

# **Medical Thoracoscopy:**

## ***Rigid thoracoscopy or flexi-rigid pleuroscopy?***

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## ABSTRACT

### PURPOSE OF REVIEW:

In managing pleural diseases, medical thoracoscopy is often performed as a diagnostic and/or therapeutic procedure particularly in undiagnosed pleural effusions. Flexi-rigid pleuroscopes are now widely available as an alternative to conventional rigid thoroscopes. There is ongoing debate on which is the better instrument. This review analyses the current literature that compared rigid and flexi-rigid approaches, and outline medical advances that may influence the future role of thoracoscopy.

### RECENT FINDINGS:

Both rigid and flexi-rigid thoroscopies are safe. Although biopsies are smaller with flexi-rigid biopsy forceps, two small randomized trials reported similar diagnostic yield using either instrument. No studies have specifically examined patient comfort or the outcome of talc poudrage using the two devices. New techniques (e.g. IT knife and cyrobiopsy) have been used as adjuncts with flexi-rigid pleuroscopy to overcome the difficulties in sampling thickened pleura.

### SUMMARY:

The rigid and flex-rigid instruments have different merits and limitations. Both approaches provide comparable diagnostic yields in the overall patient population undergoing diagnostic thoracoscopy, though their performances specifically in patients with fibrotic pleural thickening have not been examined. Operators using flexi-rigid approach should have alternative strategies for sampling thickened pleura. Advances in cytopathology and imaging-guided biopsy will likely reduce the need of medical thoracoscopy in the future.

## INTRODUCTION

Thoracoscopy employs an optical system to examine the pleural cavity and perform diagnostic and therapeutic procedures[1]. It has traditionally been divided into surgical thoracoscopy, better known as Video Assisted Thoracic Surgery (VATS), and medical thoracoscopy (pleuroscopy).

Historically, both VATS and medical thoracoscopy were performed using rigid instruments. VATS allow surgeons to replace open thoracotomy in most pulmonary (e.g. lobectomy) and pleural surgeries (e.g. pleural biopsy and pleurodesis). VATS is typically performed under general anesthesia and single-lung ventilation. Some centers however, have performed VATS wedge resection under regional anesthesia [2, 3]. Pleuroscopy/medical thoracoscopy is usually performed by pulmonologists under conscious sedation, most commonly in the work-up of undiagnosed pleural effusions, through visual inspection and biopsy of parietal pleura lesions.

With the introduction of the flexi-rigid pleuroscope in the late 1990s, proceduralists performing thoracoscopy have the option of using either rigid or flexi-rigid instruments. Opinions have been polarized as to which is the better device but comparative studies to address this question are limited. Many experienced thoracoscopists remain in favor of the rigid scope and its ability to provide sizeable biopsies whereas advocates of flexi-rigid pleuroscopy embrace the flexibility of the instrument and its ease of use. It is a common dilemma for pulmonologists setting up a new pleural service to decide which scope to invest in.

This article aims to summarize the current literature and highlight the advantages and limitations of rigid vs. flexi-rigid approaches and emerging technologies that may alter the role of pleuroscopy in the foreseeable future.

## RIGID VS FLEXI-RIGID PLEUROSCOPY: THE INSTRUMENTS

A rigid thoracoscopy set includes a telescope, light source, trocar and forceps. The conventional stainless steel rigid telescope is 27-31cm in length with a diameter of 7-12mm; the larger ones (10-12mm) often favored by surgeons. Rigid telescopes have different angles of vision permitting straight-on (0°) or oblique (30° or 50°) viewing. Trocars are made from single-use disposable plastic or stainless steel with a variable diameter from 5-13mm.[4, 5]

The autoclavable flexi-rigid (semi-rigid) pleuroscope (Olympus LTF 160 or 240) has a 22cm proximal rigid shaft and 5cm flexible distal tip with an outer diameter of 7mm. The flexible tip allows 2-way angulations (160° up and 130° down). The handle of the flexi-rigid pleuroscope is similar to that of a flexible bronchoscope complete with a 2.8mm working channel, lever and suction port (Figure 1). The scope utilizes a custom-made plastic trocar of 8mm diameter (Figure 2).[6, 7]

The key difference between the two instruments is the flexibility to navigate various parts of the pleural cavity. The rigid thoracoscope has to travel in a straight line and has limited maneuverability when examining the posterior and mediastinal aspects of the thoracic cavity, particularly if the lung remains partially or fully inflated. The operator inevitably has to angle the scope by levering it against the underlying rib. The pressure and angling of the rigid instrument over the periosteum is believed to cause pain. The flexi-rigid pleuroscope, on the other hand, provides more flexibility [6, 8] and allows the operator to negotiate around a non-deflated lung or dense adhesions. In very loculated effusions, the ability to retro-flex the pleuroscope to

biopsy the parietal pleura adjacent to the insertion site is advantageous (Figure 3). This is not feasible with rigid thoracoscopy.

For visualization and illumination, the flexi-rigid pleuroscope can be connected to existing endoscopic processors (Olympus CV-160, CLV-U40) and light sources (CV-240, EVIS-100 or 140, EVIS EXERA-145 or 160) while the rigid thoracoscope requires a separate cold light source (xenon) with a camera attached to the eye-piece of the telescope.[6, 7] The image quality is significantly better with the flexi-rigid pleuroscope.[9\*]

The ‘trade-off’ and key disadvantage of the flexi-rigid scope is the small working channel which can limit adequate biopsies. The cusps diameter of the flexible biopsy forceps (FB-55CR-1) used with the flexi-rigid scope is 2.4mm, considerably smaller than that of the optical rigid biopsy forceps (5mm) used with rigid thoroscopes (Figure 4). The flexible forceps also lack the mechanical strength in obtaining specimens from tough fibrous pleura. Therefore, the sturdier rigid biopsy forceps, usually used during rigid thoracoscopy, often facilitate bigger and deeper biopsies and are more efficient in breaking down adhesions.

