How to Cite:
Hassan, M. O. O., Elkhayat, H., Mohamed, M. S., & Latef, M. K. A. (2022). Video-assisted thoracoscopic (VATS) era in surgical treatment of spontaneous pneumothorax. *International Journal of Health Sciences*, *6*(S2), 15050–15066. https://doi.org/10.53730/ijhs.v6nS2.8984

Video-assisted thoracoscopic (VATS) era in surgical treatment of spontaneous pneumothorax

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***Abstract*---**Background: VATS is now regarded by many surgeons to be the gold standard in the surgical management of a variety of thoracic conditions, such as spontaneous pneumothorax (SP), pleural diseases, and indeterminate lung nodules. Aim and objectives: to describe different VATS techniques in patients with spontaneous pneumothorax.Summary: Several clinical management issues remain unanswered. Firstly, the duration of prolonged air leak that warrants VATS remain controversial. Current recommendations range from five days by BTS to three days advocated by our institute with more than a decade of experience with VATS for SP. Furthermore, whether VATS should be offered to all patients with low general anesthetic risk presenting with first episode of SP is unclear. Furthermore, the evolution of surgical techniques to allow ipsilateral thoracoscopic approach to treat contralateral bullous lesion may redefine the indications for CT scan in SP. Technically, the debate will continue among the surgeons on the type of VATS procedure that will minimize pneumothorax recurrence. Most surgeons will agree that some form of bullectomy (endoscopic staple or suturing) is mandatory. However, the nature of pleurodesis (mechanical, chemical, or both) that follow is often at the discretion of the individual clinician. Proper large-scale randomized trials are required to investigate these controversies in the future.

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.
Manuscript submitted: 27 March 2022, Manuscript revised: 18 May 2022, Accepted for publication: 9 June 2022

***Keywords*---**thoracoscopy, video assisted thoracic surgery, spontaneous pneumothorax.

Introduction

Spontaneous pneumothorax (SP) is a common thoracic condition with an incidence of seven to nine cases per 100,000 of the population annually (1). It has an estimated recurrence rate of 23±50% after the first episode which may rise up to 80% after the third pneumothorax. (2) Because of the advantages of video-assisted thoracoscopic surgery (VATS): - decreased postoperative pain, shorter duration of chest tube insertion and consequently shorter hospital stay, VATS is considered the gold standard surgical technique for the treatment of pneumothorax to resect blebs or bullae and to achieve satisfactory pleurodesis (3).

Several techniques have been described e.g. stapler, laser ablation, endoscopic loop ligation. (3) Minimally invasive technique using staplers to remove bullous parenchyma is the popular method by the majority of thoracic surgeons, but this technique is very expensive (4). Now, the problem of rising health care costs is faced by all countries all over the world, which has become a heavy burden on the state and individuals (5). Although endoscopic surgery offers many benefits, the need for more expensive endoscopic consumables is often associated with high costs. Therefore, avoiding the use of disposable consumables in video-assisted thoracic surgery will help to control the high costs. (6) In our study, we described a new cheap technique which is ligation of bulla by silk ligature during VATS bullectomy and we will compare this technique with using staplers in VATS bullectomy.

Pneumothorax

Pneumothorax is a worldwide disease with incidence variation between men and women. The incidence varies geographically from 7.4 per 100,000 populations per year in the United States to 37 per 100,000 populations per year in the United Kingdom. In women, the incidence is substantially less, ranging from 1.2 per 100,000 populations per year in the United States to 15.4 per 100,000 populations per year in the United Kingdom (7). The reason for these differences is not known Recurrence incidence ranging from 20% to 50% with most recurrences occurring within the first year (8).

