How, why and when - Chest US guided biopsy?

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Learning objectives

The learning objectives of this Educational exhibit are:

- Brief review of the basic concepts of chest ultrasonography, technique and ultrasound chest anatomy.

- The recognition of the usefulness of thoracic ultrasound to guide interventional procedures in the diagnostic study of thoracic masses

- The practicality of contrast enhanced ultrasound in diagnostic study of thoracic masses

- The description of clinical applications and limitations of this interventional technique

- The recognition of the advantages and disadvantages compared to other interventional procedures

- The report of some technical aspects

- The identification of the procedures' complications
Background

Imaging guided percutaneous transthoracic biopsy has become a widely accepted, effective and safe minimally invasive technique to obtain tissue specimens from a number of different thoracic lesions (1).

Computed tomography (CT) is the most common guidance technique for percutaneous transthoracic interventional procedures, as it provides relevant information about needle trajectory within the lung. However, conventional CT guidance does not allow for real-time monitoring of neither needle movement nor lesion displacement with respiration (1).

Despite being challenging, the US examination of the chest is a rapidly developing application of ultrasound (US) and may be used to evaluate a wide range of peripheral parenchymal, pleural and chest wall diseases (2).

Moreover, it is well recognized that US is being increasingly used to guide interventional procedures of the chest such as biopsy and placement of intercostal chest drains (3,4,5). Recent technical developments, such as microbubble contrast agents, are starting to be used in thoracic interventional procedures.

Major advantages of this imaging modality are real-time multiplanar monitoring of the procedure and the ability to be performed at the patient's bedside, without the use of ionizing radiation (1,3,4). Furthermore, in certain chest lesions, US guidance is comparable to CT in terms of sample accuracy, while allowing for a significant reduction in procedure time and postprocedural pneumothorax, without the use of ionizing radiation (1).
Imaging findings OR Procedure details

I. Chest Ultrasonography

Chest ultrasonography is a challenging US examination, because 99% of the ultrasound waves emitted by the transducer are reflected at the interface between the pleural membrane and the lung. This is explained by the large difference in acoustic impedance between the soft tissues and the aerated lung and also by the attenuation of ultrasound waves when propagated through aerated structures (3). However, there are several reports in the literature that show utility of ultrasound imaging in the evaluation of parenchymal, pleural and chest wall diseases (1-5).

II. Chest Ultrasonography Technique

A Chest ultrasonography may be performed with 2- 5MHz curvilinear probe, in order to display deeper structures. On the contrary, chest wall, pleura, and peripheral lungs benefit from high-resolution 7.5-10-MHz linear probe.

Usually chest US is performed with B-mode gray-scale and color Doppler. The evaluation is performed during normal respiratory motion, to assess normal lung movement, and in suspended respiration to depict details.

With B-mode gray-scale evaluation the description of the lesion is based on the comparison of the echogenicity of a lesion to the liver, describing it as hypoechoic, isoechoic, or hyperechoic.

Using color Doppler, the sensitivity of the Doppler should be set to low flow or the low-velocity scale (typically 0.25 m/sec). The wall filter is set to minimize rejection of small frequency shifts and to avoid interference from respiratory or cardiac movements (1,2). The color Doppler gain is increased until a uniform background colored "snowstorm" is obtained and then decreased until just a few random colored speckles remain (1,2). Pulsed-wave Doppler is used to evaluate vascular flow within a lesion, and the Doppler angle should be 60° or less. The pulsed-wave Doppler should be repeated at least twice to ensure reproducibility of the spectral waveform. The peak systolic velocity, end-diastolic velocity, resistive index, and pulsatility index are easily derived from the tracings (2).

Color Doppler US is helpful in distinguishing the great vessels from any mediastinal mass, and also to depict internal vascularization of lung, pleura and chest wall lesions.
There are several examination positions that the patient may adopt for chest US. The most common to evaluate posterior chest is with the patient sitting upright, (Fig. 1) while the anterior and lateral chest may be evaluated with the patient in lateral decubitus position. (Fig.2)

Nevertheless, the patient positioning depends mainly on the clinical condition, and according to our experience severely ill patients are unable to tolerate upright sitting position.

