Initial experience with video-assisted thoracoscopic bronchoplasty†

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Abstract

OBJECTIVES: Bronchial-origin involvement by endobronchial tumours or direct invasion by tumour or metastatic lymph nodes is a relative contraindication for video-assisted thoracoscopic (VATS) lobectomy. However, selected cases can be resected by VATS bronchoplasty.

METHODS: Between 2006 and 2009, 21 of 231 (9.1%) VATS lobectomy cases underwent VATS bronchoplasty. Cases with endobronchial involvement and limited non-bulky invasion of bronchus by tumour or metastatic nodes without major vascular invasion were selected for bronchoplasty by preoperative bronchoscopy and CT scan thorax. Patients underwent a simple/wedge bronchoplasty (bronchus divided at origin and closed flush or transversely), sleeve bronchoplasty or others (bronchoplasty combined with other extended resections). All bronchoplasties were done totally endoscopically by directly watching a TV monitor. Bronchial margins were all subjected to intraoperative pathological analysis. Anastomosis was done with interrupted sutures. Integrity of anastomosis was checked by intraoperative bronchoscopy. The follow-up was done by 6-monthly CT scans and bronchoscopy.

RESULTS: Eleven patients were females. Mean age was 64.9 years (range, 47–83 years). Indications were endobronchial tumours in 3, direct invasion in 6 and metastatic nodes in 12. In 4 cases, invasion was detected at the time of surgery. Mean hospital stay was 5.2 days (range, 3–8 days). Mean duration of surgery was 287 min (range, 135–540 min). Nine had simple/wedge bronchoplasty, 8, sleeve bronchoplasty and 4, extended bronchoplasties. Histology was non-small-cell carcinoma (NSCLC) in 19, carcinoid in 1 and colonic metastasis in 1. In the NSCLC, 5 patients were in stage IB, 5 in stage IIA, 2 in stage IIB and 7 in IIIA. All bronchial margins were negative for malignancy. The mean follow-up was 26.2 months (range, 6–32 months). There was no operative mortality, but 1 patient developed bronchopleural fistula. To date, there have been no local tumour recurrences.

CONCLUSIONS: Selected endobronchial and non bulky tumours with limited invasion at bronchial origin can be resected by VATS bronchoplasty.

Keywords: Thoracoscopy/VATS • Bronchoplasty

INTRODUCTION

Lobar bronchial involvement by endobronchial tumours or direct invasion by tumour or metastatic nodes has been a relative contraindication for video-assisted thoracoscopic (VATS) lobectomy [1]. This was due to the inability to staple the bronchus in a standard fashion and also oncological concerns regarding complete surgical resection. With increasing experience in VATS lobectomy and proficiency in endoscopic suturing and tying techniques, selected cases can be resected by VATS bronchoplasty. A retrospective review of these cases was done.

METHODS

Between December 2006 and 2009, 21 of 231 (9.1%) VATS lobectomy cases underwent Vats bronchoplasty. Endobronchial tumours and non-bulky tumours with limited invasion of the proximal lobar airway without major pulmonary artery invasion were carefully selected for VATS bronchoplasty by careful preoperative CT scan thorax and bronchoscopy. All had baseline pulmonary function tests and staging PET CT scans to rule out metastatic disease. 3 of 20 preoperative patients deemed suitable for bronchoplasty had to be converted to thoracotomy due to intraoperative detection of major pulmonary artery invasion needing double sleeve lobectomies. Routine mediastinoscopy was not done if PET CT scan showed no metabolically avid mediastinal lymphadenopathy.

Bronchoplasties were classified into simple or wedge bronchoplasty (where the bronchus is divided at its origin and closed flush or transversely to prevent narrowing) and sleeve bronchoplasty. In 4 cases, in addition to a bronchoplasty, other additional resections were needed to obtain R0 complete resection.

SURGICAL TECHNIQUE

The patient is placed in a lateral decubitus position with the hips flexed. The Vats lobectomy technique used is a totally...
endoscopic non-rib-spreading procedure performed by directly watching a TV monitor. The left-sided double lumen tube is routinely used for all Vats lobectomy due to ease of placement. However, early in the experience it was noted that when performing left-sided sleeve resections, a left-sided double lumen tube tends to splint and immobilizes the left main stem bronchus, making approximating and sewing of the two bronchial ends without tension difficult. Subsequent to this observation, a right-sided double lumen tube is routinely placed whenever possible for all anticipated left-sided sleeve resections.

