Image-Guided Biopsies and Interventions of Mediastinal Lesions

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KEYWORDS

• Mediastinal biopsy • Tissue sampling • Mediastinal tumor • Mediastinal ablation • Cryoablation

KEY POINTS

- For mediastinal biopsies, image guidance is necessary for targeting the lesion and developing an overall plan. Although computed tomography is the most common imaging modality used for this purpose, ultrasound may be used in some scenarios.
- Mediastinal biopsy using a coaxial needle and gun has gained acceptance over fine-needle aspiration due to increased accuracy, particularly for lymphoma.
- To avoid complications and ensure patient safety, biopsy needles should not be targeted toward pulsating organs or vascular structures.
- Mediastinal ablation procedures for limited metastasis and recurrent tumor after initial surgical resection or radiation therapy are being performed more frequently.
- Cryoablation for mediastinal neoplasms is well tolerated by patients, although the heat sink can lead to incomplete ablation and local recurrence.

INTRODUCTION

Management of mediastinal masses requires accurate diagnosis to develop appropriate treatment strategies. Image-guided transthoracic biopsy of mediastinal lesions is a minimally invasive and relatively safe procedure that can be used to obtain histologic samples under local anesthesia and conscious sedation, tailor the treatment plans, and potentially obviate more invasive diagnostic procedures. Not all mediastinal masses require biopsy, as certain lesions demonstrate characteristic imaging features that enable diagnosis. Examples of such entities that can be solely diagnosed on clinical and imaging characteristics are retrosternal goiter and asymptomatic visceral compartment cystic lesions such as bronchogenic cyst or esophageal duplication cyst.[1] In addition, in certain clinical conditions, transthoracic needle biopsy of a mediastinal lesion is contraindicated, including uncontrollable cough, bleeding diathesis (international normalized ratio [INR]>1.4; platelet count <50000/mL; increased prothrombin time with INR>1.5 or partial thromboplastin time >1.5 times greater than the normal range), bullous emphysema, and moderate-to-severe pulmonary hypertension. In addition, when there is a characteristic hydatid cyst or a vascular lesion on computed tomography (CT), biopsy should be avoided.[2–4]

Image-guided transthoracic needle biopsy is regarded as the reliable, cost-effective, and standard method of choice for obtaining specimens from mediastinal lesions. Biopsy planning can be performed via CT, magnetic resonance (MR)

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imaging or ultrasound. Each of these methods has its inherent advantages and disadvantages. Percutaneous image-guided sampling is performed by fine-needle aspiration or core needle biopsy. The choice of technique depends on the lesion characteristics, location, patient comorbidities, and the experience of the operating physician.

This article reviews the various image-guided strategies for biopsy of mediastinal lesions with focus on the diagnostic yield, clinical relevance, technical aspects of biopsy performance, and possible complications. The role of mediastinal ablation for treating conditions such as limited mediastinal metastasis and recurrent thymoma and malignant pleural mesothelioma will also be described. Finally, the use of image guidance for draining mediastinal collections and benign cystic lesions is briefly discussed.

IMAGING MODALITIES AND CLINICAL RELEVANCE

Image-guided mediastinal biopsy can be performed using different modalities including CT, MR imaging, and ultrasound, with CT remaining, which is used most frequently. The diagnostic yield is defined as the proportion of the diagnostic results achieved by image-guided biopsy, whereas diagnostic accuracy is the proportion of the correct diagnoses relative to the final diagnosis of the lesion. Overall, lymphoma and thymoma are the most common mediastinal mass lesions diagnosed with image-guided biopsy.

Tissue diagnosis is an essential step for management of prevascular mediastinal lesions, except in those with typical imaging features of a cyst. Image-guided biopsy is the least invasive initial method to obtain tissue, as it can obviate more invasive procedures such as mediastinoscopy and anterior mediastinotomy. The sensitivity of needle biopsy in diagnosing prevascular mediastinal lesions depends on tumor type. Most of the nondiagnostic mediastinal biopsies are later diagnosed as lymphoma. The diagnostic yield of percutaneous biopsy for mediastinal lymphoma varies and is based on the pathologic subtype of lymphoma. Fine-needle aspiration has low diagnostic yield for lymphoma, whereas core needle biopsy increases the diagnostic accuracy, in particular, for Hodgkin lymphoma.[5]

Computed Tomography

CT is the most commonly used modality for localization of mediastinal lesions and documentation of biopsy needle track.[6] A meta-analysis of 1345 CT-guided core needle biopsies of mediastinal masses from 18 studies found pooled diagnostic yield of 92% with 94% diagnostic accuracy. They showed that diagnostic yield and accuracy were significantly higher in studies with 3 or higher sampled cores.[7] CT scan allows for accurate targeting and assesses for complications during and immediately after biopsy, for example, pneumothorax or pleural effusion, which can be missed with ultrasound.

MR Imaging

MR imaging may have some advantages over CT, including its superior soft tissue resolution, real-time multiplanar imaging capabilities, excellent delineation of the vascular structures, and lack of ionizing radiation. It is also the preferred modality to assess the paravertebral lesions with possible neural origin. MR imaging, however, is limited by higher costs, longer procedure time, motion artifact, and paramagnetic artifact from usual biopsy needles, which can limit visualization of small lesions or the needle trajectory path in some patients. Garnon and colleagues were the first to describe the use of MR-targeted biopsy of mediastinal lesions in 16 individuals using wide-bore high-filed scanner. They reported a technical success and accuracy of 100% and 87.5%, respectively, with a mean procedure duration of 42 minutes, without any immediate complications.[8]

Ultrasound

Certain mediastinal lesions may be accessible through ultrasound guidance. The technique is practical when the mediastinal lesions are adequately imaged by ultrasound, including those located in the high prevascular mediastinum or those that are adjacent to or protrude through the chest wall. Ultrasound is cost-effective, time saving, and feasible for sampling of mediastinal lesions with diagnostic yield of 80% to 100%.[9–12] Advantages of ultrasound are continuous real-time needle and target visualization, the ability for oblique needle placement, needle slope manipulation or changing the patient's position during procedure, and the possibility to perform the targeted biopsy at the bedside of critically ill patients. These features are difficult or impossible to perform under CT guidance. The additional use of color Doppler ultrasound can help avoid the vascular structures during procedure.[13] The main limitation of ultrasound is the limited acoustic window. In the largest series of ultrasound-guided biopsies of mediastinal lesions, Petkov and colleagues[12] evaluated the efficacy of using ultrasound guidance for sampling mediastinal masses larger than 15 mm in 566 patients. The target lesion was visible on ultrasound in 54.4% (91.9% in prevascular, 0.6% in visceral, and 7.5% in paravertebral mediastinum) of the study cohort, in whom ultrasound-guided core needle biopsy was performed. In the individuals with nonvisible lesions on ultrasound, CT-guided transthoracic core needle biopsy was performed. The diagnostic yield of ultrasound-guided biopsy was 96%, comparable with 90% diagnostic accuracy in CT-guided biopsy.