Pathophysiology

Emphysema-like changes

As PSP occurs in a normal patient without known lung disease. It is important to note that this does not mean there is no underlying pathologic process. A finding of abnormal pleura is very common in PSP. Abnormalities seen in PSP include blebs and bullae, which are otherwise known as emphysema-like changes (ELCs) Abnormalities can be visualized radiographically with high-resolution computed tomography (CT) scans and macroscopically at thoracoscopy (fig.1). High-resolution CT imaging reveals these defects in approximately 80% of PSP patients. Some case series suggest that there is no association, while others suggest the presence of contralateral blebs/bullae is a risk factor for future pneumothorax. (9)

Figure 1: Apical subpleural bleb visualized via thoracoscopy (9)

Pleural porosity

ELCs are not the sole cause of PSP. Pleural porosity explains air leak that has been described in areas where no ELCs are seen. High-grade abnormalities were not seen in control patients. When studied with electron microscopy, the linings of some resected areas of ELC have been shown to be almost completely absent of mesothelial cells and have abnormal pores present (9).

Distal airway inflammation

Pathologic findings suggest an inflammatory cause to the formation of ELCs. Chronic distal airway inflammation with lymphocyte and macrophage infiltration alongside fibrotic changes and compensatory emphysema can be seen microscopically in areas of lung tissue from patients with PSP. It has been proposed that distal airway inflammation associated with PSP leads to obstructive gas trapping and consequent increases in distal airway pressure, which possibly causes air leak into the pleural space (9).

Smoking

Cigarette smoking is a significant risk factor for PSP. It is thought to be due to the consequences of airway inflammation leading to airway obstruction with a check valve phenomenon, causing air trapping and development of pneumothorax. It is found that cannabis smoking may have a causative link to spontaneous pneumothorax (10). Toxicological screening showed that tetrahydrocannabinol

(THC) which is the active ingredient in Hashish & Cannabis comes on top of the list that associated with increased risk of pneumothorax followed by Tramadol (11)

Genetics

Familial inheritance of pneumothorax describing the clustering of PSP in certain families has been published. Autosomal dominant, autosomal recessive, polygenic, and X-linked recessive inheritance mechanisms have been proposed. In one study of 198 patients with this syndrome, 48 patients (24%) had a history of pneumothorax (9). It is hypothesized that familial spontaneous pneumothorax is caused by a connective tissue disorder that exhibits mendelian inheritance and FBN1 has been postulated as the causative gene (9).

Diagnosis

Clinical diagnosis

In the absence of an associated disorder, PSP is rarely seen before puberty. It is more common in men than in women by a ratio of 6:1, and it is more common in smokers than in nonsmokers. The typical patient with SP is a young, tall, thin male in late adolescence or early adulthood (12). Many patients (especially those with PSP) therefore present several days after the onset of symptoms. The longer this period, the greater is the risk of re-expansion pulmonary edema (RPO) (13). Generally, SSP associated with clinical symptoms which are more severe than those associated with PSP, and the most prominent symptom is breathlessness that is out of proportion to the size of the pneumothorax. These clinical manifestations are therefore unreliable indicators of the size of the pneumothorax (14)

Physical signs

Physical signs of a pneumothorax may be subtle but, characteristically, include: - reduced lung expansion, hyper-resonance on percussion, decreased chest movement ipsilaterally and diminished breath sounds on the side of the pneumothorax. Added sounds such a ‘clicking’ can occasionally be audible at the cardiac apex. In association with these signs, cyanosis, sweating, severe tachypnoea, tachycardia and hypotension may indicate the presence of tension pneumothorax (14). Arterial blood gas measurements are frequently abnormal in patients with pneumothorax, with the arterial oxygen tension (PaO2) being <10.9 kPa in 75% of patients but are not required if the oxygen saturations are adequate (>92%) on breathing room air (15).

Imaging

The imaging modalities have been employed for the diagnosis and management of pneumothorax are (2): Standard erect PA chest x-ray, lateral x-rays, expiratory films, supine and lateral decubitus x-rays, ultrasound scanning, digital imaging and CT scanning.

1. Standard erect PA chest x-ray: It is considered the mainstay of clinical management of primary and secondary pneumothorax for many years, although it has some limitations such as the difficulty in accurately quantifying pneumothorax size (15). The diagnostic characteristic is displacement of the pleural line (fig.2).