The following ports are placed, a 5-mm 30° camera placed over the major fissure at 5th intercostal space, a 10-mm working port A at the 6th/7th intercostal space posterior auxiliary line, a 10-mm assistant’s retraction port C placed at the 6th/7th intercostal space posterior and inferior to the scapula tip and a 2-cm non-rib-spreading utility incision (port B) at the 3rd intercostal space mid axillary line (Fig. 1). The lobectomy is done through an anterior approach where the surgeon and camera assistant stand in front of the patient, with the second assistant and scrub nurse on the opposite side (Fig. 2). The port placements and the position of the team remain the same for all lobes of both lungs and the camera stays in the same position throughout the procedure. All lobar vessels are individually dissected and divided. The endostaplers for the vessels, bronchus and fissures are introduced through the lower-most 10-mm working port (Fig. 3). All patients undergo complete radical mediastinal lymphadenectomy in the semi-prone position, which gives excellent exposure to the mediastinum, particularly the subcarinal and paratracheal regions, with the lung falling away under gravity from the surgical field of dissection. This is particularly important on the left side, where lymph node dissection under the aortic arch can be difficult [2].

In simple bronchoplasties, the bronchus is closed flushed to the bronchial origin with interrupted sutures (Fig. 4). However, when doing a right lower lobe simple bronchoplasty, it is prudent to close the bronchus transversely to prevent narrowing of the middle lobe bronchus.

In wedge bronchoplasty due to small limited invasion by tumour or lymph nodes into the main stem bronchus, in addition to the lobar bronchial origin, a cuff of the main bronchus is removed en bloc. This is then closed again transversely to prevent narrowing of the airway (Fig. 5, Supplementary Video 1).

When possible, the anastomosis is done last to minimize any disruption from subsequent manipulation, except in right upper lobe sleeve lobectomies. Here, the paratracheal lymphadenectomy is done last after the anastomosis, to prevent the proximal bronchi from retracting under the azygos vein into the paratracheal space, which makes subsequent sewing difficult, necessitating division of the azygos vein. All bronchial margins and suspicious metastatic lymph nodes were subjected to intraoperative frozen section analysis to ensure clear tumour margins before performing the anastomosis. Sewing is routinely done with a 5 mm endoscopic needle holder. The anastomosis is done tension-free with mucosa-to-mucosa approximation by using interrupted or continuous absorbable monofilament sutures (polydioxanone PDS 40 or 50) with all knots placed on the outside. Monofilament suture allows for smooth passage of sutures through the bronchus and facilitates the sliding and tying of knots. Knots are tied either intra- or extracorporeally, usually through the utility incision.

In sleeve lobectomies, release procedures like division of the inferior ligament are routinely done to relieve tension prior to anastomosis. Exposure and sewing are enhanced by taping and retracting the main pulmonary artery routinely. A stay suture between the proximal and distal anastomosis, held by the assistant helps to approximate the two ends and relieve tension when approximating the ends. The bottom cartilaginous part of the proximal and distal anastomosis is done first, followed by the anterior front cartilaginous wall and finally the top aspect of the anastomosis (Fig. 6, Supplementary Video 2). The membranous part is always done last to avoid tension and subsequent tearing of the thin wall of the anastomosis as well as to obtain proper congruity and size matching between the distal and proximal bronchial anastomosis (Supplementary Video 2).

The integrity of the anastomosis was checked intraoperatively by bronchoscopy and insufflating air under water at 30 cm of pressure. Any narrowing or defects noted on intraoperative bronchoscopy should be revised or corrected immediately. In right-sided sleeve lobectomies, the upper lobes in particular are the easiest to perform due to the alignment of the intermediate bronchus and main right bronchus. On the left side, the overriding long course of the left main pulmonary artery and aortic arch makes sewing more difficult.

