Percutaneous image-guided lung biopsy

Percutaneous image-guided lung biopsy is most commonly performed in the investigation of patients with suspected thoracic malignancy, in whom it has a high diagnostic accuracy, sensitivity and specificity. The typical scenario is of a patient with an undiagnosed nodule or mass requiring a histological diagnosis to facilitate appropriate clinical management. With advances in targeted cancer treatment the need for plentiful tissue for molecular testing is increasing.

Clinicians requesting lung biopsies should be aware of the relative indications and contraindications of the procedure, the potential risks and the peri-procedure care. This article illustrates the patient pathway through the radiology department, reviews the technique of performing percutaneous lung biopsies under computed tomography or ultrasound guidance, and discusses potential complications.

Indications and patient selection

The commonest indication for percutaneous image-guided lung biopsy is a new or enlarging nodule or mass on chest radiography. Other indications include persistent focal infiltrates and sampling of multiple nodules (in patients without known malignancy, or with more than one primary to confirm origin). If a patient has had a negative bronchoscopy for a central lesion then computed tomography biopsy may be considered.

As with all procedures the risk:benefit ratio is considered for each patient. The clinical team and radiologist balance the diagnostic yield with risk of complications. Cross-sectional imaging obtained as part of staging (including computed tomography and positron emission tomography) may identify alternative sites for biopsy, such as adenopathy or liver lesions. Before offering this procedure to the patient, the decision is often made by the multidisciplinary team or following close discussion with the performing radiologist. *Table 1* lists essential pre-procedure investigations and patient factors assessed in determining suitability for biopsy. Patients will be required to consent before the procedure except in exceptional circumstances, and it is good practice to provide a patient information leaflet.

Lesion factors

Table 2 lists the lesion factors that the multidisciplinary team and radiologist will consider when assessing suitability for biopsy. *Figure 1* demonstrates lesions typically suitable for computed tomography *vs* ultrasound biopsy.

Dr Catriona EL Reid, Specialty Registrar, Department of Radiology, Portsmouth Hospitals NHS Trust, Portsmouth PO6 3LY

Dr Adam G Wallis, Consultant Radiologist, Department of Radiology, Portsmouth Hospitals NHS Trust, Portsmouth

Correspondence to: Dr CEL Reid (catriona.reid@porthosp.nhs.uk)

Table 1. Pre-procedure investigations and patient factors assessed in determining suitability for biopsy

Coagulation	Coagulation needs to be optimized. Recent international normalized ratio should be <1.3. Anticoagulants should be stopped as per guidelines (Patel et al, 2012)
Lung function	Lung function tests (spirometry) should be performed before biopsy. If forced expiratory volume in 1 second <35%, biopsy should not proceed without further multidisciplinary team discussion (Manhire et al, 2003) Contralateral pneumonectomy and need for positive pressure ventilation are also relative contraindications
Comorbidities	Patients should be able to lie still for up to 30 minutes – movement or other disorders that prevent this are relative contraindications Pulmonary artery hypertension is a relative contraindication
Flying	Patients are advised not to undergo biopsy if they are planning to fly within 6 weeks (Manhire et al, 2003)
Patient position	Where possible, patients will be positioned to optimize the approach which may include lying prone or in a decubitus position A posterior approach is often preferred as the posterior intercostal spaces are wider and the posterior ribs move less with respiration. Patients are less anxious as they cannot directly visualize the needle and the sensitivity of the posterior chest wall is less than the anterior

Table 2. Lesion factors assessed in determining suitability for biopsy

Location	Pleural and peripheral lung lesions abutting pleura are suitable for ultrasound biopsy. Deeper lesions are more suitable for computed tomography biopsy. Where multiple lesions are present typically that with the shortest needle path through the lung is chosen. Relative contraindications are small lesions close to diaphragms and central lesions close to large vessels
Fissures	Single pleural puncture is used to reduce pneumothorax rates and so fissures are typically avoided
Lesion density	Vascular lesions including arteriovenous malformations and aneurysms are avoided. Typically the more solid component or wall of a necrotic lesion will be targeted to increase diagnostic yield. Similarly adenocarcinoma lesions are frequently sub-solid with areas of less dense ground glass attenuation; the more solid component equates to more invasive tissue and will be preferentially targeted

