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The Era of VATS Lobectomy

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1. Introduction

Primary lung cancer remains the most lethal of all malignancies. The cornerstone of therapy for early-stage non-small cell lung cancer (NSCLC) is surgical resection by lobectomy with complete systematically lymphadenectomy (Hartwig & D'Amico, 2010). One of the initial reports on video-assisted thoracoscopic lobectomy was published 1994 by Robert McKenna (McKenna, 1994). Since then thoracoscopic techniques to perform major anatomic lung resections evolved dramatically and have gained widespread adoption. But in fact, worldwide only 20% of all lobectomies are done using a thoracoscopic approach (Buffa et al., 2008).
Germany Advantages of thoracoscopic lobectomy compared to open thoracotomy include a lower incidence of complications (Paul et al., 2010), shorter hospitalization (Scott et al., 2010), better pulmonary function (Kaseda et al., 2000), less postoperative pain (McKenna et al. 2006), decreased overall costs (Burfeind et al., 2010; Casali & Walker, 2009) and improved delivery of adjuvant chemotherapy to selected patients (Lee at al., 2011; Petersen et al., 2007). These outcomes suggest that thoracoscopic lobectomy should be considered the gold standard for patients with early-stage NSCLC (Hartwig & D'Amico 2010).

2. Definition

To discuss VATS lobectomy and its results, standardization of the terminology is essential. Thoracoscopic lobectomy is defined as the anatomic resection of an entire lobe of the lung, using a videoscope, an access and work incision. Use of a mechanical retractor or rib-spreader is obsolete. Oncologic and anatomic resection as open thoracotomy lobectomy: individual dissection and stapling of vessels and bronchus and complete hilar and mediastinal lymph node dissection (D'Amico, 2008; McKenna et al., 2006).

3. Indications

You can differentiate between general indications and relative contraindications for VATS lobectomy. General indications are important to consider when starting a VATS lobectomy program. As the skill of VATS surgeons improve during the learning curve constantly relative contraindications diminish. As long as the oncological and correct anatomic resection is not compromised any lobectomy can be performed as a VATS procedure.

3.1 General indications

Clinical stage 1 non-small cell lung cancer is the best indication for thoracoscopic lobectomy. Preferred localisation of these tumors is peripherally in the parenchyma so there is no

interference with blood vessels or bronchus during dissection. Furthermore it is easier to perform a wedge resection for frozen section if a histological result couldn't be achieved before the operation.
Tumors less than 6 cm in diameter do not compromise exposure of the lung in the thoracic cavity. Dissection becomes more difficult and dangerous the larger the tumor appears in the parenchyma. Removal of the lobe or specimen and placing into the protective bag before removal is sometimes strenuous for large tumors.
Elderly patients or patients with a compromised performance status benefit the most from a muscle sparing and no-rib spreading incision. Shorter hospitalization, lower complications and earlier mobilization are important advantages VATS lobectomy can offer this group of patients.

3.2 Relative contraindications

Advanced tumors or advanced clinical stages afford a sophisticated and experienced technique of the surgeon and the whole team. Perioperative complications are more likely to occur in tumors that invade the chest wall, pericardium or diaphragm.
Preoperative chemotherapy and especially radiotherapy destroy the tissue planes for dissection. It affords an advanced skill in thoracoscopic dissection.
Centrally located tumors make thoracoscopic preparation challenging as the great vessels might be harmed and bleeding is a major complication.
Abnormal lymph nodes which are often seen in patients with tuberculosis or other inflammatory diseases in their history might invade vessels or bronchus. In those cases dissection by VATS is often impossible.

4. Technique

There are general operative considerations for VATS lobectomy. The patient is positioned in the lateral decubitus position with flexion at the hip to spread the costal interspaces for the VATS ports. Port site placement is different among VATS surgeons but mostly 3-4 incisions

