# Transthoracic Ultrasound in Pleural Diseases

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## Contents




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## 18.1 Introduction

*The pleura was the first thoracic structure to be studied with ultrasound.*

The simplest and most immediate field of application of transthoracic ultrasound is the study of the pleura. Pulmonologists were slow to discover this precious resource, which had already aided 'difficult' thoracentesis since the 1970s, the first ever successfully performed by cardiologists [1]. In recent years, the use of pleural ultrasound has become increasingly routine due to its dynamism and simplicity [2], low cost and freedom from ionising radiation; it is repeatable, now compatible with light and portable instruments, and easy to handle and to perform [3]. It has been shown to provide diagnostic information in a short time and to assist both doctor and nurse during invasive manoeuvres, both in the endoscopic room and at the patient's bedside. It has become an irreplaceable resource before and during thoracoscopy [4] and has been able to identify with certainty and speed some complications of Interventional Pulmonology such as pneumothorax or haemothorax (◘ Table 18.1).

◘ **Table 18.1** Advantages in pleural ultrasound

| **Ultrasound in pleural diseases: why?** |
|---|
| • Easy learning |
| • No radiation |
| • Autonomy |
| • Real time |
| • Fast |
| • Very useful in babies and children |
| • Possible in pregnant women |
| • Takes advantage of decubitus and gravity |
| • 70% of pleural surface visible |
| • Fundamental in the follow-up |
| • Fundamental in invasive manoeuvres |
| • Fundamental in the evaluation of infectious effusions |

## 18.2 Technique

The difference of acoustic impedance between the thoracic wall and the air present inside the lung makes the pleural surface easily identifiable; however, this acoustic barrier unfortunately makes it impossible, in the absence of pathology, to see the organ in-depth [5].

The two probes that best allow us to study lung diseases are:

*The convex probe for effusion and its characteristics, the linear one for thoracic wall and pneumothorax*

- the convex probe, at low frequency (3.5 MHz), which allows for greater depth, reaching a depth of up to 15 cm, enabling a panoramic view of the effusion. Alternatively, the 2.5 MHz cardiac sector probe can be used. These types of probe are indispensable in the evaluation of effusion, as a guide to interventional procedures and in the study of diaphragmatic motility.
- the linear probe, at high frequency (7–15 MHz), which provides an image with a higher resolution but reaches a depth of only a few cm. This probe is very useful for a more in-depth study of the pleural surfaces and their sliding, in pneumothorax in search of the lung point (PTX), in identifying plaques and pleural thickening, and in the search for minimal pleural effusions in the costophrenic sinuses.

*70% of the pleural surface can be studied with ultrasound.*

The only limitations to ultrasound exploration are the presence of subcutaneous emphysema and the inability to explore some thoracic regions such as the retro-scapular, apical and supra-diaphragmatic regions. It is estimated that 70% of the pleural surface can be explored by ultrasound.

Regarding the way the examination is performed, patients are preferably studied in a sitting position, which facilitates the search for a pleural effusion due to gravity, and in the supine one to explore the sub-clavicular regions in search of pneumothorax [6].

*The pleural line is the main target to look for before any other.*

In healthy subjects, the parietal and visceral serosa together form an interface with a thickness of several hundreds of microns known as the pleural line, and we must start from this to begin our evaluation and then interpret the disease [7].

*Ultrasound, the only diagnostic test, studies the pleura in motion.*

The pleural line is a horizontal and luminous line a few centimetres from the skin, hyperechoic and brilliant, that normally moves synchronously with the breath that in longitudinal scan is seen between the ribs, while in the oblique one it is totally visible. This movement is called ‘sliding’ and is maximum at the base and more contained at the apex; its absence is almost always a sign of pneumothorax. It may also be absent in previous pleurodesis, pneumo/lobectomies and fibrothorax.

The ventilated pulmonary base that moves during the acts of breath covering the abdominal organs, on the other hand, constitutes the 'curtain sign' whose width on the right is clearly visible and measurable. The pleural line can move synchronously with the heartbeat, especially to the left, and this movement is more accentuated if the lung is consolidated [8].

All signs of normality and pathology depart from the pleural line, the true protagonist of thoracic ultrasound. In the normal lung, thin horizontal artefactual lines (A lines) repeat evenly and parallel below the pleural surface, while B lines are vertical hyperechoic reflections extending from the pleural line to the edge of the screen image. They move in synchrony with sliding and when present they attenuate until the A lines are cancelled. The presence of the B lines is synonymous with 'interstitial syndrome' caused by a decrease in air content and an increase in lung density, as occurs in the presence of pneumonia, pulmonary oedema, fibrosis, ARDS, neoplastic carcinosis and alveolar haemorrhages [9].

## 18.3 Pleural Effusion

*Chest ultrasound is considered the 'gold standard' for the study of pleural effusion.*

Chest ultrasound is considered the 'gold standard' for the study of pleural effusion (■ Fig. 18.1). The ultrasound examination guides the diagnostic and therapeutic strategy. In fact, in at least half of pleural effusions, there is a 'change' in the diagnostic and therapeutic management after the patient has undergone ultrasound. The pleural fluid is easily identifiable due to the presence of different degrees of echogenicity compared to other body tissues. Ultrasound is not only useful for its easy identification but is an essential tool for a more in-depth analysis of the effusion. It enables its exact location and its arrangement within the chest, as well as freedom of movement with the decubitus, allows for a very reliable estimate of the entity and evaluates the specific echogenic characteristics [10].