The application of contrast-enhanced ultrasound can increase the diagnostic yield and diagnostic accuracy of biopsy compared with conventional ultrasound guidance. Contrast-enhanced ultrasound allows detection of necrotic and nonviable areas within the mass to be precluded from sampling.[14,15]

TECHNICAL CONSIDERATIONS

Needle Selection

Several types of needles with different caliber can be used for sampling mediastinal lesions. Needle selection depends on the presumptive diagnosis, size of the lesion, lesion depth from skin, proximity of the vital structures to the biopsy path, and the operating radiologist experience. Cutting-bore or Tru-Cut guns, ranging from 14 to 20 gauge in caliber, can be used to obtain specimen for histologic evaluation and are usually introduced through a coaxial needle. The most common size combination is the 19-gauge coaxial needle and 20-gauge gun. Aspiration needles, ranging from 20 to 23 gauge in caliber are used for cytologic evaluation. Adequate tissue target sampling and diagnostic accuracy are more achievable using core needle biopsy than fine-needle aspiration.[16] Fine-needle aspiration has high sensitivity for obtaining tissue specimens from cystic masses or malignant metastatic lesions; however, it has a relatively low diagnostic yield for the diagnosis of lymphoma. A combination of fine-needle and multiple (ie, 3–5) core needle biopsies has higher diagnostic performance for this purpose. Overall, fine-needle aspiration was the preferred strategy in lesions that are adjacent to vital structures (such as the great vessels), in transpulmonary approach for biopsy, and specifically when a metastatic disease is the first clinical impression.[16] Currently, the most common biopsy technique uses the coaxial system, which is preferred by most radiologists. The guide coaxial needle is placed in a position near or in the target lesion and then a biopsy gun is advanced through the coaxial system to obtain the specimen. Coaxial systems help reduce the number of passes and the possibility of iatrogenic injury to the vital structures. Larger caliber guns can provide much better tissue samples for genetic analysis and hence improve genomic sequencing in particular for lymphoma. In circumstances where tissue is accessible and size of tumor is larger than 1.5 cm, 17-/18-gauge coaxial/gun systems are preferred.[17]

Biopsy Procedure

Image-guided mediastinal biopsy is routinely performed under conscious sedation by using midazolam and/or fentanyl citrate. In noncooperative patients and in pediatric patients, deep sedation or general anesthesia is usually necessary. Local anesthetics (eg, 5–10 mL 1% solution of Lidocaine) are administered before the procedure. Patients may be placed in the supine, prone, or lateral decubitus position based on the selected biopsy approach and the anatomic location of the target lesion. Simple positioning of the patient in the oblique decubitus can allow for mediastinal shift and the mass to move into an accessible needle trajectory approach in order to avoid traversing lung. Before beginning the procedure, the lesion is reassessed on previously acquired cross-sectional images or ultrasound. When prior fluorodeoxyglucose (FDG) PET/CT is available, the most FDG-avid portions of the mediastinal mass lesion are targeted. Repeat imaging examination may be necessary based on the individual case. When planning the path for the needle, it is important to choose a course that allows for the needle to be tangential to the mediastinal vessels in order to avoid targeting the needle toward pulsating organs or vascular structures.

For CT-guided biopsy, unenhanced CT with 3 mm slices is generally adequate to plan the procedure. In select high-risk cases, however, the use of intravenous contrast material could help delineate vascular structures, especially those that may be engulfed by tumor, in the needle trajectory. The optimal CT section is then marked on the skin with the axial laser localizer of the scanner. Radiopaque markers are positioned along the laser light beam, and the scan is repeated to localize the exact point of entry (**Fig. 1**A). A radiopaque marker is then replaced with a skin mark using an indelible pen. A repeat localizer CT is required in each step of needle advancement to ensure the safety of needle trajectory and readjust the biopsy needle when necessary (**Fig. 1**B). When the mediastinal fat contact with the biopsy needle is not satisfactory to ensure a safe needle trajectory, injection of physiologic saline or dilute contrast medium into the mediastinum can create a safe

