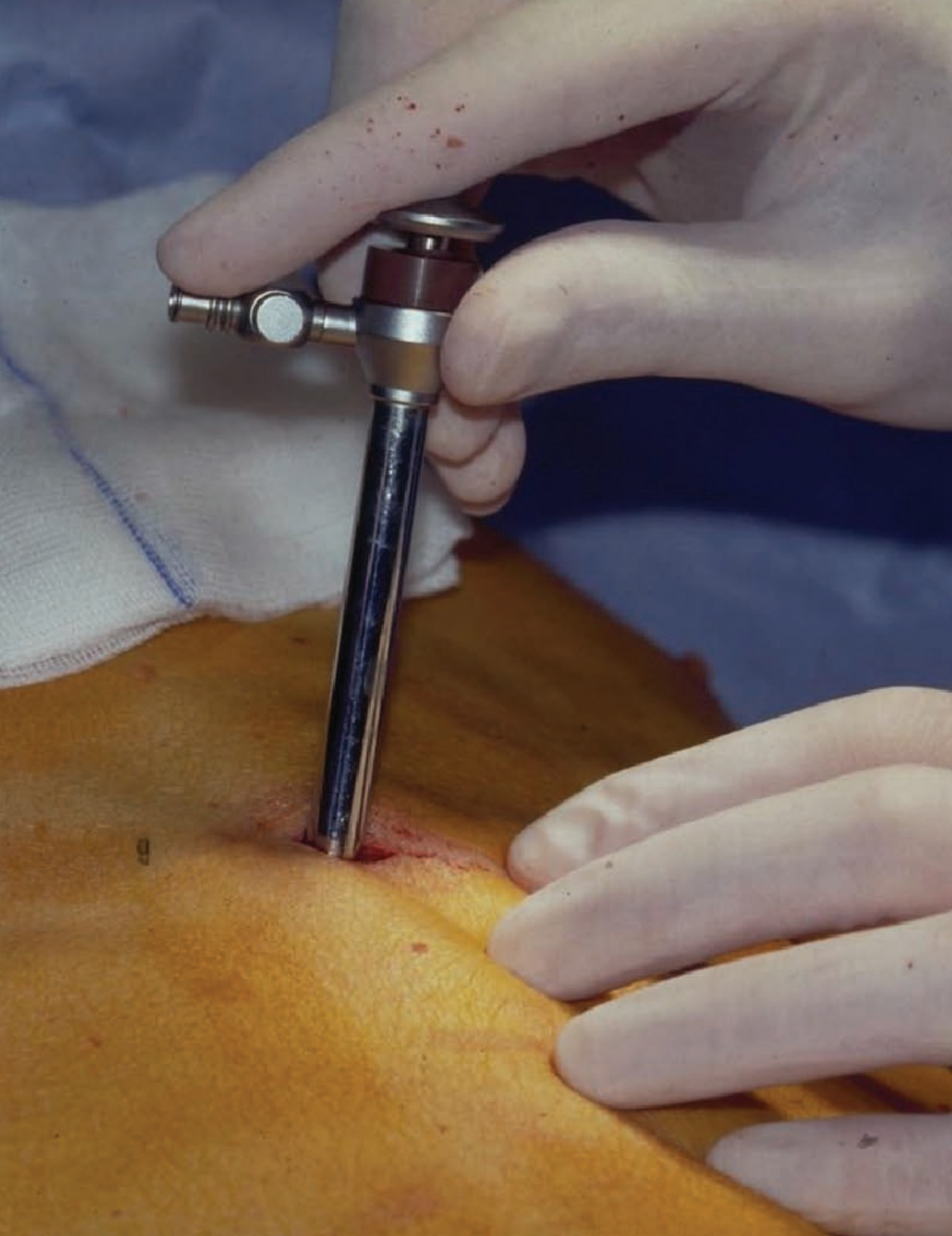

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# Medical thoracoscopy/ pleuroscopy: step by step

**Statement of interest**
None declared.

## Summary

Medical thoracoscopy/pleuroscopy is considered to be one of the main areas of interventional pulmonology and should be included in the training programme of the chest physician. As with all technical procedures, there is a learning curve before full competence in medical thoracoscopy/pleuroscopy is achieved. Therefore, appropriate training is mandatory. This article describes the knowledge and skills required, the contraindications and potential complications and their prevention and the instruments used, as well as step-by-step information on how to perform medical thoracoscopy/pleuroscopy, which is even easier to learn than flexible bronchoscopy.

## Introduction

Medical thoracoscopy/pleuroscopy is used increasingly by chest physicians and has become, after bronchoscopy, the second most important endoscopic technique in respiratory medicine [1]. It is considered to be one of the main areas of interventional pulmonology/pneumology [2] and an important part of a specialist pleural disease service [3].

