenchyma. This has limited use of USG in the chest to the diagnosis and drainage of pleural fluid collections.

More recently in the past one or two decades with the advancements of ultrasonographic technology, many newer applications of thoracic USG are being explored. The ready availability of portable USG machines in the intensive care units (ICUs) and wards has only augmented its use in critically ill patients, often as an adjunct or replacement to chest radiograph. The pediatric chest is well suited for USG due to less subcutaneous fat and partially-ossified chest wall that provides additional acoustic windows not available in older children and adults.

INDICATIONS

Ultrasonography is informative in several conditions as given in **Table 1**.

TABLE 1: Various indications for chest USG in pediatric patients.	
Lung	• Neonatal point of care USG • Congenital lung lesions • Consolidation • Lung neoplasms
Mediastinum	• Normal thymus/thymic lesions • Mediastinal lymph nodes • Mediastinal masses
Chest wall	• Vascular malformations • Neoplasms • Infections
Diaphragm	Diaphragmatic paralysis
Pleura	• Pleural effusion • Infected pleural fluid collection • Pneumothorax

EQUIPMENT

- Any standard USG scanner with color Doppler is suitable for lung sonography
- Curvilinear low-frequency transducer (2–5 MHz), linear high-frequency transducer (5–12 MHz), phased array probe
- In infants and small children, small footprint linear transducers are more useful.
- For mediastinal lymph node detection, endocavitary or microconvex (5–12 MHz) transducers are essential.

TECHNIQUE

Screening and Patient Positioning

- USG can be performed in supine, prone, or decubitus position depending on area of interest.
- Pneumothorax in an ambulatory patient should be evaluated in a sitting position and the apices are the most important area; anterior area in the basal lungs is the most important area in a supine patient.
- For ambulatory patients who can sit upright, sitting posture is ideal for lung USG.

Approaches

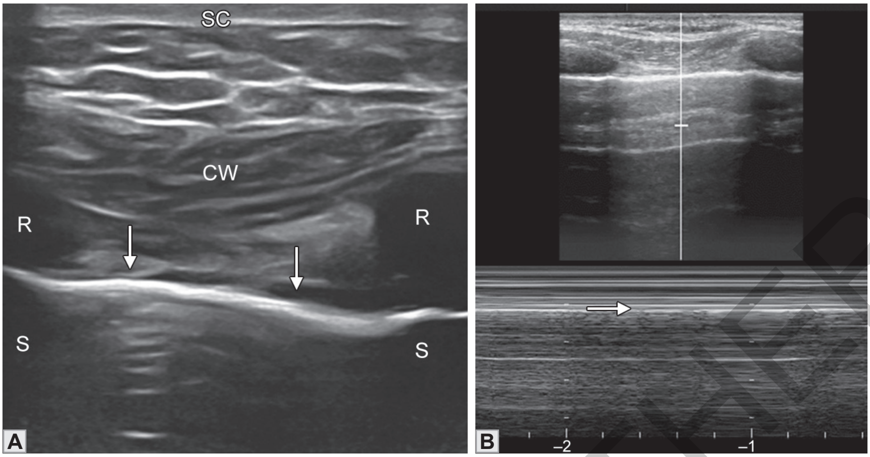
- Acoustic windows available for evaluating pediatric chest include supraclavicular, suprasternal notch, trans-sternal scan, parasternal region, intercostal spaces, transdiaphragmatic approach, and subcostal/subxiphoid scan.
- Parasternal, intercostal, and transdiaphragmatic approaches are good for lung and pleural imaging.
- Supraclavicular, suprasternal, and parasternal views are good to visualize mediastinum.
- For an area of interest detected on either chest X-ray (CXR) or general examination, scanning in different planes (sagittal, transverse, or oblique) should be performed for characterization of the abnormality.
- It can be complimented by M mode and Doppler examination in abnormal areas.
- USG approaches specific to a particular pathology are discussed along with the imaging findings later in the chapter.

