ORIGINAL ARTICLES

Video-Assisted Thoracic Surgery to Treat Spinal Deformities: Climbing the Learning Curve

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OBJECTIVE: The aim of this study was to analyze the impact of the learning curve on the preliminary results of video-assisted thoracic surgery for spinal deformities in a general hospital setting.

PATIENTS AND METHODS: We retrospectively reviewed the medical records of 15 patients who underwent video-assisted thoracic surgery performed by a multidisciplinary team comprising orthopedic and thoracic surgeons. Endoscopic anterior release and fusion were followed by posterior instrumentation in a single procedure. Demographic, orthopedic, morbidity, and mortality statistics were compiled for the 15 patients and compared to results reported for similar series.

RESULTS: Endoscopic surgery was indicated for 15 patients: 11 women (73.3%) and 4 men (26.7%). The median age was 15 years (interquartile range [IQR], 14–19 years). Three patients (20%) required conversion to thoracotomy. There were 2 serious (13.3%) and 3 minor complications (20%). They all resolved satisfactorily and there was no perioperative mortality. The median Cobb angle was 71° (IQR, 63.75°–75.25°) before surgery and 41° (IQR, 30°–50°) after surgery. Median duration of surgery was 360 minutes (IQR, 300–360 minutes), duration of postoperative recovery unit stay was 1.5 days (IQR, 1–2.75 days), and total hospital stay was 11.5 days (IQR, 8.25–14 days).

CONCLUSIONS: Despite the complexity of video-assisted thoracic surgical procedures, we believe they will become the standard approach to treating spinal deformities in the near future. By working together in general hospital settings, orthopedic and thoracic surgeons can help to overcome the steep yet manageable learning curve.

Key words: *Diskectomy. Spinal fusion. Scoliosis. Thoracoscopy. Video-assisted thoracic surgery. Endoscopic treatment of scoliosis.*

Cirugía torácica videoasistida de las deformidades espinales: afrontando la curva de aprendizaje

OBJETIVO: Analizar el impacto de la curva de aprendizaje sobre los resultados iniciales de la cirugía torácica videoasistida de las deformidades espinales realizada en un hospital general.

PACIENTES Y MÉTODOS: Se revisaron de forma retrospectiva los registros clínicos de 15 pacientes intervenidos de deformidades espinales mediante cirugía torácica videoasistida por un equipo multidisciplinario formado por cirujanos ortopédicos y torácicos. El procedimiento consistió en la liberación y fusión anteriores endoscópicas, seguidas de una instrumentación posterior en el mismo acto. Se compararon los datos demográficos, ortopédicos y de morbimortalidad con los de otras series publicadas.

RESULTADOS: Se indicó el abordaje endoscópico en 15 pacientes –11 (73,3%) mujeres y 4 (26,7%) varones–, con una edad mediana de 15 años (rango intercuartílico [RIQ]: 14-19). En 3 casos (20%) fue necesario convertir el procedimiento en una toracotomía. Se registraron complicaciones graves en 2 pacientes (13,3%) y leves en 3 (20%). Todas se resolvieron satisfactoriamente y la mortalidad perioperatoria fue nula. La mediana de los ángulos de Cobb preoperatorios era de 71º (RIQ: 63,75-75,25) y pasó a ser de 41° (RIQ: 30-50) tras la corrección. Las intervenciones duraron una mediana de 360 min (RIQ: 300-360). Los pacientes permanecieron ingresados en la unidad de reanimación una mediana de 1,5 días (RIQ: 1-2,75) y la estancia hospitalaria total fue de 11,5 días (RIQ: 8,25-14).

CONCLUSIONES: La aplicación de la cirugía torácica videoasistida a la enfermedad deformativa del raquis torácico resulta técnicamente compleja pero ineludible en un futuro inmediato, con una curva de aprendizaje dilatada pero abordable en un hospital general si se hace de forma conjunta por cirujanos ortopédicos y torácicos.

