Minimally invasive thoracic surgery: where do we stand now?

APC Yim, JKS Ho, V Abdullah

Video-assisted thoracoscopic surgery and interventional bronchoscopy represent different aspects of minimally invasive thoracic surgery. From September 1992 to February 1994, we successfully performed a total of 284 thoracoscopic procedures on 192 patients which consisted of 79 bleb eliminations and 105 mechanical pleurodesis; 26 wedge resections; eight wedge biopsies; six thoracic sympathectomies; six mediastinal mass resections; six pericardial windows; 16 guided pleural biopsies; eight guided drainages of empyema and haemothorax; 13 stagings of intrathoracic tumours; two explorations for penetrating thoracic trauma; seven talc insufflations; and two lobectomies. The median duration of post-operative chest tube drainage was two days and hospital stay four days. From April 1993 to April 1994, interventional bronchoscopy was performed on seven patients with obstructive tracheal and proximal bronchial lesions. Procedures consisted of three carbon dioxide laser reductions; two dilatations and carbon dioxide laser reductions; and two dilatations and placement of silicone Dumon stents. All patients showed immediate symptomatic improvement. We conclude that both procedures are safe and effective.

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Introduction

Video-assisted thoracoscopic surgery

Thoracoscopy was first introduced in the early 1900s by HC Jacobaeus, a European physician who used a cystoscope to examine the thoracic cavity under local anaesthesia.[1] Modern video-assisted thoracoscopy was made possible by three advances. Improved endoscopic lens systems coupled with the development of solid state systems and microcameras in the early 1980s allowed a panoramic view of the hemithorax instead of the previous tunnel view.[2] Secondly, improved anaesthetic technique with one-lung ventilation gave greater manoeuvrability of the telescope and instruments.[3] Lastly, the development of endoscopic surgical instruments, such as the linear staple cutter, opened up new vistas for a spectrum of diagnostic and therapeutic thoracoscopic procedures.[4]

Department of Surgery, The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, Hong Kong:
Cardiothoracic Unit
APC Yim, MB, BCh, American Board of Surgery
JKS Ho, MD, American Board of Surgery
Ear, Nose and Throat Division
V Abdullah, FRCS
Correspondence to: Dr APC Yim

The application of video laparoscopic techniques to thoracic surgery was initially met with some scepticism. However, video-assisted thoracoscopic surgery (VATS) is rapidly gaining acceptance and has made an important impact on the practice of thoracic surgery,[5-7] as people realise that the trauma of access is often worse than the surgery for correction.

The thorax is ideal for endoscopic procedures for many reasons. Thoracotomy is one of the most painful incisions commonly employed. This is probably not due to the length of the incision, but to the spreading of the ribs. Conventional thoracotomy requires division of the latissimus dorsi and the serratus anterior muscles and gives rise to significant functional impairment postoperatively. Selective one-lung ventilation has rendered the use of carbon dioxide (CO_2) insufflation generally unnecessary. As a result, valved ports are not required and many thoracic instruments, in addition to endoscopic instruments, can be used. Mini-thoracotomy (for hilar dissection and specimen retrieval) can co-exist with thoracoscopy and represent different ends of the continuum in video-assisted thoracic surgery.

Interventional bronchoscopy

With the introduction of the ventilating rigid bronchoscope, endoluminal thoracic surgery (i.e. interventional bronchoscopy) became possible. Interventional bronchoscopy is essential in alleviating the distressing symptom of suffocation experienced by patients with tracheo-bronchial lesions.

