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Perinatal Thoracic Mass Lesions: Pre- and Postnatal Imaging

Evan J. Zucker, MD,* Monica Epelman, MD,† and Beverley Newman, BSc, MBBCh, FACR*

Chest masses present a common problem in the perinatal period. Advances in prenatal ultrasound, supplemented by fetal magnetic resonance imaging, now allow early detection and detailed characterization of many thoracic lesions in utero. As such, in asymptomatic infants, assessment with postnatal computed tomography or magnetic resonance imaging can often be delayed for several months until the time at which surgery is being contemplated. Bronchopulmonary malformations comprise most of the thoracic masses encountered in clinical practice. However, a variety of other pathologies can mimic their appearances or produce similar effects such as hypoplasia of a lung or both lungs. Understanding of the key differentiating clinical and imaging features can assist in optimizing prognostication and timely management.

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Introduction

A variety of thoracic masses may be encountered in the perinatal period. Historically, most were detected after birth in symptomatic patients. However, in the modern era of prenatal ultrasound (US) screening, complemented by fetal magnetic resonance imaging (MRI), many chest lesions are now first visualized in utero and are asymptomatic at birth. Bronchopulmonary malformations (BPMs) comprise a substantial proportion of the chest masses encountered. Yet, many other lesions, including primary pulmonary malignancies, nonpulmonary space-occupying masses such as hernias, mediastinal and chest wall abnormalities, and certain syndromes, may resemble BPMs or cause similar sequelae such as pulmonary hypoplasia.[1-3] Knowledge of the pre- and postnatal imaging appearances of these entities helps best inform treatment decisions.

The purpose of this article is to provide an overview of perinatal thoracic mass lesions. Approaches to imaging in the pre- and postnatal period are first reviewed. Next, the clinical and radiologic features of a broad spectrum of chest lesions are discussed. Both pre- and postnatal imaging appearances are elucidated, with an emphasis on findings that allow for precise diagnosis, differentiation among similar entities, and confident management decisions.

*Department of Radiology, Stanford University School of Medicine, Lucile Packard Children's Hospital, Stanford, CA.
†Department of Medical Imaging, Nemours Children's Hospital, Orlando, FL.
Address reprint requests to Evan J. Zucker, MD, Department of Radiology, Stanford University School of Medicine, Lucile Packard Children's Hospital, 725 Welch Rd, Stanford, CA 94305. E-mail: zucker@post.harvard.edu

Prenatal Imaging Assessment

Ultrasound

US is the mainstay for evaluating fetal thoracic masses, most of which can be detected on routine 18- to 20-week scans.[4] Normal fetal lungs have a homogeneous echotexture, slightly greater than that of liver and increasing with gestational age. Focal increased lung echogenicity or cystic change suggests an underlying lesion.[5] Cardiomediastinal shift may be the only clue to an underlying chest mass, and thus it is essential to scrutinize the 4-chamber view during routine second- and third-trimester US. On such scans, the heart should be located in the left anterior quadrant just left of midline and occupy 25%-30% of the chest volume.[5-7] Once a mass has been detected, an attempt should be made to characterize it as macrocystic, microcystic (echogenic), or mixed. Its size, volume, location, and blood supply should also be documented. Associated features such as cardiomediastinal shift, ascites, pleural effusion, or other signs of hydrops fetalis should also be reported.[8] Use of 3-dimensional (3D) and 4D US permits estimation of residual fetal lung volumes.[5]

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After a thoracic lesion is identified, follow-up US is typically obtained every 4 weeks to assess for changes in size and complications. The scanning interval is shortened to at least weekly if hydrops or signs of obstruction arise. Hydrops portends a very high risk of fetal or neonatal demise. The presence of ≥ 3 of the following 4 criteria also predicts a poor prognosis: volume mass-to-head circumference ratio >1.6, transverse mass diameter-to-transverse chest diameter ratio >0.56 measured on an axial view including the 4-chamber heart, large lesion size ($>50\%$ of total fetal lung volume on the affected side), and significant mass effect as indicated by mediastinal shift, ipsilateral hemidiaphragm inversion, midline or intercostal lung herniation, or marked hypoplasia of the remaining lung.[9]

