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Original Article

Thoracoscopy-assisted mini-open approach for resection of neurogenic tumors arising at the thoracic apex

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Abstract: Objective: To present an anterior thoracoscopy-assisted mini-open approach for minimally invasive resection of neurogenic tumors located at the thoracic apex. Methods: From February 2002 to December 2013, 18 consecutive patients underwent resection of neurogenic tumors located at the thoracic apex using a thoracoscopy-assisted mini-open approach at our institution. There were 6 male and 12 female patients with an average age of 36.1 ± 10.3 years. Tumors extended into the vertebral canal with a dumbbell appearance in 3 patients. *Results:* Complete surgical excision was achieved in all patients. Tumor location was T1-2 in 5 patients, T2-T3 in 10, and T3-4 in 3. Mean operating time was 49.7 ± 15.9 minutes, and mean intraoperative blood loss was 72.6 ± 38.4 mL. Chest tube removal occurred at an average of 2.8 ± 1.1 days after surgery, and mean hospital stay was 7.6 ± 2.0 days. Mean intrathoracic neurogenic tumor extension was 5.7 ± 2.2 cm. For patients with dumbbell tumors, laminectomy was performed first to remove the intraspinal component of the tumor. No evidence of tumor recurrence was observed in any case at an average of 56.8 ± 39.1 months after surgery. Conclusion: A thoracoscopy-assisted mini-open approach can provide a simple, safe, minimally invasive, and practical treatment option for patients with neurogenic tumors located at the thoracic apex. This approach has the advantages of minimal trauma, shortened recovery time, and risk reduction of complications.

Keywords: Neurogenic tumors, thoracoscopy, thoracic apex

Introduction

Neurogenic thoracic tumors are neoplasms arising from neurogenic elements within the thorax. Although uncommon, these tumors account for 75% of posterior mediastinal neoplasms, and approximately 10% extend into the vertebral canal, which are termed “hourglass” or “dumbbell” tumors [1-3]. In the adult population, 90% of these neoplasms are benign, whereas in children, only 50% are thought to be benign [3]. In general, thoracic paravertebral neurogenic tumors tend to be found incidentally. Occasionally, however, chest radiographic findings and compressive or neurologic symptoms may be present [4, 5]. Because of doubts regarding the nature of these tumors, the possibility of continued growth, and the question of malignancy, most authors recommend that these tumors be removed surgically at the time of diagnosis [6-8].

Traditionally, although tumor resection by posterolateral thoracotomy is the standard treatment and offers excellent therapeutic outcomes [6, 9, 10], this open anterior approach may cause significant restriction to rehabilitation due to postoperative pain and complications. More recently, resection of thoracic paravertebral tumors through a thoracoscopic approach has become increasingly popular for its efficacy and reduced morbidity compared with thoracotomy [5, 8, 11, 12]. However, neurogenic tumors at the thoracic apex are adjacent to important structures, such as the stellate ganglion, brachial plexus, and subclavian artery. Thus, thoracoscopic gross total resection of these tumors remains a special challenge. In addition, inadequate maneuverability can cause uncontrollable bleeding, brachial plexus injury, or other emergencies, requiring conversion to an open procedure. The aim of this study was to review an anterior thoracoscopy-assisted mini-open approach (**Figure 1**) for minimally

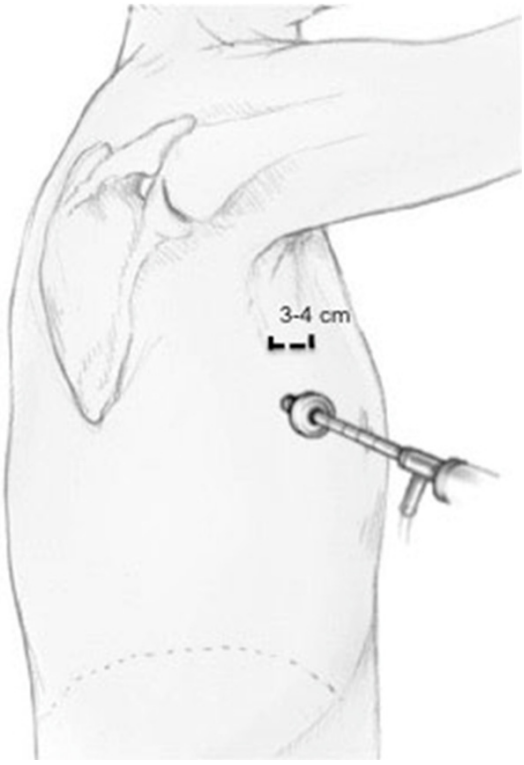

Figure 1. Illustration of the intraoperative patient positioning and incision placement. Patients were positioned placed in the lateral decubitus position, and a working port was centered over the lesion with a caudal thoracoscope port.

invasive resection of neurogenic tumors located at the thoracic apex.