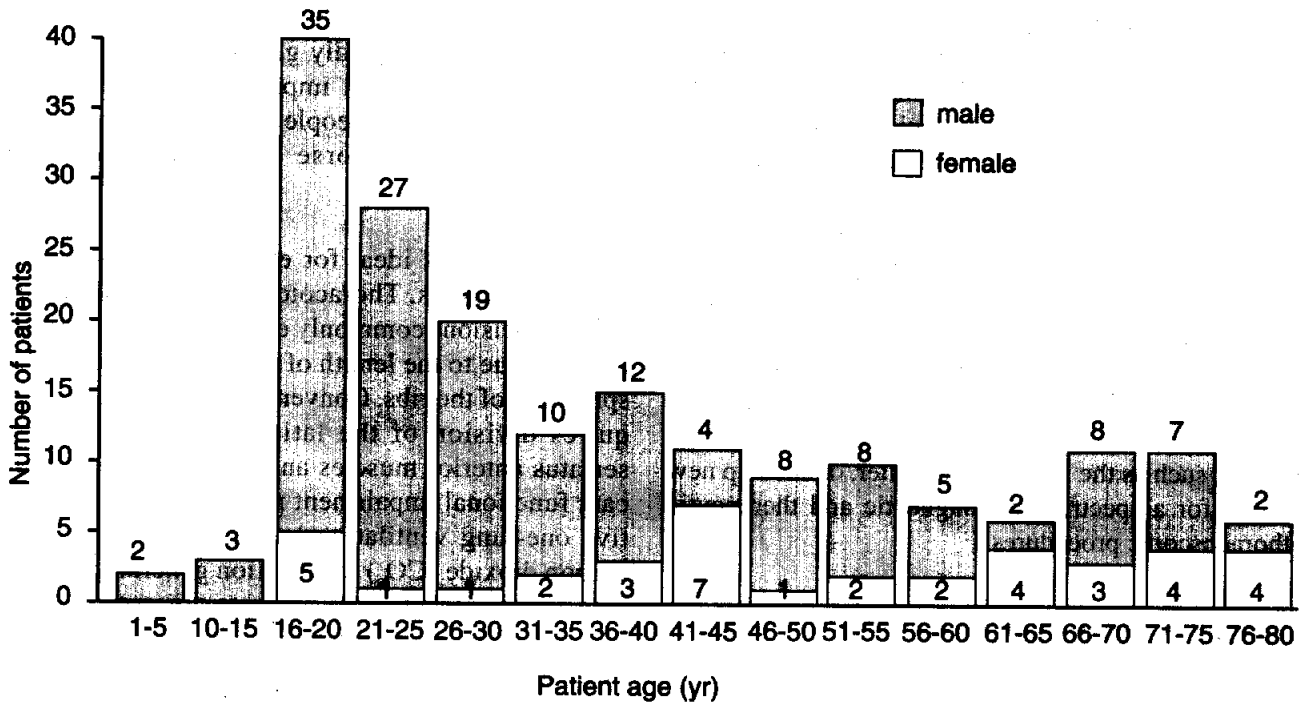
Materials and methods

Video-assisted thoracoscopic surgery

Between September 1992 and February 1994, we successfully performed a total of 284 VATS procedures on 192 patients. There were 152 male and 40 female patients ranging in age from 22 days to 78 years (Fig 1). The procedures performed consisted of 79 bleb eliminations and 105 mechanical pleurodesis for spontaneous pneumothorax; 26 wedge resections for pulmonary nodules; eight wedge biopsies for diffuse pulmonary infiltrate; six thoracic sympathectomies; six mediastinal mass resections; six pericardial windows; 16 guided pleural biopsies for undiagnosed effusions; eight guided drainages of empyema and haemothorax; 13 stagings of intrathoracic tumours; two explorations for penetrating thoracic trauma; seven talc insufflations for malignant pleural effusion; and two VATS lobectomies. During the same study period, VATS was planned but abandoned in four additional patients due to inability to tolerate selective one-lung ventilation (1), pleural symphysis (2), and inability to accurately localise the lung nodule (1).

