

**American College of Radiology
ACR Appropriateness Criteria®
Imaging of Mediastinal Masses**

Variant 1: **Clinically suspected mediastinal mass. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☼
MRI chest without and with IV contrast	Usually Appropriate	○
MRI chest without IV contrast	Usually Appropriate	○
CT chest with IV contrast	Usually Appropriate	☼☼☼
CT chest without IV contrast	Usually Appropriate	☼☼☼
US chest	Usually Not Appropriate	○
Image-guided transthoracic needle biopsy	Usually Not Appropriate	Varies
CT chest without and with IV contrast	Usually Not Appropriate	☼☼☼
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☼☼☼☼

Variant 2: **Indeterminate mediastinal mass on radiography. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI chest without and with IV contrast	Usually Appropriate	○
MRI chest without IV contrast	Usually Appropriate	○
CT chest with IV contrast	Usually Appropriate	☼☼☼
CT chest without IV contrast	Usually Appropriate	☼☼☼
US chest	Usually Not Appropriate	○
Image-guided transthoracic needle biopsy	Usually Not Appropriate	Varies
CT chest without and with IV contrast	Usually Not Appropriate	☼☼☼
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☼☼☼☼

Variant 3: **Indeterminate mediastinal mass on CT. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI chest without and with IV contrast	Usually Appropriate	○
MRI chest without IV contrast	Usually Appropriate	○
Image-guided transthoracic needle biopsy	May Be Appropriate	Varies
FDG-PET/CT skull base to mid-thigh	May Be Appropriate	☼☼☼☼
US chest	Usually Not Appropriate	○
Radiography chest	Usually Not Appropriate	☼

Variant 4: Indeterminate mediastinal mass on FDG-PET/CT. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided transthoracic needle biopsy	Usually Appropriate	Varies
MRI chest without and with IV contrast	Usually Appropriate	○
MRI chest without IV contrast	Usually Appropriate	○
CT chest with IV contrast	May Be Appropriate	⦿⦿⦿
US chest	Usually Not Appropriate	○
Radiography chest	Usually Not Appropriate	⦿
CT chest without and with IV contrast	Usually Not Appropriate	⦿⦿⦿
CT chest without IV contrast	Usually Not Appropriate	⦿⦿⦿

Variant 5: Indeterminate mediastinal mass on MRI. Next imaging study or surveillance.

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided transthoracic needle biopsy	Usually Appropriate	Varies
MRI chest without and with IV contrast	Usually Appropriate	○
MRI chest without IV contrast	May Be Appropriate	○
CT chest with IV contrast	May Be Appropriate	⦿⦿⦿
CT chest without IV contrast	May Be Appropriate	⦿⦿⦿
FDG-PET/CT skull base to mid-thigh	May Be Appropriate	⦿⦿⦿⦿
US chest	Usually Not Appropriate	○
Radiography chest	Usually Not Appropriate	⦿
CT chest without and with IV contrast	Usually Not Appropriate	⦿⦿⦿

IMAGING OF MEDIASTINAL MASSES

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Summary of Literature Review

Introduction/Background

Although the true prevalence of mediastinal masses is not known, a 0.9% prevalence of anterior or prevascular mediastinal masses was found among the 2,571 chest CTs of the 51% female cohort of the Framingham Heart Study, with a mean age of 59 years [1]. A 0.73% prevalence of prevascular mediastinal nodules was found on the chest CTs of a 63% male cohort (n = 56,358 participants), with a mean age of 52 years undergoing baseline low-dose chest CT for routine health surveillance [2]. A higher 4% prevalence of mediastinal masses was found on 589 CT pulmonary angiograms in a 63% female cohort with a mean age of 53 years [3]. On baseline lung cancer screening in the Early Lung Cancer Action Project, a 0.77% mediastinal mass prevalence was found in a cohort of 9,263 patients that was 51% female and had a median age of 65 years [4].

Although many mediastinal nodules or masses may present as incidental findings on chest radiographs and cross-sectional imaging, others present with symptoms, signs, and syndromes that include chest pain, cough, dyspnea, dysphagia, cardiac tamponade, diaphragmatic paralysis, central venous thrombosis, superior vena cava syndrome, B symptoms in the setting of lymphoma, myasthenia gravis, and other paraneoplastic syndromes. Other mediastinal masses present during staging and treatment of a known malignancy, including metastatic spread of disease to the mediastinum, rebound thymic hyperplasia, and acquired thymic cysts. Mediastinal lesions are also detected on lung cancer screening CTs [4] and during screening by cross-sectional imaging for patients with genetic mutations predisposing toward mediastinal masses, such as the succinate dehydrogenase subunits B and D mutations for paragangliomas [5,6] and the anti-*N*-methyl D-aspartate receptor antibody for teratomas [7]. Because mediastinal masses are so varied, not only in terms of benignity and malignancy but also in terms of their behavior, a general statement regarding their clinical course and treatment cannot be made.

Localization of a mediastinal mass to 1 of the 3 mediastinal compartments by chest radiography and cross-sectional imaging can narrow the differential diagnosis [8,9]. Cross-sectional imaging, by its very nature, can more definitively localize a lesion to a mediastinal compartment—hence the more recently prescribed use of cross-sectional imaging, rather than chest radiography, for definition of mediastinal compartments [10] and the use of new descriptive terms for the 3 mediastinal compartments—prevascular, visceral, and paravertebral—in lieu of anterior, middle, and posterior. A recently published international multi-institutional study confirmed the most common prevascular mediastinal lesions to be thymomas (28%), benign cysts (20%), and lymphomas (16%). Benign cysts were most common in the visceral compartment, and neurogenic tumors were most common in the paravertebral compartment [11].

The classic imaging approach to mediastinal mass evaluation found on radiography has generally entailed a step-wise progression from chest radiography to CT [12-15] to diagnostic intervention when needed [16,17], with or without an intervening PET/CT. However, more recent recognition of the long-literature-supported ability of MRI to characterize tissue and add diagnostic specificity [18-23], prevent unnecessary biopsy and surgery [24-26], and modify and guide the approach to biopsy and surgery [27] has moved MRI into a valued position in terms of workup and triage of these lesions [28-33].

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Special Imaging Considerations

For indeterminate hypervascular mediastinal masses on CT and MRI in typical locations for paraganglioma, Ga-68-DOTATATE has the potential to make a specific diagnosis [34]; however, such additional testing may not be necessary if surgery is planned, regardless of histopathology. The role of Ga-68-DOTATATE PET/CT in the clinical management of thymic epithelial tumors (TETs) and the differentiation of neuroendocrine from non-neuroendocrine tumors needs further clarification, as somatostatin receptors are present in normal thymus and most TETs [35-37]. If ectopic thyroid tissue is a diagnostic consideration for an indeterminate prevascular or visceral mediastinal mass, Tc-99m pertechnetate or I-123 scintigraphy can be performed and can yield a specific diagnosis, although I-123 scintigraphy may be preferable because of its higher uptake in thyroid tissue and less background activity [38]. If extramedullary hematopoiesis is a diagnostic consideration for a paravertebral mass or multiple paravertebral masses, then Tc-99m sulfur colloid scintigraphy can be performed and can yield a specific diagnosis [39]. Imaging of parathyroid adenomas will be covered in a separate ACR Appropriateness Criteria® topic on “Parathyroid Adenoma” and therefore will not be discussed here.

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient’s care).

Discussion of Procedures by Variant

Variant 1: Clinically suspected mediastinal mass. Initial imaging.

