Video-assisted thoracoscopic pulmonary surgery – current status and potential evolution

Abstract The current status of video-assisted thoracoscopic surgery (VATS) of the lung has been reviewed. The published data support the view that VATS pulmonary surgery is feasible and safe. It is associated with decreased perioperative pain and opiate requirement, better postoperative pulmonary function, and probable overall neutral cost impact. A VATS approach is functionally superior to open thoracotomy for wedge resection, pneumothorax surgery and bullous lung disease and may allow surgical intervention in patients with pulmonary function which is in adequate for open resection. Major VATS pulmonary resection with lobectomy and pneumonectomy can be performed for early malignant disease without compromising established surgical principles. Specific training is needed in VATS surgery and background skills in general thoracic surgery are necessary to underwrite major interventions. Decreased cytokine activation and enhanced post surgical immune function may prove to be long-term benefits of VATS surgery. [Eur J Cardio-thorac Surg (1996) 10: 161–167]

Key words Video-assisted thoracoscopic surgery · Review

Evolution of thoracoscopic pulmonary surgery

The technique of thoracoscopy is attributed to Jacobaeus whose experience and that of others has been well described [2, 11, 54]. Prior to 1990, however, thoracoscopic surgery was restricted to biopsy procedures, management of pneumothorax, empyema irrigation, sympathetic chain ablation and removal of intrathoracic foreign bodies [6, 20, 23, 44, 55].

As with other major intrathoracic interventions, thoracoscopic pulmonary surgery became feasible with the adoption of video-imaging technology in 1990 and the availability of stapling devices originally developed for laparoscopic surgery. Initial reports suggested that known applications of thoracoscopy were facilitated and described the expansion of thoracoscopic surgery to include wedge resection of pulmonary parenchyma for biopsy of interstitial lung disease or excision of the solitary pulmonary nodule [7, 13, 38].

Introduction

Video-assisted thoracoscopic (VATS) pulmonary surgery has evolved over the past 5 years to the extent that many procedures are now feasible. These include: preresectional staging of lung cancer, biopsy of pulmonary lesions, wedge resection for pulmonary parenchymal biopsy or nodule excision, lobectomy, pneumonectomy and the extirpation of bullous disease either as part of pneumothorax surgery or in the resection of large emphysematous bullae. Although the use of video-thoracoscopic techniques is expanding rapidly, it has not yet been clearly established where these techniques are indicated and, as with all novel procedures, detailed and continuing assessment and audit is needed. This paper seeks to review the current status of VATS pulmonary surgery and to identify areas of potential development.
Pulmonary lobectomy was first performed in 1991 and initially described by Roviero [46] and Lewis [37]. Subsequently, other centres confirmed that video-imaged lobectomy was feasible and safe [18, 29, 42, 47, 57] and pneumonectomy was reported as technically possible [18, 42, 47, 58].

**Surgical technique**

**Access**

Minor biopsy and assessment procedures can be performed with three or, occasionally, two 1 cm intercostal incisions or “ports”. Three ports allow triangulation of the instruments with the video-thoracoscope inserted through one port, often the central one [31], and biopsy or retraction instruments through the other ports. The video-thoracoscope position can be varied if this aids appreciation of anatomy. It is helpful to alternate the biopsy instrument and retraction instrument ports when performing a wedge resection as this manoeuvre facilitates excision of the wedge.

All current techniques for formal, major thoroscopic pulmonary resection utilise a small 5–8 cm “access” or “utility” thoracotomy in addition to two or three ports. This incision is utilised for large instruments and removal of the specimen. The placement of the access thoracotomy varies. Kirkby and associates [29] locate this somewhat posteriorly below the tip of the scapula. Lewis [37] and Guidicelli [18] describe an incision in the 5th interspace posterior to the midaxillary line, and McKenna and Roviero [42, 47] an incision in the 4th intercostal space in the anterior axillary line. We [57] have favoured an inframammary incision on the basis that the intercostal space is widest at this point and because this incision can be rapidly linked to the thoracoscope port in the event that a formal thoracotomy is required, thereby creating a standard lateral thoracotomy.