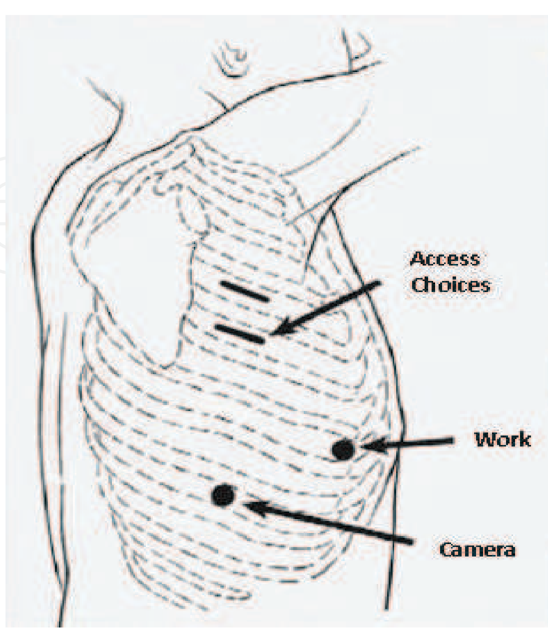

Fig. 1. Incisions for VATS lobectomy

are used. The use of endoscopic tools is essential but often standard instruments can be preferred because of better grasping strength and tactile feedback (Demmy et al., 2005). Use of an angeled scope (30 or 50 degree) for panoramic visualization is needed to provide a range of views and to minimize collision of operative instruments (Hartwig & D'Amico, 2010). Mechanical staplers are used for ligation of vessels, bronchus and parenchyma. To reduce air leaks dissection in the fissure should be avoided. The first step is to start with mobilization of hilar structures and the pulmonary vein. Further dissection follows the landmarks of artery and bronchus. When completing the operation removal of the lobectomy specimen is achieved by using a protective bag to prevent port site recurrences. Complete mediastinal lymph node dissection is either performed before the resection or at conclusion of the lobectomy.

4.1 Right upper lobe

Dissection of the parenchyma is the most difficult issue concerning the right upper lobe (RUL). Even in open thoracotomy it can be difficult to place the mechanical stapler between the parenchyma of middle and upper lobe. After mobilizing the pleura division of superior and middle lobe vein is performed followed by dividing the apical branches (truncus anterior) of the pulmonary artery. The next step is either to divide the upper lobe bronchus or to staple the fissure between upper and middle lobe to gain a better view. After identification and dividing remaining pulmonary artery (PA) branches in the fissure (segment 2) completion of the posterior fissure is done. To prevent torsion suturing or stapling of middle lobe to lower lobe is recommended as well as division of the pulmonary ligament.

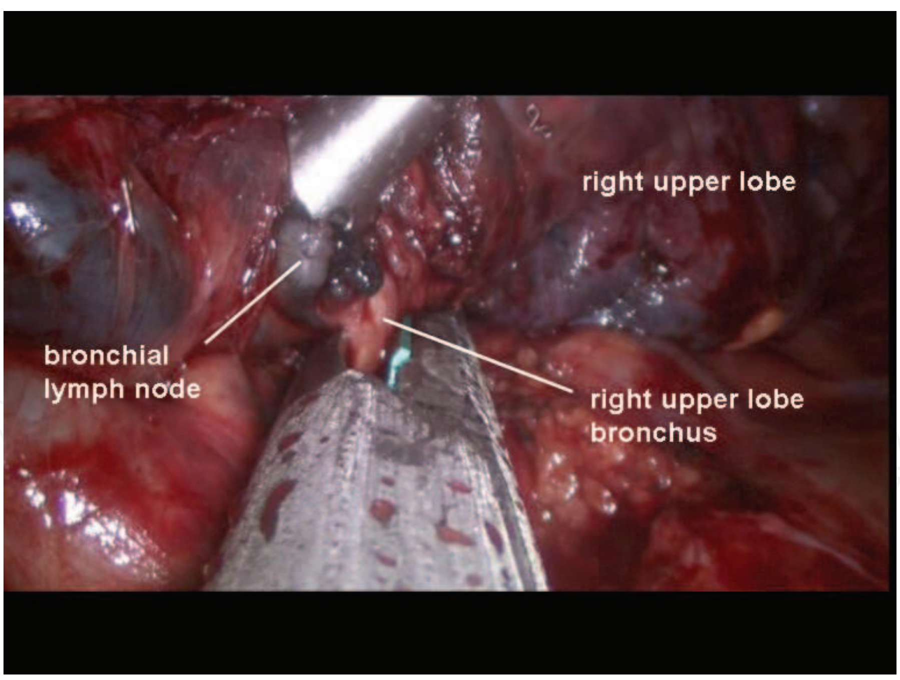

Fig. 2. Division of upper lobe bronchus with mechanical stapler

4.2 Right middle lobe

First step is to mobilize the pleura followed by dividing the middle lobe branch of the superior vein. The next step includes identification of either the middle lobe bronchus or the pulmonary artery branches to the middle lobe. It might be necessary to partially dissect the minor fissure before dividing the arteries or bronchus by stretching the lung to the chest wall. Before dividing the middle lobe arteries creation of a plane along the pulmonary artery should be performed to expose full course of the pulmonary artery. Most cases require dissection of the middle lobe bronchus before the middle lobe arteries. Last step is to complete the fissures and divide the inferior ligament.