Sonographic views of the upper anterior and middle mediastinum can be obtained via a suprasternal approach. The suprasternal approach allows adequate assessment of the upper mediastinum in 90%-95% of cases (2). This is performed with the patient in a supine position, with shoulders supported with a pillow and head extended backward. Views of the upper mediastinum should be obtained in the sagittal and axial planes (2).

III. Chest wall anatomy in US

In order to perform chest ultrasonography the radiologist must be familiar with the anatomy of the chest wall and it's appearance on the ultrasound.

Chest wall anatomy appears as a set of echogenic soft-tissue layers, representing the layers of muscles and the fascia planes. Below the soft tissue of the chest wall, the ribs appear as curvilinear structures on transverse scans, associated with posterior acoustic shadowing. When the ribs are scanned along the long axis, the anterior cortex should appear as a continuous smooth echogenic line (2).

With a high-resolution linear probe, the visceral and parietal portions of the pleura can be seen as two echogenic lines deep to the ribs (Fig 3). The visceral pleura usually appears thicker than the parietal pleura (2). With a 3.5-MHz curvilinear probe, differentiation between the visceral and parietal portions may not be possible, and they usually appear as echogenic bands measuring up to 2 mm in thickness (2). However, normal movement of the lung relative to the chest wall, which has been described as the "lung sliding" sign, should be apparent (2).

Deeper than the pleural-lung interface, the lung is air-filled and does not allow further visualization of normal lung parenchyma. The large change in acoustic impedance at the pleural-lung interface results in horizontal artifacts that are seen as a series of echogenic parallel lines equidistant from one another below the pleural line (2,3). In addition, vertically oriented "comet-tail" artifacts can also be normally seen, originating at the pleural-lung interface (2,3). The visualization of these artifacts in a healthy adult is usually confined to the last intercostal space above the diaphragm. With a curvilinear
probe, these artifacts are seen to fan out to the edge of the screen. The comet-tail artifact results from the fluid-rich subpleural interlobular septae, which are surrounded by air. Hence, these artifacts appear closely spaced, separated from each other by an average distance of 7 mm (2,3)

III. US guided thoracic intervention

Several are the reports on the literature regarding US-guided thoracic intervention. According to Koh et al, these procedures may be schematize in intervention on the pleural space, chest wall intervention and pulmonary intervention, as it is shown on figure 4.

According to our hospital experience we will approach the chest US guided biopsy procedure in a general, practical and schematic mode, taken in account that in the majority of the cases it is not possible by the time that the patient arrives to a diagnostic evaluation, to depict the real anatomic origin of the lesion.

1. Chest US-guided biopsy indications, advantages and contraindications

The main indication for chest US-guided biopsy is to obtain tissue sample for histologic diagnosis of an indeterminate chest lesion. The chest wall hosts a variety of tumors, some of which arising directly from the structures of the wall and others arising from nearby structures and posteriorly invading the chest wall (6).

Computed tomography (CT) is usually the most common guidance technique for percutaneous transthoracic interventional procedures, as it provides relevant information about needle trajectory within the lung (1). However conventional CT guidance does not allow for real-time monitoring of neither needle movement nor lesion displacement with respiration (1).

Meanwhile chest US can be used as a safe and effective method to guide biopsies of masses arising or abutting the chest wall (1,3,5). Major advantages of this imaging modality are that US enables real-time multiplanar monitoring of the procedure and can be performed at the patient's bedside, without the use of ionizing radiation (1) (Fig 5,6,7).

According to Sconfienza et al, US-guided biopsy of pleural and peripheral lung nodules, reduces median procedure duration by 42% with comparable technical success rate of the procedure to CT guidance.
Furthermore, according to our experience, chest US-guidance is not only a less consuming procedure but also a less expensive procedure for the patient and US equipment is generally more widely available. Moreover portable US machines can also be moved to the patient's bedside, so the procedure can be performed at the bedside of critically ill patients and even those situated in different positions, such as in a semi-sitting decubitus position in patients with dyspnea who cannot tolerate prone or supine positioning (1).

Regarding technical details, chest US-guided biopsy enables a more straightforward puncture of the lesion due to the real time evaluation. It also allows biopsy on several planes of the lesion and not only on an axial section like in CT-guidance.

In general contraindications to transthoracic needle biopsies are not absolute, except when patient refuses to perform the procedure or to sign the informed consent.