Figure 2: Chest radiograph showing right sided pneumothorax (16)

2. Lateral x-rays: These may provide additional information when a suspected pneumothorax is not confirmed by a PA chest film but, again, are no longer routinely used in everyday clinical practice (15).
3. Expiratory films: These are not thought to confer additional benefit in the routine assessment of pneumothorax (15).
4. Supine and lateral decubitus x-rays: These imaging techniques have mostly been employed for trauma patients who cannot be safely moved. They are generally less sensitive than erect PA x-rays for the diagnosis of pneumothorax and have been superseded by ultrasound or CT imaging for patients who cannot assume the erect posture (15).
5. Ultrasound scanning: Ultrasound has a higher sensitivity than the traditional upright anteroposterior chest radiography (CXR) for the detection of a pneumothorax. Sonographic signs, including 'lung sliding', 'B-lines' or 'comet tail artifacts', 'A-lines', and 'the lung point sign' can help in the diagnosis of a pneumothorax. Small occult pneumothorax could be missed by ultrasonography (17).
6. Digital imaging: Digital radiography (Picture-Archiving Communication Systems, PACS) has replaced conventional film-based chest radiography within the last 5 years, conferring considerable advantages such as magnification, measurement and contrast manipulation, ease of transmission, storage and reproduction (18).
7. CT scanning: This can be regarded as the 'gold standard' in the detection of small pneumothoraces and in size estimation (19). It is also useful in the presence of surgical emphysema and bullous lung disease and for identifying aberrant chest drain placement or additional lung pathology. However, practical constraints preclude its general use as the initial diagnostic modality (fig 3). (20).

Figure 3: Coronal CT scan of the chest showing a bulla located in the right lung apex (21)

More accurate CT estimates of pneumothorax highlight the poor prediction of chest radiograph–calculated pneumothorax size. Collins derived a formula based on these data using interpleural distances on an erect chest radiograph to estimate percent pneumothorax as size % = 4.2 + 4.7 × (sum of interpleural distances in centimeters at apex, midpoint of upper half of collapsed lung, and midpoint of lower half of collapsed lung) (22). The ACCP considers a small pneumothorax to be "less than 3 cm in collapse from apex to copula" (46% by the Collins formula if the lung collapses uniformly = 9 cm), while the BTS notes small to be "a rim of air less than 2 cm in collapse between the lung and the chest wall" (32% by the Collins formula = 6 cm). A simplified method classifies a large pneumothorax as complete separation of the lung from the chest wall and a small pneumothorax as partial separation (15).

Treatment of spontaneous pneumothorax

Management of spontaneous pneumothorax focuses on removal of air from the pleural space and preventing recurrences. Options for management ranging from observation to interventional drainage of air in several forms including simple aspiration, small-bore catheter insertion, and tube thoracostomy to VATS and thoracotomy with bleb excision and pleurodesis. Factors determine which is suitable depending on the size of the pneumothorax, severity of symptoms, whether there is an open (persistent air leak) or closed (no air leak) pneumothorax, and whether the pneumothorax is primary, secondary, or recurrent (fig 4) (12).