Insufflation of carbon dioxide (CO₂) into the pleural cavity has been used to facilitate lung collapse. Despite significant adverse haemodynamic effects in an animal model [27], this appears to be well tolerated in humans [62]. This difference may result from species anatomical differences and the use of a double lumen endotracheal tube in humans. However, a rise in central venous pressure is noticed in humans and it is questionable whether CO₂ insufflation is necessary for pulmonary surgical procedures, as the lung will collapse well if a double lumen tube is used and open ports created. Pleural flooding with CO₂ without elevating intrathoracic pressure could, however, be a useful precaution when electrocautery is used in the presence of significant leakage of oxygen-rich anesthetic gases and CO₂ can be used to wash out intrapleural smoke.

**Anaesthesia, preparation and positioning**

Access for thoracoscopic pulmonary surgery is facilitated by the use of double lumen intubation. Oxygen saturation can be maintained by intermittent insufflation of the collapsed lung with oxygen. The general standards of monitoring are as for a major thoracotomy and the patient should be positioned and draped so that a formal thoracotomy can be created expeditiously in the event of bleeding or the need to convert to open thoracotomy for technical reasons. A route for rapid transfusion should be available and a full thoracotomy tray must be open for patients undergoing formal resection together with a selection of vascular clamps.

**Technical operative considerations**

**Vision**

The quality of the view obtained thoracoscopically is excellent. In particular, the view of the apex of the chest is superior to an open procedure and the technique offers the advantage of magnification. Three-dimensional vision is still, however, not a fully viable concept because of cost and development considerations including user fatigue. The ability to look around structures is obviously lost. The surgeon should, therefore, possess a detailed knowledge of the topographical anatomy of the hilum and must be fully aware of the possibility of anatomical variations.

**Proprioception**

Thoracoscopic surgery greatly reduces the surgeon’s ability to use tactile feedback. The loss of the ability to grip and palpate the lung can make the localisation of nodules difficult and the assessment of hilar fixity impossible. It is feasible, however, to palpate the anterior aspect of the lung through the utility incision and more lung can be palpated in this manner by pushing the lung anteriorly towards the palpating finger. A peanut swab on a Robert’s forceps can provide a finger substitute for palpation. The loss of tactile feedback is particularly noticeable when dissecting around large hilar vessels when the surgeon has to rely on visual cues to a considerable extent.

**Instrument design**

Current thoracoscopic instrument design is still dominated by laparoscopic considerations. In general, dissection around hilar structures at open thoracotomy is facilitated by the use of large curved forceps. The desire of manufacturers to keep instrument dimensions within the limits of a 10 or 12 mm laparoscopic port has resulted in a lack of appropriate thoracic instruments which, ideally, would have conventionally sized and angled jaws mounted on appro-
priate thoracoscopic handles. As a port tube is not, in fact, necessary in thoracoscopic work except for insertion of the thoracoscope, it is not difficult to insert large bladed or acutely angled instruments through a port. Opening of the blades is, however, restricted by the limited handle movement available although this can be improved by instrument designs which place the hinge at the region of the port hole. The access thoracotomy is especially useful as conventional instruments, particularly vascular clamps, can be inserted and fully opened through that route.

Hilar structures tend to radiate centrifugally away from the mediastinum whilst laparoscopic stapling instruments are linear and tend, therefore, to come centripetally towards the hilum. This can make it awkward to place the stapling instrument across hilar structures. Although the problem can be reduced by manipulating the lung within the chest to bring the structure into the best possible relative position to the stapler, it would be much better to have “roticulating” stapling devices.