Palabras clave: *Discectomía. Fusión espinal. Escoliosis. Toracoscopia. Cirugía torácica videoasistida. Tratamiento endoscópico de la escoliosis.*

Introduction

Because of its position in the torso, the thoracic spine can be accessed using either a posterior or a transthoracic approach. The second offers a number of mechanical advantages: it allows the release, fusion, and epiphysiodesis of vertebral bodies, more effective fixation and mobility,

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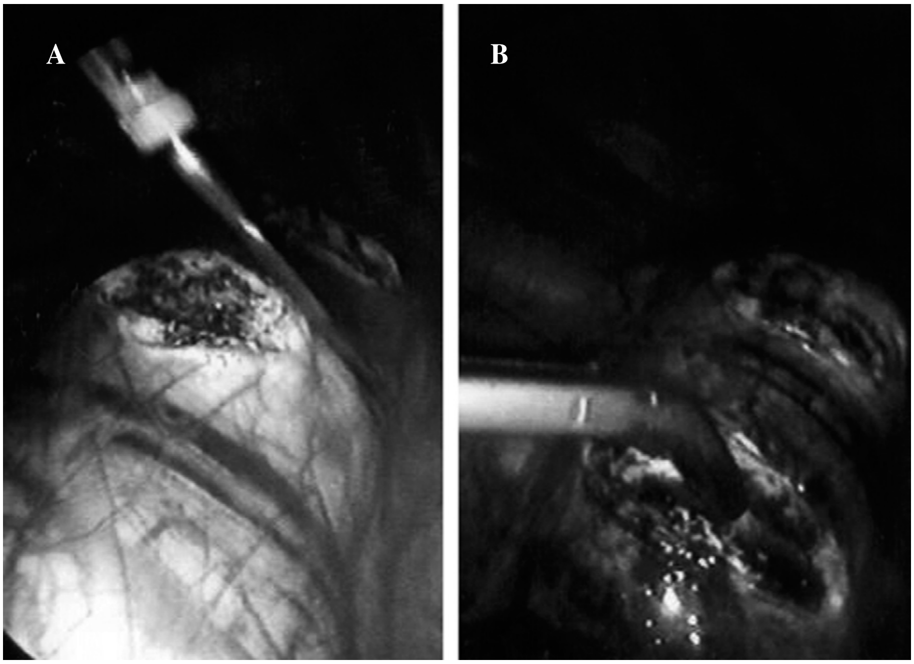

Figure 1. Endoscopic images: opening of pleura via electrocautery (A) and excision of intervertebral disk with a rongeur (B).

and a reduction in instrumentation times.[1-6] One major drawback of the transthoracic approach, however, is a higher rate of perioperative morbidity.[6-8] Since the addition of video-assisted thoracic surgery (VATS) to the therapeutic arsenal for the treatment of spinal diseases at the beginning of the 1990s,[8-10] this alternative has demonstrated many advantages, reducing pain,[11,12] blood loss, length of hospital stay, and lung and shoulder joint involvement. VATS also offers improved visualization and access to the upper and lower ends of the spine and better cosmetic results for the patient than traditional thoracotomy.[1-3,5-7,13-15]

These advantages come at a cost, however: VATS is a technically complex procedure with a steep learning curve.[2,4-7,13,14] According to several authors, the key to successfully managing this learning curve is to adopt a multidisciplinary approach and have prior training in endoscopic procedures.[1,2,6-8,15-17]

We describe our early experience with VATS to treat spinal deformities and analyze how working with a team of thoracic and orthopedic surgeons influenced our learning curve.

Patients and Methods

We performed a descriptive retrospective study of the medical records of 15 consecutive patients with spinal deformities who underwent VATS between February 1998 and August 2004. In all cases, anterior release and fusion and posterior instrumentation were combined in a single procedure. The anterior approach, used by an orthopedic surgeon and a thoracic surgeon, involved spinal release, diskectomy, arthrodesis and/or epiphysiodesis with autologous bone grafts. The entire procedure was performed endoscopically except when conversion to thoracotomy was necessary.

All of the patients were intubated with a double-lumen endotracheal tube to allow selective lung collapse. They were then placed in a lateral decubitus position and rolled 45º towards the prone position, with the convex face of the curve pointing upwards. An axillary roll was placed under the lower axilla. Patients with kyphosis were placed with their right side higher. The rolling of the patient towards the prone position helps the lung to fall towards the anterior portion of the thorax, thus facilitating access to the spinal column. The surgical drapes were placed as appropriate for a posterolateral thoracotomy and a surgical instrument kit was available during all procedures in case an emergency thoracotomy was required. Surgical access was gained through three 12-mm portals. The first portal was in the sixth or seventh intercostal space in the midaxillary line to allow optimum exploration of the hemithorax and determine the location of the 2 other portals. In most cases, those portals were located near the diaphragm and at the apex of the spinal curve to create a triangle-like arrangement. The next step was to open the pleura, incise the fibrous ring by electrocautery, excise the vertebrae and intervertebral endplates (Figure 1), and partially release the anterior longitudinal ligament. Release of the anterior ligament was more complete in patients with kyphosis. An x-ray image intensifier was used in all cases to determine the location of the discs to be excised.