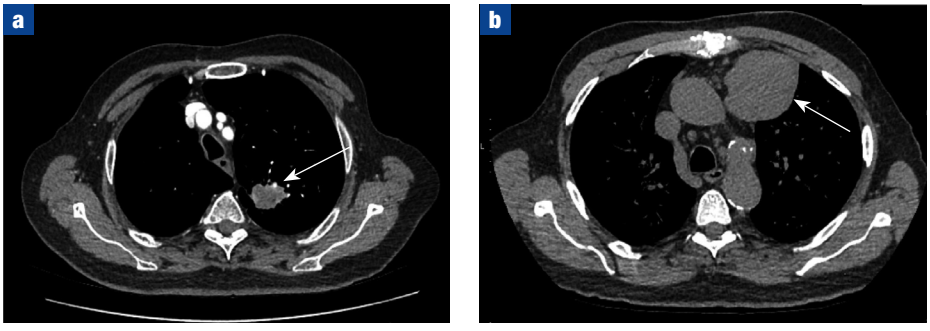

Figure 1. Axial computed tomography images of (a) a left upper lobe mass (arrow) which is suitable for computed tomography-guided biopsy and (b) an anterior left upper lobe mass (arrow) which abuts and invades the chest wall making it suitable for ultrasound-guided biopsy.

Choice of biopsy needle and sampling

Fine needle aspiration sampling has a high sensitivity and specificity for malignancy but this is reduced compared to core biopsy for benign diagnoses (Connor et al, 2000) and is typically best performed when pathology are able to perform direct cytological analysis at the time of sampling and advise on adequacy. In many cases a subsequent core biopsy is advised.

Systematic reviews show that core needle biopsy has higher accuracy than fine needle aspiration (67–90% *vs* 59–81%) (Yao et al, 2012). A large trial of the diagnostic accuracy of computed tomography-guided percutaneous lung biopsy showed diagnostic accuracy, sensitivity and specificity were 92.9%, 95.3% and 95.7% respectively (Yang et al. 2015). For this reason, in most sites across the UK, core biopsy is the preferred sampling method.

In comparison with fine needle aspiration, percutaneous image-guided lung biopsy also allows material to be analysed for surgical pathology rather than cytology, and allows more tissue to be obtained for molecular testing. Molecular profiling can help identify patients who will benefit from targeted treatment, and often repeat biopsies are needed after treatment to identify possible resistance. Examples include targeting epidermal growth factor receptor with tyrosine kinase inhibitors in patients with lung adenocarcinoma. Other mutations searched for include anaplastic lymphoma kinase and programmed death ligand-1.

The authors perform percutaneous image-guided lung biopsy using a co-axial technique which involves the insertion of an introducer needle through a single pleura puncture into the periphery of the target lesion. The inner stylet is then removed and a core biopsy needle inserted, typically with an automated spring-loaded mechanism. Typically the authors use a 17G coaxial introducer needle with an 18G core biopsy needle (*Figure 2*). Some centres use narrower gauge needles particularly for deeper lesions but this reduces sample quality.

For those patients with mediastinal adenopathy, which is not suitable for percutaneous image-guided lung biopsy, endobronchial ultrasound-guided transbronchial needle aspiration may be performed to obtain tissue. This not only provides a safe route for accessing tissue, but allows staging of the mediastinum (Yasufuku et al, 2006).