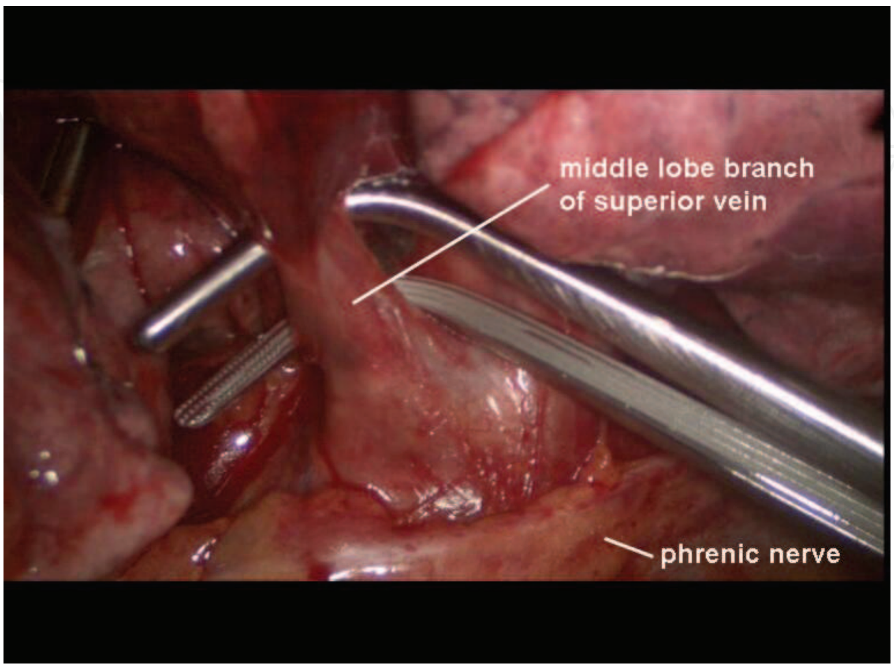

Fig. 3. Division of middle lobe branch of superior vein

4.3 Right and left lower lobe

After mobilizing the pleura division of the inferior ligament is followed by division of the inferior vein. Next step is to identify the pulmonary artery in the major fissure and complete the anterior fissure. Dissection and Division of the pulmonary artery branches to the lower lobe can then be performed. The last step consists of dissecting and dividing the lower lobe bronchus with completion of the posterior fissure. If you cannot identify the pulmonary artery branches in the major fissure you can divide and dissect the bronchus and the pulmonary artery branches from below by stretching the lung to the apex of the thoracic cavity.

4.4 Left upper lobe

Mobilizing the pleura is followed by division of the superior vein. By further mobilizing the pleura along the aorta division of the apical pulmonary artery branches is possible. Next step is to identify the lingular branch of the pulmonary artery in the fissure and staple the anterior fissure. Division of the lingular artery and the remaining pulmonary artery branches to the left upper lobe is required. In many cases division of the left upper lobe bronchus is necessary before dividing the remaining pulmonary artery branches. Last steps are completion of the posterior fissure and dividing the inferior ligament.

All lobectomies are finished by inserting the lobe into a bag and pulling it through the work incision. Air leak check is essential to see if you have to use sealants or suture the air leaks. After confirming reexpansion of the lung a chest tube is inserted and fixed.

