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REVIEW
COMPETENCE IN INTERVENTIONAL PULMONOLOGY

# Competence in pleural procedures

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## ABSTRACT

Diseases of the pleura and pleural space are common and present a significant contribution to the workload of respiratory physicians, with most cases resulting from congestive heart failure, pneumonia, and cancer. Although the radiographic and ultrasonographic detection of pleural abnormalities may be obvious, the determination of a specific diagnosis can often represent a challenge.

Invasive procedures such as pleural drainage, ultrasound/CT-guided pleural biopsy or medical thoracoscopy can be useful in determining specific diagnosis of pleural diseases.

Management of primary and secondary spontaneous pneumothorax is mandatory in an interventional pulmonology training program, while the medical or surgical treatment of the recurrence is still a matter of discussion.

Pleural drainage is a diagnostic and therapeutic procedure used in the treatment of pneumothorax and pleural effusions of different etiologies and even in palliation of symptomatic in malignant pleural effusion.

Medical thoracoscopy (MT) is a minimally invasive procedure aimed at inspecting the pleural space. It could be a diagnostic procedure in pleural effusions (suspected malignant pleural effusion, infective pleural disease such as empyema or tuberculosis) or therapeutic procedure (chemical pleurodesis or opening of loculation in empyema). Diagnostic yield is 95% in patients with pleural malignancies and higher in pleural tuberculosis. In parapneumonic complex effusion, MT obviates the need for surgery in most cases.

Thoracoscopy training should be considered being as important as bronchoscopy training for interventional pulmonology, although prior acquisition of ultrasonography and chest tube insertion skills is essential.


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Key words: Ultrasonography - Pleural effusion - Pneumothorax - Pleurodesis.

## Knowledge of the disease

Several aspects of the disease are to be known:[1-7]

• anatomy and pathophysiology, cytology of pleural fluid, difference between transudates and exudates;

• classification, epidemiology, etiology, clinical diagnosis, histopathological characteristics, treatment and follow-up of pleural diseases: parapneumonic effusion and empyema, malignant pleural effusions, malignant mesothelioma, recurrent non-malignant pleural effusions (chylothorax, hepatic hydrothorax/effusions due to refractory congestive heart failure), hemothorax, pneumothorax, pleural fistulas;

• knowledge of differential diagnosis and treatment through non-invasive (anamnesis and physical examination, pleural ultrasound, CT scans) and invasive procedures (MT with parietal pleural biopsy and pleurodesis, pleural catheter placement: chest tube, small bore catheter, and implantable tunneled catheters, percutaneous pleural biopsy, video-assisted thoracoscopic surgery − VATS).

- knowledge of appropriate timing for drainage of a pleural effusion is appropriate, including safety aspects of chest drain insertion;
- knowledge of chest drain management, including indwelling pleural catheters;
- knowledge of all treatments for pleural effusion;
- knowledge of chemical pleurodesis;
- knowledge of the role of surgery in the management of pleural effusions;
- classification, epidemiology, etiology, clinical diagnosis and treatment of pneumothorax;
- knowledge of differential diagnosis and treatment of pneumothorax through non-invasive (anamnesis and physical examination, pleural ultrasound, CT scans) and invasive procedures (thoracic aspiration, pleural catheter placement: chest tube, small bore catheter, MT, pleurodesis, VATS, thoracotomy).

### Pleural effusion

Pleural fluid allows to close apposition of the visceral and parietal pleura. A few milliliters in healthy subjects can fill a hemithorax entirely during the course of the disease. Although the radiographic and ultrasonographic detection of pleural abnormalities may be easy, determination of a specific diagnosis can often represent a challenge. Pleural effusions can develop as result of several different pulmonary, pleural or extrapulmonary disorders.[1] It can be caused by different mechanisms including increased permeability of the pleural membrane, increased pulmonary capillary pressure, decreased negative intrapleural pressure, decreased oncotic pressure and obstructed lymphatic flow. In chylothorax the presence of chyle leak in the pleural space is the consequence of a disruption or dysfunction of the flow of chyle leak through the thoracic duct.

Pleural fluid analysis can be pathognomonic in some cases, although a systematic investigative approach is often necessary. A presumptive diagnosis, based on the prethoracentesis clinical impression, can be substantiated by pleural fluid analysis in more than 50% of patients. Even with a non-diagnostic thoracentesis, pleural fluid analysis can be useful in excluding other possible causes or guiding subsequent diagnostic studies.

Thoracic ultrasound has several advantages over traditional radiographic imaging in pleural diseases: higher sensitivity in detecting pleural thickenings and loculations, the location of pleural fluid position with the patient in preprocedural decubitus, a real time guide of invasive procedures and dynamic and repeated examinations without exposure to radiation.[8-10]

Invasive procedures such as ultrasound/CT-guided pleural biopsy or MT are indicated in undetermined pleural effusions.[11] MT and chest drainage are useful in parapneumonic loculated effusions.[7, 12] Talc poudrage during MT or talc slurry via chest tube could be indicated in recurrent malignant pleural effusion.[3, 13]

### Pneumothorax

Primary spontaneous pneumothorax most commonly occurs in young, tall, lean male smokers and could be asymptomatic.[14] Initial treatment options include observation, oxygen supplementation, needle aspiration or chest tube insertion. The choice is largely determined by symptoms and hemodynamic compromise, the size and cause of the pneumothorax, whether an episode is the first or recurrent, and the success or failure of the initial management. The estimated recurrence rate is 23% to 50% after the first episode and increases to 80% after the third pneumothorax. Treatment of the recurrence is mandatory after the second episode to obtain pleurodesis either with or without blebs or bullae resection.[15]

Secondary pneumothorax occurs as a complication of an underlying lung disease and is often symptomatic, requiring immediate treatment and prevention of recurrence in the first episode.[15]

The knowledge of the etiology and management of primary and secondary spontaneous pneumothorax is mandatory in an interventional pulmonology training program, while the medical or surgical treatment of the recurrence is still a matter of discussion.

## Knowledge of instruments

### Pleural drainage

In-depth knowledge of:

- role of pleural drainage in the diagnosis and treatment algorithm;
- the different chest tubes and their correct techniques of insertion also to establish a sterile field;
- indications, contraindications and risk/benefit analysis for pleural drainage;
- prevention and management of clinical risk, informed consent and medical-legal aspects;

• sensitivity, specificity, diagnostic accuracy in all pathologies and limitations of the technique.

Pleural drainage is a diagnostic and therapeutic procedure that involves inserting a tube through the chest wall between the ribs and into the pleural cavity to enable drainage of air (pneumothorax), blood (hemothorax), fluid (pleural effusion) or pus (empyema) out of the chest.[16-18] In any patient it is essential to understand what the aim of the drainage is. The effective drainage of air, blood or fluid from the pleural space requires an adequately positioned drain and an airtight, one-way drainage system to maintain subatmospheric intrapleural pressure. This permits drainage of the pleural contents and re-expansion of the lung.

In many cases a chest tube helps to restore hemodynamic and respiratory stability by optimizing ventilation/perfusion and minimizing mediastinal shift.

The insertion of a chest drain is an easy-to-learn procedure but could be associated with significant risk.

To minimize the procedural risk it is important to know the anatomy of the chest, the radiological and ultrasound signs (see section), all types of chest tube and their differences.[19, 20]

Thoracic ultrasound must be performed before chest tube insertion to evaluate the best point of insertion of the device, the anatomic structures such as the neurovascular bundle that must be avoided along the way to the pleural space, the amount and characteristics of pleural fluid and the presence of adhesions.[21-23]

Chest tubes are made of PVC or silicon material that is thermosensitive and bio- and hemocompatibility. All chest devices have Radiopaque X-ray line. The catheters also differ in shape (straight or Angle), number of suction holes, distal open or atraumatic blunt tip and diameter (Figure 1). Conventionally, drains with a diameter greater than 14 Fr are defined as large chest tubes. The small thoracic tube has a diameter of up to 14 Fr.

Small chest tubes have a lower risk of serious complications (Table I) than large chest tubes (Table II), lower pain scores, lower analgesia requirements and a greater degree of comfort. The most common problem of small devices is the blocking of the discharge: regular flushing is probably helpful.[24-26]

Small chest tubes are the first choice in the treatment of pneumothorax, pleural effusion and empyema.[27-31] Large chest tubes can be used when small chest tubes fail.[32]

Indwelling or tunneled pleural catheter (IPC) is a drainage used in recurrent malignant pleural effusion and it can stay in place for a long time. They are implanted in chest wall and communicated with pleural space, the polyester cuff lies inside the tunnel prevents infections. This drainage can be attached to one-way bag (with or without suction) and is easy to use for patients and or caregiver. The complication and contraindications are the same of normal chest tube.[33-35]

The drainage can be positioned with differing tech-

Figure 1.—Different types of chest tube.

Table I.—*Frequency of postinsertion complications for small chest tube drains.*

| Complication | Total N.* | Calculated frequency | Range |
|---|---|---|---|
| Injury | 582 | 0.2% | 0-2% |
| Malposition | 593 | 0.6% | 0-9% |
| Empyema | 395 | 0.2% | 0-2% |
| Drain blockage | 341 | 8.1% | 2-18% |

*Total number of procedures performed from the studies found that quote this complication.

