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CT-Guided Transthoracic Needle Biopsy

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Abstract. CT-guided biopsy of pulmonary and mediastinal lesions is safe and effective. It is most valuable in those cases in which fluoroscopic guidance is not possible due to resolution or anatomic consideration. CT guidance permits puncture of lesions as small as 0.5 cm, typically not seen fluoroscopically. Sensitivity of biopsy in malignant lung lesions in our series of 83 cases was 92%. Pneumothorax is the most frequent complication (10–60%) and requires chest tube insertion in 5–15% of patients.

Key words: Lung—Cancer—Percutaneous biopsy

Transthoracic percutaneous needle biopsy of pulmonary, hilar, pleural, and mediastinal lesions is a firmly established, reliable technique for diagnosing a wide variety of chest disorders. Prior to the era of computed tomography (CT) and ultrasound (US), fluoroscopy provided the sole image guidance for percutaneous biopsies. Despite several technical advances, fluoroscopic guidance has been limited by both small lesions and those lesions deemed too difficult to access [1–5]. The cross-sectional nature of CT allows accurate resolution of mediastinal, hilar, and pulmonary anatomy and pathology, thereby depicting safe access routes for biopsy. Lesions as small as 3–5 mm are well resolved and may be approached with CT-guided fine-needle techniques. US guidance is feasible for biopsy of pleural lesions and large parenchymal masses that abut the pleura.

Increasing experience with advanced cytological techniques and close cooperation between the radiologist and the cytologist has improved overall diagnostic accuracy of thoracic biopsy. Concomitant decrease in patient risk (i.e., smaller-gauge needles, fewer number of passes) by reduction in the amount of material required for cytopathologic examination is an added benefit. The accuracy of CT-guided transthoracic needle biopsy is nearly comparable to fluoroscopically guided biopsy; this is particularly important, as CT guidance is usually chosen in difficult cases or those in which fluoroscopy has been unsuccessful [1–5].

The aims of this paper are to outline the indications and contraindications for CT-guided thoracic biopsy; the techniques, complications, and results are highlighted.

Indications

The indications for CT-guided thoracic biopsy are similar to those for fluoroscopy and include 1) diagnosing suspicious parenchymal nodules, either solitary or multiple, when primary pulmonary malignancy is considered; 2) staging and classifying suspected pulmonary metastases; 3) diagnosing suspected infectious nodules or infiltrates; 4) diagnosing hilar, mediastinal, and pleural masses; and 5) after failed fluoroscopic or bronchoscopic needle biopsy of suspicious lesions.

Contraindications

The contraindications to CT-guided thoracic biopsy are relative. Routine assessment of potential bleeding risk is mandatory. Most coagulation abnormalities encountered prior to thoracic biopsy are correctable by either discontinuation of offending medications, or transfusion therapy (platelets, fresh frozen plasma, cryoprecipitate). Patients with a dyscrasia that is not correctable are at an increased risk for hemorrhage; blood may accumulate rapidly in the

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pulmonary parenchyma or pleural space; hemoptysis and hemothorax are potential major complications.

Severe pulmonary hypertension is a relative contraindication because of possible postbiopsy hemorrhage, or even aggravation of hypertension. Vascular lesions such as arteriovenous malformations should be diagnosed by imaging; biopsy should be avoided.

Any condition that limits the patient's respiratory reserve [severe chronic obstructive pulmonary disease (COPD), contralateral pneumonectomy] puts the patient at increased risk as a pneumothorax is less likely to be tolerated than in a healthy patient. COPD is associated with increased risk of pneumothorax, although most patients can tolerate thoracic biopsy [6]. These patients must be adequately oxygenated throughout the procedure, and facilities must be readily available for expeditious treatment of complications. Patients who require mechanical ventilation are at increased risk for pneumothorax due to positive pulmonary pressures.

The cooperation of the patient is required for safe and effective thoracic biopsy. Inability of patients to remain still and control their breathing or coughing may contraindicate thoracic biopsy.

CT vs Fluoroscopic Guidance

The choice between fluoroscopic and CT-guided biopsy depends on several variables. CT is chosen over fluoroscopy when the abnormalities are seen only by CT, when the lesion is better seen by CT than by fluoroscopy, or when the lesion is adjacent to vital structures that might be injured by needles. Practical considerations that limit the use of CT are time constraints, availability, and overall cost [7, 8]. Fluoroscopy is favored for lesions that are well visualized in 90° planes. CT is useful for resolution of anatomy that is difficult to appreciate by fluoroscopy. CT also helps to determine appropriate needle pathway to avoid complications by not traversing major vessels, the heart, vascular anomalies, and thoracic structures (such as blebs that should be avoided).