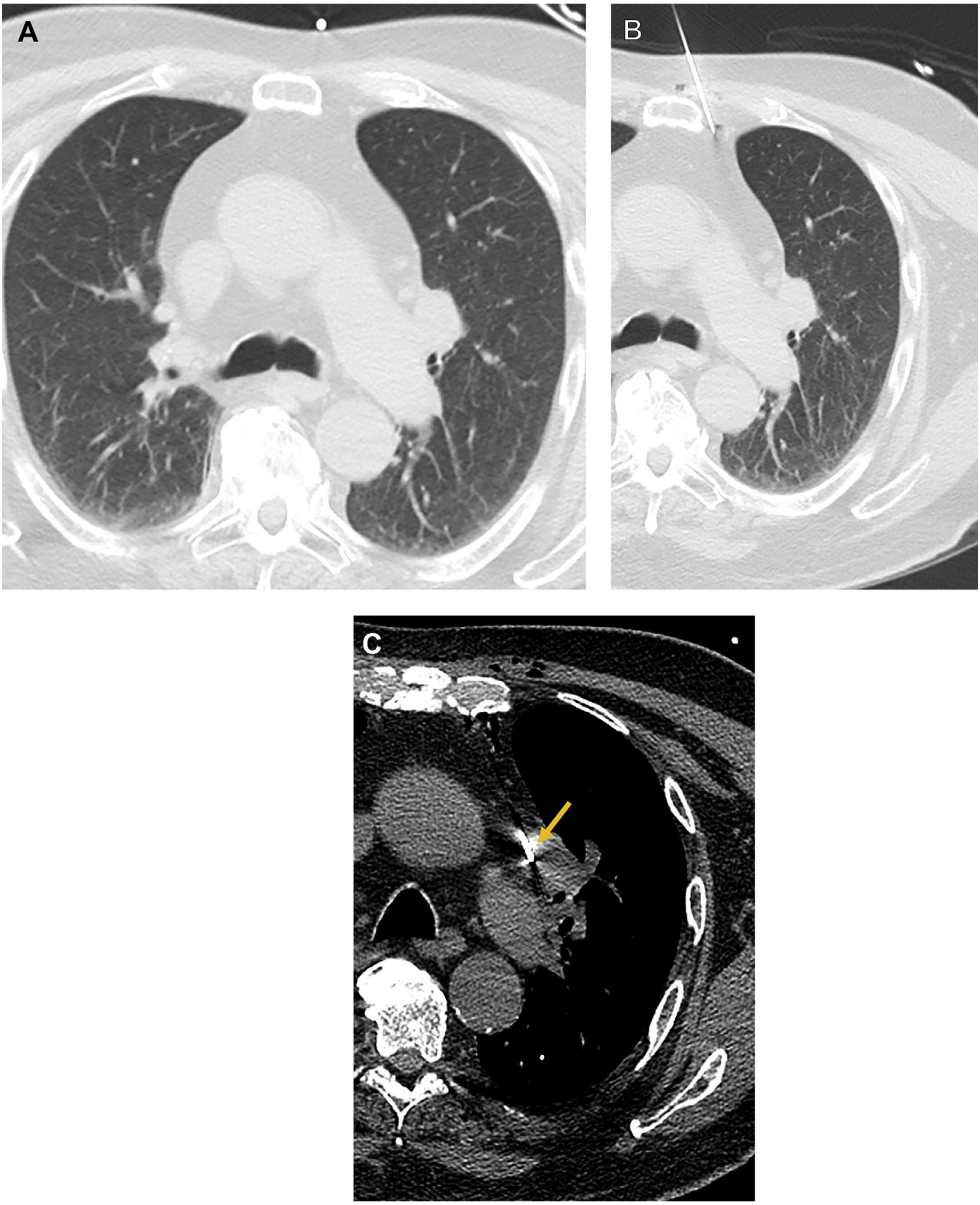

Fig. 1. CT-guided biopsy of left prevascular mediastinal mass. (*A*) A radiopaque marker is used on the skin to plan the trajectory. (*B*) The coaxial needle is incrementally advanced into the mediastinum. Using a parasternal approach, the needle is placed between the internal mammary vessels and sternum. Lidocaine can be used to displace the vessels away from the needle trajectory. (*C*) The needle is incrementally advanced until it is located within the lesion of interest (*arrow*).

extrapleural path for performing the biopsy[18] (**Fig. 1**).

For ultrasound-guided mediastinal biopsy procedures, a sector (2.0–2.5 MHz), convex (3.5–5–7.5 MHz), or linear (5–7.5–12.0 MHz) array transducer may be used by the operating radiologist based on the depth of the target lesion from skin and the available acoustic window. The gray scale B-mode imaging is used to direct the needle toward the target lesion, frequently accompanied by color doppler imaging to avoid the mediastinal vessels. In addition, a twinkling sign on color doppler ultrasound allows visualization of the biopsy needle. Needles may be introduced using a free-hand technique or a stretcher guide attached to the transducer. The free-hand technique allows manual movement of the needle into the target lesion under direct visualization.

When the radiologist will be acquiring specimens, it is important to be familiar with the biopsy system, particularly the loading of the gun and the extent of the "throw" beyond the coaxial needle. Injury by extension of the gun into vital structures is unacceptable. The number of samples obtained depends on the suspected disease and the radiologist's confidence. Typically, 2 to 5 cores are obtained per target lesion.

Iatrogenic pneumothorax can be used for mediastinal access without traversing a diseased lung. This approach adds extra time to the procedure but provides a much quicker recovery (**Fig. 2**).

Following the biopsy, patients may be observed on the scanner for 5 to 10 minutes to confirm the absence of bleeding before moving the patient to an observation unit. Patients are generally observed for at least 2 hours after the procedure to ensure hemodynamic stability and to monitor respiratory status. Imaging with chest radiographs or CT fluoroscopy is performed immediately after the procedure and 2 hours after the biopsy in patients in whom the pleura was punctured or when there has been respiratory distress.

Interventional Approaches

Mediastinal lesions can be accessed through parasternal, transsternal, suprasternal, paravertebral, subxiphoid, transpleural, and transpulmonary approaches. A transthyroid approach can also be attempted to access a retrotracheal target lesion. Transgression of the brachiocephalic vein using a small-caliber fine-needle aspiration needle is a safe and applicable method to obtain samples from target lesions through suprasternal, substernal, and parasternal approaches.

Parasternal

The parasternal route is the most common approach for sampling prevascular and visceral mediastinal lesions, specifically those that are located in the prevascular, pretracheal, paratracheal, and aorticopulmonary window stations. The technique is feasible under CT or ultrasound guidance. The biopsy needle is inserted lateral to the sternum, and the lesion is reached through the parasternal muscles and mediastinal fat. It is important to identify the internal thoracic arteries and veins to prevent vascular injury during the procedure.[19] The internal thoracic vessels can be identified within 2.5 cm of the either side of the sternum. The needle is placed either medial or lateral to the internal thoracic vessels that can be displaced by injecting saline with or without lidocaine (see **Fig. 1**B). In an ultrasound-guided parasternal approach, a small footprint probe is

