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A rib-sparing unilateral transpedicular thoracic corpectomy using the ultrasonic bone scalpel: a novel technique and pictorial guide

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Abstract

Background The thoracic corpectomy is a well-described technique for the surgical treatment of vertebral column fractures with spinal canal compromise. Traditionally, the posterolateral approach to this procedure required the removal of the approach side rib in order to introduce the corpectomy cage. This rib removal, however, has been identified as a major contributor to post-operative morbidity. Rib-sparing techniques have been shown to be beneficial in minimizing post-operative morbidity in non-spinal surgeries. Herein, we present a previously undescribed technique of a rib-sparing thoracic corpectomy that avoids sequalae of rib resection with assistance from an ultrasonic bone scalpel (UBS).

Methods A retrospective chart review was conducted on patients having undergone this thoracic corpectomy technique. Data on patient age at operation, indication for surgery, number of corpectomies per case, estimated blood loss (EBL), operative time (OT), intra-operative complications, and post-operative length of stay (LOS) were collected and analyzed. A pictorial step-by-step guide was created to highlight the advantages of an entirely posterior rib-sparing unilateral transpedicular technique for thoracic corpectomy.

Results A total of 36 corpectomies were performed on 32 patients between August 2015 and March 2023. Patients ages ranged from 17 to 85 years (mean = 63). The most common indication was oncological ($n = 22$, 69%), followed by degenerative/traumatic deformity ($n = 7$, 22%), and infection ($n = 3$, 9%). For the cases for which data was accessible, mean EBL was 853 cc and mean OT was 178 min. The average post-operative LOS was 6.5 days.

Conclusion The described surgical approach makes it possible to create a transpedicular corridor with no costectomy for implantation of an expandable titanium cage and anterior column reconstruction. The use of the UBS in this approach is critical as it minimizes bony removal and avoids sequelae of rib resection. The described technique has the potential to circumvent post-costectomy pain, thereby expediting post-operative recovery after thoracic corpectomy.

Keywords Thoracic, Corpectomy, Technique, Novel, Rib, Sparing

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Background

The thoracic corpectomy is a well-described technique for the surgical treatment of traumatic, infectious, dysplastic, and oncologic vertebral column fractures with spinal canal compromise [1, 2]. Traditionally, the posterolateral approach to this procedure required the removal of up to 6 cm of the approach side rib in order to introduce the corpectomy cage from a sufficiently lateral trajectory to reach the anterior column and avoid undue retraction of the thoracic spinal cord. This rib removal, however, has been identified as a major contributor to post-operative morbidity, including harvest site pain and consequent breathing restriction, large hospitalization costs, and the potential for post-surgical morbidity [3, 4]. Recent refinements to the approach have utilized rib fixation (i.e. costoplasty) to minimize pain due to focal rib instability with positive effects on post-op pain and hospital length of stay (LOS); however, transection with significant destabilization of the rib is still required and the surgery is performed in the lateral position [3]. The use of less invasive, rib-sparing techniques has been shown to be beneficial for minimizing post-operative pain in non-spinal surgeries such as internal mammary vessel harvesting for microsurgical breast reconstruction and mini incision donor nephrectomy for renal transplantation [5–7]. Furthermore, the implementation of the ultrasonic bone scalpel (UBS) (Misonix, Farmingdale, NY, USA) into the spine surgeon's armamentarium has been shown capable of decreasing blood loss, neural injury, procedure time, and bone loss compared to traditional methods in some series [8]. We present a previously undescribed technique that combines these tenets to achieve a rib-sparing thoracic corpectomy using the UBS.

Methods

A retrospective chart review was conducted on patients having undergone this thoracic corpectomy technique since its implementation at the senior author's institution. Data on patient age at operation, indication for surgery, number of corpectomies per case, estimated blood loss (EBL), operative time (OT), any intra-operative complications, and post-operative length of stay (LOS) were collected and analyzed. Our institution changed electronic medical records after December 2018 which limited access to more granular patient data for analysis.