Patient Preparation

Preprocedure chest radiographs are obtained and correlated with the CT findings. The coagulation profile of the patient is verified prior to the procedure. Informed consent is obtained.

The patient is positioned prone, supine, or decubitus, depending on the proximity of the lesion to the chest wall. If prone, the patient's shoulders may be abducted to displace the scapulae laterally. A pillow placed under the chest may also be used to open the posterior intercostal spaces. Breathing instructions are given to the patient such that breathing is held at normal end expiration during the needle manipulation. This is comfortable for most patients and helps ensure reliability in needle position.

Intravenous lines are placed in all patients. Monitoring apparatus and personnel are available for those patients at increased risk for complications, or who will likely require IV sedation and/or analgesia. We prefer to use Versed for sedation and Fentanyl for analgesia. The subcutaneous and intercostal tissues are anesthetized with Xylocaine. Puncture is made over the upper portion of any given rib (as opposed to below the rib) to avoid the neurovascular bundle.

CT Localization

The lesion is localized by CT with the use of a laser marker system and a graduated grid [9]. Ten millimeter-slice thickness at a table increment of 10 mm is usually adequate through the area of interest that was demonstrated previously by chest radiograph or diagnostic CT. Occasionally, 5 mm interval slices must be obtained for localization of very small lesions (less than 5 mm). IV contrast enhancement of the pulmonary and central vasculature is indicated for lesions that border the hilar and mediastinal regions. Contrast-enhanced CT also may be beneficial to separate peripheral viable tissue from necrotic areas of tumor; this information delineates more favorable areas for biopsy and may increase diagnostic yield by avoiding false-negative biopsy of necrosis [11].

The depth and angulation of the lesion from the skin surface are calculated from the computer console. The shortest direct route to the lesion is desirable for providing maximum control of the needle. Care is taken to avoid unnecessary pleural transgression, as the number of pleural needle passes correlates with the risk of pneumothorax. In selected mediastinal lesions, meticulous extrapleural routes may be feasible [10].

When confronted with a patient who has a peripheral lung mass and an enlarged hilar or mediastinal node, the central lesion is preferred for biopsy. The advantage is that simultaneous diagnosis and staging may be achieved.

Technique and Needle Systems

The choice of the needle and the biopsy system are based on ease, optimal sampling characteristics, and safety considerations. Fine-needle biopsies are possible with 20- to 25-gauge needles. Prior to making needle passes, the depth of the lesion from the skin surface is flagged on the needle using steri-strips or a Band-Aid. All needle insertions are performed after expiration of normal tidal volume. This is a crucial variable with small lesions.

We prefer to localize the lesion initially with either a 22- or 23-gauge removable hub needle (10 or 15 cm length), a 22-gauge Chiba needle, or a 22-gauge spinal needle [12]. The shortest needle length required to reach the lesion is utilized to prevent bending of needle.

Several coaxial methods are available. The first begins with insertion of a short 19-gauge needle into the superficial tissues of the chest wall; this provides guidance and stability for the inner needles; 22- or 23-gauge needles are then passed coaxially and internally (Fig. 1).

The second coaxial method is the removable hub system (Cook Inc., Bloomington, IN). This permits an outer 19- or 18-gauge coaxial needle to be passed over an inner 23- or 22-gauge needle. The inner needle has a hub that is disengaged once the lesion is reached. The outer needle is advanced to the margin of the lesion; then multiple coaxial passes with a 21- to 23-gauge needle are performed after the hubless needle is removed (Fig. 2). A final pass is obtained with the outer 18- or 19-gauge needle if safety permits and a large sample of tissue is necessary.

A third technique is the tandem approach. If the lesion is large enough, needles are placed adjacent to each other. With the tandem technique, Chiba, spinal, or any biopsy needle may be used. Initially, one needle is placed into the lesion to localize the lesion site. A second similar needle is used to perform biopsies in tandem to the path of the localizing needle (Fig. 3). A final pass is taken with the localizing needle if so desired.

At our institution, the tandem needle approach is used mainly for lesions greater than 1.5 cm; the coaxial system is preferred for smaller lesions and those lesions that border vital structures near the hila and mediastinum (Figs. 4, 5). Pleural or pleural-based lesions are biopsied using the short coaxial outer needle in the soft tissues.