Our routine technique was to induce anaesthesia thiopentone with either thiopentone sodium (4 mg to 5 mg/kg intravenously) or propofol (2 ml/kg intravenously). Endobroncheal intubation with a double lumen tube was performed three minutes after administration of vecuronium bromide (0.1 mg/kg intravenously). The position of the endobronchial tube was re-confirmed after lateral decubitus positioning. One-lung ventilation was then applied from the anaesthetic ventilator, an integral part of the Narkomed 4E anaesthetic machine and circle absorber system (North American Drager, Telford, Pennsylvania, US). Nitrous oxide, oxygen, and isoflurane anaesthesia was maintained by this system, with positive end-expiratory pressure option available, but not necessarily used. In addition to the routine monitoring for general anaesthesia, data from pulse oximetry, end-tidal capnography, airway pressure and expiratory spirometry were graphically and continuously displayed and electronically recorded.

Although selective one-lung ventilation using a double lumen tube is always preferred, we proceeded with a single lumen tube at times. In children



* One female case, 22 days old

Fig 1. Distribution of patients who underwent thoracoscopic surgery by age and sex

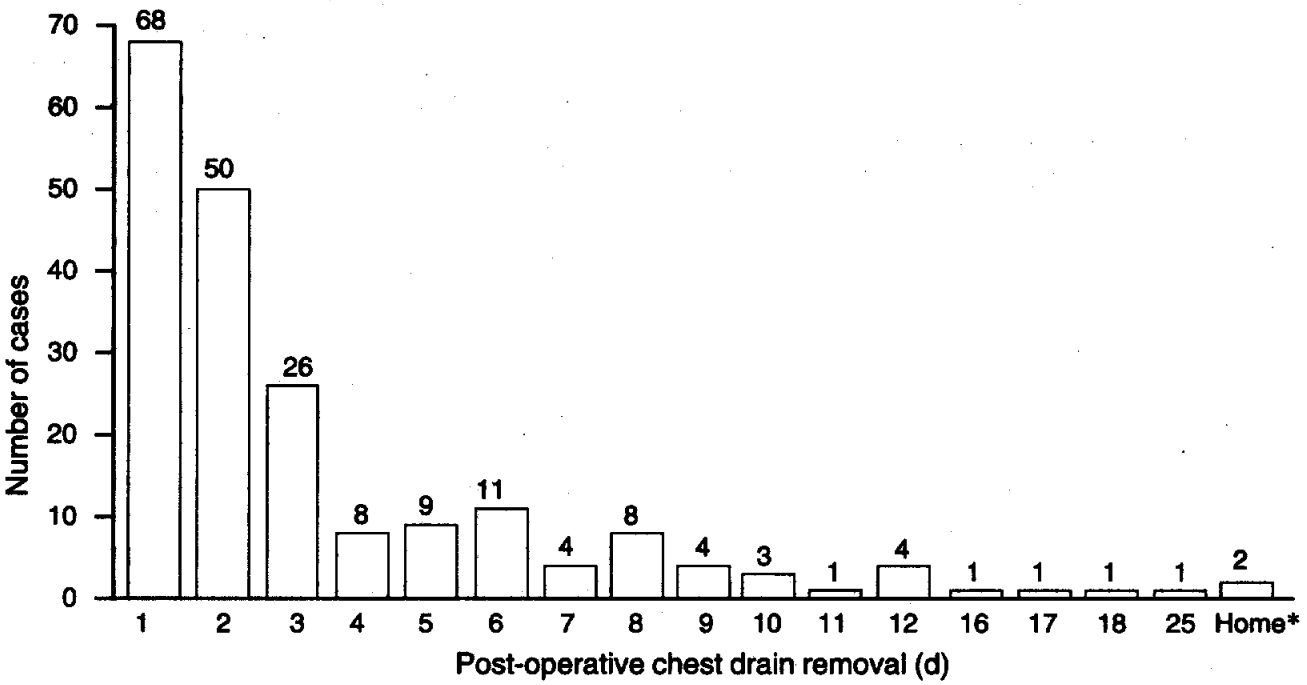
under 15 years of age, we generally attempted bronchoscopically-guided main stem bronchus intubation for partially selective ventilation, as uncuffed tubes are used. We have no experience with bronchial blockers. Our basic technique has been reported previously.[8-11]

Our preferred position in most cases was a full lateral decubitus with 30° flexion to open up the intercostal spaces.[12] Minimally invasive surgery often requires taking the maximal advantage of positioning for exposure of anatomy. In each case, the patient was prepared and draped as for a full thoracotomy.