Description of surgical technique

The technique was developed and performed by a single surgeon at a single institution. To catalog a step-by-step pictorial description of the procedure, it was recreated on both a molded plastic spine model and on a cadaveric specimen in a laboratory setting. CT images of real post-operative scans are included to demonstrate the extent of bony resection in actual patients.

The patient is positioned prone on a Jackson frame with chest bump, hip pads, and flat knee board. Neuromonitoring is utilized to monitor somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs) to detect any early signs of neural compromise during nerve root and potential thecal sac manipulation. An open subperiosteal dissection is performed in the midline avascular plane, exposing the posterior thoracic vertebra at the corpectomy level (CL) as well as two to three vertebrae cranially and caudally for the purpose of segmental instrumentation. This portion of the technique can be modified to be "mini-open," with a single midline extrafascial dissection, as desired. When performed open, the dissection is carried laterally at the CL over the costotransverse articulation to expose a few millimeters of the medial rib on the planned approach side. The chosen pedicles above and below the CL are canalized and prepared on both sides, but pedicle screws are only placed on the contralateral side at this point. In the mini-open variant, transfascial pedical screws can be placed instead using the usual combination of trephine needles, K-wires, and cannulated screw/tower systems. Then, the corpectomy can begin (Video 1).

We prefer an en bloc laminectomy using the UBS. Removal of some or all of the spinous process and lower lamina of the vertebral body above is often required for adequate visualization and to maximize working angles. The UBS is used to remove the entirety of the inferior articulating processes of the CL and the vertebra above on the approach side. Then, the uppermost portion of the superior articulating process of the CL and that of the vertebra below are resected in the same fashion, taking care not to disrupt the pedicles. The CL transverse process is then amputated at its root laterally on the approach side for the corpectomy cage, leaving enough bone to avoid disarticulation of the costotransverse joint. If additional angulation is required, the costotransverse joint may be disarticulated during this maneuver, but importantly, the rib itself is undamaged. These osteotomies result in an isolated pedicular column. A rongeur is used to remove the overlying bone until the cancellous bone of the pedicular column is seen. In rare cases, the thoracic rib angles may be too steep to permit our technique; in this case, conversion to a more traditional costotransversectomy may be necessary. At this point, we prefer to tie off and then divide the exiting nerve ramus proximal to the dorsal root ganglion to maximize the operative corridor. The tagged nerve root can be gravity retracted by suture tails and a small clamp.

A temporary rod is placed on the side contralateral to the approach for sagittal stabilization. Discectomies are performed above and below the CL in the standard fashion. Then, a box-cutting osteotome and mallet are used to remove the remaining pedicular column in quadrants

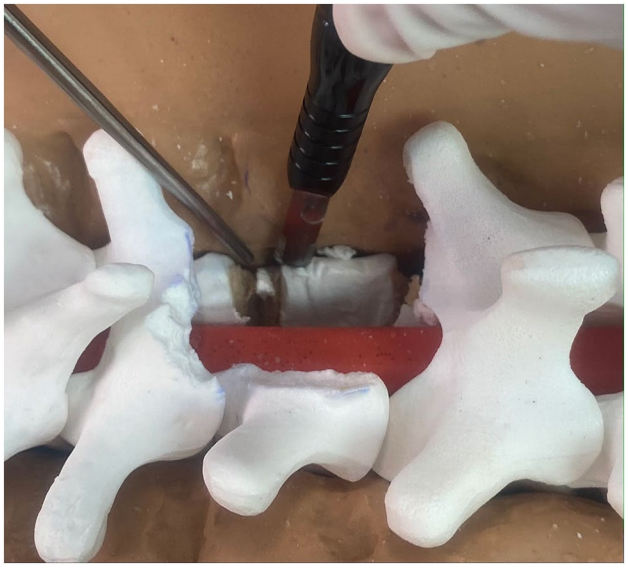

Fig. 1 The fine tip of the ultrasonic bone scalpel allows the lateral vertebral body to be carefully tailored to the desired width rather than resected en toto as demonstrated on this molded plastic spine model