The autologous bone grafts were harvested from the iliac crest or rib. Rib grafts were taken from the exposed rib segments at the site of the portal incisions. Only the upper half of the segments were extracted in order to protect the intercostal neurovascular bundle and preserve the costal arch. At the end of the procedure, lung reexpansion was confirmed before closing the portals. A 24-gauge Charrière chest tube was left in the lowest portal. It was not considered necessary to close the pleura over the grafted intervertebral spaces.

The double-lumen endotracheal tube was then replaced by a single-lumen tube and the patients were placed in a prone position for the posterior approach. In this second phase, patients with thoracic scoliosis underwent thoracoplasty—consisting of the excision of 2 to 3 posterior ribs from the apex of the curve—to improve cosmetic results. Patients without complications were extubated in the operating room or immediately afterwards in the postoperative recovery unit. The chest tube was removed once it had been confirmed that there were no air leaks and that the volume of fluid drained in 24 hours was less than 200 mL.

Patient characteristics, diagnosis, location of deformity, associated diseases, symptoms, whether there was conversion to thoracotomy (and the reason for conversion) were recorded in all cases. For patients who did not require conversion to open surgery, we also analyzed total operating time (including anterior release/fusion and posterior instrumentation), number of discs excised, performance of thoracoplasty, bone graft source (iliac crest or rib), duration of stay in the postoperative recovery unit, total hospital stay, duration of chest tube drainage, number of blood units transfused (including information on autologous blood donations), and perioperative morbidity (during surgery or within 30 days). For patients with scoliosis, we recorded the Cobb angle before surgery and at 1 month, the flexibility of the curve, and the coexistence of kyphotic deformity (scoliosis and kyphotic deformity were expressed as dichotomous variables).

Statistical Analysis

Qualitative variables were expressed as absolute frequencies and percentages and quantitative variables as medians and interquartile ranges (IQR). All analyses were performed using the Statistical Package for Social Sciences, version 9.0 for Windows (SPSS, Chicago, Illinois, USA).

Results

Endoscopic surgery was indicated in 15 patients: 11 women (73.3%) and 4 men (26.7%), aged between 13 and 43 years (median age, 15 years; IQR,14-19 years). Of these, 8 (53.3%) had a nonstructural scoliotic curve, 5 (33.3%) had a structural curve, and 2 (13.3%) had Scheuermann disease. All the deformities were located between T2 and L3. Of the 15 patients, 10 (66.7%) had related congenital malformations, 4 (26.7%) had no concomitant diseases, and 1 (6.7%) who had Scheuermann disease also had an occupational history of repeated trauma to the spine. Four patients (26.7%) had pain, 3 (20%) had motor neurological symptoms (functional impotence), and 1 (6.7%) had sensory neurological symptoms (paresthesia). Eleven patients (73.3%) had no symptoms that were attributable to spinal disease. Table 1 shows the patients' diseases and symptoms.

Three (20%) of the 15 VATS procedures had to be converted to conventional posterolateral thoracotomies: in 1 case (6.7%) because it was technically impossible to perform the diskectomy endoscopically, in another (6.7%) because bleeding in a segmental artery had to be brought under control, and in another (6.7%) because the patient was unable to tolerate single-lung ventilation. Thus, the VATS procedure was completed in 12 patients (80%).

The median duration of the 12 operations was 360 minutes (IQR, 300-360 minutes). No significant reduction in operating times was observed as the series progressed. Operating time included the anterior and posterior approaches and the time required to change the endotracheal tube and reposition the patient. The number of intervertebral discs excised was 4 in 9 patients (75%) and 3 in 3 patients (25%). A thoracoplasty of the apex of the curve was performed for cosmetic reasons in 3 patients (25%). The iliac crest rather than the rib was used to harvest the bone graft in the 3 most recent cases (25%).