Computed tomography-guided percutaneous biopsy

The premise is the use of computed tomography to guide the needle into the lesion. Two principal methods exist – conventional computed tomography and computed tomography fluoroscopy. The former involves the radiologist leaving the patient's side to enter the control room while the patient undergoes a short spiral scan at the level of the needle after each repositioning. Alternatively, if using the 'quick check' computed tomography fluoroscopy method the radiologist has control of the scanner and takes a short series of images immediately after repositioning or advancing the needle. The radiologist wears appropriate lead shielding and does not leave the patient's side. *Figure 3* shows a typical room set up for a patient undergoing computed tomography biopsy. Compared with conventional computed tomography this reduces procedure time (Kim et al, 2011) and risk of complications (Heck et al, 2006) compared to the use of conventional computed tomography, but does increase radiation dose (Prosch et al, 2012).

The access route is carefully reviewed. Care is taken to avoid chest wall vessels. Particular attention is given to avoiding internal mammary arteries when accessing anterior or mediastinal lesions. It is preferable for the anticipated needle trajectory to be directed away from major structures including the heart, aorta and pulmonary arteries.

Figure 4 illustrates the steps undertaken in performing a computed tomography biopsy. Under full aseptic technique local anaesthetic is infiltrated subcutaneously and to the level of the pleura along the anticipated needle tract. A small incision is made at the skin surface to facilitate easy passage of the co-axial needle. A co-axial technique is generally preferable as it requires only one pleural puncture for numerous samples. The co-axial needle is introduced into the subcutaneous tissues and incrementally advanced. Position of the needle is confirmed with computed tomography fluoroscopy. Care is taken to advance the needle into a position where, with correct angulation and direction, a single pleural puncture will guide it to the target lesion. Once satisfied that the positioning of the introducer needle is optimal, a swift movement of the introducer needle through the pleura to the lung reduces the chance of a pleural tear.

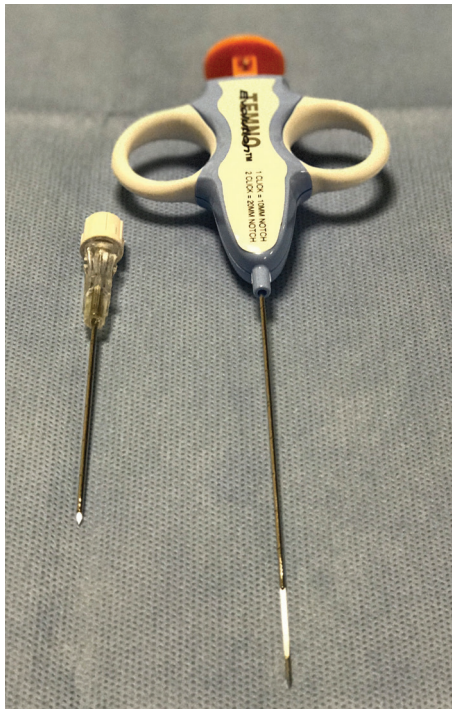

Figure 2. Coaxial Temno needle (Bard, US). The coaxial introducer (left) allows multiple samples from the same biopsy needle (right) with one percutaneous puncture.

Figure 3. Typical set up for computed tomography-guided lung biopsy. The patient is appropriately positioned on the couch having planned the access route. The radiologist wears lead shielding and has control of the gantry. The gantry laser beam helps with needle positioning and the monitors display the needle position relative to the lesion.

The introducer needle is advanced to the periphery of the target lesion and the inner stylet removed. The inner biopsy needle is then inserted down the introducer needle and fired, obtaining a core biopsy of the target lesion. Once sufficient samples are deemed to have been obtained the introduced needle is removed. A subsequent scan is performed to assess for any immediate complications. *Table 3* highlights some variations in technique encountered across centres.