The scan, preferably oblique, must start from the base, always identifying as a reference the acoustic windows of the liver on the right and the spleen on the left. Free effusion accumulates by gravity and moves along with the decubitus; it is visible first in the costophrenic angle and as it increases it fills the cavity by leaning on the lower lobe and progressively squeezing it towards the hilum. The parenchyma gradually loses its air content and is visible as a solid, floating structure within the fluid (the 'jellyfish sign'). These ultrasound signs indicate that this lung will most likely undergo re-expansion after thoracentesis. If, on the other hand, the lung is 'trapped',

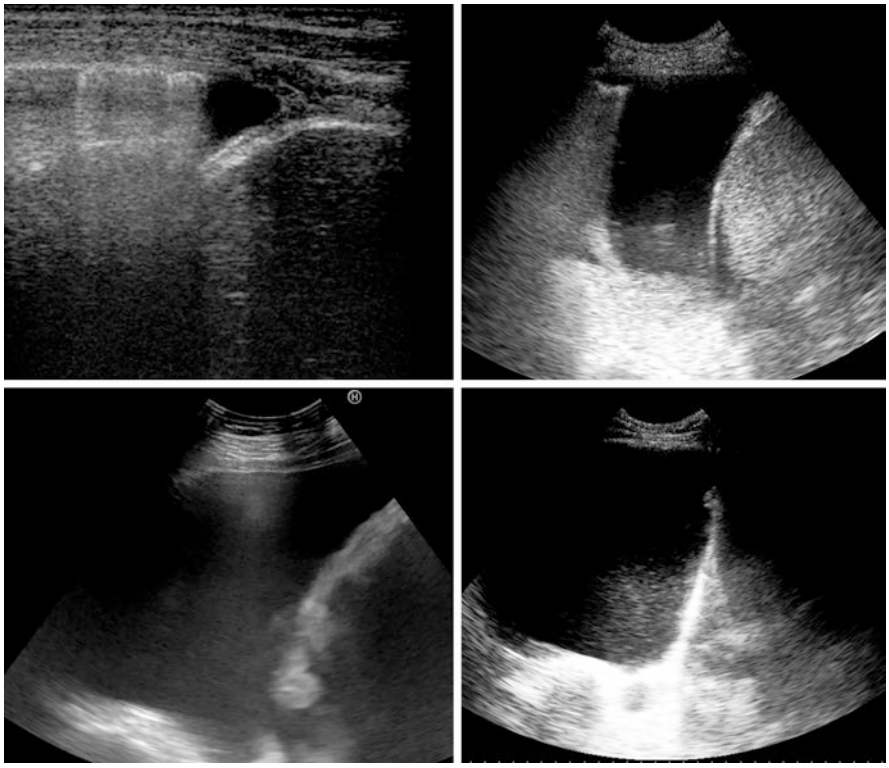

**Fig. 18.1** Free pleural effusions

it assumes a rigid shape, not very mobile, with hyperechoic contours, and in all probability will not re-expand during the evacuation manoeuvre [11].

*Dyspnoea can easily be distinguished as to cardiogenic or pulmonary origin.*

It is difficult to quantify exactly the volume of an effusion; there are various formulas but nevertheless they are seldom applied. The complex geometry of the chest and the variable constitution of the patients are obstacles to the exact estimation of the amount of fluid. An approximate measurement is expressed as 'light' if visible in only one intercostal space, 'moderate' if it occupies two intercostal spaces and 'massive' if it is seen in three or more spaces [12]. Ultrasound allows us to identify very small amounts of fluid (5 mL), whereas the chest X-ray is able to detect the effusion when at least 150 mL or more are present. A linear probe, by studying the costo-phrenic sinus, can also look for the presence of pleural adhesions or irregularities, thus increasing the probability that we are faced with a neoplastic form, while the presence of fibrin almost always identifies the infectious and/or inflammatory effusions (◘ Fig. 18.2). It is always useful to place the probe also in the contralateral hemithorax, as the bilateral nature of the fluid