CT Chest

Cross-sectional imaging can more definitively localize a lesion to a mediastinal compartment than chest radiography. Further tissue characterization of mediastinal masses beyond chest radiography is achievable by CT which can demonstrate and distinguish not only calcium and macroscopic fat but also water attenuation fluid, permitting noninvasive diagnosis of many mature teratomas [40]. Pre- and postcontrast conventional CT or dual-energy CT can show enhancing cellular components of lesions [41,42]; however, the soft-tissue contrast of CT is sometimes insufficient. For example, benign hyperattenuating thymic cysts on CT can be misinterpreted as thymomas, leading to unnecessary thymectomy [24]. Not infrequently, a mediastinal lesion is indeterminate by CT and requires further workup.

CT is superior to chest radiography for detection of invasion of the mass across tissue planes, secondary to its higher contrast resolution. Invasion of adjacent large blood vessels and the chest wall is important to identify, as it is associated with a higher probability of incomplete surgical resection of primary malignant mediastinal masses [43]. In addition, it can direct surgery when still planned and, in other cases, direct toward other forms of clinical management, including neoadjuvant chemotherapy and radiation therapy. As a supplement to static assessment of tissue plane transgression, which can be difficult, dynamic CT [44] during free-breathing or cinematic cardiac gating can be performed to assess movement of the mass relative to adjacent structures and confirm or exclude adherence of the mass to adjacent structures; however, dynamic MRI during free-breathing can accomplish the same task [45-48]. MRI remains superior to CT for detection of invasion of the mass across tissue planes, including the chest wall and diaphragm, and involvement of neurovascular structures, secondary to its higher soft-tissue contrast [49-52].

FDG-PET/CT Skull Base to Mid-Thigh

Fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT offers limited additional value beyond that of conventional CT in the initial assessment of mediastinal masses [53], with the exception of its use for primary mediastinal lymphoma staging and surveillance and detection of metastatic lymphadenopathy, the latter of which is not within the scope of this topic. With regard to prevascular mediastinal masses, a negative FDG-PET/CT has been shown to be helpful in excluding malignancy; however, a positive FDG-PET/CT has little value for discrimination between benign and malignant lesions [53]. The frequent FDG-PET/CT avidity of normal and hyperplastic thymus [54] is a confounder in FDG-PET/CT assessment of the prevascular mediastinum. Benign

thymic cysts can also be FDG-PET/CT-avid [42]. Combined use of FDG-PET/CT and dynamic contrast-enhanced (DCE) MRI has been shown to be helpful to distinguish prevascular mediastinal solid tumors from one another [55]. Higher standardized uptake values (SUVs) on FDG-PET/CT are more frequently found in high-risk thymoma, thymic carcinoma, and lymphoma than in low-risk thymoma [55-57].

MRI Chest

MRI allows further tissue characterization of mediastinal masses beyond that of CT [21] and FDG-PET/CT because of its ability to detect not only serous fluid and macroscopic fat [58,59] but also hemorrhagic and proteinaceous fluid [19,24], microscopic or intravoxel fat [22,60,61], cartilage [62,63], smooth muscle [64,65], and fibrous material [66-68], albeit not calcium. MRI can prove the cystic nature of an indeterminate, non-water attenuation thymic mass on CT, preventing unnecessary biopsy and thymectomy [20,21,24,69]. The ability of MRI to distinguish cystic from solid lesions definitively carries diagnostic importance in all compartments of the mediastinum. MRI can also show sites of restricted diffusion of water within lesions by employing diffusion-weighted imaging (DWI), further assisting in lesion characterization [70,71], and it can employ DCE and postprocessed subtraction imaging for both further differentiation of lesions [55,72] and direction of biopsy toward areas of cellularity as opposed to hemorrhagic necrosis, the latter of which can be hyperattenuating and mimic solid tissue on CT. MRI is more useful than CT for evaluation of neurogenic tumors, because of its better depiction of neural and spinal involvement [73] and can be helpful in distinguishing schwannomas, neurofibromas, and ganglioneuromas [74-77], all of which may appear similar on CT. Because of its ability to detect microscopic fat, MRI can distinguish normal and hyperplastic thymus from thymic tumors and lymphoma, whether by chemical-shift MRI in adults [22,61] or by DWI with apparent diffusion coefficient (ADC) mapping [78,79], the latter with potential to make this distinction in all age groups. MRI can also help differentiate low-risk from high-risk thymomas, thymic carcinoma, and lymphoma by the DCE pattern of these lesions [72] and by DWI [71]. CT currently cannot achieve this degree of tissue characterization.

Cross-sectional imaging by MRI remains superior to CT for detection of invasion of the mass across tissue planes, including the chest wall and diaphragm, and involvement of neurovascular structures, secondary to its higher soft-tissue contrast [48-52]. As a supplement to static assessment of tissue plane transgression, dynamic MRI [45-48] during free-breathing or cinematic cardiac gating can be performed to assess movement of the mass relative to adjacent structures, confirm or exclude adherence of the mass to adjacent structures, and observe diaphragmatic motion in real time [80-84]; paradoxical motion or lack of motion can indicate phrenic nerve involvement by the mediastinal mass, without the need to perform a subsequent fluoroscopic sniff test.

Radiography Chest

When there is a clinically suspected mediastinal mass, it is reasonable to perform a chest radiograph as an initial imaging step. Chest radiography can help localize a mass to a specific mediastinal compartment and thereby narrow the differential diagnosis [85-88]. It can also show any associated pleural, lung, and bone findings to some extent. Chest radiography offers limited assistance regarding tissue characterization of mediastinal masses, with the exception of its occasional demonstration of calcium within a lesion.

US Chest

There is little relevant literature to support the use of ultrasound (US) in the initial evaluation of a clinically suspected mediastinal mass. Because of the limited transthoracic sonographic window, US would not be useful to screen for a clinically suspected mediastinal mass. Transthoracic US can be used to evaluate mediastinal masses, when accessible to the sonographic window, delineating their size, location, cystic versus solid nature, relationship to important vascular structures, and vascularity, with some diagnostic potential [89]. Endoscopic US can similarly evaluate mediastinal masses when encompassed in the sonographic window [90]. The tissue characterization capability of US is inferior to MRI but not to CT.

Image-Guided Transthoracic Needle Biopsy

Image-guided transthoracic needle biopsy is not a form of initial imaging.

Variant 2: Indeterminate mediastinal mass on radiography. Next imaging study.

CT Chest

Cross-sectional imaging, by its very nature, can more definitively localize a lesion to a mediastinal compartment than chest radiography. Further tissue characterization of mediastinal masses beyond chest radiography is achievable by CT, which can demonstrate and distinguish not only calcium and macroscopic fat but also water attenuation fluid, thus permitting noninvasive diagnosis of many mature teratomas [40]. Pre- and postcontrast

conventional CT or dual-energy CT can show enhancing, cellular components of lesions [41,42]; however, the soft-tissue contrast of CT is sometimes insufficient. For example, benign hyperattenuating thymic cysts on CT can be misinterpreted as thymomas, leading to unnecessary thymectomy [24]. Not infrequently, a mediastinal lesion is indeterminate by CT and requires further workup.

