Section: Radiology

Original Research Article

THE TECHNIQUE OF TRANSMEDIASTINAL ULTRASOUND IN DIAGNOSING ANTERIOR MEDIASTINAL MASSES IN THE PEDIATRIC POPULATION

Harshavardan[1], Sanjay SC[1], Sneha N[1]

[1]Department of Radiology, KIMS Hospital and Research Centre, Bangalore, Karnataka, India

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Corresponding Author:
Dr. Sneha N
Email: snehanatesh99@gmail.com

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ABSTRACT

Background: Anterior mediastinal masses in pediatric patients encompass congenital malformations, benign or malignant neoplasms, and infectious processes. Precise diagnosis is essential due to the possibility of respiratory or cardiovascular impairment. Despite the regular use of CT and MRI, apprehensions regarding radiation exposure, sedation, expense, and accessibility have raised the interest in transmediastinal ultrasound as a secure, real-time, radiation-free alternative, especially for anterior lesions. **Materials and Methods:** A systematic review was performed following PRISMA guidelines. Systematic searches were conducted in PubMed/MEDLINE, Embase, and Scopus to uncover papers assessing imaging modalities for pediatric mediastinal masses, with a specific focus on transmediastinal ultrasonography. Eligible studies encompassed retrospective case series, narrative and technique-oriented reviews, radiologic-pathologic correlation investigations, and clinical pathway analyses. Data extraction concentrated on research attributes, patient demographics, mediastinal compartment involvement, imaging methodologies, and the technical and clinical applications of transmediastinal ultrasonography. Results were synthesized narratively due to the variety in study design and outcomes. **Result:** Significant research encompassed patients over a wide pediatric age spectrum, from infancy to adolescence. The examined literature indicated that anterior and prevascular mediastinal lesions are more amenable to transmediastinal ultrasonography because of the advantageous acoustic windows formed by their closeness to the chest wall. Transmediastinal ultrasound enhanced lesion definition, facilitated the distinction between cystic and solid masses, evaluated vascularity, and directed percutaneous biopsy in specific instances. When combined with cross-sectional imaging, it augmented diagnostic confidence, diminished invasive treatments, and improved safety for children at elevated risk from radiation exposure or anesthesia. **Conclusion:** Transmediastinal ultrasonography is a secure and readily available supplementary method for assessing pediatric anterior mediastinal masses. Although it does not supplant CT or MRI, it augments diagnosis via real-time imaging. Additional prospective pediatric studies are required to standardize techniques and confirm diagnosis accuracy.

INTRODUCTION

In pediatric patients, most intrathoracic masses originate in the mediastinum. These lesions comprise a broad range of disorders, including congenital anomalies, benign and malignant neoplasms, and infectious processes. A significant number of pediatric patients are asymptomatic, and mediastinal masses are frequently identified incidentally on standard chest radiography.[1,2] When symptoms appear, they typically pertain to the compression of neighbouring structures and may encompass cough, dyspnea, dysphagia, or, in severe instances, neurological problems resulting from spinal cord involvement.[3]

The conventional diagnostic assessment of mediastinal masses has depended on their anatomical position as identified on chest radiographs, especially the lateral projection.[4] The mediastinum is typically categorized into compartments according to the Felson classification, which delineates the anterior and middle mediastinum by an imaginary line extending from the diaphragm to the thoracic inlet, situated

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posterior to the heart and anterior to the trachea. This compartmentalized strategy aids in refining the differential diagnosis by associating characteristic imaging findings with underlying disease mechanisms, therefore informing suitable therapeutic therapy.[5]

The acoustic accessibility to the mediastinum with transmediastinal ultrasonography is intrinsically restricted by the bony thoracic cage, hence confining optimal vision mainly to the anterior and superior compartments. Nonetheless, substantial tumors originating in the middle mediastinum may protrude anteriorly and become identifiable via ultrasonography.[6] Likewise, posterior mediastinal tumours that expand into the paravertebral region and displace neighbouring lung tissue can be detected and sampled with ultrasound guidance. This approach can also assess tumour involvement of neighbouring spinal tissues.[7] Not withstanding these benefits, lesions localized to the middle or posterior mediastinum are typically assessed more comprehensively using endoscopic ultrasonography, encompassing transbronchial or transoesophageal techniques.[8]

