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Thoracic neuroblastoma: a retrospective review of our institutional experience with comparison of the thoracoscopic and open approaches to resection☆

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Abstract

Purpose: Neuroblastoma is the most common extracranial solid tumor in children. Twenty percent of all neuroblastomas arise in the thorax. This study evaluates the open vs thoracoscopic resection of thoracic neuroblastoma.

Methods: A retrospective chart review was conducted from the medical records of all children undergoing resection of a thoracic neuroblastoma from 1990 to 2007 at our institution. We evaluated patients who underwent open vs thoracoscopic resection and compared demographics, pathologic condition, stage, operative details, complications, and outcomes between the 2 groups.

Results: A total of 149 cases of neuroblastoma were identified during the study period, 36 (24%) of which had tumor located in the thorax. Thirty-six of these patients underwent 37 operations for primary thoracic neuroblastoma. Open thoracotomy was used in 26 cases with the thoracoscopic approach to resection used in the remaining 11. We observed no differences in patient demographics including mean age, sex, or ethnicity. Tumors in both groups were of similar histologic condition, location, surgical margin, lymph node status, and stage. The length of operation was similar between the 2 groups, but length of stay was shorter in the thoracoscopic group (2.0 days; range, 1-7 days vs 3.5 days; range, 2-8 for the open group; $P = .01$). Estimated blood loss was also less in the minimally invasive group (median, 10 mL; range, 0-75 mL vs 25 mL; 5-650 mL in the open group; $P = .02$). Review of outcomes showed no significant difference in complications, recurrence, survival, or disease-free survival between these 2 groups.

Conclusions: This retrospective review of thoracic neuroblastoma for an 18-year period shows that thoracoscopic resection is an effective approach to this tumor and offers shorter length of stay and decreased blood loss when compared to open thoracotomy.

Neuroblastoma is the most common extracranial solid tumor in children. Up to 20% of all neuroblastomas arise in the thorax. The prognosis for children with thoracic neuroblastoma is better than those with tumors at other

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sites, most likely because of a less aggressive biologic nature [1]. Resection of thoracic neuroblastoma has traditionally been approached via a posterolateral thoracotomy. However, in recent years, minimally invasive approaches have become more appealing. Studies have demonstrated shorter operative times, less postoperative pain, shorter hospital stay, and excellent cosmetic results with thoracoscopy [2]. Despite reports that suggest complete resection is not always necessary for cure for thoracic neuroblastoma [3], it has also been demonstrated that the thoracoscopic approach to resection can offer equivalent results with resection compared to open techniques. Several institutions have reported the regular application of the minimally invasive approach for thoracic neuroblastomas with good results [4-6]. Here, we review our own institutional experience with thoracic neuroblastoma for an 18-year period (1990-2007) comparing the open and minimally invasive approaches. In pursuing this study, we hypothesized that thoracoscopy offers a safe and effective means of resecting thoracic neuroblastoma while offering all of the reported benefits of minimally invasive surgery.

1. Materials and methods

After obtaining institutional review board approval (no. 0702121), we retrospectively reviewed the charts of all patients who had an operation for thoracic neuroblastoma for an 18-year period at the Children's Hospital of Pittsburgh of University of Pittsburgh Medical Center. Any patient who underwent resection of a primary neurogenic tumor of the thorax was included. One patient was excluded from the length of stay evaluation because he endured an extended intensive care unit stay secondary to what was ultimately called *wandering atelectasis*.

The charts were reviewed for patient demographics (age, race, and sex), preoperative evaluation (vanillylmandelic acid level, homovanillic acid level, size, and location of tumor on computed tomographic scan, and presence of metastases), preoperative therapy (radiation, chemotherapy, or bone marrow transplant), operative data (type of operation, estimated blood loss, fluid volume given, placement of chest tube, and the length of operation), tumor characteristics (lymph node status, stage, size, margins, and DNA), and outcomes (chest tube duration, complications, length of stay, recurrence, survival, and disease-free survival).