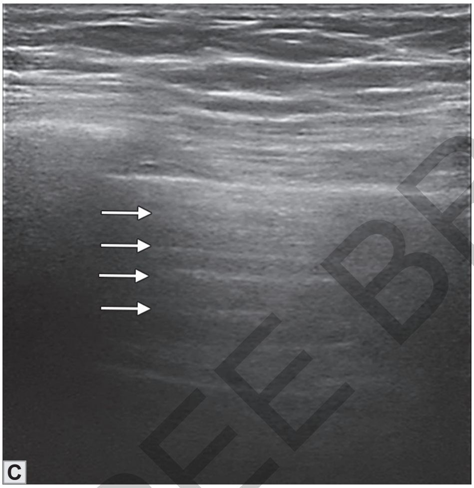
NORMAL ULTRASONOGRAPHY APPEARANCES

Normal USG signs and artifacts seen in the pediatric chest are summarized in **Table 2** and **Figures 1 and 2**.

TABLE 2: Normal signs and artifacts in pediatric chest USG.

Findings on imaging	Description	Anatomical pathological correlate
Pleural line	Hyperechoic line deep to intercostal muscles	Visceral and parietal pleura
Lung sliding	Back and forth movement of hyperechoic pleural line with respiration	Relative motion between visceral and parietal pleura
Batwing appearance	Posterior acoustic shadowing caused by ribs separated by echogenic pleural line	Ribs separated by pleura in the intercostal space
Seashore sign	Superficial horizontal lines and deep granular appearance on M-mode	Static superficial chest wall and movement of lung deep to it
A-lines	Equidistant parallel echogenic horizontal lines	Reverberation artifacts of pleural line
Z-lines	Short echogenic lines perpendicular to pleural surface, do not erase A lines	Comet-tail artifacts
Starry-sky appearance	Hypoechoic soft-tissue with hyperechoic foci in anterior mediastinum	Normal thymus





FIGS. 1A TO C: Normal chest USG appearances: A) Echogenic pleural line (arrows). Batwing appearance due to shadowing (S) by the ribs (R). SC—subcutaneous tissue, CW—chest wall muscles; (B) “Seashore sign” (arrow) on M-mode USG; (C) A lines (arrows).

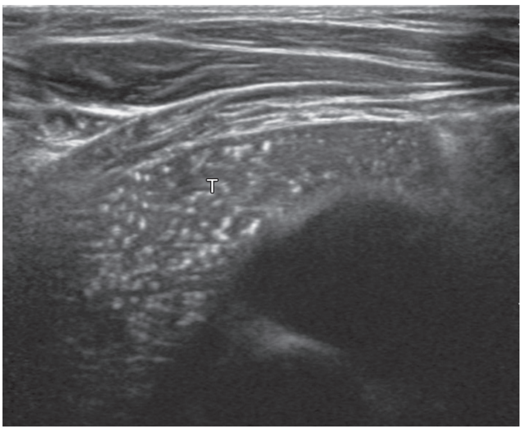


FIG. 2: Normal “starry-sky” appearance of thymus (T).

IMAGING FINDINGS

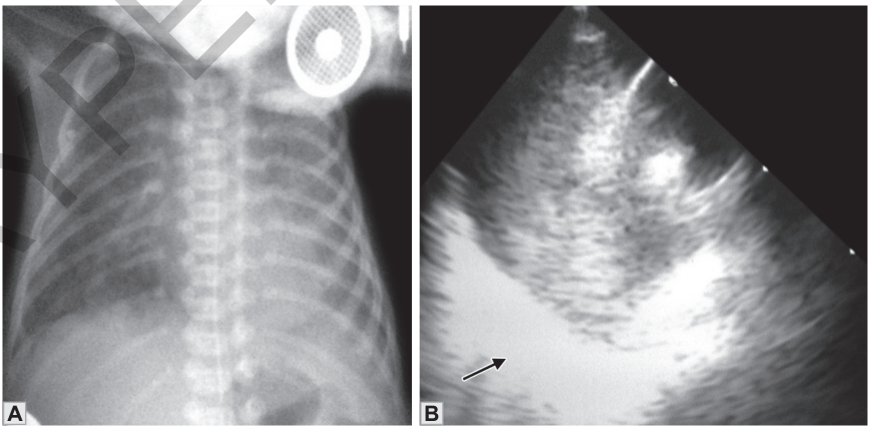
Various pediatric chest pathologies can be evaluated using USG.

Lung

- USG can be a helpful modality in various lung pathologies.
- Lung USG is performed in a supine, lateral, or prone position in neonates.
- Each hemithorax is divided into anterior, lateral, and posterior regions by the anterior and posterior axillary lines; longitudinal and transverse scans are performed in all areas.[1]
- For the relatively thinner chest walls and smaller thoraces in neonates, a high-frequency linear probe is preferred.