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FDG-PET/CT Skull Base to Mid-Thigh

FDG-PET/CT offers limited additional value beyond that of conventional CT in the assessment of mediastinal masses [53], with the exception of its use for primary mediastinal lymphoma staging and surveillance and detection of metastatic lymphadenopathy, the latter of which is not within the scope of this topic. FDG-PET/CT has become the standard for staging and assessment of treatment response for lymphomas that are FDG-PET-avid at baseline or at the time recurrence [91-97]. A caveat is that although a negative surveillance FDG-PET/CT is reassuring of a good outcome, a positive FDG-PET/CT can be misleading, as it does not always implicate residual or recurrent lymphoma [96,98]. CT and MRI can be used for surveillance of lymphadenopathy when the metabolic activity of the lymphadenopathy is not of interest and when allowed within a clinical protocol. With regard to prevascular mediastinal masses, a negative FDG-PET/CT has been shown to be helpful in excluding malignancy; however, a positive FDG-PET/CT has little value for discrimination between benign and malignant lesions [53]. The frequent FDG-PET/CT avidity of normal and hyperplastic thymus [54] is a confounder in FDG-PET/CT assessment of the prevascular mediastinum. Benign thymic cysts can also be FDG-PET/CT-avid [42]. Combined use of FDG-PET/CT and DCE MRI has been shown to be helpful to distinguish prevascular mediastinal solid tumors from one another [55]. Higher SUVs on FDG-PET/CT are more frequently found in high-risk thymoma, thymic carcinoma, and lymphoma than in low-risk thymoma [55-57]. FDG-PET/CT appears to be more sensitive than CT alone for detection of mediastinal recurrence of thymoma [99].

MRI Chest

MRI allows further tissue characterization of mediastinal masses beyond that of CT [21] and FDG-PET/CT because of its ability to detect not only serous fluid and macroscopic fat [58,59] but also hemorrhagic and proteinaceous fluid [19,24], microscopic or intravoxel fat [22,60,61], cartilage [62,63], smooth muscle [64,65], and fibrous material [66-68], albeit not calcium. MRI can prove the cystic nature of an indeterminate, non-water attenuation thymic mass on CT, preventing unnecessary biopsy and thymectomy [20,21,24,69]. The ability of MRI to distinguish cystic from solid lesions definitively carries diagnostic importance in all compartments of the mediastinum. MRI can also show sites of restricted diffusion of water within lesions by employing DWI, further assisting in lesion characterization [70,71] and can employ DCE and postprocessed subtraction imaging for further differentiation of lesions [55,72] and for direction of biopsy toward areas of cellularity, as opposed to hemorrhagic necrosis, the latter of which can be hyperattenuating and mimic solid tissue on CT. MRI is more useful than CT for evaluation of neurogenic tumors, because of its better depiction of neural and spinal involvement [73], and it can be helpful in distinguishing schwannomas, neurofibromas, and ganglioneuromas [74-77], all of which may appear similar on CT. Because of its ability to detect microscopic fat, MRI can distinguish normal and hyperplastic thymus from thymic tumors and lymphoma, whether by chemical-shift MRI in adults [22,61] or by DWI with ADC mapping [78,79], the latter with potential to make this distinction in all age groups. MRI can also help differentiate low-risk from high-risk thymomas, thymic carcinoma, and lymphoma by the DCE pattern of these lesions [72] and by DWI [71]. CT currently cannot achieve this degree of tissue characterization. MRI has been shown to be slightly superior to CT for surveillance of treated TETs, although, if there is insurmountable susceptibility artifact from sternotomy wires using fast spin-echo and other MRI techniques, alternating MRI and CT follow-up can be performed [100].

Cross-sectional imaging by MRI remains superior to CT for detection of invasion of the mass across tissue planes, including the chest wall and diaphragm, and involvement of neurovascular structures, secondary to its higher soft-

tissue contrast [48-52]. As a supplement to static assessment of tissue plane transgression, dynamic MRI [45-48] during free-breathing or cinematic cardiac gating can be performed to assess movement of the mass relative to adjacent structures, confirm or exclude adherence of the mass to adjacent structures, and observe diaphragmatic motion in real time [80-84]; paradoxical motion or lack of motion can indicate phrenic nerve involvement by the mediastinal mass, without the need to perform a subsequent fluoroscopic sniff test.

US Chest

Unless a mediastinal mass found on chest radiography is deemed fully accessible by transthoracic US, there is little relevant literature to support its use as the next step. Transthoracic US can be used to evaluate mediastinal masses, when accessible to the sonographic window, delineating their size, location, cystic versus solid nature, relationship to important vascular structures, and vascularity, with some diagnostic potential [89]. Endoscopic US can similarly evaluate mediastinal masses when encompassed in the sonographic window [90]. The tissue characterization capability of US is inferior to MRI but not to CT.

Image-Guided Transthoracic Needle Biopsy

Image-guided transthoracic needle biopsy would seldom be performed without a preceding cross-sectional imaging study.

Variant 3: Indeterminate mediastinal mass on CT. Next imaging study.

FDG-PET/CT Skull Base to Mid-Thigh

FDG-PET/CT offers limited additional value beyond that of conventional CT in the assessment of mediastinal masses [53], with the exception of its use for primary mediastinal lymphoma staging and surveillance and detection of metastatic lymphadenopathy, the latter of which is not within the scope of this topic. FDG-PET/CT has become the standard for staging and assessment of treatment response for lymphomas that are FDG-PET-avid at baseline or at the time recurrence [91-97]. A caveat is that although a negative surveillance FDG-PET/CT is reassuring of a good outcome, a positive FDG-PET/CT can be misleading, as it does not always implicate residual or recurrent lymphoma [96,98]. CT and MRI can be used for surveillance of lymphadenopathy, when the metabolic activity of the lymphadenopathy is not of interest and when allowed within a clinical protocol. With regard to prevascular mediastinal masses, a negative FDG-PET/CT has been shown to be helpful in excluding malignancy; however, a positive FDG-PET/CT has little value for discrimination between benign and malignant lesions [53]. The frequent FDG-PET/CT avidity of normal and hyperplastic thymus [54] is a confounder in FDG-PET/CT assessment of the prevascular mediastinum. Benign thymic cysts can also be FDG-PET/CT-avid [42]. Combined use of FDG-PET/CT and DCE MRI has been shown to be helpful to distinguish prevascular mediastinal solid tumors from one another [55]. Higher SUVs on FDG-PET/CT are more frequently found in high-risk thymoma, thymic carcinoma, and lymphoma than in low-risk thymoma [55-57]. FDG-PET/CT appears to be more sensitive than CT alone for detection of mediastinal recurrence of thymoma [99].

MRI Chest

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US Chest

There is little relevant literature to support US of an indeterminate mediastinal mass on CT. Transthoracic US can be used to evaluate mediastinal masses when accessible to the sonographic window, delineating their size, location, cystic versus solid nature, relationship to important vascular structures, and vascularity, with some diagnostic potential [89]. Endoscopic US can similarly evaluate mediastinal masses when encompassed in the sonographic window [90]. The tissue characterization capability of US is inferior to MRI but not to CT.

Image-Guided Transthoracic Needle Biopsy

CT-guided percutaneous needle and core biopsy of accessible mediastinal masses has been shown to be safe and to have a good diagnostic yield, with core biopsy more effective than fine-needle aspiration. Biopsy was more frequently diagnostic for TETs than for lymphoma [101-104]. A retrospective study of 293 consecutive CT-guided mediastinal biopsies performed in 285 patients showed an overall diagnostic yield of 87% for mediastinal masses with a mean size of 5.3 cm and 57% for residual masses at the site of treated lymphoma [101]. Another retrospective study of 52 patients reported a 77% diagnostic yield for needle biopsy of mediastinal masses with a mean size of 6.9 cm [102]. When the distinction of TETs from lymphoma cannot be definitively made by imaging, image-guided biopsy has a role. PET/CT guidance for biopsy reportedly yields no diagnostic advantage [104]. When the lesion is visible within the sonographic window, transthoracic US-guided biopsy of mediastinal masses is also feasible, with color Doppler and contrast-enhanced sonographic techniques providing additional value [105-108] and with core biopsy more effective than fine-needle aspiration. Endoscopic biopsy of mediastinal masses is also feasible and effective, although not in the purview of this topic [109]. DWI MR may be helpful in directing CT-guided biopsy toward sites of higher cellularity and diagnostic yield [110], as may DCE MRI with postprocessed subtraction. MR-guided percutaneous needle biopsy has also been shown to be safe and diagnostically accurate [111].

