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REVIEW

Thoracoscopy: present diagnostic and therapeutic indications

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Thoracoscopy: present diagnostic and therapeutic indications. R. Loddenkemper, C. Boutin. ©ERS Journals Ltd 1993.

ABSTRACT: Thoracoscopy is increasingly being used for diagnosis and treatment of pleuropulmonary disease. The recent revival was made possible by the tremendous advances in endoscopic technology. The main requirements for diagnostic purposes are rigid telescopes and forceps, and for interventional thoracoscopy scissors, staplers and a video recorder.

The procedure can be performed either under local or general anaesthesia, with or without double lumen intubation, after inducing an artificial pneumothorax. At the end of the procedure, a chest tube should always be inserted, even if only for a few minutes until the lung re-expands.

Main diagnostic indications are pleural effusions, pneumothorax and diffuse lung disease. Main therapeutic indications are pleurodesis by talcage in effusion and pneumothorax and a variety of diseases of the lung, the pleura and the mediastinum, where thoracotomy may be replaced by video-assisted thoracoscopy.

The well-known indications of the past remain a domain of pneumologists, whereas minimal invasive thoracotomy is the task of thoracic surgeons. For some indications no sharp line has to be drawn, provided the facilities and skills are present, including those for the management of complications.

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It was JACOBAEUS [1], an internist in Stockholm, who in 1910 introduced thoracoscopy at the same time as laparoscopy in a paper entitled "Concerning the Possibility for Using Cystoscopy in the Examination of Serous Cavities". Even though he primarily developed thoracoscopy as a diagnostic procedure, it was almost exclusively used for pneumolysis (also called "Jacobaeus operation") throughout the world, whereas diagnostic thoracoscopy did not receive the recognition it deserved: this was especially true in the United States and in the United Kingdom, where it was often considered as an invasive technique, reserved only for surgeons.

The initial evolution in the therapeutic direction probably had several causes. Firstly, the diagnostic potential was certainly not fully appreciated, and secondly, at that time, other therapeutic possibilities were not yet developed. About 1950, with the advent of antibiotic therapy for tuberculosis, the era of pneumothorax therapy came to an end. In addition, the number of tuberculous patients gradually decreased, and other diseases became increasingly important to the chest physician. Consequently, between 1962 and 1966, a generation of physicians, already familiar with the therapeutic application of thoracoscopy, began to use this technique on a much broader basis for evaluating many pulmonary diseases. During the next 20–25 yrs most of the interest in this procedure was carried forward by European investigators [2, 3]. Detailed descriptions of pleural disease, with emphasis on tuberculous and malignant effusions, appeared in the literature. Concurrently, many American surgeons seemed to prefer thoracotomy and open biopsy for evaluation of these problems. With a trend toward less invasive investigation, seen in the late 1970s and early 1980s, thoracoscopy was again viewed with new interest.

This recent revival of thoracoscopy was also made possible by the tremendous advances in endoscopic technology. Endoscopic telescopes now provide extremely high optical resolution for a very small diameter. New endoscopic instrumentation, such as forceps, scalpels, staplers, laser fibres and video cameras have an ever-increasing number of applications, including pulmonary biopsy, bleb resection, mediastinal lymph node biopsy, pericardial window or biopsy, dorsal sympathectomy and pleural brushing. Also, new anaesthetic methods allow a wide range of alternatives, from out-patient procedures to selective double-lumen intubation under general anaesthesia [4].

The purpose of this review is to describe the present role of thoracoscopy in the diagnosis and treatment of chest diseases and to discuss several open points, *e.g.* rigid or flexible instruments, local or general anaesthesia, one or more points of entry, contraindications and complications, the best techniques for pleurodesis and newer interventional indications for thoracoscopy, including minimal invasive thoracotomy, as well as the roles of the pneumologist and the thoracic surgeon.

Indications

Already in the "therapeutic era", publications from many countries emphasized the diagnostic value of thoracoscopy

in pleural effusions, spontaneous pneumothorax, focal pulmonary disease, disease of the chest wall, mediastinal tumours, diseases of the heart and great vessels, and in thoracic trauma [2]. Later, these indications were expanded by using biopsy for localized and diffuse lung diseases. Today, the most common indication for diagnostic thoracoscopy is an exudative pleural effusion, the cause of which remains undiagnosed after thoracentesis and blind needle biopsy [3]. Localized lung or chest wall lesions, as well as mediastinal tumours, have become rarer indications, due to the improvement in less invasive procedures such as flexible bronchoscopy, computed tomography and others. Representative of this change is the development in the Chest Hospital Heckeshorn, Berlin during the last two decades (table 1).

As a therapeutic procedure, thoracoscopy has been performed mainly in combination with different pleurodesis techniques in pleural effusions or in pneumothorax. Although some other treatment applications have already been used in the past [2, 3, 5, 6], only with the introduction of the newer video-assisted techniques has a steadily increasing number of interventional and surgical thoracoscopic procedures been developed, for which titles, such as "interventional, operative, surgical or therapeutic thoracoscopy" [7, 8], "videothoracoscopy" [9, 10], "imaged thoracoscopic surgery" [11, 12], "video-assisted or video-controlled thoracoscopic surgery" [13], "minimal invasive or minimal access thoracic surgery" [14], "thoracoscopic resection" [15, 16], "endoscopy-assisted minithoracotomy" [17] *etc.*, have been proposed.

Table 1. – Indications for thoracoscopy: comparison between 1971–1979 and 1980–1988, Chest Hospital Heckeshorn, Berlin (Germany)

Indications	1971–1979 (n=1,652) %	1980–1988 (n=1,519) %
Pleural effusion	48	74
Malignant	39	48
Tuberculous	24	14
Others	37	38
Diffuse lung disease	22	8
Localized lung lesion	17	6
Chest wall lesion	6	5
Mediastinal tumour	5	2
Pneumothorax	1	4
Postoperative cavity	1	1

Pleural effusion: diagnostic indications

The diagnosis of pleural effusions is the main and the oldest indication for thoracoscopy, as described by Jacobaeus himself in his earliest articles. Many unselected pleural effusions defy even the most sophisticated investigators, despite comprehensive nonsurgical evaluation. After extensive work-up, out of 1,000 consecutive patients with pleural effusions, thoracoscopy was indicated in 215 with chronic effusions, where it established the diagnosis in up to 97% [18].