Neonatal Point-of-Care USG

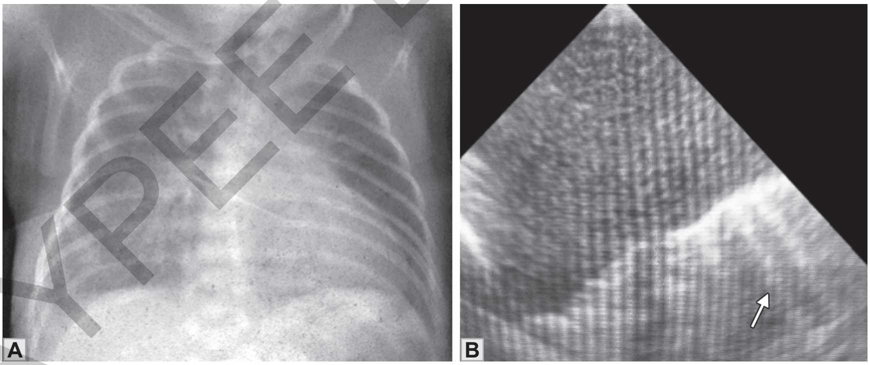
- *Respiratory distress syndrome (RDS):*
    - USG is being utilized as an alternative to radiographs for RDS.
    - Lung consolidations with air bronchograms are the most common USG manifestation of RDS.
    - Few characteristics of consolidations in RDS are more often in posterior part of lungs, subpleural in mild patients with deeper involvement in severe cases, and clear boundary with surrounding lung tissue.
    - Compact, widespread, symmetrical B-lines in bilateral lungs—analogous to "white lung" seen on chest radiographs
    - Thickened, irregular pleural line
    - Absent liver mirror image on subcostal view; replaced by dense B-lines **(Figs. 3A and B)**

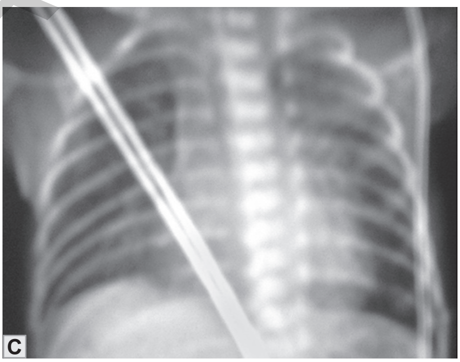


FIGS. 3A AND B: Preterm neonate with respiratory distress syndrome: (A) granular increased density in bilateral lung fields and (B) dense echogenic retrodiaphragmatic shadow (arrow).

- *Grading of RDS on USG*:[2]
  - Mild RDS, "ground glass sign", mild lung consolidation without air bronchogram
  - Moderate RDS, consolidation in some lung zones with "snowflake sign", punctate patchy air bronchogram in a consolidation
  - Severe RDS—consolidation with snowflake sign affecting all lung zones or with complications (hemorrhage, pneumothorax, persistent pulmonary hypertension, and large atelectasis)
- *Follow-up of RDS on USG*:[3]
  - USG can detect improvement in lung findings (consolidations and B-lines) after surfactant therapy.
  - Transition from consolidation to interstitial edema (coalesced B-lines) to normal lung USG pattern can be seen.
  - USG can also help in screening of neonates requiring repeat surfactant or more invasive therapies.

- *Transient tachypnea of newborn (TTN)*:
  - Double lung point—more compact B-lines in inferior lung fields
  - B-lines resolve by day 2–3 coinciding with clinical improvement **(Figs. 4A to C)**.
  - Normal pleural line
  - Associated unilateral or bilateral pleural effusion
  - Differentiating features between RDS and TTN on USG are summarized in **Table 3**.





FIGS. 4A TO C: Term neonate with transient tachypnea of the newborn: (A) right lower zone radiopacity with air bronchograms; (B) multiple B lines (arrow); and (C) complete clearing of lung opacity on 48-hour follow-up radiograph.

TABLE 3: Differentiating features of RDS versus TTN on chest USG.