Radiography Chest

After cross-sectional imaging has been performed for mediastinal mass evaluation, there is seldom a role for chest radiography.

Variant 4: Indeterminate mediastinal mass on FDG-PET/CT. Next imaging study.

CT Chest

After FDG-PET/CT has been performed for mediastinal mass evaluation, there is seldom a role for chest CT.

MRI Chest

MRI allows further tissue characterization of mediastinal masses beyond that of CT [21] and FDG-PET/CT because of its ability to detect not only serous fluid and macroscopic fat [58,59] but also hemorrhagic and proteinaceous fluid [19,24], microscopic or intravoxel fat [22,60,61], cartilage [62,63], smooth muscle [64,65], and fibrous material [66-68], albeit not calcium. MRI can prove the cystic nature of an indeterminate, non-water attenuation thymic mass on CT, preventing unnecessary biopsy and thymectomy [20,21,24,69]. The ability of MRI to distinguish cystic from solid lesions definitively carries diagnostic importance in all compartments of the mediastinum. MRI can also show sites of restricted diffusion of water within lesions by employing DWI, further assisting in lesion characterization [70,71], and can employ DCE and postprocessed subtraction imaging for further differentiation of lesions [55,72] and for direction of biopsy toward areas of cellularity, as opposed to hemorrhagic necrosis, the latter of which can be hyperattenuating and mimic solid tissue on CT. MRI is more useful than CT for evaluation of neurogenic tumors, because of its better depiction of neural and spinal involvement [73], and it can be helpful in distinguishing schwannomas, neurofibromas, and ganglioneuromas [74-77], all of which may appear similar on CT. Because of its ability to detect microscopic fat, MRI can distinguish normal and hyperplastic thymus from thymic tumors and lymphoma, whether by chemical-shift MRI in adults [22,61] or by DWI with ADC mapping [78,79], the latter with potential to make this distinction in all age groups. MRI can also help differentiate low-risk from high-risk thymomas, thymic carcinoma, and lymphoma by the DCE pattern of these lesions [72] and by DWI [71]. CT currently cannot achieve this degree of tissue characterization. MRI has been shown to be slightly superior

to CT for surveillance of treated TETs, although if there is insurmountable susceptibility artifact from sternotomy wires using fast spin-echo and other MRI techniques, alternating MRI and CT follow-up can be performed [100].

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There is little relevant literature to support US of an indeterminate mediastinal mass on FDG-PET/CT. Transthoracic US can be used to evaluate mediastinal masses when accessible to the sonographic window, delineating their size, location, cystic versus solid nature, relationship to important vascular structures, and vascularity, with some diagnostic potential [89]. Endoscopic US can similarly evaluate mediastinal masses when encompassed in the sonographic window [90]. The tissue characterization capability of US is inferior to MRI but not to CT.

Image-Guided Transthoracic Needle Biopsy

CT-guided percutaneous needle and core biopsy of accessible mediastinal masses has been shown to be safe and to have a good diagnostic yield, with core biopsy more effective than fine-needle aspiration. Biopsy was more frequently diagnostic for TETs than for lymphoma [101-104]. A retrospective study of 293 consecutive CT-guided mediastinal biopsies performed in 285 patients showed an overall diagnostic yield of 87% for mediastinal masses with a mean size of 5.3 cm and 57% for residual masses at the site of treated lymphoma [101]. Another retrospective study of 52 patients reported a 77% diagnostic yield for needle biopsy of mediastinal masses with a mean size of 6.9 cm [102]. When the distinction of TETs from lymphoma cannot be definitively made by imaging, image-guided biopsy has a role. PET/CT guidance for biopsy reportedly yields no diagnostic advantage [104]. When the lesion is visible within the sonographic window, transthoracic US-guided biopsy of mediastinal masses is also feasible, with color Doppler and contrast-enhanced sonographic techniques providing additional value [105-108], and with core biopsy more effective than fine-needle aspiration. Endoscopic biopsy of mediastinal masses is also feasible and effective, although not in the purview of this topic [109]. DWI MR may be helpful in directing CT-guided biopsy toward sites of higher cellularity and diagnostic yield [110], as may DCE MRI with postprocessed subtraction. MR-guided percutaneous needle biopsy has also been shown to be safe and diagnostically accurate [111].

Radiography Chest

After cross-sectional imaging has been performed for mediastinal mass evaluation, there is seldom a role for chest radiography.

Variant 5: Indeterminate mediastinal mass on MRI. Next imaging study or surveillance.

CT Chest

Unless there is concern for missed calcification within a mediastinal mass and any diagnostic utility such a finding may have, CT would be unlikely to add additional diagnostic information regarding a mediastinal mass beyond that offered by MRI. CT can be used as a means of follow-up of indeterminate mediastinal masses, readily showing any change in size, morphology, or attenuation of the lesion. However, surveillance by CT would be less likely to provide the level of diagnostic certainty that MR could provide at follow-up on account of MR's greater sensitivity for detection of increased lesion complexity and its greater capacity to characterize tissue. Surveillance could be performed at a 3-, 6-, or 12-month interval over 2 or more years, depending upon the level of clinical concern.

FDG-PET/CT Skull Base to Mid-Thigh

Unless the degree of metabolic activity of a mediastinal mass is sought and deemed capable of changing clinical management, FDG-PET/CT would be unlikely to add diagnostic information regarding a mediastinal mass beyond that offered by MRI. FDG-PET/CT offers limited additional value beyond that of conventional CT and MRI in the assessment of mediastinal masses [53], with the exception of its use for primary mediastinal lymphoma staging and surveillance and detection of metastatic lymphadenopathy, the latter of which is not within the scope of this topic. FDG-PET/CT has become the standard for staging and assessment of treatment response for lymphomas that are FDG-PET-avid at baseline or at the time recurrence [91-97]. A caveat is that although a negative surveillance FDG-PET/CT is reassuring of a good outcome, a positive FDG-PET/CT can be misleading, as it does not always implicate

residual or recurrent lymphoma [96,98]. With regard to prevascular mediastinal masses, a negative FDG-PET/CT has been shown to be helpful in excluding malignancy; however, a positive FDG-PET/CT has little value for discrimination between benign and malignant lesions [53]. The frequent FDG-PET/CT avidity of normal and hyperplastic thymus [54] is a confounder in FDG-PET/CT assessment of the prevascular mediastinum. Benign thymic cysts can also be FDG-PET/CT-avid [42]. Combined use of FDG-PET/CT and DCE MRI has been shown to be helpful to distinguish prevascular mediastinal solid tumors from one another [55]. Higher SUVs on FDG-PET/CT are more frequently found in high-risk thymoma, thymic carcinoma, and lymphoma than in low-risk thymoma [55-57]. FDG-PET/CT appears to be more sensitive than CT alone for detection of mediastinal recurrence of thymoma [99].

