Original Article

Minimally invasive bronchoplastic resections

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Background: Minimally invasive lung surgery has recently proven to be superior to anterolateral thoracotomy in terms of postoperative pain and quality of life for early stage lung cancer. With these advantages, it is not surprising that surgeons all around the world try to push the limits of Video-assisted thoracoscopic surgery (VATS). Aim of this study was to explore the feasibility of a minimally invasive approach to bronchoplastic resection and to point out specific technical considerations.

Methods: Between 2009 and 2015, 15 minimally invasive bronchoplastic resections were performed using a standard 3 port VATS technique. During the same time, 463 patients underwent some form of anatomic VATS lung resection (lobectomy, segmentectomy, bilobectomy or pneumonectomy) and 21 open bronchoplastic resections using a standard posterolateral thoracotomy approach. Perioperative results of the minimally invasive group were collected in a prospectively maintained database.

Results: Median age of the patients was 57 years (17–75 years). There were 8 (53.3%) female patients. Reason for resection was primary lung cancer in all patients. Final pathology was adenocarcinoma in 4, squamous cell cancer in 5, carcinoid tumors in 4 and other types of histology in 2 patients (mucoepidermoid tumor and large cell tumor). Type of bronchoplastic procedure was simple closure of the bronchus in two patients, wedge bronchoplasty in 12 patients and circumferential sleeve in one patient. Median operative time was 217 minutes (141–390 minutes). Median chest tube duration and hospital stay was 4 days (2–50 days) and 9 days (6–63 days), respectively. Postoperative complications occurred in 2 patients (13.3%), with one atelectasis prompting bronchoscopy and one chylothorax who needed re-thoracoscopy and ligation of the cystic duct.

Conclusions: Minimally invasive bronchoplastic lung resections are feasible with a low perioperative morbidity and mortality in an experienced center. Surgeons should share their experience to clarify technical considerations like optimal sewing technique.

Keywords: Video-assisted thoracoscopic surgery (VATS); bronchoplasty; minimally invasive

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Introduction

Video-assisted thoracoscopic surgery (VATS) recently was shown in a randomized controlled trial to be superior to open lung resections in terms of postoperative pain and quality of life for early stage lung cancer (1). As the technique evolves, more and more reports emerge on more complex VATS procedures like bronchoplastic resections (2-4). In 2009, we started a VATS lobectomy program. With growing experience we were able to complete extended resections by a minimally invasive approach at our institution. With this study, we aimed to review indications and the key steps of the procedure. Moreover, perioperative data including morbidity and mortality are presented.

Table 1 Demographic data

	n=15
Age, years	55 [17–75]
Gender male/female	7/8
COPD	5 (33.3%)
Coronary artery disease	0
Diabetes	0
Atrial fibrillation	0
Primary lung cancer	15 (100%)
Induction therapy	3 (20%)

COPD, chronic obstructive pulmonary disease.

This study was approved by the local Ethics Committee (UN4424).

Methods

Patient demographics

Between 2009 and 2015, 478 patients were scheduled for a VATS anatomical lung resection. We use a standardized three-incision anterior approach as described by Hansen and Petersen (5). Conversion was performed in 26 patients (5.4%) due to various causes: oncologic reasons occurred in 13 patients, bleeding in nine patients, and technical causes in four. A total of 15 (3.3%) out of 452 VATS cases were bronchoplastic resections (2 bronchial sleeve resections, 11 wedge bronchoplastic, 2 simple bronchoplastic). Median age was 57 (range, 17–75) years; more than half of the patients (8/15) were female. Primary lung cancer was the indication for surgery in all patients. Written informed consent was given by all patients. Demographic data are shown in *Table 1*.

Inidication

Simple bronchoplasties are a helpful tool when a stapler cannot be placed safely due to the proximity of the tumor to the central airway. Free resection margins were confirmed with frozen section and the orifice of the bronchus was closed using interrupted monofilament stitches (3/0–4/0). A wedge bronchoplasty was performed when during bronchoscopy a simple open transection of the bronchus did not seem suitable or frozen section did show positive margins.

Lymph node infiltration of the bronchus detected during surgery was the reason for the right upper lobe sleeve resection and was necessary to achieve tumor free margins.

Surgical technique

Simple bronchoplasty

The lobar bronchus is transected close to the origin from the central airway. The orifice is closed with single interrupted stitches starting at the ends, then placing one centrally in the orifice and extra stitches as needed.

Wedge bronchoplasty

Once, the vein and arterial branches were transected, the bronchial structure was resected in a wedge shape using a scalpel or scissors leaving the posterior bronchial aspect intact. Frozen section was used to check the resection margin. Release maneuvers like dissecting the inferior pulmonary ligament were performed prior to placing the stitches to reduce traction on the anastomosis. Monofilament absorbable sutures (3/0) were used. In most of the cases, an open needle holder was used, as it was easily passed through the minithoracotomy measuring 4 cm. Suturing was started in the corners of the orifice to prevent maladaptation. The next stitch was placed at the middle of the lumen and additional stitches were placed to complete the suture line. In order to avoid tangling of the threads, tourniquets were used for separation (*Figure 1*). Knot tying was completed using a finger, a round swab or a knot pusher as needed. The suture line was checked for air leaks using a water seal test.