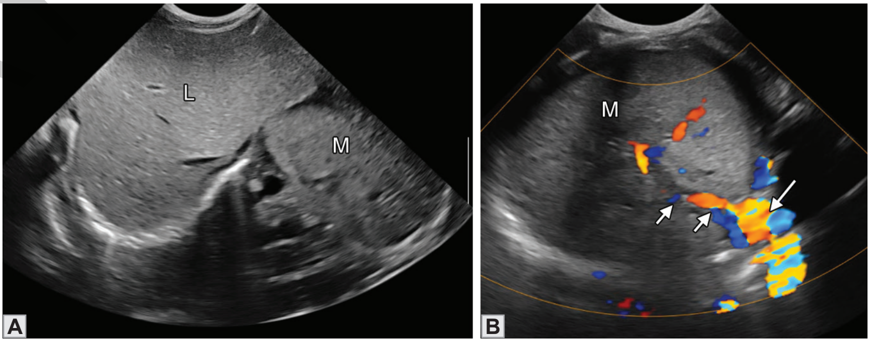
	RDS	TTN
Presentation	Preterm baby with respiratory distress soon after birth	Term baby with respiratory distress; associated with cesarean delivery or maternal diabetes
B-lines	Bilateral diffusely symmetric confluent B-lines	More compact B-lines in inferior lung fields – "double lung point"
Evolution of B-lines	Gradual reduction in number after surfactant therapy	Spontaneous resolution by day 2–3
Pleural line	Thick and irregular	Normal
Consolidation	May be seen	Absent

(RDS: respiratory distress syndrome; TTN: transient tachypnea of newborn; USG: ultrasonography)

- *Other pathologies*:
  - Meconium aspiration syndrome—lung USG can illustrate involvement of lung parenchyma by depicting B-lines indicating presence of interstitial fluid along with associated consolidation.
  - Pulmonary hemorrhage also shows condensed B-lines similar to findings in RDS.

Congenital Lung Lesions

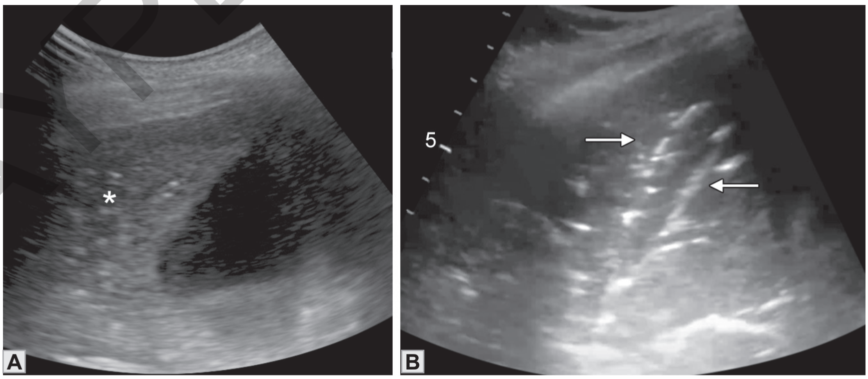
- Most common antenatally detected lung abnormalities include congenital pulmonary airway malformation (CPAM) and pulmonary sequestration.
- A postnatal CXR is must before doing USG examination in such cases.
- Both CPAM and sequestration may be seen as echogenic mass with cystic areas or homogeneous solid mass on USG.
- Anomalous vessel arising from aorta supplying the lung lesion confirms the diagnosis of pulmonary sequestration **(Figs. 5A and B)**.
- *Caveat:* Hybrid lesion can show components of both CPAM and sequestration.



FIGS. 5A AND B: Pulmonary sequestration: (A) echogenic lesion (M) in left lower lobe (L–Liver) and (B) anomalous arterial supply (short arrows) to the lesion from aorta (long arrow) on color Doppler.