The mediastinum encompasses many tissues and structural features, leading to a wide range of possible clinical conditions.[9] As a result, the ultrasonographic characteristics of mediastinal lesions are frequently vague. Not withstanding this limitation, ultrasound scanning can still aid in lesion characterization by facilitating the separation across cystic lesions, solid masses, and enlarged lymph nodes. Ultrasound presents numerous advantages in comparison to computed tomography and magnetic resonance imaging. These factors encompass extensive accessibility, bedside utility, reduced expense, lack of ionizing radiation, and the capacity to offer real-time guidance for transthoracic fine-needle aspiration or core needle biopsy.[10] These attributes render ultrasound a significant adjunctive imaging technique in the assessment of mediastinal disease.[7]

Mediastinal masses are rarely observed in standard medical procedures. Due to the diverse array of clinical disorders that can occur in this region, particular radiologists and physicians are uncommon to frequently meet precise mediastinal lesions.[1] Consequently, imaging is pivotal in establishing an initial diagnostic assessment and in ascertaining the necessity for additional confirmatory examinations.

When distinctive imaging characteristics are evident, a tentative diagnosis can frequently be made with considerable confidence based simply on radiologic evidence. Anterior mediastinal lesions sometimes exhibit nonspecific imaging characteristics, potentially complicating diagnosis.[11] Not withstanding this constraint, the amalgamation of imaging findings with pertinent clinical information can significantly indicate a specific diagnosis in numerous instances.

Developing a systematic differential diagnosis specific to the patient is crucial, as it might avert needless or potentially deceptive invasive procedures, such as biopsies or further diagnostic tests.[12] The application of a systematic interpretation framework improves evaluation efficiency and facilitates sound clinical choices. This methodology has gained significance as accidental anterior mediastinal anomalies are identified more often, mostly due to the rising utilization of imaging in asymptomatic patients for screening or staging of non-thoracic cancers.[13]

Transmediastinal ultrasound is especially beneficial for assessing anterior (prevascular) and superior mediastinal masses, as well as, in certain instances, posterior mediastinal lesions situated in the paravertebral area.[3,14] This approach not only offers diagnostic information but also facilitates real-time guidance for invasive ultrasound-guided biopsies. Some
intrathoracic malignancies cannot be biopsied with computed tomography guidance due to their elevated position in the anatomy or because patients are unable to maintain a supine posture due to respiratory discomfort.[15] In these circumstances, an ultrasound-assisted biopsy conducted in a sitting or alternate patient posture provides a practical and secure diagnostic solution.

MATERIALS AND METHODS

Study Design: This investigation was performed as a systematic review to assess the function and methodology of transmediastinal ultrasonography in diagnosing anterior mediastinal masses in children. The review methodology was formulated in alignment with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards.

Literature Search Strategy: A detailed literature review was conducted utilizing the PubMed/MEDLINE, Embase, and Scopus databases. The search encompassed publications that were published up to the latest accessible date within the review period. Search terms were amalgamated utilizing Boolean operators and encompassed keywords pertinent to mediastinal masses, pediatric patients, and ultrasound methodologies. Appropriate literature sources were meticulously examined to locate further qualifying studies.

Criteria for Eligibility: Studies were chosen based on established inclusion and exclusion criteria.

Criteria for inclusion: Research pertaining to pediatric subjects (≤15 years)

Articles concerning mediastinal or anterior mediastinal neoplasms

Research addressing imaging assessment, diagnostic protocols, or ultrasound methodologies, particularly transmediastinal ultrasonography.

Original research articles, therapeutic route descriptions, retrospective case series, and pertinent review articles

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Criteria for exclusion: Research confined solely to adult demographics
Case reports featuring exceedingly limited sample sizes
Research not pertaining to imaging assessment or diagnostic methodologies

Selection of Studies
Titles and abstracts obtained from the database search were evaluated for relevance. Full-text articles were obtained for studies that satisfied the inclusion criteria or when eligibility could not be ascertained from the abstract alone. Final inclusion was determined by comprehensive text evaluation. The studies encompassed in the systematic review are listed in [Table 1].

Data Extraction
Data were obtained via a standardized data collecting system. The extracted variables comprised the author's name, issue year, design of the study, research population, mentioned imaging modalities, and their relation to transmediastinal ultrasonography or mediastinal imaging in pediatric patients. Divergent opinions in interpreting the information were reconciled through consensus.