Open resection was achieved through standard posterolateral thoracotomy with or without lung isolation anesthetic. Thoracoscopic or video-assisted thoracoscopic surgery (VATS) resection was achieved with patients in the lateral decubitus or slightly prone position. Single-lung ventilation was used in every case possible or with CO_2 insufflation at 4 to 6 mm Hg pressure alone in infants less than 20 kg. Depending upon patient size, 3 trocars, 4-mm or 5-mm and 10-mm, were used in these operations with specimen dissection and excision performed with electrocautery or harmonic scalpel devices. The specimen was invariably removed via an endoscopic bag through an enlarged 10-mm site as necessary in all cases without the need for rib spreading (up to 2.5 cm).

Patients were analyzed as 2 separate groups: those receiving open thoracotomy and those undergoing thoracoscopy. Differences between these 2 groups were evaluated using either the χ^2 or Fisher's Exact tests for categorical variables and the Mann-Whitney test for continuous variables using SPSS software (Statistical Package for the Social Sciences, version 15.0; SPSS Inc, Chicago, Ill). A 2-sided P value of less than .05 was considered statistically significant.

2. Results

A total of 149 cases of neuroblastoma were identified between 1990 and 2007 at our institution. Of these patients, 36 were identified with thoracic neuroblastoma and underwent a total of 37 operations for resection. Open thoracotomy was the surgical approach for 26 of the 37 cases, with the thoracoscopic approach being used in the remaining 11.

The 2 groups were similar with respect to age, race, and sex. There was no difference in lymph node status, preoperative vanillylmandelic acid/homovanillic acid levels, or tumor size on preoperative computed tomographic scan. The 2 groups were also comparable with regard to preoperative chemotherapy, radiation, and bone marrow transplant. Tumors in each group were comparable for size, stage, margins, DNA status, and the presence of distant metastases. N-*myc* was amplified in 2 of the 11 tumors resected via the minimally invasive approach but in 0 of the 26 tumors resected by open thoracotomy (P = .05). Estimated blood loss was lower in the thoracoscopic group (median, 10 mL; range, 0-75 mL vs 25 mL; range, 5-650 mL in the open group; P = .02). There was no difference in length of operation, but overall length of stay was shorter in the thoracoscopic group (2.0 days; range, 1-7 days vs 3.5 days; range, 2-8 days for the open group; P = .01). Although the duration of hospitalization was less in the thoracoscopic group, the length of stay in the intensive care unit was comparable between the 2 groups. There was no difference in the number of patients who required tube thoracostomy between these 2 groups; however, the duration of tube placement was significantly less in the thoracoscopic group (Table 1).

Review of outcomes showed no significant difference in complications and that the types of complications were similar in these 2 groups. The open group had 5 complications, including Horner's syndrome (2), chylothorax (1), postoperative scoliosis (1), and severe atelectasis (1). The thoracoscopic group had 3 complications including Horner's syndrome (2) and severe atelectasis (1). Further review of outcomes showed no difference in recurrence, survival, or disease-free survival between these 2 groups (Table 1).

Table 1 Comparison of demographics, tumor stage, preoperative treatment, operative details, and outcomes between the thoracoscopic and open surgery groups

