The efficacy of video-assisted thoracoscopic surgery for anterior release and fusion in the management of pediatric spinal deformities

Christpopher W. Reilly, MD;*† Gerard P. Slobogean, BSc;† Rachel L. Choit, BSc*

Purpose: This study examined clinical and radiological outcomes following video-assisted thoracoscopic surgery (VATS) for anterior release and fusion in the correction of pediatric scoliotic deformities. **Methods:** We undertook a detailed chart and radiographic review to determine the degree of correction and perioperative morbidity and complications, if any, of a sequential group of patients who underwent VATS between 2000 and 2004 at British Columbia's Children's Hospital. We used patients who underwent open thoracotomy immediately before the adoption of the VATS technique at the same hospital to evaluate the relative efficacy of VATS. **Results:** There were 19 patients in each group, 17 with idiopathic scoliosis in the VATS group and 16 in the open thoracotomy group. Mean age, weight at surgery and preoperative Cobb angle were similar (p = 1.0, 0.8 and 0.05, respectively). There was no significant difference in operative time per level between the VATS group and the open thoracotomy group (37.2 v. 34.5 min, p = 0.2) or total blood loss (908 v. 823 mL, p = 0.5). There were no major complications encountered in the VATS group. One patient in the open thoracotomy group experienced atelectasis and subsequent lower lobe collapse. **Conclusions:** VATS has the potential to decrease postoperative morbidity while still allowing the same degree of correction as traditional open thoracotomies and is a good alternative in the pediatric population.

Objet : Dans le cadre de cette étude, on a analysé les résultats cliniques et radiologiques d'une chirurgie thoracoscopique assistée par vidéo (CTAV) pour libération antérieure et fusion afin de corriger des difformités scoliotiques pédiatriques. **Méthodes :** Nous avons entrepris une analyse détaillée de dossiers et de radiographies pour déterminer le degré de correction ainsi que la morbidité et les complications peropératoires, le cas échéant, chez un groupe de patients consécutifs ayant subi une CTAV entre 2000 et 2004 à l'Hôpital pour enfants de la Colombie-Britannique. Nous avons utilisé un groupe de patients consécutifs ayant subi une thoracotomie ouverte immédiatement avant l'adoption de la technique CTAV au même hôpital afin d'évaluer l'efficacité relative de la CTAV. **Résultats :** Chaque groupe comptait 19 patients; 17 patients étaient atteints d'une scoliose idiopathique dans le groupe CTAV et 16, dans le groupe de la thoracotomie ouverte. L'âge moyen, le poids au moment de l'intervention chirurgicale et l'angle Cobb préopératoire étaient semblables (p = 1,0, 0,8 et 0,05, respectivement). Il n'y avait pas de différence significative quant à la durée de l'intervention selon le niveau entre les sujets qui ont subi une CTAV et ceux qui ont subi la thoracotomie ouverte (37,2 c. 34,5 min, p = 0,2) ou quant à la perte totale de sang (908 c. 823 mL, p = 0,5). Les sujets qui ont subi la CTAV n'ont pas eu de complications majeures. Un patient parmi ceux qui ont subi la thoracotomie ouverte a eu une atélectasie et un affaissement subséquent du lobe inférieur. **Conclusions :** La CTAV pourrait réduire la morbidité postopératoire tout en permettant de produire le même degré de correction que les thoracotomies ouvertes traditionnelles et elle constitue une bonne solution de rechange dans la population pédiatrique.

Surgical management of scoliosis is considered when conservative treatments, such as bracing, fail to halt curve progression. Curves greater than 50° have the potential to progress in the long-term and are frequently managed with spinal instrumentation. A combined anterior and posterior approach may be required in the management of some patients. The goals of anterior approaches to the scoliotic spine in-

*From the *Department of Orthopaedics and the †Faculty of Medicine, University of British Columbia, Vancouver, BC.*

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Correspondence to: *Dr. Christopher Reilly, Department of Orthopaedics, BC Children's Hospital, A234-4480 Oak St., Vancouver BC V6H 3V4; fax 604 875-2275; creilly@cw.bc.ca*

clude impeding curve progression and preventing crankshaft by arresting the anterior growth centres of the involved vertebral bodies in young patients, improving flexibility and potential correction of severe curves by releasing anterior structures and maximizing fusion rates in patients at risk for pseudoarthrosis.[1]