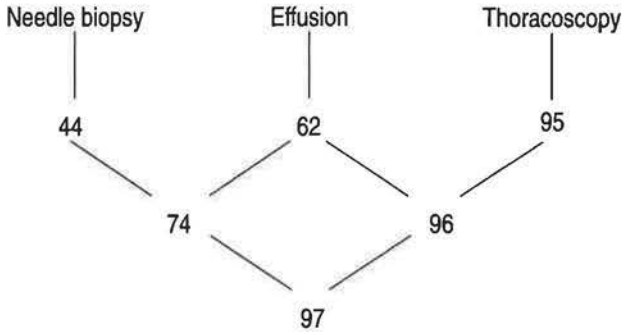

Fig 1. – Sensitivity (%) of different biopsy techniques in the diagnosis of malignant pleural effusions (cytological and histological results combined). Prospective intrapatient comparison (n=208). From LODDENKEMPER *et al.* [19].

In a prospective study, thoracoscopy had a diagnostic sensitivity of 95% in 208 cases with malignant effusions, whereas pleural fluid cytology was positive in 62%, and needle biopsy in 44% (fig. 1). The yield of thoracoscopy was very significantly higher even when the results of fluid cytology and needle biopsy were combined [19]. Because of its high diagnostic accuracy, thoracoscopy can be very helpful in staging of patients with bronchial carcinoma and pleural effusion, or with diffuse mesothelioma when surgical approach is considered. Unnecessary thoracotomy can thus be avoided. In addition, in the case of tumour secondaries from the breast, thoracoscopic biopsy may provide tissue suitable for hormone receptor assay to guide hormone therapy [20].

Metastatic pleural malignancies

Needle biopsies are successful in only 50% of metastic pleural malignancies [2, 3, 19, 21]. Moreover, unlike thoracoscopy, closed pleural biopsies are of little value for localized tumours, and of absolutely no use for metastatic tumours confined to the diaphragmatic, visceral or mediastinal pleura [22]. In fact, the success of closed techniques depends on tumour extent. The greater the extent of invasion, the more likely is closed biopsy to be successful. This explains why centres dealing with more advanced cancer report higher success rates with needle biopsy. Similarly, pleural fluid cytology exhibits variable success [23], which also depends on the type of the tumour investigated. A higher sensitivity is noted in various adenocarcinomas, whilst a lower sensitivity is seen in small cell carcinomas, malignant lymphomas and mesotheliomas. Therefore, a yield of 50–60% from pleural fluid cytology is certainly a more representative figure [24]. In 95 cases of pleurisy, SALYER *et al.* [25] obtained 53 positive needle biopsies and 69 positive cytologies, the combination of the two giving a positive yield in 86 patients (90%). Once again this high yield is achieved only in the advanced stages of disease.

The main advantage of thoracoscopy is its ability to achieve early diagnosis when pleural biopsy and fluid cytology have failed [26, 27]. In 85% of patients with malignancy, thoracoscopy revealed features suggestive of malignancy, including nodules between 1–5 mm in diameter,

larger polypoid lesions, localized tumoral masses, rough, pale, thickened pleural surface, and hard, poorly vascularized pachypleuritis [3]. However, since appearances can be misleading, macroscopic diagnosis must always be confirmed by histology. In this respect, it is important to note that some malignancies mimic nonspecific inflammation and some inflammatory lesions can look like tumours. Even mesotheliomas may have the appearance of ordinary inflammation, rather than its fairly characteristic grape-like nodular form, which was present in only 23% [3]. Histopathological findings are the only criteria for certain diagnoses.

In a review of 4,301 reported cases of diagnostic thoracoscopy using rigid instruments in cases of chronic pleural effusion from 21 different studies, from 1,472 cancer cases, 1,333 correct pathological diagnosis (92.5%) were achieved from thoracoscopic specimens [3]. But why are 7.5% of thoracoscopic biopsies negative? Several answers have been advanced:

1. In some patients with cancer, pleural effusion is due not to malignant pleural invasion but to malignant obstruction of mediastinal or pulmonary lymphatics, which are not biopsied. This has been described both in lung cancer and cancer of the breast.
2. Rarely, an effusion is the late consequence of lymphatic obstruction due to mediastinal radiotherapy, which occurred in about 1% of cases.
3. The thoracoscopist learns with experience and has a suboptimal yield initially.
4. Multiple biopsies must be taken systematically. There is no such thing as "too many". The costovertebral gutter and the diaphragm must be routinely sampled. Remember that metastases can sometimes not be recognized endoscopically.
5. If the biopsy is reported as negative in suspected malignancy, the pathologist should be asked to section all tissue, including "deepers" and to completely review all slides. This makes it possible to obtain additional diagnoses in several cases.
6. Sometimes, the pleura is covered with a fibrinous, necrotic layer, which requires removal in order to biopsy the parietal pleura behind it.
7. The major stumbling blocks for thoracoscopy in cancer patients are cases of adherent pleura. The ability to obtain a biopsy depends on the practitioner's skill in dividing and cutting adhesions, and there are some cases where biopsy is impossible. In our routine experience, we achieved 95–97% sensitivity in cancerous effusions, and false negative findings were always due to adhesions which denied access to the neoplastic tissue [2, 3].

The topography of pleural malignancies was studied by CANTO *et al.* [28, 29]. In 94% of their cases the lower half of the pleural cavity was affected, which justifies a low point of entry, either the sixth or seventh intercostal space. In 28% of cases, only the visceral pleura was involved, hence closed needle biopsy could not succeed. In breast cancer, lesions frequently occur on the anterior ipsilateral parietal pleura.

In bronchial carcinoma, thoracoscopy answers the important questions of whether the tumour has spread to the pleura or whether the effusion is secondary to venous or lymphatic obstruction or is parapneumonic. As a result, it may be possible to avoid exploratory thoracotomy or determine operability. WEISSBERG *et al.* [26] performed thoracoscopies in 45 patients with lung cancer and pleural effusion. In 37 they found pleural invasion: three patients had mediastinal disease: the remaining five patients had no evident metastatic disease and, therefore, no contraindication to resection. CANTO *et al.* [30] found similar results: eight out of 44 patients (18%) had no thoracoscopic evidence of pleural disease and six actually went to resection.

