14 New Techniques and MIS: The Thoracoscopic Approach

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14.1 Introduction

The video-assisted thoracic surgery (VATS) has gained growing popularity in the last two decades as an alternative to open thoracotomy for the treatment of several spinal conditions and now represents a keyhole in the field of “minimally invasive surgery” to the thoracic spine.

Since the early 1900s, a thoracoscopic approach was used as a diagnostic tool to evaluate pleural disease. The first report of a thoracoscopic approach was published by Jacobaeus in 1910 to diagnose and lyse the tuberculosis lung adhesion [1–3]. With the discovery of streptomycin in 1945 for tuberculosis treatment, there was a decreased in clinical application of thoracoscopy for such condition [4]. In the late 1980s, the technology of endoscopic surgery has dramatically improved. Lewis in 1991 had repopularized the use of VATS for pulmonary disease treatment. In 1993, Mack published the first study of endoscopic approaches to spinal disorders, reporting ten patients with various thoracic spinal pathologies that were effectively operated on endoscopically [5].

14.2 Indications

VATS has been used extensively in spinal deformities such as scoliosis. The use of VATS in spine surgery included the treatment of thoracic prolapsed disk diseases [6, 7], vertebral osteomyelitis [8–11], fracture management [12], vertebral interbody fusion [6], tissue biopsy [8, 13], and anterior spinal release and fusion without [4, 14–22] or with instrumentation (VAT-I) for spinal deformity correction [23–25]. As

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the knowledge and the comfort of using such techniques expanded, the indications extended to corpectomy for tumor resections [26–32].

Although VATS can be performed in such many spine conditions, it is most beneficial in the treatment of scoliotic deformity, when there is a need to a multilevel approach, from the upper to the lower thoracic spine. On the contrary, other conditions where the pathology is localized to one or two segmental levels, like thoracic disk prolapse or infection, can be managed with mini-open thoracotomy as an alternative to open traditional procedure.

The absolute contraindication for VATS includes ones' inability to tolerate single-lung ventilation, FEV 1 less than 50% [13], dense pleural adhesion, respiratory insufficiency, empyema, and failed prior thoracotomy surgery.

Video-assisted thoracoscopic surgery (VATS) has advantages over open thoracotomy, such as less postoperative pain and morbidity, earlier mobilization leading to shorter hospital stays and lower costs, and smaller scars.

14.3 Surgical Anatomy and Technique

The majority of VATS approaches is from the right side for pathology involving the middle and upper thoracic spine because there is a greater working spinal surface area lateral to the azygos vein than that to the aorta [26]. Below T-9, a left-sided approach is made possible that the aorta has moved away from the left posterolateral aspect of the spine to an anterior position as it passes through the diaphragm.

14.3.1 Surgical Techniques

Following induction of anesthesia with the placement of a double lumen intubation tube, the patient is turned to the left lateral position, with the right side of the chest upward. This position is maintained by flexion of the downside hip and knee and secured by using surgical tapes. An axillary roll is positioned to prevent pressure on the dependent shoulder [33–35].

Following the deflation of the lung and the introduction of the thoracoscopy instruments, the involved vertebra is identified under fluoroscopy and the segmental artery identified.

Regarding placement of thoracoscopic instruments, several strategies are possible.

In an *anterolateral approach*, the surgeon stands on the patient ventral side, and more spinal levels can be approached form each portal especially in the presence of a large thoracic kyphosis.

Anterolateral approach also provides a surgical plane dissection between the azygos vein and the vertebrae. The spine could be fenced by temporary gauze placement in this plane thus maintaining a clear visual to the spine and adding extra protection to the anterior spinal structures during spinal release [23].

In a *combined anterolateral and posterolateral approach*, the portals are first placed along the anterior axillary line for spinal release and fusion [16, 20, 22] and then replaced posterolaterally for spinal instrumentation [23]. A disadvantage is the potential danger of working with instrument from an anterior to posterior direction into the spinal canal.

