A novel muscle-sparing high thoracotomy for upper thoracic spine resection and reconstruction

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Abstract

Purpose High thoracotomy allows access to the anterior cervicothoracic and upper thoracic vertebrae; however, traditional techniques transect shoulder girdle muscles, leading to postoperative shoulder dysfunction. Muscle-sparing techniques diminish this concern, but often sacrifice the quality of exposure. We describe a novel muscle-sparing, high thoracotomy approach for the treatment of ventral cervicothoracic and upper thoracic spine lesions.

Methods A novel muscle-sparing, high thoracotomy approach is described, utilizing a midline posterior incision with lateral extension from the lateral decubitus position. Five patients are presented to illustrate the application of this technique in thoracic tumors with intimate spinal involvement.

Results The muscle-sparing, high thoracotomy approach afforded gross total resection and spinal reconstruction in five consecutive patients, including stage IV lung carcinoma with invasion of the T5 and T6 vertebral bodies, two malignant fibrous histiocytomas causing thoracic cord compression, a metastatic T6 lesion of unknown primary with associated cord compression; and a Pancoast tumor. All patients seen at 6 months had full symmetric shoulder range of motion postoperatively.

Conclusions The described muscle-sparing, high thoracotomy approach provides excellent exposure of the ventral cervicothoracic and upper thoracic spine without the morbidity associated with the transection of shoulder girdle muscle bellies. This technique is particularly useful in patients with primary malignant bone tumors requiring en bloc excision and metastatic tumors with large soft tissue components.

Keywords Thoracotomy · Muscle-sparing · Cervicothoracic spine · Upper thoracic spine · Spinal tumor · Spinal reconstruction

Introduction

Many tumors, infections, and deformities involving the anterior aspect of the upper thoracic vertebrae require surgical intervention for management; however, anterior exposure of the upper thoracic spine is challenging because of the

unique anatomy in this region. Specifically, the thoracic cage narrows to reach the thoracic inlet, which results in the intimate relationship of the superior mediastinal structures to the vertebral column. These structures, including the sternum, clavicles, great vessels, heart, trachea, and esophagus, impede direct anterior access to the upper thoracic vertebrae. Several approaches to access the ventral upper thoracic spine have been described with the most common technique being the classic high thoracotomy. While this approach enables adequate exposure, it is associated with significant morbidity, as transection of the shoulder girdle muscles is required [1–6]. A “muscle-sparing” approach is ideal from a functional standpoint; however, the degree of access and visibility may be compromised.

This study describes a novel technique allowing for simultaneous access to the anterior and posterior cervicothoracic and upper thoracic spine via high thoracotomy while preserving the muscles of the shoulder girdle. Additionally,

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five patients with tumors in this region treated with vertebral column reconstruction are reported. This muscle-sparing technique, which allows for the circumferential reconstruction of the spine, may decrease the likelihood of the shoulder dysfunction typically associated with standard high thoracotomy techniques.

Materials and methods

Patient information

Five patients with cancer involving the upper thoracic spine were treated with tumor resection and vertebral column reconstruction using the muscle-sparing, high thoracotomy approach. Each patient's chart was retrospectively reviewed. Demographic data and clinical course were reviewed.

Indications and patient selection

A multi-disciplinary team approach is essential to the successful treatment of patients undergoing high thoracotomy procedures for tumor resection and reconstruction. Careful consideration must be given to each patient's medical condition, capacity to withstand surgery, oncologic prognosis, adjuvant and neoadjuvant treatment plan, neurologic status, spinal stability, and pain level. The goal of operative management is typically surgical cure with complete resection of the tumor. The importance of achieving negative surgical margins on long-term survival postoperatively is well established [7, 8]. Muscle-sparing high thoracotomy should be considered for patients with lesions that require a high thoracotomy for tumor removal and is especially useful and beneficial for the removal of large benign and malignant vertebral bone tumors requiring en bloc excision, metastatic tumors with large soft tissue masses, and lung cancer with direct invasion into the spine. When possible, en bloc resection is preferable as it minimizes the risk of contaminating the thoracic cavity and, therefore, the risk for local recurrence. However, intralesional excision with gross total resection and adjuvant chemotherapy and/or radiation may be preferred in select cases, such as metastatic disease, when en bloc resection would require significantly higher surgical morbidity without obvious prognostic benefit. Consideration toward risks and benefits in such cases is complex, and the ultimate decision to proceed with surgery must be made after thorough discussion with the patient, patient family, and treating medical team members.