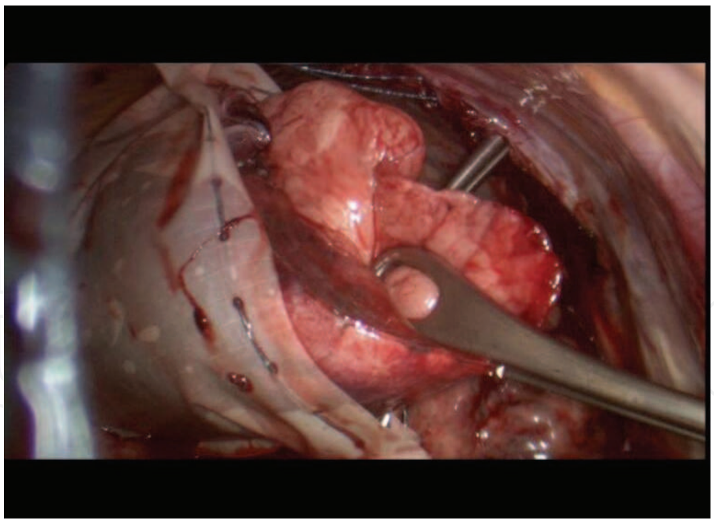

Fig. 4. Insertion of lobe into bag

Fig. 5. Pulling lobe through work incision

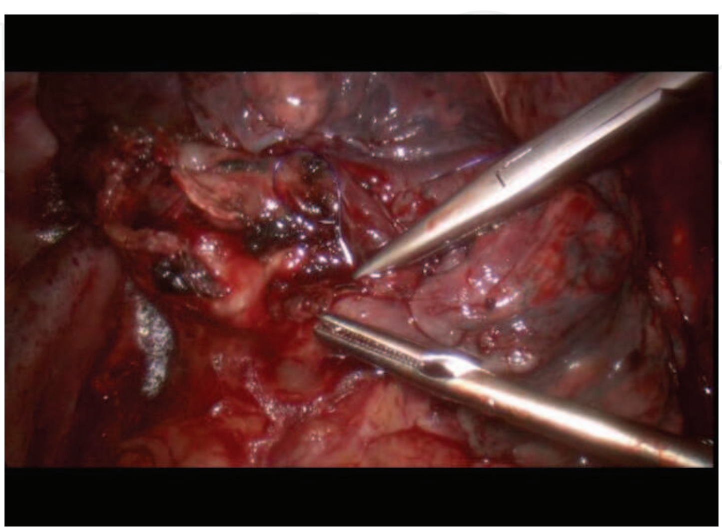

Fig. 6. Suturing parenchyma because of air leak

5. Outcomes

VATS lobectomy has gained international acceptance (D'Amico, 2008; Mahtabifard et al., 2008; McKenna et al., 2007) which contributes to outcomes and good results of thoracoscopic lobectomy when performed in an experienced institution.

5.1 Postoperative length of stay

There are multiple studies that have shown that VATS lobectomy is associated with a short postoperative length of stay (McKenna et al., 2006; McKenna et al., 2007; Paul et al., 2010; Scott et al., 2010). This might be due to the fact that length of chest tube duration is considerably reduced in most of the VATS lobectomy patients (Paul et al., 2010; Scott et al., 2010) Another reason might be that postoperative pain control is easier to manage in VATS lobectomy patients and therefore the hospitalization is shorter and patient recovery faster (Nagahiro et al., 2001).

5.2 Postoperative pulmonary function

Postoperative pulmonary function is better in patients with VATS lobectomy than with thoracotomy (Kaseda et al., 2000). The minimally invasive incision preserves the flexibility of the thorax and therefore ability to breath in the same pattern the patients are used to preoperatively.

5.3 Compliance with adjuvant chemotherapy

One of the most promising advantages associated with VATS lobectomy addresses to the ability of patients to receive and tolerate adjuvant chemotherapy (D'Amico, 2008). Delivery of adjuvant chemotherapy to eligible patients is improved with VATS lobectomy (Lee, J., 2011). Patients undergoing VATS lobectomy had fewer delayed and reduced chemotherapy doses. A higher percentage of patients undergoing thoracoscopic lobectomy received 75% or more of their planned adjuvant regimen without delayed or reduced doses (Petersen et al., 2007).

5.4 Costs

VATS lobectomy is less expensive than conventional lobectomy (Burfeind et al., 2010; Casali et al., 2009). The theatre cost of VATS lobectomy has frequently been cited as a major obstacle to its adoption. Considered only theatre costs this is true but cost analysis through 30 days postoperatively reduced the overall costs of VATS lobectomy. This is due to a significantly shorter stay and therefore by the reduced length of stay related costs (Nakajima et al., 2000).