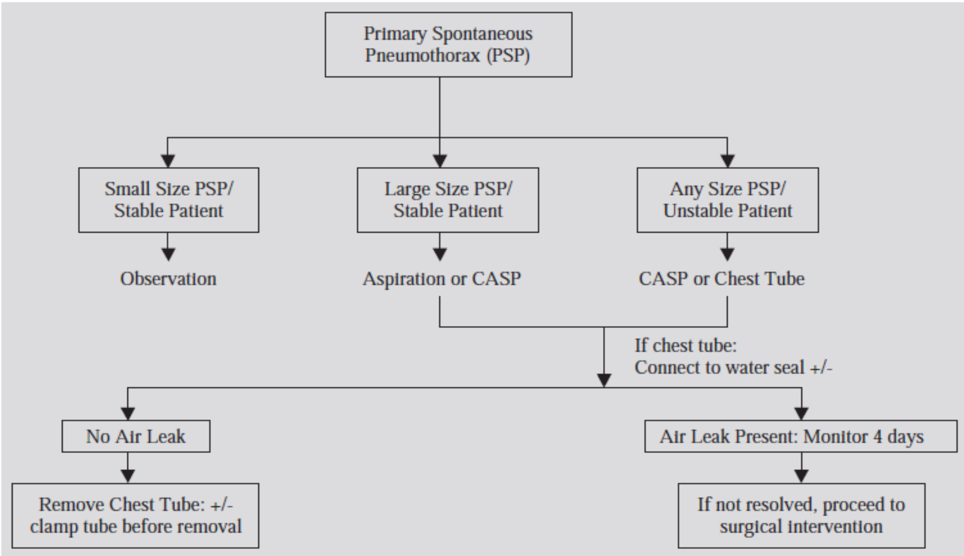

Figure 4: Algorithm for management of first episode of primary spontaneous pneumothorax. CASP, catheter aspiration of pneumothorax (fig 5) (12)

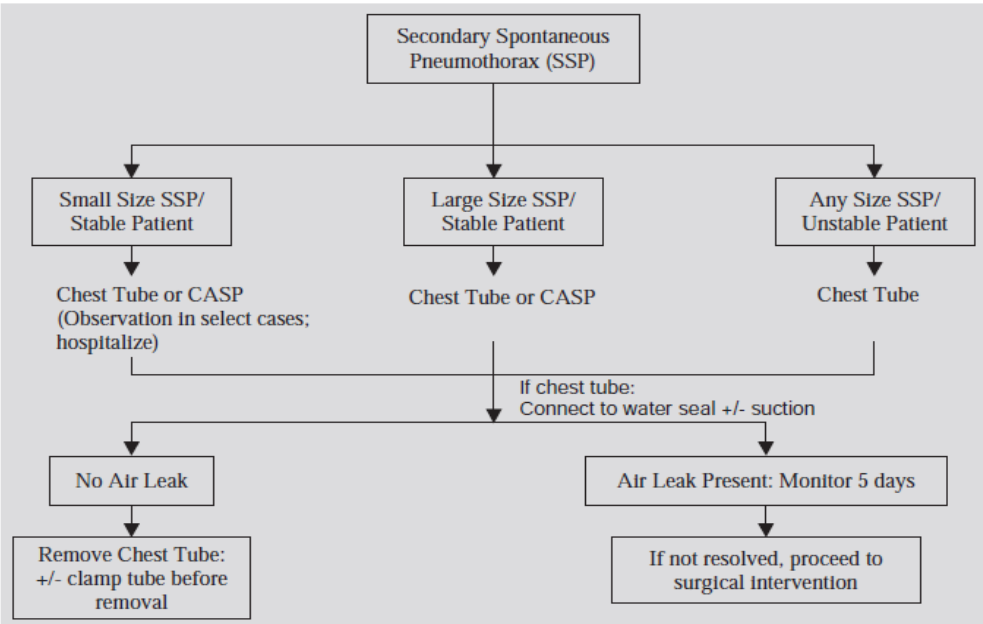

Figure 5: Algorithm for management of first episode of secondary spontaneous pneumothorax (12)

Conservative management

The conservative management consists of observation and oxygen supplementation. Observation of patients without significant breathlessness can occur in the hospital or in an outpatient setting after 6 hours of observation in the emergency department provided that the patient has easy access to medical care that air reabsorbs at a rate of 2.2% per day. The BTS guidelines note that patients with spontaneous pneumothorax admitted for care should receive high-flow (10 L/min) oxygen, with appropriate caution in COPD patients (15).

Follow-up should occur within 2 days. Fatalities have been documented during inpatient observation, as a complication of treatment, or due to misdiagnosis or concomitant hemothorax. For SSP, The ACCP and BTS guidelines reserve observation for clinically stable patients with small pneumothorax (less than 1 cm) in hospital sitting (12, 15).

In recent years there has been a move towards a more conservative approach to management, based on the principle that intrapleural air does not necessarily require a therapeutic intervention, and that management depends on the clinical symptoms and not on the size of the pneumothorax (13, 15). This conservative approach may be appropriate as tension pneumothorax from a PSP is extremely rare.