	Thoracoscopic (n = 11)	Open (n = 26)	*P*
Sex (female)	4 (36.4%)	13 (50%)	.50
Age (mo), median (range)	13 (8-156)	6 (0-72)	.07
Race			.54
African American	0 (0%)	3 (12%)	
White	11 (100%)	22 (88%)	
Stage			.61
1	4	6	
2	6	12	
3	0	3	
4	1	3	
Elevated vanillylmandelic acid /homovanillic acid	4 (36.4%)	9 (42.9%)	1.00
DNA (aneuploid)	2 (50%)	9 (50%)	1.00
N-*myc* (amplified)	2 (33.3%)	0 (0%)	.05 [a]
Chemotherapy	3 (27.3%)	3 (12%)	.343
Radiation	1 (9.1%)	2 (8%)	1.00
Bone marrow transplant	2 (18.2%)	0 (0%)	.09
Metastases	1 (9.1%)	4 (17.4%)	1.00
Positive margins	4 (57.1%)	11 (73.3%)	.63
Positive lymph nodes	5 (55.6%)	11 (61.1%)	1.00
Estimated blood loss (mL), median (range)	10 (0-75)	25 (5-650)	.02 [a]
Operative time (min), median (range)	150 (53-468)	181 (88-420)	.41
Chest tube	9 (81.8%)	24 (96%)	.16
Chest tube (d), median (range)	1 (0-2)	2 (1-4)	.001 [a]
Length of stay (d), median (range)	2.0 (1-7)	3.5 (2-8)	.013 [a]
Intensive care unit length of stay (d), median (range)	0 (0-3)	0 (0-3)	.36
Complications	3 (27.3%)	5 (20%)	.678
Recurrence	1 (9.1%)	4 (16.7%)	1.00
Survival	10 (100%) [b]	15 (100%) [b]	
Disease-free survival	9 (90%) [b]	14 (93.3%) [b]	1.00

[a] Indicates that the value is statistically significant.
[b] Indicates that some patients were lost to follow-up.

All thoracoscopic resections were done in or after the year 2000 with only 3 open resections performed during this period (total of 14 resections). There were 23 open resections between 1990 and 2000. There were no differences in patient demographics or tumor characteristics between the period 1990 to 2000 (open era) and the period 2000 to 2007 [Minimally invasive surgery (MIS) era]. As such, the only differences found between patients treated in the open era and those treated during the MIS era were the same as those found between the open thoracotomy and thoracoscopic groups.

3. Discussion

Our institution has a large experience with pediatric neuroblastoma both above and below the diaphragm. Traditionally, resection for thoracic neuroblastoma has been achieved through a posterolateral thoracotomy. After the year 2000, most thoracic neuroblastomas at our institution (11/14) have been resected using a thoracoscopic approach. The minimally invasive approach has several well-accepted advantages including enhanced visualization, shorter length of stay, and less postoperative pain [4,6,7]. We sought to confirm that in the case of thoracic neuroblastoma, a thoracoscopic approach would indeed provide patients with these advantages without negatively affecting outcome. In fact, we believe that thoracic neuroblastoma represents an ideal case for a minimally invasive technique because as complete a resection can be achieved with this approach as compared to thoracotomy and resection for tumors that do not enter the spinal foramina.

Chest wall–related complications after posterolateral thoracotomy in children are common with postoperative scoliosis seen in up to 30% of patients [8,9]. These complications are significantly increased in comparison to a muscle-sparing thoracotomy, including scoliosis (16%-30% vs 2.5%), shoulder elevation (30% vs 7.5%), winged scapula (38% vs 12.5%), and asymmetric nipples (40% vs 12.5%) [10]. One report suggests that the high complication rate associated with posterolateral thoracotomy may be related to increased neurogenic and muscular damage [11].

This risk would presumably be avoided with the thoracoscopic approach to resection.

Advocates of the VATS approach to aid in visualization and dissection as well as avoidance of postthoracotomy sequelae suggest that VATS be considered for thoracic lesions based upon certain criteria such as tumor size, location, N-*myc* amplification, and resectability [4]. In this multicenter study, they reported complete thoracoscopic resection (n = 21), no recurrences, and no conversion to open thoracotomy. We had one recurrence after thoracoscopic resection in a patient diagnosed with a ganglioneuroma that was secreting dopamine (causing symptomatic heart palpitations) who had an initial 24-hour urinary dopamine level of 2348 μg/24 h (reference range, 51-645 μg/24 h). His urinary norepinephrine and epinephrine levels were normal. After initial thoracoscopic resection, his urinary dopamine level decreased to 1100 μg/24 h but subsequently climbed to 1442 μg/24 h 2 months after his initial resection, and he developed palpitations once again. He underwent thoracoscopic reresection of the residual lesion with resolution of symptoms. His urinary dopamine level has remained in the normal range for more than 5 years since his second resection. Interestingly, he developed anhidrosis of the ipsilateral hand and face that has not changed over time, but he did not develop a Horner's syndrome.