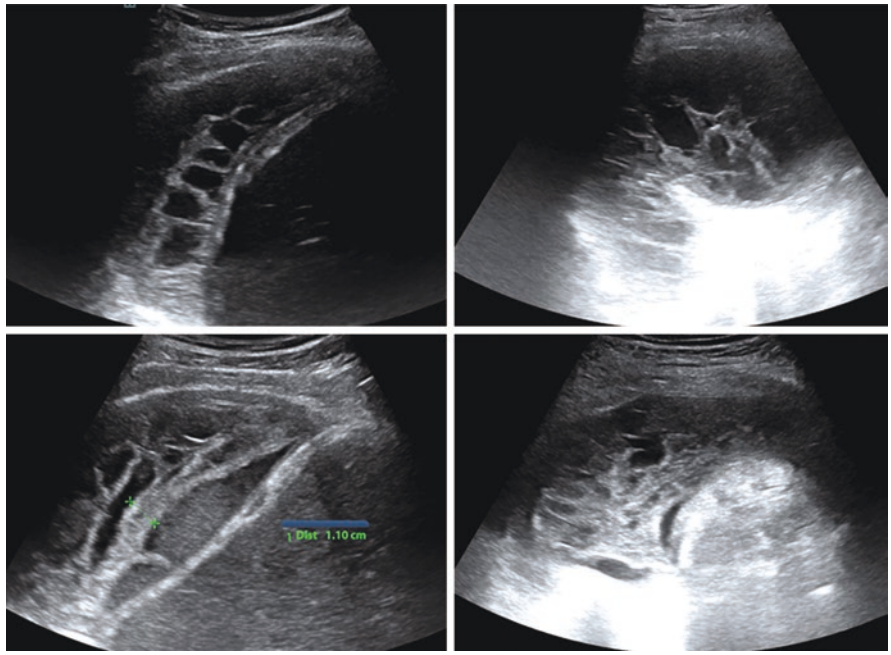


**Fig. 18.2** Parapneumonic effusion

has a great diagnostic value. In the presence of bilateral effusion, it is also necessary to evaluate the diameter of the inferior vena cava and its collapsibility with the acts of breathing, in order to rule out heart failure.

The fluid can be anechoic (and this does not mean transudate) or may contain within it more or less rigid membranes that loculate it, which can be free or fixed, thick or thin, single or multiple; pulmonary ultrasound is much more sensitive than CT for their identification. In the presence of empyema (Fig. 18.3), on the other hand, the echogenicity is very high, similar to that of the liver, sometimes granular and irregular, and there may be air inside it.

*In infectious effusion, ultrasound is more sensitive than CT to decide the treatment.*

The loculations are typical of acute and bacterial infectious effusion (Fig. 18.2), and the ultrasound dictates the behaviour to be followed: when to drain and how, which drain to use, the best position, whether to use fibrinolytics, when to decide to remove it. Septations, albeit rarely, can also occur in long-standing exudations, but can also be found in neoplastic pleural cavities, mesothelioma and especially lung neoplasms.

Tuberculous pleurisy, on the other hand, is ultrasonographically different. There is less fibrin, sometimes a millimetre of irregular parietal thickening is visible, and in almost all cases the presence of an enlarged internal mammary chain lymph node is detectable (Fig. 18.4).