Table II.—*Frequency of postinsertion complications for large chest tube drains.*

| Complication | Total N.* | Calculated frequency | Range |
|---|---|---|---|
| Injury | 1572 | 1.4% | 0-7.9% |
| Malposition | 1778 | 6.5% | 1.1-31% |
| Empyema | 1778 | 1.4% | 0-2% |
| Drain blockage | 115 | 5.2% | 5.2% |

*Total number of procedures performed from the studies found that quote this complication.

niques according to the dimensions and characteristics of the device (trocar, Sedingher, tunneled technique, etc.),[36] these techniques must be known to prevent complications and positioning errors.[37-39]

Before placing a drainage, it is important to explain the procedure to the patient in order to obtain his informed consent, evaluate the indications or contraindications (Table III, IV), comorbidities, blood tests in particular coagulation and also the imaging.

The chest tubes must be connected to a collection system that integrates the one-way valve (water or Heimlich) and collection chamber (1 or 2 bottles, Pleur_evac® or bags). A system for pressure suction control can be connected to the collection chamber (bottle) or inside it (pleur evac).[36, 40-43]

The use of integral Heimlich valves can be helpful in the posthospitalization management of pneumothorax.[44]

Aspiration can be important in persistent or slow pneumothorax resolution to cope with a leak.[45-48]

Clamping and removal time is another important aspect for the management of drainage.[16]

Prophylactic antibiotics reduces the absolute risk of empyema by 5.5-7.1% in the presence of chest trauma (penetrating or blunt).[49]

All these aspects must be part of the skill of using the chest tube.

### Medical thoracoscopy

In-depth knowledge of:

- pleural diseases and their management;
- role of MT in the diagnosis and treatment algorithm;
- MT techniques and instruments;
- indications, contraindications and risk/benefit analysis for MT;
- sensitivity, specificity, diagnostic accuracy of the various pathologies and limitations of the procedure;
- indications, contraindications and risk/benefit analysis for chest drain;
- organization of the thoracoscopy room;
- techniques required to establish a surgical sterile field;
- prevention and management of clinical risk, informed consent and medical-legal aspects.

MT is a minimally invasive procedure aimed at inspecting the pleural space with a rigid or flexi-rigid instrument, providing the physician a window into the pleural space.[50] MT can be performed under local anesthesia or conscious sedation in an endoscopy suite. MT is a safe procedure also in elderly patients with comorbidities.[51] Diagnostic and therapeutic procedures can be performed during a single examination. After pleural fluid aspiration, biopsy samples can be collected from the parietal, diaphragmatic and visceral pleura in selected patients. In the presence of loculated effusion, the procedure can be useful to cut and remove adhesions and opening the multiple loculations. Talc insufflation is recommended at the end of the procedure, to avoid the recurrence of pleural effusion.[11]

MT is an easy-to-learn and safe procedure, although it could be challenging in some circumstances. Hence, two levels of training are identified: a primary level focused on the management of indeterminate pleural effusion, malignancy and pneumothorax, and an advanced level targeted at performing the procedure in the absence of pleural effusion and in parapneumonic complex pleural effusions or empyema.[11, 52]

The use of thoracic ultrasound should be considered as part of the clinical examination before MT. It provides information about the amount of pleural fluid, its characteristics, the presence and the site of loculations, the potential presence of large adhesions and the localization of parietal neoplastic lesions. Thus it facilitates the identification of the best trocar entry site. In the postprocedural controls thoracic ultrasound allows us to monitor pulmonary re-expansion, the correct tube position and the persistence of fluid collections.[8]

TABLE III.—*Indications for chest drain insertion.*

| |
|---|
| • Pneumothorax |
| • In any ventilated patient |
| • Tension pneumothorax after initial needle relief |
| • Persistent or recurrent pneumothorax after simple aspiration |
| • Large secondary spontaneous pneumothorax in patients over 50 years |
| • Malignant pleural effusion |
| • Empyema and complicated parapneumonic pleural effusion |
| • Traumatic hemopneumothorax |
| • Postoperative thoracotomy, esophagectomy, cardiac surgery |

TABLE IV.—*Contraindications for chest drain insertion.*

| |
|---|
| • Refractory coagulopathies or platelet defect |
| • The differential diagnosis between |
| • pneumothorax and bullous disease |
| • collapse and pleural effusion |
| • Diaphragmatic hernia or hepatic hydrothorax |
| • Adherences |

## Core basic skills

### Pleural drainage

Pleural drainage skills include:

- sterile field techniques (performing all maneuvers to obtain the highest level of sterility) and techniques aimed to identification-traceability (check list: site-side-procedure);

• knowledge of the different types of chest tube and their different technique of insertion (Seldinger's method, percutaneous drainage set UNICO® or standard method using a trocar);

• management of a chest drain (medication, suction application, removal time);

• prevention, monitoring and management of possible complications related to the procedure (acute onset, …);

• giving information to patient and obtaining required consent for the procedure; information to patient of alternative diagnostic and interventional procedures;

• pre-procedure clinical and radiographic evaluation;

• performance of thoracic ultrasound (see section on "Thoracic ultrasound").

### Medical thoracoscopy

• Sterile field techniques (performing all maneuvers to obtain the highest level of sterility) and techniques aimed at identification-traceability (check list: site-side-procedure):

• performance of thoracentesis and chest drain insertion in autonomy;

• insertion and management of a chest drain using a surgical drain;

• insertion and use of thoracoscopy, including optical and biopsy collection accessories technique;

• use of coagulation systems;

• use of the talc atomizer;

• prevention, monitoring and management of possible complications related to the procedure (acute onset, …).

## Procedural description and sedation

### Pleural drainage

Common steps for all chest tubes are the following:

• radiologic studies could be undertaken to identify the cause of pleural illness;

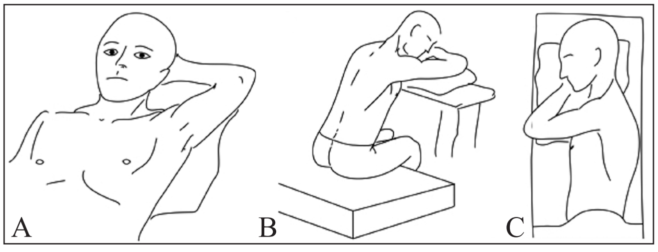


Figure 2.—A-C) Different decubitus of the patient to assess the best site of tube insertion.

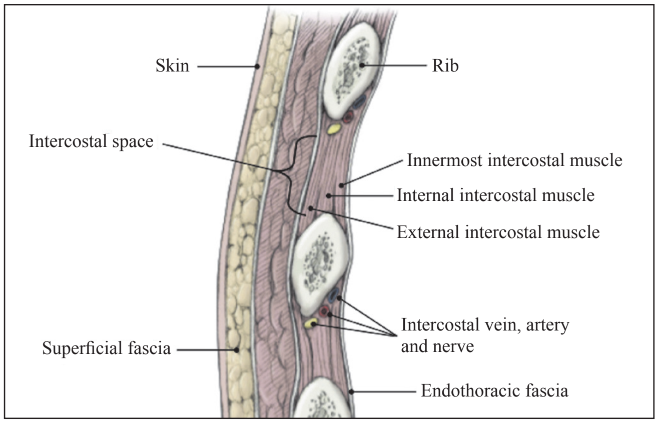


Figure 3.—Anatomy of chest wall and normal neurovascular bundle (inferior face of the ribs).

• thoracic ultrasound should be used to evaluate the fluid and air distribution so as to decide the decubitus of the patient and assess the best site of tube insertion (Figure 2). Care must be taken to identify the normal neurovascular bundle and its anatomic variations (Figure 3);

• aseptic technique is essential to avoid wound secondary infections such as empyema (approximately 2.4% secondary to trauma). The sterile field can be prepared with sterile gloves and gown and sterile towels. A full sterile technique as performed in a surgical theatre is unnecessary. A large area of skin should be cleansed, preferably using iodine or chlorhexidine;

• local anesthesia with Lidocaine should be performed before any other procedure (Figure 4). Small needles or

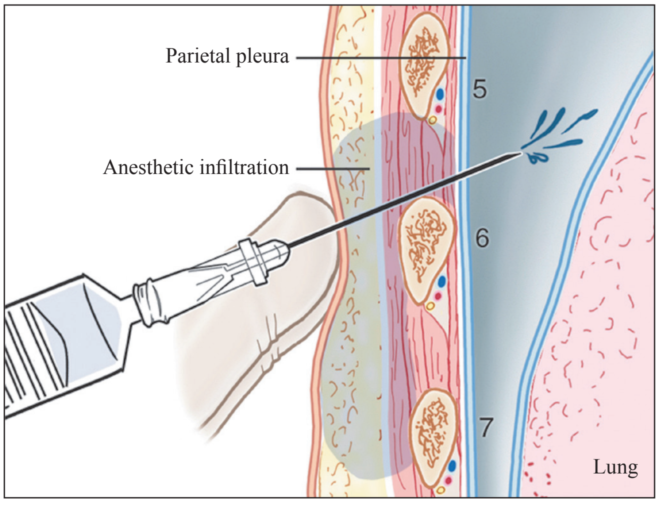


Figure 4.—Site of injection of local anesthesia.

spinal needles (in the case of a thick wall) are recommended to administer the anesthetic into the dermis, the periosteum of the rib, the intercostal muscles and the pleural surface. A needle should be used to aspirate free air or fluid from the pleural space during anesthesia to confirm the point of insertion into the chest;

- vital parameters (saturation and blood pressure) are monitored.

