Minimal Access Posterior Approach for Extrapleural Thoracic Sympathectomy: A Cadaveric Study and Cases

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OBJECTIVE: Operatively, video-assisted thoracoscopic sympathectomy (VATS) involves pleural entry and poses risk in small children and patients with pulmonary disease. A conventional posterior sympathectomy is more invasive than VATS. We investigated a cadaveric feasibility study of a minimal access posterior approach for endoscopic extrapleural sympathectomy and discuss this minimal approach in children with cardiac sympathetic pathology.

METHODS: A posterior endoscopic extrapleural approach for thoracic sympathectomy was performed using lightly embalmed cadavers; surgical corridor depth, width, and associated pleural violation were recorded. Two pediatric cases undergoing secondary prevention for breakthrough cardiac dysrhythmias using this approach are discussed: case 1, a 9-year-old girl with refractory long QT syndrome; and case 2, a 13-year-old boy with hypertrophic cardiomyopathy.

RESULTS: The cadaveric study supported 100% identification of a craniocaudal-oriented sympathetic chain using an 18-mm tubular retractor, and a 10% pleural violation rate. There were no clinically significant pneumothoraces in either proof of concept cases.

CONCLUSIONS: Minimal access posterior extrapleural sympathetic ablation is feasible to expose the sympathetic chain in the thoracic region with good visualization using either endoscopic or microscopic magnification. Single-position bilateral thoracic sympathectomy can be performed in pediatric patients with life-threatening ventricular arrhythmias. Based on the cadaveric study and the 2 preliminary cases, we believe that a posterior minimal access approach allows safe and effective access to the thoracic sympathetic chain for causes requiring sympathectomy using single positioning, with minimal risk of pneumothorax or Horner syndrome.

INTRODUCTION

Sympathetic denervation of the upper extremity is commonly performed by interruption of, or resection of, the sympathetic ganglia/chain at levels T2-T3. There are a myriad of indications for upper thoracic sympathectomy, including palmar hyperhidrosis, complex regional pain syndrome, and cardiac sympathetic denervation. Across diagnoses, sympathectomy is most commonly performed via video-assisted thoracoscopic sympathectomy (VATS), which is performed by thoracic surgeons. Alternatively, the procedure is performed via a percutaneous radiofrequency (RF) needle ablation approach; this is less invasive but has a lower success rate than VATS. VATS involves pleural entry and requires dual positioning for a bilateral approach, whereas percutaneous RF needle ablation can be performed bilaterally with the same positioning. Percutaneous RF needle ablation is associated with lower efficacy and a higher recurrence/failure rate than VATS. A posterior costotransversectomy that minimizes pleural entry can be performed bilaterally and is associated with visualization of the sympathetic chain. This method embodies added benefits over VATS and percutaneous RF needle ablation. The concept of approaching the sympathetic chain posteriorly to avoid pleural entry is not new; this was the main approach used by neurosurgeons more than 2 decades ago. In 2008, Gardner et al. reported a posterior approach to the sympathetic chain using a tubular retractor system with the use of endoscopic assistance to complete a posterior thoracoscopic sympathectomy. Here, we describe an anatomic cadaveric study of a minimal access posterior approach for extrapleural thoracic sympathectomy and detail use of the approach in 2 pediatric patients with persistent breakthrough cardiac events including sudden cardiac arrest (SCA) despite medical treatment and implantable cardioverter-defibrillator (ICD) placement.

METHODS

Cadaveric Study Surgical Approach

Five fresh, lightly embalmed cadavers (aged 18–75 years) with no known severe
scoliosis or rheumatoid arthritis of the craniocervical junction were obtained from the Oregon Health and Science University body donation program. All procedures were performed bilaterally (10 exposures, 5 cadavers) in the prone position.

Fluoroscopic guidance was used to identify the heads of the second and third ribs. Using serial dilators, access to the junction of the head of the second rib and its associated transverse process was achieved. With the aid of magnification loupes, muscle and soft tissue were mobilized off the head of the second rib and a zero angle endoscope was passed through the surgical corridor. The costovertebral joint was visualized (Figure 1). Using a high-speed drill, a portion of the transverse process of T2 as well as the head of the rib was removed until enough exposure of the inferomarginal aspect of the T2 body was achieved. The pleura was then bluntly dissected and the sympathetic chain was identified traveling in a craniocaudal orientation underneath the rib head. Care was taken to avoid violation of the pleura (Figure 2). The following parameters were measured and quantified (Figure 3): 1) bony drilling depth to visualization of the sympathetic chain, 2) craniocaudal sagittal extension, 3) drilling width for sufficient exposure of the sympathetic chain, and 4) pleural violation.

**Surgical Procedure in 2 Pediatric Proof of Concept Cases**

After induction of general endotracheal anesthesia, defibrillator pads were placed and the ICD deactivated. Patients were carefully turned prone onto a Jackson table (Mizuho OSI, Union City, California, USA), appropriate antibiotic was administered, and a team pause was performed. No palmar monitoring was performed.