We did not find CO_2 insufflation to be necessary, providing we obtained good collapse of the lung with selective one-lung ventilation. A 10.5 mm trocar (Thoracoport, Snowden & Spencer, Tucker, Georgia, US) was inserted in the sixth or seventh intercostal space between the mid and the posterior axillary line[13] for the introduction of a 10 mm 0° rigid telescope and a three-chip camera system (Stryker, Kalamazoo, Michigan, US). Exploratory thoracoscopy was then performed to identify the pulmonary, pleural, and mediastinal pathology, and appropriate sites for additional trocar placement were selected. Usually two further ports were needed for instruments. In guided pleural biopsies, the operating telescope with a 5 mm instrument channel was used (Karl Storz, Tuttlingen, Germany) and in these cases, no further ports were needed. Wedge lung resections were completed using an endoscopic stapling device (Multifire EndoGIA; United States Surgical Corporation, Connecticut, US) with or without the additional use of laser[14] (Diomed, Cambridge, UK) to thin out the lung parenchyma before the insinuation of the stapler. In mechanical pleurodesis for spontaneous pneumothorax, a piece of marlex mesh was mounted to a grasper to abrade the parietal pleura.[5] Our techniques on VATS management of pleural effusion,[15] lobectomy,[16] peripheral lung nodules,[17,18] and thymectomy[19] have been reported previously.

Interventional bronchoscopy

Over the last 12 months, the hospital's cardiothoracic unit collaborated with the ear, nose, and throat division and successfully treated seven patients with obstructive tracheal and proximal bronchial lesions. Two cases had their primary tracheal carcinomas reduced with the CO_2 laser using a rigid bronchoscope. Two cases of tracheal tuberculous strictures were widened with the CO_2 laser and one case of similar stricture was dilated and stented with the studded Dumon silicone stent (Cometh, Marseille, France).[20] One case of



Median time to removal = two days

* Two patients with empyema were discharged home with chest tubes which were trimmed and opened to the air for drainage