Patient factors may make a thoracoscopic approach difficult or impossible. These include: obesity which can make the chest wall thicker than the length of the thoracotomy bearing the thoracoscope, a small chest which reduces space in which to manipulate instruments, oozy patients where bleeding may obscure the lens or the operative field, and narrow ribs which make it difficult to insert large instruments or remove the specimen after a formal resection.

**Current status of thoracoscopic pulmonary procedures**

**Biopsy of pulmonary lesions**

Thoracoscopic guided needle biopsy of pulmonary lesions is an alternative to radiology guided biopsy, which offers several potential advantages. The thoracic cavity can be inspected at the time of the procedure, a larger sample may be obtained and, as an intercostal drain is placed following surgery, concern about post biopsy pneumothorax is unnecessary. Solitary pulmonary nodules can be managed by an excisional wedge biopsy as discussed below.

**Assessment of malignant disease**

Sampling of ipsilateral hilar and mediastinal glands can be performed but it is not reasonably feasible to sample the contralateral mediastinum and difficult to sample the anterior carinal space. Thoracoscopic assessment cannot, therefore, replace mediastinoscopy. It can, however, serve as an alternative to anterior mediastinotomy with excellent visualisation of the aortopulmonary window, azygos and lower subcarinal stations [33, 45]. Assessment of hilar fixity is, however, difficult. Thoracoscopic assessment can exclude causes of inoperability which may not be apparent using other conventional investigative techniques prior to thoracotomy. Parietal pleural seedlings, ulcerating hilar tumour and tumour transgressing a fissure, for example, are easily detected at thoracoscopy. It would seem logical, therefore, to recommend pre-resectional thoracoscopy in all malignant cases even when open thoracotomy is planned, as such a strategy would further reduce the open and close thoracotomy rate.

**Pulmonary wedge resection**

Video-assisted thoracoscopic surgery pulmonary wedge resection has been widely practised for isolated pulmonary nodules. The technique is generally simple and utilises endostapling instruments occasionally supplemented by laser [34]. Wedge excision is, however, best suited to a peripheral pulmonary lesion, as attempted excision of a centrally placed mass carries a potential risk of haemorrhage or intrapulmonary haematomas. Also, localisation of the lesion can be difficult [1, 40] and is easier with peripheral lesions. At present palpation remains the most sensitive method but is of limited application during thoracoscopy. A variety of methods have, therefore, been employed to aid localisation of peripheral nodules including palpation devices, ultrasound probes, needle guidance and preoperative injection of a dye marker [28, 36, 39, 41, 50, 51]. Despite such measures a proportion of intrapulmonary nodules evade thoracoscopic localisation so that recourse to open thoracotomy is required. Successful wedge resection can be followed by frozen section analysis and a decision then made whether to proceed to a formal anatomical resection.

The role of VATS wedge resection in the management of malignant disease remains controversial as does open wedge resection. Those who utilise wedge resection for primary treatment of early peripheral carcinoma face the same arguments with regard to local recurrence whether a thoracoscopic or open approach is employed [16, 61]. Thoracoscopic resection can, however, potentially extend wedge excision of malignant lesions to those with inadequate respiratory reserve for open thoracotomy [52]. Resection of metastases can be achieved thoracoscopically [32], but multiple small metastatic lesions as, for example, with osteogenic sarcoma are probably better excised at an open procedure, as this facilitates detection of small lesions by palpation.

Thoracoscopic parenchymal biopsy for intersitial lung disease is simple and has advantages over conventional biopsy through a limited thoracotomy. The lung can be inspected and samples taken from the most appropriate areas rather than simply the area underlying the minithoracotomy site. Biopsy specimens may be removed without difficulty from several lobes. It is likely that respiratory mechanics are less disturbed in this group of compromised patients. Diagnostic accuracy is at least as good as for open biopsy [5, 30] and, typically, postoperative stay is reduced to about 2 days.