Circumferential bronchoplasty

For the right upper circumferential sleeve resection, the main and intermediate bronchus were transected using a scalpel and scissors. Resection margins were checked with frozen section and the pulmonary ligament was dissected to lower traction on the anastomosis. The anastomosis was completed using interrupted sutures (monofilament absorbable 3/0): the first stitch was placed at the distant edge of the bronchus and the knot was tied immediately. Further stitches were placed in both directions, the cartilaginous part and the membranous part of the bronchus and tied immediately. Once half of the anastomosis was completed, all remaining stitches were placed and tourniquets were used to control the threads. These sutures were tied at the end of the anastomosis. A water seal test was performed to check for air leaks. The anastomosis was covered using the

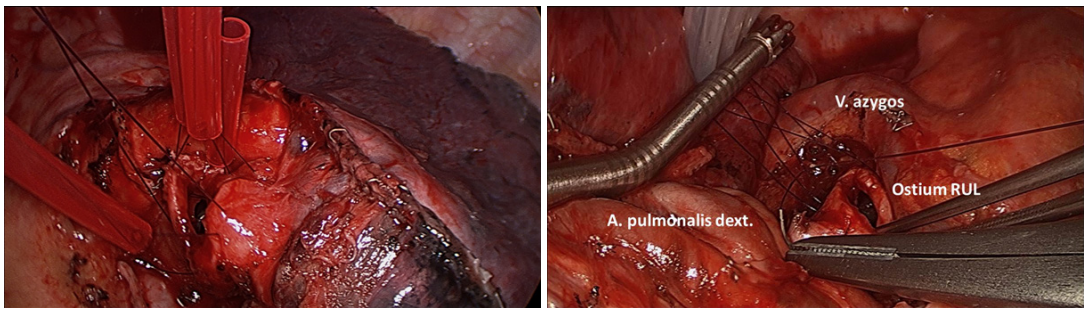

Figure 1 Use of tourniquets to avoid tangling of threads.

Table 2 Histology and UICC stages of the resected tumors

	Bronchoplasty, n=15
Histology	
Adeno-carcinoma	4
Squamous cell carcinoma	5
Low two middle grade neuroendocrine carcinoma	4
Large cell carcinoma	1
Mucoepidermoid carcinoma	1
UICC stage	
UICC IA	3
UICC IB	1
UICC IIA	2
UICC IIB	5
UICC IIIA	1
UICC yIA	2
UICC yIIA	1
UICC yIIIA	0

UICC, union internationale contre le cancer.

azygos vein (right upper sleeve lobectomy).

Results

Median operative time was 217 minutes (range, 117–390 minutes). All patients were extubated in the operative room. Median chest tube duration was 4 days (range, 2–50 days). Median length of hospital stay was 9 days (range, 6–63 days). There was no in-hospital mortality. Major complications with need for reinterventions occurred in one patient (6.7%) with a chylothorax. The patient had high output over the chest drain and chylomicrons were verified. He refused to undergo re-thoracoscopy after unsuccessful conservative management (oral diet and also npo). Finally, we performed re-thoracoscopy and clipped the thoracic duct. Drainage of chylous fluid stopped and the patient was discharged (pod 63). Minor complication was atelectasis (one patient) with need for bronchoscopy after an upper lobe wedge bronchoplasty to resolve mucus plugging. During the study period, six patients scheduled for a minimally invasive approach had to be converted to open pneumonectomy because of oncologic reasons.

Three patients did undergo induction treatment (chemotherapy only, no radiotherapy) prior to VATS bronchoplastic resection. Final pathology was adenocarcinoma in 4, squamous cell cancer in 5, carcinoid tumors in 4 and other types of histology in 2 patients (mucoepidermoid tumor and large cell tumor). *Table 2* summarizes pathologic results and tumor stages. After a median follow up of 26 months, none of the patients had local tumor recurrence. One patient was diagnosed a second lung primary and 3 patients with advanced tumor stages had distant recurrent disease (brain, bone, liver and diffuse pulmonary metastases).

Discussion

Minimally invasive surgeons have proven on several occasions that a VATS approach for early stage lung cancer is superior to open surgery in many different aspects. Recently, a long awaited prospective randomized trial to show a significant benefit in reducing pain and increasing quality of life was published (1).

Various techniques have been reported with different numbers of incisions; also robotic assisted surgery was established as a valid platform for anatomic lung resections.