Patient positioning

In the setting of a planned single-stage muscle-sparing high thoracotomy, the lateral decubitus position is preferred. This

allows access to the anterior and posterior cervicothoracic, upper and middle thoracic spine as well as the thoracic cavity for tumoral resection and subsequent reconstruction.

In certain instances, procedural staging may be necessary. This takes into consideration the technical challenges of tumoral resection as well as spinal reconstruction. For example, obtaining satisfactory spinal alignment across the cervicothoracic junction is possible from the lateral decubitus position; however, it is technically much more challenging. In patients that can tolerate staged surgery, initial posterior instrumentation from the prone position allows for simpler assessment of cervicothoracic alignment and offers provisional spinal stabilization prior to tumor resection and anterior spinal reconstruction. It also allows removal of the posterior elements, as well as transection of the posterior longitudinal ligament, which initiates mobilization of the tumor and facilitates resection of the tumor. Muscle-sparing high thoracotomy can subsequently be performed from the lateral decubitus position.

Surgical technique

The patient is carefully positioned so that the neck and spine remain in neutral alignment. A three-point Mayfield head holder is effective in maintaining head and neck position throughout the duration of the case. The single pin is placed anteriorly, directly in the center of the forehead, with the double pins positioned posteriorly. This aids in maintaining neutral rotation. Care is taken to ensure that the tip of the nose, lips, and chin are positioned in line with the center of the sternal notch and xiphoid process. This ensures that there is no lateral tilt of the neck. The patient is positioned in the lateral decubitus position on a bean bag. The head, shoulders, and pelvis remain collinear to minimize fixation of the cervical spine in rotation. Fluoroscopy can aid in confirming appropriate positioning. Subsequently, the back and chest, along with the entire ipsilateral upper extremity, are prepared and draped past the midline.

A longitudinal posterior midline incision extending at least three spinous processes above and below the lesion is then made (Fig. 1a). The midline raphe from which the left and right trapezius, levator scapula, and rhomboid muscles originate is identified and split longitudinally over the spinous processes. These muscles can be elevated en bloc in a blunt manner off the chest wall. When necessary, a second anterolateral incision can be made distally at a right angle to the posterior midline incision to facilitate additional lateral access to the chest cavity. This is most useful for larger tumors where more extensive rib resection is necessary with posterolateral extension of the tumor. In such cases, the caudal insertion of the trapezius muscle may require transection to facilitate further mobilization, creating a musculocutaneous flap that can be retracted

Fig. 1 Approach to the cervicothoracic and upper thoracic spine utilizing a muscle-sparing high thoracotomy. **a** The origin of the trapezius, levator scapulae, and rhomboids are dissected from the spinous processes at the midline raphe with the patient in the lateral decubi-

tus position. **b** The anterior aspect of the spine is exposed via mobilization of the paraspinal musculature and subsequent posterior rib resection

anteriorly. This exposes the paraspinal muscles, which are then mobilized. Longitudinal, sharp dissection along the medial origins and lateral insertions of these muscles facilitates blunt elevation from the underlying chest wall. A Penrose drain can be placed around the paraspinal muscles to facilitate this mobilization and retraction during the remainder of the procedure. The ribs are now completely exposed.

Direct access to the thoracic cavity can then be achieved through the appropriate intercostal space, with or without transection of the ribs (Fig. 1b). The vertebral lesion along with its surrounding soft tissue mass is then exposed and carefully removed, either with an en bloc or intralesional excision under direct visualization. The lung resection can be performed in this position for patients with lung lesions invading the vertebra. The anterior column is reconstructed using a carbon fiber or titanium mesh cage and bone graft along with anterior spinal instrumentation. Unilateral or bilateral exposure of the posterior elements of the thoracic spine is performed through the same posterior midline incision to allow simultaneous access to the anterior and posterior aspects of the spine. Circumferential reconstruction is completed with posterior instrumented fusion. A layered wound closure is performed over a deep drain and a chest tube. The paraspinal muscles are returned to their anatomic position or mobilized medially to cover the posterior spinal instrumentation. The tendinous origins of the muscles of the shoulder girdle are reapproximated anatomicallly to the tendinous origins of their contralateral counterparts utilizing interrupted sutures along the midline raphe. The subcutaneous tissue and skin are closed in the usual fashion.