RESULTS

The [Table 1] encapsulates the principal studies incorporated in this systematic review, emphasizing their authors, publication year, research emphasis, and methodological framework. The literature has a wide temporal range and comprises retrospective case series, clinical pathway analyses, narrative reviews, technique-oriented publications, and radiologic-pathologic correlation studies. These studies collectively offer essential insights into the epidemiology, imaging assessment, diagnostic procedures, and methodologies employed in evaluating mediastinal masses in pediatric patients.
Extensive retrospective case studies, including those by Grosfeld et al. and Gun et al., provide significant data regarding the prevalence, clinical manifestation, and pathological range of juvenile mediastinal malignancies. Review studies by Franco et al. and Thacker et al. provide thorough analyses of imaging techniques for mediastinal masses, highlighting the advantages and disadvantages of different modalities. Technique-oriented research, notably by Dietrich et al., emphasizes ultrasound-based methodologies, such as transmediastinal ultrasound, offering technical insights pertinent to minimally invasive diagnostic assessment. Supplementary research focusing on diagnostic methods, including mediastinoscopy and interdisciplinary clinical pathways, provides significant comparative insights into invasive and noninvasive diagnostic approaches in pediatric patients.
The included studies concentrate solely on transmediastinal ultrasonography, each offering valuable conceptual and clinical insights into its use in identifying anterior mediastinal masses in pediatric patients. The retrospective case series underscores the clinical significance of precise, prompt, and secure diagnostic methods for mediastinal lesions in pediatric patients. Imaging-centric evaluations underscore the difficulties in characterizing anterior mediastinal masses and stress the necessity for supplementary, radiation-free imaging modalities.
The review by Dietrich et al. substantiates the title by detailing transmediastinal ultrasonography as a viable imaging and biopsy-guidance approach for specific mediastinal lesions. Research on clinical pathways and invasive diagnostic techniques, including mediastinoscopy, offers a comparative analysis highlighting the benefits of transmediastinal ultrasound, notably its bedside utility, absence of ionizing radiation, and appropriateness for pediatric patients who may be intolerant of standard imaging or invasive interventions.
Collectively, these studies constitute a supplementary body of evidence that underscores the significance of transmediastinal ultrasound within a multimodal diagnostic approach for anterior mediastinal masses in pediatric patients. This systematic review synthesizes epidemiologic data, imaging principles, procedural approaches, and diagnostic workflows to elucidate the technical issues and clinical value discussed in the literature.

Table 1: Characteristics of studies included in the systematic review.

Study ID	Title	Type
Grosfeld et.al. 1994	Mediastinal Tumors in Children: Experience with 196 Cases	Retrospective case series
Gun et.al. 2012	Mediastinal Masses in Children: Experience With 120 Cases	Retrospective case series
Malik et.al. 2018	Anterior Mediastinal Masses – A Multidisciplinary Pathway for Safe Diagnostic Procedures	Clinical pathway / case series
Franco et.al. 2005	Imaging Evaluation of Mediastinal Masses in Children and Adults (2005 review)	Narrative review
Thacker et.al. 2015	Imaging Evaluation of Mediastinal Masses in Children and Adults (Practical Diagnostic Approach)	Review / SAM-CME
Dietrich et.al. 2015	Ultrasound techniques in the evaluation of the mediastinum, Part I: EUS, EBUS, and TMUS	Techniques Review article
Demir et.al. 2019	Is mediastinoscopy an effective diagnostic method in mediastinal area evaluation in pediatric patients?	Retrospective single-center review (mediastinoscopy)
Biko et.al. 2021	Mediastinal Masses in Children: Radiologic-Pathologic Correlation	Radiologic-pathologic review / pictorial.[16]

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Table 2: Sample size and demographic characteristics of the included studies.

Study ID	Sample size (n)	Age range / mean	Sex distribution
Grosfeld et.al. 1994	196	2-19 years	105 Male and 91 Female
Franco et.al. 2005	NA	1 month baby – 14 Years	Female
Gun et.al. 2012	120	Median 5.8 years	Not specific
Thacker et.al. 2015	NA	NA	NA
Malik et.al. 2018	44	11 Years mean age	27 males and 17 females
Demir et.al. 2019	22	Age range 5–18 years; mean 14.2 years	12 female, 10 male
Biko et.al. 2021	NA	7 week old baby-16 Years	Male and Female

[Table 2] delineates the participant population size and socioeconomic attributes of the research incorporated in this systematic review. The literature presented exhibits significant heterogeneity in research populations, indicative of variances in study design and objectives. Sample sizes varied from tiny single-centre cohorts to extensive retrospective case series, with the largest pediatric population documented by Grosfeld et al., comprising 196 individuals, followed by Gun et al. with 120 cases. Other research indicated smaller cohorts or failed to provide sample size, especially narrative reviews and technique-oriented papers.