Compared with "surgical" thoracoscopy, which is better termed "video-assisted thoracic surgery" (VATS) and is performed in an operating room under general anaesthesia with selective intubation, medical thoracoscopy/pleuroscopy can be performed in an endoscopy suite under local anaesthesia or conscious sedation, using non-disposable rigid or semi-flexible (semi-rigid) instruments. Thus, medical thoracoscopy/pleuroscopy is considerably less invasive and less expensive.

The main indications for medical thoracoscopy/pleuroscopy (table 1) are described in detail in [1] and are summarised in [4]. The European Respiratory Society School has been running hands-on courses on medical thoracoscopy/pleuroscopy for several years and has recently produced a video on the topic [5].

In many European countries, medical thoracoscopy/pleuroscopy is already part of the respiratory training programme and it is included in the HERMES curriculum in adult respiratory medicine as a procedure where at least competence level 2 (knowledge/skill sufficient to manage with supervision) should be reached [6].

In this article, we describe the clinical prerequisites, the contraindications and the potential complications (and their prevention) as well as the main steps of the technique, which are outlined in more detail in [1].

### Knowledge and skills required

As with all technical procedures, there is a learning curve before full competence in medical thoracoscopy/pleuroscopy is achieved.

HERMES syllabus link: module D.2.10

***Table 1*** *Indications for medical thoracoscopy/pleuroscopy*

| Diagnostic |
|---|
| • Pleural effusions of indeterminate origin |
| • Staging of lung cancer with pleural effusion and of diffuse malignant mesothelioma |
| • Hormone receptor determination in breast cancer and culture in tuberculous pleurisy |
| • Staging of pneumothorax |
| • Diffuse lung diseases |
| • Localised chest wall (and lung) lesions |
| **Therapeutic** |
| • Talc poudrage in malignant and chronic, recurrent non-malignant pleural effusions |
| • Talc poudrage in pneumothorax |
| • Parapneumonic effusions and empyema (opening of loculations) |

Therefore, appropriate training is mandatory. The technique is very similar to chest-tube insertion by means of a trocar; the difference being that, in addition, the pleural cavity can be visualised and biopsies can be taken from all areas of the pleural cavity including the chest wall, diaphragm, mediastinum and lung (fig. 1).

To learn medical thoracoscopy/pleuroscopy, a respiratory physician needs to know the exact topographical anatomy of the thorax, the pathophysiology and pathology of respiratory diseases, their diagnostic approach and their management options, in particular with regards to pleural diseases, as well as the clinical prerequisites, contraindications and complications. He or she must also know the details of the technique of medical thoracoscopy/pleuroscopy including all instruments used, the different options of access to the pleural space, the technique of coagulation, *etc*. In addition, he or she should already have certain skills in the diagnosis and treatment of respiratory diseases, particularly pleural diseases. These skills are listed in table 2.

Technical skills are best learned under the direct supervision of an experienced thoracoscopist. Because manual dexterity, confidence and expertise vary from one physician to another, it is difficult to specify a minimum number of procedures necessary to obtain the skill or to maintain competence. It is unlikely that any specific number of procedures will bring key competence. However, a minimum of 20 procedures is desirable to achieve sufficient familiarity with the instrumentation and interpretation of normal and pathological thoracoscopic findings. Procedural competence can probably be maintained if about 10–12 thoracoscopies are performed yearly.

Adequate training in both cognitive and technical aspects of thoracoscopy is essential. This is unlikely to be provided by a single two-day course, although training courses should be encouraged and may be extremely beneficial. By attending hands-on training seminars, lectures and symposia, physicians can learn basic concepts and acquire greater understanding of the appropriate indications, risks, benefits and limitations of thoracoscopic/pleuroscopic interventions. These sessions should allow physicians to achieve familiarity and comfort with basic thoracoscopic/pleuroscopic techniques and instrumentation. Physicians should be encouraged to work with a mentor within their community until the necessary criteria are met for medical

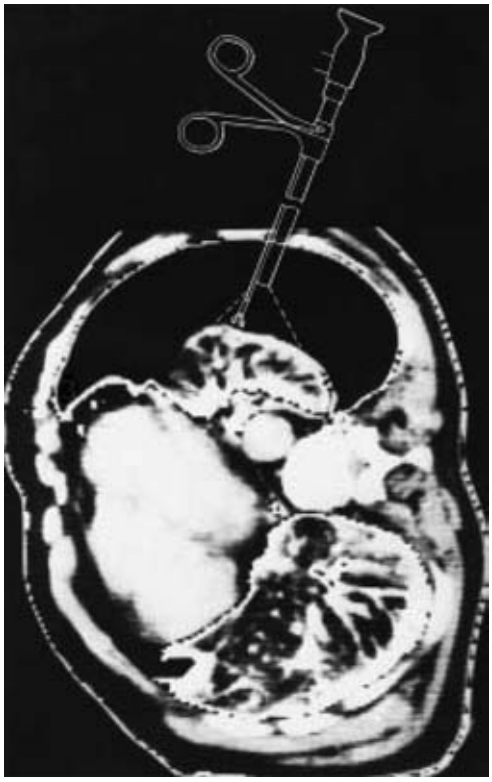

***Figure 1***
*Computed tomography simulation of medical thoracoscopy with rigid instruments (right thoracic cavity in left lateral position). Visualisation of the chest wall pleura, diaphragm, lung, anterior and (partially) posterior mediastinum is possible. Reproduced from [7], with permission from the publisher.*

thoracoscopy/pleuroscopy privileges within their own institutions.