MRI Chest

Sometimes a mediastinal mass is found and incompletely evaluated on a pulmonary MR angiography or a neck, breast, abdominal, spine, or chest wall MRI and more dedicated chest MR evaluation is needed. When a mediastinal mass is indeterminate on MRI after more comprehensive evaluation, a short-term follow-up chest MRI can be performed, rather than proceeding to biopsy or resection, at a 3-, 6-, or 12-month interval over 2 or more years, depending upon the level of clinical concern. MRI can not only provide information about any interval change in size or morphology, which CT can accomplish but can also provide additional detail regarding lesion complexity and tissue characterization beyond that of CT [21] and FDG-PET/CT. This added value is due to its ability to detect not only serous fluid and macroscopic fat [58,59] but also hemorrhagic and proteinaceous fluid [19,24], microscopic or intravoxel fat [22,60,61], cartilage [62,63], smooth muscle [64,65], and fibrous material [66-68], albeit not calcium. MRI can prove the cystic nature of an indeterminate, non-water attenuation thymic mass on CT, preventing unnecessary biopsy and thymectomy [20,21,24,69]. The ability of MRI to distinguish cystic from solid lesions definitively carries diagnostic importance in all compartments of the mediastinum. MRI can also show sites of restricted diffusion of water within lesions by employing DWI, further assisting in lesion characterization [70,71], and can employ DCE and postprocessed subtraction imaging for further differentiation of lesions [55,72] and for direction of biopsy toward areas of cellularity, as opposed to hemorrhagic necrosis, the latter of which can be hyperattenuating and mimic solid tissue on CT. MRI is more useful than CT for evaluation of neurogenic tumors, because of its better depiction of neural and spinal involvement [73], and can be helpful in distinguishing schwannomas, neurofibromas, and ganglioneuromas [74-77], all of which may appear similar on CT. Because of its ability to detect microscopic fat, MRI can distinguish normal and hyperplastic thymus from thymic tumors and lymphoma, whether by chemical-shift MRI in adults [22,61] or by DWI with ADC mapping [78,79], the latter with potential to make this distinction in all age groups. MRI can also help differentiate low-risk from high-risk thymomas, thymic carcinoma, and lymphoma by the DCE pattern of these lesions [72] and by DWI [71]. CT currently cannot achieve this degree of tissue characterization. MRI has been shown to be slightly superior to CT for surveillance of treated TETs, although if there is insurmountable susceptibility artifact from sternotomy wires despite use of fast spin-echo and other MRI techniques, alternating MRI and CT follow-up can be performed [100].

Cross-sectional imaging by MRI remains superior to CT for detection of invasion of the mass across tissue planes, including the chest wall and diaphragm, and involvement of neurovascular structures, secondary to its higher soft-tissue contrast [48-52]. As a supplement to static assessment of tissue plane transgression, dynamic MRI [45-48] during free-breathing or cinematic cardiac gating can be performed to assess movement of the mass relative to adjacent structures, to confirm or exclude adherence of the mass to adjacent structures, and to observe diaphragmatic motion in real time [80-84]; paradoxical motion or lack of motion can indicate phrenic nerve involvement by the mediastinal mass, without the need to perform a subsequent fluoroscopic sniff test.

US Chest

Transthoracic US is unlikely to offer additional information regarding mediastinal mass characterization beyond that of MRI.

Image-Guided Transthoracic Needle Biopsy

CT-guided percutaneous needle and core biopsy of accessible mediastinal masses has been shown to be safe and to have a good diagnostic yield, with core biopsy more effective than fine-needle aspiration. Biopsy was more frequently diagnostic for TETs than for lymphoma [101-104]. A retrospective study of 293 consecutive CT-guided mediastinal biopsies performed in 285 patients showed an overall diagnostic yield of 87% for mediastinal masses with a mean size of 5.3 cm and 57% for residual masses at the site of treated lymphoma [101]. Another retrospective study of 52 patients reported a 77% diagnostic yield for needle biopsy of mediastinal masses with a mean size of 6.9 cm [102]. When the distinction of TETs from lymphoma cannot be definitively made by imaging, image-guided

biopsy has a role. PET/CT guidance for biopsy reportedly yields no diagnostic advantage [104]. When the lesion is visible within the sonographic window, transthoracic US-guided biopsy of mediastinal masses is also feasible, with color Doppler and contrast-enhanced sonographic techniques providing additional value [105-108], and with core biopsy more effective than fine-needle aspiration. Endoscopic biopsy of mediastinal masses is also feasible and effective, although not in the purview of this topic [109]. DWI MR may be helpful in directing CT-guided biopsy toward sites of higher cellularity and diagnostic yield [110], as may DCE MRI with postprocessed subtraction. MR-guided percutaneous needle biopsy has also been shown to be safe and diagnostically accurate [111].

Radiography Chest

After cross-sectional imaging has been performed for mediastinal mass evaluation, there is a seldom a role for chest radiography.

Summary of Recommendations

- **Variant 1:** Radiography chest or MRI chest without and with intravenous (IV) contrast or MRI chest without IV contrast or CT chest without IV contrast or CT chest with IV contrast or CT chest without IV contrast is usually appropriate for the initial imaging of patients with clinically suspected mediastinal mass. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 2:** MRI chest without and with IV contrast or MRI chest without IV contrast or CT chest with IV contrast or CT chest without IV contrast is usually appropriate for the next imaging study of patients with indeterminate mediastinal mass on radiography. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 3:** MRI chest without and with IV contrast or MRI chest without IV contrast is usually appropriate for the next imaging study of patients with indeterminate mediastinal mass on CT. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 4:** Image-guided transthoracic needle biopsy or MRI chest without and with IV contrast or MRI chest without IV contrast is usually appropriate for the next imaging study of patients with indeterminate mediastinal mass on FDG-PET/CT. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 5:** Image-guided transthoracic needle biopsy or MRI chest without and with IV contrast is usually appropriate for the next imaging study or surveillance of patients with indeterminate mediastinal mass on MRI. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [112].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
⦿	<0.1 mSv	<0.03 mSv
⦿⦿	0.1-1 mSv	0.03-0.3 mSv
⦿⦿⦿	1-10 mSv	0.3-3 mSv
⦿⦿⦿⦿	10-30 mSv	3-10 mSv
⦿⦿⦿⦿⦿	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

References

1. Araki T, Nishino M, Gao W, et al. Anterior Mediastinal Masses in the Framingham Heart Study: Prevalence and CT Image Characteristics. *Eur J Radiol Open* 2015;2:26-31.