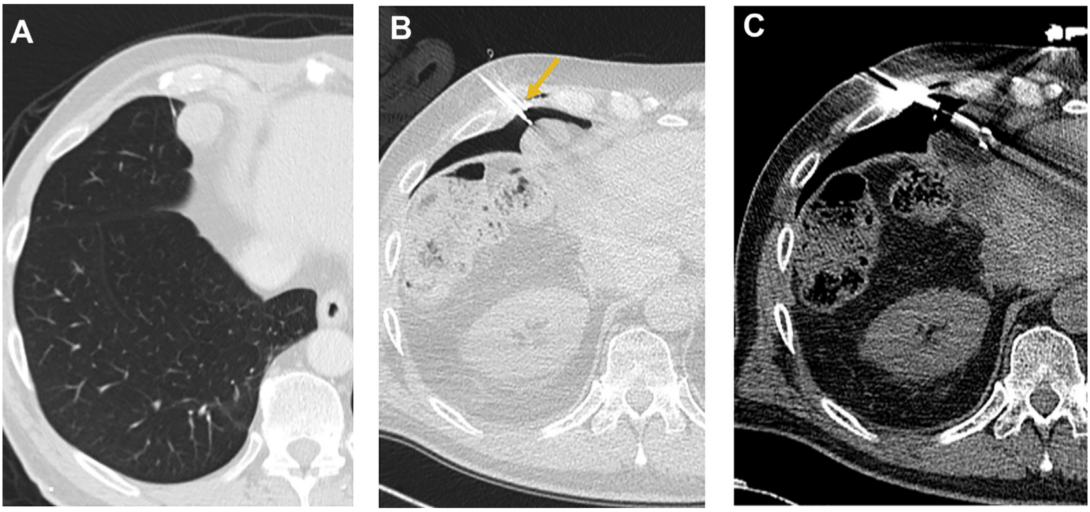

Fig. 2. CT-guided biopsy of endometrial carcinoma metastasis. (*A*) Unenhanced axial CT demonstrates the metastasis in the right cardiophrenic angle of the right prevascular mediastinum. (*B*) A coaxial needle was used to induce a small pneumothorax (*arrow*) followed by introduction of a second needle for biopsy and histopathological evaluation. (*C*) At the same visit, following the confirmation of metastasis, the lesion was treated with cryoablation. Two probes are present in the lesion, and a low-density cryozone ("iceball") is seen surrounding the tumor.

required considering the limited acoustic window resulting from anterior curvature of the ribs and costal cartilages (**Fig. 3**).

Transsternal

This approach is reserved for prevascular mediastinal lesions, which are not readily accessible visceral and paravertebral mediastinal compartment lesions.[20] Mediastinal lesions can be accessed by this method without traversing pulmonary parenchyma or the risk of injury to internal thoracic vessels. The procedure, however, carries a small risk of injury to major vessels in the prevascular mediastinum. A coaxial bone biopsy system with an eccentric drill is used in this method. The procedure is performed under local anesthesia, and the anesthetic agent is administered to coat the anterior and posterior sternal periosteum (**Fig. 4**). Injection of the anesthetic agent before puncturing the posterior cortex of sternum can decrease possible patient discomfort.[20–22] The technique, however, has several limitations. It is not feasible in patients with previous sternotomy. In addition, the needle trajectory cannot be manipulated after sternal insertion. Further movement of arms and thorax cavity should be minimized after needle insertion, as it might alter the anatomy of the mediastinal mass. The amount of contact between sternum and mediastinum might change during biopsy, which can potentially cause pleural damage.

Suprasternal

This approach is practical under CT or ultrasound guidance for sampling high mediastinal lesions, specifically those that are located in the prevascular, pretracheal, right paratracheal, or aorticopulmonary window stations. The needle needs to be directed caudally while patient is lying in the supine position with a hyperextended neck.[10,23]

Paravertebral

This route is used for sampling paravertebral mediastinal and subcarinal lesions.[24–26] The patient may be placed in the prone, prone oblique, or lateral decubitus position, and the needle is introduced typically from right paravertebral space, between the endothoracic fascia and the parietal pleura to access the target lesion. When the access route is not wide enough, saline or dilute contrast material can be used for widening the extrapleural paravertebral space and displacing the mediastinal structures out of the needle path (**Fig. 5**). This approach can potentially cause injury to esophagus, azygos vein, vagus nerve, and intercostal vessels and nerves.[25]

Subxiphoid

A subxiphoid approach is used for drainage of pericardial effusions and sampling pericardial masses.[27] In this approach, the needle is placed below the xiphoid process and is angled cranially under CT or ultrasound guidance.

Transpleural

This approach is performed under CT guidance and requires the presence of a large pleural effusion or pneumothorax as a window. The patient position is flexible, and, therefore, this path might be beneficial for patients who have dyspnea and difficulty lying supine or in the prone positions.[24]

Transpulmonary

This approach is reserved for the target lesions that cannot be safely accessed with other routes. Mediastinal lymph nodes can be efficiently sampled with an 18-gauge core coaxial needle using the transpulmonary route. The procedure is performed under CT guidance with penetration of the pulmonary parenchyma and pleural layers and therefore carries the highest risk of

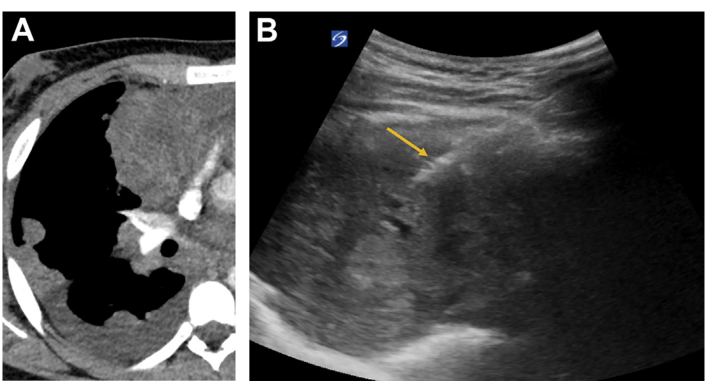

Fig. 3. Ultrasound-guided biopsy of a seminoma metastasis. (*A*) Contrast-enhanced axial CT demonstrates the right prevascular mediastinal mass with an adequate acoustic window for ultrasound-guided biopsy. (*B*) Ultrasound image shows a coaxial needle in the mass with a bright acoustic shadow (*arrow*). The edge of the sternum and intercostal muscles are clearly delineated with ultrasound.