For large chest tube:

- perform the "common step";
- take great care to identify the normal neurovascular bundle and its anatomic variations;
- make a 1-2 cm incision in the skin with a sterile lancet (Figure 5);
- make a controlled dissection through the intercostal muscles using blunt-tipped scissors or a Kelly clamp, creating a track extending over the top and into the intercostal space (Figure 6). Be sure to enter the intercostal space with the blunt-tipped scissors or the Kelly clamp closed; going over the top of the rib avoids injuring the neurovascular bundle that is present underneath the inner aspect of the rib;
- open the pleural surface using blunt-tipped scissors or a Kelly clamp. Using the index finger, sweep the inside of the chest cavity feeling for adhesions; make sure that you are in the intrathoracic cavity and not in the intraperitoneal cavity (Figure 7). Finger maneuver is not mandatory when using ultrasound guidance;

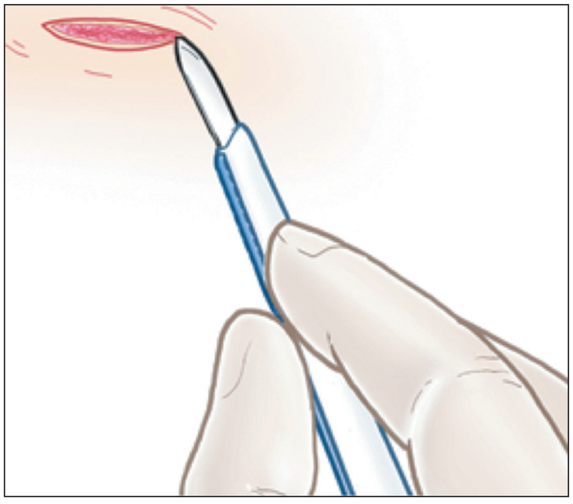

Figure 5.—Large chest tube insertion: skin incision with a surgical lancet.

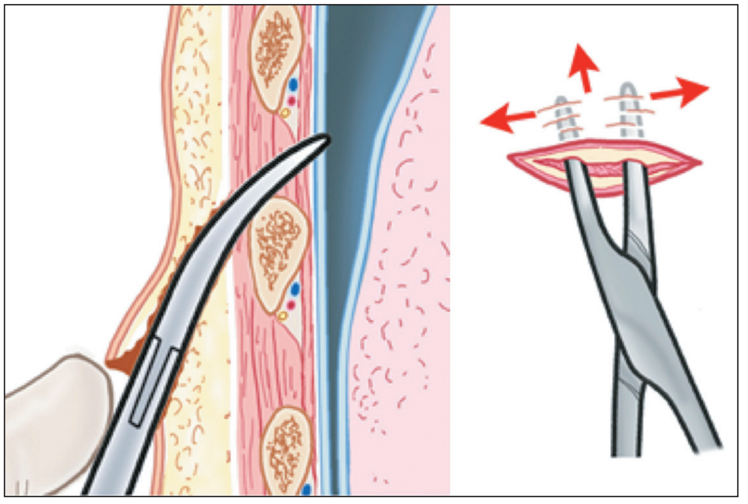

Figure 6.—Large chest tube insertion. Controlled dissection through the intercostal muscles using a Kelly clamp.

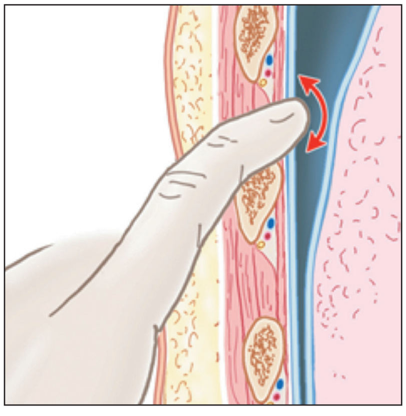

Figure 7.—Large chest tube insertion. Finger used to enlarge the way through the intercostal muscles and swept the inside of the chest cavity feeling for adhesions.

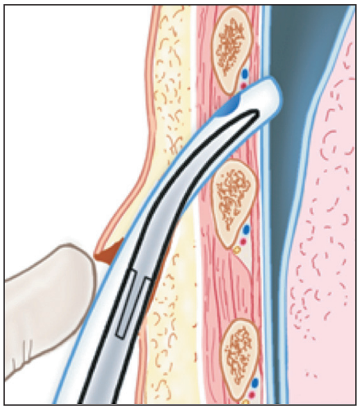

Figure 9.—Kelly clamp push the chest tube through the chest wall into the pleural cavity.

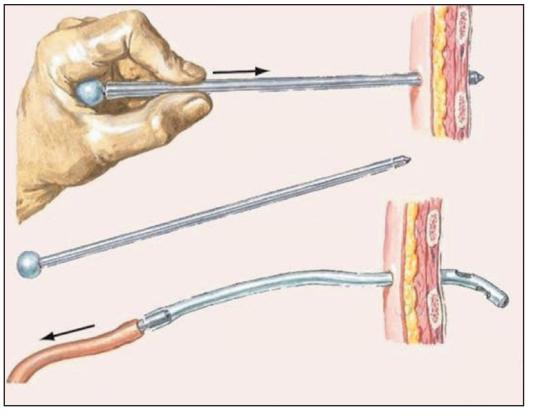

Figure 8.—Trocar chest tube inserted through the chest wall. One hand pushes the trocar.

- insert chest tube:
  - with trocar system: insert the drainage through the skin, one hand grasping the distal end pushing the chest tube through the intercostal space, the other hand guiding the drain modulating the force and the insertion speed, acting as a brake. Once the pleural space has been cleared, direct the pleural drainage, remove the trocar and concurrently push the chest tube for at least 10-12 cm if possible, making sure, however, that the suction holes are in the pleural cavity (Figure 8).
  - without trocar system: take the chest tube with the Kelly clamp and forceps still in place and advance the tip of the chest tube along your index finger to ensure you enter the intrathoracic cavity. Once you have checked that the chest tube is in the right place, remove the Kelly clamp and advance the tube further to all drain holes within the thoracic cavity (Figure 9).
- verify that air or liquid escapes from the chest tube;
- the chest tube must be connected to an underwater device or a thoracic drainage device;
- secure the chest tube with a suture to the skin to prevent inadvertent removal of the chest tube or exposure of the holes in the chest tube.

For small chest tube and Seldinger chest tube the procedure is the following:

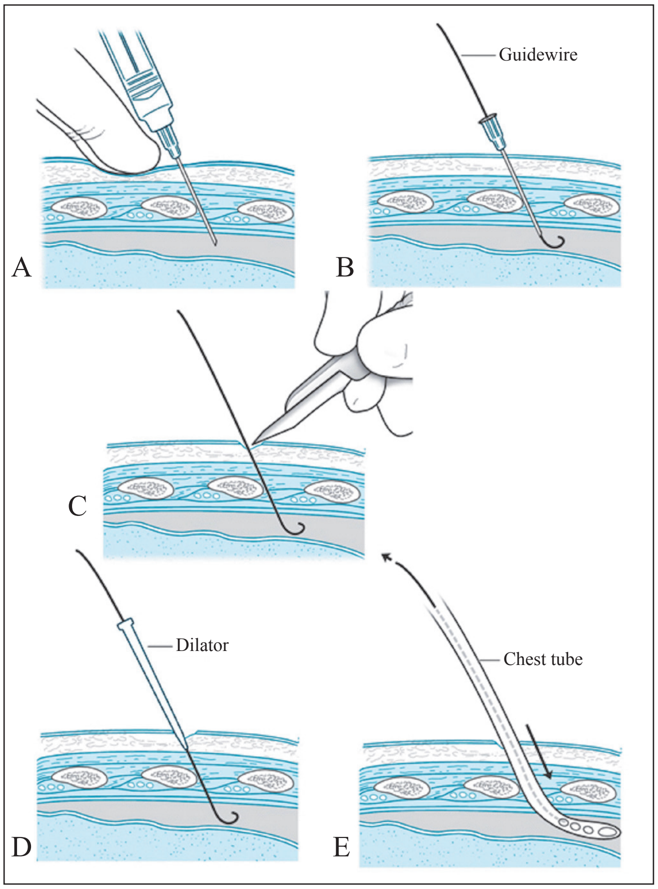


Figure 10.—Seldinger chest tube insertion. A) Introducer needle over the upper border of the rib; B) the "J" end of the wire through the needle; C) wire guide in place - needle removed. Skin incision with surgical lancet; D) dilators dilate the tract and opening into the pleural space (rotating and advancing in sequence (small to large); E) the chest tube over the wire guide push into the pleural space.

Figure 12.—UNICO® chest tube insertion. One hand grasping the distal end pushing the chest tube through the intercostal space, the other hand guiding the drain modulating the force and the insertion speed, acting as a brake.