A granular or gritty sensation is felt when entering some lesions with the initial needle, but this is a variable finding. After verification of needle position within the lesion on CT, direct suction is applied with a 20-cc syringe coated with 1 : 1,000 Heparin using 5–10 cc of vacuum. A rotating motion, limited in depth by the size of the lesion, is used to ensure that adequate material is aspirated within the needle bore. Prior to removing the needle from the lesion, the vacuum is released gradually and the needle is withdrawn. With any of the above methods, the number of biopsy passes varies, depending on quick stain results, visual appearance of the sample, and what the suspected biopsy may yield.

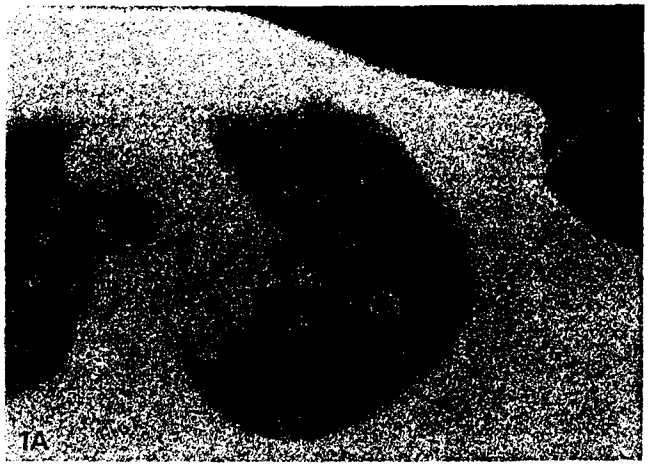
Processing the Tissue

Specimens are prepared under direct supervision of the cytopathologist or technician in the CT suite. Diagnostic material is injected directly onto a glass slide and fixed in 95% alcohol. The needle is flushed with Hank's solution (a balanced salt solution) and injected into a sterile container. The specimen may be subjected to cell filtration and centrifugation for further cytologic studies such as electron microscopy, T and B lymphocyte markers, immunochemistry, and special stains. Cell blocks are obtained when feasible. Gram stain and culture are performed when infection is suspected. The initial biopsy specimens are examined immediately with a modified Papanicolaou "quick stain." In this interim period, a few CT images may be obtained to evaluate potential complications such as pneumothorax, parenchymal hemorrhage, and hemothorax.

If there is adequate material to establish the diagnosis, no further passes are necessary. If more material is required, either to make a diagnosis or for further characterization of tissue, additional passes are made. The average number of passes to make a diagnosis for these small and difficult lesions is three to four, with a range of one to six. The success rate is directly related to obtaining sufficient material through meticulous radiologic technique and by experienced, skillful cytopathological interpretation. The average time required for CT-guided biopsy ranges from 30 min to 3 h, with an average of 1- to 1½ h. Shorter duration time occurs with larger peripheral lesions (>1 cm), when a pneumothorax does not occur, with increased experience of the operators, and when diagnosis is made on the initial pass(es).