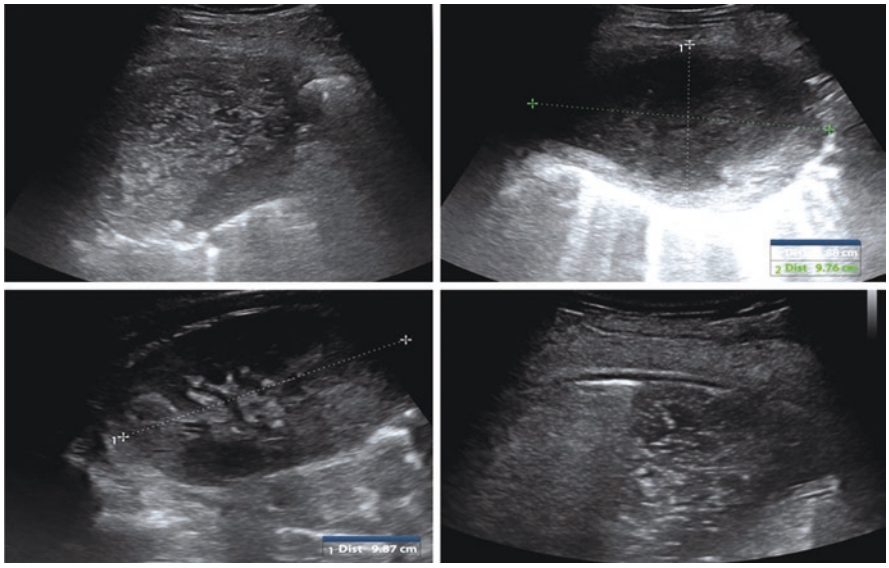


**Fig. 18.3** Empyema

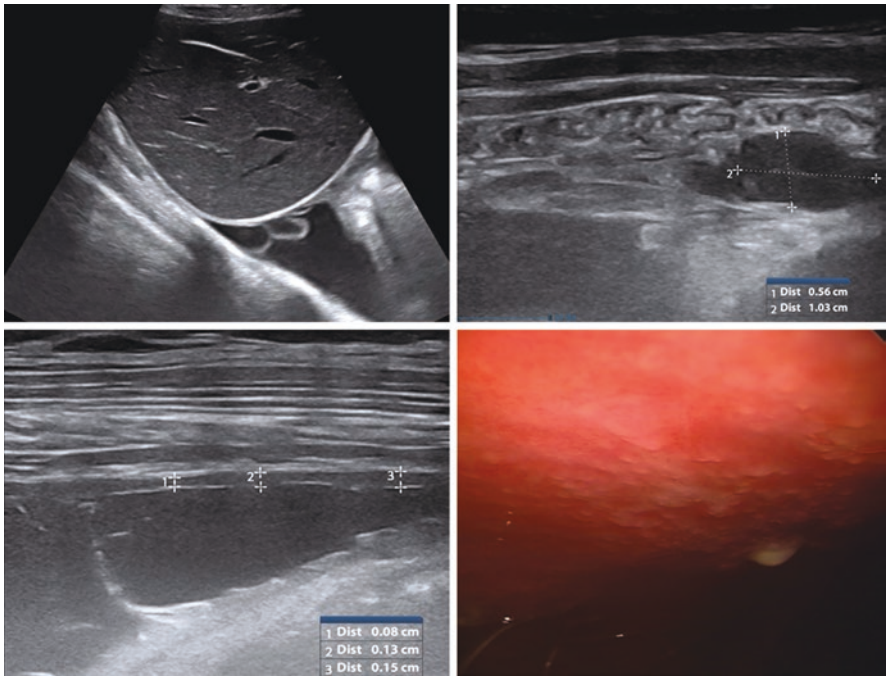


**Fig. 18.4** Pleural tuberculosis

The presence of fluid makes visible the diaphragm and lung parenchyma, which can be the site of collateral anomalies such as nodules, infiltrations or parenchymal abscesses. The absence of air-bronchograms inside the collapsed lung and its rigidity may lead to the suspicion of atelectasis or 'trapped lung' [13].

## 18.4 Pneumothorax

*Pneumothorax is easily identifiable, especially in urgency.*

Ultrasound diagnosis of pneumothorax (PNX), with very high sensitivity and specificity, must be included among the most recent and most clinically useful achievements. The possibility of making a safe and quick diagnosis at the patient's bedside has a very high value in this disease. Although CT remains the gold standard, ultrasound has become a safe and reliable procedure, overtaking traditional radiology [14].

The signs are many and pathognomonic, reliable and safe: first of all, the absence of sliding and the disappearance of B-lines; the increase in horizontal artefacts; where possible, the identification of the 'lung point' (that is, the exact point where the parenchyma detaches from the wall); the disappearance of the lung-pulse [15]. Since the free air collects in the upper spaces, the PNX should be sought with the linear probe anteriorly in the sub-clavicular area with the patient in the supine position. The pleural spaces should be explored longitudinally from the sternum to the mid-clavicular line and from the clavicle to the anterior diaphragm. This ultrasound picture can be part of a differential diagnosis with some conditions of reduced lung compliance where sliding is reduced, such as atelectasis or a congenital or acquired symphysis.

## 18.5 Thickening and Neoplasia

Another anomaly that can be easily identified with ultrasound is the thickening of the serosa. It appears as an echo-free stripe that moves the pleural line deeply. It is essential to evaluate the edges and infiltration towards the thoracic wall but also in the parenchyma; the irregularity and depth raise the suspicion of neoplasia, mainly mesothelioma. However, the edges are smooth and respect the sliding in the benign forms, as in asbestos hyaline plaques. In fact, pleural hyaline plaques usually appear as hypoanechoic, elliptical and smooth lesions, not modified by the decubitus, the diaphragmatic ones being the most difficult to identify. Inside them, there may be calcifications that occur with the typical posterior acoustic shadowing [16].

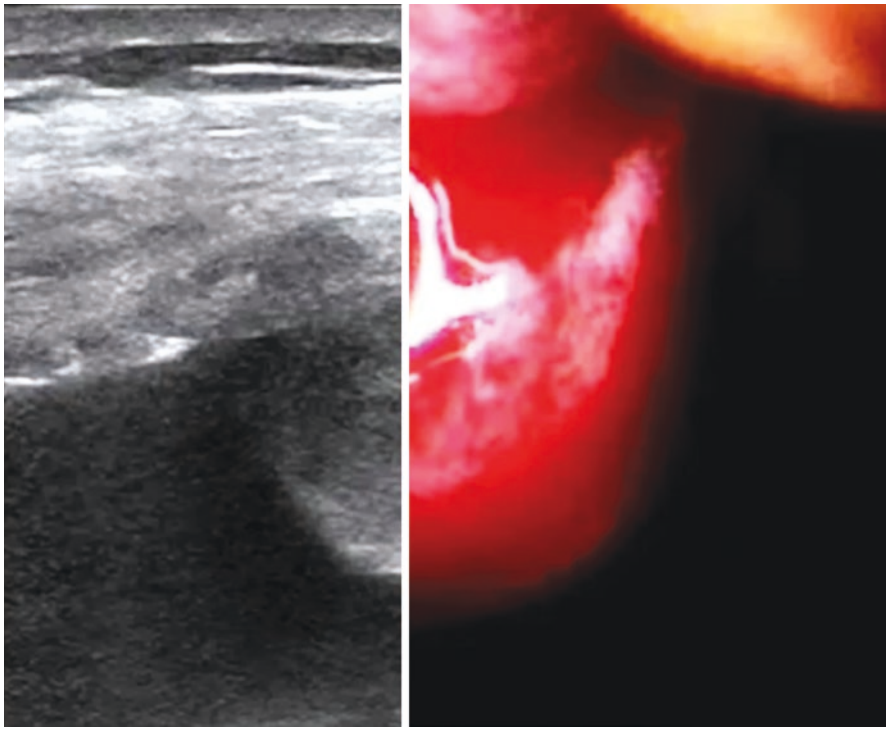

**Fig. 18.5** Metastatic nodule

Another extensive field in which ultrasound diagnosis has acquired increasing importance is that of pleuro-pulmonary neoplasms, primary and secondary, whether associated with pleural effusion or not (Fig. 18.5).