This difference is probably of less clinical importance if the patient has nodular pleural abnormalities (often seen with metastatic carcinomas) (Figure 5) which are easy to capture even with flexible biopsy forceps but is a significant limitation in patients with densely thickened pleura[8] (Figure 6). The latter can be seen with patients with mesothelioma (especially the sarcomatoid subtype) and fibrothorax from any chronic pleuritis. This is noteworthy as mesothelioma is consistently the most

common cause of false negative biopsies in patient with pleural malignancies undergoing medical thoracoscopy in published series even when rigid scopes were used.[10-12]

### RIGID VS FLEXI-RIGID PLEUROSCOPY: DIAGNOSTIC YIELD

International guidelines suggest thoracoscopy be considered for the 25% of exudative pleural effusions that remain undiagnosed after thoracentesis and/or closed pleural biopsy.[13, 14] In tuberculous pleuritis, the combined yield of histology and culture for rigid thoracoscopy was nearly 100%.[15, 16]

In malignant pleural diseases, rigid thoracoscopy achieved a high diagnostic yield of 95% in one study.[16] However, in three other series of medical thoracoscopy, patients with a thorascopic biopsy result of ‘non-specific pleuritis’ had a 10-15% chance of having an underlying pleural malignancy; most commonly mesothelioma.[10-12]

Published data on flexi-rigid pleuroscopy remain relatively limited. Most studies were small and did not necessarily contain the necessary variety of pleural malignancies (e.g. mesothelioma) and the range of diagnostic difficulties.

A systematic review by Mohan et al.[17] included five studies (154 patients) on flexi-rigid pleuroscopy in the diagnosis of undiagnosed pleural effusions and showed a pooled sensitivity of 97%, specificity of 100%, a positive likelihood ratio (PLR) of 5.47 and negative likelihood ratio (NLR) 0.08. These studies were also reported in a more recent meta-analysis by Agarwal et al.[18\*\*] that included 17 studies (755 patients), nine of which prospective and only one was a randomized trial. Flexi-rigid pleuroscopy showed a good sensitivity (91%) and specificity (100%) in diagnosing exudative pleural effusions. The PLR and NLR were 4.92 and 0.08 respectively.



Although larger specimens are preferred, two randomized trials and one prospective comparative study showed no significant difference in diagnostic yield between rigid and flexi-rigid pleuroscopy. Khan et al.[19\*] studied 66 patients (42 with malignancy and 2 with tuberculosis) from two centers in a non-randomized study, and reported similar diagnostic yields between the flexi-rigid and rigid thoracoscopy (92.3% vs. 96.3%).

Rozman et al.[20\*\*] published the first randomized study with 84 patients comparing the diagnostic adequacy of biopsy specimens obtained at rigid and flexi-rigid pleuroscopy. They found similar diagnostic accuracy with rigid (100%) and flexi-rigid instruments (97.6%) even though specimens obtained through the rigid forceps were considerably larger (24.7 vs. 11.7mm<sup>2</sup>). The negative predictive values for rigid and flexi-rigid biopsies were 100% and 92.3% respectively. In this cohort, 60% of patients had malignant pleural disease of which two-thirds were mesothelioma.

In another study, Dhooria et al.[9\*] randomized 90 patients to undergo rigid or flexi-rigid pleuroscopy. The diagnostic yield for rigid thoracoscopy was noted to be superior to flexi-rigid pleuroscopy on an intention-to-treat analysis (97.8% vs. 73.3%) but was similar (100% vs. 94.3%) after excluding patients in whom pleuroscopy were not feasible due to extensive adhesions. One major limitation in this study was patient selection. Seven of the 45 patients from the flexi-rigid thoracoscopy arm crossed over to the rigid thoracoscopy arm because of the lack of pleural space and only a quarter of the whole cohort had prior CT-chest or thoracic ultrasound. Unlike the previous studies, malignancy was the final etiology in only a third of the patients while a quarter was due to tuberculosis.

These studies have obvious limitations but nonetheless there has not been clear evidence to suggest that smaller biopsies result in inferior diagnostic accuracy. The size of biopsies from the flexi-rigid scope would be comparable to those from standard bronchoscopes, which is usually adequate for endobronchial tissue sampling.

## ADDITIONAL TECHNIQUES TO AID FLEXI-RIGID PLEUROSCOPY

Procuring adequate samples from thickened pleura remain the most important limitation of flexi-rigid pleuroscopy. Patients with mesothelioma or benign fibrothorax (e.g. benign asbestos pleural disease, TB pleural fibrosis etc) are often challenges for users of flexi-rigid pleuroscopes. Cytology has lower yield with mesothelioma and current guidelines[21] favor histological specimens over pleural fluid cytology in diagnosing mesothelioma. Therefore, obtaining representative biopsy samples is crucial in these patients.

To overcome the limitation of small biopsies by flexi-rigid pleuroscope, different strategies have been explored. Taking repeated “bites” from the same site with the flexible forceps to obtain tissue of sufficient depth[7] and peeling away the pleura and removing it together with the pleuroscope through the trocar[20\*\*] are tedious and time-consuming. Alternatively, swapping flexi-rigid pleuroscopy over to rigid thoracoscopy during the procedure is an option. However, not all units are equipped with both types of instruments.

A simpler alternative is to insert a second entry port for the rigid optical biopsy forceps. The flexi-rigid scope then provides the direct vision to guide biopsies with the rigid forceps[5]. This method combines the better optics of the flexi-rigid pleuroscope with the larger biopsies from using rigid forceps.

Several accessories have been designed to improve the biopsy of thickened pleura to be used via the working channel of the flexi-rigid pleuroscope, without the need of creating a second entry port. The insulated-tip (IT) knife consists of a conventional

diathermic knife with a ceramic ball at the tip to limit the depth of the cut. Sasada et al.[22] showed, in a study of 20 patients, that the IT knife allowed full-thickness parietal pleural biopsy with a higher diagnostic yield (85%) when compared to the standard flexible forceps (60%).

Biopsy via a cryoprobe is another tool being tested. Since its first use in 1968, cryosurgical technique has mainly been employed in management of obstructive endobronchial tumors. The equipment consists of a console, cryogen and cryoprobe. The Joule-Thomson effect states that a compressed gas released at a high flow rapidly expands and creates a very low temperature.[23] The cryoprobe is compatible with the working channel of the flexi-rigid pleuroscope and pressed against the targeted pleural lesion (Figure 7). The tissue is frozen under direct vision, detached with a tug and removed together with scope. Anecdotally, cryobiopsy can help to obtain larger size pleural samples even in thickened pleura.