Diffuse malignant mesothelioma

Diagnosis of malignant mesothelioma depends primarily on histological findings. In the past, histologists were reluctant to advance a diagnosis without an autopsy report to bolster their findings. Nowadays, with the increased incidence of this disease and the availability of immunohistochemical techniques, histologists are more forthcoming, although they still frequently hide behind the cover of a "panel". Obtaining biopsy samples for diagnosis of mesothelioma is one of the best indications for thoracoscopy. Endoscopy is much less invasive than thoracotomy, and allows equally good tissue sampling for pathological diagnosis [18, 19, 31–34]. By allowing direct visualization of lesions, thoracoscopy facilitates the choice of biopsy sites and correlation of staging with survival. It also allows pulmonary biopsies to document prior exposure to asbestos.

In a series of 157 patients with diffuse malignant mesothelioma, the results were as follows [3]: thoracoscopy was indicated in practically all cases. The symptoms were chronic pleurisy in 88% of patients; empyema in 2%, chronic spontaneous pneumothorax in 1%, and radiologically detected pleural nodules without effusion in 9%. Of these patients, 80% recalled previous exposure to asbestos. In 75% of patients the pleural cavity was completely free, or displayed only loose or fibrinous adherences that did not impede thoracoscopic examination. In 25% of the patients the procedure was hindered by adhesions and electrocoagulation, or yttrium aluminium garnet (YAG) laser was required to sever adhesions and obtain a cavity of at least 10 cm. Although complete examination was not possible in the presence of extensive adhesions, biopsy samples of malignant lesions from the parietal and visceral pleura could be obtained in almost every case.

In this total series, the following lesions were observed in the parietal pleura or diaphragm:

- nodules or masses ranging 5 mm to 10 cm in 92 patients (49%);
- a grape-like aspect characteristic of mesothelioma in 25 patients (13%);
- thickening of the pleura in 21 patients (11%), this thickening was more or less regular with elevated, pale, hard, poorly vascularized tissue suggesting malignancy;
- malignant-looking pachypleuritis in association with nodules or masses in 63 patients (34%);
- a nonspecific inflammatory aspect with fine granulations (1–2 mm in diameter), lymphangitis, congestion, hypervascularization or local thickening of the pleura in 12 patients (7%).

Thoracoscopic biopsy was positive in 150 out of 153 cases (98%). In the remaining three patients, thick adhesions prevented collection of specimens and the diagnosis was mesothelial hyperplasia. In these three cases, definitive diagnosis was achieved by Abram's needle biopsy in one patient, repeat thoracoscopy in one patient, and surgical biopsy in one patient. In 135 cases (72%), the histological type was epithelial, in 38 cases (20%) it was mixed, and in 15 cases (8%) it was fibrosarcomatous.

In contrast with the high sensitivity of thoracoscopy, the combined sensitivity of fluid cytology and needle biopsy was only 38%. HERBERT and GALLAGHER [35] concluded that the overall sensitivity of these conventional methods is poor, and most investigators prefer open surgical biopsy. We prefer thoracoscopy, because it is far less painful and safer for the patient.

Thoracoscopic findings seem to have a high prognostic value, since they reflect the natural history of the disease and allow accurate staging [36]. In 50% of cases, patients with the longest survivals had tumour with an inflammatory or nonspecific lymphangitic aspect. The mean survival for 12 patients was 28.3 months. In the other 50% of these cases, small diameter nodules (less than 5 mm), fine granulations or slight pleural thickening were observed. In this early stage of the disease, the mediastinum as well as the visceral pleura appears normal through the thoracoscope as well as on computed tomographic (CT) scan. No lesions were observed at any time exclusively on the visceral or mediastinal pleura in these cases. This is consistent with the location of benign asbestos plaques only on the parietal pleura or diaphragmatic pleura. As reported by ADAMS *et al.* [37] in 19 out of 20 patients, the visceral pleura was always less involved than the parietal pleura or diaphragm [36]. If the visceral pleura is involved to any extent, mesothelioma has a very unfavourable prognosis. Conversely, the median survival for 48 patients with normal visceral pleura was 22.4 months.

Based on these findings, we propose subdividing stage I as described by BUTCHART *et al.* [38] and CHAHINIAN [39] into stage IA and IB. In stage IA, the parietal and/or diaphragmatic pleura are involved, but the visceral pleura and mediastinum are disease-free (26 patients in this series). In stage IB, the parietal, diaphragmatic and visceral pleura are involved, but the mediastinal pleura remains disease-free (70 patients). The median survival is 30 months for stage IA patients as compared to only 11 months for stage IB. The survival in stage II, which is characterized by invasion of the mediastinum, is only 10 months, suggesting that mediastinal involvement occurs promptly after visceral pleura invasion.

Tuberculous pleural effusions

Much less common at present, tuberculosis now causes less than 10% of all effusions seen in Europe and the USA, and a still lower percentage of all chronic cases. Although the yield of blind needle biopsy averages 69% with a range of 28–88% (review of the literature on 1,325 cases [40]), the diagnostic accuracy is much greater when the thoracoscope is used, because the pathologist is provided with multiple, selected biopsies.

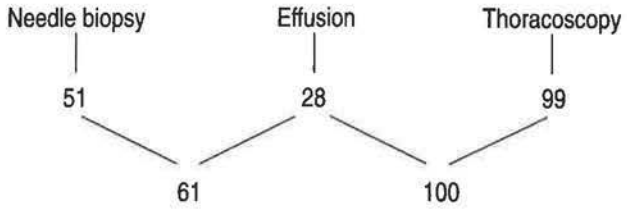

Fig. 2. – Sensitivity (%) of different biopsy techniques in the diagnosis of tuberculous pleural effusions (histological and bacteriological results combined). Prospective intrapatient comparison (n=100). From LODDENKEMPER *et al.* [41].