The median duration of the postoperative recovery unit stay was 1.5 days (IQR, 1-2.75 days) and the total hospital stay was 11.5 days (IQR, 8.25-14 days). The chest tubes were removed on postoperative day 3.5 (IQR, day 3-5). A median of 2.5 units of blood (IQR, 2-4 units) was required for each patient. Two units of autologous blood were used in 4 (33.3%) patients.

Five patients (41.7%) had postoperative complications. There were 3 cases of atelectasis (24.9%), 1 case of acute respiratory failure (8.3%), and 1 case of pneumothorax with persistent air leak lasting longer than 5 days (8.3%). Two (16.7%) of the above complications were serious, requiring prolonged endotracheal intubation in 1 patient with acute respiratory failure and reinsertion of the endotracheal tube and mechanical ventilation in another patient with massive atelectasis in 1 lung. All the complications resolved satisfactorily and there were no perioperative deaths. Figure 2 shows the overall results for the 15 patients included in the study.

TABLE 1
Patient Medical Histories and Symptoms

Case	Sex	Age, y	Diagnosis	Comorbidity	Pain	Paresthesia	Functional Impotence
1	Female	14	Structural scoliosis	Cerebral palsy	No	No	No
2	Male	43	Scheuermann disease	Repeated trauma.	Yes	Yes	Yes
3	Male	15	Nonstructural scoliosis	Cryptorchidism. Hernia. Heart disease Strabismus.	No	No	No
4	Male	19	Structural scoliosis	Cerebral palsy. Hydrocephaly. Brain tumor	No	No	No
5	Male	32	Nonstructural scoliosis	Hemivertebra T10. Asymmetric vertebral fusion.	No	No	No
6	Female	26	Scheuermann disease	No	Yes	No	Yes
7	Female	18	Structural scoliosis	Craniosynostosis. Obesity	Yes	No	Yes
8	Female	13	Structural scoliosis	No	No	No	No
9	Female	18	Nonstructural scoliosis	Congenital hip dislocation. Flat foot	Yes	No	No
10	Female	16	Nonstructural scoliosis	No	No	No	No
11	Female	15	Nonstructural scoliosis	No	No	No	No
12	Female	13	Nonstructural scoliosis	Pectus excavatum	No	No	No
13	Female	14	Structural scoliosis	Rett syndrome. Valgus flat foot	No	No	No
14	Female	15	Nonstructural scoliosis	Syringomyelia	No	No	No
15	Female	13	Nonstructural scoliosis	Overlapping syndromes. Psychomotor delay Impaired vision.	No	No	No

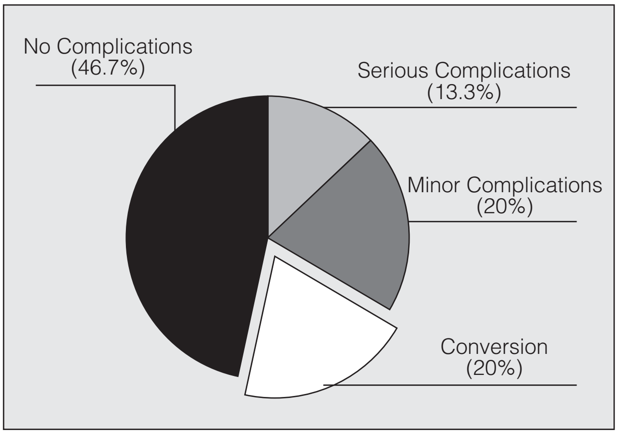

Figure 2. Summary of overall results for 15 patients included in the study.

TABLE 2
Correction of Scoliosis Using Endoscopic Anterior Approach

Case	Type of Curve	Kyphosis	No. Discs Excised	Cobb Angle	
				Preoperative	Postoperative
1	Structural	Yes	4	80º	30º
3	Nonstructural	No	4	65º	30º
7	Structural	Yes	4	70º	40º
8	Structural	No	3	50º	50º
10	Nonstructural	No	4	75º	50º
11	Nonstructural	No	4	76º	25º
12	Nonstructural	No	4	75º	45º
13	Structural	Yes	4	72º	43º
14	Nonstructural	No	4	60º	31º
15	Nonstructural	Yes	4	65º	50º

Of the 10 patients diagnosed with scoliosis who underwent VATS, 4 (40%) had a structural curve and 6 (60%) had a nonstructural curve. Scoliosis was diagnosed in 6 cases (60%) and scoliosis and kyphosis in 4 cases (40%). The median Cobb angle was 71º before surgery (IQR, 63.73º-75.25º) and 41º (IQR, 30º-50º) following surgery. Table 2 shows a breakdown of these data per patient.