5.5 Morbidity and mortality

Morbidity and mortality associated with thoracoscopic lobectomy is lower than for conventional thoracotomy and resection (Demmy & Curts, 1999; Onaitis et al., 2006; Paul et al., 2010; Rueth & Andrade, 2010; Scott et al., 2010). Thoracoscopic lobectomy, using a case-matched strategy, showed a reduced specific complication rate in favour for VATS lobectomy (Paul et al., 2010). Patients with thoracoscopic resection had fewer reintubations postopertively. Similar overall cardiovascular morbidity was significantly lower in VATS lobectomy patients, with a significant reduction noted in atrial arrhythmias requiring treatment.

The frequency of blood transfusion was also significantly lower following VATS lobectomy.

5.6 Lymph node dissection

Possible advantages of complete mediastinal lymph node dissection include improvement on local control and survival, so consistently VATS lobectomy is challenged to support the concept that complete mediastinal lymph node dissection can be performed (Flores & Alam, 2008). There are similarities in all studies comparing lymph node dissection by VATS to thoracotomy: the number of lymph nodes resected by VATS tend to be slightly less than in open thoracotomy, but statistically difference cannot be proven (Denlinger et al., 2010; Kondo et al., 1998; Scott et al., 2010; Watanabe et al., 2005). Technically lymph node dissection by VATS is possible (Cassina et al., 1995), concentration and focussing are required. Therefore it might make sense to do the lymph node dissection before performing lobectomy. Another approach is to switch operating and assisting surgeon for lymph node dissection, to guarantee a fresh mind.

5.7 Survival

The true measure of any cancer treatment is survival. A VATS approach does not compromise survival for lung cancer patients. 5-year survival for VATS lobectomy show outcomes that are typically expected for surgical treatment of lung cancer (McKenna et al., 2006; Walker et al., 2003; Yamamoto et al., 2010; Rueth & Andrade, 2010). With no proven difference in stage specific survival VATS lobectomy can be recommended for clinical stage I and II non-small cell lung cancer.

5.8 Complications

There are many series that report VATS lobectomy to be a safe and reasonable procedure. Table 1 shows typical complications after VATS lobectomy. Mortality rates for VATS lobectomy vary from 0% to 2,6% (McKenna et al., 2006; Roviario et al., 2003; Walker et al., 2003).

Major complications		Minor complications	
Readmission	1% - 2%	Atrial fibrillation	3% - 12%
Pneumonia	2%	Air leak	5%
Myocardial infarction	1%	Transfusion	<5%
Empyema	<1%	Serous drainage	<2%
Broncho pleural fistula	<1%	Subcutaneous emphysema	1%
Stroke	<1%	Gastrointestinal	<1%

Table 1. Typical complications after VATS resections

6. Learning and teaching

Among the younger generation of thoracic surgeons there is a strong belief that the routine use of minimal-invasive methods for major pulmonary resection is on its way. To integrate VATS procedures into the curriculum training programs are indispensible. There are many requirements for developing a VATS lobectomy program. The individual surgeon must be experienced with other VATS procedures, such as wedge resections or pleurectomies (Chin & Swanson, 2008). The surgeon must also be familiar with basic video skills like camera work, stapling, dissecting and suturing. The practice should include a minimal number of 50 lobectomies per year (McKenna, 2008).

6.1 Introduction

If the surgeons and the program have the technology and preconditions developing a VATS lobectomy program can proceed (McKenna, 2008). The first surgeons who started VATS lobectomy were pioneers who had to break new ground and develop new technologies.
For practicing thoracic surgeons there are many methods to gain the skill to perform VATS lobectomy. There are many journal articles, lately published atlases and videos in the internet about the technical details of how to perform the operation. Often these steps are not sufficient to learn the technique. Tissue simulators are an alternative (Meyerson et al., 2010) and they might become an integral part of surgical education. There are courses offered by professional societies, industry or practicing surgeons. The observation of the VATS lobectomy procedure is perhaps the most beneficial. The observing surgeon can precisely see the proper placement of the incisions, the use of the instruments and has the ability to ask the operating surgeon questions about the procedure and dissecting steps. Observation should take place over a period of time, not just for one or two days. During subsequent observations you see more troubleshooting aspects of VATS lobectomy and how to handle them in a professional way. In this way the observing surgeon gets a realistic understanding of the operation.