In an all *posterolateral approach*, all access portals are placed between the mid- and posterior axillary lines [24, 25]. The surgeon stands to face the back of the patient; both discectomy with fusion and instrumentation could be performed via these posterolateral portals without the need of additional anterolateral portals.

Comparing with conventional posterior instrumentation and fusion, an all posterolateral approach carries increased technical difficulties in performing a thorough discectomy and a lack of protection to the anterior vascular structure during the anterior longitudinal ligament release.

14.3.2 Discectomy

A successful intervertebral fusion and deformity correction requires a thorough discectomy [13] and end plate clearance. The parietal pleura on the spinal column is incised longitudinally along the peak of the disk where it is most avascular.

Intervertebral segmental vessels should be cauterized slowly, layer by layer; clear surgical field with minimal bleeding facilitates the thoracoscopic procedure.

Once the intervertebral disk is exposed beneath the pleura, the annulus is incised by a long handled no. 15 scalpel blade. A pituitary rongeur is used to remove the annulus disk complex. The cartilaginous end plates are separated from the subchondral vertebral bone by using a sharp cut Cobb elevator; and the final clearance of the disk space is carried out by a combination of straight and angled pituitary rongeurs and cup curettes.

Partial released of the anterior longitudinal ligament (ALL) is often adequate [25], and the residual ALL may assist in retaining the bone graft in the disk space. The posterior longitudinal ligament (PLL) is not incised during anterior spinal release and may act as a protective barrier to the spinal cord.

The resection of the proximal 2 cm of rib head (except when the level was below T11) is required to achieve thorough clearance at the posterolateral corner of the disk [6]. The foraminal ligaments are then cut to expose the superior edge of the pedicle. The superior part of the pedicle is resected to expose the spinal canal.

14.3.3 Spinal Deformity Correction

14.3.3.1 Portal Localization

Incisions for the thoracoscopic ports are centered over the ribs. Entry into the chest is made over the cephalad and caudal edges of each rib resulting in eight entry portals from just four chest wall incisions. Typically, the third and ninth rib incisions are placed at the mid-axillary line, while the fifth and seventh rib incisions are at the posterior axillary line. If the instrumentation needs to be performed from T6 to L1, the incision array is moved caudally, onto the fourth, sixth, eighth, and tenth ribs [36].

A 2-cm skin incision is cut parallel to the rib. Lung ventilation in the operative side is blocked, and one-lung ventilation on the nonoperative side is achieved. The partial pleura on the chest wall is incised at the superior border of the rib. Gentle dissection must be employed to avoid iatrogenic pulmonary parenchyma injury during the first portal insertion. The remaining portals are inserted under direct thoracoscopic vision.

14.3.3.2 Spinal Fusion

Following after discectomies, segment of the rib under the skin incisions are removed via open rib harvesting technique and rib cutter. This provides autogenous rib graft for intervertebral body fusion and a possible thoracoplasty effect. Alternatively, the rib graft can be harvested via a closed endoscopic technique [37], or iliac crest graft could be used [17].

14.3.3.3 Vertebral Bone Screw Insertion

The vertebral screw entry point is located just anterior and inferior to the corresponding rib head. Instrument directed into the spine should be placed perpendicular to the imaginary plane between the X-ray tube and the image intensifier on either ends of the C-arm. This would avoid iatrogenic spinal canal penetration by instruments [36].

The exact techniques of screw insertion will depend on the particular type of thoracoscopic instrumentation used. The final screw position should be in the middle of the vertebral body and parallel to its vertebral end plates. Bicortical screw purchase is preferable. It is critical to ensure that each screw head is placed against the near cortex of each vertebra.

Instrumentation systems that allow for small screw length increments (e.g., 2.5 mm per interval) are preferable to avoid the placement of excessive long screws, where the screw tip could impinge on the aorta on the contralateral side of screw insertion [36].