Concerning to relative contraindications, the most important and first to consider issue is the presence of a bleeding diathesis. Recent platelet count, prothrombin time (PT), and partial thromboplastin time (PTT) with international normalization ratio (INR) should be obtained. Temporary discontinuation of anticoagulants such as warfarin, heparin, and aspirin is necessary (7).

2. Contrast enhanced chest ultrasonography

In 2011 the EFSUMB (European federation of societies for ultrasound in medicine and biology) published recommendations on the clinical practice of contrast enhanced ultrasound (CEUS) for non-hepatic applications. These guidelines indicate the use of US endovenous contrast in chest / lung and pleural only in peripheral lesions visible on US (8).

Despite some reports on the literature using CEUS to characterized pulmonary lesions by different CEUS-patterns of arterial supply, no true consistent result has yet been reported (9,10). On the other hand there are also reports advocating the use of CEUS to guide percutaneous liver biopsies due to the easy display of necrotic areas versus viable tumoral areas that provide more specimen material (11).

In our institution we are performing initial studies with CEUS on chest wall lesions in order to depict vascularization of the lesions. We first evaluate the lesion with B-mode ultrasonography and then we perform an injection of microbubble contrast agent (SonoVue, Bracco Spa). We adjust the dose of contrast according to the depth of the
lesion and type of probe we intent to use. With an evaluation with a curvilinear probe we injected IV via a 20-gauge cannula a volume of 1.5 mL followed by a 5-mL saline flush. The tissue enhancement of the lesions is evaluated using spleen and thoracic muscles enhancement as reference. All CEUS studies are analyzed on the basis of review of sonographic unit-stored clips stored during the exam.

According to our brief experience, CEUS applied to chest lesions allows not only to depict viable areas for biopsy but also to evaluate the lesion's vascularization. (Fig 8,9,10,11).

3. Technical considerations of Chest US-guided biopsy

3.1 Pre-procedure steps

• Diagnostic Evaluation and review

Previous to any procedure a complete diagnostic evaluation and review of the patient clinical condition should be done, taking in account the patient's clinical history, current medication and clinical condition, in order to assess if the patient is able to tolerate the procedure or to choose the best position to performed it. A review all the previous imaging studies of the patient such as chest radiograph, chest CT, lung positron emission tomography (PET) or chest ultrasound (US) in order to determine lesion location, as also to depict thoracic anatomy and anatomical variants should be done.

• Explanation of the procedure and Informed Consent

It is important before planning the technical details of the procedure to communicate with the patient and provide all the information about the procedure in order to promote the patient's confidence and trust. A brief explanation of the indications, contraindications and possible complications of the procedure, according to our experience, usually result in lower levels of anxiety and better collaboration during the procedure.

Chest US-guided biopsy is an invasive procedure with potential complications, thus obtaining informed consent with the patient and his or her family (with clear understanding of the procedure and potential risks) is important due to ethical and legal issues.

• Laboratory values review and medications

Just like in other US-guided biopsy procedures, it is important to review before hand all the recent laboratory values. Recent platelet count, prothrombin time (PT) or INR and
partial thromboplastin time (PTT) should be obtained (7). Temporary discontinuation of anticoagulants such as warfarin, heparin, and aspirin is necessary.

3.2 Procedure steps

- **Interventional table preparation and team working**

The first step of the technical procedure is to setup the interventional working table with all the material that will be used during the biopsy. All the materials placed on the table is sterile.

All the material is illustrated on figure 12

Materials used, like the needle types and percutaneous approach are similar to other US-guided biopsy procedures. In our institution we use the free-hand technique as described in the literature.

- **Patient positioning**

Unlike percutaneous CT-guided biopsy, with US guidance the patient positioning may be done in multiple ways, taking in consideration not only the location of the lesion, as also the comfort of the patient.

- **Sedation and anaesthesia**

The use of sedatives depends on patient clinical and psychological condition. According to our experience, we advocated the use of conscious sedation with midazolam or diazepam (depending on the clinical history of the patient) for anxious patients and elderly patients who are already undergoing pain and stress due to the underlying condition.

Regarding anaesthesia, all patients in our department are injected with 1% or 2% lidocaine thru a 25-gauge needle.