We observed a significant decrease in intraoperative blood loss, length of stay, and chest tube duration for patients managed thoracoscopically. Similar results have been reported in other studies [5,7,12]. In some cases, a chest tube was not placed at all after either thoracoscopy or thoracotomy. This technique has been demonstrated to be safe in selected cases [13]. Smaller wounds, minimal rib trauma, and shorter chest tube duration may contribute to the faster postoperative recovery and shorter length of stay after thoracoscopic resection compared to thoracotomy patients. Others have described shorter operative times for the thoracoscopic approach to thoracic neuroblastomas compared to open resection, although these differences were not statistically significant [5]. We found a similar result in our series.

Thoracic neuroblastomas will frequently enter multiple spinal foramina. Attempts at removal or dissection close to the spinal nerve roots may result in injury or cerebral spinal fluid leak by direct trauma or dispersion of heat by electrocautery. Because the visualization afforded by thoracoscopy is superior, tumors entering spinal foramina can be easily identified, and an adequate, safe, controlled resection can be performed as indicated. LaCreuse et al [4] has suggested that tumors extending into the paraspinal space may not be amenable or reasonable to approach minimally invasively. We would agree with this statement but had no such tumors in our thoracoscopic group.

There were no differences in recurrence, survival, or disease-free survival in the thoracoscopic vs open thoracotomy groups. It has been shown that tumors with N-*myc* amplification have a poorer prognosis overall [14]. Although we had more tumors with N-*myc* amplification in the thoracoscopic group, there was no difference in outcomes compared to the open group that suggests that the operative approach using thoracoscopy was at least as good for resection as the open approach. Suita et al [1] demonstrated improved outcomes with patients with mediastinal neuroblastoma compared to neuroblastoma at all other sites although they proposed that the improved outcomes were related to biologic factors of the tumor more than the extent of surgical resection. They found no differences in the incidence of complications between the open and thoracoscopic resection patients. Interestingly, the incidence of Horner's syndrome was 11% overall in our series (4/37) that is consistent with the reported incidence of 3% to 29% [4-6,15,16]. The incidence of Horner's syndrome is likely related to the location of the tumor in the superior cervical sympathetic chain ganglion and not the mode of resection.

We believe our data demonstrate that the thoracoscopic approach can yield similar outcomes and complication profiles to open thoracotomy for the resection of thoracic neuroblastomas. There may also be some added advantages to the minimally invasive approach, including decreased blood loss and shorter length of stay. We are aware of the limitations of a retrospective study. Although both groups had similar patients and tumors, there exists some level of surgeon bias when choosing the operative approach. In addition, because the thoracoscopic approach has been used more recently, there has been shorter follow-up that is a possible bias when comparing recurrence and survival with the open group.

In conclusion, we describe 2 eras of surgical management of thoracic neuroblastoma at our institution, the open era (1990-2000) and the MIS era (2000-2007). There were no differences between the patients or aggressiveness of disease between these 2 eras. Our outcomes in the MIS era were similar to those in the open era, but we were able to achieve these outcomes with less intraoperative blood loss, a shorter duration of indwelling chest tubes, and with a shorter overall length of stay. This experience suggests that the minimally invasive approach is at least as good as the open approach for thoracic neuroblastoma. We would recommend that prospective evaluations should be performed to control for biases present in a retrospective review and to provide further evidence for our conclusions.

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