6.2 Learning curve

The learning curve for VATS lobectomy varies considerably as the procedure is still performed at relatively few centers and the learning curve is very shallow (Petersen & Hansen, 2010). To learn VATS lobectomy it might be helpful to switch from a posterolateral thoracotomy to muscle-sparing anterior thoracotomy and, ultimately to VATS lobectomy (Ng et al., 2006). For training reason every operation for operable lung cancer should start thoracoscopically to gain practice step by step (Belgers et al., 2010). In this way all the involved surgeons can learn the correct sequence of the resection. The best way to safely learn VATS lobectomy is to be guided through the operation by a consultant surgeon (Ferguson & Walker, 2006; Petersen & Hansen, 2010). Using this method VATS lobectomy can safely be taught in a surgical institution experienced in VATS lobectomies. The surgical outcome for the training surgeon is comparable to the outcome of the experienced surgeon. The learning curve is reflected in a longer operating time for the training surgeon, which must be taken into account when starting VATS lobectomy programs. In view of the limited number of centres performing VATS lobectomy at high levels, training should be coordinated at a national level to concentrate experience and improve uptake of this technique.

7. Pitfalls of VATS lobectomy – a short troubleshooting guide

7.1 Vessels

If dissection is efficiently done the use of vessel loops enlarges the space behind the pulmonary vessels by pulling on the loop. Before launching the stapler putting the sucker or a right-angled clamp behind the vessel is auxiliary. This maneuver proofs that there is no excess tissue behind the pulmonary vessel. Slightly rotation of the stapler facilitates passage. In difficult cases a common technique is to secure the cut end of a rubber catheter (8F to 14 F) to the anvil of the stapler. This serves to guide the stapler around the pulmonary vessel. For very small vessels (≤5mm) harmonic scalpel or bipolar dissecting instruments can be safely used.

In case of bleeding application of a peanut or ring forceps sponge on the vessel stops bleeding and gives the surgeons a survey where the bleeding exactly comes from. If appropriate use of a clip or 4-0 Prolene is recommended, in more severe bleeding converting to open thoracotomy is unavoidable but safe if the ring forceps sponge is in place.

7.2 Parenchyma

Dissection of the parenchyma is especially difficult on the right side (minor fissure). Marking the fissure with electrocautery is auxiliary to insert the stapler in the right anatomic position. Before dividing any fissure identification of the pulmonary vessels is crucial. For mild adhesions in the fissure application of the harmonic scalpel is recommended, once the anatomic structures are identified application of a stapler is recommended. In case of air leaks in the parenchyma suturing or application of a biological sealant is essential.

7.3 Lymph node dissection

For carinal lymph node dissection dividing the pulmonary ligament is crucial, to create a plane that leads into the carina. For exposure of the carina application of a small lung clamp into the carina and spreading it offers more space in a tiny anatomic compartment. A step which is specially needed on the left side. Dissection of paratracheal lymph nodes starts below the azygos vein. Dividing the azygos vein is possible but not essential. Mobilization of the lymph nodes below the azygos vein facilitates en bloc resection of the paratracheal lymph nodes. By grasping the mobilized lymph node package from above the azygos vein and gradually dissecting along the trachea and superior cava vein completes paratracheal lymph node dissection. For lymph node dissection use of the harmonic scalpel is recommended.