A competent medical thoracoscopist/pleuroscopist should be more than a master of the instruments within the pleural space, being rather a complete consultant for pleuropulmonary disorders (''window to the pleural space''). A good opportunity to learn inspection of the pleural space and its pathological situation is often by observation of the procedures on the video screen or *via* live transmission of images to a larger group. One should always start with easy situations, such as large pleural effusion or pneumothorax when placement of a chest tube is indicated. Medical thoracoscopy/pleuroscopy is a safe procedure, even easier to learn than flexible bronchoscopy, provided sufficient experience with chest-tube placement has been gained.

## Clinical prerequisites for medical thoracoscopy/pleuroscopy

Medical thoracoscopy/pleuroscopy must be considered an invasive procedure that the chest physician should use only when other, simpler methods fail to yield a diagnosis or when less invasive therapeutic measures are not available or less promising. For each individual, the risk/benefit ratio must be considered. Therefore, a careful evaluation of the patient as well as of the indications and contraindications to the procedure is mandatory. Medical thoracoscopy/pleuroscopy is safe if the patient is evaluated carefully, the thoracoscopist is adequately trained, the contraindications are observed and complications are prevented.

The history of the patient reveals information about the acute or chronic evolution of the disease, drug intolerance and possible underlying previous or concomitant pulmonary or extrapulmonary diseases. The patient's history may also provide important information on possible risk factors. There should be knowledge of the preceding drug therapy, in particular of anticoagulant treatment, which may be an absolute or relative contraindication to the investigation. Systemic immunosuppressive treatment, especially with corticosteroids, may cause a delayed closure of biopsy sites of the lung. It is important to notify the pathologist about previous therapy with cytostatic agents or radiotherapy as well as about occupational exposures, *e.g.* to asbestos. The microbiologist needs information on previous antibiotic therapy.

***Table 2*** *Skills required before performing medical thoracoscopy/pleuroscopy*

- Diagnostic and therapeutic thoracentesis
- Performance of local anaesthesia
- Closed-needle biopsy of the pleura
- Familiarity with chest tubes and pleural drainage
- Closed chest tube insertion
- Pleurodesis techniques
- Flexible bronchoscopy
- Rigid bronchoscopy (optional)
- Use of either the semi-rigid pleuroscope or the rigid thoracoscope (or both)
- Use of biopsy forceps and other instruments
- Use of coagulation systems
- Use of the talc atomiser/talc spray
- Use of video-endoscopic equipment
- Ultrasonography and/or fluoroscopy (optional)

Besides a detailed history, a thorough physical examination is a vital component of a pre-thoracoscopic evaluation. Routine postero-anterior and lateral chest radiography frequently has to be supplemented with a CT scan or ultrasonography, which also provides the basis for determining the optimal point of insertion of the thoracoscope. These techniques often also prove or exclude the presence of pleural thickening, which points to possible symphysis by adhesions. This could be a contraindication for medical thoracoscopy/pleuroscopy, since the presence of an adequate pleural space is an absolute prerequisite. However, neither CT scan nor ultrasonography provides 100% accuracy in excluding adhesions.

The patient's respiratory status must be evaluated, at a minimum, with blood gas analysis and, if necessary, with pulmonary function tests. An ECG should be obtained to exclude a recent myocardial infarction or significant arrhythmia. The clinical laboratory should provide the coagulation parameters, serum electrolytes, serum creatinine, glucose, liver function studies and a complete blood count as well as a blood group typing.

If convinced, by applying strict criteria, that medical thoracoscopy/pleuroscopy is indicated, the physician should have little difficulty in explaining the need for the procedure to the patient and in obtaining informed consent. To be certain that the patient fully understands what is to be done and why the procedure is necessary, a hand-out with detailed explanations

of the procedure should be provided, followed by verbal explanation and discussion. This includes an explanation of the planned technique, the management of post-thoracoscopic pain and other possible, so-called typical complications, as well as the expected diagnostic and therapeutic results. It is only then that the patient can truly provide informed consent.

## Contraindications

Medical thoracoscopy/pleuroscopy is a safe procedure, with only a few absolute and relative contraindications (table 3). An absolute contraindication is the lack of pleural space resulting from extensive adhesions of the pleural layer (*e.g.*, in pleural fibrosis, after infections, or previous pleurodesis), since it is impossible to carry out the procedure if the pleural space has been obliterated. A partial pneumothorax of at least 100–200 mL or of approximately 2–4 cm in depth must be present or induced. Otherwise, the thoracoscope/pleuroscope cannot be inserted safely without danger of injuring the lung or other organs. Sometimes this technical difficulty may be overcome by enlarging the skin incision and digitally dissecting the lung away from the chest wall.