Anterior access to the thoracic spine has traditionally been gained by a posterolateral thoracotomy or a thoracolumbar incision. Although this is an effective exposure, there is the potential for significant postoperative morbidity, including pain and compromised pulmonary function.[2,3] In recent years, with the advent of minimally invasive surgical methods, video-assisted thoracoscopic surgery (VATS) has emerged as an alternative means of accessing the anterior spine for soft tissue release, discectomy and fusion in the management of scoliosis and kyphosis.[1,4–10] The indications for VATS are largely the same as for the open procedure with the exception of patients under 20 kg and patients with very large rigid curves, typically over 140°, which are not as amenable to thoracoscopic release.[4,11] It has been suggested that the minimally invasive nature of VATS results in less postoperative morbidity than the traditional open thoracotomy, while still achieving the same degree of correction.[5,10] The purpose of this review is to report the experience of a Canadian centre in the use of VATS as an alternative method of anterior release and fusion in the correction of pediatric spinal deformities.

Methods

Following approval from 2 Institutional Review Boards, we reviewed all patients who had undergone VATS for anterior release and fusion in the management of a spinal deformity at British Columbia's Children's Hospital between August 2000 and March 2004. The VATS technique was first used at our institution in August 2000 and was immediately adopted as our preferred technique for anterior release. To evaluate the efficacy of the VATS technique, we selected the same number of sequential patients who underwent open thoracic release as a comparison group. Therefore, this comparison examines our first VATS procedures and our last open release patients. We excluded patients who had undergone anterior instrumentation. One pediatric spinal surgeon performed the VATS procedure and either this surgeon or one other pediatric spinal surgeon performed the open thoracotomy. All patients underwent same-day posterior instrumentation and fusion after the anterior procedure.

VATS technique

All patients in this series were recommended surgical management due to curve progression. An anterior procedure was recommended for 1 of 3 reasons. In skeletally immature patients, an anterior growth arrest was added to prevent crankshaft; these curves were usually small flexible curves. In mature patients with large stiff curves, an anterior release was typically added to improve correction. In some patients (generally those with neuromuscular disorder and moderate to severe curvesan), an anterior procedure was added to reduce the rate of pseudoarthrosis.

The same VATS technique was used in all patients. The patient is positioned in the lateral decubitus position with the convex side up (Fig. 1). It is important to prep and drape the patient as for a thoracotomy because of the potential need for conversion. General anaesthetic is administered via endobronchial intubation to allow single lung ventilation. Spinal cord monitoring is used in a standard fashion. In our centre, the orthopedic team performs all