In one middle lobe cancer, the middle lobe pulmonary artery branch together with the bronchus was, involved by tumour at the origin. A small-side biting vascular clamp was placed...
through the utility incision for proximal control of the main pulmonary artery before the arterial branch was divided and closed with a Prolene 50 suture tied intracorporeally. As the clamp was in the way of the needle holder, it was introduced through one lower intercostal space through the same utility incision. Another middle lobe tumour due to invasion of the intermediate bronchus and main pulmonary artery in the inter-lobar fissure was subject to bilobectomy (middle and lower lobe) and division and closure of the intermediate bronchus at the upper lobe takeoff. One left lower lobe tumour due to invasion of pericardium and inferior pulmonary vein and a simple bronchoplasty with excision of pericardium and intrapericardial division of inferior pulmonary vein. One patient who had left upper lobe tumour with chest wall and pericardial invasion with bronchial origin invasion had ligation of the pulmonary arterial branches first, followed by division of the bronchus flush at its origin. The lobectomy was completed after the superior pulmonary vein was ligated intrapericardially with a cuff of pericardium. Once the lobe was completely mobilized, the utility incision was extended over the area of rib invasion and three segments of rib were resected en bloc with the upper lobe. After the specimen was removed through this defect, the bronchus was closed with
interrupted sutures and the pericardial defect was closed with equine pericardial. A Prolene mesh was used to close the chest wall defect (Fig. 7).

None of the anastomosis was buttressed with flap or any vascularized tissue. All patients were followed up by 6-monthly serial CT scan thorax and bronchoscopy for local and systemic recurrences.
RESULTS

Eleven patients were females, and 10 were males. Mean age was 64.9 years (range 47–83 years). Indications for bronchoplasty were endobronchial tumours in 3, direct invasion of lobar bronchus by tumour in 6, and metastatic lymph nodes in 12. Seventeen were elective bronchoplasties and 4 were incidental cases where bronchial invasion was detected only at the time of VATS lobectomy. Mean hospital stay was 5.2 days (range, 3–8 days). Mean duration of surgery was 287 min (range, 135–540 min). Nine had simple or wedge bronchoplasty, 8 sleeve bronchoplasties and 4 complex or extended bronchoplasties. The breakdown of the type of bronchoplasties to the various lobes is given in Table 1. Right upper lobe sleeve lobectomies were the commonest, being the easiest to perform. Nineteen were for non-small-cell lung carcinoma (NSCLC) 1 for carcinoid and 1 for colonic metastasis. In the NSCLC, 5 were in stage Ib, 5 in Ila, 2 in IIb and 7 in IIIa. The mean follow-up was 26.2 months (range, 6–32 months). There was no mortality. To date, 1 patient developed bronchopleural fistula 8 weeks after surgery. He developed a small 5 mm fistula at the superior edge of the left upper lobe stump. This patient had simple bronchoplasty with pericardial and chest wall resection. The previous Prolene mesh over the chest wall defect was removed and a latissimus dorsi myocutaneous flap was used to close the fistula and the chest wall through the defect. To date, no anastomotic strictures or local tumour recurrence were noted. One patient had brain relapse at 18 months. All patients in pathological stages 2 and above were routinely referred for adjuvant chemotherapy.

DISCUSSION

VATS resections for lung cancer can be divided into standard resections, limited or sub-lobar resections and extended resections. A VATS standard resection consists of VATS lobectomy with lymphadenectomy. It has become the standard of care in most centres with long-term survivals similar to conventional thoracotomy. It is confined to early-stage peripheral lung cancers where the lobar vascular and bronchial structures with the fissures can be divided using endostaplers. There have been many described variations in the technique of standard VATS lobectomy (anterior vs posterior, fissureless vs fissure based, uniport vs multiport, totally VATS vs robotic assisted). However, the general consensus on the definition of VATS lobectomy is that it should be a totally endoscopic procedure done by watching a TV monitor using a number of non-rib-spreading port incisions for safe individual ligation and division of the anatomical hilar structures of the lobe and associated with some type of lymphadenectomy (lymph node sampling or lobe based lymphadenectomy or radical lymphadenectomy) [1, 3–5].

