US Guidance for Thoracic Biopsy: A Valuable Alternative to CT[1]

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PURPOSE: To determine the role, accuracy, and selection criteria of ultrasonographic (US) guidance for biopsy of thoracic lesions.

MATERIALS AND METHODS: Imaging-guided thoracic biopsies ($n = 86$) were performed in 84 consecutive patients. US guidance was used for lesions abutting the chest wall; computed tomographic (CT) guidance was used for all masses surrounded by aerated lung. Mass location and size, guidance modality, histologic results, procedure time, and complications were recorded.

RESULTS: Thirty-four lesions (19 parenchymal, six pleural, six chest wall, three mediastinal) were amenable to US-guided biopsy. The mean mass diameter was 4.3 cm, the mean number of passes was 3.2, and the mean procedure time was 31.4 minutes. A histologic diagnosis was achieved in 31 (91%) patients, including all with small (<2-cm) masses ($n = 9$). There was one case of pneumothorax. CT guidance was used in 52 (60%) of 86 cases. Lesions were parenchymal ($n = 41$), pleural ($n = 1$), and mediastinal and hilar ($n = 10$). The mean diameter was 2.9 cm, the mean number of passes was 2.3, and the mean procedure time was 45.2 minutes. A histologic diagnosis was achieved in 37 (71%) patients, including 18 of 27 with a small mass. Complications included pneumothorax ($n = 21$) and parenchymal hemorrhage ($n = 2$).

CONCLUSION: US is an effective and safe alternative to CT for guidance at biopsy of masses abutting the chest wall. Real-time US visualization allows accurate needle placement, shorter procedure time, and performance in debilitated and less cooperative patients.

Imaging-guided percutaneous transthoracic biopsy has become a widely accepted and effective minimally invasive technique for the diagnosis of a variety of intrathoracic lesions that are not readily accessible with bronchoscopy. In the United States, this procedure is generally performed under fluoroscopic or computed tomographic (CT) guidance. Fluoroscopy offers the advantage of real-time guidance, speed, a lower rate of pneumothoraces, and lower cost. However, many lesions are not amenable to fluoroscopic guidance because of their small size, their proximity to major vessels or the diaphragm, or if they are obscured by a pleural effusion or atelectasis. CT is the preferred guidance modality for difficult parenchymal lesions and hilar and mediastinal masses (1,2). CT guidance is easy to learn and displays the needle tip exquisitely, but its main drawback is the lack of real-time guidance, the need to perform multiple section acquisitions, the longer procedure time, and a higher frequency of pneumothorax.

Although CT is favored in this country by many radiologists who perform percutaneous interventional procedures, ultrasonography (US) is gaining acceptance as an effective guidance modality, even for difficult or small lesions. Several recently published articles (3–6) have illustrated its role as the ''undiscovered jewel of interventional radiology'' (3). In the chest, the role of US has traditionally been limited to evaluation for pleural effusion and guidance for thoracentesis, although its role in the diagnosis of pulmonary, pleural, and mediastinal masses has been emphasized, primarily by authors in Europe and Asia (7–14). Until recently, all imaging-guided thoracic biopsies at our institution were routinely performed with CT guidance. For abdominal biopsies, we favor the use of US guidance because we have found it to be faster, easier, and less cumbersome. Our preliminary

encouraging results with US guidance for percutaneous biopsy of thoracic lesions led us to modify our approach and to use this modality whenever possible.

The purpose of the present study was to determine the criteria for triaging patients referred for thoracic biopsy and to demonstrate the effect of US guidance on procedure time, diagnostic yield, and complication rate.

MATERIALS AND METHODS

From June 1, 1997, to February 28, 1998, 84 consecutive patients underwent 86 percutaneous transthoracic biopsies. The procedure was requested because of a newly discovered mass in 43 patients or to evaluate for possible metastases in 34 patients with known malignancy (seven with breast cancer; six with head and neck cancer; five with lymphoma; two each with lung cancer, colon cancer, melanoma, myeloma, or sarcoma; and one each with meningioma or prostate, pancreatic, parotid, lung, or hepatocellular cancer). Biopsy of a nodular area of opacity or cavity wall was requested in seven patients, including two with serologic results that were positive for the human immunodeficiency virus and one who had undergone lung transplantation. Two patients had undergone a previous lobectomy, and recurrence near the resection site was suspected.