Within the current British Thoracic Society (BTS) guidelines (from 2010), there is a significant emphasis on a conservative approach to treatment with management predominantly based on clinical symptoms (13, 15). In contrast, the American College of Chest Physicians (ACCP) Delphi consensus statement (from 2001) recommended a more aggressive approach, with intercostal drain placement recommended in any pneumothorax larger than 20% of the hemithorax, irrespective of the symptoms (13).

Drainage

First episodes of PSPs that are large, symptomatic, or progressive may be treated with drainage by simple aspiration with a plastic intravenous catheter, thoracentesis catheter, small-bore (8.5- to 14-Fr) catheter, or by insertion of a small to midsize chest tube (16–28 Fr). Reexpansion of the lung is marked by the onset of cough and some chest discomfort (12).

Needle aspiration

Removal of air from the pleural space can be achieved with needle aspiration or chest drain insertion. BTS and ACCP guidelines differ in their view of the utility of needle aspiration, with BTS guidelines suggesting aspiration as an initial intervention in patients with a large or symptomatic primary pneumothorax and ACCP guidelines. It should be noted that failure with aspiration occurs at a frequency of 25–50% in PSP and that after a failed aspiration there is no evidence to support a second aspiration over chest drain insertion (13).

Small-bore chest drains

A variety of small-bore catheters and pigtails are available; sizes vary from 8.5 to 14 Fr, and these catheters can be easily introduced utilizing the Seldinger technique (23). A simplified stepwise management of PSP has been reported utilizing an 8.5-Fr multiperforated pigtail catheter (24, 25). Recurrence prevention (VATS excision of blebs and pleurodesis) was offered for failures after 48 hours on suction. The 24-hour and 1- week success rates were 61% and 85% respectively, with an actuarial 1-year recurrence rate of 24%. SSP patients who are stable and not at risk for large air leaks can be managed with a small chest tube (16–22 Fr), although small-bore catheters are also appropriate in selected cases (12, 25).

Tube thoracostomy (ICT)

The need for ICT placement in firs attack of pneumothorax is debated between ACCP guidelines and BTS guidelines. ACCP guidelines advocate its placement in clinically stable patient with large sized pneumothorax, while BTS guidelines indicate its use in cases that had failed aspiration or CASP drainage to control the symptoms (15).

Small- or large-bore chest tubes?

Smaller bore (11–13 French) tubes seemed to perform better than larger drains (20–28 French) regarding short-term outcomes (26). This finding was also noted in two non-randomized studies in young adolescents, in whom small-bore pigtail catheters were found to be as effective as large-bore catheters (27, 28). Two prospective French studies have shown that ambulatory management of a first episode of PSP with a small-bore drain and a one-way valve is considered reasonable alternative to manual aspiration or chest tube drainage and results in significant reductions in overall hospital costs (28).

Role of suction

Lung re-expansion is achieved in up to 70% of patients with chest tube drainage alone by day 3 without suction (28). Expert opinion suggests there is no role for the immediate use of suction in all cases (13, 15). The use of a digital suction device, capable of quantifying air leak, has been demonstrated to reduce duration of drainage as well as the duration and cost of hospitalization in patients with an air leak after spontaneous pneumothorax (29).

Recurrence prevention and chemical pleurodesis

Chemical pleurodesis with the instillation of substances into the pleural space based on that method will lead to an aseptic inflammation leading to dense adhesions with subsequent pleural symphysis. Many sclerosing agents suitable for instillation into the pleural space have been studied. Tetracycline used to be recommended as the first line sclerosant therapy for both primary and secondary pneumothoraces as it proved to be the most effective sclerosant in animal models (29). Recently, however, parenteral tetracycline for pleurodesis has become more difficult to obtain owing to problems with the manufacturing process. Minocycline and doxycycline have also been shown to be reasonable alternative sclerosing agents (30).