Patients were prepared and draped in sterile manner and the incisions were planned using fluoroscopic landmarks, and a midline incision was opened sharply, exposing the T1 spinal process, to which a spinous process clamp and reference arc from the neuronavigation system (Stryker, Kalamazoo, Michigan, USA) was affixed. A stereotactic image was acquired, accuracy verified, and a new 2.54-cm (1-inch) left parasagittal incision created (Figure 4A). A muscle splitting minimal access technique was used to dock the tubular retractor system between T2 and T3 and confirmed using neuronavigation (Figure 4B).

The tubular retractor was anchored to the bed frame (Figure 4C), providing a surgical corridor for the instruments (Figure 4D). Given the technical necessity of 2 operators to maintain visualization during the approach using the endoscope in the cadaveric exposures, we elected to use the operative microscope for magnification during these cases. We identified the costovertebral joint and proceeded to drill a costotransversectomy, which provided surgical access to the paravertebral sulcus, where the craniocaudal-oriented sympathetic chain was easily identified (Figure 3A). The chain was isolated at T2 sympathetic ganglia using a nerve hook, cauterized using bipolar electrocautery, and sectioned using microscissors; each section was sent for pathologic examination. This approach was duplicated after adjusting the angle of the tubular retractor system cephalad to visualize and section T1 and caudad to visualize and section T3 (Figure 5). A new parasagittal incision was used to access the T4 and T5 sympathetic ganglia as previously described. In case 2, the same minimal access approach using neuronavigation was repeated on the right side, resulting in bilateral T1-T5 sympathectomies. Hemostasis was achieved using bipolar electrocautery. All wounds were irrigated copiously and closed in a layered fashion.

**RESULTS**

**Cadaveric Study**

Endoscopic sympathetic chain exposure was successfully achieved in all cases ($n = 5$) and sides ($n = 10$). The sympathetic chain was often ribbon shaped not cylindrical. Sagittal drill extension, defined as the craniocaudal direction, ranged from 11 to 17 mm and width was $< 18$ mm, which is the diameter of the final tubular retractor. Medial-lateral drilling width was $12-18$ mm. Drilling depth was the most variable result and was usually deeper than anticipated in most cases ($1.0-3.5$ cm; mean, $2.3$ cm) (Table 1). Pleural violation occurred in 1 of 10 exposures. The ideal docking location for the tube was the costovertebral junction with greater exposure of the transverse process than of the rib. A perpendicular trajectory allowed improved drilling of the head of the rib and smaller drilling area compared with an oblique trajectory.

**Proof of Concept**

A 9-year-old girl was diagnosed with genotype-negative malignant long QT syndrome after a sudden syncopal event. She was implanted with an ICD and experienced multiple defibrillations despite escalating polypharmacy. She underwent
left cardiac sympathetic denervation and continued on escalating propranolol therapy without event for 3 months; however, at between 3 and 6 months follow-up, she experienced 3 defibrillations, resulting in syncope. Repeat sympathectomy occurred at 19 months, resulting in interruption of the right T1-5 sympathetic chain. Routine chest radiography after each surgery was negative for pneumothorax and there were no signs of Horner syndrome. In this case, there was an incomplete response to sympathectomy but improvement over multiple weekly defibrillations preoperatively.5

A 13-year-old boy was diagnosed with hypertrophic cardiomyopathy in the setting of a significant family history of ventricular dysrhythmias and SCA. An ICD was placed and 4 defibrillation episodes occurred over 3 years. Interrogation of the ICD after a syncopal episode showed sustained ventricular fibrillation requiring 9 sequential defibrillations. β-Blocker medications were increased, ICD settings modified, and he was referred and underwent bilateral cardiac sympathetic denervation via a minimally invasive posterior extrapleural approach. Postoperatively, there were no signs of Horner syndrome, and there was asymptomatic bilateral small apical pneumothoraces on routine postoperative chest radiography, which did not require thoracostomy tubes. At 13 months follow-up, the patient continued on sotalol and nadolol, and in this case, there have been no cardiac shocks and the patient is symptom free.5

**DISCUSSION**

Interruption of the thoracic sympathetic chain is a surgical procedure, which is intended to denervate the upper extremity of the heart (left T1-T5 sympathetic chain). This procedure is again finding favor as a treatment for the potentially sudden cardiac death and fatal long QT segment syndrome.7 The use of VATS requires changing position in cases in which bilateral interruption is needed. The alternatives to thoracoscopic sympathectomy are RF sympathectomy or what is now almost an obsolete procedure: posterior open sympathectomy.

Posterior approaches allow for sectioning of both sides using the same position with essentially the same approach. RF is minimally invasive but is less efficient compared with open approaches. The trajectory that the RF needle follows can be conceptualized as a potential surgical corridor, if the corridor can be minimized to a tube or a tunnel. We proposed using the endoscope as a substitute for a needle or RF electrodes to achieve visibility of the sympathetic chains. We selected the thoracic sympathetic chain because there was a known posterior surgical approach, which we believed could be reduced to a minimal access approach.