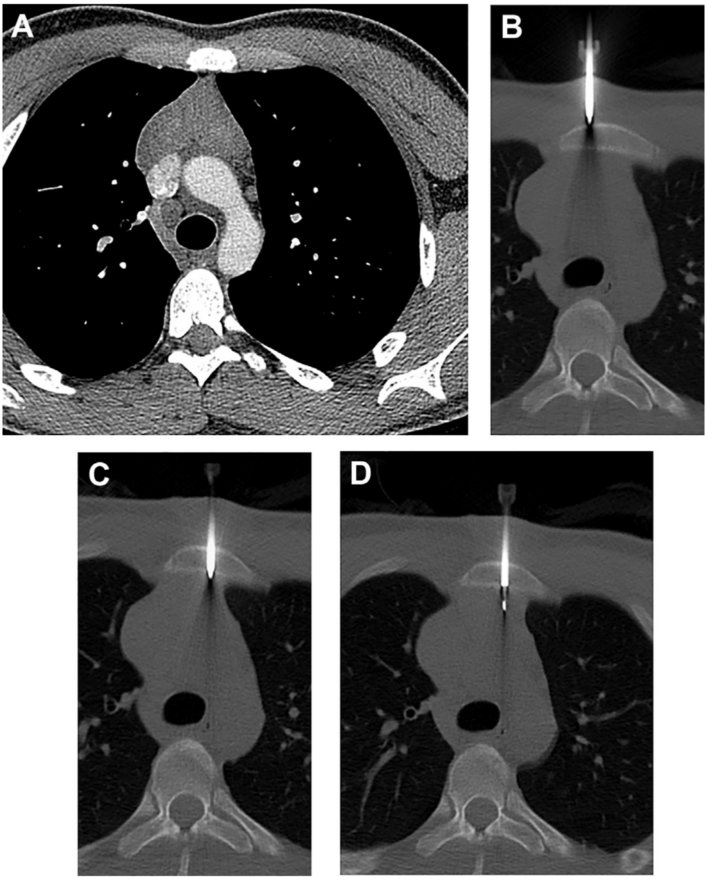

Fig. 4. CT-guided biopsy of a prevascular mediastinal mass in a 27-year-old man with night sweats. (*A*) Contrast-enhanced axial CT demonstrates a lobular mass in the prevascular mediastinum that was concerning for lymphoma. (*B, C*) Large-bore coaxial bone biopsy system is used to drill through the sternum. Once the posterior membrane is traversed, a coaxial needle can be used to sample the mediastinum. (*D*) Biopsy gun is placed through the bone biopsy coaxial needle to sample the mediastinal mass.

pneumothorax and alveolar hemorrhage, compared with other routes[24,28,29] (**Fig. 6**).

MEDIASTINAL ABLATIONS

Over the past several years, ablation modalities have improved to allow for treatment of an ever-expanding list of indications and placement of needles into the mediastinum for performing the procedures. Radiofrequency ablation was the initial ablation modality used in the mediastinum, with a series performed on mediastinal lymph nodes[30] demonstrating local control of up to 75% at 1 year for lymph nodes below 2 cm. However, the control was poor for lymph nodes larger than 2 cm.

Another more common indication for mediastinal ablation is local control of tumor following surgical resection or radiation therapy. Cryoablation has been used to provide local control of disease in patients with recurrent malignant pleural mesothelioma with many of the recurrences in the prevascular and paravertebral mediastinum. These recurrences were treated with cryoablation with a local control rate of 100% of cases at 30 days, 92.5% at 6 months, 90.8% at 1 year, 87.3% at 2 years, and 73.7% at 3 years[31] (**Fig. 7**). Another cohort that benefited from ablation was patients with thymoma who had undergone surgical resection with local recurrence and distant drop metastasis.[32] Cryoablation of these recurrent tumors provided local control of up to 90%. The recurrences after ablation were seen next to the thoracic aorta, which did not allow for complete ablation due to heat sink effect from the aorta.

Another indication for mediastinal ablation is the possible abscopal effect it may have during ongoing treatment with immunotherapy. Cryoablation is known to release tumor antigens that can induce an immune response against distant tumor cells; however, this immune response may not be large enough, and combining cryoablation with immune modulators has been shown to have a more symbiotic and robust response (**Fig. 8**).

OTHER IMAGE-GUIDED INTERVENTIONS

Percutaneous image-guided drainage can be used for treatment of mediastinal abscesses,

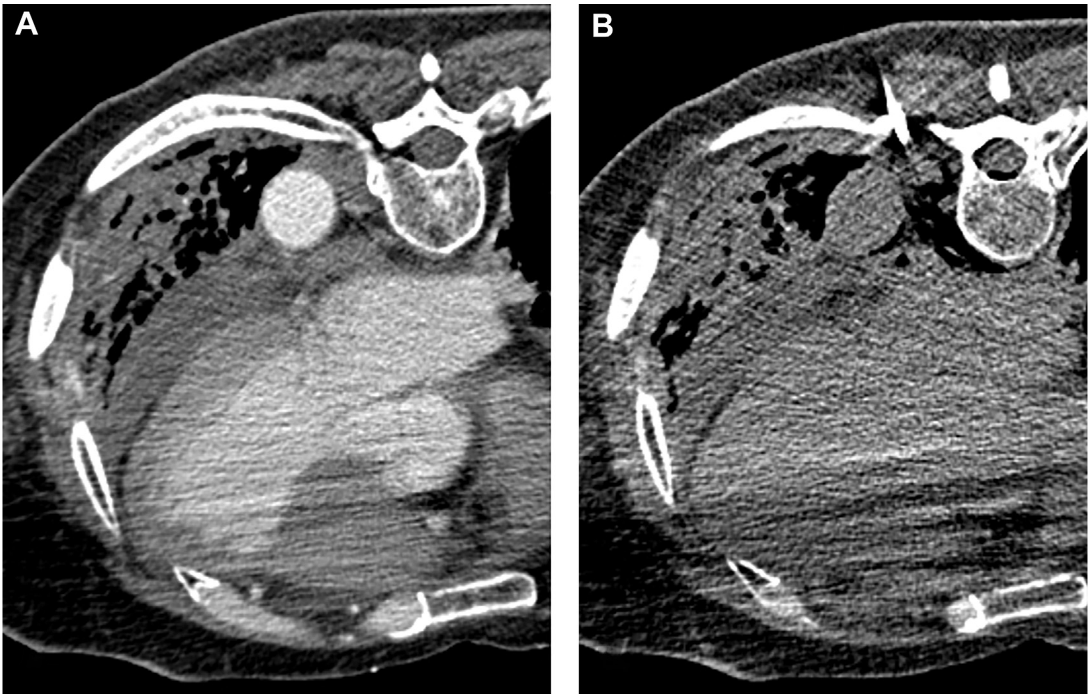

Fig. 5. CT-guided biopsy of a paravertebral mediastinal mass in a patient with prior thymoma. (*A*) Contrast-enhanced axial CT demonstrates a mass in the paravertebral mediastinum insinuating itself between the aorta and the spine. (*B*) A paravertebral approach is used to biopsy the lesion that was confirmed as recurrence.