Consolidation

- Consolidated airless lung simulates appearance of liver—“hepatization” **(Fig. 6A)**.
- Residual air within the bronchi is seen as branching echogenic foci, “sonographic air bronchogram”, usually show movement with respiration—“dynamic air bronchogram” **(Fig. 6B)**.
- Fluid may replace the air within the bronchi—“fluid bronchogram”.
- The echogenic pleural line is seen broken into fragments at the area of subpleural consolidation—“shred sign” **(Fig. 6C)**.
- B-lines can be seen along the margin of consolidation. B-lines are vertical (perpendicular) echogenic lines which erase A-lines and extend till the edge of screen **(Fig. 6D)**.
- Consolidated lung shows normal “tree-like branching vascularity” as compared to abnormally oriented vessels in a mass **(Fig. 6E)**.
- USG is helpful for follow-up of pediatric patients with consolidation and monitoring of complications including formation of lung abscess or areas of breakdown in acute necrotizing pneumonia.
- Underlying congenital/acquired cysts (such as hydatid cyst or duplication cyst) can present as nonresolving/recurrent pneumonia. If the consolidation has an area of contact with the lateral thoracic wall, thoracic USG can diagnose the underlying lesion and demarcate the consolidation from the lesion.
- USG can help in characterizing the nature of an area of opacity on a CXR by differentiating among consolidation, mass, and atelectasis. The differentiating features on USG are given in **Table 4**.
- In a child with respiratory distress presenting with opaque hemithorax on CXR, USG can help in differentiating among pulmonary, pleural, and mediastinal pathologies and their characterization.



FIGS. 6A TO E: *Continued*

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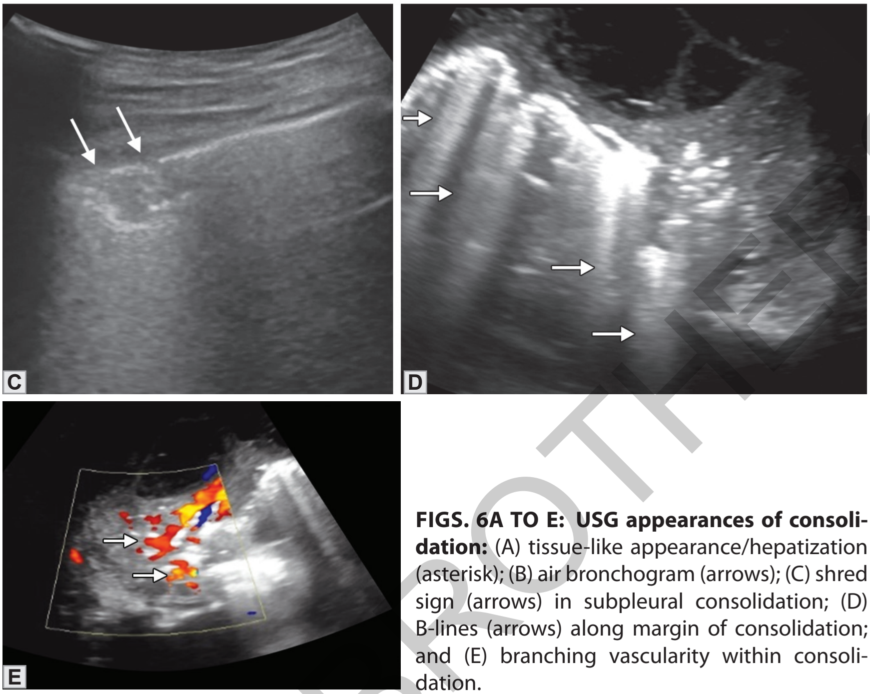


FIGS. 6A TO E: USG appearances of consolidation: (A) tissue-like appearance/hepatization (asterisk); (B) air bronchogram (arrows); (C) shred sign (arrows) in subpleural consolidation; (D) B-lines (arrows) along margin of consolidation; and (E) branching vascularity within consolidation.

TABLE 4: Differentials of pulmonary consolidation.

Imaging features	Consolidation	Mass lesion (neoplasm)	Collapse
Dynamic air bronchogram	Present	Absent	Absent in obstructive collapse
Fluid bronchogram	May be seen	Absent	Seen in obstructive collapse
Pulmonary vessels on color Doppler	Normal distribution and branching	Abnormal orientation, may be reduced or increased	Crowded

Lung Neoplasms

- Pediatric lung neoplasms are rare; but mostly malignant.
- Important differentials in infants include pleuropulmonary blastoma and infantile fibrosarcoma; and in older children include inflammatory myofibroblastic tumors, carcinoids, and respiratory papillomatosis.
- Role of USG is limited to peripheral lung masses for distinction from adjoining consolidation and differentiation of cystic versus solid component.