The dosage of intrapleural tetracycline requires clarification. It is found that a reduction in the recurrence rate in a group receiving 500 mg tetracycline via chest drains compared with those treated by tube drainage alone. This reduction was not significant (31). Adequate analgesia may be achieved with the administration of intrapleural local anesthesia. Standard doses (200 mg (20 ml) of 1% lidocaine) are significantly less effective than larger doses (250 mg (25 ml) of 1% lidocaine), the higher doses having been shown to increase the number of pain-free episodes from 10% to 70% with no appreciable toxicity (32).

Surgical options

Chee et al., (33) showed that 100% of primary pneumothoraces with a persistent air leak for >7 days and treated by tube drainage had resolved by 14 days. Also, 79% of those with secondary pneumothoraces and a persistent air leak had resolved by 14 days, with no mortality in either group (15, 33). Each case should be assessed individually on its own merit. Patients with pneumothoraces should be managed by a respiratory physician, and a thoracic surgical opinion will often form an early part of the management plan (15).

VATS versus open thoracotomy

VATS allow less invasive access to the thoracic cavity and represents the surgical treatment of choice (34). However, several studies showed increase in recurrence rate of pneumothorax after VATS in comparison with open thoracotomy (3.8% vs 1.8% respectively) (35). A subsequent analysis did not confirm these findings when looking at randomized trials alone and showed a reduction in analgesia use and shorter hospital stays in patients treated by VATS compared with open thoracotomy (36). In addition to demonstrating equivalent success rates for VATS compared with open thoracotomy, randomized controlled trials have demonstrated physiological benefits of VATS over thoracotomy including post-operative spirometry and gas exchange (13).

a randomized study in 2007 was done by Pompeo et al. (37) comparing awake VATS (with thoracic epidural analgesia) with conventional general anesthesia. They were able to demonstrate a significant reduction not only in peri-operative pain score and nursing care, but in length of hospital stay and total costs. Such a new approach is interesting, as many other groups have reported less invasive VATS strategies using small caliber instruments or uniport access to the thoracic cavity (38).

Different VATS techniques

The standard VATS procedure involves using 3 to 4 incisions made in a triangular configuration for scope and instrument insertion (triport VATS) (fig. 6).

Figure 6: Images demonstrate multiport VATS technique (39)

The classical triport VATS was refined to biport VATS including camera port and working port for instruments (40). Alternatively, VATS with a single port has also been described (uniport VATS) for more less invasiveness (fig. 7) (41).

Figure 7: Image demonstrate instrument arrangement in uniport VATS (39)

Techniques for VATS blebectomy/bullectomy: Stapler resection, Ligation by silk or endoscopic loop ligation, Bulla suturing, Electrocoagulation (diathermy) and laser ablation. Minimally invasive technique using staplers to remove bullous parenchyma is the popular method by the majority of thoracic surgeons, but this technique is very expensive. In our study, we will describe a new cheap technique which is ligation of bulla by silk ligature during VATS bullectomy and we will compare this technique with using staplers in VATS bullectomy.