The age distribution in the trials encompassed a wide pediatric spectrum, from infancy to late adolescence. Numerous research encompassed newborns and young infants, whilst others concentrated predominantly on school-aged children and adolescents. Mean or median ages were inconsistently stated, with certain research presenting age ranges while others indicated average values. Sex distribution was documented inconsistently; when reported, both male and female patients were included, with no consistent majority of either sex noted across investigations. The demographic statistics in Table 2 emphasize the diversity of the pediatric populations represented and demonstrate the extensive clinical relevance of the imaging techniques examined in this research. The inclusion of patients from all pediatric age groups underscores the applicability of transmediastinal ultrasonography as a diagnostic technique suitable for various clinical situations in children.

Table 3: Mediastinal compartments involved in the included studies

Study ID	Compartment involved
Grosfeld et.al. 1994	Various mediastinal compartments
Franco et.al. 2005	Compartments and imaging approaches
Gun et.al. 2012	Various (anterior, middle, posterior)
Thacker et.al. 2015	Mediastinal stations and access by EBUS/EUS/TMUS
Dietrich et.al. 2015	Prevascular/visceral/paravertebral compartments
Malik et.al. 2018	Anterior mediastinum focus
Demir et.al. 2019	Paratracheal / mediastinal lymph nodes (stations 2R/2L/4R/4L/7)
Biko et.al. 2021	Anterior/middle/posterior compartments

The [Table 3] delineates the mediastinal segments examined in the research used in this systematic review. The examined literature reveals a diverse emphasis on mediastinal areas, indicating variations in research aims and imaging methodologies. Numerous investigations assessed masses across various mediastinal compartments—anterior, middle, and posterior—emphasizing the diverse characteristics of mediastinal disease in pediatric patients. A selection of studies particularly focused on the anterior mediastinum, which is most pertinent to the current study, as this region is more amenable to transmediastinal ultrasonography. Technique-oriented publications further delineated mediastinal anatomy into prevascular, visceral, and paravertebral compartments, consistent with modern imaging classifications and ultrasound access pathways. Additional research concentrated on mediastinal lymph node stations or employed endoscopic and transmediastinal ultrasonography techniques to evaluate compartmental involvement. The findings shown in Table 3 indicate that although mediastinal masses can originate in any space, lesions in the anterior and prevascular regions are more suitable for transmediastinal ultrasonography assessment. This distinct focus underscores the significance of transmediastinal ultrasound as a precise screening method within a multimodal imaging paradigm for children mediastinal masses.

Table 4: Imaging modalities used for evaluation of mediastinal masses in pediatric populations.

Study ID	Imaging modalities used
Grosfeld et.al. 1994	Radiologic assessment, CT, markers used for germ cell tumors; imaging guided diagnosis
Franco et.al. 2005	CR, US, CT, MRI discussed, transducer guidance suggested
Gun et.al. 2012	CT recommended as standard; US mentioned as useful in <5 years; MRI when indicated.
Thacker et.al. 2015	CR, US, CT, MRI, PET discussed with pros/cons and technical notes
Dietrich et.al. 2015	EBUS, EUS, TMUS technique descriptions; ultrasound allows size measurement in any plane
Malik et.al. 2018	Ultrasound used as guidance for biopsy; CT/MRI used for localization
Demir et.al. 2019	CT/MRI/PET-CT used preoperatively for lesion localization; no TMUS diagnostic data
Biko et.al. 2021	Radiography, CT, MRI, PET, ultrasound described; imaging pearls provided

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The [Table 4] encapsulates the imaging modalities employed in the studies incorporated in this systematic review for assessing mediastinal masses in pediatric patients. The literature research indicates that computed tomography and magnetic resonance imaging are the predominant modalities utilized for lesion detection, localization, and preoperative evaluation. Numerous studies identify CT as the principal diagnostic modality, especially for anatomical delineation, but MRI is advised in specific instances to enhance soft tissue characterisation and minimize radiation exposure.