There were 38 female and 46 male patients, aged 7–81 years (average age, 61 years). All patients had undergone a complete diagnostic thoracic CT examination, the results of which were reviewed at the time of biopsy scheduling to determine which guidance modality should be chosen.

Lesions were considered to be suitable for US-guided biopsy if they were in contact with the chest wall for at least 1 cm, regardless of their size and location. Location behind a rib was not considered to be a contraindication to US guidance. All masses and areas of opacity with aerated lung interposed between the mass and the chest wall were scheduled for CT-guided biopsy. The location of the 86 lesions included lung parenchyma (n = 60); pleura (n = 7); chest wall (n = 6); and the anterior (n = 4), posterior (n = 2), and middle mediastinum and hilum (n = 7). Five parenchymal lesions and two of the six ill-defined opacities were cavitary. The maximum size of the mass was recorded.

At the time of biopsy, all patients had normal or corrected coagulation parameters (prothrombin time and activated partial thromboplastin time) and platelet count. Written informed consent was obtained in all cases. Patients scheduled for US-guided biopsy were advised in advance of the possibility of transfer to the CT suite if their lesion was not successfully visualized at US.

The technique for CT-guided biopsies has been previously described (1,2): Preliminary 5-mm-collimated CT scans were obtained to localize the lesion and select the optimal approach. A Somatom Plus (Siemens Medical Systems, Iselin, NJ) CT unit was used. The skin entry site was marked by using the laser light from the CT gantry and a grid placed on the patient's skin. Local anesthesia (2% lidocaine) up to the pleura was administered. Additional scans were obtained during passage of the needle through the chest wall and into the lesion to allow adjustment of the needle direction and to document the position of the needle tip inside the target prior to sampling. All scans for biopsy guidance were obtained without the administration of intravenous contrast material and were generally obtained at the end of expiration to achieve maximum consistency.

Our technique for US-guided biopsy was as follows: Pertinent images from the diagnostic CT scan were reviewed in the US suite, and preliminary localizing scans were obtained by using commercially available 3.5- or 4-MHz multifrequency sector transducers or a 5-MHz linear transducer (Acuson, Mountain View, Calif). When necessary, color Doppler was used to detect potential vessels in the path of the needle. Patients were given various breathing instructions, depending on the location of the lesion, to enable optimal visibility. Scans were obtained with the patient in the supine, prone, decubitus, or, when patients were dyspneic and could not comfortably lie flat (n = 3), semisitting position.

The biopsy was performed by using a 3.5-MHz sector transducer (most commonly) or a 5-MHz linear transducer (occasionally) with a needle-guide attachment. The transducer was held parallel to the rib space to ensure maximum contact with the chest wall and allow easy passage of the needle through the rib cage. Local anesthesia (2% lidocaine) was administered through the needle guide. Fine-needle aspiration was performed by using a 21-gauge needle (PerCú Cut; E-Z-Em, Westbury, NY) or a 22-gauge needle (Franseen; Bauer Medical, Clearwater, Fla). Cores were obtained by using a 20-gauge biopsy gun (Temno or Achieva; Bauer Medical). The biopsy needle was advanced through the needle guide into the lesion during suspended respiration under real-time visualization. After the needle tip was confirmed to be in the desired location, the biopsy was performed during continuous observation of the position of the needle tip to ensure that needle excursions were limited to the lesion. In large lesions, the periphery of the mass or areas deemed less necrotic on the basis of their US appearance were specifically targeted.

Biopsies were performed either by one of a group of four attending radiologists (S.S., U.M.H., J.H.W., P.A.S.) with special expertise in CT- and US-guided procedures or by residents and fellows under the close supervision of the attending radiologist.

The specimens were handled similarly regardless of the guidance modality used: Each fine-needle aspirate was immediately smeared onto glass slides, air dried, and stained with a modified Wright-Giemsa method (Diff-Quik; Dade International, Miami, Fla); a preliminary evaluation for specimen adequacy was given by the cytopathologist in attendance. Additional fine-needle aspirates and core biopsy specimens were obtained as necessary to achieve a preliminary diagnosis or until patient tolerance or development of a complication prevented further attempts.