Fig 2. Duration of chest drain following thoracoscopic surgery

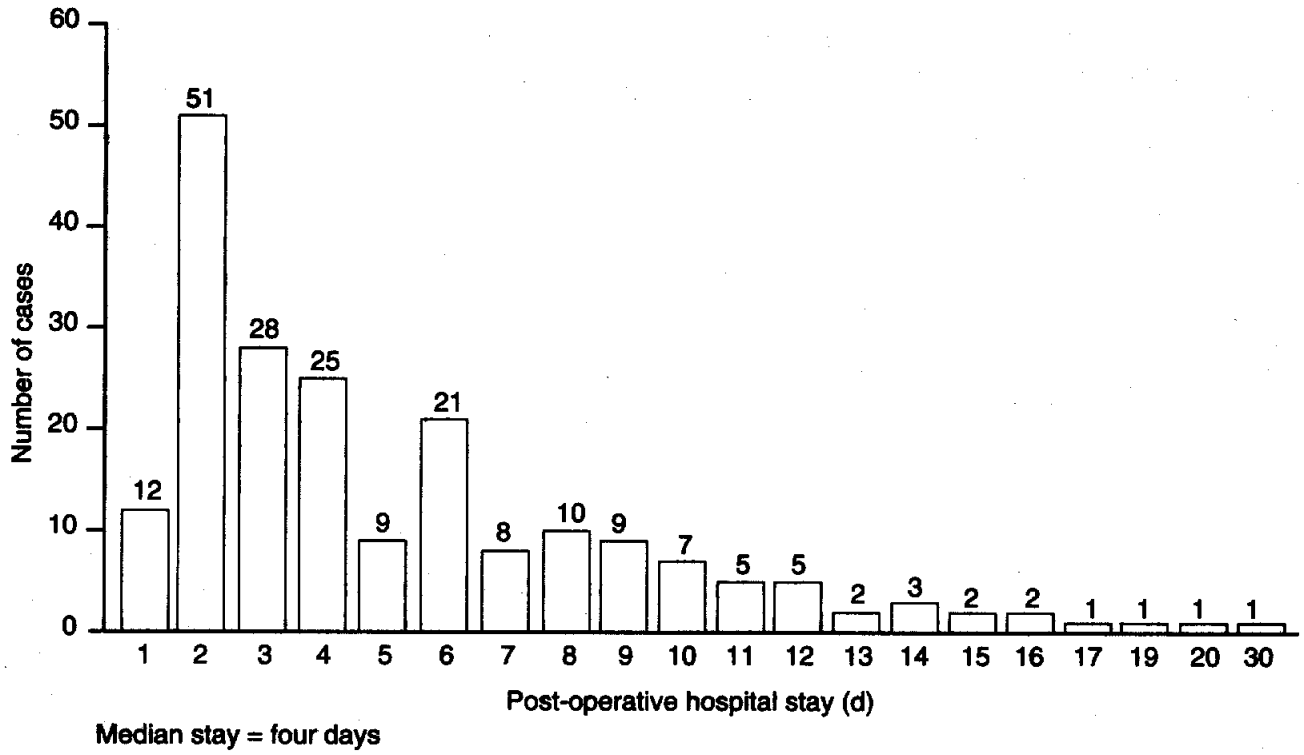


Fig 3. Post-operative hospital stay following thoracoscopic surgery

carcinoma of the oesophagus infiltrating the left main bronchus had the left upper lobe bronchus recannulated with the CO_2 laser. Another case of oesophageal carcinoma infiltrating the trachea received a Dumon stent.

Results

Video-assisted thoracoscopic surgery

There were no procedure-related mortalities and no intraoperative complications. Three patients with advanced malignancy (2) and end-stage cirrhosis (1) died postoperatively from progression of their disease at 13 days, 15 days, and five months, respectively. One patient with metastatic osteosarcoma treated by chemotherapy died from arrhythmia on postoperative day 3 after a completely uneventful wedge resection. Retrospectively, this was probably related to hyperkalaemia. No patients needed to go to the intensive care unit postoperatively unless they came from there (two patients). The median duration of postoperative chest tube drainage was two days (Fig 2) and the median hospital stay was four days (Fig 3). The latter included patients with chronic or terminal illness as well as newly diagnosed cases of malignancy.

The average postoperative parenteral narcotic (pethidine) requirement after VATS was 120 mg. This is significantly less than the average requirement (450 mg) seen following conventional thoracotomy, in a historical control group of 30 patients (Yim AP, unpublished data).

Spontaneous pneumothorax

One hundred and five patients with primary spontaneous pneumothorax (PSP) underwent VATS. Apical bullae, mostly of Reid's type I or II[21] were identified in 90 cases (87%). All bullae larger than 0.5 cm were eliminated either by exclusion using endoloop (5); ablation with argon coagulation (6); or resection using endoscopic stapler (65). Mechanical pleurodesis with marlex mesh was performed in all cases.[8,9]