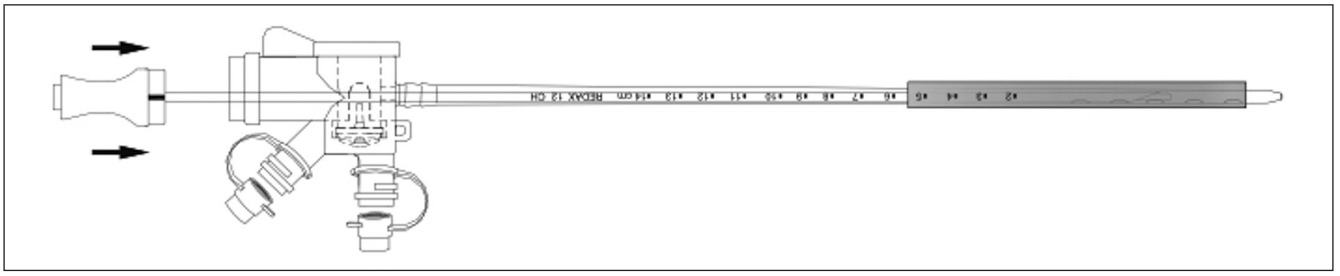

Figure 11.—UNICO® chest tube insertion. The Verres needle inserted through the rear opening drainage until the handle is completely resting against the device.

• perform the “common step”;
• take great care to identify the normal neurovascular bundle and its anatomic variations;
• advance the introducer needle over the upper border of the rib into the pleural space (Figure 10A);
• advance the “J” end of the wire through the needle and into the pleural space (Figure 10B);
• make a small skin incision slightly larger than the diameter of the chest tube (Figure 10C);
• remove the needle, leaving the wire guide in place;
• dilate the tract and opening into the pleural space by rotating and advancing in sequence (small to large) the supplied dilators along the same axis as the wire guide to prevent kinking. Introduction into the pleural space is facilitated by advancing dilators (Figure 10D);
• advance the chest tube inserter/chest tube assembly over the wire guide and into the pleural space (Figure 10E);
• verify that air or liquid escapes from the chest tube;
• remove the wire guide and chest tube inserter, leaving the chest tube in place, inserting it for at least 10-12 cm if possible;
• the chest tube must be connected to an underwater device or a thoracic drainage device;
• secure the chest tube with a suture to the skin to prevent inadvertent removal of the chest tube or exposure of the holes in the chest tube.

The procedure for the UNICO® chest tube is:
• perform the “common step”;
• take great care to identify the normal neurovascular bundle and its anatomic variations.
• make a 1-cm incision in the skin with a sterile lancet (Figure 5);
• insert the needle through the rear opening until the handle is completely resting against the device. The needle and its protective stylet must protrude a few millimetres from the end of the catheter (Figure 11);
• grip the device firmly with both hands, one hand grasping the distal end pushing the chest tube through the intercostal space, the other hand guiding the drain modulating the force and the insertion speed, acting as a brake (Figure 12);
• insert the device and apply light pressure until the green colour on the visual indicator disappears (Figure 13);
• continue the insertion until the green on the indicator reappears; this means that the tip of the needle has entered the pleural space and the protective stylet is once again in the extended position, permitting its safe functioning (Figure 14);
• the entrance into the cavity may be accompanied by a clicking noise;
• verify that air or liquid escapes from the chest tube;
• move the device’s handle in order to orient the direction of insertion of the catheter;
• begin extracting the needle and, at the same time, position the catheter (Figure 15);

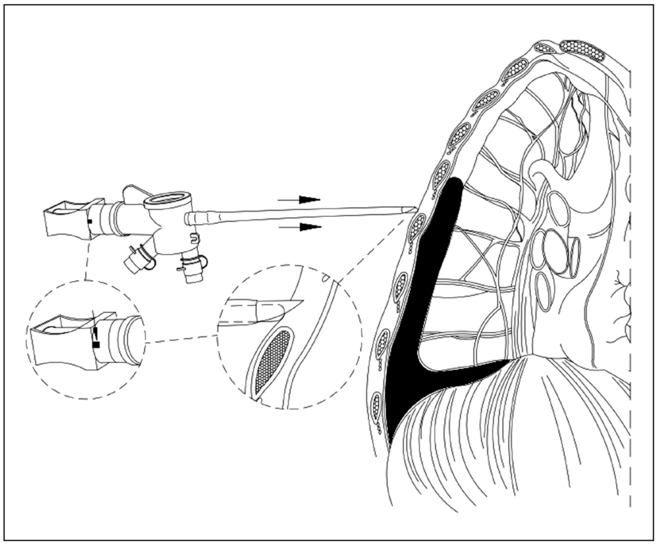

Figure 13.—UNICO® chest tube insertion. Chest tube inserted through the chest wall. The green color on the visual indicator disappears; protective stylet moves inside the needle, the cutting edge uncovered.

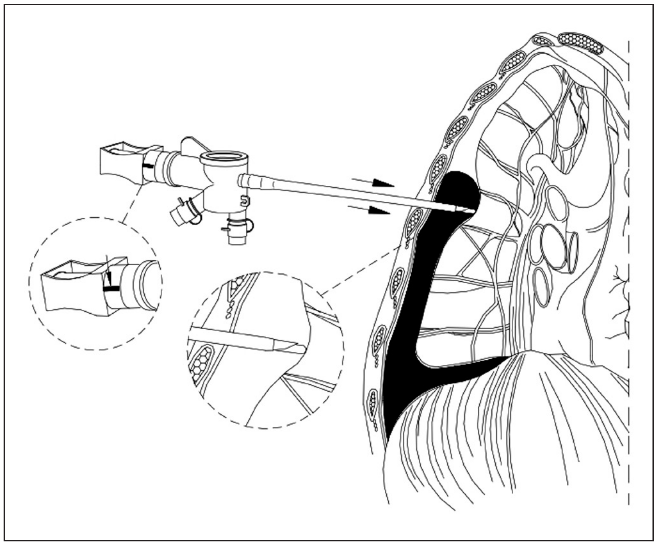

Figure 14.—UNICO® chest tube insertion. Chest tube arrived in the pleural space. The green on the indicator reappears; protective stylet moves outside the needle, the cutting edge covered.

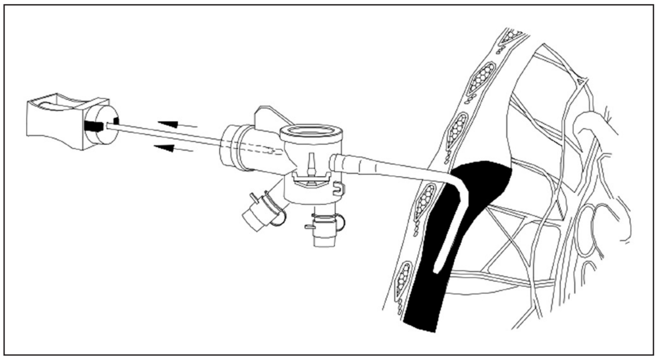

Figure 15.—UNICO® chest tube insertion: removed the Verres needle and, at the same time, continued to push the chest tube in the pleural space.

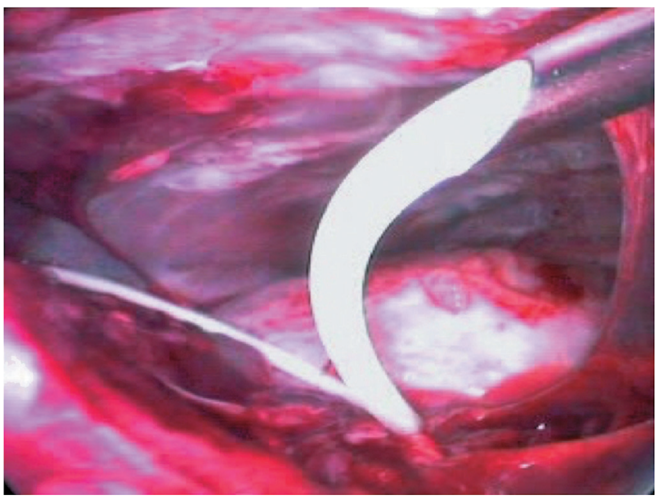

Figure 16.—Pleurocath® chest tube insertion: flexible catheter through needle introducer see from the pleural space.

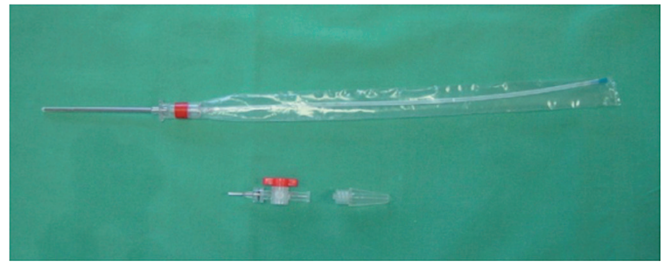

Figure 17.—Pleurocath® chest tube insertion: the catheter into the sterile protective wrapping.

Figure 18.—Pleurocath® chest tube insertion: the chest tube secure to skin and connected to Heimlich valve.

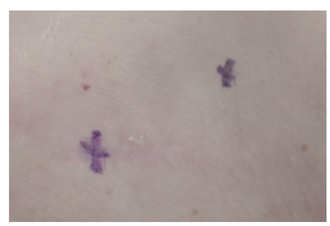

Figure 19.—PleurX™ chest tube insertion: point marks over the skin.

• secure the chest tube with a suture to the skin to prevent inadvertent removal of the chest tube or exposure of the holes in the chest tube.

For Pleurocath®, the procedure should be the following:

• perform the "common step".

• take great care to identify the normal neurovascular bundle and its anatomic variations.

• insert the tip of the metal cannula using both hands. Once in the pleural space do not advance the metal cannula any further.

• advance the flexible catheter into the pleural space to the desired length (Figure 16).

• remove the cap from the end of the catheter and the sterile protective wrapping (Figure 17).

• remove the metal cannula and hold onto the flexible catheter at the skin.

