Virtually No Thoracic Lesion Inaccessible: A Pictorial Case Review

Bradley B. Pua, MD¹ David Li, MD, PhD¹ Brian W. Sullivan, RA¹ David C. Madoff, MD, FSIR¹

¹Division of Interventional Radiology, Weill Cornell Medical College, New York, New York

Address for correspondence Bradley B. Pua, MD, Division of Interventional Radiology, Weill Cornell Medical College, 525 East 68th Street, Payson Pavilion, 5, New York, NY 10065 (e-mail: brp9018@med.cornell.edu).

Semin Intervent Radiol 2013;30:206–214

Abstract

Keywords

- biopsy
- ablation
- lung cancer
- thoracic
- technique
- interventional radiology

Access route considerations in percutaneous intrathoracic biopsy or ablation offers its own unique set of challenges, with special consideration toward reducing the rate of pneumothorax. This review highlights several novel and atypical methods to improve access to intrathoracic lesions through a series of representative cases. These methods include patient positioning, curved needles, hydrodissection, induced/artificial pneumothorax, and use of specialized equipment functions. No intrathoracic lesion should be considered “inaccessible” either for biopsy or treatment by percutaneous approaches without consideration of performing these adjunctive techniques.

Objectives: Upon completion of this article, the reader will be able to discuss alternative techniques to accessing difficult to reach thoracic lesions for biopsy and placement of ablation probes.

Accreditation: This activity has been planned and implemented in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education through the joint sponsorship of Tufts University School of Medicine (TUSM) and Thieme Medical Publishers, New York. TUSM is accredited by the ACCME to provide continuing medical education for physicians.

Credit: Tufts University School of Medicine designates this journal-based CME activity for a maximum of **1 AMA PRA Category 1 Credit™**. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Percutaneous biopsy or ablation in the thorax offers its own unique set of challenges. In addition to the usual access pearls such as avoidance of critical structures and limited access sites secondary to ribs and the upper extremities, one must contend with respiratory motion while limiting the risks of pneumothorax. Access route considerations and lung biopsy are largely focused on reducing the rate of pneumothorax, with reported rates as high as 64%.^{1–9} Standard considerations in planning a

percutaneous approach (described in more detail elsewhere in this issue of *Seminars*) include limiting the number of punctures of the visceral pleural surface (either by reducing the number of passes or the number of fissures crossed by any single pass), decreasing the distance of lung traversed (lesion depth), avoidance of bullae, and patient positioning to decrease respiratory excursion. Alternative considerations in lung biopsy include avoidance of pulmonary vasculature to prevent pulmonary hemorrhage, which may ultimately obscure the target or result in hemoptysis.

This article offers a compilation of cases of both percutaneous biopsy and ablation using adjunctive techniques. Even with something as simple as patient positioning, previously inaccessible lesions often become easily accessible.

Patient Positioning

Proper patient positioning is a simple and highly effective means of providing alternative access routes to thoracic lesions and should not be ignored. Previously inaccessible lesions often become easily accessible with simple arm maneuvers such as raising or lowering the arms, internally rotating the shoulder to shift the scapula laterally.^{5,10} This easily performed technique can create greater exposure of potential lesions, limiting the number of pleural punctures necessary.

Issue Theme Pulmonary Malignancies;
Guest Editors, Bradley B. Pua, MD and
David C. Madoff, MD, FSIR

Copyright © 2013 by Thieme Medical
Publishers, Inc., 333 Seventh Avenue,
New York, NY 10001, USA.
Tel: +1(212) 584-4662.

DOI <http://dx.doi.org/10.1055/s-0033-1342963>.
ISSN 0739-9529.

The following example presents a case where internal rotation of the scapula achieves accessibility to the target lesion.

Case 1

A 62-year-old man with an increasing right upper lobe lung nodule on imaging presented for biopsy. The lesion was laterally located, and the overlying scapula resulted in a poor window for limiting the number of pleural punctures. With internal rotation of the shoulder and placement of a roll below the patient's chest (ipsilateral to lesion side), the scapula was rotated laterally with respect to the nodule, resulting in successful targeting of the lesion (→Fig. 1). There were no postprocedural complications and pathology was diagnostic.