Materials and methods

Patient population

Approval was obtained from our Institutional Review Board before initiation of the study, and written informed consent was obtained from all patients to authorize data collection. We conducted a retrospective review of 18 patients who were admitted for resection of thoracic paravertebral tumors in the Department of Spinal Surgery of the Second Xiangya Hospital from February 2002 to December 2013. There were 6 male and 12 female patients with an average age of 36.1 ± 10.3 years (range, 18-53 years). Ten patients were asymptomatic, 3 had radicular symptoms and chest pain, 2 presented with Horner's syndrome, 2 had lower extremity weakness, and 1 had upper extremity tingling (**Table 1**). Preoperative plain chest radiography (**Figure 2A**, **2B**), computed tomography (**Figure 2C**), and magnetic resonance imaging (**Figure 2D**) showed that all tumors were located at the thoracic apex, with the superior border of the tumor higher than the superior edge of the first rib.

Surgical technique

Under general anesthesia, all patients were intubated with a double-lumen endotracheal tube and positioned in the lateral decubitus position on the opposite side as the tumor. Apart from the standard monitoring required for anesthetized patients, more specialized equipment was utilized to measure somatosensory- and motor-evoked potentials during tumor excision to avoid root avulsion injury to the spinal cord. Orientation using fluoroscopy was performed prior to skin incision. An initial 10-mm incision was made in the fifth or sixth intercostal space near the anterior axillary line for insertion of a 25 thoracoscope to inspect the lung and thorax. Under thoracoscopic visualization, the level(s) of the tumor were located. Then, a 3 to 4-cm skin incision was made between the anterior and posterior axillary line above the target level to provide a working channel (**Figure 1**). After segmental rib resection, a rib spreader was used to expose the thoracic cavity and protect the neurovascular bundle (intercostal vein, artery, and nerve) (**Figure 2E**).

Once the tumor was identified, with gentle traction on the tumor, blunt dissection using a mounted pledget was performed for well-defined tissue planes. Vascular branches of intercostal vessels and feeding vessels to the tumor were clipped and divided. Tumors without spinal extension had their nerve origin divided while avoiding excessive traction to prevent spinal cord injury. In most cases, dissection was simple and straightforward. The tumor was enucleated using conventional instruments without significant difficulty, and then resected (**Figure 2F**) and extracted through the extended manipulating channel. A chest tube was placed prior to wound closure (**Figure 2G**).

For dumbbell tumors, in which a significant component of the tumor extended into the spinal canal, a combined approach was used. First, dissection of the intraspinal component was performed to free the tumor from its relation to the cord. This step was performed using a posterior approach with the patient in the

Table 1. Clinical summary of patients

Case No.	Sex	Age, y	Symptoms	Location	DB	OT, min	Size, cm	Complications	Pathology
1	F	42	None	T2-3	No	50	4.5	Transient intercostal pain	Schwannoma
2	M	25	Radicular chest pain	T2-3	No	65	6.0	None	Schwannoma
3	F	30	None	T2-3	No	45	4.0	None	Neurofibroma
4	F	33	None	T1-2	No	55	4.5	None	Schwannoma
5	F	53	Radicular chest pain	T2-3	No	35	6.5	None	Schwannoma
6	M	18	None	T2-3	No	30	3.5	None	Schwannoma
7	M	28	Horner's syndrome	T1-2	No	90	5.5	None	Schwannoma
8	F	47	None	T2-3	No	40	7.0	Transient intercostal pain	Schwannoma
9	F	32	Radicular chest pain	T2-3	Yes	50	9.5	Transient intercostal pain	Neurofibroma
10	F	20	None	T3-4	No	35	5.0	None	Schwannoma
11	M	50	Upper extremity tingling	T1-2	No	55	6.0	None	Neurofibroma
12	F	36	Horner's syndrome	T1-2	No	75	4.0	None	Ganglioneuroma
13	M	29	Lower extremity weakness	T3-4	Yes	60	11.5	Paresthesia	Neurofibroma
14	F	31	None	T2-3	No	30	5.0	None	Schwannoma
15	F	45	None	T1-2	No	55	2.5	None	Ganglioneuroma
16	M	42	None	T2-3	No	35	5.5	None	Neurofibroma
17	F	33	None	T2-3	No	40	4.5	None	Schwannoma
18	F	47	Lower extremity weakness	T3-4	Yes	50	7.0	None	Schwannoma