• secure the chest tube with a suture to the skin to prevent inadvertent removal of the chest tube or exposure of the holes in the chest tube (Figure 18).

PleurX™ entails the following:

• perform the "common step";

• take great care to identify the normal neurovascular bundle and its anatomic variations;

• mark two point over the skin, the first in the point of access of guide wire insertion, the second 4–6 cm medial to the first for the catheter exit site (Figure 19);

• through the first point advance the introducer needle over the upper border of the rib into the pleural space (Figure 20);

• advance the "J" end of the wire through the needle and into the pleural space (Figure 21);

• remove the needle, leaving the wire guide in place (Figure 22);

Figure 20.—PleurX™ chest tube insertion: the introducer needle puts through the point over the pleural space.

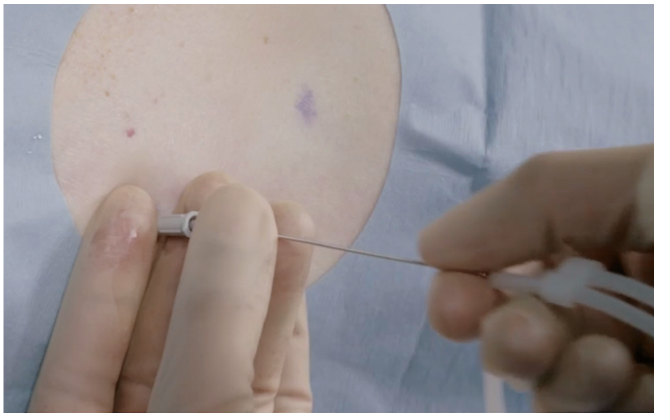

Figure 21.—PleurX™ chest tube insertion: the wire guide through the needle and into the pleural space.

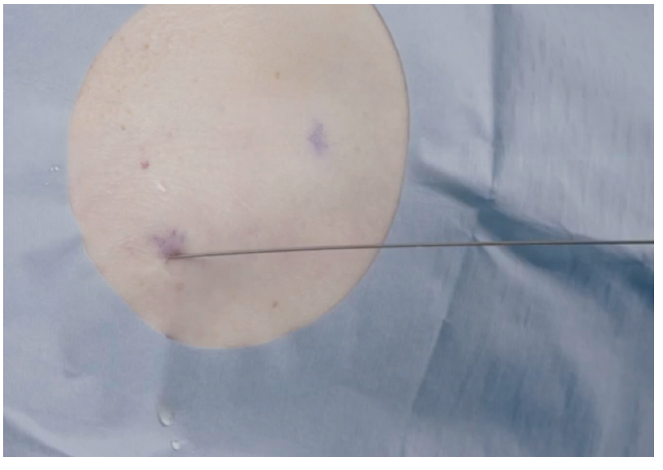

Figure 22.—PleurX™ chest tube insertion: the wire guide in place without needle.

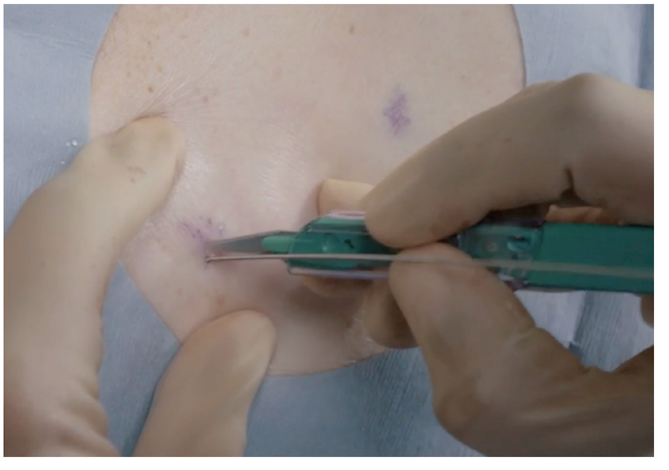

Figure 23.—PleurX™ chest tube insertion: skin incision slightly larger than the diameter of the chest tube.

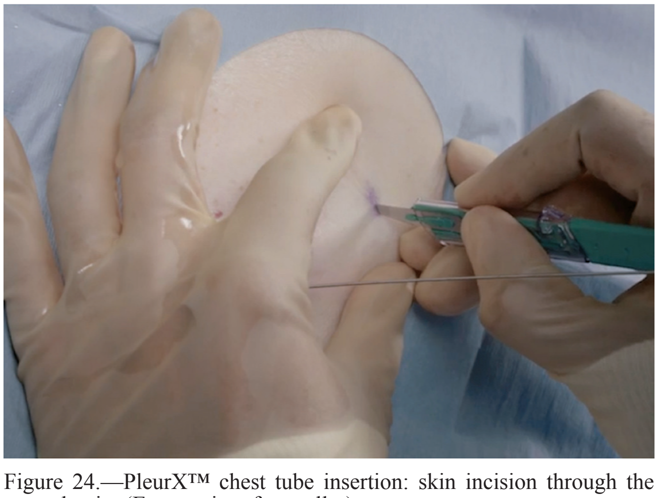

Figure 24.—PleurX™ chest tube insertion: skin incision through the second point (Entry point of tunneller).

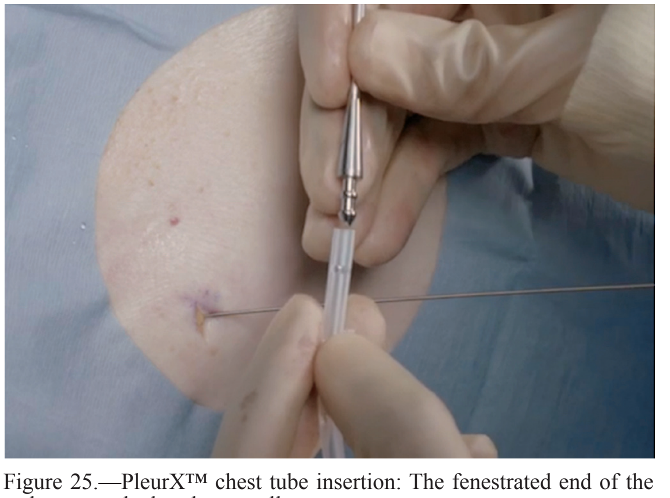

Figure 25.—PleurX™ chest tube insertion: The fenestrated end of the catheter attached to the tunneller.

- make a small skin incision slightly larger than the diameter of the chest tube (Figure 23);
- make a small skin incision through the second point (Figure 24);
- the fenestrated end of the catheter is attached to the tunneller (Figure 25);
- the tunneler and catheter are passed subcutaneously from the second incision down to and out through the first incision. The catheter is drawn until the polyester cuff lies inside the tunnel 1 cm from the second incision (Figure 26, 27, 28);
- the catheter is placed subcutaneously;
- dilate the tract and opening into the pleural space by rotating the supplied dilator along the same axis as the wire guide to prevent kinking (Figure 29);

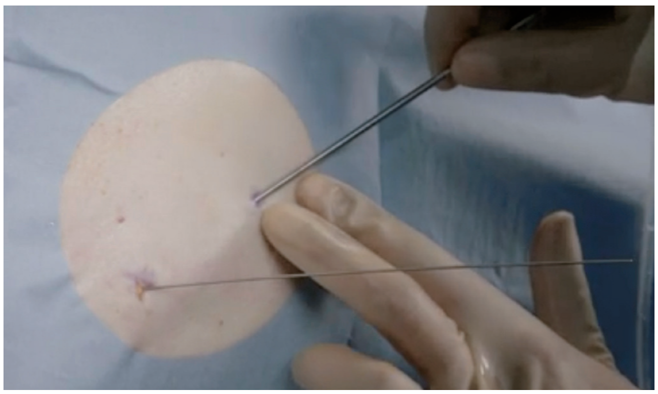
Figure 26.—PleurX™ chest tube insertion: The tunnel inserted in the entry point.

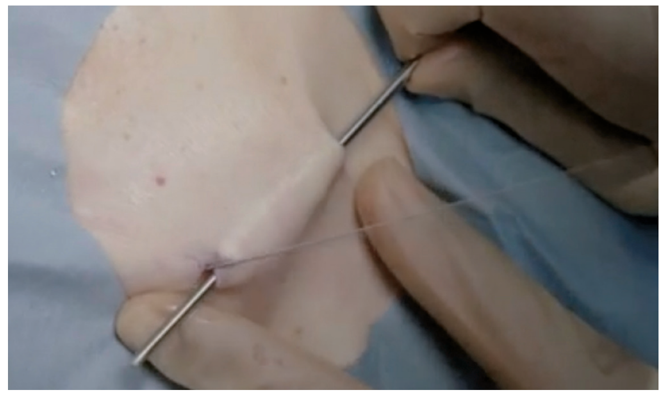
Figure 27.—PleurX™ chest tube insertion: the tunneller exit to first skin point subcutaneous space from the second incision down to and out through the first incision.

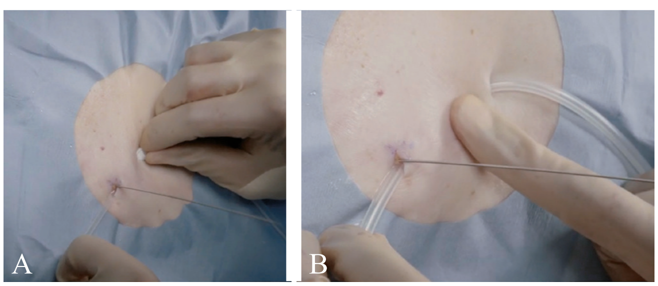

Figure 28.—PleurX™ chest tube insertion. A) The drainage is moved through the subcutaneous space; B) Until the polyester cuff lies is inside the tunnel 1 cm from the second incision.