until flush with the posterior vertebral body. We prefer to use this same instrument to perform the corpectomy through the created corridor having found this to be an efficient and effective mean of coring out the vertebral body. A rim of anterior body cortex is left intact to prevent cage migration. Pituitary rongeurs are used to remove bony pieces and pulp. Next, a Woodson dental is used to confirm separation between the ventral thecal sac and remaining posterior longitudinal ligament and posterior vertebral body. In cases of revision surgery or infectious oncological indications requiring thoracic corpectomy, epidural fibrosis is typically anticipated preoperatively, and standard microsurgical techniques are employed to separate the dura from surrounding structures. Iatrogenic durotomies are managed on a case-by-case basis, with a preference for primary suture repair. If primary repair is ineffective, a combination of tamponade, various synthetic onlays, sealants, and robust soft tissue coverage over the defect, along with gravity-only drainage systems, may be used. A heel-shaped tamp is then introduced into this plane; a large reverse angle curette can also serve this purpose. Downward blows to the tamp safely collapse the remaining posterior body into the previously created cavity, and bony pieces are removed.

The lateral cortex of the vertebral body is shaved using the USB only as much as is necessary for cage introduction (Fig. 1, Video 1). By leaving this lateral cortex intact, the costocentral articulation, and thus the rib itself, remains undisturbed. Critical to this technique is the use of an expandable, modular corpectomy cage which can be appropriately sized, placed, and expanded to achieve the

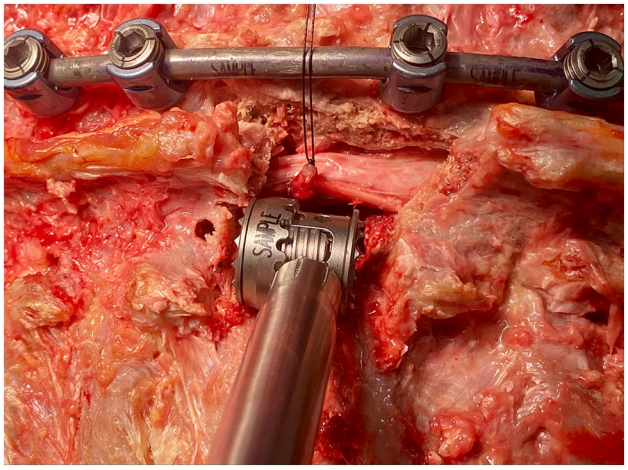

Fig. 2 A titanium expandable corpectomy cage fits into the bespoke bony window using only the tagged nerve for gentle gravity retraction as demonstrated in this cadaveric specimen

Table 1 Baseline characteristics, indications, and perioperative outcomes of patients who underwent rib-sparing unilateral transpedicular thoracic corpectomy

Baseline Characteristics:	
Number of Patients	32
Mean Age	63
Indication (%):	
Oncologic	22 (69%)
Infectious	3 (9%)
Degenerative/Traumatic	7 (22%)
Perioperative Outcomes:	
Number of Corpectomies	36
Mean EBL (mL)	853
Mean Operative Time (minutes)	178
Mean Length of Stay (days)	6.5
Complications (%)	
Iatrogenic Durotomy ($n=1$), Post-operative infection ($n=1$)	2 (6.1%)
None	31(93.9%)

desired anterior column reconstruction. We prefer a titanium expandable cage with modular end caps (VLIFT→, Stryker, Kalamazoo, MI, USA) for this purpose. The cage is placed midline and anterior as possible to maximize stability against the apophyseal ring and deformity correction. No retraction of the thecal sac beyond the minimal rotation achieved from the tagged nerve is required to introduce the cage (Fig. 2, Video 1). Standard multilevel instrumentation then concludes the case.