Postprocedure

Follow-up chest radiographs are obtained immediately after and approximately 3–4 h later to detect complications. If the patient remains asymptomatic and the chest radiographs are negative, no further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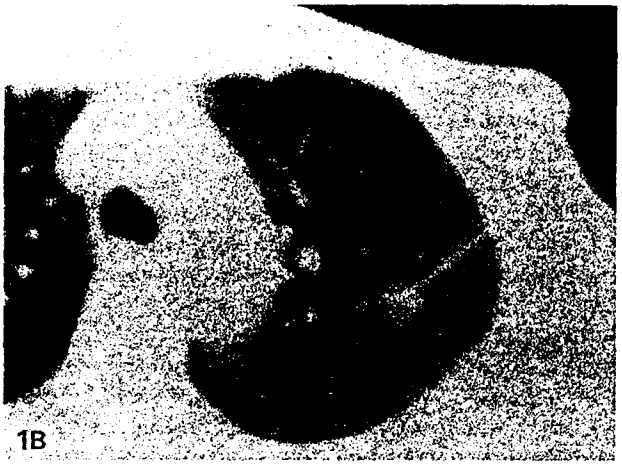
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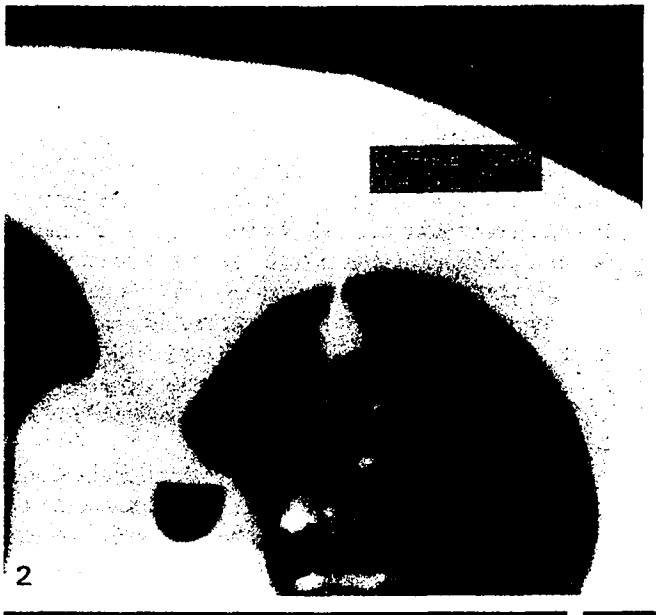
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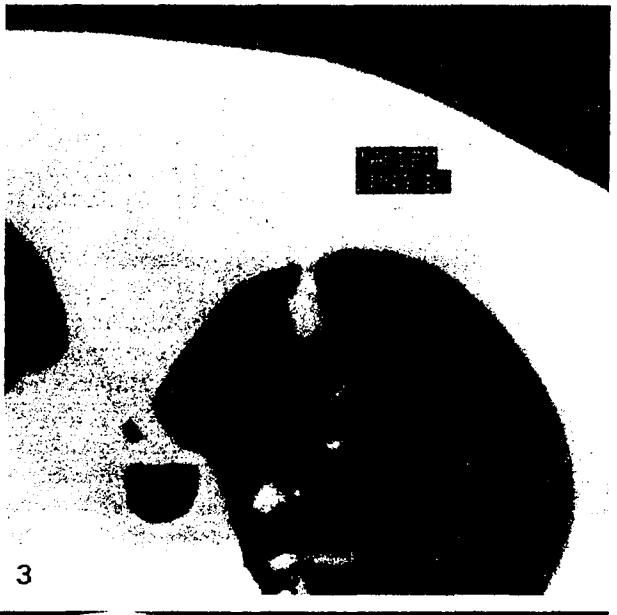
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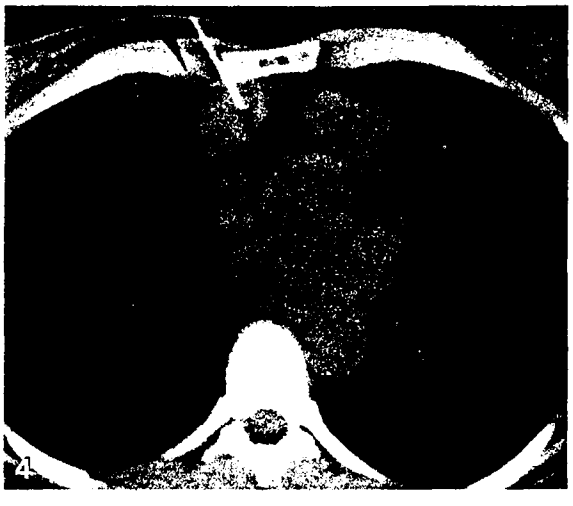
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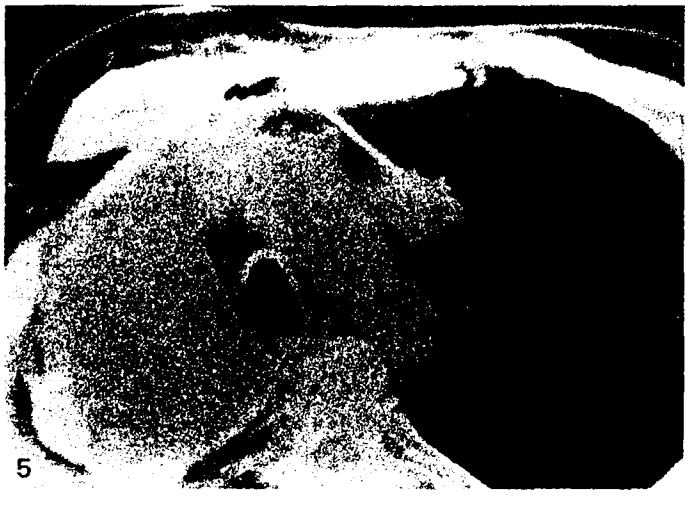
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follow-up is necessary if no complaints have developed for 4 h. The majority of pneumothoraces develop within 1 h of the procedure, but there are exceptions [13]. Delayed pneumothoraces are a definite risk and therefore adequate clinical and radiologic follow-up must be available.