Coagulopathies usually provide only relative contraindications. More severe coagulopathies are a contraindication at least to biopsy procedures that do not allow immediate local control. The platelet count should be in >60,000, and the international normalised ratio (INR) <1.2; otherwise, a correction of the coagulopathy must be undertaken prior to the procedure. There are no published studies on the risk of bleeding in patients with aspirin or clopidogrel medication in medical thoracoscopy/pleuroscopy. The risk of bleeding is also higher in patients with renal insufficiency and elevated nitrogen urea or creatinine.

Great care should be taken in the face of hypoxaemia, in particular in the presence of hypercarbia. Depending on the severity of the respiratory insufficiency, this may provide an absolute contraindication. The only exception would be patients with massive pleural effusion or tension pneumothorax, in whom it can be anticipated that the procedure will provide therapeutic benefit with improvement of gas exchange due to re-expansion of the compressed or collapsed lung. However, even in very ill patients on a ventilator, medical thoracoscopy/pleuroscopy can be performed without significant complications.

Several other factors may make it necessary to postpone the procedure but are rarely prohibitive, *e.g.*, persistent cough, fever or an unstable cardiovascular status. Medical thoracoscopy should not be performed following a recent myocardial infarction or in the face of serious arrhythmia, unless the latter is due to marked hypoxaemia as in patients with tension pneumothorax. The patient should be free of infection, unless a parapneumonic effusion or empyema is present, which provides a therapeutic indication to carry out medical thoracoscopy/pleuroscopy. A markedly reduced general health status with an expected short survival should exclude performance of the examination unless it is likely to improve the patient's situation, for example in case of pneumothorax or empyema. Contraindications for pulmonary biopsy are suspicion of arteriovenous aneurysm, vascular tumours and hydatid cysts. Taking biopsy samples of honeycomb lung from end-stage pulmonary fibrosis should also be avoided, as it contributes to a high incidence of bronchopleural fistula.

## Complications and their prevention

Medical thoracoscopy/pleuroscopy is a safe and effective modality in the diagnosis and

***Table 3*** *Absolute and relative contraindications to medical thoracoscopy/pleuroscopy*

| Absolute | Relative |
|---|---|
| Lack of pleural space due to:<br>• Advanced empyema<br>• Pleural thickening of unknown aetiology<br>• Suspected mesothelioma where the visceral and parietal surfaces are fused<br>• Previous pleurodesis | Inability to tolerate lateral decubitus position<br>Unstable cardiovascular or haemodynamic status<br>Presence of severe, uncorrectable hypoxaemia despite oxygen therapy<br>Bleeding diathesis<br>Pulmonary arterial hypertension<br>Refractory cough<br>Drug hypersensitivity<br>Reduced general health status with short suspected survival |

treatment of several pleuro-pulmonary diseases if certain standard criteria are fulfilled. The advantages of the technique should be weighed against the discomfort of the patient and the slight potential for morbidity and mortality. Although the risks are low, it is important that adequate precautions are taken, including the recommended technical procedure as well as monitoring of cardiac and haemodynamic parameters and oxygen saturation during the procedure. As for all conscious sedation protocols, patients should refrain from eating and drinking 6–8 h before the procedure to reduce the risk of aspiration.

Complications that may be associated with medical thoracoscopy/pleuroscopy can be separated into those that may occur before, during or after the procedure (table 4).

The patient may experience short pain during penetration of the parietal pleura by the pneumothorax needle or during local anaesthesia. Additional pain may occur in patients with dense adhesions but this is always associated with an increase in intrapleural pressure since the lung cannot collapse sufficiently. In the presence of effective local anaesthesia and well-titrated sedation, little discomfort is felt, even when instruments with larger diameter are used. When biopsies of the parietal pleura are taken, patients must be warned of the associated brief discomfort and should be advised that they may cough when the lung is biopsied. Prior to talc insufflation, which may be painful, additional analgesics (alternatively, intrapleural lidocaine spray) should be given to the patient.

The procedure may cause hypoxia for several reasons: depression due to the anaesthesia, healthy lung in the lateral decubitus position, collapse of the investigated lung due to the induced pneumothorax. Oxygen saturation usually decreases only insignificantly during the procedure, and nasal oxygen may be provided prophylactically. Some authors also advocate the simultaneous cutaneous measurement of carbon dioxide, since significant hypoventilation might occur during the sedation.

Cardiac arrhythmias are rare, except for a slight sinus tachycardia. With the removal of large pleural effusions, one should be alert to the development of hypotension because of the associated considerable volume loss. Some authors recommend atropin to suppress vasovagal reflexes, but it is not clear whether atropin is necessary as a routine premedication.