Results

A total of 36 corpectomies were performed on 32 patients between August 2015 and March 2023 (Table 1). Patients ages ranged from 17 to 85 years (mean=63). The most common indication was oncological ($n=22$, 69%), followed by degenerative/traumatic deformity ($n=7$, 22%), and infection ($n=3$, 9%). EBL averaged 853 cc for

the 30/32 cases for which data was accessible. The average OT was 178 min for the 29/32 cases that data was available. The average post-operative LOS was 6.5 days across all cases. One iatrogenic durotomy representing the only intra-operative complication occurred (3%) which was clinically inconsequential after primary repair. There was only one patient (3%) with a post-operative complication attributable to surgery: a surgical site infection three weeks afterward that required wound washout without hardware revision. The remainder of that patient's recovery was unremarkable. A different patient had a fall during home rehabilitation resulting in fracture of the corpectomy cage into the caudal vertebral body which necessitated operative revision for neural decompression and spinal stabilization. This anomalous incident was considered unrelated to the operation itself.

Illustrative case 1

A female in her late 70s presented to the hospital with progressive and intractable mechanical back pain. On radiographic workup, she was found to have diffuse skeletal metastases with no known primary cancer. She had several vertebral column lesions. The largest lesion was at the T8 vertebral body level which had caused a mild pathologic fracture (Fig. 3). The tumor extended to the posterior elements and epidural space causing severe spinal cord compression. After discussion with the patient and a multidisciplinary oncological team, she underwent a right-sided rib-sparing transpedicular corpectomy of T8 for histopathological diagnosis, en bloc tumor resection with a goal of preservation of neurological function, and anterior column reconstruction with mechanical stabilization (Fig. 4). Her case was uncomplicated, and she remained neurologically intact post-operatively. She was

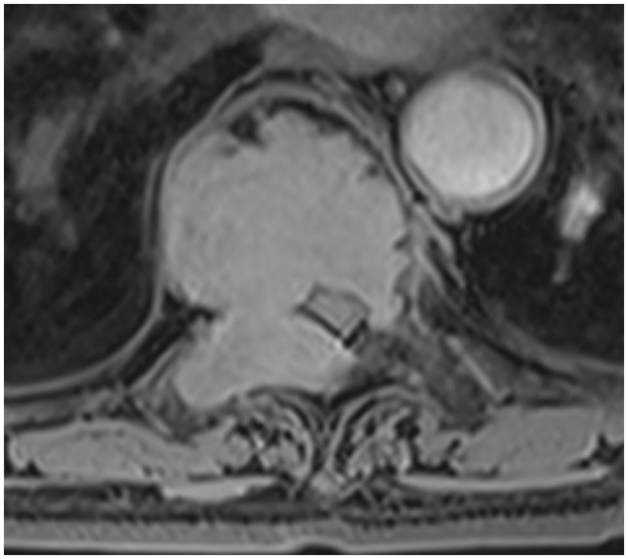

Fig. 3 An axial post-gadolinium T1-weighted image of the thoracic spine in an elderly female demonstrating a homogeneously enhancing mass at T8 with pathology consistent with a plasma cell neoplasm