Three recurrences occurred out of a total of 105 cases of treated PSP, with a mean follow-up period of 12 months.[22] The first of these was a 34-year-old male with recurrent left pneumothorax treated by thoracoscopic mechanical pleurodesis. No bullae were identified. The chest drain was removed on the second postoperative day and the patient was discharged. However, he returned one week later with recurrent left pneumothorax confined to the lateral chest wall. He was treated with chest tube drainage followed by intrapleural injections of tetracycline. The pneumothorax resolved and the patient had no further complications. The second patient was a 17-year-old male who received argon ablation of his apical bleb. He made an uneventful recovery but returned five weeks later with recurrent pneumothorax. Repeat thoraco-

scopy showed a ruptured apical bleb with no sign of prior coagulation. The bleb was staple-resected and there have been no further complications since. The third patient was a 21-year-old male who was found to have a 0.5 cm apical bleb on his first thoracoscopy. We elected not to resect the bleb and performed a routine marlex mesh pleurodesis. The patient returned two months later and a repeated thoracoscopy revealed an air leak from the same bleb which was then resected. There have been no further complications since.

Complications included one postoperative haemothorax from bleeding of an intercostal vessel at the chest tube site which required evacuation using VATS; one wound cellulitis which resolved on oral antibiotics; and six persistent air leaks which lasted for more than 10 days (five of which occurred during our initial experience in the first six months). Some of these leaks were caused by visceral tears from the use of atraumatic graspers. Two persistent leaks resulted from the use of argon coagulation and one from slippage of the endoloop as the lung re-expanded. Fibrin glue (Tisseel, Immuno AG, Vienna, Austria) applied over the area of leak (under local anaesthesia using a flexible bronchoscope placed through a truncated chest tube) successfully sealed the leak in six cases. One of the two persistent leaks which resulted from argon beam coagulation, failed to be sealed by fibrin glue treatment twice. Chest X-ray showed a residual apical pneumothorax. Repeat VATS was not possible because of adhesions. This patient eventually underwent a transaxillary thoracotomy for control. At operation, leaks were identified from ruptured apical blebs which had little evidence of prior coagulation. The bleb was resected and there have been no further complications since.

Pulmonary function tests were performed one to two weeks after surgery on all patients and no significant deterioration was noted compared with normal controls following VATS (Yim AP, unpublished data).

Wedge resections for pulmonary nodules and diffuse pulmonary infiltrate

Thirty two patients underwent wedge resections for pulmonary nodules (26) or diffuse pulmonary infiltrate (8). Of the 26 pulmonary nodules, seven were benign. Conditions included bronchiectasis and segmental collapse (1), tuberculoma (2), non-specific granuloma (3), and sclerosing haemangioma (1). Nineteen were malignant and included metastatic rhabdomyosarcoma (1), metastatic osteosarcoma (9), metastatic adenocarcinoma (5), and primary lung carcinoma (4). As mentioned, we generally do not plan thoracoscopic resection if we strongly suspect primary lung cancer. However, in these two patients, their general condition was so poor that they could not tolerate conventional thoracotomy and lobectomy. We obtained clear margins in all our resected specimens. Eight resections were performed for diffuse pulmonary infiltrate and the diagnoses included fibrosing alveolitis (1), radiation pneumonitis (3), and organising pneumonia without evidence of bronchiolitis obliterans (4). Complications included two patients with persistent postoperative air leak over 10 days. All were successfully treated with fibrin glue.

Thoracic sympathectomy

Six sympathectomies were performed in three patients with palmar hyperhidrosis, Buerger's disease, and Raynaud's disease. All had good relief of symptoms and postoperative skin temperature of the upper extremities was about 2°C higher than preoperatively. We routinely avoided excising any stellate ganglion to prevent the development of Horner's syndrome and usually excised the sympathetic chain from the upper border of the second rib down to the lower border of the fourth rib.