Ultrasound-guided percutaneous biopsy

Lesions that are amenable to ultrasound-guided procedures are either pleurally based or abut the pleura. Ultrasound cannot visualize lesions that are deep to normal lung as ultrasound waves do not penetrate gas-containing structures. Ultrasound-guided

Figure 4. Example of computed tomography fluoroscopic biopsy of a right upper lobe nodule. **a**. Initial scan shows position of lesion with markers to plan approach. **b**. After sterilization, local anaesthetic is infiltrated to the level of the pleura. A 21G needle used to infiltrate the anaesthetic is seen in this image. **c**. After making a small incision the co-axial needle is advanced and appropriately directed at the target lesion. **d**. Using a single pleural puncture the coaxial needle is advanced to the periphery of the lesion. The inner stylet can then be removed and cores taken with the biopsy needle. **e**. Post-procedure computed tomography shows absence of pneumothorax and minor haemorrhage along the needle tract through the nodule.

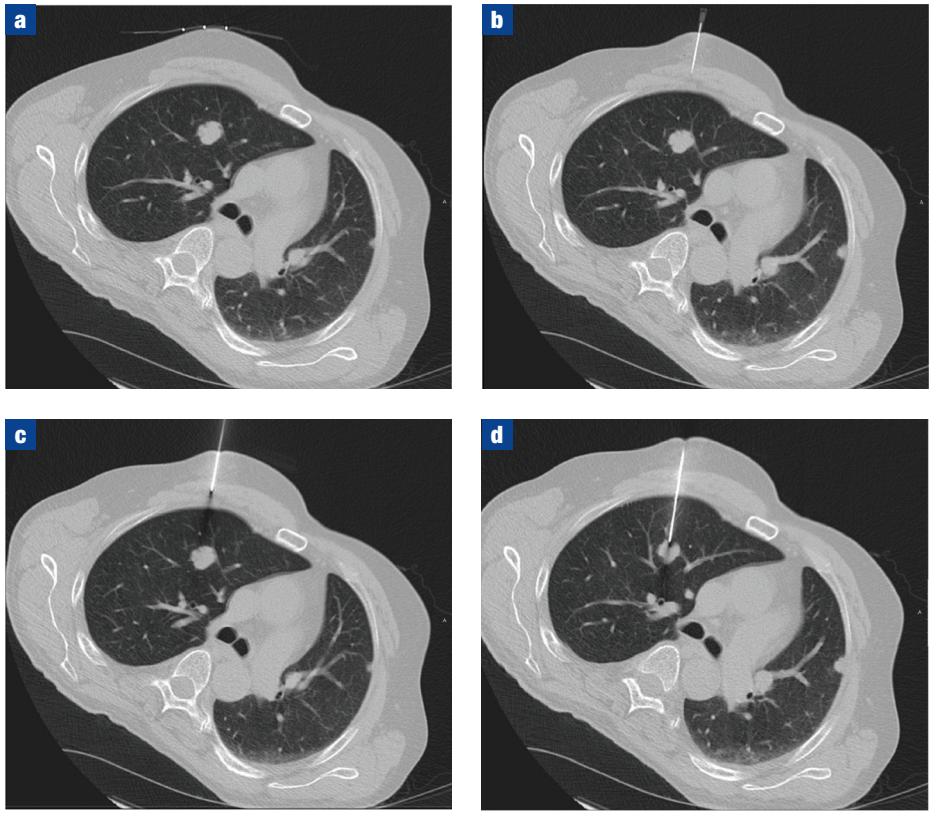

Table 3. Variations in technique

Conscious sedation (typically fentanyl and midazolam) is typically not used for computed tomography biopsies in the UK but is more commonplace in North America
Gantry angulation can be helpful for lesions where a direct axial route through the intercostal space is not possible
Some centres use special measures to reduce the risk of pneumothorax following the procedure including insertion of saline or hydrogel plugs down the needle after biopsy (Li et al, 2015; Vestering and Braak, 2015)

procedures are generally considered safer, quicker and less expensive than computed tomography-guided procedures (Sheth et al, 1999) with reduced pneumothorax rate because of the peripheral location.