Prone Positioning

Prone positioning offers many advantages including minimizing the extent of respiratory excursion, decreasing patient anxiety by shielding them from visualization of the biopsy needle, as well as allowing them to recover postprocedure in a more comfortable supine position with the biopsy side down. Recovering patients with the biopsy puncture site down has been associated with a decreased rate of chest tube placement for pneumothorax (21 to 3%).¹¹

Given the theoretical advantage of decreased respiratory motion and increased tamponade effect on the punctured lung, Rozenblit et al performed ipsilateral side down biopsies in a series of 17 patients.¹² In their study, patients were positioned in an ipsilateral position with the operator accessing the lesions either via an anterior or posterior approach. The study addressed the feasibility of the approach without providing relative pneumothorax rates. In a separate study, Kinoshita et al performed puncture site down biopsies with a modified computed tomography (CT) gantry to allow access to the gantry side of the patient ("puncture window") and a movable needle holder below the window.¹³ This retrospective review performed on 236 patients demonstrated a reduction in pneumothorax rate with their technique as compared with standard access positions from 41.6 to 12.9%, and pneumothorax requiring chest tube insertion rate from 18.0 to 2.7%. However, the cohorts of patients evaluated were different because their modified technique patients were performed during a later time period, raising possible bias due to increased operator experience and technological advancements.

Overall, significant variability exists in the literature regarding patient positioning, and we have found that remaining flexible toward patient positioning has been most successful in access route planning. Finding the appropriate balance between optimal patient positioning for comfort and lesion accessibility, and limiting procedural time and patient radiation dose from repeated CT scanning, is necessary. As operators gain experience, anticipation of optimal patient positioning without multiple iterations and repeat scanning can be achieved.

Case 2 represents an example where decubitus positioning ultimately achieved the greatest accessibility to the target lesion.

Figure 1 (A) Limited noncontrast computed tomography image through the chest demonstrates the target spiculated right lower lobe lesion (image reversed during biopsy). In the current position, the scapula precludes a posterior-lateral approach, necessitating an approach requiring three pleural surface punctures (right upper and lower lobe). (B) After internally rotating the ipsilateral chest and placing a roll underneath the ipsilateral chest, the scapula was rotated laterally, revealing a window to access the right lower lobe lesion directly. (C) Biopsy needle within the target lesion.

Case 2

A 71-year-old woman with stage III colon carcinoma with a growing right lower lobe nodule noted on surveillance imaging presented for biopsy. The lesion was difficult to access, having both significant depth from the chest wall as well as being immediately adjacent to the diaphragm on prone

Figure 2 (A) Initial axial computed tomography (CT) image of the target lesion. (B) Left lateral decubitus position showing decrease in the anticipated traversed lung. (C) Repeated axial CT scan with five slices at 2.5 mm was performed in two separate breath holds to confirm stable position of the lesion. (D) Biopsy needle advanced into the target lesion.

positioning. As depicted in ►**Fig. 2**, left lateral decubitus positioning and strict breath-hold technique were ultimately successful in targeting the lesion. There were no postprocedural complications, and the specimen was diagnostic.

Curved Needle

A complementary technique to patient positioning includes using a curved needle via a preexisting coaxial system, allowing for more control of the needle tip. This technique can limit the number of pleural punctures if the original coaxial needle is off alignment by reducing the need for coaxial needle repositioning, and it is also helpful in accessing difficult to reach lesions. Limited data have been published regarding this technique for both lung and abdominal and pelvic biopsies.^{5,14,15} There is considerable future promise in increasing control of needles, and both steerable needles and electromagnetic navigation of needles have already been applied for lung radiofrequency ablation.^{16,17}

In the following case example, a curved needle is used to achieve accessibility to a thoracic target lesion.

Case 3

A 58-year-old woman presents status post left completion pneumonectomy with a new hypermetabolic right upper

lobe lung nodule on surveillance imaging. Alteration in the normal anatomy postpneumonectomy with associated mediastinal shift and hyperexpansion of the right upper lobe resulted in the target lesion being immediately posterior to the sternum. Patient positioning was unsuccessful in improving accessibility of the lesion; ultimate biopsy success was obtained by using a curved biopsy needle through a coaxial system (►**Fig. 3**). There were no postprocedural complications, and the obtained specimen was diagnostic.