At the completion of the procedure, all patients underwent expiratory chest radiography to detect a pneumothorax, and all outpatients were monitored for 3–4 hours in the recovery area. Positional restrictions were observed in all patients to decrease the risk of postprocedural pneumothorax.

For each biopsy, the procedure time from preparation of the skin to placement of a bandage on the puncture site was recorded. This did not include time spent for localizing the lesion. The total number of fine-needle aspirates and core biopsy specimens also was noted.

The success of each procedure was established at a review of the final pathology report and cultures when appropriate. We attempted to obtain clinical and/or imaging follow-up in cases where a diagnosis of malignancy was not established.

The location and size of the lesion, the number and type (fine-needle and core) of passes made, the procedure time, the diagnostic yield, and any complications were recorded. The two-tailed Student t test was used to compare procedure time and time per number of passes for each guidance modality, and a P value of less than .05 was considered to be statistically significant.

RESULTS

Of the 86 biopsies, 34 (40%) were performed with US guidance, and 52 (60%) were performed with CT guidance. CT guidance was used for all lesions surrounded by aerated lung, because such lesions would not be expected to be visible at US. Of the masses in contact with the chest wall, biopsy specimens in six were obtained with CT guidance: In two cases, the lesions either were not clearly seen at US or a safe approach was not found; in three cases, US was not attempted because of the patient's or the attending physician's preference (early in our experience) or because an immediate preprocedural CT examination was deemed necessary. In the last case, a cavitary mass was well visualized at US and the procedure was started, but because of preliminary nondiagnostic material, the procedure was completed under CT guidance, which allowed more clear demonstration of the cavity and aspiration of the cavity fluid.

At US, small peripheral masses appeared hypoechoic, and the echogenic interface between the lesion and the surrounding aerated lung was clearly demarcated (Fig 1). Larger and cavitary lesions were more heterogeneous (Figs 2, 3). The mean mass diameter was 4.3 cm (range, 1.2–10.0 cm) for lesions sampled at US-guided biopsy and 2.9 cm (range, 1–12 cm) for those sampled at CT-guided biopsy. Color Doppler US was used before and during the procedure in nine patients to identify major vessels or to detect tumor vascularity in necrotic masses. The characteristics, location, and size of the lesions are summarized in Table 1.

For US-guided biopsies, the average number of passes was 3.2 (range, 1–8); for CT-guided biopsies, the average number of passes was 2.3 (range, 1–6). Core biopsies were performed with US guidance in 14 cases and with CT guidance in seven cases (Table 2).

A definitive diagnosis was achieved in 68 (81%) of the 84 patients. Two patients underwent a repeat successful CT-guided biopsy after an initial nondiagnostic CT-guided biopsy. US-guided biopsy was successful in 31 (91%) of 34 cases, including in all nine masses that were 2 cm or smaller in diameter (Fig 4). Histopathologic diagnoses included primary or secondary carcinoma in 21 patients; lymphoma in four patients; scar tissue without tumor in two patients with a history of lobectomy for lung cancer; and, in one patient each, plasmocytoma, inflammatory pseudotumor, pneumonia, and lymphoid tissue. CT-guided biopsy results yielded a diagnosis in 37 (71%) of 52 cases, including 18 (67%) of 27 masses 2 cm in diameter or smaller. Histopathologic findings included primary or secondary carcinoma in 28 patients, inflammation in three patients with a nodular consolidation, aspergilloma in two patients, lymphoma in two patients, hamartoma in one patient, and lipoid pneumonia in one patient.

If the two cases where a repeat CT-guided biopsy was successful are excluded, there were 16 nondiagnostic biopsies, three with US guidance and 13 with CT guidance. Two of the three nondiagnostic US-guided biopsies were of ill-defined opacities that had resolved at follow-up, and one was a sampling of a cavity wall in a patient with sarcoidosis. Of the 13 CT-guided biopsies, eight were of deep parenchymal or hilar masses with a diameter of 2 cm or smaller. In two of these patients, development of a pneumothorax or parenchymal hemorrhage led to premature termination of the procedure after the first needle pass. Clinical or surgical follow-up results in these eight small masses revealed carcinoma in four patients, a desmoplastic mesothelioma in one patient, nodal involvement with histoplasmosis in one patient, and resolution of a presumed small inflammatory mass in one patient. No follow-up was available in one patient. Of the five larger lesions, two resolved, one proved to be a benign schwannoma, and two were lost to follow-up.