In a prospective study, the immediate diagnosis in 100 TB cases could be established histologically by thoracoscopy in 94%, compared to needle biopsy with 38% positive results [41]. This may be of great clinical importance, because the antituberculous chemotherapy can be started without delay. Figure 2 gives the overall sensitivity of the biopsy methods used in tuberculous pleurisy, including histological and bacteriological results. Needle biopsies were positive in 51%, whereas thoracoscopic biopsies were positive in 99%, again demonstrating superiority.

In addition, the percentage of positive TB cultures was twice as high from thoracoscopic biopsies, including cultures from fibrinous adhesions (78%), as the percentage in pleural effusions and needle biopsies combined (39%), allowing bacteriological confirmation of the diagnosis and sensitivity tests. In five of the 78 positive cases (6.4%) a primary resistance against one or multiple antituberculous drugs was found, which had some influence on therapy and prognosis.

It is of interest that the chance of positive TB cultures is much higher in cases with fibrin production (87%). This type, with a diffusely thickened pleura, multiple adhesions and sometimes formation of encapsulating membranes with fluid loculations, was present in 75% of cases. By comparison, the picture of sago-like pleuritis with miliary tuberculous granulomas was seen in only 25%. Here, a positive TB culture was obtained from all materials in only 50%, giving a highly significant difference ($p<0.0005$). In this study, the chance of positive TB cultures from pleural effusion was also statistically much better in cases with a pleural glucose <50 mg·dl^{-1} (59% positive *versus* 25% with glucose >50 mg·dl^{-1}, $p<0.005$), but the first group comprised only 17% of the patients.

Other pleural effusions

In the case of effusions that are neither malignant nor tuberculous, thoracoscopy may give macroscopic clues to their aetiology, for example in rheumatoid effusions, effusions following pancreatitis, liver cirrhosis, extension from the abdominal cavity, or trauma [2]. Certainly, in these entities history, pleural fluid analyses, physical and other examinations are usually diagnostic.

When the pleural effusions are secondary to underlying primary pulmonary problems, such as pulmonary infarct, carcinoma of the lung or pneumonia, the diagnosis can frequently be made on macroscopic examination, and confirmed microscopically from a biopsy of the lung. Thoracoscopy

is also ideal in the diagnosis of benign asbestos-related pleural effusions which, by definition, present a diagnosis of exclusion [3]. Fibrohyaline or calcified, thick and pearly white pleural plaques may be found in asbestotic effusions. Thoracoscopic pulmonary biopsy may demonstrate high concentrations of asbestos fibres or fibrosis, providing further support to the diagnosis of industrial disease [34]. The main value of thoracoscopy in other pleural effusions of undetermined origin lies in the considerable accuracy, allowing the exclusion of malignant or tuberculous disease [40]. By means of thoracoscopy, the proportion of so-called idiopathic pleural effusions falls markedly below 10%, whereas studies which have not used thoracoscopy report failure to obtain a diagnosis in over 20%. Only in those rare undiagnosed cases thought to be due to a disease for which there might be specific therapy, might it be worthwhile to consider as a further diagnostic step exploratory thoracotomy, eventually combined with decortication.

Pleural effusion: therapeutic indications

Pleurodesis can be achieved by a range of methods, including surgery and chemical agents. Several excellent critical reviews of all known pleurodesis procedures [39, 42–44] for chronic pleural effusions have been published. Our analysis of the main randomized studies have indicated that the most efficient products were talc, tetracycline and bleomycin. Other substances that have been used successfully, albeit less frequently, include biological products such as *Cornynebacterium parvum* [45], quinacrine [46] and doxycycline [47]. HAUSHEER and YARBRO [43] consider bleomycin to be the most effective, but many authors have reported adverse effects. Three randomized studies including a total of 111 patients, compared talc and tetracycline [47–49]. Out of 47 patients treated with talc and 46 treated with tetracycline, 44 and 33, respectively, were cured. Results with tetracycline depended on the dosage and the duration of the pleural drainage. Two other important considerations in choosing between talc and tetracycline are the duration of postoperative drainage and the relapse rate. The duration of pleural drainage is a key factor in patient comfort. The mean duration of drainage after talcage was 3–4 days, whereas with tetracycline it varied from only 1–2 days [50], up to 11 [47], or 16 days [51].

Pleurodesis should be permanent, and not all reports have objectively evaluated this criterion [52]. Response cannot be considered as complete if the effusion relapses. In a prospective study, the immediate success rate with tetracycline was 90%, but the relapse rate at 6 months was 50%, whereas no recurrences were observed after talcage [49]. In the series reported by OSTROWSKI [53], the success rate was 69% at one month and 54% after 3 months. GRAVELYN *et al.* [54] reported complete success in 15.6% of cases, moderate relapse in 43.8% and failure requiring drainage in 40.6%. In the study reported by DUNKEL [55], 28 out of 60 patients had late relapses. SHERMAN *et al.* [56] reported an immediate success rate of 94% response, but only 49% of patients were asymptomatic after 3 months. In contrast with these high relapse rates with tetracycline, BONIFACE and GUERIN [57] reported that only 10% of patients in whom pleurodesis was initially successful required a second poudrage. One explanation for this result is that, because they are soluble, tetracycline and bleomycin may gradually disappear from the pleural cavity. WOOTEN *et al.* [58] noted that 4 h after the pleural injection of 20 $mg \cdot kg^{-1}$ tetracycline, blood concentrations were 3.6 ± 0.9 $\mu g \cdot ml^{-1}$. Talc is insoluble and remains in the pleural cavity indefinitely, thus achieving permanent pleurodesis [59, 60]. Certainly, in the case of malignant effusion, the main action of sealant agents is fibrotic rather than cytotoxic [61].

Complications of talc poudrage have been reported [3]. The main postoperative problem is pain. The level of pain after poudrage is comparable to the level after tetracycline. More serious complications have been reported, and some authors have even suggested that talc poudrage is dangerous. RINALDO *et al.* [62] reported three cases of acute respiratory failure after instillation of 10 g of talc suspended in 250 ml of saline. This dose is much higher than the amount sprayed into the thoracic cavity during thoracoscopy. BOUCHAMA *et al.* [63] reported one acute pneumonia. TODD *et al.* [64] observed seven cases of respiratory failure and/or pneumonia out of 146 patients, but gave no precise details. These complications appear to be rare.