A thorough scan can allow for the precise definition of the localisation of the tumour (extrapleural, pleural or parenchymal), local infiltration, the extent of the mass and its nature (solid, cystic or complex) (Fig. 18.6).

Extrapleural tumours move the pleural line deeply by deviating its underlying straight profile and are often associated with destruction of the ribs or muscle infiltration. If, on the other hand, the lesions are in the cavity, it is necessary to distinguish the pleural ones that do not move with sliding but respect it from the peripheral pulmonary ones that instead tend to move with the breath. On the other hand, the identification of central tumours is impossible due to the interposition of an aerated lung between the lesion and the probe. The invasion of the wall can be evaluated more accurately with ultrasound than with CT [17].

Malignant mesothelioma arises in the pleural cavity and ultrasound can detect it at an early stage (Fig. 18.7).

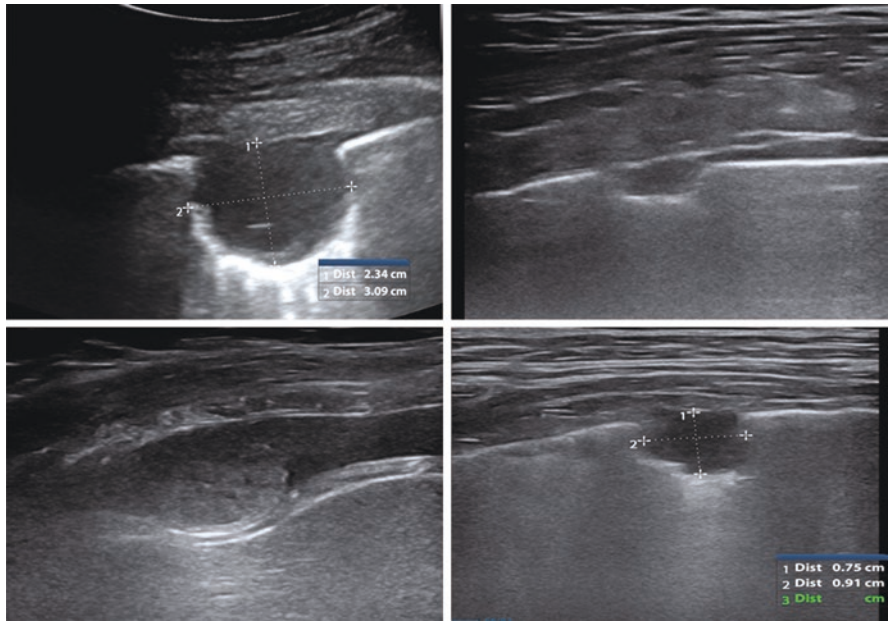


**Fig. 18.6** Intrathoracic metastasis

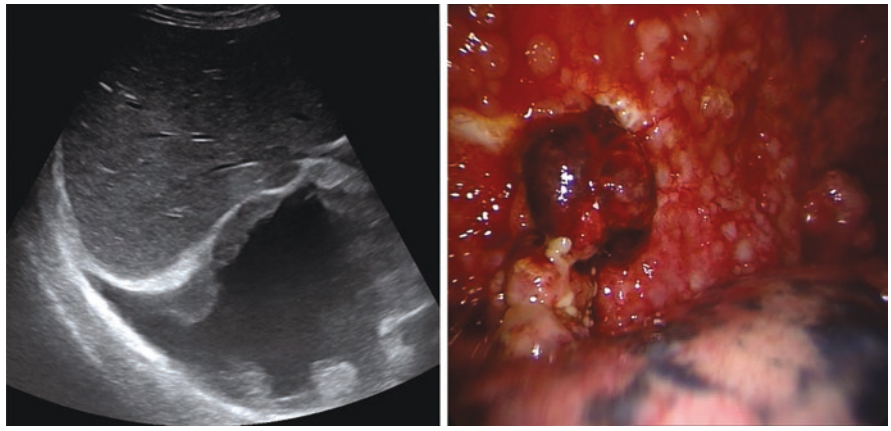

**Fig. 18.7** Malignant mesothelioma



Attention should always be paid to the costo-phrenic sinus, the real thermometer of the pleural cavity. It should be studied in all positions: if there is fluid, it acts as a contrast for the possible presence of a suspicious thickening or even better for neoplastic nodulation, generally with a large implant base. We