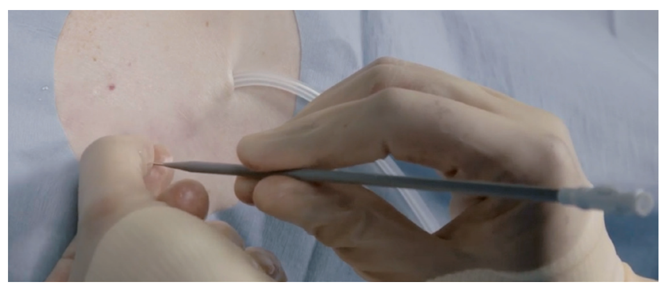
Figure 29.—PleurX™ chest tube insertion. Use of supplied dilator through the first incision to opening into the pleural space.


Figure 30.—PleurX™ chest tube insertion. The peel-away introducer is positioned over the guide wire.


Figure 31.—PleurX™ chest tube insertion. The catheter is inserted into the introducer until the pleural space.

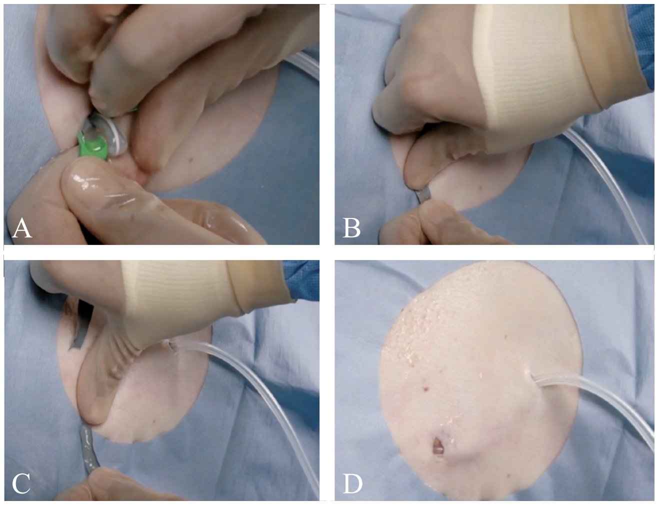


Figure 32.—PleurX™ chest tube insertion. A-C) The peel-away introducer is removed; D) catheter into the pleural and subcutaneous space.

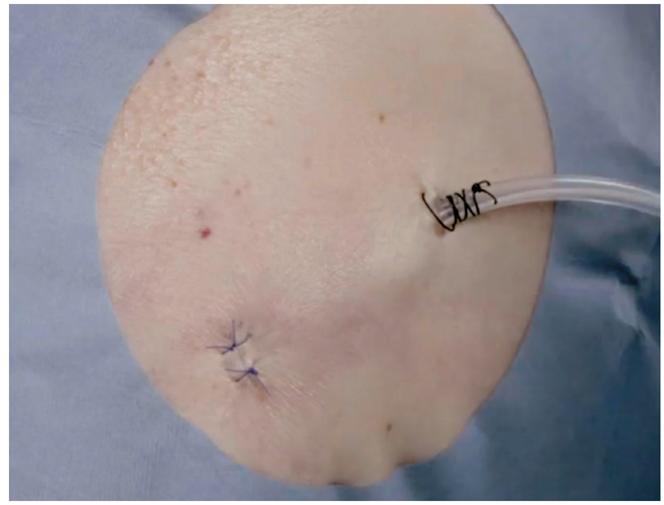

Figure 33.—PleurX™ chest tube insertion. The skin incisions are sutured and the catheter is sutured to the skin.

• the peel-away introducer is positioned over the guide wire (Figure 30);

• the fenestrated end of the catheter is inserted into the introducer and positioned in the pleural space (Figure 31);

• the peel-away introducer is removed leaving only the catheter into the pleural space (Figure 32);

• the catheter is connected to a catheter bag and opened to ensure free flow of fluid;

• the skin incisions are sutured and the catheter is sutured to the skin (Figure 33).

*Drainage systems*

A chest drain should be connected to a drainage system that contains a valve mechanism to prevent fluid or air from entering the pleural cavity:

• underwater seal bottle (one, two or three chambers) (Figure 34);

• pleur evac (Figure 35);

• Heimlich flutter valves (Figure 36);

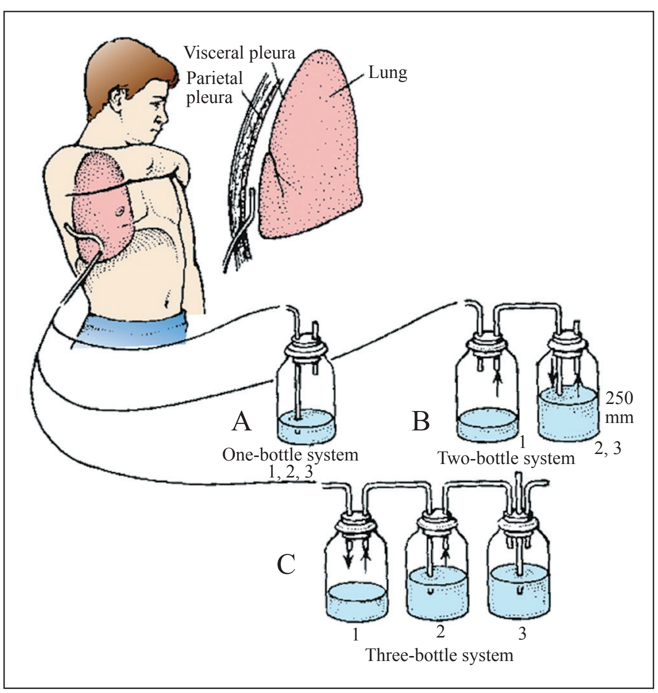


Figure 34.—Underwater seal bottle. A) One chambers (water valve inside the collection chamber); B) two chambers (water valve and the collection chamber); C) three chambers (water valve separated, collection chamber and suction chambers).

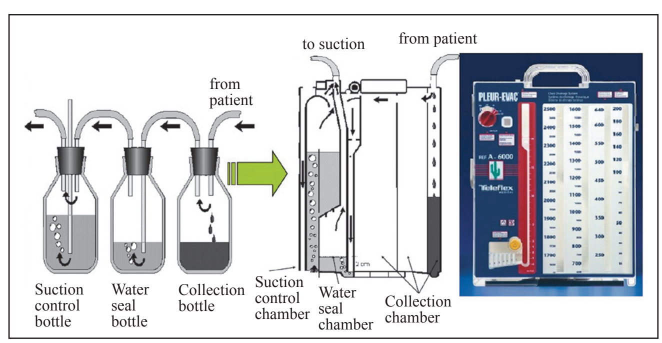


Figure 35.—Pleur evac system with three chambers (water valve separated, collection chamber and suction chambers).

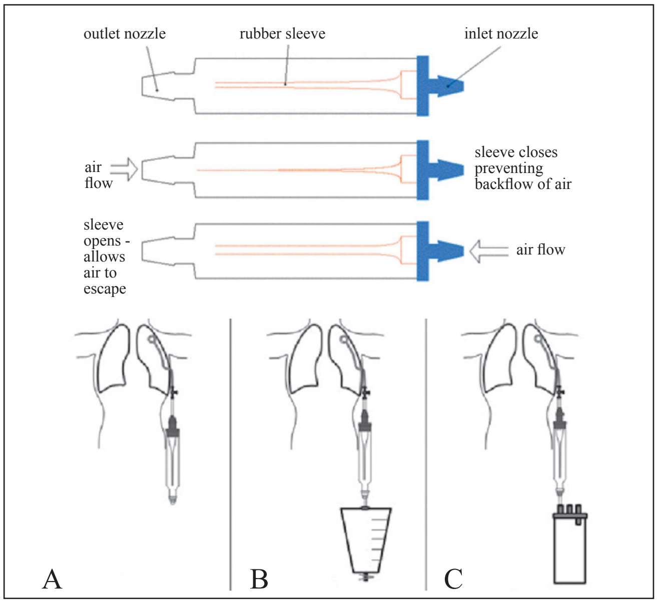


Figure 36.—Heimlich flutter valves (air of fluid can move only in one direction),

Figure 37.—Drainage bag with an incorporated flutter valve,


• drainage bag with an incorporated flutter valve (Figure 37).

*Postprocedural aspect*

Aspiration by the underwater seal at a level of 10-20 cm H2O using a high-volume low-pressure system (*e.g.*, Vernon-Thompson) (Figure 38).