which result from esophageal perforation, infectious process, or iatrogenic injuries.[33,34] The trocar and Seldinger techniques are the two standard approaches commonly used. The tandem trocar technique is a single-step procedure in which a localizing needle is first placed into the mediastinal collection followed by enlargement of a skin incision using a metal forceps and, finally, pushing a drainage catheter parallel (tandem) to the localizing needle. This technique is typically feasible for drainage of large and superficial collections. In the Seldinger technique, a 17- to 19-gauge needle is placed into the mediastinal collection and a fluid sample is obtained, followed by the

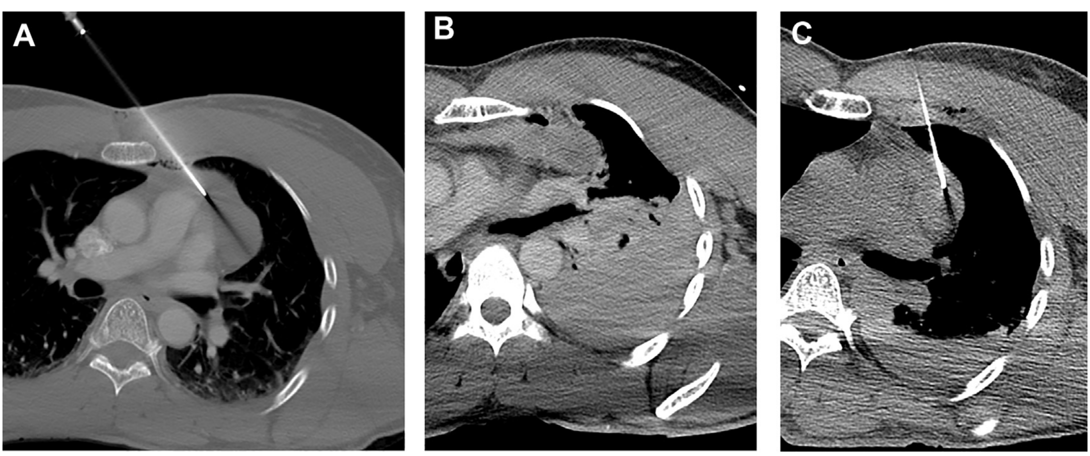

Fig. 6. CT-guided biopsy of a prevascular mediastinal mass in a 47-year-old woman. (*A*) Parasternal approach was selected for targeting the mass. (*B*) After obtaining the first sample, the patient complained of excruciating pain. A subsequent CT image demonstrates mediastinal and left pleural hemorrhage. (*C*) A repeat biopsy was performed 3 days later using a transpulmonary approach.

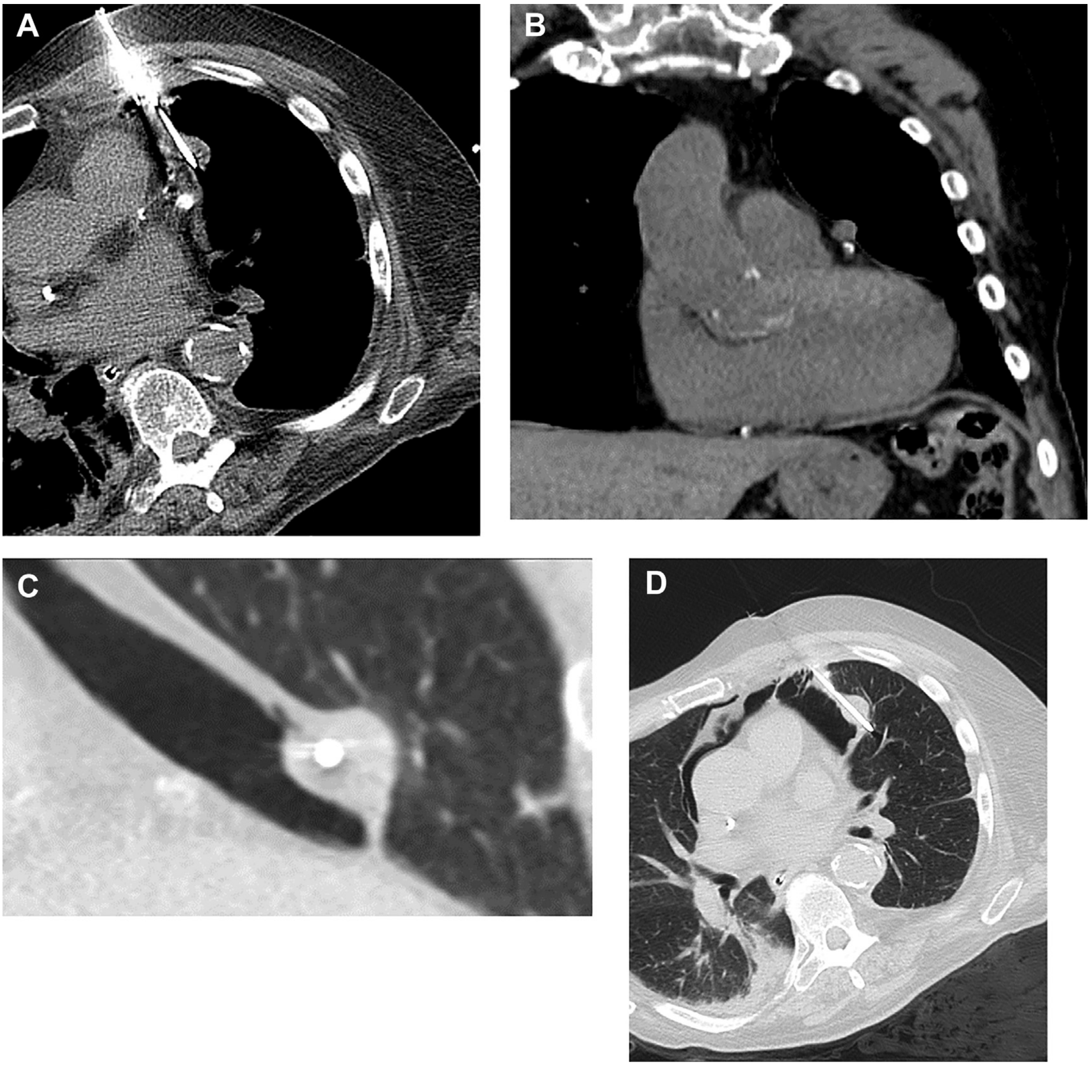

Fig. 7. CT-guided biopsy of recurrent mesothelioma. (*A, B*) CT images show that a prevascular mediastinal approach was used to place the cryoablation probe into the recurrent mesothelioma. (*C, D*) Pneumomediastinum was induced to displace the tumor from the left anterior descending coronary artery. The probe was also angulated laterally to increase the gap. Cryoablation was performed without any complications.