These tools, and others in development, can potentially allow adequate sampling of thickened pleura, thus offset the key limitation of flexi-rigid pleuroscopy.

## RIGID VS FLEXI-RIGID PLEUROSCOPY: SAFETY

Medical thoracoscopy, either by rigid or flexi-rigid instruments, is a safe procedure in experienced hands. The combined mortality rate from 47 studies was 0.34% (95% CI 0.19-0.54%)[14]. In the three recent comparative trials, no procedure-related death was reported.[9\*, 19\*, 20\*\*] The pooled rate of major adverse events was 1.8% (95% CI 1.4-2.2%).[14] These include empyema, severe bleeding, port site metastasis, persistent air leak and pneumonia. Rozman et al.[20\*\*] found that one (2.6%) patient developed severe bleeding after pleural biopsy during rigid thoracoscopy while another (2.4%) developed empyema one-week after flexi-rigid pleuroscopy with pleurodesis. Both patients recovered with treatment.

Dhooria et al.[9\*] found no case of significant bleeding but three cases (3/47, 6.4%) of empyema or persistent air leak from the rigid thoracoscopy arm and one case (1/35, 2.9%) from the flexi-rigid pleuroscopy arm. They attributed the higher rate of empyema and persistent air leak to extensive adhesiolysis for complicated parapneumonic effusions. The pooled incidence of minor complications was 7.3% (95%CI 6.3-8.4%) including pyrexia, subcutaneous emphysema, skin infection and minor hemorrhage.[14]

In terms of peri-procedural pain, larger trocars used during rigid thoracoscopy can cause greater discomfort. The requirement for sedative and analgesics was higher with rigid thoracoscopy in the study by Dhooria et al.[9\*]

## RIGID VS FLEXI-RIGID PLEUROSCOPY FOR OTHER INDICATIONS

Aside from diagnostic purposes, medical thoracoscopy is often used to perform thoracoscopic talc poudrage (insufflations of talc as a dry powder) pleurodesis in patients with recurrent effusions. Noppen et al.[24] also showed that thoracoscopic talc poudrage was efficacious for recurrent spontaneous pneumothoraces.

No data exist comparing the efficacy of rigid vs. flexi-rigid pleuroscopy in pleurodesis outcome. It is unlikely that the choice of pleuroscope will influence the outcome of talc poudrage as the insufflated powder can distribute itself fairly evenly within the pleural surface regardless of the scopes used. Indeed, no significant benefits in pleurodesis outcome have been shown with talc delivered as poudrage or at the bedside as slurry via a chest tube. In a randomized trial of 501 patients with malignant pleural effusion, successful pleurodesis after 30-days by talc poudrage was similar to talc slurry (78% vs 71%).[25] Two other randomized trials have also shown no advantage of talc poudrage over talc slurry.[26, 27] Thoracoscopic talc poudrage had no benefits over chest tube pleurodesis using iodine in another small randomized trial.[28] Hence, the outcome difference between talc delivered by rigid or flexi-rigid routes is likely to be negligible.

Ravaglia et al.[29] showed that medical thoracoscopy was successful in treating patients with multiloculated empyema (91.7%) but less so in organized ones (50%). The rigid thoracoscope with its optical forceps are more suited for removing adhesions. However, the advent of intrapleural therapy with tissue plasminogen activator and deoxyribonuclease has significantly changed the management of pleural infection. This combination therapy cured 96% of patients without requiring surgery

in a randomized trial.[30] As this therapy is increasingly adopted worldwide, the role of medical thoracoscopy in empyema is likely to become obsolete.

## FUTURE DIRECTIONS

Thoracoscopy has played a significant role in the work-up of pleural effusions in the past 100 years since its first introduction. However, the need for pleuroscopy is likely to reduce as other less invasive alternatives advance (see our other review [31]). For example, modern cytological assessment (with better immunohistochemical and molecular markers) has high sensitivity for most metastatic carcinomas and even for mesothelioma, reducing the need for tissue biopsy. In a recent study of 815 mesothelioma patients, pleural fluid cytology was positive in 68% and verified as accurate against post-mortem findings.[32\*]

Imaging-guided biopsies are attractive alternatives. Ultrasound-guided bedside pleural biopsy has a high yield in suitable patients[33], and is growing in popularity. Maskell et al.[34] showed that CT guided pleural biopsy was useful in over 80% of patients presented with pleural thickening. Although not formally proven, the sensitivity of imaging-guided biopsy can be further improved with fluorodeoxyglucose positron emission tomography (FDG-PET), especially in patients with diffuse pleural thickening. Targeting FDG-avid areas with imaging-guided biopsy is useful in selected cases (Figure 8).

Conversely, the usefulness of thoracoscopy as a diagnostic tool has likely reached its peak; attempts to improve the diagnostic yield with thoracoscopy have been disappointing. Autofluorescence[35] and narrow band imaging[36, 37] have been evaluated as an adjunct for diagnostic thoracoscopy but have failed to show significant additional advantages.



## CONCLUSION

Rigid thoracoscopy and flexi-rigid pleuroscopy instruments present different advantages and disadvantages. Recent studies have shown that both instruments provide high diagnostic yields. The studies to date however are small and it is perhaps too simplistic to believe that one technique is superior to the other. The ideal pleural service should be equipped with both to tailor for individual patients' pleural conditions. Operators of flexi-rigid pleuroscopy must have alternative techniques available for patients with thickened pleura to ensure adequate samples are obtained. The advances in imaging techniques mean that imaging-guided pleural biopsy will be increasingly used for this group of patients.

## KEY POINTS

- In the small studies published to date, both flexi-rigid and rigid thorascopies have similar diagnostic accuracy despite differences in biopsy size.
- In using flexi-rigid pleuroscopy, special techniques and adjuncts are needed to overcome difficulties in sampling densely thickened pleura.
- Advances in cytopathology and image guided-biopsy will likely reduce the need for diagnostic thoracoscopy in the future.