2. Yoon SH, Choi SH, Kang CH, Goo JM. Incidental Anterior Mediastinal Nodular Lesions on Chest CT in Asymptomatic Subjects. *J Thorac Oncol* 2018;13:359-66.
3. Hall WB, Truitt SG, Scheunemann LP, et al. The prevalence of clinically relevant incidental findings on chest computed tomographic angiograms ordered to diagnose pulmonary embolism. *Arch Intern Med* 2009;169:1961-5.
4. Henschke CI, Lee IJ, Wu N, et al. CT screening for lung cancer: prevalence and incidence of mediastinal masses. *Radiology* 2006;239:586-90.
5. Neumann HP, Pawlu C, Peczkowska M, et al. Distinct clinical features of paraganglioma syndromes associated with SDHB and SDHD gene mutations. *JAMA* 2004;292:943-51.
6. Gimm O, Armanios M, Dziema H, Neumann HP, Eng C. Somatic and occult germ-line mutations in SDHD, a mitochondrial complex II gene, in nonfamilial pheochromocytoma. *Cancer Res* 2000;60:6822-5.
7. Dalmau J, Tuzun E, Wu HY, et al. Paraneoplastic anti-N-methyl-D-aspartate receptor encephalitis associated with ovarian teratoma. *Ann Neurol* 2007;61:25-36.
8. Carter BW, Tomiyama N, Bhora FY, et al. A modern definition of mediastinal compartments. *J Thorac Oncol* 2014;9:S97-101.
9. Thacker PG, Mahani MG, Heider A, Lee EY. Imaging Evaluation of Mediastinal Masses in Children and Adults: Practical Diagnostic Approach Based on A New Classification System. *J Thorac Imaging* 2015;30:247-67.
10. Carter BW, Benveniste MF, Madan R, et al. ITMIG Classification of Mediastinal Compartments and Multidisciplinary Approach to Mediastinal Masses. *Radiographics* 2017;37:413-36.
11. Roden AC, Fang W, Shen Y, et al. Distribution of Mediastinal Lesions Across Multi-Institutional, International, Radiology Databases. *J Thorac Oncol* 2020;15:568-79.
12. Whitten CR, Khan S, Munneke GJ, Grubnic S. A diagnostic approach to mediastinal abnormalities. *Radiographics* 2007;27:657-71.
13. McErlean A, Huang J, Zabor EC, Moskowitz CS, Ginsberg MS. Distinguishing benign thymic lesions from early-stage thymic malignancies on computed tomography. *J Thorac Oncol* 2013;8:967-73.
14. Gezer NS, Balci P, Tuna KC, Akin IB, Baris MM, Oray NC. Utility of chest CT after a chest X-ray in patients presenting to the ED with non-traumatic thoracic emergencies. *Am J Emerg Med* 2017;35:623-27.
15. Tomiyama N, Honda O, Tsubamoto M, et al. Anterior mediastinal tumors: diagnostic accuracy of CT and MRI. *Eur J Radiol* 2009;69:280-8.
16. Date H. Diagnostic strategies for mediastinal tumors and cysts. *Thorac Surg Clin* 2009;19:29-35, vi.
17. American College of Radiology. ACR Appropriateness Criteria®: Radiologic Management of Thoracic Nodules and Masses. Available at: <https://acsearch.acr.org/docs/69343/Narrative/>. Accessed September 30, 2020.
18. McAdams HP, Kirejczyk WM, Rosado-de-Christenson ML, Matsumoto S. Bronchogenic cyst: imaging features with clinical and histopathologic correlation. *Radiology* 2000;217:441-6.
19. Molina PL, Siegel MJ, Glazer HS. Thymic masses on MR imaging. *AJR Am J Roentgenol* 1990;155:495-500.
20. Ackman JB, Wu CC. MRI of the thymus. *AJR Am J Roentgenol* 2011;197:W15-20.
21. Ackman JB. MR Imaging of Mediastinal Masses. *Magn Reson Imaging Clin N Am* 2015;23:141-64.
22. Inaoka T, Takahashi K, Mineta M, et al. Thymic hyperplasia and thymus gland tumors: differentiation with chemical shift MR imaging. *Radiology* 2007;243:869-76.
23. Priola AM, Priola SM, Giraudo MT, et al. Chemical-shift and diffusion-weighted magnetic resonance imaging of thymus in myasthenia gravis: usefulness of quantitative assessment. *Invest Radiol* 2015;50:228-38.
24. Ackman JB, Verzosa S, Kovach AE, et al. High rate of unnecessary thymectomy and its cause. Can computed tomography distinguish thymoma, lymphoma, thymic hyperplasia, and thymic cysts? *Eur J Radiol* 2015;84:524-33.
25. Ackman JB. Corrigendum to 'High rate of unnecessary thymectomy and its cause. Can computed tomography distinguish thymoma, lymphoma, thymic hyperplasia, and thymic cysts?' [EURR 84 (3) (2015) 524-533]. *Eur J Radiol* 2017;90:262-63.
26. Kent MS, Wang T, Gangadharan SP, Whyte RI. What is the prevalence of a "nontherapeutic" thymectomy? *Ann Thorac Surg* 2014;97:276-82; discussion 82.
27. Ackman JB, Gaissert HA, Lanuti M, et al. Impact of Nonvascular Thoracic MR Imaging on the Clinical Decision Making of Thoracic Surgeons: A 2-year Prospective Study. *Radiology* 2016;280:464-74.

28. Carter BW, Okumura M, Detterbeck FC, Marom EM. Approaching the patient with an anterior mediastinal mass: a guide for radiologists. *J Thorac Oncol* 2014;9:S110-8.
29. Carter BW, Marom EM, Detterbeck FC. Approaching the patient with an anterior mediastinal mass: a guide for clinicians. *J Thorac Oncol* 2014;9:S102-9.
30. Manson DE. Magnetic resonance imaging of the mediastinum, chest wall and pleura in children. *Pediatr Radiol* 2016;46:902-15.
31. Takahashi K, Al-Janabi NJ. Computed tomography and magnetic resonance imaging of mediastinal tumors. *J Magn Reson Imaging* 2010;32:1325-39.
32. Ottlakan A, Borda B, Morvay Z, Maraz A, Furak J. The Effect of Diagnostic Imaging on Surgical Treatment Planning in Diseases of the Thymus. *Contrast Media Mol Imaging* 2017;2017:9307292.
33. Kauczor HU, Ley S. Thoracic magnetic resonance imaging 1985 to 2010. *J Thorac Imaging* 2010;25:34-8.
34. Chang CA, Pattison DA, Tothill RW, et al. (68)Ga-DOTATATE and (18)F-FDG PET/CT in Paraganglioma and Pheochromocytoma: utility, patterns and heterogeneity. *Cancer Imaging* 2016;16:22.
35. Ferone D, Montella L, De Chiara A, Hofland LJ, Lamberts SW, Palmieri G. Somatostatin receptor expression in thymic tumors. *Front Biosci (Landmark Ed)* 2009;14:3304-9.
36. Ferone D, van Hagen MP, Kwekkeboom DJ, et al. Somatostatin receptor subtypes in human thymoma and inhibition of cell proliferation by octreotide in vitro. *J Clin Endocrinol Metab* 2000;85:1719-26.
37. Ferone D, van Hagen PM, van Koetsveld PM, et al. In vitro characterization of somatostatin receptors in the human thymus and effects of somatostatin and octreotide on cultured thymic epithelial cells. *Endocrinology* 1999;140:373-80.
38. Buckley JA, Stark P. Intrathoracic mediastinal thyroid goiter: imaging manifestations. *AJR Am J Roentgenol* 1999;173:471-5.
39. Bronn LJ, Paquelet JR, Tetelman MR. Intrathoracic extramedullary hematopoiesis: appearance on 99mTc sulfur colloid marrow scan. *AJR Am J Roentgenol* 1980;134:1254-5.
40. Moeller KH, Rosado-de-Christenson ML, Templeton PA. Mediastinal mature teratoma: imaging features. *AJR Am J Roentgenol* 1997;169:985-90.
41. Lee SH, Hur J, Kim YJ, Lee HJ, Hong YJ, Choi BW. Additional value of dual-energy CT to differentiate between benign and malignant mediastinal tumors: an initial experience. *Eur J Radiol* 2013;82:2043-9.
42. Lee SH, Yoon SH, Nam JG, et al. Distinguishing between Thymic Epithelial Tumors and Benign Cysts via Computed Tomography. *Korean J Radiol* 2019;20:671-82.
43. Gross JL, Rosalino UA, Younes RN, Haddad FJ, Silva RA, Rocha AB. Characteristics associated with complete surgical resection of primary malignant mediastinal tumors. *J Bras Pneumol* 2009;35:832-8.
44. Murata K, Takahashi M, Mori M, et al. Chest wall and mediastinal invasion by lung cancer: evaluation with multisection expiratory dynamic CT. *Radiology* 1994;191:251-5.
45. Seo JS, Kim YJ, Choi BW, Choe KO. Usefulness of magnetic resonance imaging for evaluation of cardiovascular invasion: evaluation of sliding motion between thoracic mass and adjacent structures on cine MR images. *J Magn Reson Imaging* 2005;22:234-41.
46. Shiotani S, Sugimura K, Sugihara M, et al. Diagnosis of chest wall invasion by lung cancer: useful criteria for exclusion of the possibility of chest wall invasion with MR imaging. *Radiat Med* 2000;18:283-90.
47. Kajiwarra N, Akata S, Uchida O, et al. Cine MRI enables better therapeutic planning than CT in cases of possible lung cancer chest wall invasion. *Lung Cancer* 2010;69:203-8.
48. Akata S, Kajiwarra N, Park J, et al. Evaluation of chest wall invasion by lung cancer using respiratory dynamic MRI. *J Med Imaging Radiat Oncol* 2008;52:36-9.
49. Carter BW, Benveniste MF, Betancourt SL, et al. Imaging Evaluation of Malignant Chest Wall Neoplasms. *Radiographics* 2016;36:1285-306.
50. Heelan RT, Demas BE, Caravelli JF, et al. Superior sulcus tumors: CT and MR imaging. *Radiology* 1989;170:637-41.
51. Guimaraes MD, Hochhegger B, Santos MK, et al. Magnetic resonance imaging of the chest in the evaluation of cancer patients: state of the art. *Radiol Bras* 2015;48:33-42.
52. Hierholzer J, Luo L, Bittner RC, et al. MRI and CT in the differential diagnosis of pleural disease. *Chest* 2000;118:604-9.
53. Proli C, De Sousa P, Jordan S, et al. A diagnostic cohort study on the accuracy of 18-fluorodeoxyglucose ((18)FDG) positron emission tomography (PET)-CT for evaluation of malignancy in anterior mediastinal lesions: the DECiMaL study. *BMJ Open* 2018;8:e019471.