Mediastinum

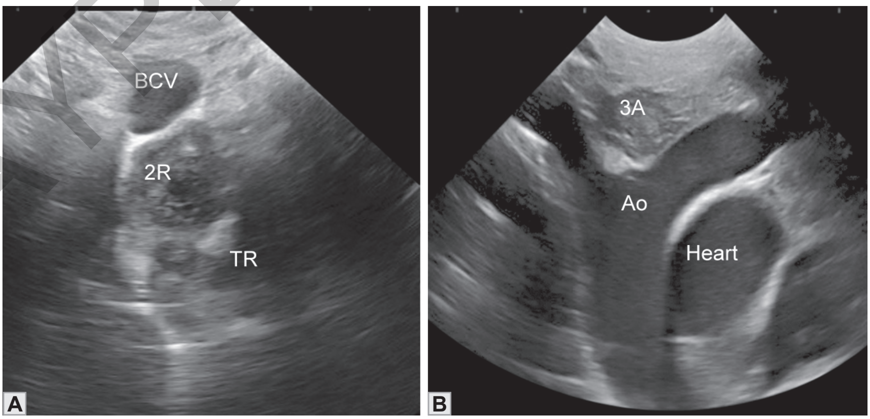
Various mediastinal structures and pathologies can be well evaluated on USG.

Normal and Abnormal Thymus

- Normally located in superior mediastinum anterior to the great vessels
- Due to its variable shape and size, thymus can mimic a mediastinal or lung mass on a CXR.
- Characteristic "starry-sky" appearance (hypoechoic with hyperechoic specks) helps in identification of thymic tissue in ectopic location (most commonly neck).
- Normal thymus does not exert any mass effect on adjacent structures and does not show any calcification or necrosis—any of these features are suspicious for pathologies such as lymphoproliferative infiltration or thymic neoplasms.

Mediastinal Lymph Nodes

- Assessment of mediastinal nodes is a relatively new domain of thoracic ultrasound.
- For assessment of right paratracheal and left paratracheal nodes, suprasternal approach using an intracavitary probe and parasternal approaches using small footprint linear probe can be used **(Fig. 7A)**.
- For the prevascular and subcarinal nodes, suprasternal notch approach with an intracavitary/microconvex probe is the most suitable **(Fig. 7B)**.
- Lower mediastinal and posterior mediastinal nodes are usually not visualized using ultrasound.
- Mediastinal nodal enlargement can be defined according to predefined size criteria: >15 mm short axis if single; >10 mm short axis if multiple.[4]



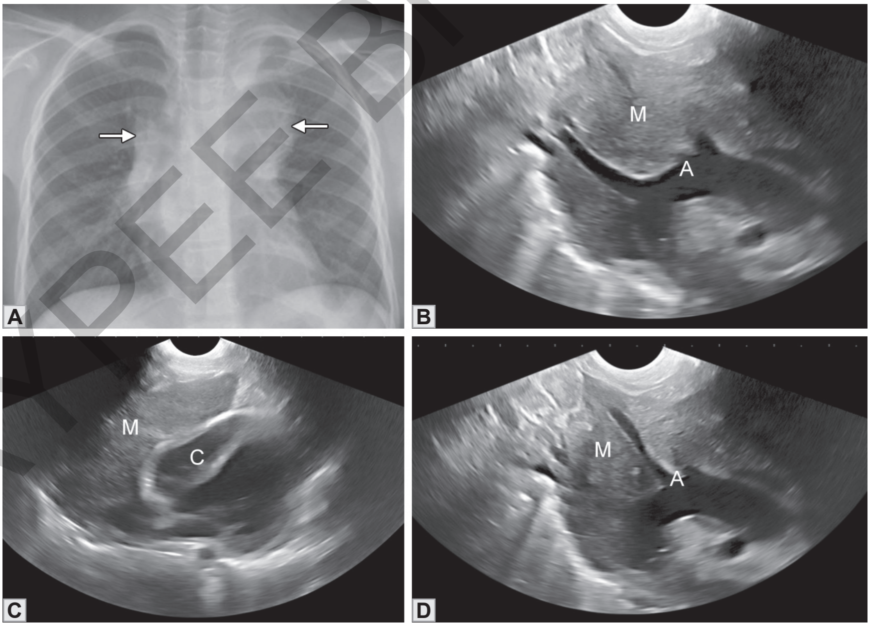
FIGS. 7A AND B: Mediastinal lymphadenopathy: (A) station 2R (anterior and to the right of trachea) lymph node and (B) station 3A (prevascular) lymph node.