The procedure uses ultrasound to guide the needle to the lesion. *Figure 5* is a typical example. Again it is important to optimize patient positioning for ease of access to the lesion. An initial scan will confirm the position of the target lesion. The skin site will be sterilized and under aseptic conditions the needle can be visualized continuously under ultrasound guidance to the lesion whereupon samples are taken as per computed tomography biopsy.

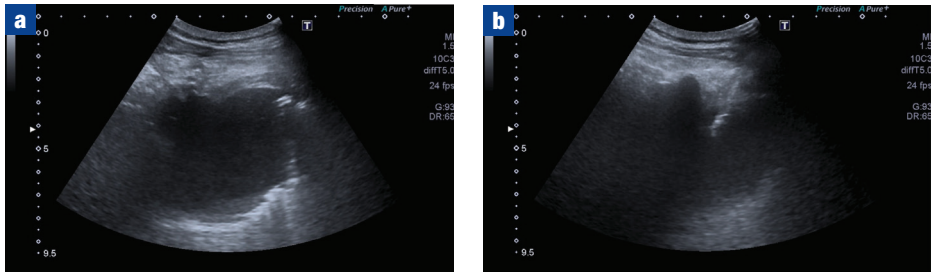

Figure 5. Ultrasound-guided biopsy. **a**. Initial ultrasound scan shows a mass abutting pleura. **b**. Ultrasound is used to demonstrate the co-axial needle advancing into the mass in 'real time' before samples are taken.

Post-procedure care

The patient is transferred to the recovery area. If there is a small pneumothorax or perilesional haemorrhage the patient will typically lie biopsy-side down. The patient is advised to try and avoid coughing or deep respiration which can increase intrathoracic pressure and the likelihood of pneumothorax. If there is a small pneumothorax low flow oxygen is applied (Wu et al, 2011). The authors obtain a chest radiograph at 1 hour and if no complication is shown and the patient is well, he/she is discharged with no need for a more prolonged period of hospital observation.

If a pneumothorax is visible, a repeat chest radiograph is performed an hour later and if stable or improved, the patient can be discharged. If worsened, ambulatory drainage systems are available to facilitate early discharge of patients with a pneumothorax (Tavare et al, 2016). At the authors' institution, a pleural vent is used to facilitate same day discharge (*Figure 6*). This is not only beneficial for the patient in avoiding overnight stays but results in cost savings and increased productivity.

Following ultrasound biopsy if the needle has been directly visualized into a pleural lesion with no parenchymal puncture it is typically not necessary to perform a chest radiograph before discharge. If a peripheral parenchymal lesion is biopsied then discharge is as per computed tomography-guided biopsy.

Complications

The main complication is pneumothorax. The risk of this is increased if the patient has background lung disease, a fissure has to be crossed, if there is a long needle path across the lung, repeated pleural puncture or smaller lesion size. The incidence of pneumothorax has been described between 9% and 54% (Boskovic et al, 2014) but the majority of these are self limiting and do not require intercostal drainage. The British Thoracic Society guidelines suggest that radiologists should aim for fewer than 3% of pneumothoraces requiring drainage, although this will depend on patient selection (Manhire et al, 2003).

Haemoptysis is a commonly occurring complication with a number of patients experiencing small volume haemoptysis. This is increased for sub-solid or consolidative lesions and those close to vessels. Some tumours are more vascular and can cause immediate moderate–large volumes of haemoptysis following biopsy. Haemoptysis has been reported in 1.2–5% of patients (Richardson et al, 2002).

A rare but life-threatening complication, air embolism, has been reported in up to 0.21% of cases, with patients with background lung disease at increased risk (Hare et al, 2011).