Magnetic Resonance Imaging

Fetal MRI complements US in the assessment of prenatal chest masses.[3] Although its added clinical value for thoracic indications is still debated, MRI has shown increasing benefit as the technology has matured over the past 2 decades.[10,11] In a widely reported series of fetal thoracic abnormalities, MRI compared with US offered additional information in 38% of cases and changed management in 8% of cases.[12,13] In general, the goals of fetal chest MRI are to further evaluate a lesion's morphology and its effects on the normal lung, more accurately estimate the volumes of the normal and abnormal lung, and better inform management decisions (such as, pregnancy termination, early delivery, and fetal intervention, eg, thoracoamniotic shunting).[9] MRI can be particularly useful during the third trimester, when many solid lesions become imperceptible by US.[3]

Fetal MRI has traditionally been performed at 1.5 T. However, recent advances permit imaging at 3 T, thereby capitalizing on the higher signal-to-noise ratio.[11,14] A typical protocol includes both T2-weighted and T1-weighted sequences obtained in various planes through the fetal axis. T2-weighted sequences provide greater tissue contrast and may include single-shot fast spin-echo or half-Fourier acquisition single-shot turbo spin-echo as well as balanced sequences such as fast imaging with steady-state acquisition or balanced fast field-echo. Vessels also appear hyperintense on gradient-echo images, thus permitting fetal vascular assessment, as gadolinium-based contrast is contraindicated in pregnancy.[15,16] T1-weighted sequences provide less robust tissue contrast. Nevertheless, they are useful in delineating such structures as meconium-containing bowel and liver, both of which appear T1 hyperintense and might be contained in a congenital diaphragmatic hernia (CDH), for example (detailed later). Thyroid tissue, blood products, calcification, and fat content also are usually T1 hyperintense.[15] Diffusion-weighted imaging and MR spectroscopy are used by some centers to evaluate fetal lung maturity but remain investigational.[15,17]

Normally, the fetal trachea, bronchi, and lungs are T2 hyperintense relative to the chest wall musculature. With increasing gestational age, the lungs mature and produce a greater amount of alveolar fluid. Thus, they appear increasingly T2 hyperintense relative to liver.[15,18] In general, many prenatal pulmonary lesions are T2 hyperintense relative to normal lung during the second trimester but may become isointense or hypointense during the third trimester.[3,13]

Fetal lung volumes can be readily calculated by drawing a region of interest around the visible pulmonary parenchyma for each slice, excluding lesions and mediastinal structures, and multiplying the measured area by the slice thickness and interslice gap. These numbers are then summed to produce a volume.[11,17] However, reference values for normal lung volumes as a function of gestational age remain controversial. Even the most widely quoted data by Rypens et al show considerable overlap between normal and pathologic volume measurements.[11,17,19,20] Some advocate a correction factor based on such measurements as liver volume, fetal body volume, and sonographic fetal weight and head circumference.[17] Others suggest calculating a "percent predicted lung volume (PPLV)," equal to the "observed" lung volume by region-of-interest measurement divided by the "predicted" lung volume.[11] Predicted lung volume equals $(0.47 \times \text{liver volume}) + (0.76 \times \text{biparietal diameter}) - (0.39 \times \text{femur length}) - 18.9$.[17] Such calculations may provide greater prognostic value than uncorrected measurements, although this remains an area of active investigation.[11]

Postnatal Imaging Assessment

Radiography

Radiographs are typically the first postnatal imaging modality for evaluation of perinatal thoracic lesions, even those that are detected prenatally and asymptomatic. Posterioanterior and lateral chest radiographs are preferred. Appearances vary depending on the lesion and may include a focal consolidation, mass or hyperlucency, airway or vascular abnormalities, thoracic asymmetry or nonchest findings such as vertebral segmentation anomalies. Even if an exact diagnosis cannot be made, radiographs nonetheless assist in guiding further imaging workup.[6,7]

Ultrasound

Readily available and radiation-free US is not always considered but is often useful especially in the early postnatal imaging assessment of a thoracic mass. Sonographic visualization of nonaerated intrathoracic structures, especially those abutting the mediastinum, diaphragm, or chest wall, is excellent in the neonate and infant, unlike in the older child or adult. Scans are typically obtained with a high-frequency 10-15 MHz linear transducer in at least 2 orthogonal planes, using transsternal, parasternal, intercostal, and subdiaphragmatic windows. Doppler evaluation should be performed to assist in identifying anomalous vasculature.[6,7]

Computed Tomography

Multidetector computed tomography (MDCT), with multiplanar reformats, 3D reconstructions, and CT angiographic technique, has revolutionized the evaluation of chest masses in