A different approach to malignant pleural effusions is possible by intrapleural immunotherapy [65, 66], which can be administered after thoracoscopic placement of a port-a-cath to treat cancer by inserting a drain in the pleural cavity. Proper placement of the catheter under thoracoscopic control ensures that the drug is applied directly to the lesions. The subcutaneous location of the site reduces the risk of infection.

The main indications for intrapleural immunotherapy are stage I or II mesothelioma, pleural adenocarcinoma of unknown origin, and metastatic cancer that is resistant to conventional chemotherapy. In the latter indication interleukin-2 or γ-interferon may restore the response to chemotherapy. In stage I mesothelioma, nearly 40% of patients respond to γ-interferon or interleukin-2.

Management of empyema

Thoracoscopy can be very useful in the management of empyema. Especially in the case of multiple loculations, it is possible to open these spaces, to remove the fibrinous adhesions and to create one single cavity, which can be drained and irrigated much more successfully [67, 68]. This has also been achieved by video-assisted technique [7]. Treatment should be carried out early in the course of empyema, before the adhesions become too fibrous and adherent.

Spontaneous pneumothorax: diagnostic indications

If possible, *i.e.* if the skills and the facilities are available, thoracoscopy should be performed in cases of spontaneous pneumothorax before applying continuous suction drainage. This not only allows the diagnosis of bullae, fistulae, *etc.*, but may also provide important information regarding therapy [2, 3].

SATTLER [69] was the first, in 1937, to identify emphysematous bullae under thoracoscopic view in spontaneous pneumothorax. In his series, ruptured bullae were identified in 63% of the patients, whereas no evident bullae or air leaks were seen in the others. Bullous perforations were subsequently reported by others [70]. Thoracoscopic studies in Utrecht, The Netherlands, by SWIERENGA *et al.* [71, 72], and WAGENAAR [73], were confirmed by VANDERSCHUEREN [74, 75].

Among 126 patients, Vanderschueren distinguished the following four stages of spontaneous pneumothorax:
Stage I: idiopathic pneumothorax, the lung being endoscopically normal (40% of cases);
Stage II: pneumothorax with pleuropulmonary adhesions (12%);
Stage III: pneumothorax with small bullae and blebs, <2 cm in diameter (31%);
Stage IV: pneumothorax with numerous large bullae >2 cm in diameter (17%).

Because modern magnifying telescopes and video recordings provide greater detail than older devices, minute blebs and small emphysematous bullae, about 1–2 mm in diameter, have been identified as the cause of the pneumothorax in stage I pneumothorax. These lesions are too fine to be seen on CT scan. This finding refutes the notion of a thoracoscopically normal lung in patients with an "idiopathic" spontaneous pneumothorax.

In stage II pneumothorax, adhesions can make thoracoscopy of the pleural cavity difficult. A few adhesions may be cut to facilitate observation, but there is generally no point in trying to break all the adhesions. An exception to this rule is made for adhesions that prevent ruptured emphysematous bullae from closing. Pneumothorax is sometimes complicated by haemorrhage due to spontaneously torn adhesions. Bleeding can be stopped by coagulating the vessel.

In stage III pneumothorax, emphysematous lesions are clearly visible on the surface of the lung. Blebs have a very thin avascular wall, are transparent, and vary in size from less than 1 mm upwards, but rarely exceed 1 cm in diameter. They do not communicate directly with the alveoli and bronchioles.

Stage IV pneumothorax is characterized by dystrophic bullous changes, with numerous bullae and blebs >2 cm in diameter. The visibility of bullae and blebs can be enhanced if the patient can perform a Valsalva manoeuvre, or by creating positive airway pressure with the anaesthesia mask. Leaks can be detected by making the patient breathe an aerosol of fluorescein for about 20 min prior to thoracoscopy; the leak will appear yellowish during thoracoscopic examination [3].

Two obvious benefits are provided by diagnostic thoracoscopy in pneumothorax. Firstly, the lesions are precisely assessed under direct vision, and the necessary therapeutic measures can be determined (or even applied) as well as the best location for the chest tube placement. Secondly, it can be used for teaching purposes, because the thoracic organs can be best seen in a spontaneous pneumothorax, where the pleura is thin and transparent. This is a practical opportunity for the young pulmologist to learn his or her way around the thoracic cavity and to gain confidence in handling the various instruments.

Spontaneous pneumothorax: therapeutic indications

There is no consensus among pneumologists as to the best management technique for spontaneous pneumothorax. Indeed this topic often provokes heated discussions, resulting partly from the subjective element involved in any therapeutic decision-making process, and partly from disagreement about the risk of spontaneous recurrences (estimates range 20–50%). Confronted with a 28% recurrence rate, after a first pneumothorax (table 2), the conservative physician will claim a 72% success rate, whilst his more active counterpart will say that the risk of relapse is unacceptably high, since safe therapeutic methods of pleurodesis are available. In fact, the recurrence rate is not precisely known. In an epidemiological study, MELTON *et al.* [76] estimated the incidence of a first episode to be 8.6 in 100,000 and that of a second episode to be 8.2 in 100,000. Since these two figures are not significantly different, it seems safe to assume that the recurrence rate is high. Regardless of the technique, the main objectives in management of spontaneous pneumothorax are to achieve permanent pleurodesis and to treat the causal pulmonary lesions.

In an effort to avoid thoracotomy, various thoracoscopic methods of pleurodesis have been proposed for patients with spontaneous pneumothorax:

Table 2. – Spontaneous pneumothorax relapse rates after various treatments (compiled from 75 published series)

Treatment	Series n	Years	Total cases n	Failure/relapse average %
Rest	13	1961–1983	912	28
Drainage	13	1961–1989	1627	21
Cyclines	10	1982–1989	202	20
Fibrin glue	8	1978–1987	493	15.2
Talc	13	1947–1989	505	7.3
Talc (personal series)		1985	100	5
Thoracotomy	18	1949–1984	1143	1.5

From BOUTIN *et al.* [3].

Tetracycline. In a review of 10 studies, including 202 patients in whom pleurodesis was achieved using tetracycline, the overall recurrence rate was 20% [3]. In a randomized study, LIGHT *et al.* [77] compared tetracycline and simple drainage, and clearly showed the benefit of tetracycline, albeit with a recurrence rate of 20%.