A major concern often expressed regarding medical thoracoscopy/pleuroscopy is the risk of bleeding and the need for surgical back-up. In this regard, the reported incidence of significant bleeding requiring transfusion or surgical intervention is exceedingly low. Superficial bleeding at the site of entry ceases as a result of compression following introduction of the trocar. If haemorrhage occurs after the taking of biopsies, this is in general only very slight and ceases spontaneously if the suggested precautions are observed. If bleeding does not stop or if an intercostal vessel has been biopsied inadvertently, the bleeding area should be compressed and/or cauterised with electrocoagulation. Injury to the lung or other organs is almost always avoided by proceeding carefully, in particular when adhesions between the chest wall and the lung are present.

***Table 4*** *Potential complications of medical thoracoscopy/pleuroscopy*

| |
|---|
| **Before the procedure** |
| • Air embolism, subcutaneous emphysema and pain during pneumothorax induction |
| • Shortness of breath after pneumothorax induction |
| • Hypersensitivity reaction to local anaesthetic |
| **During the procedure** |
| • Pain |
| • Hypoxaemia |
| • Hypoventilation |
| • Cardiac arrhythmias |
| • Hypotension |
| • Haemorrhage |
| • Injury to lung or other organs |
| **After the procedure** |
| • Re-expansion pulmonary oedema |
| • Pain |
| • Postoperative fever |
| • Wound infection |
| • Hypotension |
| • Empyema |
| • Subcutaneous emphysema |
| • Persisting pneumothorax |
| • Prolonged air leakage |
| • Continuing pleural fluid production |
| • Early and late complications after talc pleurodesis |
| • Seeding of chest wall by tumour cells |
| • Mortality |

Potential post-thoracoscopic complications are re-expansion pulmonary oedema, pain, postoperative fever, wound infection, empyema, subcutaneous emphysema, persisting pneumothorax and prolonged air leakage, particularly after lung biopsies with a stiff or trapped lung. Mortality is reported to be an extremely rare event with only one death in 8,000 cases (mortality rate of 0.01%).

Complications can best be prevented by observing a few simple rules: postpone for several days if severe cough is present; measure blood gases; monitor cardiac status; and oxygenate the patient during the procedure. Coagulate and ensure haemostasis if haemorrhage exceeds 20 mL, and insert a chest tube until no air leakage is detected. To prevent subcutaneous emphysema, start a lung expansion protocol on the day after medical thoracoscopy/pleuroscopy. To prevent atelectasis, start gentle suction to avoid re-expansion pulmonary oedema. To prevent invasion of the insertion track of the thoracoscope in malignant mesothelioma, consider radiation therapy of 7 Grays per day for 3 days to the incision area (if thoracentesis or closed-needle biopsies have been taken, their tracks may also receive radiation), although this is controversial.

## Endoscopy room and personnel requirements

Medical thoracoscopy/pleuroscopy can be performed in a clean endoscopy suite. Cleanliness requirements are greater than for endoscopy *via* natural orifices, for example bronchoscopy, but less than in cardiac catheterisation. Thus, the procedure is best performed in rooms used for laparoscopy or in a clean bronchoscopy unit. Electrical systems should be properly insulated and protected against overload. Additionally, a premedication area, a washroom and an area for cleaning and sterilising instruments should be provided.

A properly equipped endoscopy room should contain the equipment listed in table 5.

Personnel required are the physician performing the medical thoracoscopy/pleuroscopy and an endoscopy assistant (or an endoscopy nurse) to assist with the instrumentation, and additionally a circulator nurse outside the sterile field to bring necessary equipment. Finally, depending on local custom, a nurse responsible for monitoring the patient's oxygenation, cardiac, and ventilatory parameters as well as for titration of sedation according to patient comfort is desirable. In an emergency, the procedure can be performed with only a physician and a nurse, but this is less efficient and may prolong the procedure. All members of the team should be familiar with the procedure and have the knowledge, competence, and resources necessary to respond to an emergency situation.

***Table 5*** *Equipment of the endoscopy room*

- Thoracoscopy table
- Sterile table for instruments
- Pneumothorax apparatus (optional)
- Aspiration equipment for the pleural fluid
- Simple anaesthetic equipment, with air-feed and oxygen
- Overhead light
- Electrocautery (optional: laser equipment)
- Separate mobile carts for endoscopic light sources, video equipment, and equipment for colour photography
- Ultrasonography (optional: fluoroscope)

## Equipment

Since the first detailed description by Jacobaeus in 1910 [8], rigid endoscopic instruments such as stainless-steel trocars and telescopes have been pivotal in the performance of thoracoscopy (fig. 2). With the introduction of the semi-rigid (semi-flexible) pleuroscope (Olympus Corporation, Tokyo, Japan), similar in design and handling to the flexible bronchoscope, pleuroscopy is now frequently performed with this technique, analogous to flexible bronchoscopy (fig. 3). Equipment requirements include trocar, thoracoscope/pleuroscope, biopsy forceps, unipolar coagulation forceps, light sources, video system, aspiration system, talc, chest tubes and drainage systems. The usual diameter of the rigid thoracoscope is 9 mm, that of the semi-rigid pleuroscope 7 mm.