**Lobectomy**

Experience with pulmonary lobectomy is growing rapidly [18, 29, 37, 42, 47, 57]. It is now clear that it is possible to perform an anatomical resection, and that ipsilateral mediastinal nodes can be removed if so desired [18, 42]. The approach taken by all but Lewis [37] is to dissect the hilar structures and control each in turn in an entirely analogous technique to an open procedure. The limiting factors are: operative safety in view of the significant risk of haemorrhage; operating time which generally averages 150 min; tumour size; adhesions and difficulties with currently available instruments. Other than known benign disease, our current indications, which are similar to those of others, are: preoperative T1/T2, N0/N1, peripheral pulmonary lesion with negative mediastinoscopy and no evidence of other pulmonary lesions on computed tomography (CT) scan. There is a steep learning curve and new techniques have been necessary to perform the procedure most effectively. These include the use of proximally placed vascular clamps prior to sectioning large vessels with the Endovascular stapler and placing the specimen in a plastic bag within the pleural cavity to avoid the risk of tumour seeding. When extracting the lobe through the minithoracotomy, experience differs between centres, but somewhere between 10 and 30% of attempted cases require to be completed as open procedures for one of the above reasons. Whereas most techniques utilise video-imaging and avoid the use of a rib spreader, an alternate strategy has been described by Guidoeli [18, 19] who utilises a minithoracoto-
my held open by a retractor for direct visualisation and as the main route for surgery performed with conventional instruments. The video-thoracoscope was used to provide supplementary vision. This technique has provided a different method of obtaining minimal access resection.

Pneumonectomy

Published experience with VATS pneumonectomy is extremely limited [10, 18, 42, 47], perhaps reflecting the fact that pneumonectomy is often dictated by hilar involvement which itself militates against a thoracoscopic approach. However, it is feasible in highly selected cases. These are essentially small early lesions which require pneumonectomy because of: their endobronchial location, involvement of several lobes across fissure(s) or attachment to the pulmonary artery within the hilum. As with lobectomy, a dissectional technique is used with the hilar structures being divided individually and all hilar nodes removed. Mediastinal node dissection is performed as considered necessary. In our experience the advantages of thoracoscopic resection are seen more clearly with pneumonectomy as the drain is removed early and rapid mobilisation is achieved. Main bronchus closure required the use of a standard stapler inserted through the access thoracotomy until the recent availability of 4.8 mm endoscopic staplers.

Management of bullous lung disease

Apical “blebs” and small bullae associated with pneumothorax can be managed effectively with thoracoscopic snare ligation or endostaple excision [24, 25, 59, 60]. The view of the apex of the upper lobe obtained at thoracoscopy is superior to that gained at a minithoracotomy and this may facilitate location of the bullae. After excision of the bullae, pleural abrasion or pleurectomy can be performed as preferred. Medium-term follow-up of pneumothorax patients at 18–24 months suggests results equal to conventional open thoracotomy [25, 60].

Thoracoscopic reduction of diffuse bullous emphysema using a CO₂ laser has been practised in the management of this condition for some years [55]. Linear staplers may also, however, be used to excise or reduce giant bullae [3, 56] and to perform thoracoscopic lung volume reduction surgery. One potential disadvantage of staple closure in emphysematous patients has been air leakage from the staple line which can be reduced by buttressing the staples with various materials including pencycardium, polydioxone, Teflon and polyglycolic acid [8]. As with excision of a pulmonary nodule, VATS management of secondary pneumothorax may allow a surgical approach to be extended to those patients who would otherwise be of dubious fitness for an open procedure [59].

Auditing the outcome of VAT pulmonary surgery

Many publications testify to the possibility of performing VATS procedures but there are remarkably few reports presenting data auditing specific outcome measures beyond survival and operative complications.