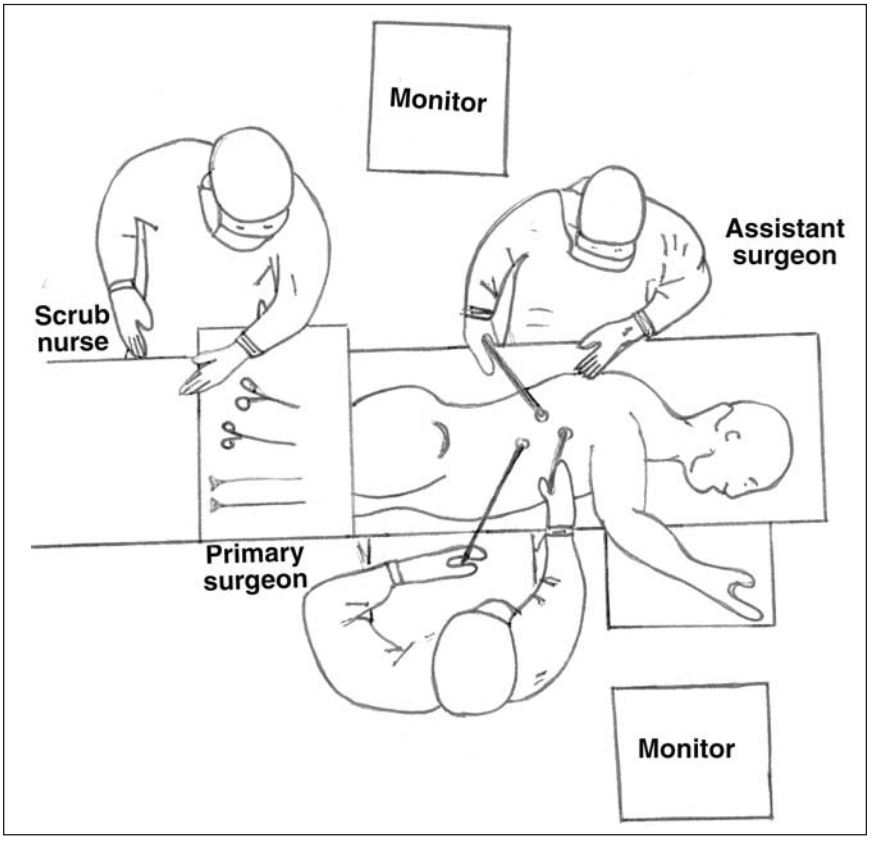

FIG. 1. Operating room setup and patient positioning. The primary surgeon stands anterior to the patient.

portions of the procedure; the aid of a thoracic surgeon is not used. Because our experience with the technique has increased, we have moved from using 4 portals to our current practice of using 3 portals: 1 at the posterior axillary line at the apex of the curve, which acts as a scope portal, and 2 along the anterior axillary line, avoiding the anterior border of the latissimus dorsi (Fig. 2). Each port is used to access 3 rib interspaces, allowing the direct removal of 3 disks through each portal. As our experience has increased, a standard thoracoscopic anterior release has allowed for the removal of 6 disks. Angled rongeurs facilitate disk excision. Rigid 12-mm thoracoports easily allow the passage of a 1-cm scope and thoracoscopic spinal instruments, while minimizing intercostal nerve injury. Flexiports were used for the early patients in this series. They do not allow for direct visualization of the anatomy through the port, which is a useful orientation technique.

Establishing thoracic ports, opening the pleura, dividing the segmental vessels and visualizing the disks can be completed with no measurable blood loss. Bleeding originates from epidural veins or the bony end plate. End plate bleeding can lead to significant blood loss but, more importantly, it limits disk excision by limiting visibility. Inadvertent end plate injury accounts for most of this blood loss during disk excision. A standard 30° scope will not allow the surgeon to achieve a view down the disk space, and part of the disk must be excised by triangulation and palpation. This leads to increased blood loss through repetitive end plate injury by the rongeurs. A 45° thoracoscope provides excellent inline disk visualization and allows the surgeon to avoid inadvertent end plate injury. Prewarming the thoracoscope in a warm bath or an assistant's hand will minimize fogging at the start of the case. Endobronchial intubation greatly facilitates visualization in the chest. In most cases, no ongoing lung retraction is required. Initially, lung collapse can be encouraged using gentle pressure with a fan retractor. Rotation of the table toward the operating surgeon standing anterior to the patient improves visualization.

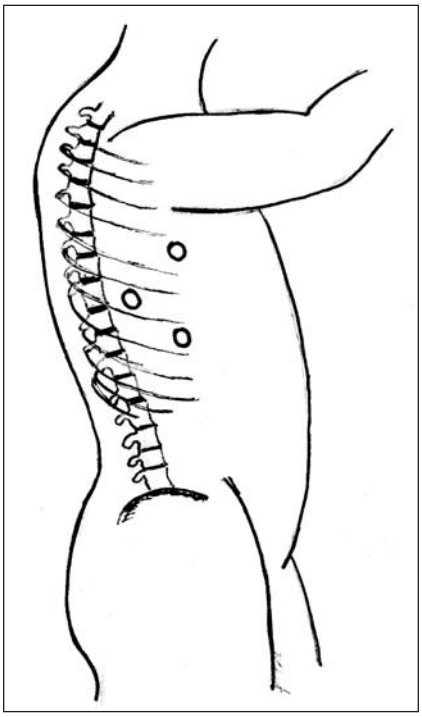

FIG. 2. Location of portals. The scope portal is placed along the posterior axillary line at the apex of the curve.