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## FIGURE LEGENDS:

Figure 1:  
Flexi-rigid pleuroscope  
Source: Original

Figure 2:  
Custom-made trocar for the flexi-rigid pleuroscope  
Source: Original

Figure 3:  
Retro-flexion of the tip of the flexi-rigid pleuroscope  
Source: Original

Figure 4:  
Rigid optical biopsy forceps and flexible biopsy forceps – showing the smaller size of the latter  
Source: Original

Figure 5:  
Malignant pleural nodule: such lesions are easy to biopsy regardless if flexi-rigid or rigid instruments are used  
Source: Original

Figure 6:  
Densely thickened pleura: tissue biopsy is easier in this type of lesions using rigid biopsy forceps  
Source: Original

Figure 7:  
Biopsy of the pleura with the cryoprobe  
Source: Original

Figure 8:  
(Left) FDG-avid area demonstrated on PET  
(Right) CT-guided pleural biopsy of FDG-avid region  
Source: Original

## REFERENCES AND RECOMMENDED READING:

Papers of particular interest, published within the annual period of review have been highlighted as:

\* of special interest

\*\* of outstanding interest

1. Moisiuc FV, Colt HG. Thoracoscopy: origins revisited. *Respiration; international review of thoracic diseases*. 2007;74(3):344-55. PubMed PMID: 17191037.
2. Pompeo E. Awake thoracic surgery--is it worth the trouble? *Seminars in thoracic and cardiovascular surgery*. 2012 Summer;24(2):106-14. PubMed PMID: 22920526.
3. Rocco G, Romano V, Accardo R, Tempesta A, La Manna C, La Rocca A, et al. Awake single-access (uniportal) video-assisted thoracoscopic surgery for peripheral pulmonary nodules in a complete ambulatory setting. *The Annals of thoracic surgery*. 2010 May;89(5):1625-7. PubMed PMID: 20417792.
4. Loddenkemper R. Medical Thoracoscopy/Pleuroscopy. In: Ernst A, Herth F, editors. *Principles and Practice of Interventional Pulmonology*. New York, Heidelberg, Dordrecht, London: Springer; 2013. p. 605-21.
5. Rodriguez-Panadero F, Janssen JP, Astoul P. Thoracoscopy: general overview and place in the diagnosis and management of pleural effusion. *The European respiratory journal*. 2006 Aug;28(2):409-22. PubMed PMID: 16880371.
6. Ernst A, Hersh CP, Herth F, Thurer R, LoCicero J, 3rd, Beamis J, et al. A novel instrument for the evaluation of the pleural space: an experience in 34 patients. *Chest*. 2002 Nov;122(5):1530-4. PubMed PMID: 12426249.
7. Lee P, Hsu A, Lo C, Colt HG. Prospective evaluation of flex-rigid pleuroscopy for indeterminate pleural effusion: accuracy, safety and outcome. *Respirology*. 2007 Nov;12(6):881-6. PubMed PMID: 17986118.
8. McLean AN, Bicknell SR, McAlpine LG, Peacock AJ. Investigation of pleural effusion: an evaluation of the new Olympus LTF semiflexible thoracofiberscope and comparison with Abram's needle biopsy. *Chest*. 1998 Jul;114(1):150-3. PubMed PMID: 9674462.
- \*9. Dhooria S, Singh N, Aggarwal AN, Gupta D, Agarwal R. A randomized trial comparing the diagnostic yield of rigid and semirigid thoracoscopy in undiagnosed pleural effusions. *Respiratory care*. 2013 Oct 8. PubMed PMID: 24106326.

90 patients with undetermined exudative pleural effusions were randomized to either rigid or semi-rigid thoracoscopy. The diagnostic yield of rigid (100%) and semi-rigid thoracoscopy (94.3%) were similar after excluding non-feasible biopsies.

10. Davies HE, Nicholson JE, Rahman NM, Wilkinson EM, Davies RJ, Lee YC. Outcome of patients with nonspecific pleuritis/fibrosis on thoracoscopic pleural biopsies. *European journal of cardio-thoracic surgery : official journal of the European Association for Cardio-thoracic Surgery*. 2010 Oct;38(4):472-7. PubMed PMID: 20219385.
11. Janssen JP, Ramlal S, Mravunac M. The long-term follow up of exudative pleural effusion after nondiagnostic thoracoscopy. *J Bronchol*. 2004;11:169-74. English.
12. Venekamp LN, Velkeniers B, Noppen M. Does 'idiopathic pleuritis' exist? Natural history of non-specific pleuritis diagnosed after thoracoscopy. *Respiration*;

international review of thoracic diseases. 2005 Jan-Feb;72(1):74-8. PubMed PMID: 15753638.

13. Prakash UB, Reiman HM. Comparison of needle biopsy with cytologic analysis for the evaluation of pleural effusion: analysis of 414 cases. Mayo Clinic proceedings. 1985 Mar;60(3):158-64. PubMed PMID: 3974296.

14. Rahman NM, Ali NJ, Brown G, Chapman SJ, Davies RJ, Downer NJ, et al. Local anaesthetic thoracoscopy: British Thoracic Society Pleural Disease Guideline 2010. Thorax. 2010 Aug;65 Suppl 2:ii54-60. PubMed PMID: 20696694.

15. Diacon AH, Van de Wal BW, Wyser C, Smedema JP, Bezuidenhout J, Bolliger CT, et al. Diagnostic tools in tuberculous pleurisy: a direct comparative study. The European respiratory journal. 2003 Oct;22(4):589-91. PubMed PMID: 14582908.

16. Loddenkemper R. Thoracoscopy--state of the art. The European respiratory journal. 1998 Jan;11(1):213-21. PubMed PMID: 9543295.

17. Mohan A, Chandra S, Agarwal D, Naik S, Munavvar M. Utility of semirigid thoracoscopy in the diagnosis of pleural effusions: a systematic review. Journal of bronchology & interventional pulmonology. 2010 Jul;17(3):195-201. PubMed PMID: 23168883.

\*\*18. Agarwal R, Aggarwal AN, Gupta D. Diagnostic Accuracy and Safety of Semirigid Thoracoscopy in Exudative Pleural Effusions: A Meta-analysis. Chest. 2013 Dec 1;144(6):1857-67. PubMed PMID: 23928984.