Besides larger biopsy sizes, the advantage of rigid thoracoscopic instruments (Karl Storz GmbH, Tuttlingen, and Richard Wolf GmbH, Knittlingen, both Germany) is that the rigid forceps allows taking of biopsies from very dense lesions. The rigid instruments are also more suitable when more elaborate procedures are indicated or when it is necessary to control haemorrhage after biopsy. Rigid instruments are less expensive, more robust, have a longer endurance, and may need maintenance and repair less often.

The advantage of the semi-rigid pleuroscope is that it has the "look and feel" of a flexible bronchoscope, and thus may "lower the threshold" for medical thoracoscopy/pleuroscopy for the respiratory physician. It may also be helpful psychologically in overcoming fear of using the rigid instruments, which are often regarded as more dangerous. In addition, it helps maintain a clear optical field by allowing concurrent suctioning, which is analogous to the suction techniques used during flexible bronchoscopy, and it may allow the physician to overcome a limited view by manoeuvring its flexible tip in different directions and around adhesions. Its flexible tip facilitates the homogeneous insufflation of talc (*via* a catheter), introduced through the working channel, into all areas of the parietal and visceral pleura.

## Phases of medical thoracoscopy/pleuroscopy

The consecutive phases of medical thoracoscopy/pleuroscopy are listed in table 6.

The patient usually lies on the healthy side in a lateral decubitus position with the involved side up. An axillary point of entry is selected as standard in most cases: entry in the midaxillary line at the level of the fourth or fifth intercostal space allows best complete thoracic cavity inspection. Metastatic tumors or diffuse malignant mesothelioma are commonly found in the inferior costovertebral angles and on the diaphragmatic surface. Entry in the fifth or sixth or seventh intercostal space permits direct visualisation of these lesions.

In unusual cases, other points of entry are used depending on the clinical setting and/or the chest radiography, computed tomography, or ultrasound results. For instance, the second or third anterior intercostal spaces are chosen in cases of pneumothorax when anterior or superior blebs are suspected. The lesions are approached most easily from the opposite side. Every effort must be made to identify the precise level of lesions on the radiograph/CT image so that the appropriate intercostal space can be used for the point of entry.

## Techniques for introduction of the endoscope

The single-puncture technique is the easiest method to learn and is commonly used by respiratory physicians. A double-puncture method, usually performed under general anaesthesia, will increase the diagnostic and therapeutic benefit of the procedure in selected cases. With the double-puncture method, the second site of entry is selected closer to the area of interest.

## Access to the pleural space

Since it is impossible to perform the procedure if the pleural space is completely obliterated, lack of a sufficiently large pleural space is

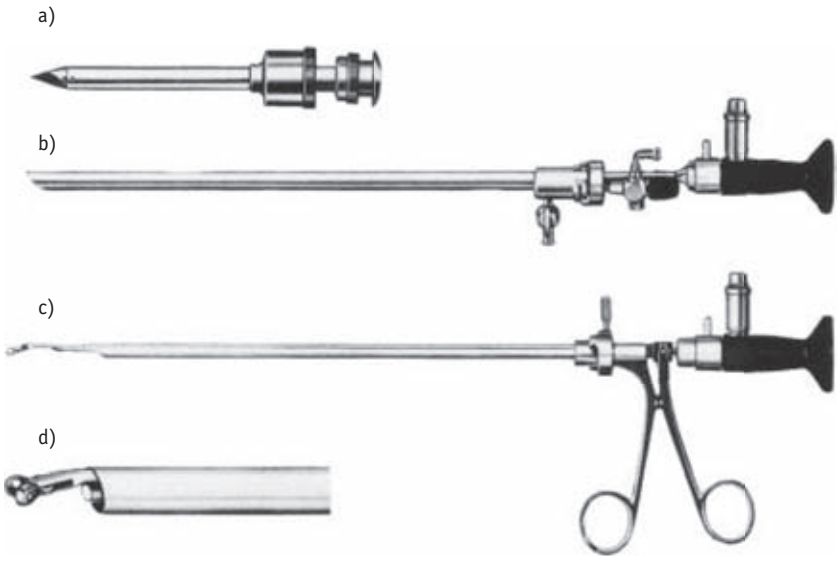


***Figure 2***
*Rigid instruments for medical thoracoscopy: a) trocar and cannula with valve; b) single-incision thoracoscope (9-mm diameter); c) biopsy forceps with straight optics; d) magnification of optics and forceps in the thoracoscope shaft ready for biopsy. Reproduced from [7], with permission from the publisher.*