Table 3 Overview of Minimally invasive bronchoplastic lung resections in the literature

Authors	n	Type of bronchoplasty	OR time, minutes	LOS	Follow-up months	Locoregional recurrence
Chen, 2016 (8)	32	SL	271 (±67.5)	9,7 (±4.1)	21 (±11.7)	0
Agasthian, 2013 (4)	21	SI, W, SL	287 [135–580]	5.2 [3–8]	26.2 [6–32]	0
Li, 2013 (9)	15	SL	165 [120–180]	7 [5–10]	1-16	0
Mahtabifard, 2008 (3)	13	SL	167 [90–300]	3 [2–8]	n/a	N/A
Shao, 2016 (10)	6	SL	182 [110–260]	9,2 [7–12]	19.2 [7–34]	N/A
Dylewski, 2011 (11)	3	Robotic-SL	N/A	N/A	N/A	N/A
Schmid, 2011 (12)	1	Robotic-SL	360	15	54	0
Own data	15	SI, W, SL	217 [141–390]	10 [6–63]	26 [5–71]	0

LOS, length of stay; N/A, not applicable; i.e., not stated in the manuscript; OR, Operative Room; SI, simple bronchoplasty; SL, circumferential sleeve bronchoplasty; W, wedge bronchoplasty.

Figure 2 CT scan after right upper wedge bronchoplasty with no stenosis 12 months after surgery.

All of the techniques seem to be reasonable with only little if any difference in postoperative outcome (6,7). With more technical expertise and confidence, the minimally invasive approach is applied to more complex procedures like segmentectomy, pneumonectomy and even bronchoplastic.

In *Table 3*, various reports on VATS sleeve resections are shown. Concurrent to the definition of VATS lobectomies as totally endoscopic procedures using a number of non-rib-spreading port incisions for safe individual ligation and division of the hilar structures of the lobe with some type of lymphadenectomy (8), several other reports of larger series were excluded in this table.

Different invasion of the tumor towards the central airway require different surgical approaches. We do agree that a simple bronchoplasty is not a real bronchoplastic resection including resection of a central part of the airway. However, bronchial closure with interrupted stitches is technically more challenging than using a stapling device. Moreover, from a training-point of view, it is the first approach to minimally invasive suturing and bronchial anastomosis.

Wedge bronchoplastic have also raised some concern within the literature. A wedge bronchoplasty is technically easier to perform than a circumferential bronchoplasty as it avoids rotation of the remaining lobe. Furthermore, it preserves the blood supply for the airway resulting in better healing and—at least theoretically—in less anastomotic leakage. Recent studies did show oncologic equivalency to sleeve bronchoplastic for small tumors with limited invasion of the bronchus (13).

A wedge bronchoplasty usually results in higher tension on the anastomosis than a circumferential sleeve bronchoplasty. It has been suggested, that the largest distance between the upper and lower edge of the bronchus should not be longer than the transverse diameter of the bronchus (13). If this cannot be achieved, a circumferential sleeve should be performed to prevent stenosis of the airway. None of our patients with wedge bronchoplasty did report symptoms suggestive for anastomotic stenosis like coughing, wheezing or recurrent infections. *Figure 2* shows a CT scan at the level of the anastomosis, again confirming a wide and non-stenotic airway.

In all our cases, we did use interrupted sutures instead

of a running suture. Main reason for this decision was the fact, that tension on the suture is less well controlled in a minimally invasive setting, increasing the risk of anastomotic leakage. However, direct vision via the monitor ensures adequate knot tying and a patent anastomosis. We agree that a running suture might shorten operative time and causes less confusion compared to a high number of loose threads for interrupted sutures. In our setting, the use of tourniquets eased the handling of sutures within the thoracic cavity.

We once again want to stress the fact, that intraoperative frozen section is mandatory for all types of bronchoplastic procedures, as local recurrence can only be treated with pneumonectomy.

Even though arterial sleeve resections are reported in the recent literature, we consider a major tumor invasion of the main pulmonary vessels a contra-indication for a minimally invasive procedure in our department. Performing a proper vascular anastomosis is challenging in open surgery; it needs further refinement of minimally invasive instruments and techniques. For future innovation in minimally invasive thoracic surgery, this might be one of the real advantages of robotic assisted surgery (12,14,15).

Extended VATS procedures need a certain level of training and experience. We performed our first minimally invasive sleeve lobectomy in 2009, completing the anastomosis with the use of a da Vinci robot (12). We did perform the next bronchoplasty after another three years and the experience of almost 200 anatomic VATS resections, indicating the need of minimally invasive skills and confidence to incorporate these extended resections into daily surgical routine. In fairness, we must state, that surgeons in our institution are all well trained in minimally invasive general surgery.

Within the last year, more literature on minimally invasive bronchoplasty was published. Fortunately, a few of these were backed by video material (8). This new way of sharing knowledge will help surgeons all over the world to implement a minimally invasive approach to bronchoplastic procedures.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the local Ethics Committee (UN4424). Written informed consent was given by all patients.

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