Patients on whom procedures are performed as an outpatient are observed in the radiology department for several hours after the procedure and until the 4-h chest radiograph. If there is a small or no pneumothorax, the patient is discharged with pertinent instructions and information to contact the Interventional Radiology team at any time if he or she becomes symptomatic.

Complications

The most common complication of thoracic biopsy is pneumothorax, the risk of which is influenced by several factors. The incidence of pneumothorax increases with central lesions such as those in the mediastinum [14]. Although the work of Berquist et al. [14] showed no difference for central vs peripheral lesions, others have shown that increasing distance of a lesion from the skin surface increases the probability of pneumothorax. [15]. Conflicting reports arise as to whether the size of the lesion is a significant [6, 16] or insignificant [14, 15] predictor of pneumothorax. Cavitary lesions may predispose to an overall increase in complications including pneumothorax, parenchymal hemorrhage, and hemothorax [14]. Patients with COPD based on pulmonary function tests and plain film radiographs have a high propensity for developing a pneumothorax after biopsy; the need for a chest tube is also more common [17].

The number of needle passes has a variable effect upon the development of the pneumothorax. An increased number of needle passes usually are needed for deep and small lesions; this results in a greater number of pleural passes and increased rate of pneumothorax. The coaxial technique obviates the need for multiple pleural punctures, but it does require a larger outer needle. In our experience, the need for a chest tube does not differ appreciably between the tandem and the coaxial techniques [17].

The frequency of pneumothorax after CT-guided thoracic biopsy ranges from 0 to 60%, with an average of 37% [1–5, 18, 19]. This is slightly higher than the average rate of 25–30% following fluoroscopically guided thoracic biopsy [20–24]. The difference is likely due to skewed cases undergoing CT-guided biopsy, i.e., difficult lesions in which multiple passes often are necessary. In addition, the longer time of many of the procedures probably contributes to the increased likelihood of pneumothorax.

Pneumothoraces that require chest tube insertion occur in approximately 10–15% of CT-guided thoracic biopsy cases [1–5, 18, 19]. Indications for chest tube insertion include symptoms, pneumothorax larger than 30%, progressive enlargement at 4 h, need to continue the biopsy, and pneumothorax that is unlikely to be tolerated due to an underlying medical problem.

An effective immediate course of action to treat pneumothorax is to insert a 7 Fr catheter and to attach a Heimlich valve. The catheter is placed anteriorly into the second intercostal space in the midclavicular line (Fig. 6) [25]. Not only can a pneumothorax be managed appropriately with a 7 Fr catheter, but if the pneumothorax is produced during the biopsy, the lung should reexpand sufficiently to allow the procedure to continue.

Postbiopsy pulmonary hemorrhage is recognized more frequently by CT than clinically. One may see a small parenchymal infiltrate develop at the site of biopsy either during CT or on the postbiopsy radiographs. Patients experience mild hemoptysis in approximately 10% of cases; the hemoptysis usually is self-limited. Reported cases of severe hemorrhage after biopsy or even death are reported exclusively with large bore needles [6]. If significant hemorrhage occurs with fine-needle biopsy, then a significant coagulation disorder or vascular lesion should be suspected. Hemothorax and hemopericardium are uncommon complications that may follow thoracic biopsy [6]. Pericardial tamponade after lung biopsy has been reported [26].

Sporadic cases of air embolism have been reported following thoracic biopsy. These occurred following sudden elevation of bronchial airway pressures such as with coughing, positive pressure venti-

Fig. 1. Extrapleural coaxial biopsy of peripheral nodule. **A** Nineteen-g needle in soft tissues in line with the lesion (note postmastectomy changes). **B** Twenty-two-g Chiba needle in lesion placed coaxially through 19-g needle.

Fig. 2. Transpleural removable hub coaxial biopsy of peripheral nodule. The 19-g outer cannula is in the lesion. Multiple passes with 22-g inner needles revealed carcinoma.