Abbreviations: DB, dumbell; OT, operating time.

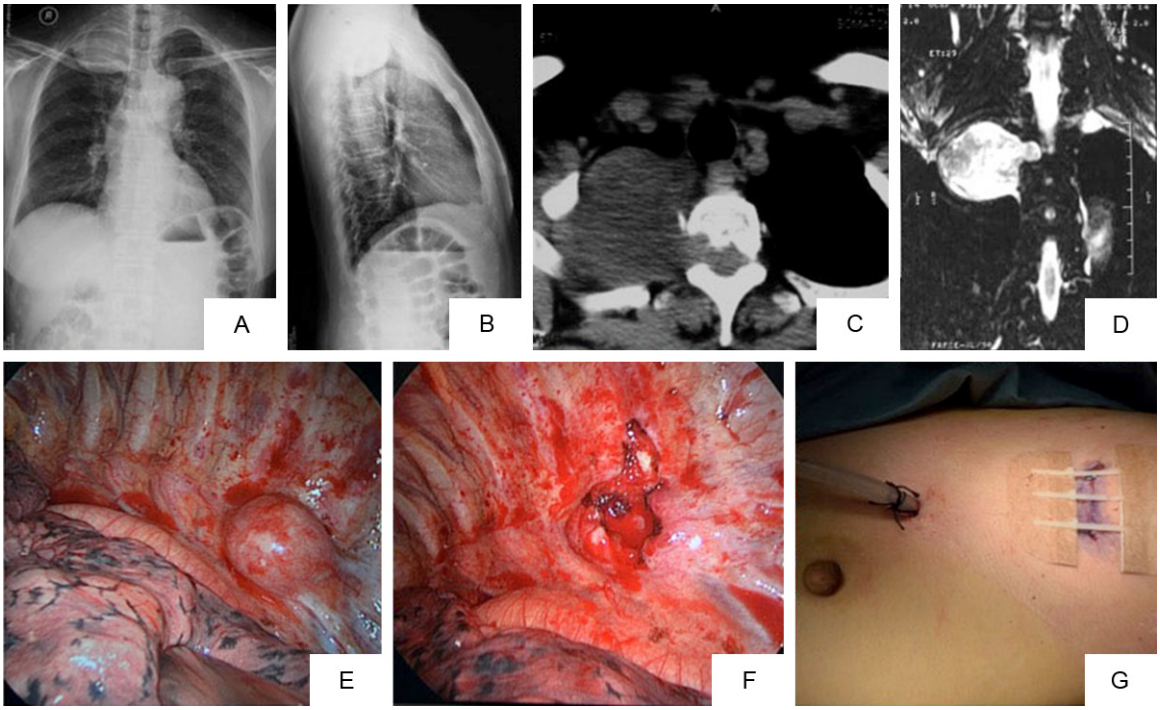

Figure 2. A 47-year-old woman with a neurogenic thoracic paravertebral tumor located at T2. A, B. Anteroposterior (AP) X-ray and lateral plain radiographs, showing a circle-shaped shadow in the right upper thoracic region. C, D. Computed tomography scan and T2-weighted coronal magnetic resonance images, demonstrating a tumor mass with a high-intensity shadow located at the posterior mediastinum and extending into the T2-3 intervertebral foramina. E-G. Tumor was removed completely using a thoracoscopy-assisted mini-open approach. A chest tube was placed and removed 3 to 5 days after surgery.