A meta-analysis that included 17 studies (755 patients). Semi-rigid thoracoscopy was shown to be efficacious and safe in diagnosing undetermined exudative pleural effusions.

\*19. Khan MA, Ambalavanan S, Thomson D, Miles J, Munavvar M. A comparison of the diagnostic yield of rigid and semirigid thoroscopes. Journal of bronchology & interventional pulmonology. 2012 Apr;19(2):98-101. PubMed PMID: 23207350.

A comparison between diagnostic yields of thorascopic pleural biopsy in unilateral exudative pleural effusions showed a positive diagnosis of 96.3% (rigid group) and 92.3% (semirigid group).

\*\*20. Rozman A, Camlek L, Marc-Malovrh M, Triller N, Kern I. Rigid versus semi-rigid thoracoscopy for the diagnosis of pleural disease: a randomized pilot study. Respirology. 2013 May;18(4):704-10. PubMed PMID: 23418922.

The first randomized prospective study (84 patients) to compare diagnostic accuracy between rigid and semi-rigid thoracoscopy. Diagnostic yields of both techniques were comparable despite differences in the size of the biopsies.

21. Husain AN, Colby T, Ordonez N, Krausz T, Attanoos R, Beasley MB, et al. Guidelines for pathologic diagnosis of malignant mesothelioma: 2012 update of the consensus statement from the International Mesothelioma Interest Group. Archives of pathology & laboratory medicine. 2013 May;137(5):647-67. PubMed PMID: 22929121.

22. Sasada S, Kawahara K, Kusunoki Y, Okamoto N, Iwasaki T, Suzuki H, et al. A new electrocautery pleural biopsy technique using an insulated-tip diathermic knife

during semirigid pleuroscopy. *Surgical endoscopy*. 2009 Aug;23(8):1901-7. PubMed PMID: 19118434.

23. Babiak A, Hetzel J, Krishna G, Fritz P, Moeller P, Balli T, et al. Transbronchial cryobiopsy: a new tool for lung biopsies. *Respiration; international review of thoracic diseases*. 2009;78(2):203-8. PubMed PMID: 19246874.
24. Noppen M, Meysman M, d'Haese J, Monsieur I, Verhaeghe W, Schlessers M, et al. Comparison of video-assisted thoracoscopic talcage for recurrent primary versus persistent secondary spontaneous pneumothorax. *The European respiratory journal*. 1997 Feb;10(2):412-6. PubMed PMID: 9042642.
25. Dresler CM, Olak J, Herndon JE, 2nd, Richards WG, Scalzetti E, Fleishman SB, et al. Phase III intergroup study of talc poudrage vs talc slurry sclerosis for malignant pleural effusion. *Chest*. 2005 Mar;127(3):909-15. PubMed PMID: 15764775.
26. Terra RM, Junqueira JJ, Teixeira LR, Vargas FS, Pego-Fernandes PM, Jatene FB. Is full postpleurodesis lung expansion a determinant of a successful outcome after talc pleurodesis? *Chest*. 2009 Aug;136(2):361-8. PubMed PMID: 19349389.
27. Yim AP, Chan AT, Lee TW, Wan IY, Ho JK. Thoracoscopic talc insufflation versus talc slurry for symptomatic malignant pleural effusion. *The Annals of thoracic surgery*. 1996 Dec;62(6):1655-8. PubMed PMID: 8957368.
28. Mohsen TA, Zeid AA, Meshref M, Tawfeek N, Redmond K, Ananiadou OG, et al. Local iodine pleurodesis versus thoracoscopic talc insufflation in recurrent malignant pleural effusion: a prospective randomized control trial. *European journal of cardio-thoracic surgery : official journal of the European Association for Cardio-thoracic Surgery*. 2011 Aug;40(2):282-6. PubMed PMID: 20961772.
29. Ravaglia C, Gurioli C, Tomassetti S, Casoni GL, Romagnoli M, Gurioli C, et al. Is medical thoracoscopy efficient in the management of multiloculated and organized thoracic empyema? *Respiration; international review of thoracic diseases*. 2012;84(3):219-24. PubMed PMID: 22832393.
30. Rahman NM, Maskell NA, West A, Teoh R, Arnold A, Mackinlay C, et al. Intrapleural use of tissue plasminogen activator and DNase in pleural infection. *The New England journal of medicine*. 2011 Aug 11;365(6):518-26. PubMed PMID: 21830966.
31. Davies HE, Rosenstengel A, Lee YC. The diminishing role of surgery in pleural disease. *Current opinion in pulmonary medicine*. 2011 Jul;17(4):247-54. PubMed PMID: 21537191.
- \*32. Segal A, Sterrett GF, Frost FA, Shilkin KB, Olsen NJ, Musk AW, et al. A diagnosis of malignant pleural mesothelioma can be made by effusion cytology: results of a 20 year audit. *Pathology*. 2013 Jan;45(1):44-8. PubMed PMID: 23222247.

This is a study of 815 patients with malignant pleural mesothelioma in Western Australia. The absolute sensitivity of pleural fluid cytology proven by biopsy/necropsy was 68%. The positive predictive value was 99%.

33. Koegelenberg CF, Diacon AH. Pleural controversy: close needle pleural biopsy or thoracoscopy-which first? *Respirology*. 2011 Jul;16(5):738-46. PubMed PMID: 21435098.
34. Maskell NA, Gleeson FV, Davies RJ. Standard pleural biopsy versus CT-guided cutting-needle biopsy for diagnosis of malignant disease in pleural effusions: a randomised controlled trial. *Lancet*. 2003 Apr 19;361(9366):1326-30. PubMed PMID: 12711467.