Hydrodissection

Hydrodissection to displace adjacent critical structures and create access windows has been a strategy used in the setting of a variety of abdominal procedures such as biopsy,^{18,19} abscess drainage,²⁰ and radiofrequency ablations.^{21–27} In abdominal radiofrequency ablations, hydrodissection has the added benefit of providing thermal protection of the adjacent structures in addition to greater accessibility of the target.^{21–27} Reports describing the use of hydrodissection for percutaneous approach access to intrathoracic lesions has been fairly limited; initially described by Langham et al, hydrodissection has been used to create artificial windows to access mediastinal lesions for biopsy.^{28–30} In the following case example, hydrodissection was used to assist in targeting a mediastinal lesion.

Figure 3 (A) Prebiopsy axial computed tomography demonstrates the target lesion immediately posterior to the sternum. (B) Decubitus positioning without improvement in lesion accessibility. (C, D) A 22-gauge needle was gently curved manually over a syringe and introduced through a 19-gauge straight coaxial needle to access the lesion.

Case 4

An 82-year-old man presented with a history of lung carcinoma, status post right upper lobectomy, with a newly found hypermetabolic aortopulmonary lymph node with multiple comorbidities that precluded surgical or bronchoscopic biopsy (►Fig. 4). The target lesion was located immediately anterior to the right main pulmonary artery, without significant anterior mediastinal fat/tissue to initially allow purely mediastinal transgression. Normal saline was instilled through a coaxial needle to create a mediastinal window artificially through which the target lymph node was successfully biopsied. There were no postprocedural complications, and pathology was diagnostic. As illustrated in this case, it is of the utmost importance to clearly identify the internal mammary vessels because they may be in close proximity to the biopsy needle.

The following case example is similar to case 4 in which fluid is injected into the mediastinal space to displace lung parenchyma to facilitate biopsy. This case exemplifies the ability to expand any potential space in the thorax.

Case 5

A 72-year-old woman with a history of breast carcinoma presents with newly discovered hypermetabolic aortopulmonary lymph node, with comorbidities precluding surgical or bronchoscopic biopsy. Similar to case 4, the target lesion was located immediately anterior to the aortic arch, without significant anterior mediastinal fat/tissue to allow mediastinal transgression. In this case, normal saline was instilled

through a coaxial needle to expand the mediastinal space artificially (►Fig. 5). Without utilization of this adjunctive technique, a transpleural approach would have been necessary. This technique allowed for a safe biopsy without the risk of pneumothorax.

Artificial/Induced Pneumothorax

The pleural cavity is the potential space that exists between the normally opposed parietal and visceral pleural surfaces, lining the inner chest wall and outer lung parenchyma, respectively. With a standard percutaneous transthoracic lung biopsy, both pleural surfaces are transgressed, initially the parietal surface, followed by the visceral surface. Puncture of the visceral surface creates the possibility of a persistent air leak from the underlying aerated lung, resulting in a pneumothorax. In the literature, there have been several reports of creation of an artificial pneumothorax to avoid visceral pleural transgression in accessing mediastinal lesions.^{28,31,32} With this technique, the risk of air leak and subsequent chest tube placement can be avoided.

In the following case example, we demonstrate induction and subsequent aspiration of a pneumothorax as an effective means of creating a window through the pleural space, obviating the need for chest tube insertion.