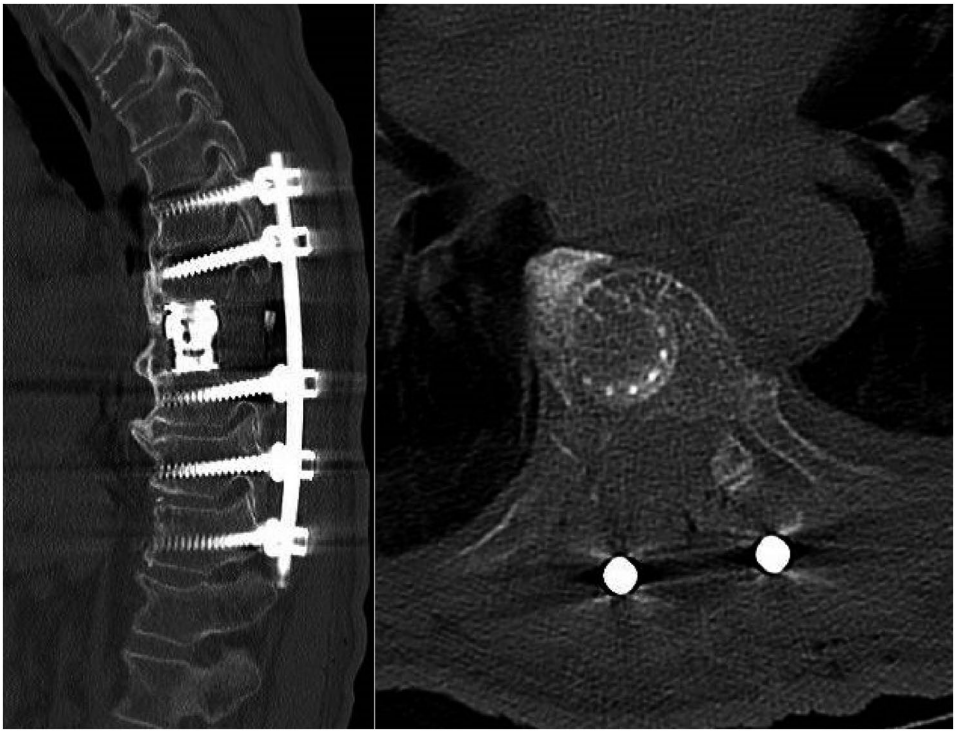

Fig. 4 Sagittal (left) and axial (right) slices from the patient's post-operative CT scan demonstrating the sagittal anterior column reconstruction and intact costocentral articulation on the transpedicular approach side, respectively

discharged for rehabilitation and outpatient treatment of what was found to be a plasma cell neoplasm.

Illustrative case 2

A male in his mid 80s with persistent methicillin-resistant *Staphylococcus aureus* bacteremia and disc-osteomyelitis of the T3 and T4 vertebral bodies with acute kyphotic deformity, bony retropulsion, and epidural phlegmon despite an appropriate IV antibiotic regimen presented with intractable upper back pain leaving him bedridden (Fig. 5). Given his progressive deformity and rapidly diminishing quality of life in a setting of no neurological deficit, he underwent left-sided rib-sparing transpedicular corpectomies of T3 and T4 for source control via debridement, alleviation of mechanical back pain, preservation of neurological function, and correction of his sagittal deformity (Fig. 6). Notably, the lateral cortex of the T4 vertebral body had been eroded by chronic infection; Nevertheless, the remaining rib head was able to be spared during the approach. His case was uncomplicated, and his mechanical back pain resolved post-operatively with expected back, but not respiratory, pain. He was discharged to a skilled nursing facility neurologically intact with pain controlled to continue outpatient antibiotic therapy.