Fig. 3. Tandem technique biopsy of peripheral pulmonary nodule. Note adjacent needles in the lesion.

Fig. 4. Anterior mediastinal biopsy with 19-g needle revealed lymphoma. Note needle medial to internal mammary vessels (arrowhead).

Fig. 5. Paraaortic mediastinal biopsy. The patient is status post-right pneumonectomy for lung cancer. Removable hub, coaxial method of biopsy. Diagnosis: metastatic adenocarcinoma.

Fig. 6. Fluoroscopically guided insertion of 7 Fr Sacks for drainage of pneumothorax. The lung totally reexpanded soon after Heimlich valve was connected to the catheter.

lation, or the Valsalva maneuver [27, 28]. Patients unable to coordinate their respiratory efforts are potentially at risk for this disastrous, yet avoidable complication.

Malignant seeding of cells along the needle tract is extremely rare [29].

Results

Large reviews demonstrate an accuracy approaching 90–95% for fluoroscopically guided lung biopsy [20–23, 30]. CT-guided thoracic biopsy has an overall diagnostic accuracy of approximately 85% for lung cancer [1–5, 18, 19]. The patient population is different, with the more difficult cases being done under CT. In our recent experience, diagnosis of a malignant lesion was possible in 76 of 83 malignant lung lesions (92%) [1]. The diagnostic success for benign lesions was only 10 of 18 cases (56%); this is comparable to fluoroscopic biopsy, in which accuracy varies anywhere from 50–70% [20–24, 30]. For selected cases, the accuracy of CT-guided thoracic biopsy may approach 100%; Gatenby et al. [5] successfully diagnosed 15/15 apical lung masses as malignant. Fluoroscopy and bronchoscopy had failed to make a diagnosis in these patients.

In our series, diagnosis was achieved in 22 of 23 malignant lesions in the mediastinum (96%) and 6 of 7 benign lesions (86%) [1]. Sider and Davis [18] experienced similar success with CT-guided thoracic biopsy of malignant hilar lesions; 19 of 20 (95%) lesions were diagnosed correctly by percutaneous biopsy after unsuccessful bronchoscopic attempts.

CT-assisted fluoroscopic biopsy of hilar and mediastinal lesions is another method used to diagnose some thoracic lesions [7, 8]. Gobien et al. [34] provided accurate diagnoses in all 17 patients in whom this method was used. Fluoroscopically guided thoracic biopsy of hilar and mediastinal lesions is accurate, yielding a malignant diagnosis in approximately 90% of cases [24, 31, 32]. The limiting factor in CT-assisted fluoroscopic or simple fluoroscopic thoracic biopsy of hilar and mediastinal lesions is size; lesions smaller than 1–1.5 cm usually are not seen fluoroscopically. The advantage of CT is that lesions less than 1.5 cm and as small as 3 mm may be diagnosed by CT-guided thoracic biopsy. The needle should be seen reliably within the lesion in all cases undergoing CT-guided biopsy.

An initial nondiagnostic biopsy needs follow-up examination in the form of repeat biopsy, imaging, or operation [33]. Of 26 cases in which no diagnosis was obtained at initial biopsy in our study, 11 were later found to be malignant (42%) [1]. Similarly, Calhoun et al. [33] demonstrated that 33% of their initial nondiagnostic biopsies eventually proved to be malignant.

Gobien et al. [34] have stressed the importance of the systematic application of cytopathological and microbiological techniques to increase the accuracy of a negative biopsy. These principles, when combined with the assurance of highly accurate needle placement by CT guidance, should improve the negative predictive value of needle biopsy.

Conclusions

CT-guided transthoracic needle biopsy is proven to be safe and effective in providing early diagnosis of pulmonary, hilar, or mediastinal lesions. Fluoroscopy is the modality of choice for thoracic biopsy because of accessibility, lower cost, and technical simplicity. CT-guided thoracic biopsy is a valuable adjunct to fluoroscopic thoracic biopsy, with similar diagnostic efficacy and low risk of major complications. Its greatest use lies in those cases in which fluoroscopy is not possible because of resolution limits or anatomic considerations, or those cases in

which fluoroscopic thoracic biopsy has been nondiagnostic.

The cost of CT-guided thoracic biopsy is comparable to that of fluoroscopic biopsy at our insitution. Either procedure is a safe, cost-effective measure for diagnosing thoracic lesions, particularly if the alternative is mediastinoscopy or thoracotomy [35]. Significant reduction in the morbidity and mortality are additional benefits.

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