Case 6

A 72-year-old man with myeloproliferative disorder in an accelerated phase with new-onset left laryngeal nerve palsy was found to have an enlarged aortopulmonary lymph node

Figure 4 (A) Aortopulmonary window lymph node. (B) A 19-gauge Temno (Cardinal Health, Dublin, OH) outer cannula in anteriormost aspect of the mediastinum via a parasternal approach. (C) After access to the mediastinal fat was obtained, 150 mL of normal saline was infused slowly, pushing the lung away from the intended path. (D) Biopsy needle within the target lymph node. (E, F) Postprocedure images in (E) mediastinal and (F) lung windows demonstrate the absence of complications such as pneumothorax or mediastinal hematoma.

on imaging. The lesion was thought not to be amenable to bronchoscopic evaluation. The target lesion was surrounded by the aorta anteriorly and posteriorly, the trachea medially, and lung parenchyma laterally. Although the safest percutaneous access route for the lesion (to avoid the major airways and vasculature) was via a lateral approach, this approach would require transgression of two pleural surfaces. An artificial pneumothorax was therefore created with a 5F Yueh needle-catheter system that was advanced into the left pleural space, creating a window for successful biopsy (►Fig. 6). Following biopsy, the outer cannula was withdrawn to within the thoracic cavity and the induced/artificial pneumothorax maximally aspirated. The visceral pleural was never transgressed during the procedure, and the patient was discharged home after an uneventful recovery.

The principles just described can be applied to improve access for percutaneous thermal ablation of intrathoracic

lesions as well as for biopsies. In percutaneous ablations, additional consideration of potential injury to adjacent structures within the treatment zone is required. Thus many lesions that are accessible for biopsy are not necessarily candidates for ablation.

In the following two case examples, we demonstrate ablation of a target lesion by artificially inducing a pneumothorax, and of an intraparenchymal lesion adjacent to the chest wall by relocating the lesion using the “stick function” of the microwave ablation probe.

Case 7

A 63-year-old woman presented with a history of colon cancer metastatic to the lung and liver. A hypermetabolic right middle lobe nodule was targeted for radiofrequency ablation (►Fig. 7). This nodule was immediately adjacent to the pericardium,

Figure 5 (A) Noncontrast computed tomography (CT) demonstrates an enlarged aorticopulmonary lymph node (target). (B) The biopsy needle was advanced into the mediastinum, taking care to identify the internal mammary vessels. Saline was infused to expand the potential space and displace the lung parenchyma. (C) CT in lung windows demonstrates the biopsy needle within the target lesion without transgressing the lung. (D) Postprocedure CT demonstrates residual fluid within the anterior mediastinum and no evidence of pneumothorax or mediastinal hematoma.

Figure 6 (A) Noncontrast computed tomography (CT) demonstrates the target enlarged lymph node straddled by the aorta and pulmonary artery. (B) A Yueh needle was placed into the pleural space and air injected into the thoracic cavity to create an artificial pneumothorax. (C) After the artificial pneumothorax was induced, the biopsy needle was advanced into the target lesion. Note that because the lung is collapsed during this procedure, the visceral pleura is never traversed. (D) CT at the conclusion of the procedure after aspiration of the artificially created pneumothorax showing no evidence of residual pneumothorax.

Figure 7 (A) Noncontrast computed tomography in lung windows demonstrates a nodule within the right middle lobe abutting the pericardium. (B) Radiofrequency (RF) probe is positioned within the lesion. At this current location, ablation would risk injury to the adjacent pericardium. (C) A catheter was advanced into the pleural space and an artificial pneumothorax was created by injecting ambient air. (D) Torque was applied to the RF probe allowing the lung to be moved away from the pericardium. (E) Postablation images with the artificial pneumothorax aspirated to near resolution demonstrates ground-glass opacity representing the ablated tissue surrounding the target lesion.

where radiofrequency ablation has the potential for associated thermal injury. After insertion of the radiofrequency probe, a 5F Yueh catheter was introduced through the parietal pleural into the pleural space and an artificial pneumothorax was created, forming an air gap between the lesion and the pericardium. At this point ablation was safely performed, and the patient experienced no postprocedural complications.

Case 8

A 55-year-old woman with a history of chronic obstructive pulmonary disease, metastatic leiomyosarcoma to the lungs status post right upper lobectomy. She had worsening left apical upper lobe nodules refractory to chemotherapy, resulting in significant shortness of breath. Both were targeted for microwave ablation. The superior lesion was noted to be immediately abutting the pleura, where microwave thermal

ablation has the potential to damage the chest wall and intercostal nerves (►Fig. 8). After insertion of the microwave probe, the “stick function” was used, where thermal cooling resulted in a nontherapeutic ice ball that created secure contact with the probe. Forward pressure was then applied to the probe and the lesion moved more centrally, at which point ablation was safely performed avoiding chest wall and intercostal nerve damage. The patient was discharged from the hospital the following day without complications.