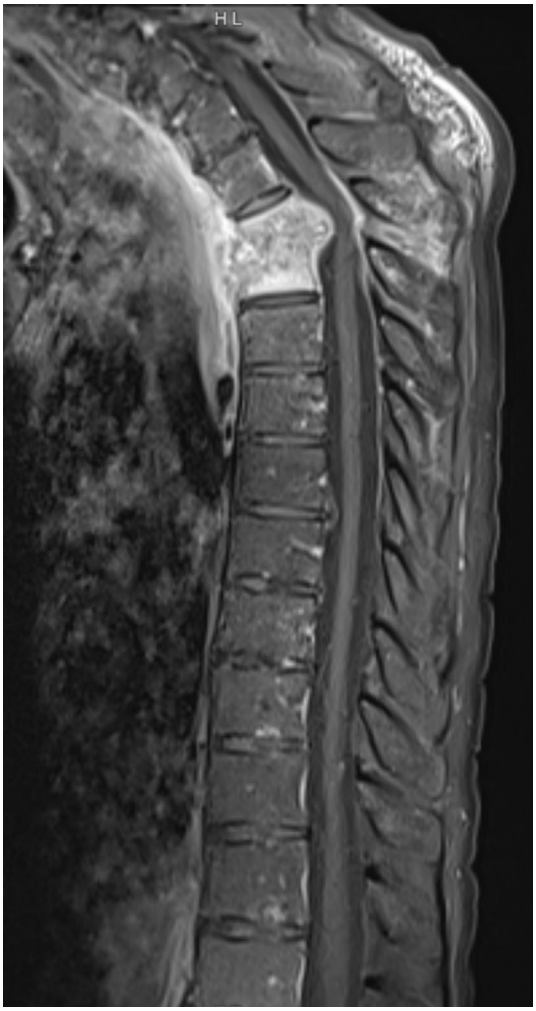

Fig. 5 A sagittal post-gadolinium T1-weighted image of the thoracic spine in an elderly male demonstrating disc-osteomyelitis of the T3 and T4 vertebral bodies with acute kyphotic deformity, bony retropulsion, and epidural phlegmon

Discussion

There are several well-described approaches to pathology of the thoracic spine. These include, from anterior to lateral to posterior, transsternal, transthoracic, transabdominal, extracavitary [9, 10], lateral extracavitary, costotransverse, and transpedicular corridors. Many of these have variants and each has advantages and disadvantages as well as inherent limitations which have been previously studied and described (Table 2) [9, 11]. Of the posterior approaches, the main limitation and challenge is the steep obliquity at which the vertebral body is approached, mandating rib manipulation to varying degrees to accommodate a corpectomy cage sufficient for anterior column reconstruction. Often, the harvested rib acts is used as autograft, which is thought by some authors to offset the morbidity of its resection to an extent [12].

The closest approximations to the technique described here are the transcostovertebral and transpedicular approaches as originally described by Dihn et al. and Roy-Camille [13, 14]. Our technique incorporates tenets of both approaches. As in the transcostovertebral approach, there are rare instances when we need to remove posterior rib cortex for particularly steep posterior articulations. However, unlike this approach's original description, ours is not limited to discal pathology [14]. Nuance differs between authors, but currently described transpedicular approaches for thoracic corpectomy still require an up to 6 cm costectomy or costotomy in order to introduce grafts or expandable cages [11, 14–21]. Minimally invasive tubular retractors have sought to mitigate morbidity attributable to the soft tissue dissection required by transpedicular approaches with good effect [22]. Experts in the field have likewise described hinge costoplasty techniques to this end [3, 11]. While this certainly ameliorates post-operative morbidity, it may also add complexity and operative time. This transpedicular thoracic corpectomy technique avoids said morbidity by avoiding manipulation, destabilization, or resection of the corresponding rib head.

Rib resection is correlated with significant peri- and post-operative pain, a fact that has been extensively documented in cardiothoracic surgery literature [3, 12]. Furthermore, long operative times and significant perioperative blood loss due to extensive rib resection both

Fig. 6 Sagittal (**A**), axial T3 level (**B**), and axial T4 level (**C**) slices from the patient's post-operative CT scan demonstrating the two-level sagittal anterior column reconstruction and unresected rib heads at both transpedicular levels on the approach side. The lateral vertebral body at T4 had been eroded by infection pre-operatively

increase the risk for post-operative complications [2, 20]. Greater peri-operative pain, along with other potential complications of costectomy such as pleural violation, hemo/pneumothorax or approach-mandated need for post-operative chest tube, can increase the LOS for patients undergoing lateral, posterolateral, and posterior thoracic corpectomies [1, 17]. As reported in the literature, the mean LOS for posterior thoracic corpectomies involving significant costectomies is 10.5 days [16, 23–25]. When compared with the literature, post-operatively our patients saved an average of 4.0 days. Improved pain control likewise facilitates patient recovery as rapid mobilization and rehabilitation decreases the long-term complications associated with prolonged immobilization [16, 26]. In addition to improving post-operative pain and minimizing potential complications, rib-sparing procedures, for thin patients in particular, avoid contour deformities at the resection site– improving patient satisfaction with cosmesis [5].