Pleural effusion

We performed guided pleural biopsies in 16 patients with idiopathic pleural effusions. All of them had previous thoracocentesis and eight had blind pleural biopsies that were nondiagnostic. The diagnosis was established in all 16 patients, of whom 12 were found to have pleural metastases (nine adenocarcinoma, two squamous cell carcinoma, one small cell carcinoma); and four were found to be benign (including one with tuberculosis). Seven patients with empyema were successfully treated by VATS drainage which allowed the breakdown of loculations and limited decortication which freed the trapped lung to re-expand under direct vision.[15]

Video-assisted thoracoscopic lobectomies

Video-assisted thoracoscopic lobectomies were successfully performed in two patients with stage I squamous cell lung carcinoma. Both patients had uneventful postoperative courses. Another patient had a thoracotomy for hilar control because the endoscopic staple cutter transected the pulmonary vein without stapling.[16,23] Prompt vascular control was obtained. The patient lost 500 ml of blood and the postoperative recovery was otherwise uneventful.

Staging of intrathoracic tumours

From March 1993, we routinely performed video thoracoscopy on all patients scheduled for thoracotomy

and lung resection for primary lung carcinoma. In two cases, thoracotomy was avoided because pleural metastasis and positive mediastinal lymph nodes were found.

Pericardial window

Six pericardial windows were performed for malignant pericardial effusions associated with tamponade. In one patient with associated malignant pleural effusion, talc insufflation of the pleural and pericardial cavity were performed. All six patients had good haemodynamic improvement following the procedure. One patient with associated malignant pleural effusion died two weeks postoperatively from disease progression.

Mediastinal masses

Six mediastinal masses were resected or biopsied using VATS which included one neurogenic tumour; one thymic hyperplasia; one residual germ cell tumour; two thymectomies for myasthenia gravis;[19] and one biopsy for metastatic thymoma. Average blood loss was less than 50 ml. The median postoperative chest tube duration and hospital stay were one and four days, respectively.

Talc insufflation

We are conducting a randomised prospective study which compares talc slurry with thoracoscopic talc insufflation[24] for symptomatic malignant pleural effusion. The latter technique has the advantage that adhesions can be taken down and loculated effusion drained. We used 5 gm of purified talc delivered via atomizer (Wolf, Kittlingen, Postfach, Germany) under thoracoscopic guidance.

Miscellaneous procedures

Video-assisted thoracoscopic surgery was used to explore the left hemithorax in two cases of penetrating trauma to the precordium. Both patients were haemodynamically stable and VATS confirmed the absence of penetration through the pericardium. We resected a giant bulla in one patient which improved his dyspnoea.[11]

Interventional bronchoscopy

Of the interventional bronchoscopy group, all seven patients had immediate symptomatic relief of dyspnoea and these were associated with improvement in exercise tolerance. However, CO_2 laser treatment alone, or laser with dilatation on both benign and malignant strictures were associated with a high incidence of recurrence. Although our experience with the Dumon stents is limited, we were impressed with the results, as both patients continued to enjoy good relief at 10 and 12 weeks postoperatively. On repeat bronchoscopic examinations in the outpatient department, no crusting over the stents has been seen.

Discussion

Video-assisted thoracoscopic surgery

The advantages of VATS over conventional thoracotomy are many. The minimally invasive procedure gives rise to much less postoperative discomfort and the morbidity from atelectasis and pulmonary infections[25] is expected to be much reduced and the hospital stay shortened. This technique permits an excellent view of the entire parietal pleura and lung surface and is certainly superior to the tunnel view achieved with a minithoracotomy, as in open lung biopsy. In many procedures, VATS shortens operating time as little time is wasted on opening and closing the patient. The risk of transmission of hepatitis, and now acquired immunodeficiency syndrome, are increasing problems for health care workers. Video-assisted thoracoscopic surgery is essentially a no-touch technique and minimises the risk of disease transmission.