The concept of approaching the sympathetic chain posteriorly to avoid pleural entry is not new. Thoracoscopic approaches are mainstream, but pleural entry is necessary. The main objective of this anatomic feasibility study was to determine the possibility of posteriorly exposing the sympathetic chain without pleural entry. In 2008, Gardner et al.1 reported a posterior approach to the sympathetic chain using a tubular retractor system with the use of surgical microscopy. According to Hardy and Bay,1 posterior exposure of the sympathetic chain in the upper thoracic spine entails a miniature costotransversectomy of the third rib (Figure 1), which allows the exposure of both the second and the third sympathetic ganglia. Those are particularly important to sympathetic denervation of the upper extremity, which is one of many applications of this procedure. In 2010 Taghva et al.9 published a technical case report using a minimal access dilator for circumferential spinal decompression of the thoracic spine, an approach that involves posterolateral minimal access exposure of the spine; nevertheless, they used surgical microscope for the procedure and relatively larger dilator systems.

Kim et al., in 2009,10 performed a cadaveric feasibility study involving 6 cadavers to show the possibility of the posterolateral thoracic corpectomy and reported the ability to remove 80% of the vertebral body using minimal access techniques. These investigators provided a proof of concept that posterolateral spine exposure using tubular retractor and minimal access was feasible.

In this cadaveric study, we show that it is feasible to expose the sympathetic chain in the thoracic region using a tubular retractor via a minimal access approach with the use of an endoscope. We found that drilling depth was variable and that an 18-mm retractor was sufficient and that the sympathetic chain was more or less flattened when visualized from a posterior approach. The exposure of the sympathetic chain was feasible and straightforward given the cranio-caudal orientation of the chain. Pleural violation occurred in 1 of 10 exposures, which we suspect would improve as
familiarity with the procedure improved. A rate of 10% pleural entry is superior to the 100% pleural violation with VATS. Therefore, this approach has the potential to decrease the incidence of pneumothorax or hemothorax after sympathectomy. A posterior approach requires bony drilling, which is not needed with thoracoscopic sympathectomy; however, we believe that the extent of bony drilling is not significant enough to cause instability or pain. Tubular retractor systems are most commonly used with microscopic magnification instead of endoscopic magnification; an endoscope holder was used once the chain was exposed, but until then, bimanual work with an assistant was required either for camera guidance or for suction. The endoscope was also repeatedly obscured with dissection debris. Limitations of the study were related to the cadaveric nature, lacking respiratory variations, and active bleeding, which certainly complicate a living surgical field.

A posterior approach is not the only approach that can achieve bilateral extrapleural access to the sympathetic chain. Percutaneous sympathectomy can be performed bilaterally with the same positioning, although it is associated with lower efficacy and a higher recurrence/failure rate than thoracoscopic sympathectomy. The supraclavicular approach shows initial development of Horner syndrome in 100% of patients, with resolution in only 3 of 10 patients, as reported in 1 study. The extremely high risk of Horner syndrome with a supraclavicular approach is to the result of injury of the ocular sympathetic neurons, which emerge from the first 2 thoracic segments and converge within the stellate ganglion. Surgical cardiac denervation via interruption of the thoracic sympathetic chain is an effective surgical treatment for refractory SCA in children and is well established as primary and secondary prevention using VATS. A literature search produces many institutional studies and individual case reports of left cardiac sympathetic denervation via VATS. Most procedures are for primary cardiac dysrhythmias, including long QT syndrome. Nonsurgical structural disease, including hypertrophic cardiomyopathy, is an uncommonly reported indication for VATS, with many fewer cases reported as part of institutional studies.
We applied the lessons learned from the cadaveric feasibility study to 2 pediatric cases of secondary prevention for cardiac dysrhythmias. Cadaveric options are limited, and child thoraces are not commonly available for research purposes; however, there is a clinical need for sympathectomy procedures in children. Using a minimal access approach through an 18-mm tubular retractor, the pleural violation rate was clinically insignificant and sympathetic denervation was comparable with that of VATS as reported in the literature. Neither patient had postoperative Horner syndrome, clinically significant pneumothorax, or continuing pain requiring analgesia as a result of bony resection. Complete bilateral denervation surgery can be performed with a single prone positioning.

This procedure does require rib head resection, although the periosteum remains intact. We do not know the potential for regrowth in children or the future implications of removing sequential rib heads. The application of a minimally invasive tubular

Figure 4. (A) 1-cm incision overlying the costovertebral joint leads to (B) placement of a minimally invasive tubular retractor, which is (C) anchored to the bed frame providing a (D) surgical corridor.

Figure 5. Intraoperative view through a tubular retractor shows division of the sympathetic chain using microscissors (white arrowhead) and close association of parietal pleura (black arrowhead).
This approach could be added to the armamentarium of pediatric, functional, and spine neurosurgeons.

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**REFERENCES**


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