Conclusions

Percutaneous lung biopsy is a commonly performed procedure in the diagnosis of lung lesions particularly lung cancer. Understanding the patient pathway in radiology is important for referring clinicians. Multidisciplinary team discussion with radiologists is important to determine optimum sampling technique. Percutaneous image-guided lung biopsy is a safe and effective means of obtaining tissue and the increased demand for tissue to undertake molecular testing means that percutaneous image-guided lung biopsy is pivotal in the lung cancer diagnosis pathway. The

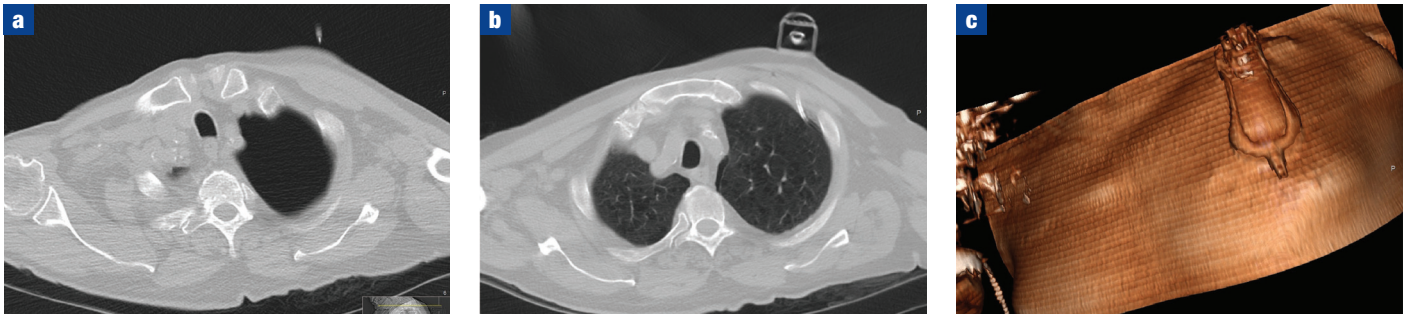

Figure 6. **a**. Axial computed tomography image demonstrating a left pneumothorax which had developed following percutaneous lung biopsy in this 70-year-old patient with emphysema and a left upper lobe mass. **b**. A pleural vent was placed with immediate near complete resolution of the pneumothorax and facilitated same day discharge. **c**. Three-dimensional reconstruction demonstrates the pleural vent sitting flush with the skin of the left chest wall. The vent was removed 2 days later without complication and an unnecessary hospital stay was prevented.

KEY POINTS

- Image-guided lung biopsy is essential for the diagnosis and management of lung and pleural lesions.
- The decision to perform percutaneous lung biopsy is typically undertaken by the multidisciplinary team in conjunction with the performing radiologist.
- Depending on patient and lesion factors the biopsy may be performed under computed tomography or ultrasound guidance.
- Both are commonly performed, effective and safe ways of yielding good samples of tissue for diagnosis and molecular testing.
- The rate of complications is low with <3% of procedures requiring drainage, many of which can be managed with ambulatory drainage systems facilitating early discharge.

procedure has a low rate of complications and advances in pneumothorax management are such that even if complications do occur many patients can be discharged home the same day. **BJHM**

Conflict of interest: none.

Boskovic T, Stanic J, Pena-Karan S et al (2014) Pneumothorax after transthoracic needle biopsy of lung lesions under CT guidance. *J Thorac Dis* **6** (Suppl 1): S99–S107. https://doi.org/10.3978/j.issn.2072-1439.2013.12.08

Connor S, Dyer J, Guest P (2000) Image-guided automated needle biopsy of 106 thoracic lesions: a retrospective review of diagnostic accuracy and complication rates. *Eur Radiol* **10**(3): 490–494. https://doi.org/10.1007/s003300050082

Hare SS, Gupta A, Goncalves ATC, Souza CA, Matzinger F, Seely JM (2011) Systemic arterial air embolism after percutaneous lung biopsy. *Clin Radiol* **66**(7): 589–596. https://doi.org/10.1016/j.crad.2011.03.005