Pain

The most obvious potential benefit of a thoracoscopic approach to pulmonary surgery is the reduction of both acute and chronic post-operative pain. Waller [60], in a randomised study of 30 VATS versus 30 open pleurectomy cases found decreased morphine consumption in the first 12 h after surgery (25 mg vs 34 mg). Rubin [48], in a report concerning a mixed group of 71 VATS procedures compared with 21 open thoracotomy cases measured narcotic requirement in days and found values of 3.4±2.1 for VATS cases and 6.1±3.6 for open cases (P<0.01). In our very early experience [57] of patients undergoing 11 VATS or 33 open lobectomy procedures, acute postoperative pain was reduced with the VATS approach and hourly morphine consumption delivered via patient-controlled analgesia was 1.36 mg/h for VATS cases as opposed to 1.87 mg/h for open cases (P<0.01). The need for postoperative intercostal blocks was also reduced. These findings have been confirmed in our continuing audit of both lobectomy and wedge excision cases. Guidicelli [19] compared 44 video-assisted minithoracotomy with 23 open muscle-sparing thoracotomies and also found a statistically significant reduction in early (<1 week) postoperative pain in the minithoracotomy group (P<0.006).

Landreneau [35] attempted to analyse chronic pain by a questionnaire-based study comparing 165 patients who had undergone a lateral thoracotomy, mostly muscle-sparing, with 178 patients who had undergone a VATS procedure, mostly for wedge excision. This study showed that less than 1 year after the procedure, the presence of pain, the perceived magnitude of the pain and shoulder function were superior with VATS resection. After 1 year there was no difference. In our own experience of VATS major resection, we have had only one case of post-thoracotomy pain syndrome in a VATS major resection series of over 100 lobectomy and pneumonectomy procedures.

Postoperative comfort and function have also been studied in patients undergoing biopsies, pneumothorax surgery and wedge excisions in terms of return to normal activities. In one telephone survey [12], 81 VATS patients returned to full activity at a mean of 9 days as compared to 19.4 days for 19 others in whom the procedure had been converted to an open thoracotomy. Return to preoperative functional status was also examined by Rubin [48] and found to be 12±11.2 days with VATS and 21.4±9.5 days after open thoracotomy (P<0.01).

Postoperative respiratory function

Comparison between muscle-sparing and standard thoracotomy has shown decreased pain with a muscle-sparing approach but no improvement in postoperative pulmonary function [21]. By contrast, Waller’s study of VATS pleurectomy, when compared with open pleurectomy via a standard limited thoracotomy approach [60], did demonstrate a statistically significant reduction in postoperative fall in forced expiratory volume in 1s (FEV₁) (25% VATS vs 43% open, P<0.05) and forced vital capacity (FVC) (19% VATS...
vs 39% open P<0.01) measured at 3 days post surgery. Although Guidicelli and colleagues [19] were not able to demonstrate a similar difference in FEV₁ or FVC reduction between their video-assisted minithoracotomy procedure and open muscle-sparing thoracotomy, this may perhaps reflect the effect of the rib spreader used in their particular technique.

Cost considerations

Comparisons of relative costs between VATS and open thoracic procedures are fraught with difficulties relating to: allocation of hospital bed day costs, transatlantic differences in convalescent practice and intangible considerations such as the true costs of late pain, delayed return to work and diminished performance in the workplace. There is, however, no dispute that procedural costs are considerably increased with VAT surgery. These costs are frequently offset, however, by reduced high dependency and overall hospital stay. Molin and colleagues [43], in a retrospective review of 16 VATS pulmonary biopsies versus 21 open biopsies, appeared to find a higher cost with VATS biopsy. This study however simply confirmed higher procedural costs, as there was no reduction in patient stay (5 days postoperatively in both groups) associated with VATS biopsy. This experience is somewhat at variance with that reported by most authors, who have found a reduced inpatient stay with VATS lung biopsy. For example, our own review [5] of 50 pulmonary biopsy cases: 25 VATS, 25 open, suggested that the VATS technique was in fact cheaper overall despite higher procedural costs, as the VATS cases stayed in hospital for a mean of 1.4 days rather than the 3.1 days required in the open group. There does not seem to be a statistically significant cost difference in the US between VATS wedge resection of pulmonary nodule and open excision of pulmonary nodule [1, 22]. In our experience, VATS lobectomy, incurs an overall increase in operative costs of £600–£1000 depending upon the degree of completeness of the fissures and the particular lobe to be resected. However, even our early data [57] suggested a substantial reduction (15 h) in high dependency stay.