Results

The muscle-sparing, high thoracotomy approach was utilized in the treatment of five patients with cancer involving the cervicothoracic and upper thoracic spine. Successful gross total resection of each tumor was achieved. In cases where en bloc resection could be performed, negative margins were confirmed. All patients had normal neurologic function and spinal stability without evidence of local recurrence during follow-up. In patients seen at 6 months postoperatively, shoulder range of motion in forward flexion and abduction was symmetric to the contralateral side or within 10°. A summary of each patient's hospital course, postoperative follow-up, shoulder function, and survival can be found in Table 1. Each patient's individual case is presented below.

Case 1

A 52-year-old man diagnosed with stage IV lung carcinoma measuring 4 × 5 × 7-cm with invasion of the T5 and T6 vertebral bodies underwent planned single-stage en bloc excision of the right upper lobe of the lung and the right one half of the T5 and T6 vertebral bodies using the muscle-sparing, high thoracotomy approach. Subperiosteal dissection along the posterior elements of the thoracic spine was performed from T3 to T9. Approximately 10 cm of the right fourth, fifth, and sixth ribs were excised to gain adequate exposure to the tumor. A laminectomy at T5 and T6 was performed and the right T5, T6, and T7 nerve roots were ligated and transected. Bilateral pedicle screws were placed from T3 to T9 followed by placement of a left-sided posterior rod bent into thoracic kyphosis for

Table 1 Summary of each patient's clinical course, follow up, and survival

Patient	Diagnosis/resection	EBL (cc)	Admission duration (days)	Admission complications	Survival (months)	Cause of death	Shoulder function (6 months)
Case 1	Stage IV lung carcinoma/en bloc upper lobectomy, T5–T6 parasagittal hemi-corpectomy	2600	10	None	4	Pulmonary embolus	Unable to obtain ^a
Case 2	Malignant fibrous histiocytoma/marginal excision of soft tissue component, T3 intralesional corpectomy	1100	9	None	21	Unknown	FF 170° Abd 160°
Case 3	Metastatic carcinoma (unknown primary)/T5 en bloc corpectomy	1800	7	None	26	Metastatic carcinoma	FF 170° Abd 170°
Case 4	Radiation-associated malignant fibrous histiocytoma/C6–T3 en bloc spondylectomy	3200	56	ARDS, pneumonia	4	Sudden death; suspected pulmonary embolus	Unable to obtain ^a
Case 5	Non-small cell pancreatic tumor/marginal excision intrathoracic component, intralesional T2–T3 corpectomy	4000	16	Pneumonia	109	Alive	FF 170° Abd 160° QuickDASH 13.6 ^b

^aThese patients were deceased prior to the 6 month follow up visit

^bOne patient is currently alive; thus, QuickDASH score is available for this patient

stability. An osteotome was used to transect the T5 and T6 vertebral bodies parasagittally, and a right upper lobectomy was performed by the thoracic surgeon. The mass was successfully removed en bloc with the sagittally transected vertebral bodies of T5 and T6. A carbon fiber cage filled with autograft rib mixed with allograft bone was placed and a single-rod anterior column reconstruction was performed between T4 and T7. Subsequently, the right posterior rod was placed followed by application of both posterior and anteroposterior crosslinks (Fig. 2a–c).

Case 2

A 62-year-old woman presented with T3 spinal cord compression secondary to metastatic malignant fibrous histiocytoma with an associated 6 × 5 × 4-cm soft tissue mass. She underwent a muscle-sparing, high thoracotomy with partial excision of the left fourth rib. Planned gross total excision was performed with a marginal excision of the soft tissue mass combined with an intralesional excision of the tumor involving the T3 vertebral body. Anterior reconstruction was performed using a titanium mesh cage and a single-rod anterior construct. Posterior pedicle instrumentation was placed to provide additional stability. The patient had full,

symmetric range of motion of her shoulder postoperatively without visible atrophy at 6 months (Fig. 3a–d).

Case 3

A 57-year-old woman presented with T5 spinal cord compression and associated paraplegia. Staging studies indicated a solitary lesion. Needle biopsy findings were non-diagnostic, thus an open biopsy was indicated. Given the concern that an en bloc resection might be necessary, a muscle-sparing, high thoracotomy that included the removal of the posterior aspect of the fifth rib. Findings from frozen section analysis were consistent with a metastatic carcinoma of unknown origin. Subsequently, a T5 corpectomy was performed en bloc and thorough decompression of the spinal cord was achieved. A carbon fiber cage was used to reconstruct the T5 vertebral body, after which a single-rod construct was placed anteriorly and posteriorly.