On average, groups studying traditional open posterior thoracic corpectomies have reported EBL of 1687 cc, operative time of 357 min, and complication rates up to 21.1% [8, 16, 23–25]. Since introducing the UBS to this technique, our group has averaged an operative time of 178 min and EBL of 853 cc – effectively halving EBL and operative time compared to the literature. Our thoracic corpectomy technique is made facile (if not enabled by) this tool's ease of use, relative tissue selectivity, limited bony removal, and ability to coagulate cancellous and nutrient vessels. These technical improvements can lower both surgical duration and the need for blood product transfusion and may promote earlier arthrodesis – findings that have been recapitulated by other adopters of the technology [2, 8]. Because the ultrasonic osteotome preferentially cuts only non-elastic tissue, its ability to reduce the incidence (1.5–5.7%) of iatrogenic durotomy is appreciated by surgeons [8]. This point is particularly salient given the prospective randomized trial by Todeschi et al. [27] which showed that a staged anterolateral corpectomy strategy caused fewer durotomies compared to single stage posterior only approaches for thoracolumbar burst fractures. In our series with a posterior only technique, just one patient (3%) experienced an iatrogenic durotomy.

Historically, techniques have been described that also spared the costotransverse joint [21]. However, Steinmann pins and bone cement were used for reconstruction in these cases, allowing for much narrower corridors. The indication for costoplasty, costotomy, or costectomy is predicated on the need to create a sufficiently sized corridor both for the corpectomy to be performed and for subsequent cage placement and anterior column reconstruction from a posterolateral trajectory. Given the relatively small bony window created by the aforementioned surgical steps, a concordantly small implant must be used. An expandable corpectomy cage is a sine qua non of our technique. Several groups have reported on their experiences using modular thoracic corpectomy cages with high rates of arthrodesis, restoration of sagittal vertical alignment, and ease of use [12, 19, 26–29]. The need for additional posterior stabilization after anterior cage reconstruction to increase construct stiffness, thereby maintaining deformity correction and preventing graft subsidence, has been known for decades

Table 2 A brief review of approaches for thoracic corpectomy

Corridor	Trajectory	Accessible spinal levels	Access Surgeon Required?	Positioning	Advantages	Limitations	Variations
Transsternal	Anterior/Anterolateral	T1-T4	Variable	Supine	Direct visualization of major vessels. Ventral pathology readily addressed with straightforward anterior column release for deformity.	Mobilization of major vessels, esophagus. Dorsal pathology inaccessible. Second stage posterior stabilization required.	Not applicable
Transthoracic	Anterior/Anterolateral	T3-T10 **T10-L1 with transdiaphragmatic*	Yes	Lateral decubitus	Direct visualization of major vessels. Ventral pathology readily addressed with straightforward anterior column release for deformity.	Mobilization of major vessels, esophagus. Morbidity of thoracotomy (need for lung deflation, post-operative chest tube, etc.). Dorsal pathology inaccessible. Second stage posterior stabilization required.	1. Video-assisted thoracscopy 2. Transdiaphragmatic MIS and mini-open variants for each.
Retroperitoneal	Anterolateral	T12-L2	Variable	Lateral decubitus	Straightforward corpectomy and anterior column release for deformity. Bilateral decompression possible. Avoids the spinal canal. Large cage/graft.	Risk to the lumbosacral plexus. Inadvertent peritoneal entry and injury to its vessels and viscera. Dorsal pathology inaccessible.	Can be combined with retropleural approach for expanded access to the lower thoracic vertebra. Single position (e.g., prone lateral) surgery for concurrent posterior instrumentation.
Extracavitary	Lateral/Posterolateral	T1-T12 **Parascapular limited to T1-T4*	No	Prone	Circumferential access to the spinal canal. Familiar approach. Posterior tension band remains intact. Straightforward posterior instrumentation.	Requires extensive soft tissue dissection and rib resection. Challenging working angles with limited vertebral body resection. Risk of pleural/lung injury. Morbidity of costectomy/costotomy.	1. Retropleural 2. Parascapular 3. Lateral MIS and mini-open variants for each. Costoplasty possible.
Transcostal	Posterolateral	T1-T12	No	Prone	Circumferential decompression possible when bilateral. Familiar approach. Straightforward posterior instrumentation.	Morbidity of costectomy/costotomy. Disruption of the posterior tension band. Higher risk of durotomy and neurological injury.	1. Costotransversectomy 2. Transcostovertebral MIS and mini-open variants for each. Costoplasty possible.
Transpedicular	Posterior	T1-T12	No	Prone	Circumferential decompression possible when bilateral. Familiar approach. Straightforward posterior instrumentation.	Morbidity of costectomy/costotomy. Disruption of the posterior tension band. Higher risk of durotomy and neurological injury.	MIS and mini-open variants for each. Costoplasty possible.