Clamping the chest tube is not recommended for poten-

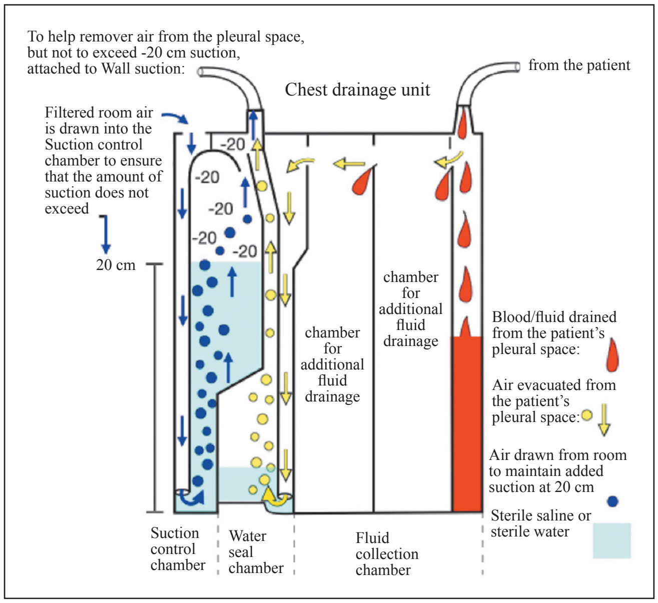


Figure 38.—Pleur evac: 3-chamber suction system. Controlled aspiration is performed by the underwater seal at a level of 10-20 cm $H_2O$ using a high-volume low-pressure system.

Figure 39.—Instruments for rigid thoracoscopy**:** trocar and canula, 0 degree direct thoracoscope, 5 mm optical biopsy forceps (double spoon) for use under direct vision, 400 watt cold light, manual insufflator and sterile graded (French) talc, needles and syringes for administration of local anesthetic, basic surgical instruments (scalpel, needle holders, scissors, sutures), swabs and dressing.

tially fatal complications, particularly in the presence of a bubbling chest tube. The chest tube can be clamped to prevent the re-expansion of pulmonary edema or to evaluate a recurrent pneumothorax before removing the drainage.

The chest tube should be removed once the fluid drainage has decreased to less than 200 mL per day, on resolution of the pneumothorax or when the drain is no longer functioning. There is no difference between removing the chest tube in inspiration or in expiration with a Valsalva maneuver.

Once the chest tube is removed, the cutaneous wound is repaired with sutures or steri strips and covered with gauze.

## Thoracoscopy

The procedure is performed in endoscopy suite or operating room with assistance from the anaesthetist.[53] Procedural steps are:

- preparation of instruments for thoracoscopy (Figure 39);
- patient placed in lateral decubitus position (Figure 40);
- vital parameter monitoring;
- thoracic ultrasound to assess the best site of trocar insertion according to presence, quantity and characteristics of pleural effusion (Figure 41);
- sterile field preparation;
- premedication and local anesthesia administration (Figure 42A);
- conscious state or deep sedation;

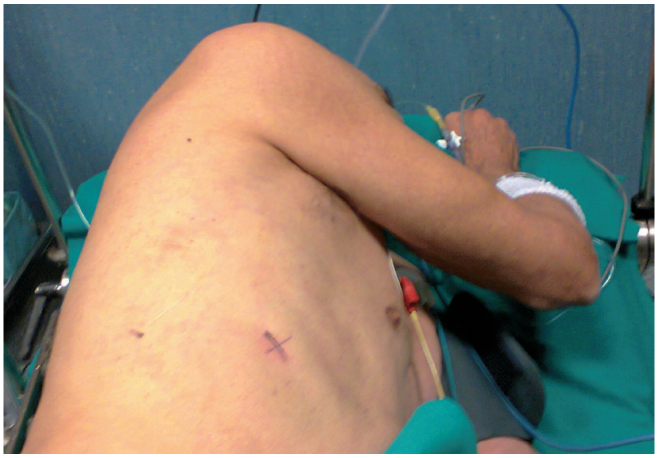

Figure 40.—Patient position: the patient lies on the healthy side in a lateral decubitus position with the involved side up. The r entry site for thoracoscopy was previously identified sonographically and marked on the skin.

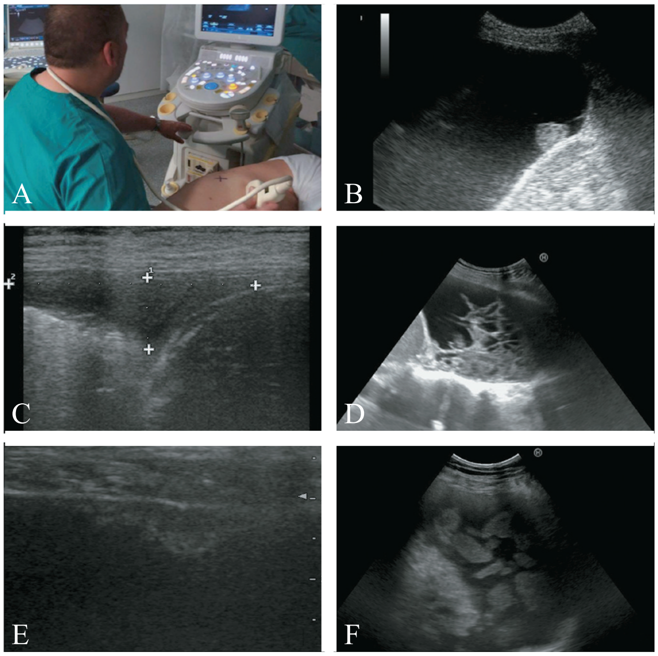

Figure 41.—Ultrasound-guided medical thoracoscopy access: A) operator performing chest ultrasound looking for the right thoracoscopic entry side; B) pleural effusion and nodule on the diaphragm; C) small amount of pleural effusion in costo-phrenic angle; D) pleural effusion with alveolar appearance; E) pleural nodule in the absence of pleural effusion; F) ultrasound appearance of clots in hemothorax.

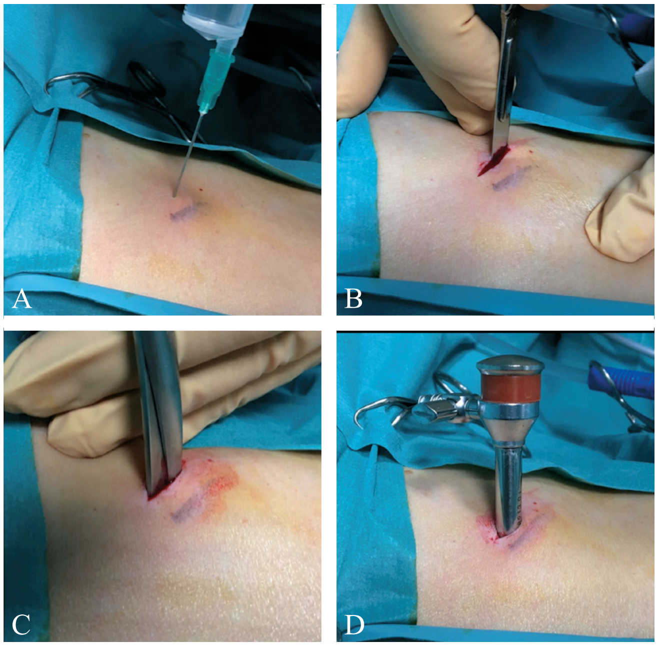

Figure 42.—Access to pleural space step by step. A) Local anesthesia; B) A 1-cm skin incision with the scalpel through the skin and subcutaneous tissue; C) blunt dissection with round scissor trough the chest wall into the pleural cavity; D) trocar insertion in the pleural space.

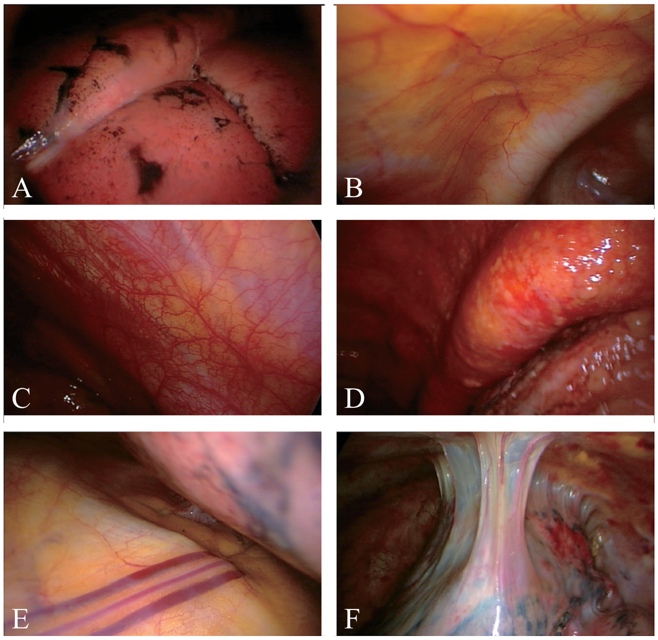


Figure 43.—Thoracoscopic pleural space inspection. A) visceral pleural with its fissures and anthracotic areas; B, C) parietal pleura and its vascularization; D) diaphragmatic pleura and its pillars covered with nodules; E) internal mammary vessels; F) adhesions between visceral and parietal pleura.