Conclusion

This review focused on several novel and atypical methods to improve access to intrathoracic lesions. These methods include atypical patient positioning, curved needles, hydrodissection, induced/artificial pneumothoraces, and the use of specialized equipment functions. No intrathoracic lesion

Figure 8 (A) Computed tomography scan of the chest demonstrates a left upper lobe lesion abutting the chest wall. (B) A microwave ablation probe was advanced into the target lesion. (C, D) A nontherapeutic ice ball was created and forward pressure was placed on the probe (C). (D) The same lesion one slice (2.5 mm) above (C) that exemplifies the degree to which the lesion was displaced. (E) Postablation images demonstrate ground-glass opacity surrounding the target lesion.

should be considered inaccessible either for biopsy or treatment by percutaneous approaches without careful consideration of performing such adjunctive techniques.

References

- 1 Kazerooni EA, Lim FT, Mikhail A, Martinez FJ. Risk of pneumothorax in CT-guided transthoracic needle aspiration biopsy of the lung. *Radiology* 1996;198(2):371-375
- 2 Cox JE, Chiles C, McManus CM, Aquino SL, Choplin RH. Transthoracic needle aspiration biopsy: variables that affect risk of pneumothorax. *Radiology* 1999;212(1):165-168
- 3 Geraghty PR, Kee ST, McFarlane G, Razavi MK, Sze DY, Dake MD. CT-guided transthoracic needle aspiration biopsy of pulmonary nodules: needle size and pneumothorax rate. *Radiology* 2003;229(2):475-481
- 4 Westcott JL. Percutaneous transthoracic needle biopsy. *Radiology* 1988;169(3):593-601
- 5 Cham MD, Lane ME, Henschke CI, Yankelevitz DF. Lung biopsy: special techniques. *Semin Respir Crit Care Med* 2008;29(4):335-349
- 6 Larscheid RC, Thorpe PE, Scott WJ. Percutaneous transthoracic needle aspiration biopsy: a comprehensive review of its current role in the diagnosis and treatment of lung tumors. *Chest* 1998;114(3):704-709
- 7 Fish GD, Stanley JH, Miller KS, Schabel SI, Sutherland SE. Post-biopsy pneumothorax: estimating the risk by chest radiography and pulmonary function tests. *AJR Am J Roentgenol* 1988;150(1):71-74
- 8 Miller KS, Fish GB, Stanley JH, Schabel SI. Prediction of pneumothorax rate in percutaneous needle aspiration of the lung. *Chest* 1988;93(4):742-745
- 9 Topal U, Ediz B. Transthoracic needle biopsy: factors effecting risk of pneumothorax. *Eur J Radiol* 2003;48(3):263-267
- 10 Yankelevitz DF, Davis SD, Chiarella DA, Henschke CI. Pitfalls in CT-guided transthoracic needle biopsy of pulmonary nodules. *Radiographics* 1996;16(5):1073-1084