35. Chrysanthidis MG, Janssen JP. Autofluorescence videothoracoscopy in exudative pleural effusions: preliminary results. *The European respiratory journal*. 2005 Dec;26(6):989-92. PubMed PMID: 16319326.
36. Ishida A, Ishikawa F, Nakamura M, Miyazu YM, Mineshita M, Kurimoto N, et al. Narrow band imaging applied to pleuroscopy for the assessment of vascular patterns of the pleura. *Respiration; international review of thoracic diseases*. 2009;78(4):432-9. PubMed PMID: 19844135.
37. Schonfeld N, Schwarz C, Kollmeier J, Blum T, Bauer TT, Ott S. Narrow band imaging (NBI) during medical thoracoscopy: first impressions. *Journal of occupational medicine and toxicology*. 2009;4:24. PubMed PMID: 19709438. Pubmed Central PMCID: 2748073.

Figure 1:  
Flexi-rigid pleuroscope  
Source: Original



Figure 2:  
Custom-made trocar for the flexi-rigid pleuroscope  
Source: Original

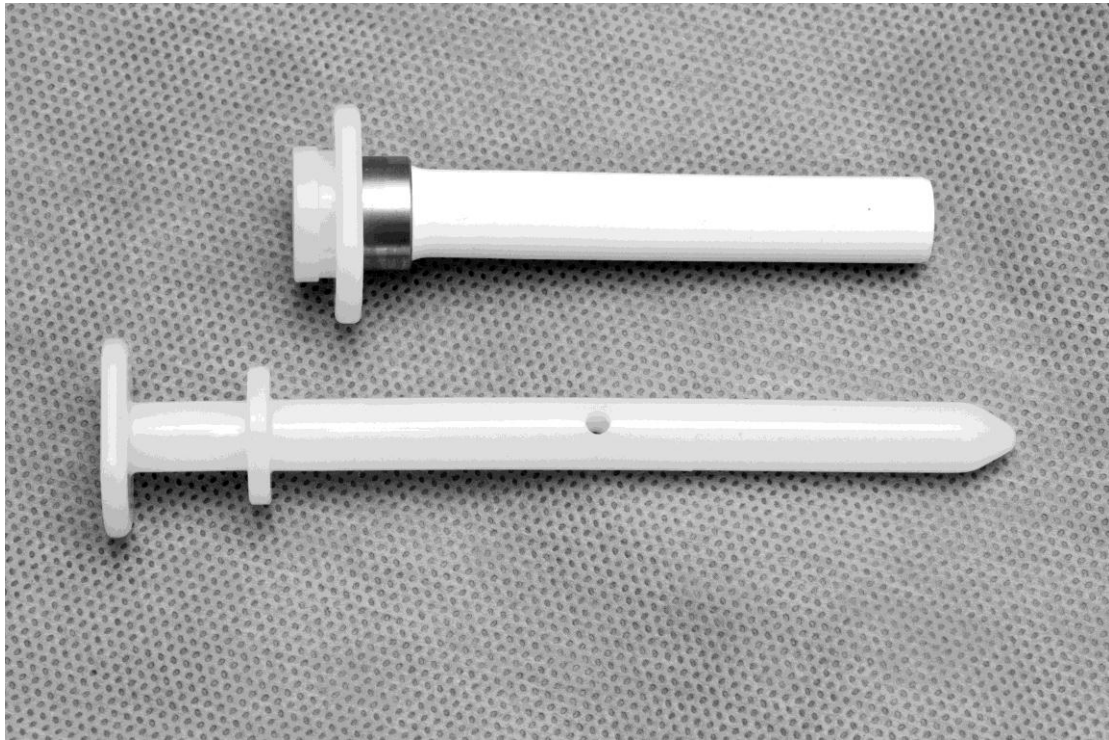




Figure 3:  
Retro-flexion of the tip of the flexi-rigid pleuroscope  
Source: Original



Figure 4:  
Rigid optical biopsy forceps and flexible biopsy forceps – showing the smaller size of  
the latter  
Source: Original

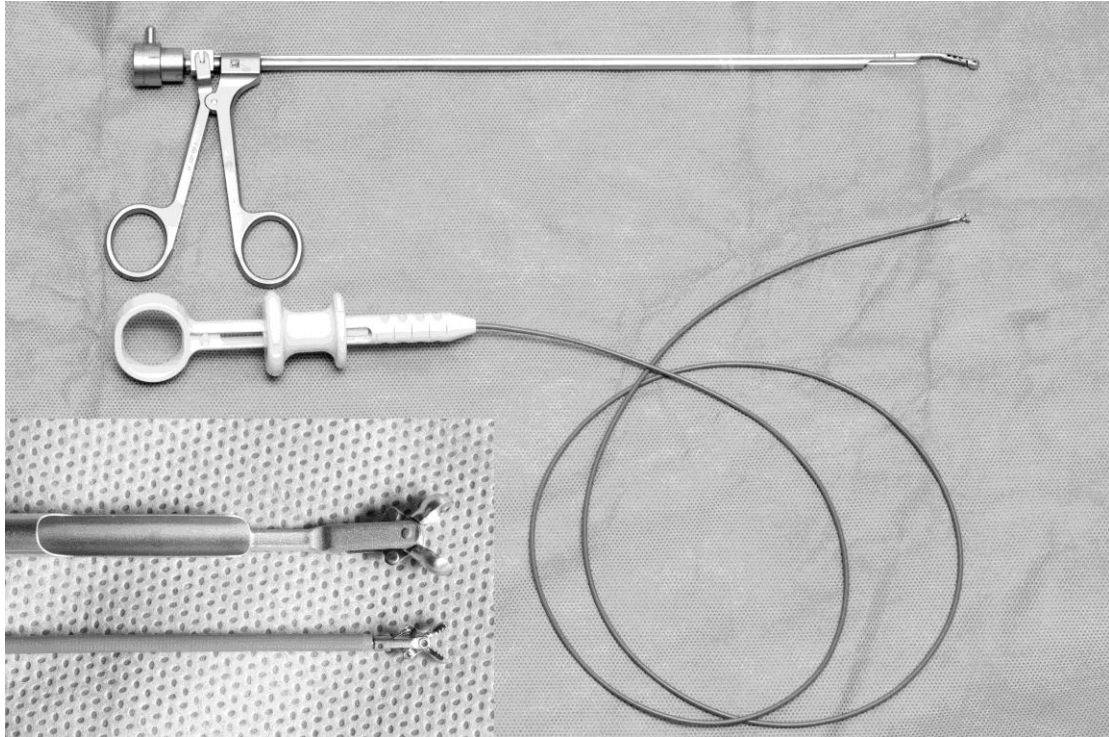


Figure 5:

Malignant pleural nodule: such lesions are easy to biopsy regardless if flexi-rigid or rigid instruments are used

Source: Original

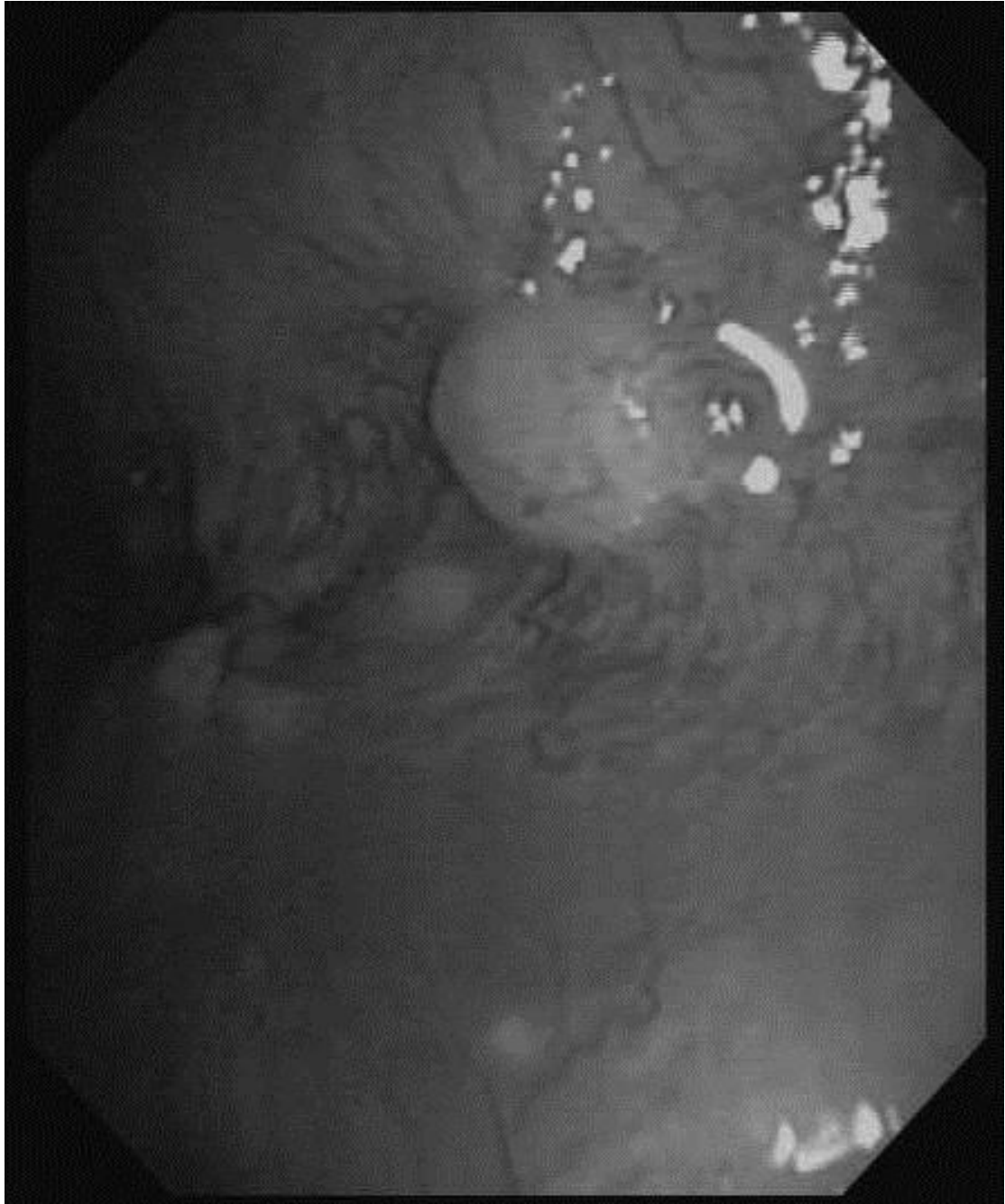


Figure 6:  
Densely thickened pleura: tissue biopsy is easier in this type of lesions using rigid  
biopsy forceps  
Source: Original