Fibrin glue. In a review of eight series, in which pleurodesis was achieved with fibrin glue, the overall recurrence rate was 15% [3]. Results of an experimental study performed showed that the mesothelium was intact and the pleura could be peeled away easily at autopsy [78]. This indicates that Tissucol does not cause pleural fibrosis.

Talc. In a review of 13 reports, including 505 patients in whom pleurodesis was achieved using talc, the overall recurrence rate was only 7% [3], with even lower rates in two large studies [75, 79]. In the most recent study, VISKUM *et al.* [80] re-examined 99 patients 22–35 yrs after talc poudrage for idiopathic spontaneous pneumothorax, and found that only 2.5% had relapsed. Thus, talc poudrage is quite similar to thoracotomy in terms of recurrence rate, and its effectiveness has been confirmed in humans and in animal models [59, 81].

Pleural abrasion. In terms of recurrence and tolerance, the long-term results of pleural abrasion seem to be even better than talcage. Abrasion can be accomplished using a compress attached to the end of the endoscopic forceps or with a nylon swab. A dedicated instrument, called a "pleural abrader", is also available. The technique is simple. It consists in passing the device over the surface of the pleura from the apex to the diaphragm and from the internal mammary vessels to the dorsal sympathetic chain. The mean duration of drainage is 3–4 days, during which 50–250 ml of reddish fluid is collected. Abrasion does require general anaesthesia, but not necessarily selective intubation, and can be performed by a surgeon or physician trained in thoracoscopy. No complications have been reported in the literature. At the present time, follow-up is too short to draw any definite conclusions. In his series of 60 patients with an mean follow-up of 32 months, NKERE *et al.* [82] observed only one recurrence.

Partial pleurectomy. Like pleural abrasion, partial pleurectomy can be performed as an interventional thoracoscopic technique that eliminates the need for thoracotomy. The technique described by LÉVI *et al.* [83] is performed by the extra-pleural route. A simpler technique *via* the endopleural route has been proposed by others [7, 84]. Apical pleurectomy is performed down to the fourth intercostal space, thus allowing symphysis of the apex of the lung, *i.e.* the most frequent location of causal lesions.

Treating the underlying lesions. The choice of therapy depends on the size of the lesion(s). Small blebs or emphysematous bullae up to 1.5 cm can be sealed using a CO_2 [85] or YAG laser [3], at a power setting of 20–40 W, or by electrocautery [6]. The lesion is vapourized, and the opening is immediately sealed by retraction of the lung parenchyma. For lesions larger than 1.5 cm a snare or a stapler can be used [7, 10]. The stapler, which requires a third point of entry, is very reliable but, at present, the cost is high.

Based on present results, thoracoscopy appears to be a promising technique for the treatment of spontaneous pneumothorax, and it is likely that it will replace conventional surgical procedures, such as thoracotomy.

For primary spontaneous pneumothorax, pleural abrasion or partial pleurectomy resection of bullae, if necessary, is the method of choice after the first episode in patients under 50 yrs. This approach is cost-effective, because young patients usually recover uneventfully and require brief drain placement (mean duration 4±1 days). In patients with respiratory distress or those over the age of 50 yrs with diffuse lesions, talc poudrage is the more suitable technique because it can be performed in 10–15 min and, thus, reduces the risk of respiratory failure.

Little information has been published about endoscopic management of secondary spontaneous pneumothorax. Empirically, talc poudrage would seem to present several advantages for patients in respiratory distress. It is well-tolerated, and can be performed quickly under neuroleptanalgesia. However, other methods deserve further study [75].

Diffuse pulmonary diseases

Diffuse lung diseases, currently of great interest because of the increased prophylactic and therapeutic potential, provide an excellent indication for diagnostic thoracoscopy. An overview of the total lung surface, assisted by the magnification of the thoracoscope, allows harvesting of representative samples of abnormal areas of parenchyma.

In a review of the literature, the sensitivity of thoracoscopic lung biopsies was 93% in 1,031 cases with varying aetiologies [3]. In a large series of 467 patients with diffuse lung diseases, the overall sensitivity was 86%, but differed depending upon the underlying disease [86]. Best results were obtained in patients with sarcoidosis stage II and III (n=104), with a sensitivity of 0.98. In diffuse malignant lung diseases (n=97), sensitivity was 0.90, and in fibrotic lung diseases (n=142) 0.86. For patients with a wide range of various diffuse lung diseases (n=124), sensitivity ranged 0.42–0.81.

Despite its excellent results in stage II sarcoidosis, thoracoscopy remains the method of second choice after transbronchial lung biopsy *via* the fibrebronchoscope, which is less invasive and achieves comparable results. However, thoracoscopy is a valuable tool in stage III sarcoidosis, where the main pathological finding is tissue fibrosis. Similarly, in lymphangiosis carcinomatosa, the first diagnostic approach should be fibreoptic transbronchial biopsy combined with bronchoalveolar lavage, which has been shown to be also highly effective in identifying uncommon organisms from the lung, *e.g. Pneumocystis carinii,* cytomegalovirus and *Toxoplasma gondii.* On the other hand, thoracoscopy has been applied with a high diagnostic yield in immunocompromised patients [87], and may be the method of choice for idiopathic pulmonary fibrosis, collagenous diseases, and other rare interstitial lung diseases, for which the sensitivity of bronchoscopic biopsies is still low [88].

In comparison with bronchoscopy, thoracoscopy is more invasive but presents several advantages [2, 3, 87].

Thoracoscopy provides significantly larger samples, and allows the physician to choose the biopsy site. Unlike transbronchial biopsy, thoracoscopy enables electrocoagulation or laser, so that bleeding following thoracoscopic parenchymal biopsy can be managed without difficulty. The sensitivity of the transbronchial peripheral biopsy fluctuates between 90% for sarcoidosis and distinctly lower values for other diffuse lung diseases. Due to the smaller biopsies, the specificity of the transbronchial peripheral biopsy is lower, although no exact data are available in the literature. The mortality rate is very low for both methods; below 0.01% for thoracoscopy [3].