Limited or VATS sublobar resections are confined to small, early preinvasive cancers [6]. With increasing experience with standard VATS lobectomy techniques, indications have been extended to more complex and locally advanced cancers. These include VATS lobectomy with chest wall, diaphragm or pericardial resections and bronchoplasty for central tumours. Bronchoplasty has been a relative contraindication because of oncological concerns in obtaining a complete resection and technical difficulties, as it requires the surgeon to be proficient in endoscopic sewing and tying. To overcome the technical difficulties of sewing in a limited, confined space through a narrow intercostal area, various modifications of VATS bronchoplasties were attempted. This included hybrid procedures where instead of sleeve bronchoplasty, a modified VATS wedge bronchoplasty was done through a mini-thoracotomy [7, 8]. Other hybrid procedures include lobectomy done by VATS and then using the da Vinci robot when sewing the anastomosis [9, 10]. However, Mckenna was the first to describe a series of totally endoscopic VATS sleeve lobectomies [11].

Prior to 2006, in my practice, VATS lobectomy was confined to peripheral tumours with conversion to thoracotomy if bronchoplasty was needed at the time of surgery. Since 2006, however, with increase in experience in standard VATS lobectomy techniques and proficiency in sewing and tying, this was extended to VATS lobectomy needing bronchoplasty. During this period, only 2% of VATS lobectomies had VATS extended resections for chest wall, diaphragm and pericardial resections.

Due to oncological concerns of complete resection and risk of tumour breakage and seedling, only small tumours with limited invasion of the main bronchus without major invasion of the pulmonary artery were selected for VATS bronchoplasty by careful preoperative screening using CT scan thorax, PET CT and bronchoscopy. Inspite of the careful screening, 3 cases needed conversion to thoracotomy due to major invasion of the pulmonary artery at the time of VATS. 4 cases undergoing standard VATS lobectomy needed incidental bronchoplasty at the time of VATS due to lymph node invasion of the bronchus detected only at the time of standard VATS lobectomy.

All lung cancer patients undergo PET staging and it remains the main-stay of staging modality in our practice. Prior to the introduction of EBUS bronchoscopy, routine preoperative mediastinal lymph node staging was not practiced. Selective preoperative mediastinoscopy was only done when there was PET avid lymphadenopathy. Fourteen of the 21 patients in pathological stages 2 and 3 had mild or non-avid lymphadenopathy on preoperative PET and thus were not subjected to mediastinoscopy. To overcome this under staging failures, since 2010, preoperative EBUS bronchoscopy has been done routinely for mediastinal lymph node staging for all lung cancers. If positive for metastatic cancer, patients undergo neoadjuvant chemotherapy before surgery.

Simple bronchoplasty is the easiest to perform, followed by wedge and then sleeve. Recent studies have shown that wedge bronchoplasties are a good oncological equivalent to sleeve...
bronchoplasties, particularly for small tumours with limited invasion of the bronchus [12, 13]. Besides enabling better preservation of airway vascular supply, they are also easier to perform by VATS without the need to convert to thoracotomy and allow surgeons embarking on VATS bronchoplasty to perfect their sewing and tying before doing full-sleeve lobectomies.

Right-sided sleeve bronchoplasties are easier to perform by VATS than left-sided as sewing under the arch and the overriding main pulmonary artery is more difficult. Whenever possible, it is best to place a right-sided double lumen tube when performing a left-sided sleeve to allow for a tension-free anastomosis to be performed. Routine taping and retracting of the main pulmonary artery through the utility incision increases exposure when sewing.

The principles of sleeve bronchoplasties are the same as for open thoracotomy [14]. The anastomosis should, when possible, be done last to prevent injury or disruption to the anastomosis. The anastomosis should be performed tension-free with mucosa-to-mucosa approximation without telescoping, using monofilament absorbable sutures. The monofilament sutures allow for smooth placement and sliding of knots. Routine release of the inferior ligament and placement of stay suture between the proximal and distal anastomosis help relief of tension when sewing and tying. Sewing should always start on the inferior part of the cartilaginous part of the anastomosis, then move up the anterior wall and finally, the superior wall. Size matching of incongruous proximal and distal ends is achieved by performing the membranous part of the anastomosis last as it allows for size matching and prevents tearing of the thin-wall part of the bronchus. This part of the anastomosis is best done by rotating the patient anteriorly towards the surgeon in a 45–60° semi-prone position where the falling away of the lung under gravity allows for an easy anastomosis. In endobronchial tumours like carcinoma and lung cancers with limited invasion of the bronchial origin, leaving a few millimetre sliver of normal bronchial wall inferiorly between the proximal and distal anastomosis helps facilitate sewing by preventing rotation and malalignment of the airways.