Heck SL, Blom P, Berstad A (2006) Accuracy and complications in computed tomography fluoroscopy-guided needle biopsies of lung masses. *Eur Radiol* **16**(6): 1387–1392. https://doi.org/10.1007/s00330-006-0152-2

Kim GR, Hur J, Lee SM et al (2011) CT fluoroscopy-guided lung biopsy versus conventional CT-guided lung biopsy: a prospective controlled study to assess radiation doses and diagnostic performance. *Eur Radiol* **21**(2): 232–239. https://doi.org/10.1007/s00330-010-1936-y

Li Y, Du Y, Luo TY et al (2015) Usefulness of normal saline for sealing the needle track after CT-guided lung biopsy. *Clin Radiol* **70**(11): 1192–1197. https://doi.org/10.1016/j.crad.2015.06.081

Manhire A, Charig M, Clelland C et al; BTS (2003) Guidelines for radiologically guided lung biopsy. *Thorax* **58**(11): 920–936. https://doi.org/10.1136/thorax.58.11.920

Patel IJ, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, Saad WA; Standards of Practice Committee, with Cardiovascular and Interventional Radiological Society of Europe (CIRSE) Endorsement (2012) Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. *J Vasc Interv Radiol* **23**(6): 727–736. https://doi.org/10.1016/j.jvir.2012.02.012

Prosch H, Stadler A, Schilling M, Bürklin S, Eisenhuber E, Schober E, Mostbeck G (2012) CT fluoroscopy-guided vs. multislice CT biopsy mode-guided lung biopsies: Accuracy, complications and radiation dose. *Eur J Radiol* **81**(5): 1029–1033. https://doi.org/10.1016/j.ejrad.2011.01.064

Richardson CM, Pointon KS, Manhire AR, Macfarlane JT (2002) Percutaneous lung biopsies: a survey of UK practice based on 5444 biopsies. *Br J Radiol* **75**(897): 731–735. https://doi.org/10.1259/bjr.75.897.750731

Sheth S, Hamper UM, Stanley DB, Wheeler JH, Smith PA (1999) US guidance for thoracic biopsy: a valuable alternative to CT. *Radiology* **210**(3): 721–726. https://doi.org/10.1148/radiology.210.3.r99mr23721

Tavare AN, Creer DD, Khan S, Vancheeswaran R, Hare SS (2016) Ambulatory percutaneous lung biopsy with early discharge and Heimlich valve management of iatrogenic pneumothorax: more for less. *Thorax* **71**(2): 190–192. https://doi.org/10.1136/thoraxjnl-2015-207352

Vestering MM, Braak SJ (2015) Where are we on (preventing) pneumothorax after (cone-beam) computed tomography-guided lung biopsy? *J Thorac Dis* **7**(9): E341–E343. https://doi.org/10.3978/j.issn.2072-1439.2015.09.27

Wu CC, Maher MM, Shepard JAO (2011) Complications of CT-guided percutaneous needle biopsy of the chest: prevention and management. *AJR Am J Roentgenol* **196**(6): W678–W682. https://doi.org/10.2214/AJR.10.4659

Yang W, Sun W, Li Q et al (2015) Diagnostic accuracy of CT-guided transthoracic needle biopsy for solitary pulmonary nodules. *PLoS ONE* **10**(6): e0131373. https://doi.org/10.1371/journal.pone.0131373

Yao X, Gomes MM, Tsao MS, Allen CJ, Geddie W, Sekhon H (2012) Fine-needle aspiration biopsy versus core-needle biopsy in diagnosing lung cancer: a systematic review. *Curr Oncol* **19**(1): e16–e27. https://doi.org/10.3747/co.19.871

Yasufuku K, Nakajima T, Motoori K, Sekine Y, Shibuya K, Hiroshima K, Fujisawa T (2006) Comparison of endobronchial ultrasound, positron emission tomography, and CT for lymph node staging of lung cancer. *Chest* **130**(3): 710–718. https://doi.org/10.1378/chest.130.3.710