Table 2. Published results of thoracoscopic excision of thoracic paravertebral tumor

Author	No. of cases	Pathology	No. of symptomatic cases	Surgical approach	OT, min	Size, cm	No. of conversions	Complications	Follow-up, mo	No. of recurrences
Riquet [15]	18	11 schw; 2 GN; 2 NF	None	Thoracoscopy	92	1.5-6	3	4 persistent pain; 1 nerve palsy	2-35	-
Hazelrigg [23]	23	20 NF; 3 GN	None	Thoracoscopy	83	-	4	3 nerve palsy; 2 ileus; 1 pleural effusion; 1 transient pain	-	-
Liu [8]	143	33 schw; 72 NF; 7 para; 31 GN	38	Thoracoscopy	40	1.5-8	None	1 empyema; 9 paresthesia	29	None
Han [20]	7	5 schw; 1 para; 1 GBM	None	Thoracoscopy; laminectomy	251	4-7	None	1 Horner's syndrome; 2 transient pain	12.5	None
Barrenechea [24]	13	4 NF; 8 schw; 1 other	8	Thoracoscopy; laminectomy	229.5	3-9	None	1 tongue swelling; 1 ulnar neuropathy; 1 hyperesthesia	31.7	1
Cardillo [16]	57	48 schw; 2 NF; 7 GN	7	Thoracoscopy	111.4	2-9	13	4 transient pain; 1 phrenic nerve palsy	73	None
Li [17]	58	25 schw; 23 NF; 8 GN; 2 para	16	Thoracoscopy	127.2	2-11	5	4 Horner's syndrome; 2 hypohidrosis; 1 CFL	44.9	None
Yang [19]	19	18 NF; 1 GN	4	Thoracoscopy	93.2	1.7-6	None	1 Horner's syndrome; 4 brachial plexus injury	81	None
Present study	28	10 schw; 15 NF; 2 GN; 1 para	10	Thoracoscopy- assisted mini-open	49.7	2-13	None	4 transient pain; 2 paresthesia	56.8	None

Abbreviations: CFL, cerebrospinal fluid leakage; GBM, glioblastoma; GN, ganglioneuroma; NF, neurofibroma; para, paraganglioma; schw, schwannoma.

prone position. Then, unilateral laminectomy or complete facetectomy was performed. Associated fusion was necessary because of instability related to facetectomy.

Results

Complete surgical excision was achieved in all patients by the same spine surgery team. In 15 patients, gross total resection was achieved through a thoracoscopy-assisted mini-open approach. Three patients also required partial laminectomy to remove the intraspinal component of the tumor. The tumor was located at T1-2 in 5 patients, T2-3 in 10, and T3-4 in 3. Mean operating time for the mini-open approach was 49.7 ± 15.9 minutes (range, 30-90 minutes), and mean intraoperative blood loss was 72.6 ± 38.4 mL (range, 50-165 mL). Chest tube removal occurred at an average of 2.8 ± 1.1 days (range, 1-4 days) after surgery, and mean hospital stay was 7.6 ± 2.0 days (range, 5-10 days). Mean intrathoracic neurogenic tumor extension was 5.7 ± 2.2 cm (range, 2.5-11.5 cm). Histopathology revealed schwannoma in 11 patients, neurofibroma in 5, and ganglioneuroma in 2 (**Table 1**).

Postoperative outcomes

All surgical and postsurgical outcomes were satisfactory, and no mortality occurred. Preoperative symptoms of Horner's syndrome and limb weakness or tingling resolved postoperatively. Postoperative morbidities included 3 patients with prolonged radicular pain, which was managed with narcotics, and 1 patient with paresthesia over the chest wall in the dermatomal distribution of the intercostal nerve at 3 months postoperatively. At the final follow-up, all patients were free of symptoms. No evidence of tumor recurrence was observed in any case at an average of 56.8 ± 39.1 months (range, 17-122 months) after surgery.

Discussion

Gross total resection is the most important objective in patients with thoracic paravertebral neurogenic tumors. Obtaining tissue for diagnosis, relieving the mass effect within the chest, preventing tumor growth within the spinal canal, and preventing malignant transformation also are beneficial. Since Landreneau *et al.* [12] first reported use of a thoracoscope for resection of posterior mediastinal neurogenic tumors in 1992, thoracoscopic surgery has been documented as a good alternative method for excision of this type of tumor [5, 8, 11] (**Table 2**).