In this series, a longitudinal incision was created in the pleura, and segmental vessels were divided with a harmonic scalpel. This allows for excellent exposure of the spine. Gauze sponges can be packed in the mediastinal-pleural gutter to protect the vascular structures and thoracic duct during disk excision. It is also possible to complete disk excision through small pleural windows preserving the segmental vessels. Vessel preservation is now a standard technique at our institution.

The discectomies are completed with a combination of electrocautery, harmonic scalpel, curettes and long thoracoscopic biters. Complete disc removal down to the bony end plate is completed, and gelfoam is packed into the disc space to maintain hemostasis. Allograft bone has been used in all thoracoscopic anterior release cases in this series. The bone is packed into the disc spaces with a funnel, after disc excision. In all open thoracic discectomy cases in this series, the approach incorporates rib excision to improve exposure and provide autogenous bone graft. The pleura is closed with a running suture, made with an autosuture device, and a chest tube is inserted into one of the portals. The remaining portals are closed in layers. Following completion of the anterior procedure, the endobronchial tube is changed to an endotracheal tube, and the patient is repositioned and prepped for the posterior instrumentation and fusion.

Clinical data collection

The purpose of this study was to compare the perioperative parameters and outcomes of VATS with open thoracotomy for anterior release and fusion in the treatment of pediatric spinal deformities. Specifically, the primary outcome measure was the difference in the degree of correction, as measured by preoperative and 4-month postoperative Cobb angles on standing posteroanterior radiographs. The percentage of correction attained was calculated for each patient. Demographic parameters, such as age and weight at the time of surgery, sex and diagnosis, were collected for all patients. Operative parameters included the number of levels released, time for the anterior procedure and estimated blood loss during the anterior procedure. Anterior operative time and blood loss were normalized for each patient by the number of levels released. Postoperative measures included chest tube output in the first 24 hours, homologous transfusion requirements, hours of ventilator use, hours of intensive care unit (ICU) stay, days of chest tube use and total length of hospital stay. The presence of any complications, either intra- or postoperatively, were recorded.

Statistical analysis

Means and standard deviations (SDs) were compared with a Student's t test, and $p \leq 0.05$ was considered to be statistically significant.

Results

We included in the study 19 sequential pediatric patients who underwent VATS for anterior release and fusion at our institution in the correction of spinal deformity. No patients required conversion to an open procedure. Nineteen sequential pediatric patients who had undergone an open thoracotomy immediately before our adoption of the VATS technique served as the comparison group. Demographic parameters were similar between the groups. There were 17 patients with idiopathic scoliosis in the VATS group and 16 in the open thoracotomy group. The VATS group comprised 13 female patients and 6 male patients, and the open group comprised 16 female patients and 3 male patients. The mean age at surgery was identical, at 13.2 (SD 1.7) years. There was no significant difference in weight between the VATS group (45.2, SD 12.9 kg) and the open thoracotomy group (46.1, SD 12.4 kg), $p = 0.8$. Table 1 and Table 2 summarize the intraoperative and postoperative parameters for the groups and the significance level found.

The VATS group had more levels released, at 5.1 versus 4.8 discs removed, which was statistically significant ($p = 0.03$). However, there was no significant difference between the VATS and the open thoracotomy group for total anterior operating time or operating time per level. Similarly, there was no significant difference found in terms of total estimated blood loss for the anterior procedure or estimated blood loss per level during the anterior procedure. The VATS group did demonstrate a higher chest tube output volume in the first 24 hours following surgery ($p = 0.02$) and, on average, retained their chest tube for a longer period ($p = 0.01$). There was no significant difference between length of ventilator use, length of ICU stay or total length of hospital stay. One patient in the open thoracotomy group required re-intubation.

Complications

There were no complications encountered in the VATS group during the procedure, the hospital stay or in follow-up. Intercostal neurapraxia has been a concern in thoracoscopic spinal procedures.[10] No neurapraxias were noted at follow-up in the thoracoscopic group. In the open thoracotomy group, complications included a posterior wound seroma requiring evacuation, a left lower lobe collapse secondary to atelectassis that recovered with physiotherapy, bilateral pleural effusions and chest tube malalignment that required repositioning. There were no neurological complications in the VATS group. One patient in the open thoracotomy group experienced a right lower extremity neurological deficit that spontaneously recovered in the immediate postoperative period. There were no vascular complications in either group.