14.4 VATS Results in Various Spine Conditions

14.4.1 Thoracic Disk Disease

Rosenthal and Dickman reported the results of 55 consecutive patients undergoing VATS discectomy [7]. Seventy-nine percent of the radiculopathic patients recovered completely. When compared the VATS results to their patient treated by costotransversectomy or thoracotomy, they found VATS was associated with 50% less blood loss and an hour less operative time. Anand and Regan [6] reported their results of 100 consecutive cases of thoracic disease treated by VATS. They classified the disease according to the symptoms: Grade 1 (pure axial), Grade 2 (pure radicular), Grade 3A (axial and thoracic radicular), Grade 3B (axial with lower leg pain), Grade 4 (myelopathic), and Grade 5 (paralytic). An overall subjective patient satisfactory rate was 84%, and objective long-term clinical success was obtained in 70% of patients at 2 years.

14.4.2 Spine Fracture

Dickman et al. reported a comparable outcome in fracture management between VAT-vertebrectomy and open thoracotomy group [26].

14.4.3 Spine Tumor

Many authors had described the use of VATS in management of primary and metastatic spinal tumors [9, 28, 30–32]. Konno et al. reported the use of a combined hemi-laminectomy with medial facetectomy via a standard posterior approach and thoracoscopic resection for the management of five dumbbell-type thoracic cord tumors. No instrumentation was used. All patients regained their ability to walk. There was no recurrence of tumor and spinal instability at 3 years after the operation. In a series of 41 patients with metastatic tumor decompressed by VATS, there were two (5%) perioperative deaths, and both were related to respiratory complications [29].

Moreover thoracoscopy was increasingly used for vertebrectomy in the mid-1990s [26]. As the knowledge and the comfort of using such techniques expanded, the indications extended to vertebrectomy for tumor resections [26, 27]. The improved exposure, reduction in operative time, and blood loss, as well as improved recovery times, were notable. As a matter of fact, a thoracoscopic-assisted anterior approach could reduce the duration and the morbidity of a vertebrectomy without affecting oncological management.

14.4.4 Vertebral Osteomyelitis

The use of VATS to obtain tissue confirmation for a faster and more reliable diagnosis of thoracic spinal tuberculosis has been reported [8]. Endoscopic approach to the treatment of thoracic vertebral osteomyelitis may reduce the surgical morbidity that is otherwise untolerated in these sick patients [9–11, 29].

Vertebral tuberculosis constitutes 50% of all cases, 44% of which occur in the dorsal spine [38]. Thoracoscopic surgery obtains radical debridement, leading to a direct visualization of the dural sac and kyphotic deformity correction with interbody cage and anterior screwing [39]. Huang et al. showed the reliability and effectiveness of thoracoscopy in the management of ten patients with dorsal tuberculous spondylitis [9]. There was no recurrence of infection at the 24-month follow-up examination.

Muckley et al. reported the management of three elderly patients with pyogenic vertebral osteomyelitis and epidural abscess by VAT-I [11]. Radical debridement; ipsilateral pedicle resection of the pathological vertebrae, leading to direct visualization of the dural sac; and spinal canal decompression were performed. Interbody fusion and kyphotic deformity correction were achieved with an expandable titanium interbody fusion cage containing autogenous bone graft and gentamycin-impregnated collagen sponge. The construct was further stabilized with an anterior fixation system. There was no recurrence of infection and no loss of postoperative kyphotic correction at 2 years. Operative time and blood lost were comparable to open techniques.

14.4.5 Scoliosis Correction

Thoracoscopic surgery for scoliosis can be performed in two forms: anterior spinal release with fusion without [4, 14–18, 20–22] or with anterior instrumentation [23–25]. Anterior spinal release is used for severe or rigid curves or in young patients where there is a need to achieve anterior and posterior spinal fusion, as the first stage of a two-stage procedure. The second stage is conventional posterior fusion and instrumentation [40].