There were 23 procedure-related complications of CT-guided biopsy: 21 pneumothoraces and two intraparenchymal hemorrhages. One pneumothorax was encountered in the US-guided biopsy group. Six pneumothoraces required placement of a chest tube; the remainder were small and asymptomatic and resolved spontaneously.

The average procedure time was 31.4 minutes (range, 15–55 minutes) for US-guided biopsy and 45.2 minutes (range, 15–90 minutes) for CT-guided biopsy. When the number of passes performed was considered, the average time per pass was 14.6 minutes (range, 6.2–25.0 minutes) for US-guided biopsy and 23.4 minutes (range, 6.7–42.5 minutes) for CT-guided biopsy. The average procedure time and the average time per pass were both statistically significantly shorter for US-guided than for CT-guided biopsy ($P < .05$).

DISCUSSION

Our results show that US is a safe and effective guidance modality for transthoracic percutaneous biopsy of many thoracic lesions. In fact, we were able to perform US-guided biopsy in 40% of our patients. Results of several other studies (7–14) have shown that US can be successfully used for biopsy of mediastinal, pleural, or even pulmonary masses. Wernecke and colleagues (7) were able to use US as a guidance modality for biopsy of 67% of mediastinal lesions. A rate of 25 of 41 was reported by Rubens et al (12). Other authors (8–11,13,14) have successfully diagnosed pulmonary and pleural lesions by using US. In our series, US-guided biopsy was significantly faster than CT-guided biopsy and yielded diagnostic results in a high percentage of cases, even when the target lesion was small.

Chest CT is the optimal imaging study for help in detecting or confirming the presence of thoracic lesions; US has no role for detection except perhaps in patients with pleural effusion. Clear advantages of CT-guided biopsy include exquisite depiction of the lesion and of the relationship of the lesion to major vascular structures, thereby allowing planning of a safe approach. Documentation of the position of the needle tip within the mass also is easier.

CT-guided biopsy is not without drawbacks, however. The most glaring disadvantage of CT-guided biopsy is the lack of real-time visualization during performance of the procedure. Sampling of the lesion is, in essence, performed blindly. Although this may not be an issue in cases of a large mass, biopsy of adjacent normal tissue can occur if the needle inadvertently slips out of a small nodule. In small or difficult lesions, multiple section acquisitions and needle repositioning may be necessary, which will increase the length of time during which the needle traverses the pleura. Another disadvantage of CT-guided biopsy is that the approach for needle placement is usually limited to the axial plane. Angled approaches with gantry tilt or a semicoronal route for biopsy of anterior mediastinal masses have been described (15,16), but they are cumbersome and require excellent patient cooperation.

For lesions that abut the chest wall, when no aerated lung is interposed between the footprint of the transducer and the lesion, US may be an attractive guidance modality. It offers a valuable combination of cross-sectional display of anatomy (including depiction of vascular anatomy with color Doppler and evaluation of the internal echotexture of the lesion) and real-time visualization.

With careful review of the diagnostic chest CT scans and some practice, peripheral lesions can easily be found at US. Most small parenchymal and pleural masses are hypoechoic. The interface between the lesion and the echogenic shadowing surrounding aerated lung is clearly demarcated. In only three cases in our study did US fail to demonstrate the lesion clearly enough to allow US-guided biopsy to proceed.