54. Jerushalmi J, Frenkel A, Bar-Shalom R, Khoury J, Israel O. Physiologic thymic uptake of 18F-FDG in children and young adults: a PET/CT evaluation of incidence, patterns, and relationship to treatment. *J Nucl Med* 2009;50:849-53.
55. Yabuuchi H, Matsuo Y, Abe K, et al. Anterior mediastinal solid tumours in adults: characterisation using dynamic contrast-enhanced MRI, diffusion-weighted MRI, and FDG-PET/CT. *Clin Radiol* 2015;70:1289-98.
56. Kitami A, Sano F, Ohashi S, et al. The Usefulness of Positron-Emission Tomography Findings in the Management of Anterior Mediastinal Tumors. *Ann Thorac Cardiovasc Surg* 2017;23:26-30.
57. Luzzi L, Campione A, Gorla A, et al. Role of fluorine-fluorodeoxyglucose positron emission tomography/computed tomography in preoperative assessment of anterior mediastinal masses. *Eur J Cardiothorac Surg* 2009;36:475-9.
58. Prunte R, Restrepo CS, Ocazionez D, Suby-Long T, Vargas D. Fatty lesions in and around the heart: a pictorial review. *Br J Radiol* 2015;88:20150157.
59. Totanarungroj K, Watcharaporn C, Muangman N. Helpful CT findings for giving specific diagnosis of anterior mediastinal tumors. *J Med Assoc Thai* 2010;93:489-96.
60. Mitchell DG, Crovello M, Matteucci T, Petersen RO, Miettinen MM. Benign adrenocortical masses: diagnosis with chemical shift MR imaging. *Radiology* 1992;185:345-51.
61. Priola AM, Priola SM, Ciccone G, et al. Differentiation of rebound and lymphoid thymic hyperplasia from anterior mediastinal tumors with dual-echo chemical-shift MR imaging in adulthood: reliability of the chemical-shift ratio and signal intensity index. *Radiology* 2015;274:238-49.
62. Douis H, Saifuddin A. The imaging of cartilaginous bone tumours. I. Benign lesions. *Skeletal Radiol* 2012;41:1195-212.
63. Shiraj S, Kim HK, Anton C, Horn PS, Laor T. Spatial variation of T2 relaxation times of patellar cartilage and physeal patency: an in vivo study in children and young adults. *AJR Am J Roentgenol* 2014;202:W292-7.
64. Hricak H, Tscholakoff D, Heinrichs L, et al. Uterine leiomyomas: correlation of MR, histopathologic findings, and symptoms. *Radiology* 1986;158:385-91.
65. Levesque MH, Aisagbonhi O, Digumarthy S, Wright CD, Ackman JB. Primary Paratracheal Leiomyoma: Increased Preoperative Diagnostic Specificity With Magnetic Resonance Imaging. *Ann Thorac Surg* 2016;102:e151-4.
66. Garrana SH, Buckley JR, Rosado-de-Christenson ML, Martinez-Jimenez S, Munoz P, Borsa JJ. Multimodality Imaging of Focal and Diffuse Fibrosing Mediastinitis. *Radiographics* 2019;39:651-67.
67. Chung JH, Cox CW, Forssen AV, Biederer J, Puderbach M, Lynch DA. The dark lymph node sign on magnetic resonance imaging: a novel finding in patients with sarcoidosis. *J Thorac Imaging* 2014;29:125-9.
68. Khashper A, Addley HC, Abourobah N, Nougaret S, Sala E, Reinhold C. T2-hypointense adnexal lesions: an imaging algorithm. *Radiographics* 2012;32:1047-64.
69. Madan R, Ratanaprasatporn L, Ratanaprasatporn L, Carter BW, Ackman JB. Cystic mediastinal masses and the role of MRI. *Clin Imaging* 2018;50:68-77.
70. Shin KE, Yi CA, Kim TS, et al. Diffusion-weighted MRI for distinguishing non-neoplastic cysts from solid masses in the mediastinum: problem-solving in mediastinal masses of indeterminate internal characteristics on CT. *Eur Radiol* 2014;24:677-84.
71. Abdel Razek AA, Khairy M, Nada N. Diffusion-weighted MR imaging in thymic epithelial tumors: correlation with World Health Organization classification and clinical staging. *Radiology* 2014;273:268-75.
72. Sakai S, Murayama S, Soeda H, Matsuo Y, Ono M, Masuda K. Differential diagnosis between thymoma and non-thymoma by dynamic MR imaging. *Acta Radiol* 2002;43:262-8.
73. Erasmus JJ, McAdams HP, Donnelly LF, Spritzer CE. MR imaging of mediastinal masses. *Magn Reson Imaging Clin N Am* 2000;8:59-89.
74. Tanaka O, Kiryu T, Hirose Y, Iwata H, Hoshi H. Neurogenic tumors of the mediastinum and chest wall: MR imaging appearance. *J Thorac Imaging*. Vol 20. 2005/11/12 ed; 2005:316-20.
75. Nakazono T, White CS, Yamasaki F, et al. MRI findings of mediastinal neurogenic tumors. *AJR Am J Roentgenol* 2011;197:W643-52.
76. Guan YB, Zhang WD, Zeng QS, Chen GQ, He JX. CT and MRI findings of thoracic ganglioneuroma. *Br J Radiol* 2012;85:e365-72.