Traditionally, in my practice, sleeve bronchial anastomoses were done by continuous suture without tissue buttressing unless the stump had been radiated or infected [15, 16]. In VATS bronchoplasty interrupted sutures were preferred as it allowed for better size matching and prevented loosening and entanglement of the sutures. However, with increasing experience in this technique, continuous suturing will become the eventual norm.

All bronchial margins should be confirmed to be negative on frozen section on pathological analysis before approximating the anastomosis. All anastomoses should be checked by intraoperative bronchoscopy. Unsatisfactory anastomoses should be revised immediately either by VATS or open thoracotomy without resorting to VATS pneumonectomy. VATS pneumonectomy is also not done if it is not possible to obtain clean margins at the time of VATS bronchoplasty. Instead, the patient is converted to open thoracotomy and the anastomosis is completed by further mobilization and release of the proximal and distal airways. Using this strategy, no patient required a pneumonectomy.

Though this is a small retrospective series due to the number of patients who were suitable for this procedure, the mortality, morbidity, anastomotic complications and local recurrence rates have been comparable to open techniques [16]. The 1 patient with a small pin hole bronchial fistula had a complex extended resection of an intrapericardial ligation of the superior pulmonary vein, with resection of pericardium and chest wall, which may have contributed to the fistula. Therefore, complex or extended bronchoplasty may benefit from routine prophylactic anastomotic buttressing with vascularized tissue.

**CONCLUSION**

Carefully selected endobronchial and non-bulky locally invasive tumours of lobar bronchial origin can be safely resected by VATS bronchoplasty techniques. With continued increased experience in minimally invasive techniques, particularly in robotic technology, VATS bronchoplasty would be further refined and simplified to be extended to most VATS lobectomies needing bronchoplasty.

**SUPPLEMENTARY MATERIAL**

Supplementary material (Videos 1 and 2) is available at EJCTS online.

Video 1: Wedge VATS bronchoplasty.

Video 2: Right VATS upper lobe sleeve bronchoplasty with pre- and intraoperative bronchoscopy.

**Conflict of interest:** none declared.
Dr A. Turna (İstanbul, Turkey): Do you think that it is necessary to perform bronchoscopy before the operation routinely? And the second question is, do you perform pneumonectomy if it is needed, too?

Dr Agathian: All patients had preoperative bronchoscopy, because you need to assess suitability for VATS bronchoplastic. Because if it's going to be very far apart, the anastomosis is going to be very tricky, especially on the left side, because the pulmonary artery and aortic arch come in the way when anastomosing. Also, if you put a double lumen tube on the left side, the tube immobilizes and splints the left main stem and makes approximation without tension difficult. One of the things we have learned from the two cases we did was to place a right side double lumen tube when doing left-sided sleeve lobectomies.

The other thing is, of course, if your margins are going to be positive, then you have to do a pneumonectomy. But I think it is one of the things that we have been sort of cheating on, which is that we choose very simple cases, non-bulky, small tumours, very small limited disease of the upper lobe especially. I think those are the good cases to start with, because the important thing is if you do bulky tumours, you are going to end up breaking the capsule and you're going to seed the tumour and oncologically compromise the surgery.

Dr D. Walker (Leicester, UK): Can you just tell me when you convert, would you go ahead and do a VATS pneumonectomy or would you open and try and do a more proximal sleeve?

Dr Agathian: I usually do a more proximal sleeve. That's the first thing. In fact, in three cases we did open because we could not detect on CT a major vascular invasion.

The challenge for me when doing cases with vascular invasion, is where to put your vascular clamps. So that will be the next challenge in VATS, because I think bronchoplasty will become routine eventually, especially with robotics, because robotics will be ideal for such a case. But how do you place the vascular clamps to do the sewing for vessels? That will be the next challenge or the solution to VATS angioplasty. The vascular surgeons in India are doing it.

Dr R. Santosham (Chennai, India): How many cases of open bronchoplasties had you done before you started VATS bronchoplasties?