Real-time visualization gives the operator the ability to monitor the position of the needle tip relative to the lesion at all times during the procedure. In our study, the most important resulting benefit was a significantly faster procedure time. US-guided biopsy allows needle placement and biopsy during a single breath hold, which decreases the time the needle stays across the pleura. This is particularly useful in small juxta-

TABLE 1
Characteristics of Lesions at US-guided and CT-guided Biopsies

Type of Biopsy	Location of Lesion*							Mean Lesion Diameter (cm)†	No. of Small (≤2-cm) Lesions	No. of Cavitary Lesions
	Intra-parenchymal	Parenchymal Peripheral	Pleural	Chest Wall	Anterior Mediastinal	Middle Mediastinal and Hilar	Posterior Mediastinal			
US-guided	0	19	6	6	3	0	0	4.3 (1.2–10.0)	9	2
CT-guided	38	3	1	0	1‡	7	2	2.9 (1–12)	27	5

* Data are the number of lesions.
† Numbers in parentheses are the range.
‡ US-guided biopsy was performed first and was followed by CT-guided biopsy.

TABLE 2
Characteristics of US-guided and CT-guided Biopsies

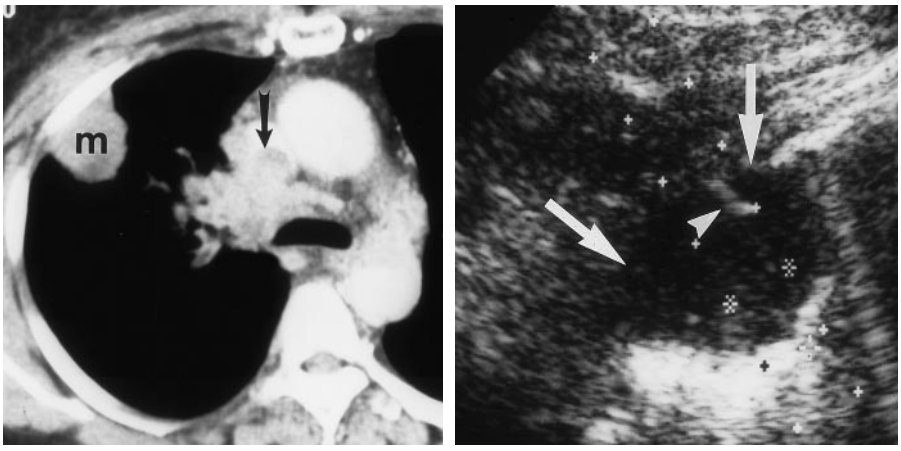
Type of Biopsy	Mean No. of Passes*	No. of Core Biopsies	Procedure Time (min)†	Time per Pass (min)*	No. of Diagnostic Biopsies	No. of Diagnostic Biopsies of Small Lesions‡	Complications
US-guided	3.2 (1–8)	14	31.4 (15–55)	14.6 (6.3–25.0)	31	9 of 9	Pneumothorax (n = 1)
CT-guided	2.3 (1–6)	7	45.2 (15–90)	23.4 (6.7–42.5)	37	18 of 27	Pneumothorax (n = 21), chest tube placement (n = 6), parenchymal hemorrhage (n = 2)

* Numbers in parentheses are the range.
† Procedure time available for 69 biopsies. Numbers in parentheses are the range.
‡ Small lesions had a diameter of 2 cm or smaller.

diaphragmatic masses, where even a slight variation in respiratory excursion can affect the position of the lesion. Small peripheral tumors also may be challenging and time-consuming at CT-guided biopsy if they are hidden behind a rib, because needle passage may unexpectedly become obstructed by overlying bone (2,17). These lesions can be approached successfully with US-guided biopsy. It is possible to assess the degree of respiratory excursion that will clear the mass from under the rib, to coach the patient appropriately, and to sample the lesion while it is in a favorable location (Fig 4).