With regard to sensitivity and invasiveness, thoracoscopy ranks between open lung biopsy and transbronchial biopsy. Although thoracoscopy is less traumatic than open surgical lung biopsy, the latter provides significantly larger surgical bioptates and results in a higher degree of sensitivity (averaging up to 95%), and specificity. An important advantage of open lung biopsy is that the drainage times are very short, since the defect can be closed by means of a primary suture. The mortality rate for open lung biopsy averages 1.5%. The advantage of being able to assess the structures by palpation during surgery is compensated for by the magnifying power of thoracoscopic optics.

Additional decision criteria to determine which method should be selected are the logistic possibilities available and personal experience. We feel that at least aged patients or patients in a poor general state of health are a good indication for thoracoscopy, if transbronchial lung biopsies are inconclusive. Moreover, thoracoscopy is a good choice in patients in whom a pneumothorax is present or has developed as a complication of transbronchial peripheral biopsy, or in whom a pleural effusion has occurred. Some tentative diagnoses, such as idiopathic pulmonary fibrosis, would give rise to a preference for thoracoscopy, since thoracoscopy provides good results in such cases. On the other hand, open lung biopsy is used in cases of patients displaying at least a borderline respiratory insufficiency, or in which the pleural cavity is, in terms of radiological criteria, obliterated, or when the patient is very unco-operative. A radiologically confirmed suspicion of histiocytosis X is more an indication for open biopsy, since, in this disease thoracoscopic results tend to be poor [2, 86].

Nowadays, video-assisted thoracoscopic lung biopsies by means of a stapler or a snare, allows the removal of fragments as large as those obtained by open lung biopsy [12, 17]. This procedure, which is best performed under general anaesthesia with double lumen intubation, may eventually replace thoracotomy, but results do not yet allow meaningful comparison of the two techniques.

A valuable modification, so-called direct thoracoscopy [89], makes use of the mediastinoscope and general anaesthesia with single lung ventilation. This technique shares the advantages that it is performed through a very small incision and that there are no additional costs for the expensive staplers.

Localized pulmonary diseases

Obtaining a diagnosis in localized lung disease by means of thoracoscopy is not nearly as likely as with diffuse pulmonary disease. However, thoracoscopy might occasionally be worthwhile, if abnormal areas are adjacent to the pleura, if other methods are unsuccessful, and if, for various reasons, surgery cannot be undertaken or can only be undertaken with great risk, especially if a pneumothorax has developed after nondiagnostic needle aspiration.

There are mainly anecdotal reports in the literature [2, 90]. In a retrospective analysis [91] of 240 patients with a solitary lung lesion adjacent to the visceral pleura, the overall diagnostic sensitivity was 0.47, varying with different aetiologies: in 129 cases with a malignant tumour the sensitivity was 0.37, in 23 cases with benign tumour 0.68, and in 88 cases with various other diseases 0.55. If only those cases were considered in which thoracoscopy was performed merely for diagnostic reasons, sensitivity was as high as 0.63. In contrast, the sensitivity was low (0.46) in those cases in whom a pneumothorax as sequelae of a previous biopsy procedure was used for a thoracoscopic attempt.

Today, small peripheral benign and malignant tumours [16, 92] have been resected by video-assisted thoracic surgery. The case reports include pulmonary metastases [93] as well as bronchial carcinoma, which has been removed by wedge resections [15], or even by lobectomy [8, 9]. But, whether these minimally invasive techniques can replace conventional resections after thoracotomy in the radical surgical approach to malignancies, has still to be evaluated and discussed in the future.

Diseases in the region of the chest wall, diaphragm and thoracic spine

Pathological changes in the chest cage close to the pleura provide an ideal indication for thoracoscopy if the pleural space is not obliterated. Hyaline pleural plaques, localized pleural mesothelioma, lipoma, neurinoma, rib metastases, rib erosions, *etc.* can nearly always be macroscopically characterized and, if necessary, biopsied. Very discrete metastases are sometimes found in the region of the diaphragm and the posterior chest wall, with or without associated pleural effusion. The diaphragm is readily visualized. There are mainly case reports in the literature [2, 94]. In a retrospective study, 133 cases with chest wall lesions of different origin have been analysed [91]. The diagnostic sensitivity was as high as 0.80, but today the indication for thoracoscopy has decreased substantially due to computed tomography, which allows the diagnosis of pleural plaques, lipomas and cysts, usually without difficulty. But here, in addition, minimal invasive techniques *via* the thoracoscope allow the surgical removal of localized benign or malignant lesions [8, 9, 95]. Thoracoscopy is well-suited to establishing or ruling out post-traumatic rupture of the diaphragm and other complications of chest trauma [2].

Hyperhydrosis (and vasomotor syndrome of the upper limb)

Sympathectomy *via* the axillary route was first proposed as a treatment of palmar and axillary hyperhydrosis by Kux [5] in 1954. The procedure has also been used to treat

patients with Raynaud's disease and arteritis of the upper limbs. The method is simple [96], at the beginning of the procedure an artificial pneumothorax is induced by insufflating one litre of air into the chest cavity. Next, two points of entry are made in the third intercostal space: a 7 mm incision for the endosope and a 5 mm incision for the coagulating forceps. The second, third and fourth ganglions are sectioned, and their connecting branches are coagulated. As soon as air is aspirated and the lung re-expands against the wall, the two incisions are closed by means of a subcutaneous suture. Depending on the case, the patient can be discharged the same or the next day. The key to preventing Horner's syndrome is to avoid the stellate ganglion. For hyperhydrosis, the success rate is close to 100%.

Mediastinal tumours and lymph nodes

Mediastinal tumours provide a good indication for diagnostic and therapeutic thoracoscopy [2]. Neurofibroma, Schwannoma, pleuropericardial and bronchogenic cysts [97], as well as a mediastinal goitre have been resected by video-assisted techniques [11]. Even oesophagectomies have been performed [98].

Mediastinal lymphomas have been approached by thoracoscopic needle punctures [2]. The value of lymph node resection is now evaluated by video-assisted techniques, particularly in the staging and treatment of lung cancer in areas which cannot be reached by mediastinoscopy [8, 9].