Compared with thoracotomy, thoracoscopic surgery provides significant reductions in postoperative pain, pulmonary complications, and shoulder girdle dysfunction, as well as shortened hospital stays. Liu *et al.* [8] performed a retrospective review of 143 patients who underwent thoracoscopic resection of neurogenic tumors in the chest cavity, with a mean operating time of 40 minutes, negligible blood loss, and mean hospital stay of 4.1 days. However, most of these tumors were located in the upper half or third of the chest. The technical accuracy of thoracoscopic surgery is inferior to that of general thoracotomy at present, and length of surgery is longer because it is difficult to use thoracoscopic instruments precisely in cases of unexpected bleeding or other emergencies [13, 14]. Riquet *et al.* [15] and Cardillo *et al.* [16] reported that the rate of conversion to thoracotomy was 16.7% (3/18) and 22.8% (13/57), respectively, due to large tumor volume and difficulty locating the tumor under thoracoscopy. According to the literature, tumors larger than 6 cm, those located at the apex of the chest cavity, and those in the costodiaphragmatic location are considered contraindicated for thoracoscopic surgery [17, 18]. Using a mini-open approach, modified extended manipulating channels can be created to allow use of a combination of thoracoscopic and conventional spinal instruments designed to isolate the tumor by blunt dissection. This technique is not as limited in maneuverability as thoracoscopic surgery. In our series, the intrathoracic tumors were located from T1 to T4 and ranged from 2 to 13 cm in size. We achieved complete tumor resection in all cases, and blood loss, operating time, and length of hospital stay were similar to thoracoscopic surgery (**Table 2**). Of note, the procedure was performed through a 3 to 4-cm incision; therefore, the cosmetic appearance was satisfactory following the procedure.

In removal of such tumors, complications related to the complicated and intricate anatomy of the thoracic spine and the proximity of the thoracic organs, shoulders, scapulae, and thoracic

cage should be considered. These features render thoracoscopic surgery difficult. In addition, inadequate room for maneuverability can cause uncontrollable bleeding or injury to the surrounding nerves associated with electrocoagulation [15, 16, 19]. Yang *et al.* [19] reported higher incidence of brachial plexus injury in patients undergoing thoracoscopic surgery (21.1%; 4/19) compared with thoracotomy (2.3%; 1/44). Takeda *et al.* [4] and Han *et al.* [20] reported that postoperative Horner's syndrome occurred because of the proximity to the sympathetic ganglion. However, in our series, none of the above complications occurred. Postoperatively, 4 patients experienced complete relief of preoperative symptoms of Horner's syndrome and lower extremity weakness. Conventional thoracoscopic surgery is limited by the small size of the utility port and reduced maneuvering angle, making en block tumor resection difficult. However, our procedure does not have this limited maneuverability, facilitating en bloc resection, which eliminates residual tissue and reduces tumor recurrence. In fact, there was no tumor recurrence during the follow-up period in our study.

The learning curve associated with thoracoscopy is a major consideration for initial adoption of such technique for spine surgeons who do not perform thoracoscopic surgery frequently. Much time and effort are required to negotiate this difficult learning curve. The procedure described in our series, employing a 3 to 4-cm incision and endoscopic port, is easier to perform. This approach provides adequate visualization of the thoracic spine, including vessels, nerves, and visceral structures, which can be easily identified by spine surgeons, while a direct three-dimensional view makes the procedure easier. However, patients with pleural symphysis and those with severe underlying lung disease or poor lung function, who are unable to tolerate selective one-lung ventilation during general anesthesia, are contraindicated for this procedure as well as conventional thoracoscopic techniques [21, 22]. Additionally, patients with thoracic paravertebral tumors extending into the vertebral canal also require a posterior operation to remove the intraspinal component of the tumor.

However, there were some limitations to this retrospective study. First, we did not have a control group for comparison, such as patients who underwent a thoracoscopic technique or traditional thoracotomy. In addition, because of the small sample size and higher probability of error, the clinical efficacy lacks concurrent controls and the data have a certain limitation.

In conclusion, an anterior thoracoscopy-assisted mini-open approach can be a safe and effective minimally invasive procedure for resection of paravertebral neurogenic tumors arising at the thoracic apex. The shorter learning curve makes this procedure more accessible to spine surgeons, and involves less trauma, shorter hospital stay, and less pain and disability, while minimizing the risk of complications.

Disclosure of conflict of interest

None.

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