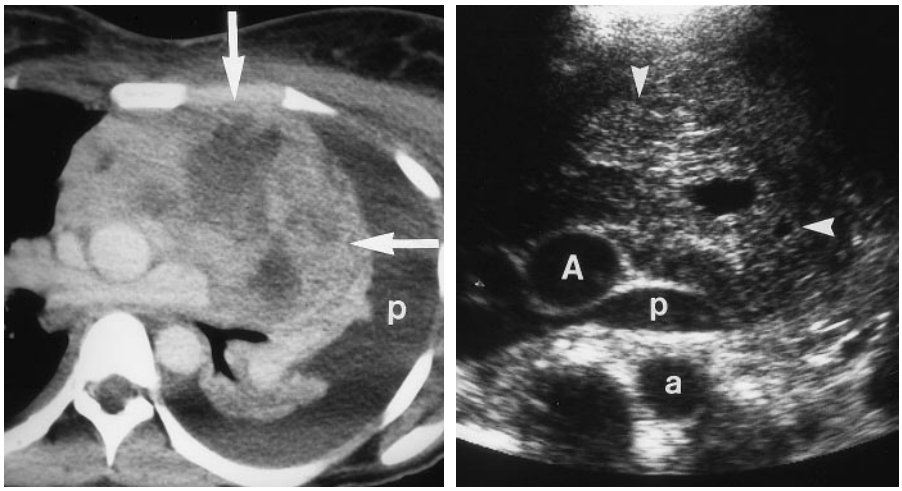
Another advantage of US-guided thoracic biopsy is its multiplanar capability, which allows the use of an oblique, angled approach if necessary. Because of the rib cage, this flexibility is less than that in abdominal or pelvic procedures, but a semicoronal suprasternal access to mediastinal masses has been used successfully, provided that the major vessels are not in the projected path of the needle (12).

US-guided biopsy requires less patient cooperation and can be successful even in sick, dyspneic patients (12). Minor patient movements are easily compensated for, so that the procedure can be successfully completed without the need for extra time to relocalize. Another distinct advantage of US-guided biopsy is that the procedure can be performed at the bedside in critically ill patients. "Creative positioning" allows the procedure to proceed in a more comfortable fashion for the patient: We performed US-guided thoracic biopsy in the semisitting position in three patients with dyspnea who could not tolerate prone or supine positions. The decubitus position also is useful in patients with severe back pain or if there is a need to shift a pleural effusion to a favorable location.



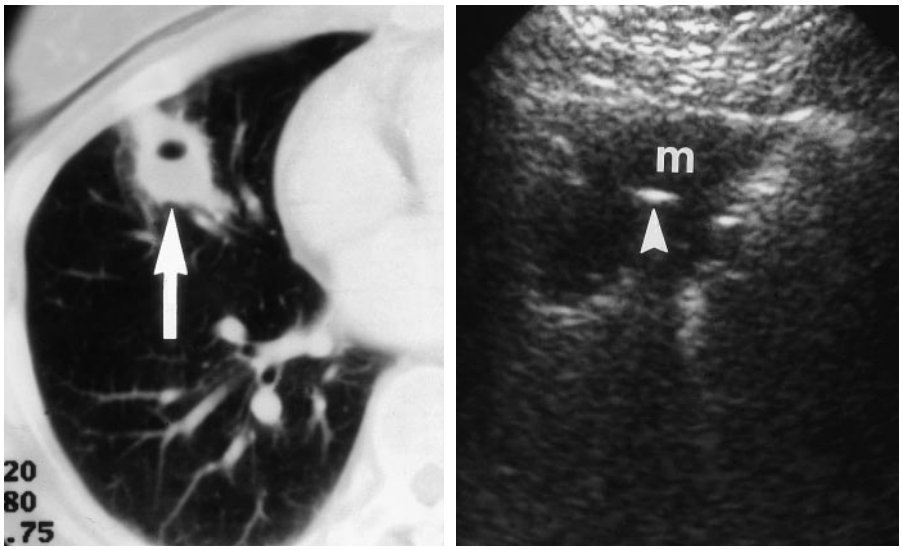
a. **b.**

Figure 1. Images in a 63-year-old woman with dyspnea and clinical superior vena cava syndrome. **(a)** Contrast-enhanced axial CT scan obtained just above the level of the aortic arch shows a right suprahilar mass (arrow) invading the superior vena cava, which rendered the mass unresectable on the basis of imaging criteria. Also visible is a 3-cm peripheral parenchymal mass (*m*). **(b)** Sagittal right chest US scan obtained during the biopsy shows a peripheral hypoechoic mass (arrows). The echogenic interface between the lesion and aerated lung is clearly visible. The biopsy needle tip (arrowhead) is visible within the mass. Cursors (+, ∗) indicate the projected path of the needle. This dyspneic patient could not lie supine, and the procedure was performed in the semisitting position. The histopathologic diagnosis was squamous cell carcinoma.