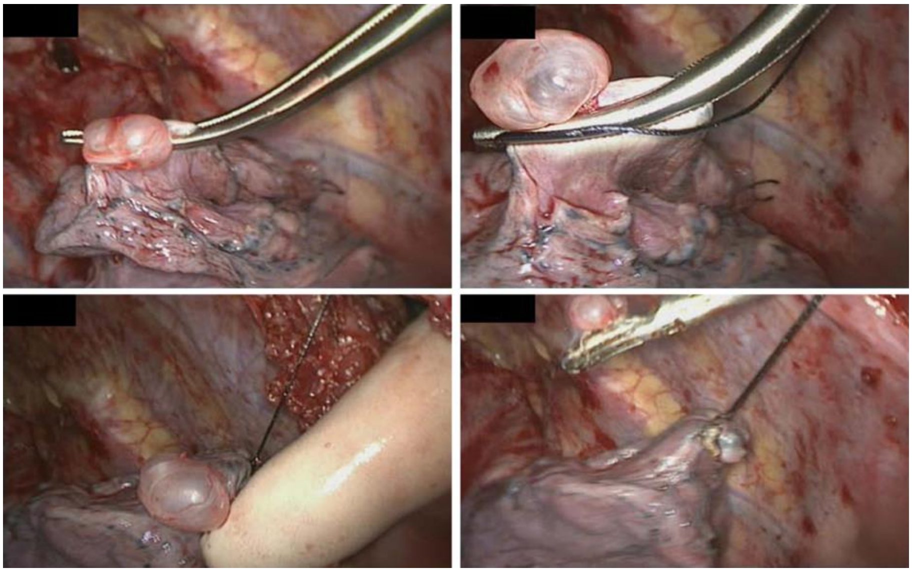

Figure 8: Techniques for VATS blebectomy/bullectomy

New procedures in surgery for pneumothorax

A. Needlescopic VATS for pneumothorax: It is a further evolution of VATS. Compared to the 10 mm wide ports used for conventional VATS, Needlescopic VATS uses a video-thoracoscope and instruments only 2-3 mm in diameter, thereby greatly reducing the size of the ports. The tiny wounds ensure not only reduced pain but cause less compression of the intercostal nerves during manipulation intra-operatively (42).
B. Non-intubated VATS on awake patients: Non-intubated VATS (NI-VATS) is a novel approach that aims to benefit the patient by obtaining the minimal surgical and anaesthetic intervention. In the last years, NI-VATS approach has encouraging results in surgery for pneumothorax (43) (fig. 8).
   Surgical technique is not different from GA-VATS procedures, the concern should be focus in locoregional anesthesia, and adapt surgeon’s skills to NI-VATS field (mediastinal movement, diaphragmatic motion, initial cough reflex…) (44).
   NI-VATS strategies in PSP treatment
   Loco-regional strategies as thoracic epidural anesthesia (TEA) in NI-VATS protocols are well described since 2011 by Chen and colleagues (45).
   In 2015 Li et al. (46) presented the first descriptive study including 32 patients of PSP treated by NI-VATS bullectomy by using epidural catheter and sedation (without intubation). With the limitations of a descriptive study, the results were similar to standard GA-VATS approach for PSP treatment (46). The average time of surgery was 49 min with postoperative feeding time of 6 h, mean postoperative chest tube drainage was 19.3 hours and hospital stay was hours 41.6 hours, respectively.
C. Robotic assisted thoracoscopic surgery (RATS):
   Another approach is the use of robotic surgical systems for pneumothorax surgery (47). RATS provide a 3-dimensional visualization, 7 degrees of freedom of motion and improved visual haptics (fig.9) (48). Some prefer it

> because of several advantages over VATS, including intuitive movements, tremor filtration, more degrees of manipulative freedom, motion scaling, and high definition stereoscopic vision. These advantages promise to make robotic surgery more accessible than VATS (49).

However, robot assisted surgery: does not reduce wound number or size; increases the cost, time, and complexity of surgery; and has never been proven to offer any outcome advantages over VATS for treating PSP. Ten years after the introduction of the robotic systems, these have never fully been established as a mainstream option for PSP surgery (42, 49).

Figure 9: Images demonstrating setup for Robotic Assisted Thoracoscopic Surgery RATS (photo courtesy; Hussein Elkhayat)

Summary

Over the past decade, video assisted thoracic surgery (VATS) has changed the way spontaneous pneumothorax (SP) is managed. Benefits of VATS include less postoperative pain, shorter hospital stay, and attenuated postoperative inflammatory response are evident compared with open thoracic procedures. Furthermore, the increasing acceptance by patients and referring physicians is testament to its success. Recent studies and the authors decade of experience in management of SP by VATS show that it is quick, safe, and effective, with recurrence rates generally comparable to open procedures, with some exceptions. However, selecting the correct procedure and patient, as well as knowing the limitations of the surgeons and techniques are paramount for success. Even to this day, there are considerable variations in the treatment of SP and large-scale controlled studies are needed to better define timing of surgery and the role of the different procedures in the treatment and prevention of SP.

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