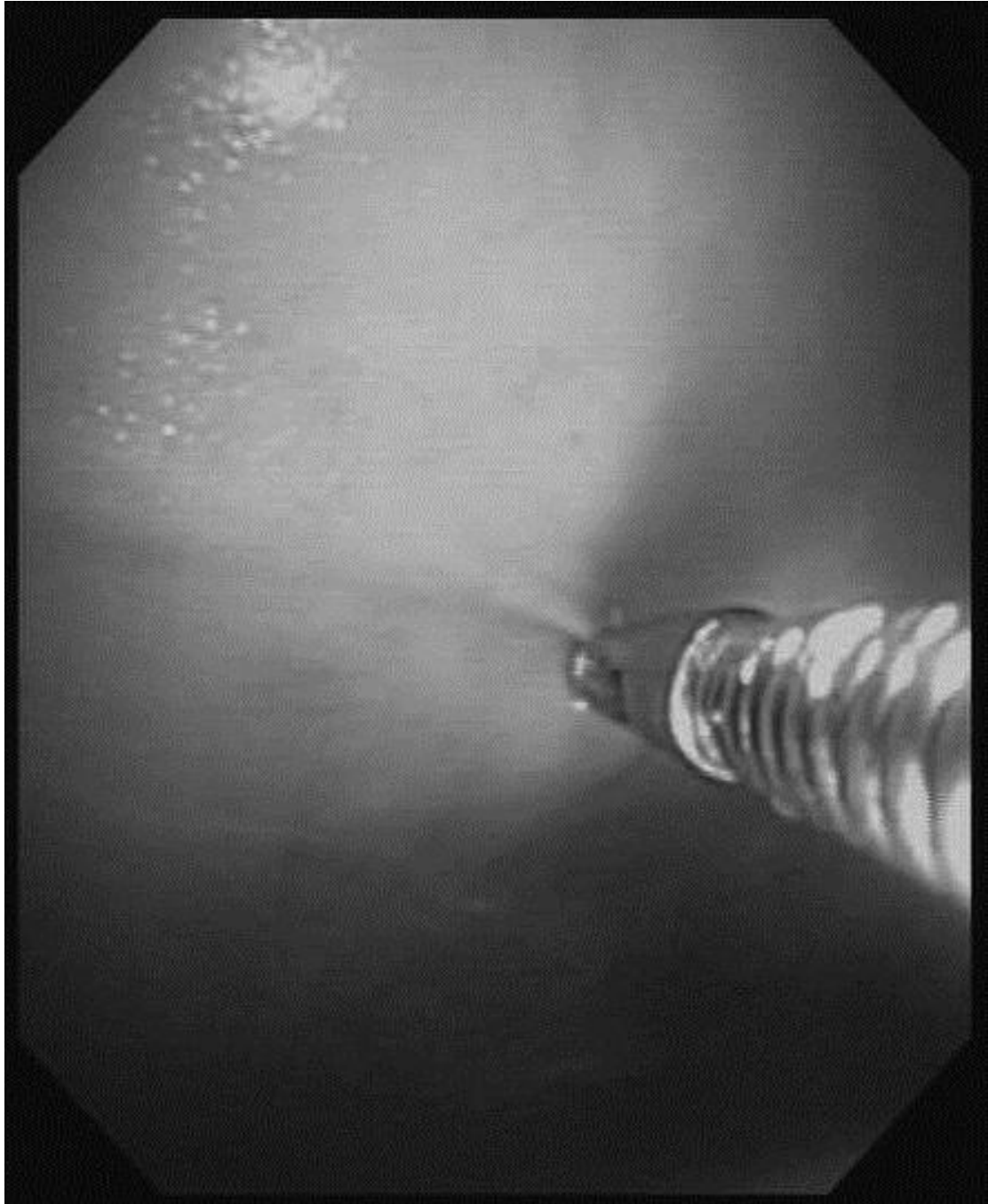


Figure 7:  
Biopsy of the pleura with the cryoprobe  
Source: Original

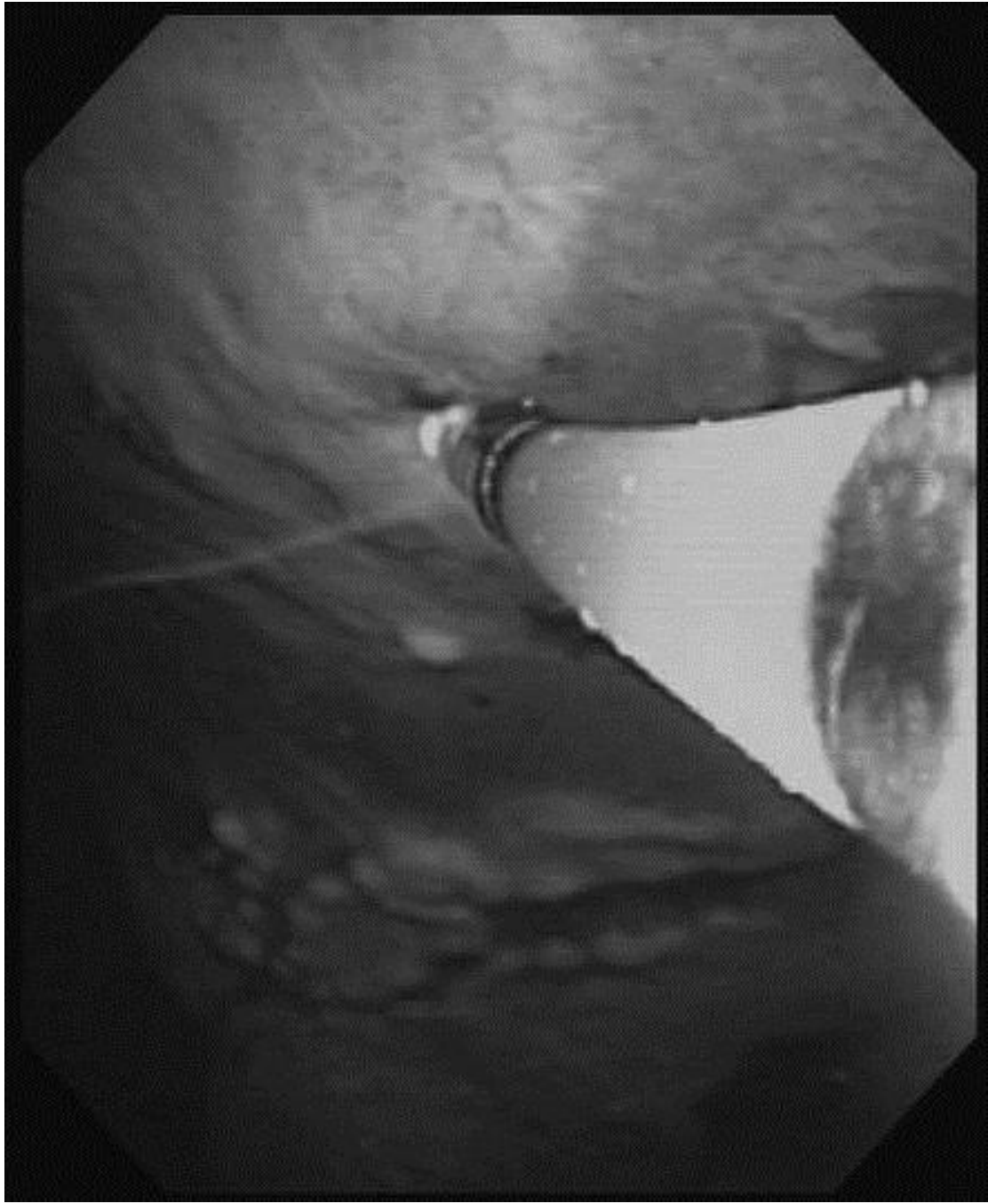


Figure 8:  
 (Left) FDG-avid area demonstrated on PET  
 (Right) CT-guided pleural biopsy of FDG-avid region  
 Source: Original