Pericardoscopy

Pericardoscopy was proposed by JACOBAEUS [1] in his first publication. However, there were only two case reports published in the past. One describes successful pericardial fenestration by the use of a neodymium (Nd)YAG laser [99], the other the rapid diagnosis of a cardiac herniation following a left-sided pneumonectomy [100].

Today, a pericardial biopsy or the creation of a pericardial window in patients with pericardial tamponade can easily be achieved by video-assisted thoracoscopy [101].

Techniques of thoracoscopy

The different techniques of diagnostic and therapeutic thoracoscopy, as performed by the pneumologist, are described in detail elsewhere [2, 3].

Both our methods use rigid instruments and differ only in minor points. The one favours a single incision 9 mm thoracoscope, with a working channel for accessory instruments and optical biopsy forceps, local anaesthesia and induction of the pneumothorax under fluoroscopic control [2]. The other favours two entries, one with a 7 mm trocar for the examination telescope and the other with a 5 mm trocar for accessory instruments including the biopsy forceps, local, neurolept or general anaesthesia and induction of pneumothorax the day before the examination [3]. However, the experienced thoracoscopist will certainly use a combination of these techniques, depending upon the individual situation.

Flexible instruments (fibrebronchoscope and colonoscope) have also been used, which in comparison to the rigid bronchoscope have several disadvantages, particularly the less adequate orientation within the thorax and the smaller biopsies [102, 103]. Most endoscopists surely use the instruments only because rigid instruments are not available to them or appear dangerous [90]. For the future, special instruments with a rigid shaft and a flexible tip are under development.

In contrast, video-assisted thoracoscopy is performed almost exclusively in general anaesthesia with double-lumen endotracheal intubation, allowing single-lung ventilation and the collapse of the lung on the examined side. Usually, three or more trocars are used for the introduction of the monitoring device and different instruments, by which not only diagnostic examinations but also thoracic surgical procedures can be performed. An additional smaller skin incision may become necessary for the removal of larger tumours or pieces of tissue.

Contraindications

Contraindications are uncommon and rarely absolute. The main limitation is the size of the free pleural space, which must be at least 10 cm in diameter. If extensive adhesions are present, an extended [104], or direct [89], thoracoscopy without creating a pneumothorax can be carried out, but this requires special skills and should not be undertaken without special training. The same is true for the minimally invasive techniques.

Several factors may make it necessary to delay thoracoscopy but are rarely prohibitive, *e.g.* persistent cough, hypoxaemia, hypocoagulability (prothrombin time <40–60% and/or platelet count less than 40,000–60,000 platelets·mm^{-3}) and cardiological abnormalities. The thoracoscopist must evaluate the benefit/risk ratio in each case [2, 3].

The contraindications for pulmonary biopsy are as follows [3]: 1) mean pulmonary arterial pressure >35 mmHg; 2) an X-ray film with a honeycomb image of the lung or end-stage interstitial fibrosis; 3) suspicion of arteriovenous pulmonary aneurysm; 4) hydatic cyst; and 5) vascular tumour.

Most of these contraindications do not exist for video-controlled thoracic surgery. However, here the higher risk of general anaesthesia with double-lumen endotracheal intubation and single-lung ventilation must certainly be considered. Since, during the procedure, an open thoracotomy may become necessary, appropriate selection criteria should be observed.

Complications and their prevention

Thoracoscopy is one of the safest pneumological examinations. VISKUM and ENK [105] noted only one death in 8,000 cases reviewed, due to mediastinal and subcutaneous emphysema. In another review of 4,300 cases, the mortality rate was 0.09% [31]. The most serious, but fortunately least frequent, complication is severe haemorrhage as a

complication of blood vessel injury during the procedure. However, this complication can be avoided by using safe points of entry and a cautious biopsy technique [2, 3]. In the case of smaller bleedings, electrocoagulation may become necessary. In our experience, there was never the need for a surgical intervention to stop a bleeding caused by thoracoscopy. Following lung biopsy, a bronchopleural fistula may result. This may require longer than the usual suction periods of 3–5 days, particularly in cases with stiff lungs [2, 3, 86]. Here, the other minimally invasive techniques which allow the closure of fistulae after biopsy certainly have advantages [12, 17].

Other complications, such as benign cardiac arrhythmias, low grade hypotension or hypoxaemia, can be prevented almost completely by administration of oxygen [106]. The most serious complication of pneumothorax induction is air or gas embolism, which fortunately happens very rarely (<0.1%), as long as the necessary precautionary measures are observed [2, 105].

During the procedure, cardiorespiratory function should be monitored by electrocardiography (ECG), and measurement of blood pressure and O_2 saturation. Following thoracoscopy, a drainage tube should be introduced and connected to a suction system for as long as necessary [2, 3]. In cases of mesothelioma, 10–12 days after thoracoscopy, radiotherapy may be carried out in order to prevent the late complications of tumour growth at the sites of entry [107].

Conclusions

Thoracoscopy has become the second most important endoscopic technique after flexible bronchoscopy. Primarily developed as a diagnostic procedure, it was applied between 1915–1955 almost exclusively for therapeutic purposes (pneumothorax therapy of tuberculosis). During the following decades, it found many diagnostic applications and was taken up again at the end of the 1980s as a therapeutic procedure on a much broader basis in several medical and surgical indications. This has been stressed during the last years by many publications and editorials [4, 8, 13, 14, 108–110].

Because both pneumologists and thoracic surgeons are involved in this rapidly changing field, interdisciplinary communication is necessary, which facilitates the exchange of technical advances and new applications. Because thoracoscopy has, in the past, been a domain of the pneumologist, there is no need for a change in favour of thoracic surgeons concerning the well-known indications. But, there are certainly indications reserved for thoracic surgeons, particularly those where thoracoscopy is performed as a minimally invasive video-assisted procedure instead of (or without) a thoracotomy.

The surgical advantages of this endoscopic therapy are obvious, because it is less invasive and more cost-efficient than conventional surgery. It shortens the duration of hospitalization, is less painful and reduces morbidity. However, at present, there is, a need to evaluate the safety and effectiveness of thoracoscopic techniques and also to provide training in both the medical and surgical methods of thoracoscopy [4, 14].

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