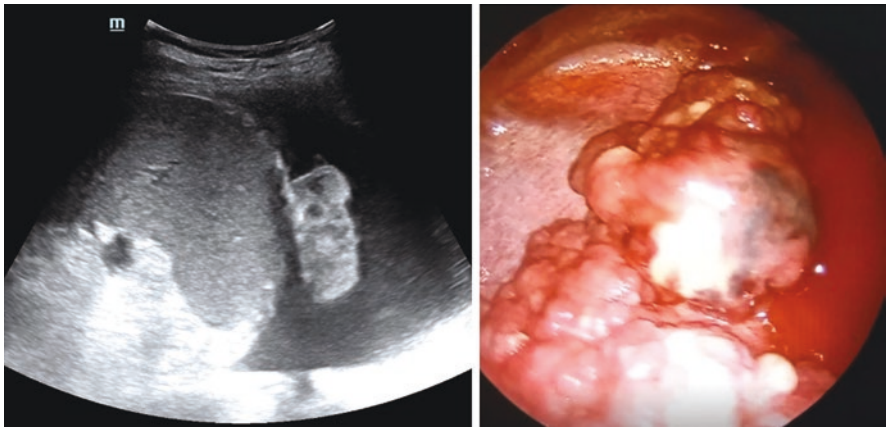

**Fig. 18.8** Invasion of the diaphragm by mesothelioma

must also remember that a thickening should be placed in a differential diagnosis with the sub-pleural fat, always present above all anteriorly, and also with the physiological diaphragmatic pillars, which, however, can be modified in shape and size with the respiratory cycle. In mesothelioma, pleural effusion is almost always unilateral and associated with a history of asbestos exposure; it almost always presents as a hypoanechoic thickening with irregular edges, which can range from a few millimetres to several centimetres, sometimes visible as a single mass, other times already boundless in the abdomen and infiltrating the thoracic wall. Its growth is variable and ultrasound is able to evaluate its evolution. The diaphragm is another excellent ultrasound window in the suspicion of mesothelioma (Fig. 18.8): It can be studied both obliquely near the sliding and subcostally. Its irregularity and thickening (greater than 5 mm) warrant a further diagnostic step, especially if in the presence of fluid (Fig. 18.9).

The concomitant search for lamellar pleural plaques in the most usual sites, such as the retromammary site, is important. The associated fluid is usually corpuscular and moderately echogenic but can be completely anechoic, with the rare but possible concomitant presence of abundant fibrin which can simulate an infectious genesis. Mesothelioma frequently shows laminar progression, which differentiates it from pleural metastases. Locally advanced cancer can invade the chest wall as well as the sites of previous drains or needle or trocar entries and ultrasound can precisely study the anatomy [18].

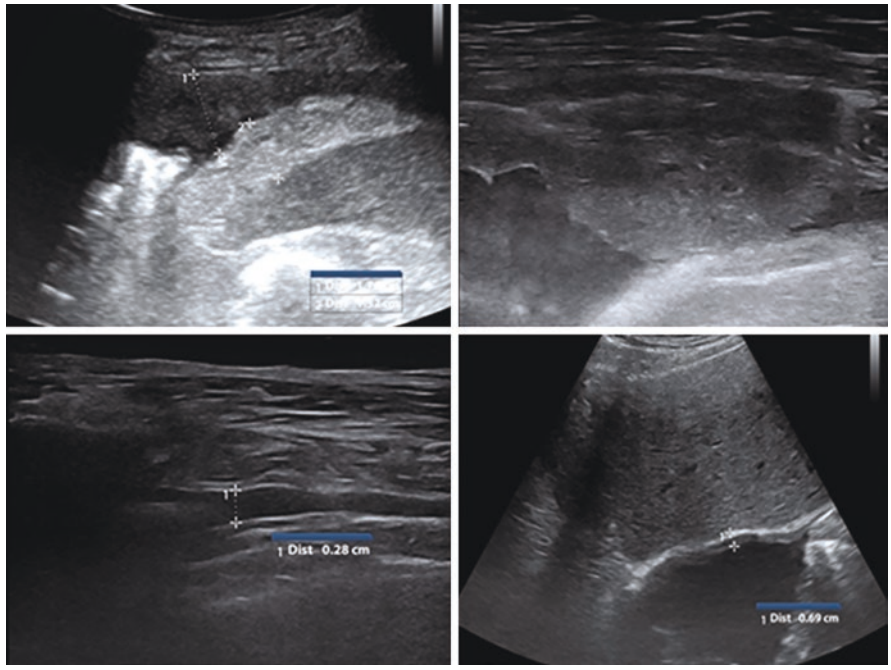


**Fig. 18.9** Thickening of diaphragm by mesothelioma

## 18.6 Interventional Ultrasound

*Its role in interventional pulmonology is irreplaceable.*

Interventional ultrasound (US) has proved to be fundamental as a safe and reliable guide in 'real-time' interventional manoeuvres, from simple thoracentesis to the correct positioning of a drain. In addition, thoracic ultrasound has become an indispensable tool for planning medical thoracoscopy in difficult cases, when for example there is pleural irregularity and the strong suspicion of neoplasm without the presence of fluid (Fig. 18.10).

With the ultrasound support, the classic 'safety triangle' has been re-sized; even areas such as the paravertebral, anterior and upper axillary ones can be safely and effectively used for access [19].