Correction

Table 3 summarizes the mean and standard deviations of Cobb measurements and the significance level

Table 1

Intraoperative parameters

	Parameter; mean (and standard deviation)					
Treatment group	Anterior levels released	Anterior OR time, min	Time/level, min	Anterior EBL, mL	EBL/level, mL	Homologous units
VATS	5.1 (0.2)	188.0 (30)	37.2 (5.9)	909 (409)	180 (82)	0.37 (0.83)
Open laparoscopy	4.8 (0.4)	165.6 (39)	34.5 (7.5)	826 (320)	174 (72)	0.21 (0.63)
p value	0.03	0.06	0.2	0.5	0.8	0.5

EBL = estimated blood loss; OR = operating room; VATS = video-assisted thoracoscopic surgery.

Table 2

Postoperative parameters

	Parameter; mean (and standard deviation)				
Treatment group	24-h chest tube output, mL	Chest tube use, d	Ventilator use, h	ICU stay, h	Hospital stay, d
VATS	769 (303)	3.3 (0.9)	6.5 (6.9)	27.5 (22.3)	7.1 (1.3)
Open laparoscopy	568 (209)	2.6 (0.8)	5.4 (7.1)	22.7 (8.9)	6.8 (2.0)
p value	0.02	0.01	0.6	0.4	0.6

ICU = intensive care unit; OR = operating room; VATS = video-assisted thoracoscopic surgery.

found. There was no significant difference in preoperative curve size. There was, however, a significant difference found for both the postoperative curve size ($p = 0.00$) and the amount of correction attained ($p = 0.01$): the VATS group attained a 78.9% correction, compared with 67.6% correction in the open thoracotomy group.

Discussion

It is generally accepted that traditional open thoracotomy approaches provide excellent exposure of the anterior thoracic spine for disc excision and release. The downside of the procedure is the potential for significant perioperative morbidity. The open approach is associated with significant blood loss and pain, due to rib resection and muscle dissection, and the patient is left with a large scar.[6] Pulmonary complications such as atelectasis, pneumonia and pneumothoraces are also commonly associated with this approach.[2,3,7] A prospective evaluation of pulmonary function following open thoracotomy for anterior spinal fusion in adolescents found a significant decline in function in the immediate postoperative period, and patients took up to 2 years to return to preoperative levels.[3] Another major disadvantage of open thoracotomies is that postoperative pain can interfere with rehabilitation and the return to normal activities. The open approach is much more invasive, involving direct dissection through the latissimus dorsi, serratus anterior and intercostal musculature and requires rib resection. The extensive muscle dissection needed for exposure restricts postoperative upper extremity function and contributes to pain-related morbidity.[2,12]

VATS has gained significant acceptance as an alternative to open thoracotomy in the treatment of spinal deformities, since reported by Mack and others,[10] because it has been shown to achieve similar results with less complications.[1,5,7,12] Its use is indicated in the same patient populations, with the exception of large rigid curves greater than 140° and in very small pediatric patients, typically less than 20 kg, due to the decreased working space within the chest.[1,13] Holcomb and colleagues[7] were the first in the literature to report on the use of VATS for the correction of spinal deformities in children. We reviewed the cases of 8 pediatric patients who underwent thoracoscopic anterior discectomy and fusion followed by posterior instrumentation and fusion at our institution. In this series, one patient suffered injury to an intercostal vessel that required immediate transfusion; we encountered no other complications. The conclusion was that VATS had the potential to provide the same results as open thoracotomy with less morbidity.[7]

Similarly, Newton and colleagues[1] evaluated the safety and efficacy of thoracoscopic anterior releases in 14 consecutive patients and compared the results with a control group of 18 patients who underwent open anterior releases (before the use of thoracoscopic techniques at their institution). The authors found that both groups spent comparable time in the acute care units, and their total length of stay was similar, when broken down by diagnosis, with patients with an underlying neuromuscular disorder staying longer. Curve correction was similar between the 2 approaches, and the authors found thoracoscopy to be a safe and efficacious alternative to open thoracotomy.[1]