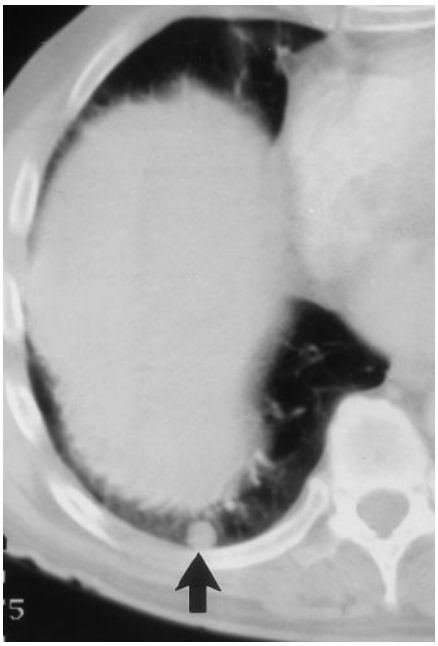
a. b.

Figure 2. Images in a 26-year-old woman with fever and weight loss. **(a)** Contrast-enhanced axial CT scan shows a large, partially necrotic anterior mediastinal mass (arrows) displacing the great vessels posteriorly. A left pleural effusion (*p*) is present. **(b)** Transverse left chest US scan shows a heterogeneous mass; areas of necrosis (arrowheads) appear cystic, as well as echogenic. The ascending aorta (*A*), descending aorta (*a*), and pulmonary artery (*p*) are easily identified. Color Doppler US (not shown) was used to avoid the anterior mammary artery and to target viable perfused tissue. The histopathologic diagnosis was B-cell lymphoma.

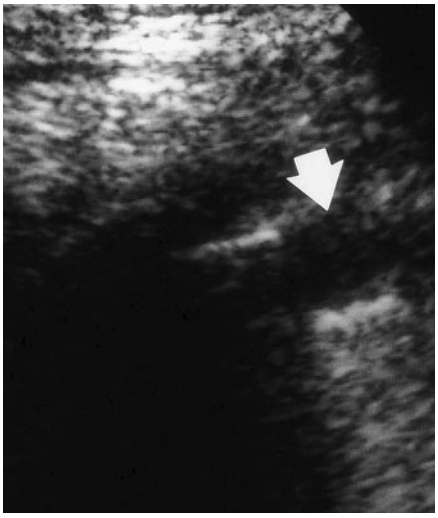


a. b.

Figure 3. Images in a 59-year-old woman with a cavitary mass. **(a)** Axial chest CT scan shows a peripheral cavitary mass (arrow). **(b)** Transverse right chest US scan demonstrates a hypoechoic mass (*m*). The cavity appears as a small, central, echogenic focus (arrowhead). The histopathologic diagnosis was an inflammatory pseudotumor.



a.



b.

Figure 4. Images in a 79-year-old man with a large liver mass and an elevated α-fetoprotein level. **(a)** Axial chest CT scan shows a 1.2-cm juxtadiaphragmatic nodule (arrow). **(b)** Transverse right chest US scan demonstrates the small hypoechoic lesion (arrow). The mass was hidden behind a rib and was accessible only during deep inspiration. The histopathologic diagnosis was malignant neoplasm consistent with metastatic hepatocellular carcinoma.

US-guided biopsy allows precise targeting of specific areas of the mass, which is an asset in large masses where biopsy of the central necrotic area may result in a false-negative result. This area of necrosis may be difficult to identify on nonenhanced CT scans. Analysis of the internal echotexture of the mass can be quite helpful, because areas of necrosis often appear cystic or hypoechoic (18). Evaluation of tumor vascularity with color Doppler allows sampling of well-perfused areas of the tumor, which are more likely to yield diagnostic material.

We used the needle-guide attachment for almost all thoracic biopsies. It allows accurate, rapid, and efficient passage of the needle into the lesion, usually during a single breath hold. It is easier to teach residents and fellows how to perform a US-guided biopsy with the needle-guide technique. The US transducer we use most frequently for biopsy is a 3.5-MHz sector probe, which has a small footprint that allows easy intercostal placement. The transducer is held parallel to the rib space to ensure maximum contact and optimal imag-

ing of the mass, as well as room for needle entry. For very thin patients, the availability of a higher frequency (5- or 7.5-MHz) transducer may be advantageous.