advancement of an 8- to 16-French pigtail catheter over a guidewire into the fluid collection. Both techniques require frequent intermittent CT acquisition during the procedure. Once the catheter location is confirmed inside the collection, the catheter is secured to the skin. Complete resolution is reported in 95.6% of the patients, with a mean catheter drainage time of 13.6 days, obviating further surgical intervention.[33] CT-guided drainage is also potentially useful for treatment of postoperative collections including those related to esophageal anastomotic leaks. Typically, surgical intervention is used for tissue debridement and mediastinal drainage in patients with postoperative anastomotic leak. If a CT-guided procedure is preferred, the drainage catheter needs to be placed close to the anastomotic leakage site to ensure effective drainage.[35]

Bronchogenic cysts may require therapeutic intervention when they produce significant clinical symptoms. Percutaneous transthoracic needle aspiration is an effective method for confirming the diagnosis and draining a suspected bronchogenic cyst. Simple aspiration may cause recurrence due to incomplete obliteration of the cyst lining; therefore, intracystic sclerotherapy with a sclerosant agent such as ethanol or bleomycin may be more efficient.[36,37]

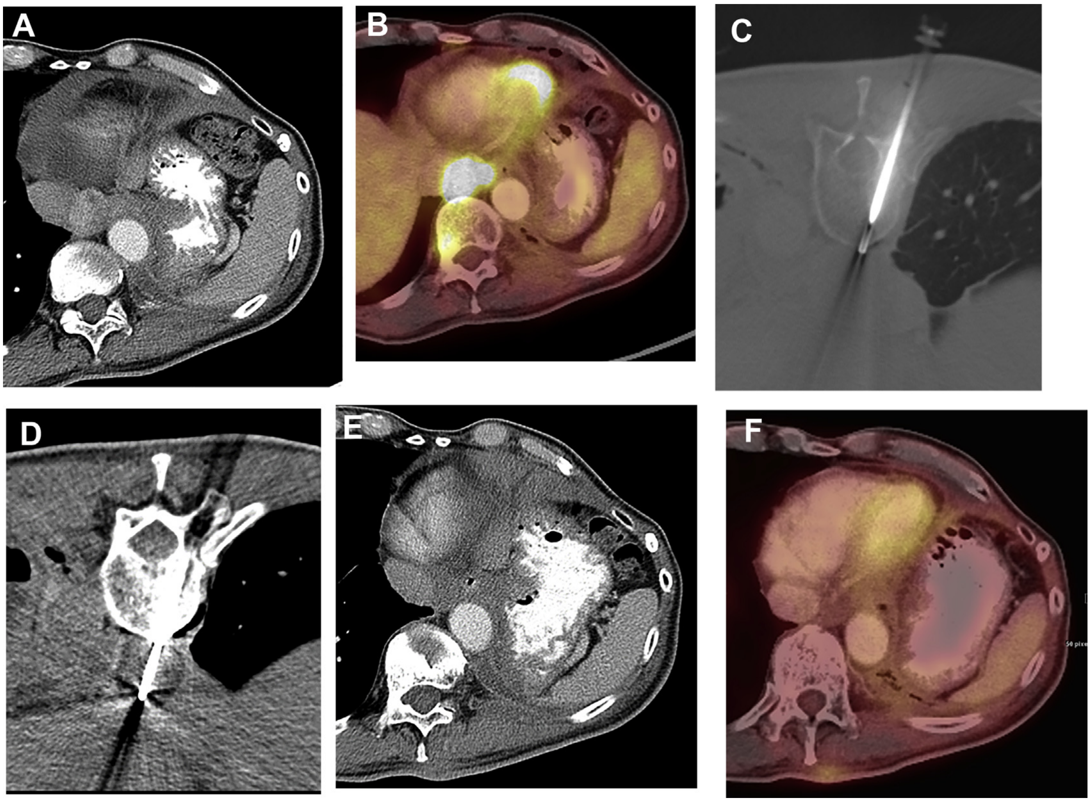

Fig. 8. CT-guided biopsy of a paravertebral mass in a 72-year-old man. (*A, B*) CT and FDG PET/CT demonstrate a paravertebral mass between the inferior vena cava, esophagus, and heart. Given the solitary lesion and planned immunotherapy, the plan was to perform cryoablation to take advantage of local control and abscopal effect. (*C, D*) Transvertebral approach was selected to avoid traversing the contralateral pleura and the possibility of seeding. The bone trocar is used to create a tract, and a cryoablation probe is placed through the trocar. An "iceball" is seen surrounding the cryoprobes. (*E, F*) FDG PET/CT performed 3 months later demonstrates a better than expected response to cryoablation, which may or may not be from an abscopal effect and cryoimmune response.

COMPLICATIONS

Several postprocedural complications have been described in image-guided mediastinal biopsies, including pneumothorax, chest wall hematoma, hemothorax, hemoptysis, and vasovagal syncope.[25] In a meta-analysis of 1345 core needle biopsies of mediastinal lesions, the total complication rate and major complication rates were 13% and 2%, respectively.[7] The figures are significantly lower than the reported complication rate of 38.8% for CT-guided lung biopsy mainly because of the lower rate of pneumothorax.[38] Biopsy of lesions in the visceral mediastinum is associated with a relatively higher risk of postprocedural complications, of which hemorrhage is the most common complication[39] (see **Fig. 6**B). The application of a small-caliber needle (18 gauge or higher) is associated with a significant decrease in the rate of postprocedural complications. Because no significant difference in the diagnostic accuracy has been found between 18-gauge and 20-gauge needles in the meta-analysis by Lee and colleagues,[7] the use of 20-gauge needle for core needle biopsy of mediastinal lesions may be sufficient, with the exception of lymphomas, which may require a greater amount of tissue.