Thoracentesis, a routine and simple act, should always be performed with ultrasound guidance, studying the area chosen first with the convex probe to delimit the limits of the effusion and its relationships with the nearby parenchyma, and then with the linear probe with the Doppler probe to delineate the vascularisation of the wall in the area chosen for the puncture. It is preferable to insert the needle freehand and immediately afterwards follow the outflow of the fluid by identifying the tip of the needle throughout the manoeuvre. It is a good idea to

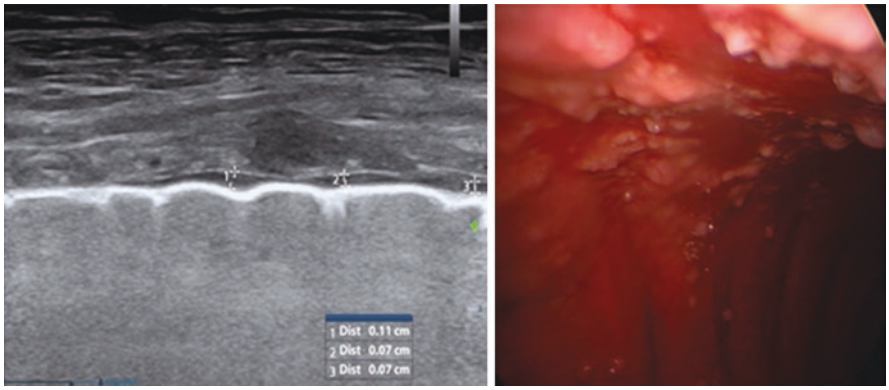


**Fig. 18.10** Small nodules in ovarian pleural metastasis

introduce the needle halfway between the lower and upper limits of the effusion so that the diaphragm rising during the manoeuvre does not touch the needle. Ultrasound-guided thoracentesis has not eliminated complications such as pneumothorax or haemothorax, although it has greatly reduced them, making the procedure extremely safe.

Equal effectiveness is achieved in the positioning of the echo-guided drain, both small and large calibre. 'Difficult' areas such as the posterior paravertebral site, and those of complicated and rigid loculated effusions, are reachable in echo-guiding, as are the anterior areas. Visualisation of the drain is relatively simple although not always possible [20].

Ultrasound can also guide biopsies of chest wall lesions (Fig. 18.11), pleural thickening and nodules, but also of peripheral lung lesions that are in direct contact with the visceral pleura.

Reliability is similar to that performed with a CT guide but with enormous time savings and without exposing the patient and operator to ionising radiation. There are fixed guides to be applied to the probe that direct the needle by creating a track on the screen but sometimes make the system more rigid. The 'free hand' technique with the lateral needle and its total vision throughout the introduction is preferable, keeping the tip always identifiable. Small movements of the needle inclination and consensual adjustments of the probe almost always allow for a good result of the manoeuvre. The target is also previously studied in terms of its dimensions, contour, echogenicity and vascularity, and the access strategy is planned. It is good practice to precede the manoeuvre with good anaesthesia and an increase in Time Gain Compensation (TGC) on the superficial sections to better guide the direction of the needle immediately. The instruments are the same as for normal biopsies,

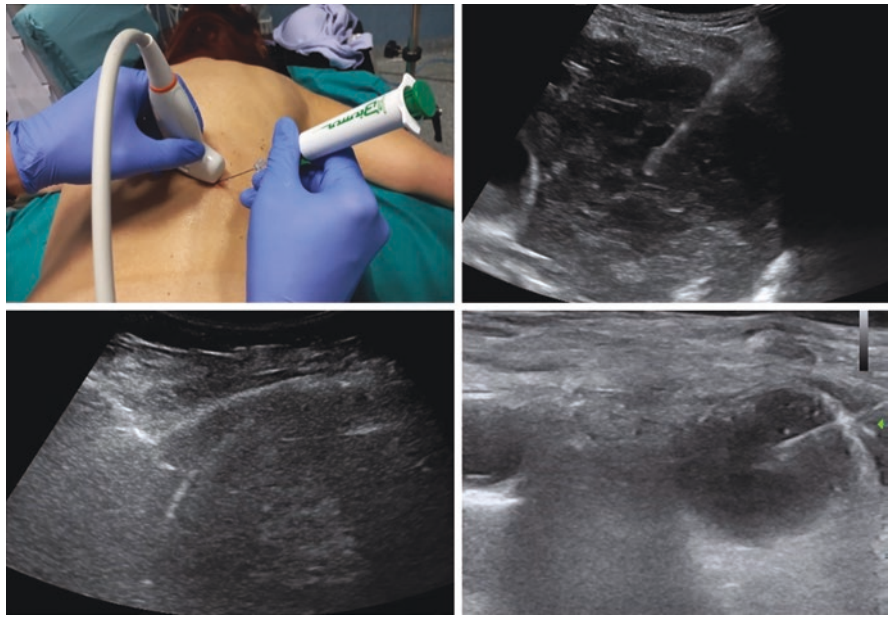

**Fig. 18.11** Ultrasound-guided biopsy

small light tru-cuts and manoeuvrable with one hand (the probe in the other), of 21 G if centred on the parenchyma, 18 G if on the chest wall and pleura [21].

All anomalies of the chest, if visible with ultrasound, can be punctured, aiding the diagnosis and staging of pleural diseases. Wall swelling, costal osteolysis, parasternal neoformations and axillary or laterocervical lymph nodes are easily reachable, with very high diagnostic rates.