Dr Agathian: Sleeves we have been doing a long time, and we reported about 120 cases of open sleeve. But the thing which I changed is when I do an open sleeve, I do a continuous suture. I just use a continuous absorbable monofilament suture like PDS and do it as for a bowel anastomosis. But unfortunately I find it difficult to do it for VATS bronchoplasty, because we tried continuous and it gets in your way because the space is limited.

The main problem when you do open arterial sleeve for VATS is that the PA comes in the way. I have a case where the right main pulmonary artery was injured during sleeve sewing here, and I had to spend the next 15 min trying to fix the hole in the PA. So interrupted sutures are easier, but it's a bit more tedious. But I think if you use a robot, maybe you will be able to do a continuous suturing much more easily.

Dr S. Bolukbas (Wiesbaden, Germany): Excellent surgical skills. But I am a little bit astonished about your definitions. You talked about angioplasty, and according to Rendina's definition for angioplasty, you have to perform a circumferential resection of the pulmonary artery and do an anastomosis, otherwise it was only a simple bronchoplasty on the pulmonary artery. And the other point, you showed us a dissection of the bronchus close to the main bronchus, but it was a simple suturing of the bronchus, not a bronchial angioplasty.

Dr Agathian: To answer your question, as I just told him, to do a complete angioplasty through VATS involves a technique which is evolving. Angioplasties can be classified as simple angioplasties, as where you cut and just overrun it, or patch angioplasty, or double sleeve lobectomies. So there are various kinds of angioplasties, as I have already described. The ones we have done are simple and you can probably start with that. I have been doing VATS lobectomies since 1999, and in 2006 we embarked on this, because endoscopic surgical sewing skills take time to develop.

The question is if you really want to do a proper vascular angioplasty, the next step, of course, after you have mastered sewing, is how to place your vascular clamps. So these are isolated cases which we detected at the time of VATS. I don't have the answers to all your questions but hope it will be clearer as the technique evolves.

The other thing is, if you divide the proximal and distal bronchus completely (we used to divide completely in the first two sleeve lobectomies), the whole bronchus is like two parts and to re-sew back is difficult. So what we do now is we leave a sliver of bronchus inferiorly between the two ends so there is no rotation and this helps in the sewing, because you do not have the privilege of an assistant helping you, as in an open case, because it is only done by you. So you have to set yourself up for a comfortable anatomic position. So maybe when you do bronchoplastic procedures by VATS, especially in the initial learning stage, you may have to improve technically without compromising efficacy.
Dr B. Passlick (Freiburg, Germany): You told us that you use a utility incision of only 2 or a maximum of 3 cm. Would you have more freedom for your needle holder if you used an incision like 4 or 5 cm? You have to do it anyway to get the lobe out. So if you do a VATS procedure, a bronchoplasty, why don’t you use a little bit larger incision and then it is much easier?

Dr Agasthian: There are other surgeons who do that. In China there is a surgeon who does all his procedures through the utility incision. He does the angioplasties through a big hybrid incision; he looks through the incision and he does it. But I am a very traditionally trained laparoscopic surgeon, so I need to try and triangulate. I can’t do it through the same incision. I find it is difficult to sew through an incision without triangulating. But technically how you do it is up to you. I think you can use two-port, three-port; it doesn’t matter. But I think as far as it being totally endoscopic, nobody is going to argue with you.

Dr J. Schirren (Wiesbaden, Germany): I have to ask you, in the beginning of sleeve resection in open surgery there was a small start and they cut, as you showed, only the upper part from the cartilage, and the lower part, the pars membranacea, is intact, and it is the so-called ‘tilt plasty.’ And we all know from open surgery that this is not the best for the patient, because the wall of the pars membranacea will not be tight, you have some problems, and also from the oncological point of view, sometimes you have lymphatic spread around.

And why do you start with these mistakes from open surgery in this new area of VATS lobectomy? I think you should translate the experience from open to VATS and start there, not take the mistakes from open into the new technique.

Dr Agasthian: I totally agree with you. I hope that in three years’ time I will be able to achieve complete totally endoscopic sewing, because it is still an idea which is also evolving. I don’t have the right answer for you. But I totally agree with you, and hopefully in five years maybe most of the issues will be resolved with better instrumentation and better techniques. Of course, somebody else is thinking about a new way of doing it.