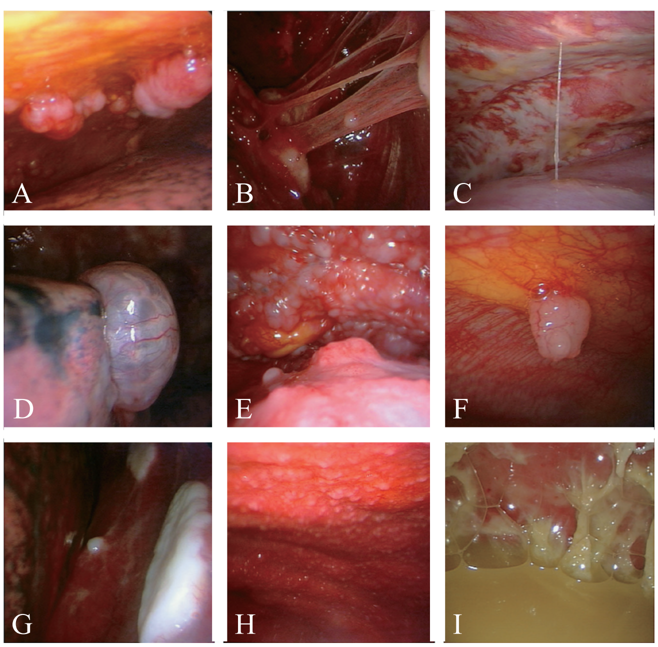


Figure 44.—Pathological endoscopic pictures. A) Row of nodules on the parietal pleura; B) fibrin adhesions with nodules; C) diffuse parietal pleural thickening; D) nodule on the visceral pleura; E) diffuse nodules on the parietal and visceral pleura; F) parietal pleura's solitary mucinous nodule; G) white nodules of the parietal pleura; H) diffuse dissemination of micro-nodules on the parietal pleura; I) extensive fibrin deposition with septations and pockets of pus.

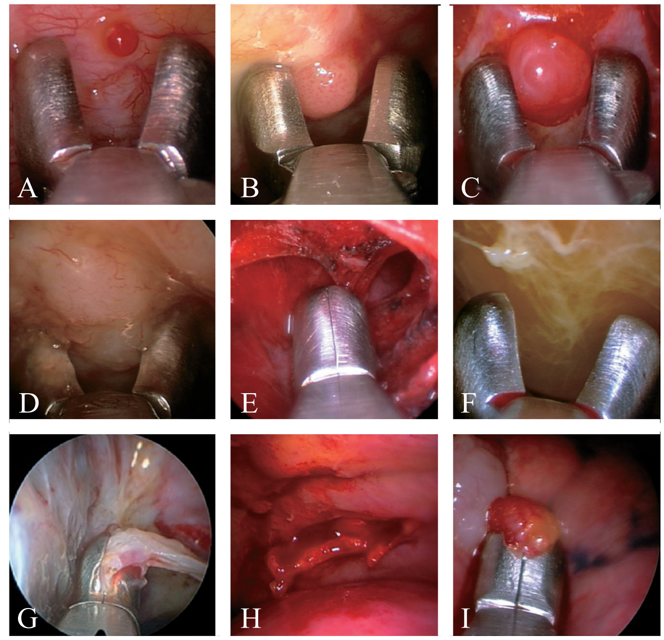


Figure 45.—Biopsies performed under direct vision using the optical biopsy forceps. A-C) Biopsies of parietal pleural nodules; D) biopsy of diffuse parietal pleural thickening; E) division of adhesions between visceral and parietal pleura; F) opening multiple loculations in a case of empyema; G) parietal pleura biopsy by a lateral "lift and peel" technique; H) bloody scar on parietal pleura surface after biopsy; I) biopsy of a nodule on the visceral pleura.

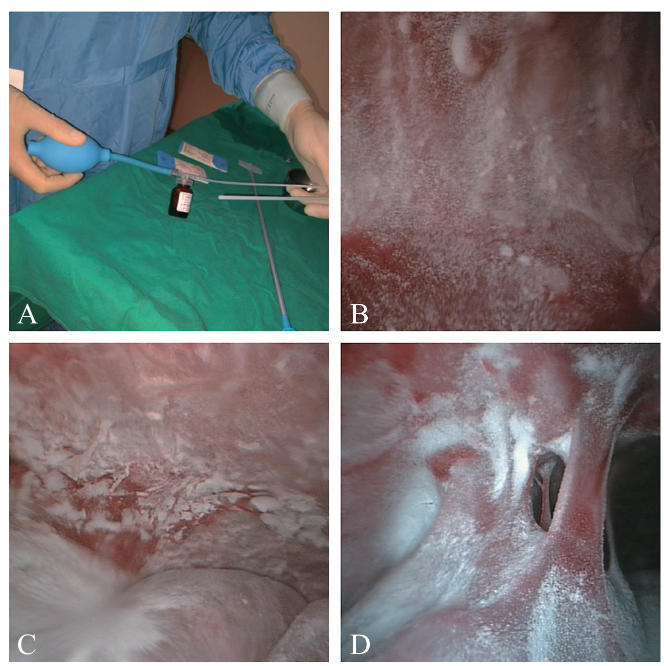


Figure 46.—Steril talc insufflation. A) Talc placed in plastic container with attached an insufflator; B-D) uniform distribution of the talc on all pleural surfaces included adhesions confirmed by direct vision.

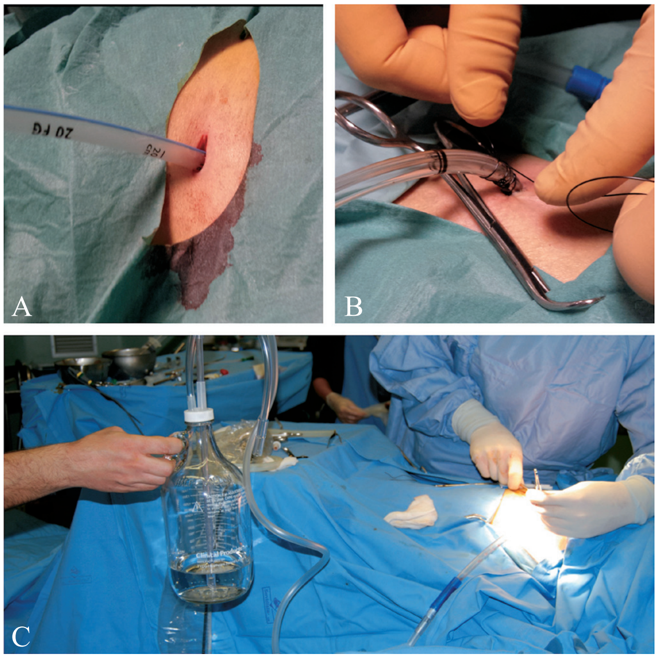

Figure 47.—Chest drain insertion. A) Chest tube20 French placed via thoracoscopic insertion site; B) chest tube hold with a suture tied close to the patient's skin and firmly around the chest tube; C) chest tube connected to a underwater seal bottle.

- thoracoscopy access port creation (Figure 42B, C);
- trocar introduction (Figure 42D);
- pleural fluid aspiration;
- pleural cavity inspection (Figure 43, 44);
- cutting and removal of adhesions and opening of the multiple loculations (if indicated) (Figure 45E, F);
- parietal pleura biopsies (Figure 45A-D, G-I);
- hemostasis control;
- sterile Talc insufflation (if indicated) (Figure 46);
- chest drain insertion and control of its correct function (Figure 47A, C);
- access to port suture and drainage secure (Figure 47B).

## Theoretical and practical training

### Pleural drainage

A drainage course must be performed at a specialized center and could be divided into a theoretical and a practical part.

The goal of the first step is to acquire the knowledge of thoracic drainage (insertion techniques, indications and contraindications and the management of complications).

The practical part can be performed using:[54-59] mannequins, plastic models and simulators, in order to learn the procedure and to improve the trainee's skills, a simulation on animal models or on animal organs, and a training on patients under supervision until the trainee has achieved competence.

### Thoracoscopy

In the practical training, thoracoscopy entails:

- theoretical and practical lessons in medical thoracoscopy and pleural procedures, and ERS course;
- case report discussions with experts (*e.g.* Pleural Hub Facebook group);
- live sessions: practical sessions and simulated clinical cases;
- mannequins and plastic models that could be perforated, with simulation practice in order to learn the procedure and improve coordination among team members in managing complications;
- virtual reality simulation to develop the manual dexterity and skills needed for the procedures (available for VATS lobectomy);
- simulation on animal models *in vivo* or on individual organs;
- recording procedures performed as lead operator in trainee's own center so that they could be viewed once again, as part of the learning process;
- attendance at a thoracoscopy course;
- training spent in a high volume center, with the opportunity to perform more than 20 supervised thoracoscopies[60] until trainee has achieved sufficient qualitative level of competence.

## Quantitative and qualitative assessment

### Pleural drainage

- Ten drainages under supervision to obtain the qualification and 3 procedures per year to maintain it;
- a questionnaire on the insertion of a chest tube (TZANS, "Insertion of chest tubes and management of chest drains in adults") can be used to evaluate the competence.[61]
- management of patient comfort and complications;
- case-based questionnaires, including evaluation of correct decision-making;
- DOPS (*e.g.* UGSTAT and EUTAT, TUBE-iCOMPT (the Chest Tube Insertion Competency Test: a 5-domain 100-point assessment tool in line with British Thoracic Society guidelines and international consensus).[62-65]

### Thoracoscopy

Ongoing procedure numbers: 10 per year, although this might be fewer in those centers where there is a high throughput of other pleural procedures.[60, 66, 67]

- DOPS: a dedicated tool for medical Thoracoscopy assessment as used for VATS technique,[68] during the procedures or on video recording
- Outcome measures:
  - >80% sensitivity for malignancy;
  - success rate of therapeutic measures such as pleurodesis: >70% success rate of pleurodesis 1 month post thoracoscopy.

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