Arlet published a meta-analysis of anterior thoracoscopic spine release in scoliotic deformity surgery [41]. He found an average of four to seven disks was excised with an operative time varied between 150 and 240 min. The average Cobb angle of the structural curve was 65°. The percentage of curve correction was 55–63% after VATS and posterior spine fusion. The total complication reported was 18%, and most were pulmonary complications noted in patients with neuromuscular deformity. In one series, the author noted a 28% cost increased in VATS when compared to standard thoracotomy. The conversion rate from VATS into thoracotomy found in series with over 100 cases was from 0 to 3% [15–20].

Liu operated on patients with adolescent idiopathic scoliosis either performing thoracoscopic fusion or anterior instrumentation. The author found no difference in outcome between the two groups with regard to postoperative Cobb angle, thoracic kyphosis, and lumbar lordosis at different time points in 2 years. Operative time was significantly longer than for conventional posterior instrumented fusion (7 h versus 4 h); blood loss was less; and ICU stay was longer with the thoracoscopic method compared to posterior instrumentation [36].

Newton et al., in a report to the Scoliosis Research Society in 2002, compared anterior thoracoscopic instrumented fusion to anterior open and posterior instrumented fusion in a cohort of patients from a number of surgeons. He found similar outcomes in all three approaches. There was a trend toward better correction in the posterior instrumented group, but the differences were not statistically significant.

14.5 Complications

Complications associated with thoracoscopic procedures are similar to those of open thoracotomy, with variations in the incidence. In addition, anesthesia, patient positioning, port placement and access, and instrument manipulation also contribute to other specific complications [42].

Complications related to anesthesia are mainly related to single-lung ventilation: incorrect placement, inaccurate tubing size, and over- or underinflation of the bronchial cuff that can lead to air leaks into the operated lung [43]. Some patients may also have pulmonary blebs, which spontaneously burst and cause a pneumothorax, resulting in hypercarbia, hemodynamic instability, and even venous gas embolism. Ventilation-perfusion mismatch resulting in arterial desaturation may occur secondary to both lungs being perfused while one lung is ventilated [43].

Lateral decubitus positioning may affect the brachial plexus either by pressure on the side the patient is lying on or by over-abducting the arm on the operated side.

Regarding complications related to endoscope placement, injury to the lung parenchyma and other vessels may occur [10, 43, 44] as the initial port is placed blindly. Lung adhesions may be the cause of lung injury during port placement and postoperative air leaks.

Injury to large intrathoracic vessels may also occur with instrumentation. Endoscopic instruments and retractors placed in the chest cavity can cause injury to the lung parenchyma and to large vessels in the chest cavity, leading to air leaks postoperatively and excessive blood loss intraoperatively [10, 43, 45, 46]. Burns from the tips of the endoscopes may occur when they get extremely hot. Postoperative intercostal neuralgia may occur as a result of pressure on the intercostals nerves by rigid thoracoscopic ports or during trocar placement [10, 29, 43]. McAfee et al. [10] reported intercostal neuralgia as the most common complication encountered in VATS in spinal disorders (7.7%), followed by symptomatic atelectasis (6.4%). Other VATS-related complications that have been reported are excessive (>2000 cc) intraoperative blood loss (2.5–5.5%) [10, 29], pneumonia (1–3%) [15, 20, 29], wound infections (1–3%) [20, 29], chylothorax (1%) [20, 29], hemidiaphragm [10] and pericardial penetration [29], tension pneumothorax [15, 47], and long thoracic nerve injury [25].

Proper techniques, such as entering the chest very gently, avoiding the neurovascular bundle, placing all ports other than the initial port under endoscopic monitoring, and visualizing instruments from entry to exit, can avoid injury to the diaphragm and large intrathoracic vessels.

Obtaining an adequate emergency, vascular control in thoracoscopic surgery is potentially difficult. Sucato et al. has highlighted the possibility of injury to the thoracic aorta from vertebral body screws at the apex of the scoliotic curve [39]. This is because the thoracic aorta often lies on the left side of the vertebral body in scoliosis instead of the more anterior position in normal patients, and inappropriately long screws inserted from the right side could penetrate the thoracic aorta.

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