Alveolar hemorrhage and hemoptysis are rare and mainly occur when the pulmonary parenchyma is markedly traversed by the biopsy needle (eg, when a transpulmonary approach is used for sampling the target lesion). Pneumothorax is by far the most common complication of transthoracic mediastinal biopsy. Small self-resolving pneumothoraces occur in 3.8% of CT-guided biopsy of prevascular mediastinal lesions.[5] The transpulmonary approach has the highest risk of pneumothorax. The most significant risk factors for developing pneumothorax in this technique include the distance between the pleura and the target lesion and the number of times in which the visceral pleura is penetrated.[28] Several

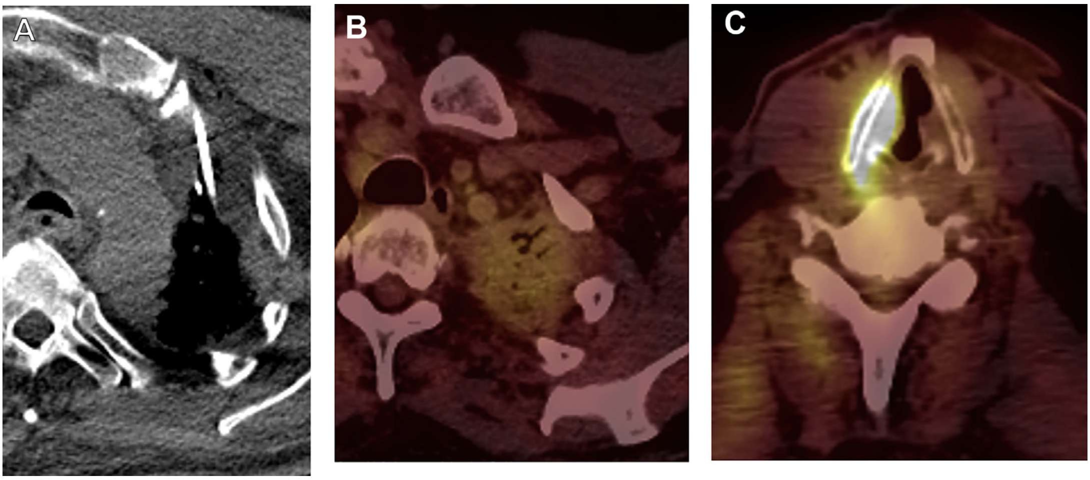

Fig. 9. CT-guided biopsy of recurrent mesothelioma. (*A*) CT demonstrates cryoablation with the hypodense "iceball" surrounding the needle and encroaching on the aortic arch. This trajectory is the expected location of the path taken by the recurrent laryngeal nerve. (*B, C*) FDG PET/CT obtained after ablation demonstrates residual ablation zone with no metabolic activity. However, evaluation of the vocal cords shows no activity in the left vocal cord, confirming paralysis due to nerve injury.

strategies may help decrease the rate of pneumothorax,[24] including the use of safer biopsy approaches such as transsternal and suprasternal routes, extrapleural saline injection,[40] manipulating patient position, and a protective "artificial pneumothorax." In the artificial pneumothorax technique,[41] about 200 mL of air is administered into the pleural space to deviate the lung away from the trajectory of the biopsy path and to sample the target lesion through air-containing pleura. After collecting satisfactory samples, the air is aspirated from the pleural space (see **Fig. 2**). If a pneumothorax develops during the procedure, the pleural air can be aspirated using the introducer needle or a separate needle.[42] An 18- to 20-gauge coaxial needle or small caliber catheter is inserted into the pleural space under real-time CT fluoroscopy and, using an extension tube and a 3-way stopcock, is connected to a 20 to 50 mL syringe. Manual pleural air aspiration by this method obviates use of chest tube placement in roughly 85% of the patients. When a pneumothorax persists, or is recurrent or large, chest tube placement should be considered.

It is stated that ultrasound-guided biopsy has lower complication rates than CT-guided biopsy. For example, Petkov and colleagues[12] reported a complication rate of 2.6% with ultrasound guidance versus 14.6% with CT guidance. The findings need to be interpreted with caution, as CT guidance is chosen for difficult-to-access or sonographically invisible lesions, which are more prone to procedural complications.

Nerve injury is uncommon with biopsies and is more frequent with ablations. The nerves most commonly injured include the recurrent laryngeal nerve, lower trunk of the brachial plexus, and the phrenic nerve. It is essential to plan the ablation with accurate understanding of nerve anatomy and using dissection techniques with fluid or air to avoid injury.[43] However, there are times in which the nerve may need to be sacrificed to obtain complete ablation and cover the tumor margins (**Fig. 9**).

FUTURE DIRECTIONS

In the era of precision medicine, patient-specific, evidence-based planning for sampling of mediastinal lesions is of great importance. The use of advanced imaging techniques with combination anatomic and functional information such as PET/CT allows localization of the specific component of the target lesion for more precise biopsy planning. The use of fusion techniques and development of robotic-assisted devices and navigational systems will improve access to target lesions, decrease the procedure time, and increase the accuracy. Several more flexible needles are being developed, which will allow steering the needle from outside of the body to reach to the specific target.

SUMMARY

Image-guided biopsy is safe and associated with high diagnostic yield and accuracy for histologic evaluation of mediastinal masses. Although CT remains the imaging modality of choice image guidance, ultrasound and MR imaging can be used in certain clinical scenarios. Mediastinal ablation can be performed in select patients with an ever-expanding list of indications and adequate local control rate. Finally, CT-guided drainage is an effective procedure for treatment of mediastinal collections and benign cystic lesions.

CLINICS CARE POINTS

- Image guided biopsy of mediastinal lesions is safe and provides a high diagnostic yield.
- The choice of imaging modality and the biopsy approach should be decided on a patient-by-patient basis.
- The core needle biopsy has a higher diagnostic yield for the diagnosis of mediastinal lymphoma.
- The coaxial system is the preferred method of sampling mediastinal lesions.
- Cryoablation of recurrent thymoma or malignant pleural mesothelioma has a short-term local control rate of 90-100%.
- Image-guided drainage is a safe and effective procedure for the treatment of mediastinal collections and benign mediastinal cystic lesions.

DISCLOSURE

The authors have nothing to disclose.

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