Patients undergoing major VATS resection are, however, frequently detained by postoperative air leak necessitating a pleural drain. Measures to shorten air leakage [8, 20] may further reduce costs by allowing earlier discharge. With increasing experience and improved techniques to minimise air leakage, it would seem probable that the overall effect of VATS may be neutral in regard to costs.

Safety

The use of VATS techniques in the treatment of pulmonary disease raises concern over the adequacy of the procedure, particulary in the context of malignant disease [15, 17]. It is essential that established surgical techniques and principles should not be altered simply to allow a VAT approach. The use of wedge resection for malignant disease where a lobectomy could be tolerated is unacceptable in view of the risk of local recurrence [16, 61]. All those reporting VAT lobectomy using dissectional techniques [18, 29, 42, 46, 47, 57] have stressed that node and tumour clearance is equal to that which they would seek to achieve with an open procedure, and this must be a fundamental principle. If the resection cannot be achieved according to that criterion, the procedure should be converted to an open thoracotomy and this decision recognised as good judgement rather than failure of VATS resection. It is also certain that great care must be taken to deliver malignant specimens through access ports or minithoracotomy incisions within suitable bags so as to remove the risk of tumour implantation.

Apart from adequacy of the procedure, safety is also determined by the risk of operative misadventure. The single most important factor in thoracoscopic surgery is the skill base and temperament of the surgeon. Bleeding is an ever present risk which is minimised by appropriate strategies to avoid and control this event [9]. A detailed understanding of hilar anatomy is important in reducing the risk, and the ability to open the chest expeditiously to salvage a difficult situation is fundamental. Manipulation of laparoscopic instruments under video-imaging requires new skills which should be acquired by progressing from simulation to simple procedures before embarking upon major resection. Video-assisted thoracoscopic surgery procedures should, therefore, only be undertaken by surgeons with appropriate training in general thoracic surgery and in video-assisted thoracic surgery [53].

Conclusion

The debate between proponents of a thoracoscopic and an open approach has largely focused on: technical feasibility, pain reduction, relative cost both procedural and in-patient, safety issues and the adequacy of resection in malignant disease.

The available data would suggest that simple parenchymal biopsy, wedge resection and pneumothorax surgery are probably better performed thoracoscopically. Management of bullous lung disease can be undertaken with functional benefit thoracoscopically but, in advanced cases, the difficulty of prolonged air leak still exists. For formal pulmonary resection, the two techniques are in reality, complimentary rather than competitive. Thoracoscopic resection is advantageous in appropriately selected early lesions. Advanced tumours are likely to be adequately managed only by open resection for the foreseeable future but, even when an open procedure is planned, thoracoscopic immediate
pre-resection assessment should probably become standard practice as it provides a method of further reducing the open and close thoracotomy rate.

There are, however, issues which have not yet been adequately considered in relation to VATS pulmonary resection for malignant disease. Tissue trauma and cytokine activation are reduced following laparoscopic cholecystectomy [26]. Detailed studies of thoracoscopic procedures are awaited but reduced interleukin 6 production would appear to be a function of thoracoscopic surgery also (R. Förster, personal communication). Blood loss is often negligible with thoracoscopic resection and tissue handling is necessarily lessened. It is tempting to postulate that, by reducing the trauma of resection, immune function [4, 14, 49] is better preserved at the time of excising a malignant lesion and that an advantage may therefore be conferred to patients with malignant disease by performing a thoracoscopic resection. This question, which we are currently studying, awaits laboratory data and long-term survival studies but remains potentially one of the most important aspects in the evolving field of VATS pulmonary surgery.

References
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