Tissue adequate for cytologic or histologic diagnosis was obtained at 31 of 34 US-guided biopsies and at 37 of 52 CT-guided biopsies. There are several possible explanations for the higher diagnostic yield achieved with US-guided biopsy. A peripheral location or larger lesion size, as well as better patient tolerance, allowed a greater number of passes and performance of a larger number of core biopsies in the US-guided biopsy group. The nature of the lesions also may be a factor: A higher proportion of cavitary masses and inflammatory lesions were sampled with CT guidance, whereas a higher percentage of malignant lesions happened to be amenable to US guidance in our series.

There also was a higher rate of complications associated with CT-guided biopsy. A higher frequency of pneumothorax is a known disadvantage of CT-guided biopsy and may be related to the fact that the needle stays across the pleura for a longer time. In addition, all lesions accessible at US-guided biopsy were peripheral and did not require the traversal of aerated lung, whereas it is likely that most difficult, small, deep lesions are sampled at CT-guided biopsy, which also may account for the higher complication rate.

There are several limitations to our study. This was not a randomized series; therefore, direct comparison with regard to the effectiveness of CT-guided versus US-guided thoracic biopsy is not possible. Many thoracic lesions are surrounded by aerated lung and are not amenable to US-guided biopsy. Biopsies of peripheral masses may be easier and faster to perform regardless of the guidance modality used; therefore, results from US-guided biopsy would always be more favorable. However, technical difficulties that can be encountered with CT-guided thoracic biopsy of small peripheral lesions are well recognized (2,17). Another limitation was the fact that all attending physicians were experienced and comfortable with the performance of US-guided thoracic biopsy, which may not be true of all chest radiologists in this country.

In summary, the results from our small series demonstrate that, with proper triaging of patients, US-guided thoracic biopsy may be an attractive and safe alternative to CT-guided biopsy, with a high success rate in masses that abut the chest wall, including apical, anterior mediastinal, and juxtadiaphragmatic lesions, as well as in parenchymal masses with adjacent pleural effusions. This technique is particularly well suited for sick patients who are less able to cooperate, and US-guided biopsy should be added to the armamentarium of thoracic interventional procedures. Our algorithm for triaging patients referred for thoracic biopsies is presented in Figure 5.

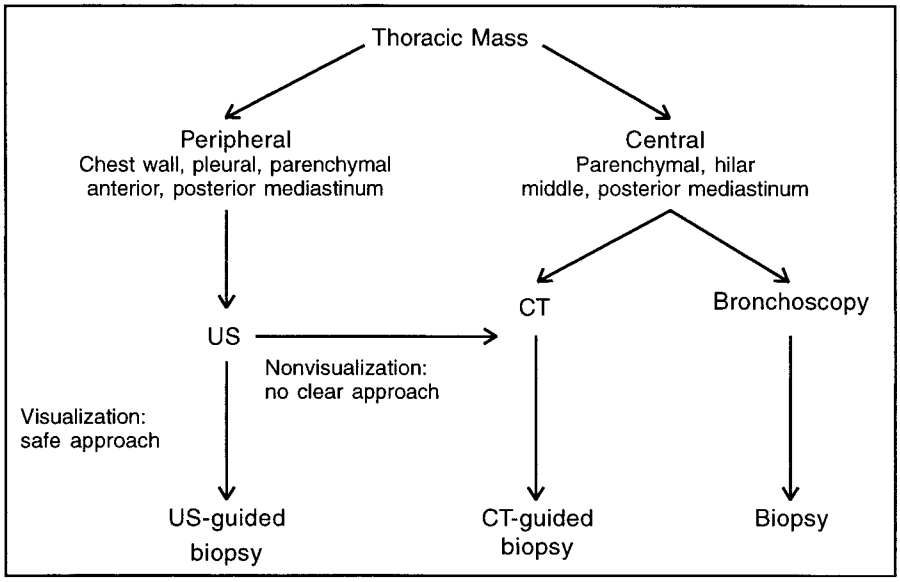


Figure 5. Diagram shows the algorithm for triaging patients for thoracic biopsies.

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