- 11 Moore EH, LeBlanc J, Montesi SA, Richardson ML, Shepard JA, McCloud TC. Effect of patient positioning after needle aspiration lung biopsy. *Radiology* 1991;181(2):385–387
- 12 Rozenblit AM, Tuvia J, Rozenblit GN, Klink A. CT-guided transthoracic needle biopsy using an ipsilateral dependent position. *AJR Am J Roentgenol* 2000;174(6):1759–1764
- 13 Kinoshita F, Kato T, Sugiura K, et al. CT-guided transthoracic needle biopsy using a puncture site-down positioning technique. *AJR Am J Roentgenol* 2006;187(4):926–932
- 14 Gupta S, Ahrar K, Morello FA Jr, Wallace MJ, Madoff DC, Hicks ME. Using a coaxial technique with a curved inner needle for CT-guided fine-needle aspiration biopsy. *AJR Am J Roentgenol* 2002;179(1):109–112
- 15 Carrasco CH, Wallace S, Charnsangavej C. Aspiration biopsy: use of a curved needle. *Radiology* 1985;155(1):254
- 16 Amalou H, Wood BJ. Electromagnetic tracking navigation to guide radiofrequency ablation of a lung tumor. *J Bronchology Interv Pulmonol* 2012;19(4):323–327
- 17 Wood BJ, Kruecker J, Abi-Jaoudeh N, et al. Navigation systems for ablation. *J Vasc Interv Radiol* 2010;21(8, Suppl):S257–S263
- 18 Gupta S, Madoff DC. Image-guided percutaneous needle biopsy in cancer diagnosis and staging. *Tech Vasc Interv Radiol* 2007;10(2):88–101
- 19 Gupta S, Nguyen HL, Morello FA Jr, et al. Various approaches for CT-guided percutaneous biopsy of deep pelvic lesions: anatomic and technical considerations. *Radiographics* 2004;24(1):175–189
- 20 Arellano RS, Gervais DA, Mueller PR. CT-guided drainage of abdominal abscesses: hydrodissection to create access routes for percutaneous drainage. *AJR Am J Roentgenol* 2011;196(1):189–191
- 21 Arellano RS, Flanders VL, Lee SI, Mueller PR, Gervais DA. Imaging-guided percutaneous radiofrequency ablation of retroperitoneal metastatic disease in patients with gynecologic malignancies: clinical experience with eight patients. *AJR Am J Roentgenol* 2010;194(6):1635–1638
- 22 Gervais DA, Arellano RS, McGovern FJ, McDougal WS, Mueller PR. Radiofrequency ablation of renal cell carcinoma: part 2, Lessons learned with ablation of 100 tumors. *AJR Am J Roentgenol* 2005;185(1):72–80
- 23 Gervais DA, McGovern FJ, Arellano RS, McDougal WS, Mueller PR. Radiofrequency ablation of renal cell carcinoma: part 1, Indications, results, and role in patient management over a 6-year period and ablation of 100 tumors. *AJR Am J Roentgenol* 2005;185(1):64–71
- 24 Lee SJ, Choyke LT, Locklin JK, Wood BJ. Use of hydrodissection to prevent nerve and muscular damage during radiofrequency ablation of kidney tumors. *J Vasc Interv Radiol* 2006;17(12):1967–1969
- 25 Ginat DT, Saad W, Davies M, Walman D, Erturk E. Bowel displacement for CT-guided tumor radiofrequency ablation: techniques and anatomic considerations. *J Endourol* 2009;23(8):1259–1264
- 26 Ginat DT, Saad WE. Bowel displacement and protection techniques during percutaneous renal tumor thermal ablation. *Tech Vasc Interv Radiol* 2010;13(2):66–74
- 27 DeBenedictis CM, Beland MD, Dupuy DE, Mayo-Smith WW. Utility of iodinated contrast medium in hydrodissection fluid when performing renal tumor ablation. *J Vasc Interv Radiol* 2010;21(5):745–747
- 28 Gupta S, Seaberg K, Wallace MJ, et al. Imaging-guided percutaneous biopsy of mediastinal lesions: different approaches and anatomic considerations. *Radiographics* 2005;25(3):763–786; discussion 786–788
- 29 Langen HJ, Jochims M, Schneider W, Günther RW. Distension of extrapleural spaces with contrast medium or air: value in creating safe percutaneous access to the mediastinum in cadavers. *AJR Am J Roentgenol* 1995;164(4):843–849
- 30 Langen HJ, Klose KC, Keulers P, Adam G, Jochims M, Günther RW. Artificial widening of the mediastinum to gain access for extrapleural biopsy: clinical results. *Radiology* 1995;196(3):703–706
- 31 Protopapas Z, Westcott JL. Transthoracic hilar and mediastinal biopsy. *Radiol Clin North Am* 2000;38(2):281–291
- 32 Bressler EL, Kirkham JA. Mediastinal masses: alternative approaches to CT-guided needle biopsy. *Radiology* 1994;191(2):391–396