(Ao: aorta; BCV: brachiocephalic vein; TR: trachea)

- Necrosis on USG is seen as hypoechoic/anechoic central area in a node.
- Calcifications can be seen as punctate or coarse hyperechoic foci.
- Nonvisualization of the echogenic fat between two nodes signifies matting of lymph nodes, giving a multilocular appearance.

Mediastinal Masses

- USG can determine cystic or solid nature of the mass as well as depict internal areas of vascularity, cavitation, necrosis, or calcifications.
- Cystic mediastinal lesions include developmental cysts (foregut duplication and neurenteric cysts) and venolymphatic malformations.
- Unlike in adults, developmental cysts comprise a significant proportion of mediastinal masses in childhood—high-resolution USG transducer can detect the diagnostic "gut signature" in a duplication cyst.
- Germ cell tumors are usually seen as heterogeneous anterior mediastinal masses with variable presence of calcifications.
- Neurogenic tumors are seen as solid lobulated hypoechoic posterior mediastinal masses with presence of calcific flecks within.
- Mediastinal lymphomas usually appear as homogeneous solid hypoechoic mediastinal masses encasing the mediastinal structures **(Figs. 8A to D)**.



FIGS. 8A TO D: Mediastinal lymphoma: (A) lobulated mediastinal mass (arrows) extending to both sides of midline; (B to D) hypoechoic solid mass (M) lesion encasing the aortic arch (A) and having a broad area of contact with cardiac margins (C).

Chest Wall

- Most nontender palpable chest wall abnormalities in asymptomatic children are due to developmental variants—prominent rib convexities, bifid ribs, asymmetrical costal cartilage, or anterior angulation of xiphoid process—USG can obviate need for further imaging in these cases.
- USG can help in localization of the chest wall lesion and solid versus cystic characterization.

Vascular Malformations

- *Venous malformation*: Compressible anechoic cystic spaces with venous flow on Doppler; phleboliths ±
- *Arteriovenous malformation*: Tangle of vessels (nidus) showing arterial low-resistance blood flow with prominent feeding arteries and draining veins
- Magnetic resonance imaging is better for characterization of extent of the lesion.

Neoplasms

- Benign tumors are more common than malignant.
- *Hemangioma*: Benign vascular tumor; usually hyperechoic with high internal vessel density in proliferative phase.
- Most malignant chest wall tumors are osseous in origin.
- Most common malignant pediatric chest wall masses include small round cell tumors including Ewing sarcoma, rhabdomyosarcoma, and lymphoma.
- USG can depict solid nature of the mass, epicenter (intra- or extrathoracic) of the mass and underlying rib destruction.
- USG-guided biopsy can be done to reach a histopathological diagnosis.

Infections

- Soft-tissue or subperiosteal abscesses can be well-depicted on USG.
- *Empyema necessitans*: Extension of pleural empyema into chest wall; most commonly tubercular in etiology.

Diaphragm

- Diaphragmatic paralysis secondary to phrenic nerve injury is poorly tolerated by infants—early detection is important.
- Subxiphoid approach allows side-by-side comparison of both hemidiaphragms.
- M-mode provides quantitative estimate about diaphragmatic excursion **(Fig. 9)**; <4 mm excursion of one hemidiaphragm or $>50\%$ difference in excursion between hemidiaphragms signifies diaphragmatic dysfunction.[5]
- USG can also show juxtadiaphragmatic masses in chest or abdomen that could potentially be responsible for diaphragmatic dysfunction.

Imaging of PEDIATRIC CHEST

Salient Features

- This book provides a comprehensive overview of various aspects of chest disorders in children, including infections, pediatric interstitial lung diseases, congenital vascular anomalies, and lung and mediastinal tumors.
- It provides structured reporting formats for common disorders, with explanations for their application, aiming to simplify comprehension and improve reporting standards for all readers.
- The book has numerous high-quality illustrations and detailed flowcharts as part of a "pattern-based imaging approach" for enhanced comprehension.
- It is updated with recent advancements in interventional radiology and genetic and molecular testing.
- The book is beneficial to radiologists, pediatricians, residents, and trainees.

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