Discussion

A description of the first thoracoscopy performed in Stockholm, Sweden, with a modified version of a cystoscope was published in 1910 by Jacobaeus,[18] who was not a surgeon but a professor of medicine. Jacobaeus described how he had used the procedure to lyse lung adhesions for lung collapse therapy in patients with pulmonary tuberculosis. The procedure was adopted by doctors all over the world and enjoyed widespread use until the arrival of streptomycin in 1945, after which it was relegated to relatively minor diagnostic procedures.[19] The addition of video images to "classical" thoracoscopy at the beginning of the 1990s was the birth of what is now known as VATS. This new technique quickly found new applications,[20] one of which was spinal surgery.[9,10] Mack and colleagues,[8] for example, reported how they used VATS in 10 spine surgery procedures, including 3 anterior release and fusion approaches, to treat kyphosis and/or scoliosis in 1993. In 1998, Freixinet and colleagues,[21] working in Spain, reported a series of 35 transthoracic approaches to the spine which included 2 (3.6%) video-assisted procedures.

VATS was rapidly embraced by spinal orthopedic surgeons in the hope that it would minimize postoperative morbidity without sacrificing the mechanical advantages that anterior release and fusion afford: greater correction of structural and/or very pronounced curves, fusion of vertebral bodies in progressive deformities, and epiphysiodesis in skeletally immature patients to prevent the crankshaft phenomenon.[2,6,13,15] A constraint, however, was the continued need for posterior instrumentation in all cases. In recent years, efforts have focused on designing anterior instruments that can be inserted endoscopically, eliminating the need for posterior incisions.[1-3,13,22-25] The aim is to achieve proper stabilization and greater spinal flexibility[3,4] with shorter fixation devices. Results from biomechanical tests[24,25] and clinical practice[3,5,6] have shown that VATS is comparable to conventional open surgery (thoracotomy) in terms of correcting thoracic spine deformities but that VATS has the added advantage of reducing postoperative morbidity.[1-3,5-7,13-15]

The advances made so far, however, have increased the complexity of an already demanding procedure, so much so that some authors advise against the use of endoscopic instrumentation in routine practice.[4,14] Furthermore, we are dealing with a condition that is not very common.[8] This makes it difficult for surgeons working in general hospital settings to achieve a critical mass of patients that will allow them to progress along the learning curve. In fact, the majority of large published series are from specialized centers. Since the procedure was first described,[8] numerous publications have highlighted the importance of combining experience in orthopedic surgery and VATS to minimize the impact of the learning curve on results.[1,2,6-8,15-17] The program we launched in our center in 1998 for thoracoscopic anterior release and fusion with posterior instrumentation combines the experience of 3 departments: orthopedic surgery, traumatology, and thoracic surgery. Although our study spans a period of over 6 years, it includes just 15 operations, all of which can be considered to form part of our learning curve. A reduction in operating time is an objective sign of learning and, according to several authors, progress is achieved in between 13 and 30 cases.[1,5,6] The similar length of all the procedures in our case is consistent with our position on the learning curve, and the size of our series is very close to the 13 cases described by Huang and colleagues.[5]

It is not possible to compare our results with many of those published in the spinal surgery literature due to differences in study design. Nevertheless, Table 3 shows results from our series and 2 others which used a similar method. Patient age, duration of postoperative recovery unit stay, duration of chest tube drainage, and total hospital stay are easy factors to analyze and there were no major differences between the 3 studies.

The first difference we found with respect to the other 2 studies was that we had a smaller number of patients for the duration of the study and a higher number of conversions to thoracotomy (3 [20%]). On analyzing the reasons for conversion, however, we believe that this difference is only partly attributable to the learning curve. Single-lung ventilation intolerance is a contraindication for VATS regardless of the level of surgical expertise.[2,6] This would mean that the actual number of conversions attributable to surgical technique was 2 (13.3%).