***Figure 3***
*The semi-rigid (semi-flexible) pleuroscope. Reprinted with permission from Olympus Corporation, Tokyo, Japan.*

***Table 6*** *Phases of medical thoracoscopy/pleuroscopy*

- Preparation of the patient (information, fasting status, shaving of the skin)
- Premedication (optional)
- Radiographic review is mandatory in each patient
- Positioning of the patient
- Intravenous line, nasal oxygen, ECG electrodes, blood pressure meter, oximeter
- Choice of entry site on the basis of radiography/computed tomography or ultrasound/fluoroscopy 'on the table'
- Careful aspiration of fluids in case of pleural effusion
- Insufflation (or spontaneous entrance) of air if necessary
- Induction of pneumothorax if indicated
- Careful local anaesthesia plus sedation as needed
- Introduction of the trocar after a small skin incision
- Inspection of the thoracic cavity using thoracoscope/pleuroscope
- Documentation by photography or video
- Insufflation of additional air/$CO_2$ into the pleural cavity if necessary
- Section of adhesions preventing inspection if necessary
- Obtaining of multiple biopsy samples
- Control of bleeding
- Talc pleurodesis if necessary after additional analgesics
- Systematic suction drainage
- Surveillance during recovery

an absolute contraindication. Thus, the most important prerequisite for the procedure is a freely accessible pleural space that allows introduction of the trocar and thoracoscope/pleuroscope without injury to the lung or other organs (it should be recalled that the diaphragm lies in a much higher position in the supine patient than in the upright patient).

The simplest access is available in case of a pre-existing complete pneumothorax. If the pre-existing pneumothorax is only partial, due to adhesions, these should be localised by imaging to avoid introduction of the trocar in the area of adhesions.

In the presence of a larger pleural effusion, the trocar can be introduced directly without producing a pneumothorax (if fluid is readily aspirated as the pleural space is entered), although this may carry a somewhat greater risk of injury in case of unsuspected adhesions. In a smaller effusion, a needle puncture should be performed at the level of greatest opacification/dullness under sonographic (or fluoroscopic) guidance. When pleural fluid is aspirated, the syringe is removed from the needle and air will enter the pleural space either spontaneously or when asking the patient to take a few deep breaths, or by using a pneumothorax apparatus.

If it is difficult to aspirate pleural fluid, pneumothorax can be induced with special pneumothorax needles under pressure control, ideally with a manometer or a pneumothorax apparatus. In case of difficulties in creating a pneumothorax because of adhesions, the blunt dissection technique is recommended, particularly in case of pleural adhesions.

## Anaesthesia for medical thoracoscopy/pleuroscopy

Medical thoracoscopy/pleuroscopy is commonly performed under local anaesthesia with moderate sedation, which is quite well tolerated by patients. The term 'conscious sedation' is widely used in the literature and refers to patients who remain awake or arousable during the procedure while given mild anxiolytics and pain medications. With conscious sedation, an anaesthetist is not needed, which reduces costs.

General anaesthesia may be preferable in some special indications, such as idiosyncratic or allergic sensitivities to local anaesthetics, in anxious or uncooperative patients including children, or for advanced procedures such as sympathectomy.

An excellent alternative is intravenously administered propofol (with or without premedication), which provides sedation similarly to midazolam, but with a faster onset of action and a more rapid recovery.

Medical thoracoscopy/pleuroscopy may be a painful and unpleasant procedure, unpleasant because of the position of the patient, instrument manipulations, and vagus-mediated reflexes, and painful during certain well-defined periods as at the beginning of local anaesthesia, during the examination, *i.e.* by the pressure of the endoscope acting as a lever on the ribs, during removal of adhesions by coagulation, at biopsies of the chest-wall pleura, and, in particular, in the minutes following insufflation of talc.

In general, the pleura is more algesic in younger than in older patients and in patients with a normal surface of the parietal pleura than in those with, for instance far advanced tumour spread on the pleura. Different individual sensitivities to pain can be observed during performance of local anaesthesia or later when taking biopsies, and the pain medication can be adapted accordingly.

Local anaesthesia has to be administered carefully step by step (skin, subcutaneous tissue, and intercostal muscle down to parietal pleura, and at the caudal rim of the upper and the cranial rim of the lower rib to anaesthetise the intercostal nerve as well as the periostum of the ribs) while taking care, by repeated aspiration, that the tip of the needle is not located in the adjacent intercostal artery.

## Performance of medical thoracoscopy/pleuroscopy

The physician and assistant nurse clean their hands with a standard surgical scrub technique and then put on a sterile gown and gloves. The patient's skin is prepared by shaving and disinfecting a large area to include from the sternum to the clavicle and across the axilla past the scapula to the spinous processes, and down to the base of the thorax. Then the patient is covered with sterile sheets. Usually, the thoracoscopist faces the patient during the procedure (but may change position if needed), while the assistant is across the table.