Finally, ultrasound allows for the identification of any post-procedural complications such as pneumothorax or haemothorax. The diagnostic yield, in expert hands, exceeds 90% [22].

*Ultrasound allows for diagnostic thoracoscopy without pleural effusion and with difficult access.*

For medical thoracoscopy, the classic methodology involved a preparatory pneumothorax; however, over time ultrasound has gradually replaced this practice, making the examination more incisive and safer (■ Table 18.2). The presence of fluid in lateral decubitus before the examination is easily detected and the entrance point becomes easy to identify. Ultrasound also provides other preliminary information useful during endoscopy: the involvement of the diaphragm, the presence of masses and/or adhesions that must be avoided during the insertion of the trocar, the state of the lung parenchyma, the Echogeniciy of effusions of the material present and the distribution of the effusion within the thorax (■ Table 18.2).

**Table 18.2** Advantages of echo-guided in medical thoracoscopy

| Echo-guided thoracoscopy: advantages |
|---|
| • Pre-endoscopic panorama |
| • No preparatory pneumothorax |
| • Measures the amount of liquid |
| • Defines the arrangement of the liquid |
| • Predicts the consistency of the liquid |
| • Enables unusual inputs |
| • Identifies pockets |
| • Aids in decision on pleurodesis |
| • Identifies incarcerated lung |
| • Finds the diaphragm position |
| • Plans the exam strategy |
| • Useful at the post-examination stage |

The examination has recently become feasible even in the absence of pleural fluid when it can be essential to perform biopsies on small nodules or thickenings that cannot be reached from the outside or located in difficult locations such as the retroscapular area. A meticulous analysis of the 'sliding' in all quadrants, first in a sitting position where its expression is maximum and then in lateral decubitus, provides valuable information on the collapsibility of the lung. If sliding is present, it is possible to effect a cautious entry using blunt-tipped scissors and subsequent introduction of the trocar (generally 7 mm in diameter in medical thoracoscopy) without producing damage and with the immediate formation of a pleural chamber suitable for exploration and subsequent biopsies. An alternative is the technique of creating the preparatory pneumothorax with blunt needles such as those used by Boutin, introduced into the cavity, always in the presence of sliding, before the introduction of the trocar.

In infectious effusions (Fig. 18.12), ultrasounds become not only useful but indispensable. The pockets of fibrin, present even in the first hours of the disease, are easily identified and monitored. Evolution can be very fast; hence, timely ultrasound is decisive in the strategy to be adopted. If the settings are many and rapidly evolving, the ultrasound guides the timing of the interventions, when to place the drain in the first

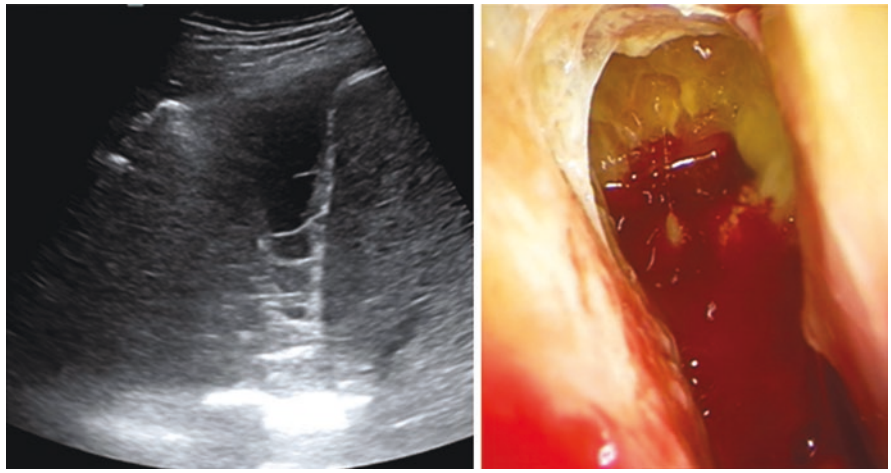

**Fig. 18.12** Guided ultrasound thoracoscopy

place but also whether to switch immediately to thoracoscopy with mechanical lavage of the cavity, hence guaranteeing early healing, shorter hospitalisation and reduced recourse to surgery. It also guides the access points in the larger sacs, determining the endoscopic operative strategy.

After the examination, ultrasound enables us to monitor parenchymal re-expansion as well as to control the trend of residual loculations and to guide any fibrinolytic therapy.

Even after pleurodesis, a good ultrasound examination can provide valuable information as to its effectiveness and maintenance over time.

## 18.7 Conclusions

*Ultrasound has made the pulmonologist much more independent of other specialists.*

In summary, this chapter is intended as an invitation to the increasingly widespread use of chest ultrasound by the pulmonologist who, if he wishes to rise to the challenge of modernity, must acquire the appropriate skills and technology. Ultrasounds are indicated in any setting, in the ward and in emergencies, in follow-ups and in specialist clinics. The pleura is thus the ideal subject for studying with ultrasound. Historically, it was the first 'organ' widely analysed with ultrasound. The Pulmonologist may have been late in noticing the importance of ultrasound for the examination of the pleura, but is rapidly closing the gap by bringing new and passionate contributions but above all by using it every day in routine clinical activity.

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