There was also a high percentage of perioperative complications in our series. The most common complication was atelectasis (3 cases [24.9%]). This is consistent with the findings of the majority of the publications reviewed, which cite atelectasia and neuralgia as the most common complications.[1,14,15,17] Based on our experience in general thoracic surgery, we believe that although respiratory complications like atelectasis and respiratory failure are somewhat linked to operating time, they are heavily dependent on the patients' general preoperative condition, and particularly on their ability to participate in postoperative respiratory rehabilitation programs.[2,3] For this reason, we believe that the higher percentage of complications in our series could be related to the higher level of comorbidity in our patients. The percentage of complications was 16.67% in the series of Krasna and colleagues,[7] which included patients with idiopathic scoliosis and kyphosis, but 23.08% in the series reported by Huang and colleagues,[5] which included patients with idiopathic scoliosis, Scheuermann disease, neuromuscular disorders, and spinal abnormalities. Early and colleagues,[26] on reviewing a group of pediatric patients, 81 of whom underwent VATS, found a significantly larger number of excised discs, blood loss, and length of stay in patients with associated neuromuscular disorders than in those without. This association was also described by Newton and colleagues,[6] but they did not cite prolonged endotracheal intubation or atelectasis among the complications. We firmly believe that the learning curve is just one of the factors responsible for our higher number of complications and that a careful selection of patients is key to obtaining optimal results. We cannot ignore, however, that it is precisely those patients who are most at risk from developing complications that could benefit most from this minimally invasive technique. All the complications in our series resolved satisfactorily and we experienced none of the serious complications cited by other authors and listed in Table 4.

Another difference we found was the number of discs excised: a median of 4 in our series and 5 (maximum of 8) in the series of Krasna and colleagues,[7] and a mean of 6 in that of Huang and colleagues.[5] Although the excision of a larger number of discs requires a more aggressive approach and an increasingly greater number of portals, it also allows more patients to benefit from the procedure. In our series, we selected patients with deformities that could be accessed using conventional thoracoscopy through 3 portals, and this could be one of the reasons why our cumulative number of cases was small. Given our results, however, we feel optimistic about approaching increasingly long segments of the spine endoscopically. By doing so, we will be offering the procedure to more patients and gaining more experience. Newton and colleagues[6] reported an increase in the number of discs excised as their series progressed. Such an increase could, therefore, be both cause and consequence of training. If this were the case, we would be faced with a circular process in which learning would increase exponentially.

TABLE 3
Comparison of Our Results With Those of 2 Studies Reviewed

	Present Series	Krasna et al[7]	Huang et al[5]
Duration of study, mo	79	82	50
No. of cases	15	24	26
Age, y	15*	16*	13.3†
Conversion to thoracotomy	3	1	0
No. of portals	3	3-4	3-4
No. of discs excised	4*	5*	6†
Duration of recovery unit stay, d	1.5*	2*	3.5†
Duration of chest tube drainage, d	3.5*	3*	4.8†
Duration of hospital stay, d	11.5*	6*	10†
No. of perioperative complications	5	4	6

*Values are expressed as medians.
†Values are expressed as means.

TABLE 4
Serious Complications Described in Endoscopic Spinal Column Surgery

Pneumonia
Infection of surgical wound
Infection of bone graft
Pneumothorax
Contralateral tension pneumothorax
Hemothorax
Pleural effusion
Chylothorax
Empyema
Esophageal perforation
Laceration of great vessels
Pulmonary laceration
Dura mater lesion
Neurological lesion
Diaphragmatic perforation
Perforation of abdominal organ
Incorrect fusion level

Surgeons wishing to perform video-assisted vertebral instrumentation must first acquire experience in anterior release and fusion and anterior instrumentation via thoracotomy.[1,13] We believe that the development and simplification of endoscopic devices will make these techniques accessible to the majority of orthopedic and thoracic surgery teams in the near future, resulting in broader indications for VATS procedures and more opportunities for surgeons to perfect their technical expertise. Experimental surgical models can play an important role in this process,[4,6,24,25] but first it is necessary to acquire clinical experience with simpler procedures like anterior release and fusion.

As demonstrated by our experience, training can take place in a safe environment, at least when it is conducted as part of a coordinated effort between thoracic surgeons with experience in VATS and orthopedic surgeons with training in spinal surgery. Even though we work in a general hospital setting, the 15 procedures we have described produced satisfactory orthopedic results, an acceptable morbidity rate, and zero mortality.

In conclusion, despite the complexity of video-assisted thoracic surgical procedures, we believe they will become the standard approach to treating spinal deformities in the near future. By working together in general hospital settings, orthopedic and thoracic surgeons can help to overcome the steep yet perfectly manageable learning curve.

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