[30]. This concept is particularly important when using a titanium alloy cage, such as our preference, given the greater difference in elastic modulus between titanium and spongiosum. Notably, although we do not regularly employ navigation for this procedure, some groups have found lower rates of cage malposition and thus subsidence when expandable cages are placed with stereotactic guidance [29].

Limitations

A primary limitation of this study is the use of hospital LOS as a surrogate for direct pain score outcomes, which were not formally collected during the study period. The stability of the costocentral and often even the costotransverse articulation is the primary advantage of our technique when compared to other thoracic corpectomy techniques. However, while appropriate in cases of moderate deformity, it may be unsuitable for cases of severe deformity where the anterior- and lateral-most vertebral cortex must also be resected to achieve anterior column reconstruction, such as: gibbus deformity, advanced Kummell's disease, ankylosing spondylitis, Klippel-Fiel abnormalities, or Charcot spinal arthropathy. In such cases, the rib may indeed need to be disarticulated or resected to achieve the desired correction. Our technique's theorized amelioration of post-operative corpectomy pain should be validated with formal pain score recordings or diligent tracking of post-operative pain medication usage. Additionally, further prospective studies across multiple institutions and larger cohorts are warranted to recommend the application of this technique into everyday clinical practice.

Conclusion

A rib-sparing thoracic corpectomy can be effectively, efficiently, and safely performed using a combination of the UBS and a modular, expandable cage during a single stage posterior-only unilateral transpedicular approach with which most spine surgeons are familiar. This technique may reduce post-operative morbidity associated with rib manipulation required by alternative approaches. A prospective quantitative study on post-operative pain control, including patient-reported scores and pain medication usage, can further test this presumption.

Abbreviations

CL	Corpectomy level
EBL	Estimated blood loss
LOS	Length of stay
OT	Operative time
UBS	Ultrasonic bone scalpel

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Not applicable.

Author contributions

Study conception and design was performed by Chase H. Foster, MD, David W. Herzig, MD, Zachary T. Levine, MD, and Jay W. Rhee, MD. Material preparation, data collection and analysis was performed by Chase H. Foster, MD. The first draft of the manuscript was written by Chase H. Foster, MD, Aadit P. Mehta, BS, and Calvin Floyd, BS. All authors reviewed and edited previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to the presence of HIPAA protected personal health information, but are available from the corresponding author as de-identified data upon reasonable request.

Declarations

Ethics approval

This research study was conducted retrospectively with minimal risk from data obtained for clinical purposes and from non-human subjects. Therefore, this study was exempt from IRB approval at Holy Cross Hospital.

Consent to participate

A waiver of informed consent to participate was granted by the Holy Cross Hospital IRB as this study was IRB exempt due to its minimal risk and retrospective chart review design with no direct patient interaction.

Consent for publication

Consent for publication is not required for this study, as no identifying personal details or images of participants are included. All data presented is fully anonymized, ensuring compliance with ethical standards for patient confidentiality and privacy.

Competing interests

Author Jay W. Rhee, MD is a consultant for Misonix and Stryker. The remaining authors have no relevant financial or non-financial interests to disclose.

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