We believe that VATS should be the treatment of choice for spontaneous pneumothorax as the conventional means of chest tube drainage with or without sclerosant is associated with a high recurrence rate (at least 14%).[26] One major concern is the cost of equipment and endoscopic instrumentation. Although this is balanced by the substantial benefits of less patient discomfort, shortened hospitalisation times, an earlier return to work, and fewer recurrences (for pneumothorax), the cost-effectiveness of this approach has not been formally studied. We attempted to cut down the cost of the procedure by using argon coagulation rather than endoscopic staplers, but the results achieved with the former were inferior and we have stopped using argon coagulation for bullae ablation.

It is our opinion that VATS should be the preferred procedure for the diagnosis of idiopathic pleural effusion when less invasive methods fail to establish a diagnosis.[27,28] Pleural metastases are often located at sites which are not amenable to the percutaneous approach.[29] This procedure is also the preferred approach for thoracic sympathectomy as unnecessary dissection is avoided in order to get to the right plane. We believe VATS will play an increasingly important role in the diagnosis of small, peripheral, pulmonary nodules (in the lateral third of the lung and less than 3 cm in size).[4] Our experience with VATS lobectomy is too limited to allow us to meaningfully compare this with con-

ventional lobectomy. This is partly because suitable patients (i.e. those with peripheral tumours less than 5 cm in size, without chest wall or nodal involvement, and ideally with a complete fissure) are difficult to recruit. It is important to be very careful when applying VATS to lung cancer, as we must not allow our enthusiasm to compromise cancer surgery with a curative intent.[16,30]

Video-assisted thoracoscopic surgery and conventional open procedures represent different ends of a continuum in thoracic surgery and should not be viewed as mutually exclusive, but as complementary systems. For example, in a median sternotomy for bilateral pulmonary metastasis, a posteriorly located lung nodule in the lower lobe could be visualised and resected by VATS technique. This location would be difficult to approach entirely from the front. Also, one should not view conversion to open thoracotomy as a failure. If exposure is inadequate or if complications are encountered, one should not struggle to succeed at the expense of the patient. Consent for possible thoracotomy should be routinely obtained in all cases. As endoscopic instrumentation develops, more procedures will become feasible. It is our responsibility to test these ideas in a laboratory setting, and then introduce them into clinical trials, adhering to strict surgical principles.

Interventional bronchoscopy

Use of the CO_2 laser in the treatment of tuberculous strictures has already been reported.[31] It should be emphasised that its use in tumour reduction is suboptimal and hence must be employed judiciously and cautiously as its effect is superficial and the coagulative ability is poor. Until the fibreoptically transmissible Nd:YAG, KTP-532, argon or diode lasers are available locally for bronchoscopic use, the CO_2 laser represents a reasonable substitute.[32]

The flexible bronchoscope is a very useful diagnostic instrument because it is able to negotiate corners and crevices. The side channel allows the passage of optical fibres and hence, transmission of suitable lasers. Deficiencies include the inability to afford ventilation and the lack of an efficient suction channel to evacuate large clots and debris which may obstruct the airway during interventional procedures. The authors prefer to use a universal rigid bronchoscope which is an effective endotracheal ventilation tube and allows the delivery of different types of optically transmissible laser, intervention with dilators, forceps, and large suction cannulas. Probing and tamponade are convenient and placement of stents can be effectively performed via special introducers. Gas induction and assisted spontaneous breathing is the preferred anaesthetic technique.

As was mentioned earlier, the effective and sustained relief of symptoms afforded by the studded Dumon silicone stents should not be discounted and evaluation of its long term use in suitable patients should continue. We are impressed by these silicone stents at 10 and 12 weeks post-insertion in our two patients. There is no evidence of them slipping because of their studs, nor any signs of crusting. The lack of crusting, which is common in tracheostomy tubes, suggests that as long as no external vent is present (which precludes the entry of cold, dry air) these stents will attain the same temperature and humidity as their surroundings, making crusting less likely to occur.

Interventional bronchoscopic procedures will continue to contribute to airway palliation in suitably selected cases, and should be encouraged as they enable asphyxiating patients to return home to their families in comfort.

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