- **Procedure steps**

1. Review patient clinical history, medication, recent laboratory values and previous imaging evaluations.
2. Explain the procedure and obtain the informed consent.
3. Perform a first control ultrasound in grey scale of the lesion and surrounding chest. Evaluate with Doppler the vascularization of the lesion and surrounding vascular structures.
4. Plan an access route to the lesion and measure the distance between the lesion and the skin and also distance to lung or vital structures as great vessels or heart.
5. Prepare the skin site using a cleaning solution like povidone-iodine.
6. Inject with a subcutaneous needle the local anesthetic (lidocaine 1% or 2%). Infiltrate subcutaneous tissues. The injection of lidocaine might be done under US control in order to assess needle trajectory and surrounding structures.
7. Perform a small incision on the site of the anesthetic injection and insert the needle biopsy.
8. Position the needle tip in areas with more solid appearance. This may be depicted by the iso/hyperecogenic areas in opposite to hypoechochogenic zones that commonly are cystic or necrotic. Fig.13
9. Once the needle tip is clearly visualized and the performing radiologist is confident the needle throw will not risk complications, the needle biopsy can be fired under US visualization.
10. Remove the needle and deliver the specimen to the previously prepared specimen vial in order to be sent to pathology analysis.

3.2 Post-procedure care

After the procedure, ultrasound can be used to search for possible complications. Usually, pain is well tolerated but this also depends on the patient clinical and psychological condition and mild oral analgesia may be prescribed for 24-48 h following the biopsy.


Complications of chest US-guided biopsy are similar to complications from other image-guided biopsy procedures of the lung and include infection of the pucture site, hemorrhage, pneumothorax, hemoptysis, hemothorax, and lung infection (7).
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Fig. 1: US evaluation of posterior chest with the patient sitting upright

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**Fig. 2:** US evaluation of lateral chest with the patient in lateral decubitus position

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**Fig. 3:** US appearance of the chest wall. Below the relatively echogenic subcutaneous tissue, the intercostal muscles appear with multiple echogenic fascial planes. The pleural interface appears as an echogenic line.

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**Fig. 4**: Ultrasound guided thoracic interventions schematized according to pleural space, chest wall and lung.

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Fig. 5: A 79-year-old male with a Pancoast tumor: Thoracic CT shows a 8 x 7 cm heterogeneous left upper lobe mass, invading the superior mediastinum and adjacent ribs

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Fig. 6: A 79-year-old male with a Pancoast tumor: Chest radiogram showed 8 cm rounded left upper lobe mass with silhouette sign with the mediastinum in keeping with Pancoast tumor.

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Fig. 7: A 79-year-old male with a Pancoast tumor: US-guided biopsy of the lesion by ultrasonography apical approach. In comparison to CT, a major advantage of US is its true multiplanar nature, allowing real-time corrections of the needle's orientation.

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Fig. 8: A 81-year-old male with a sarcomatoid carcinoma of the chest wall: Chest radiogram shows a 6 cm oval shaped opacity in the right lung

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Fig. 9: A 81-year-old male with a sarcomatoid carcinoma of the chest wall: Chest radiogram shows a 6 cm oval shaped opacity in the right lung

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**Fig. 10:** A 81-year-old male with a sarcomatoid carcinoma of the chest wall: B-mode US evaluation shows a thoracic lesion that displays an heterogeneous appearance with central hyperechogenic areas and surrounding hypoechogenic peripheral zone. Pleural line is noted.

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Fig. 11: A 81-year-old male with a sarcomatoid carcinoma of the chest wall: CEUS evaluation in dual mode, with double window a) B-mode and b) CEUS mode. After contrast injection of 1.5ml a central and peripheral enhancement due to the vascularity of the lesion is seen. The pattern of enhancement rises from the periphery to the center of the lesion and follows the root of the intercostal adjacent arteries. The time of enhancement in arterial phase is simultaneous to the intercostal arteries, indicating non-pulmonary and non-bronchial vascularization.

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Fig. 12: Worktable setup for a percutaneous biopsy procedure with all the material that will be typically needed

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**Fig. 13:** A 59-year old female with a chest wall sarcoma: Biopsy was performed by ultrasound guidance with a curvilinear US probe

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Conclusion

Chest US-guided procedures are well-established techniques that, in daily work, add value to the thoracic interventional workflow. Chest interventional US allows, in suitable lesions, bedside evaluation, procedure planning and execution, significant reduction in procedure time and a wider range of multiplanar approaches, as opposite to conventional CT, in a radiation free environment.
References