Although thoracoscopy has potentially fewer associated complications, adverse effects have been reported.[14–16] Tension pneumothorax due to the over advancement of a guide wire into the opposite hemithorax has been described in the literature.[14] Crawford and colleagues[5] suggested that tension pneumothorax is a potential complication of VATS because it requires single lung ventilation and a highly skilled surgeon. There is little controversy concerning the steep learning curve associated with performing thoracoscopic procedures for both the surgical and the anaesthetic teams.[2,5,7,10,11] Another consideration in using VATS is that, while the rib resection in open thoracotomies does increase postoperative pain, it also provides autologous bone for grafting. Patients undergoing VATS in this series had allograft bone graft placed in the disk spaces, which may increase the risk of pseudoarthrosis. However, in this series, all patients had a same-day posterior spinal instrumentation and fusion, minimizing the risk. If the patient is at high risk for pseudoarthrosis, iliac crest bone graft can be harvested in the lateral position during the initial equipment set-up. Iliac crest harvest is a standard practice in thoracoscopic anterior instrumentation cases at our institution.

VATS has gained significant acceptance as an alternative to open thoracotomy in the treatment of spinal deformities because it has been shown to achieve similar results with less complications.[1,5,7,8,12] At our institution, VATS has been used to achieve anterior release and spinal fusion in 19 pediatric patients with

Table 3

Preoperative and postoperative thoracic Cobb measurements

Treatment group	Measurement; mean (and standard deviation)				
	Preoperative Cobb, °	Postoperative Cobb, °	Percent correction, %	Bending curve, °	Bending curve, %
VATS	67.0 (12.9)	13.6 (7.2)	78.8 (13.2)	49.9 (13.8)	24.7 (16.2)
Open laparoscopy	75.9 (14.6)	24.1 (9.3)	67.6 (12.7)	59.1 (13.6)	22.1 (10.0)
p value	0.0524	0.0004	0.0105	0.0499	0.5483

VATS = video-assisted thoracoscopic surgery.

scoliosis. No patients required conversion to an open thoracotomy. The only significant difference in terms of perioperative morbidity was that the VATS group had increased chest tube output and, on average, retained their chest tubes for one extra day. The lack of reduction in hospital stay is likely due to the fact that, although the anterior procedure is less invasive, the patient still has to recover from the extensive posterior procedure, as other authors have speculated.[7] Interestingly, the VATS group had more levels released and attained a better correction. The increased correction could be due to the evolution of posterior constructs, since some of the patients in the open thoracotomy group were instrumented before 1999 and all of the patients in the VATS group were instrumented between 2000 and 2004. However, the VATS procedure does have the potential to improve access on the convexity of the deformity. In patients with stiff chest wall deformities, accessing the highest and lowest disk spaces through a single thoracotomy can be challenging. In some cases, a rib osteotomy or second intercostal approach may be required. The VATS ports allow a direct line of approach to the disk without excessive chest wall distraction. Our findings of more levels released and greater correction in the VATS group may reflect this advantage.

There was no difference in hospital stay, operative time or ICU stay, a notable observation for a Canadian centre with limited resources. This group of thoracoscopic patients also represents our initial experience, and further improvements in the technique may produce greater advantages. We have not commented on postoperative pain in this series. All patients underwent same-day posterior procedures. Defining meaningful comparison of postoperative pain ratings or narcotic use was not possible in this retrospective group. However, intuitively, it would seem that the large decrease in dissection provided by the port access would reduce postoperative chest pain, which correlates with our clinical impression. It is possible that thoracoscopic procedures will also avoid the significant compromise in pulmonary function seen in open thoracotomy patients.

To the best of our knowledge, this is the first review in the English literature of a Canadian centre's experience with VATS for anterior release and fusion in the pediatric population. There is, however, a report in the French literature of a series of 8 patients from another Canadian centre.[9] In this review, the VATS technique compared favourably with the open thoracic release and fusion groups in our centre. This review also confirms that we are achieving similar success with the VATS procedure. We believe that its continued use should be promoted in Canadian centres as a safe and successful alternative to open thoracotomy for the correction of severe spinal deformities in the pediatric population.

Competing interests: None declared.

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