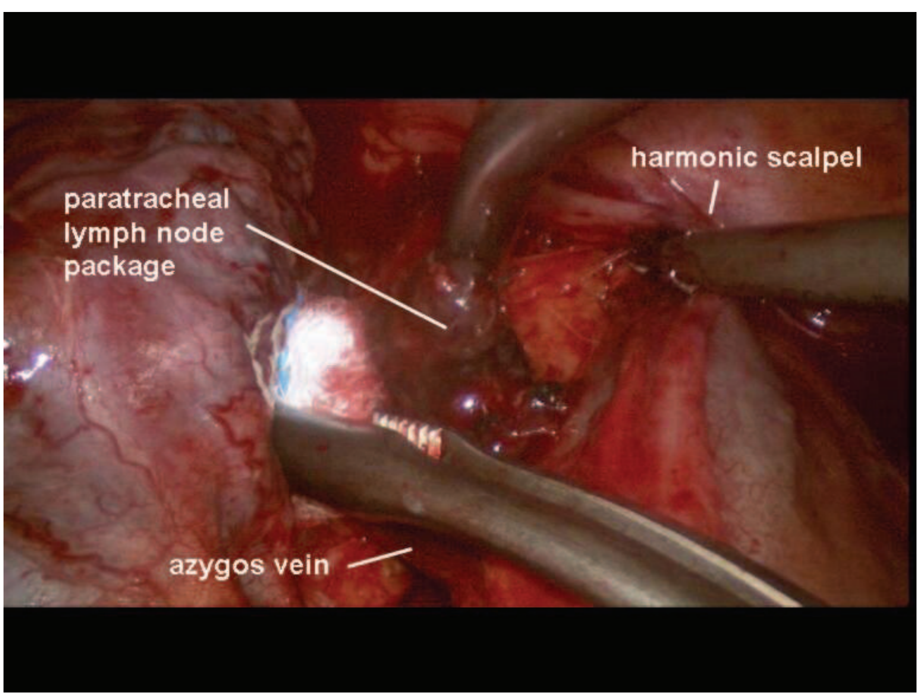

Fig. 7. En bloc nodal dissection paratracheal right

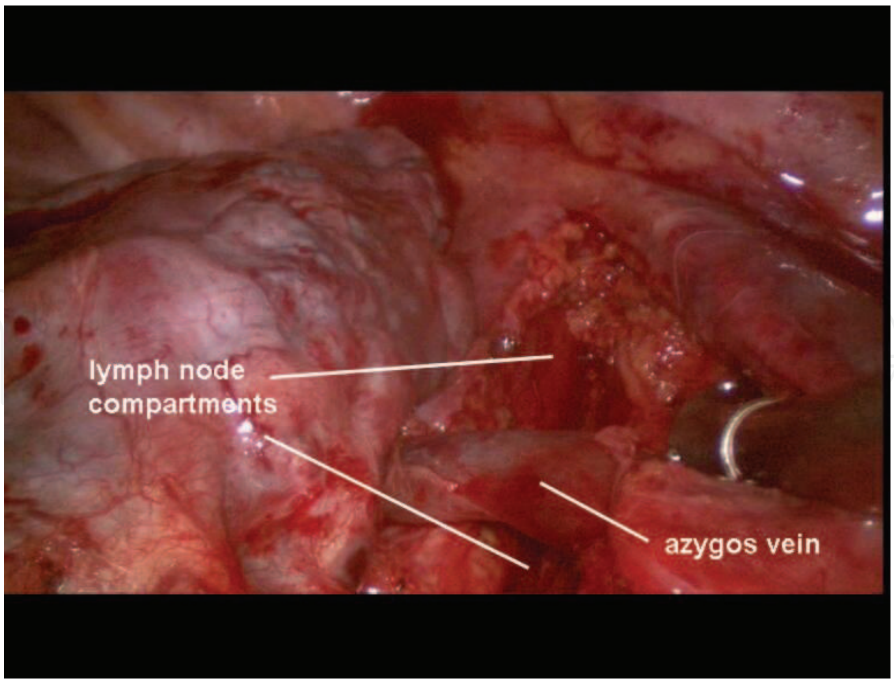

Fig. 8. Right paratracheal region after lymph node dissection

7.4 Extraction sac

Triangulate opening of the extraction sac in a small thoracic cavity is important to get the lobe into the extraction sac. To have no problems with this maneuver fix the sac with four stitches to big lung forceps, insert the forceps with the attached sac, open the forceps and the attached sac opens automatically. This technique avoids triangulate opening of the sac with two extra forceps. Insertion of the small end of the specimen first is auxiliary. Extracting the sac is completed by pulling alternately on one side seam then the other. Rarely a rip osteotomy is required.

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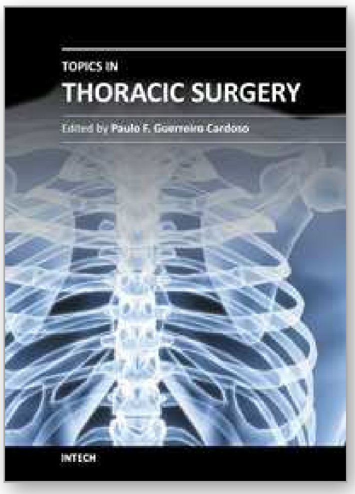

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