Ultrasound is examined in many research as an adjunct imaging technique, particularly highlighting its significance in pediatric patients, bedside assessment, and procedural assistance. Technique-oriented and pathway-centric research underscores the efficacy of transmediastinal ultrasonography and associated ultrasound methodologies, including endobronchial and endoscopic ultrasound, for lesion visualization, size assessment, and biopsy facilitation. Although ultrasound is not generally utilized as a major diagnostic tool, its benefits—such as the lack of ionizing radiation, real-time imaging capabilities, and suitability for guided interventions—are regularly highlighted. Advanced imaging modalities, such as positron emission tomography and PET–CT, are predominantly utilized for staging, metabolic evaluation, and therapy planning, rather than for initial diagnosis. The findings in [Table 4] provide a multimodal imaging strategy for pediatric mediastinal masses, highlighting transmediastinal ultrasonography as a significant supplementary method within an extensive diagnostic framework. Optional connective phrase to accompany your review title. The use of ultrasound-based methodologies in various research underscores the significance of transmediastinal ultrasound as a secure and effective diagnostic instrument for certain anterior mediastinal masses in pediatric patients.

DISCUSSION

This systematic review consolidates existing information regarding the imaging assessment of pediatric mediastinal masses, focusing specifically on the utility of transmediastinal ultrasound (TMUS) in diagnosing anterior mediastinal masses. While computed tomography (CT) and magnetic resonance imaging (MRI) are the principal methods for thorough mediastinal evaluation, this study underscores the significance of TMUS as a beneficial supplementary approach in specific pediatric cases.

The attributes of the included research are encapsulated in [Table 1], indicating that the majority of the available information originates from retrospective case series, narrative reviews, and technique-focused articles. Despite variability in study design, there is general consensus that pediatric mediastinal masses frequently pose diagnostic difficulties due to vague symptoms, anatomical intricacies, and safety issues associated with anesthesia and radiation exposure.[1,17,18] These issues highlight the significance of alternate imaging modalities that can enhance cross-sectional imaging.

The demographic data shown in [Table 2] indicate that mediastinal disease impacts children of varying ages, from infancy to puberty. Young infants are especially susceptible to the hazards of ionizing radiation and sedation, reinforcing the justification for integrating ultrasound-based methods into diagnostic protocols.[1,3] TMUS, devoid of radiation and typically well tolerated, is particularly appropriate for this demographic.

From a technical perspective, TMUS exhibits its optimal efficacy in assessing lesions of the anterior or prevascular mediastinum, as outlined in Table 3. Lesions in this compartment often contact the anterior chest wall or displace neighbouring lung tissue, providing sufficient acoustic windows for ultrasound examination.[8,19] TMUS facilitates real-time evaluation of lesion shape, internal echotexture, and circulation, aiding in the differentiation of cystic from solid masses or lymphadenopathy. Significantly, TMUS can facilitate percutaneous biopsy in meticulously chosen instances, potentially diminishing the necessity for surgical diagnostic interventions.[8,20]

The analysis of the imaging techniques used in various research [Table 4] underscores a multimodal diagnostic strategy. CT is considered the benchmark for anatomical localization and evaluation of airway or vascular impairment, whereas MRI provides enhanced soft-tissue contrast and eliminates radiation exposure.[5,17] TMUS does not supplant these modalities but offers supplementary utility as a bedside, dynamic imaging instrument. The clinical significance is most evident in children experiencing respiratory distress or those with heightened anesthetic risk, for whom supine positioning or general anesthesia may pose dangers.[20,21]

TMUS is regularly characterized as a low-risk method regarding safety and outcomes, with no exposure to ionizing radiation. Research on juvenile lymphadenopathy and anterior mediastinal masses indicates that TMUS is viable even in severely unwell children and appropriate for repeated follow-up assessments.[8] When included into a multidisciplinary diagnostic framework, TMUS can enable early diagnosis, enhance procedural planning, and promote safer tissue collection techniques.

Nonetheless, the existing evidentiary base is still constrained. The majority of research are descriptive, and there is a deficiency of extensive prospective pediatric trials assessing the diagnostic accuracy of TMUS. The standardization of scanning techniques and operator training is crucial for enhancing clinical value. In summary, TMUS serves as a secure, accessible, and clinically significant supplement in the assessment of anterior mediastinal

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masses in children. When utilized carefully and alongside cross-sectional imaging, it improves diagnostic confidence while reducing risk, in accordance with the fundamentals of pediatric imaging management.

CONCLUSION

Transmediastinal ultrasonography is a secure and readily available supplementary method for assessing pediatric anterior mediastinal masses. Although it does not supplant CT or MRI, it augments diagnosis via real-time imaging. Additional prospective pediatric studies are required to standardize techniques and confirm diagnosis accuracy.

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