77. Ozawa Y, Kobayashi S, Hara M, Shibamoto Y. Morphological differences between schwannomas and ganglioneuromas in the mediastinum: utility of the craniocaudal length to major axis ratio. *Br J Radiol* 2014;87:20130777.
78. Priola AM, Gned D, Marci V, Veltri A, Priola SM. Diffusion-weighted MRI in a case of nonsuppressing rebound thymic hyperplasia on chemical-shift MRI. *Jpn J Radiol* 2015;33:158-63.
79. Priola AM, Priola SM, Gned D, Giraudo MT, Veltri A. Nonsuppressing normal thymus on chemical-shift MR imaging and anterior mediastinal lymphoma: differentiation with diffusion-weighted MR imaging by using the apparent diffusion coefficient. *Eur Radiol* 2018;28:1427-37.
80. Kiryu S, Loring SH, Mori Y, Rofsky NM, Hatabu H, Takahashi M. Quantitative analysis of the velocity and synchronicity of diaphragmatic motion: dynamic MRI in different postures. *Magnetic resonance imaging* 2006;24:1325-32.
81. Kolar P, Neuwirth J, Sanda J, et al. Analysis of diaphragm movement during tidal breathing and during its activation while breath holding using MRI synchronized with spirometry. *Physiological research / Academia Scientiarum Bohemoslovaca* 2009;58:383-92.
82. Kolar P, Sulc J, Kyncl M, et al. Stabilizing function of the diaphragm: dynamic MRI and synchronized spirometric assessment. *J Appl Physiol* (1985) 2010;109:1064-71.
83. Gierada DS, Curtin JJ, Erickson SJ, Prost RW, Strandt JA, Goodman LR. Diaphragmatic motion: fast gradient-recalled-echo MR imaging in healthy subjects. *Radiology* 1995;194:879-84.
84. Unal O, Arslan H, Uzun K, Ozbay B, Sakarya ME. Evaluation of diaphragmatic movement with MR fluoroscopy in chronic obstructive pulmonary disease. *Clin Imaging* 2000;24:347-50.
85. Feragalli B, Mantini C, Patea RL, De Filippis F, Di Nicola E, Storto ML. Radiographic evaluation of mediastinal lines as a diagnostic approach to occult or subtle mediastinal abnormalities. *Radiol Med* 2011;116:532-47.
86. Proto AV. Mediastinal anatomy: emphasis on conventional images with anatomic and computed tomographic correlations. *J Thorac Imaging* 1987;2:1-48.
87. Giron J, Fajadet P, Sans N, et al. Diagnostic approach to mediastinal masses. *Eur J Radiol* 1998;27:21-42.
88. Gibbs JM, Chandrasekhar CA, Ferguson EC, Oldham SA. Lines and stripes: where did they go?--From conventional radiography to CT. *Radiographics* 2007;27:33-48.
89. Wang D, Zhang J, Liu Y, et al. Diagnostic Value of Transthoracic Echocardiography Combined With Contrast-Enhanced Ultrasonography in Mediastinal Masses. *J Ultrasound Med* 2019;38:415-22.
90. Zhou WW, Wang HW, Liu NN, et al. Diagnosis of malignancy of adult mediastinal tumors by conventional and transesophageal echocardiography. *Chin Med J (Engl)* 2015;128:1047-51.
91. Martelli M, Ceriani L, Zucca E, et al. [18F]fluorodeoxyglucose positron emission tomography predicts survival after chemoimmunotherapy for primary mediastinal large B-cell lymphoma: results of the International Extranodal Lymphoma Study Group IELSG-26 Study. *J Clin Oncol* 2014;32:1769-75.
92. Ceriani L, Martelli M, Zinzani PL, et al. Utility of baseline 18FDG-PET/CT functional parameters in defining prognosis of primary mediastinal (thymic) large B-cell lymphoma. *Blood* 2015;126:950-6.
93. Nagle SJ, Chong EA, Chekol S, et al. The role of FDG-PET imaging as a prognostic marker of outcome in primary mediastinal B-cell lymphoma. *Cancer Med* 2015;4:7-15.
94. Filippi AR, Piva C, Levis M, et al. Prognostic Role of Pre-Radiation Therapy (18)F-Fluorodeoxyglucose Positron Emission Tomography for Primary Mediastinal B-Cell Lymphomas Treated with R-CHOP or R-CHOP-Like Chemotherapy Plus Radiation. *Int J Radiat Oncol Biol Phys* 2016;95:1239-43.
95. Ceriani L, Milan L, Martelli M, et al. Metabolic heterogeneity on baseline 18FDG-PET/CT scan is a predictor of outcome in primary mediastinal B-cell lymphoma. *Blood* 2018;132:179-86.
96. Lazarovici J, Terroir M, Arfi-Rouche J, et al. Poor predictive value of positive interim FDG-PET/CT in primary mediastinal large B-cell lymphoma. *Eur J Nucl Med Mol Imaging* 2017;44:2018-24.
97. Cheson BD. Staging and response assessment in lymphomas: the new Lugano classification. *Chin Clin Oncol* 2015;4:5.
98. Cheah CY, Hofman MS, Seymour JF, et al. The utility and limitations of (18)F-fluorodeoxyglucose positron emission tomography with computed tomography in patients with primary mediastinal B-cell lymphoma: single institution experience and literature review. *Leuk Lymphoma* 2015;56:49-56.
99. El-Bawab HY, Abouzied MM, Rafay MA, Hajjar WM, Saleh WM, Alkattan KM. Clinical use of combined positron emission tomography and computed tomography in thymoma recurrence. *Interact Cardiovasc Thorac Surg* 2010;11:395-9.

100. Kerpel A, Beytelman A, Ofek E, Marom EM. Magnetic Resonance Imaging for the Follow-up of Treated Thymic Epithelial Malignancies. *J Thorac Imaging* 2019;34:345-50.
101. de Margerie-Mellon C, de Bazelaire C, Amorim S, et al. Diagnostic Yield and Safety of Computed Tomography-guided Mediastinal Core Needle Biopsies. *J Thorac Imaging* 2015;30:319-27.
102. Petranovic M, Gilman MD, Muniappan A, et al. Diagnostic Yield of CT-Guided Percutaneous Transthoracic Needle Biopsy for Diagnosis of Anterior Mediastinal Masses. *AJR Am J Roentgenol* 2015;205:774-9.
103. Piplani S, Mannan R, Lalit M, Manjari M, Bhasin TS, Bawa J. Cytologic-radiologic correlation using transthoracic CT-guided FNA for lung and mediastinal masses: our experience. *Anal Cell Pathol (Amst)* 2014;2014:343461.
104. Yokoyama K, Ikeda O, Kawanaka K, et al. Comparison of CT-guided percutaneous biopsy with and without registration of prior PET/CT images to diagnose mediastinal tumors. *Cardiovasc Intervent Radiol* 2014;37:1306-11.
105. Cao BS, Wu JH, Li XL, Deng J, Liao GQ. Sonographically guided transthoracic biopsy of peripheral lung and mediastinal lesions: role of contrast-enhanced sonography. *J Ultrasound Med* 2011;30:1479-90.
106. Chen HJ, Liao WC, Liang SJ, Li CH, Tu CY, Hsu WH. Diagnostic impact of color Doppler ultrasound-guided core biopsy on fine-needle aspiration of anterior mediastinal masses. *Ultrasound Med Biol* 2014;40:2768-76.
107. Koegelenberg CF, Bolliger CT, Irusen EM, et al. The diagnostic yield and safety of ultrasound-assisted transthoracic fine-needle aspiration of drowned lung. *Respiration* 2011;81:26-31.
108. Zhou JH, Shan HB, Ou W, et al. Contrast-Enhanced Ultrasound Improves the Pathological Outcomes of US-Guided Core Needle Biopsy That Targets the Viable Area of Anterior Mediastinal Masses. *Biomed Res Int* 2018;2018:9825709.
109. Wahidi MM, Herth F, Yasufuku K, et al. Technical Aspects of Endobronchial Ultrasound-Guided Transbronchial Needle Aspiration: CHEST Guideline and Expert Panel Report. *Chest* 2016;149:816-35.
110. Guimaraes MD, Hochhegger B, Benveniste MF, et al. Improving CT-guided transthoracic biopsy of mediastinal lesions by diffusion-weighted magnetic resonance imaging. *Clinics (Sao Paulo)* 2014;69:787-91.
111. Garnon J, Ramamurthy N, Caudrelier J J, et al. MRI-Guided Percutaneous Biopsy of Mediastinal Masses Using a Large Bore Magnet: Technical Feasibility. *CardioVascular and Interventional Radiology* 2015;39:761-67.
112. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed September 30, 2020.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.