Then the following steps are taken: at the selected point of entry (usually near the midaxillary line), a vertical incision is made with the scalpel through the skin and subcutaneous tissue, appropriate to the size of the trocar to be used, usually of approximately 10 mm, parallel with and in the middle of the selected intercostal space. Then the trocar is inserted in a corkscrew motion until the sudden release of resistance (after passing the costal pleura) is felt, while holding the handle of the trocar firmly in the palm of the hand, as the extended index finger, for safety's sake, limits the depth of insertion needed to reach the pleural space, previously established with the local anaesthetic needle. While the trocar is in the pleural cavity, the trocar is removed and the cannula should lie 1–3 cm within the pleural cavity and be held in position by the assistant. Then the thoracoscope is placed in the cannula and advanced into the pleural cavity under direct vision through the trocar. If necessary, the pleural fluid is removed with a suction catheter or directly through the working channel of the semi-rigid pleuroscope. In cases of a large pleural effusion, the fluid should be aspirated completely and not too hastily. This is without risk of development of immediate re-expansion oedema, as long as air is allowed to enter the pleural space through the cannula to replace the aspirated volume, thus maintaining normal intrapleural pressure.

The pleural space can be inspected through the thoracoscope/pleuroscope, either directly or indirectly by video. The endoscope is advanced towards the back and directed towards the diaphragm in the costophrenic angle. After completely removing the fluid, systematic exploration of the chest cavity is performed by manoeuvring the thoracoscope/pleuroscope. For the rigid endoscope, oblique telescopes are valuable in difficult cases to ensure adequate pleural inspection. Usually orientation is simple, although sometimes fine adhesions resembling spider webs may interfere with complete examination of the pleural cavity. These can be mechanically separated. Fibrous bands or vascular adhesions should be avoided, but can, if necessary, be cauterized by electrocautery.

Suspicious areas are biopsied through the working channel of the thoracoscope/pleuroscope. Often, multiple biopsies are necessary. If lesions are present on the parietal pleura, rather than visceral pleural lesions, these should be biopsied, thus avoiding the risk of prolonged air leak. Typically, two to six biopsies of a suspicious pleural lesion will establish the diagnosis. Sufficient quantities of tissue must be obtained, especially if hormonal receptor studies are required for tumours such as carcinoma of the breast. In the presence of undiagnosed pleural effusions, biopsies should be taken at a minimum from microscopically suspicious lesions at the anterior and posterior chest wall and the diaphragm for histological evaluation, and, if suspicious for tuberculosis, also for mycobacterial culture.

## Thoracoscopic talc pleurodesis

Thoracoscopic talc pleurodesis is the most widely reported method of instillation of talc into the pleural cavity (talc poudrage). It is used mainly for treatment of malignant or chronic recurrent nonmalignant pleural effusions, but also in persistent or recurrent pneumothorax. Prior to the insufflation, all pleural fluid should be removed. Another important prerequisite for a successful pleurodesis is that the lung is able to expand completely after the performance of talc poudrage, which may not be achievable in case of a trapped lung. Both the visceral and the parietal pleura have to come into close apposition to achieve a lasting pleurodesis. Furthermore, the success of pleurodesis depends on the presence of pleural mesothelial cells, since these are actively invoved in the creation of the symphysis. Both the re-expansion potential of the lung as well as the extent of pleural involvement by tumour can be jugded thoracoscopically.

Talc is hydrated magnesium silicate. Several mineral contaminants may be present but medicinal talc is asbestos free, with variable particle size generally $<$50 μm. In Europe, commercial talc for pleurodesis is manufactured by Novatech (La Ciotat, France). It is size-calibrated, with a median particle diameter of 31.1 μm, and it has been shown that, due to the larger size, no acute respiratory distress syndrome is caused. Although an optimal dose of talc for poudrage has not been established, usually a dose of ~5 g (4–8 g or ~8–12 mL) of sterile talc is recommended, whereas for pneumothorax patients 2–3 g of talc is sufficient.

The talc is insufflated into the pleural space at the end of thoracoscopy through a catheter (or cannula) placed in the working channel of the thoracoscope/pleuroscope. The flexible catheter (or the cannula) is connected to a small bottle containing talc and to a pneumatic atomizer. Uniform distribution of the talc on all pleural surfaces is confirmed by direct vision. Talc application may be painful, although in malignant pleural effusions less so than in pneumothorax, where the normal parietal pleura is more algesic. Accordingly, additional analgesics should be given directly before beginning the insufflation. Alternatively, lidocaine can be administered *via* spray catheter directly to the chest wall pleura.

## Post-thoracoscopic chest-tube insertion

At the conclusion of the procedure, a chest tube is inserted to drain residual air and fluid from the pleural cavity, allowing the lung to re-expand. The indications for removal of chest tubes placed for various pathological processes are as varied as the indications for tube placement. In general, absence of air leakage and cessation of fluid flow ($<$100–150 mL daily) are reasonable guidelines.

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