Case 4

A 44-year-old woman with a C7–T2 radiation-associated malignant fibrous histiocytoma measuring 4 × 4 × 3-cm underwent a three-stage en bloc excision. First, standard

Fig. 2 **a** Preoperative T1-weighted axial MRI demonstrating stage IV lung carcinoma with invasion of the T5 vertebra. **b** Intraoperative photograph demonstrating simultaneous anterior and posterior spinal exposure and reconstruction with a stackable carbon fiber cage

and cross-linked anterior and posterior instrumentation. **c** Immediate postoperative lateral radiograph demonstrating anterior and posterior spinal reconstruction following tumor resection

Fig. 3 **a** Preoperative T1-weighted sagittal and **b** T2-weighted axial MRI demonstrating a destructive lesion of the T3 vertebra with an associated large soft tissue mass. **c, d** Postoperative clinic photos demonstrate excellent shoulder range of motion without visible atro-

phy. Additionally, the surgical incision used for the left-sided muscle-sparing high thoracotomy is evident with the described lateral extension. A right-sided surgical scar is evident as well from a prior intervention

posterior spinal instrumentation was placed from C2 to T5 with laminectomies at C6–T2. Subsequently, anterior release was performed with C6–7 and T2–3 discectomies through an extended median sternotomy with clam shell extension. The third stage of the procedure consisted of a right-sided muscle-sparing, high thoracotomy performed to facilitate en bloc excision of the tumor. The anterior column was reconstructed with a titanium mesh cage from C6 to T3. The posterior instrumentation was simultaneously exposed and secured in this position.

Case 5

A 60-year-old woman with a left-sided Pancoast tumor measuring $8 \times 8 \times 6$ -cm arising from the upper lobe of the left lung and invading the T2 and T3 vertebral bodies underwent a three-staged tumor resection and spinal reconstruction procedure. A staged procedure was decided upon given the size and complexity of the tumoral involvement

and the intimate association with adjacent vital anatomy. In the first stage, bilateral posterior spinal instrumentation was placed and fusion from C2 to T6 accomplished through a standard posterior midline incision with the patient in the prone position. The second stage of the procedure consisted of an anterior corpectomy of T2 and T3 with removal of the tumor from the aorta, a wedge resection of the left upper lung lobe, and anterior spinal column reconstruction from T1 to T4 using a mesh cage and a plate performed through a median sternotomy with carotid to subclavian bypass grafting. In the third stage performed 7 days later, a muscle-sparing, high thoracotomy was performed in which remaining tumor directly opposed to the posterolateral aspect of the spine was removed. Estimated blood loss from the three procedures was 4 L total. Her hospital course was complicated by left-sided pneumonia. She was discharged 16 days postoperatively. The patient recovered well from the surgery and had excellent shoulder range of motion postoperatively. She is currently still living 9 years postoperatively. She lives

independently and reports no functional limitations with her shoulder. QuickDASH outcome score was 13.6 at 9 years with a significant portion of her upper extremity discomfort arising from lateral epicondylitis at the forearm.

Discussion

The superior mediastinal anatomy surrounds the upper thoracic spine, impeding direct surgical access to this area. Traditionally, ventral and dorsal approaches have been utilized to access the upper thoracic spine. Ventrally, this includes the anterior cervicothoracic and transthoracic techniques [2, 9]. The lower cervical and upper three thoracic vertebrae may be exposed by a low anterior cervical incision combined with a median sternotomy [10] or manubriotomy, with or without clavicle excision [11, 12]; however, the low anterior cervical approach itself is not extensible and limits access to C6 through T2. Moreover, approaches consisting of a median sternotomy or manubriotomy provide only limited caudal exposure beyond the cephalad aspect of T3 [13]. In these approaches, the recurrent laryngeal nerve, trachea, esophagus, great vessels, and thoracic duct must also be mobilized, which places each of these structures at increased risk of injury [2]. Ventral approaches below T3 traditionally are performed through a standard high thoracotomy with the patient in the lateral decubitus position [14]; however, this technique describes transection of the shoulder girdle muscle bellies (trapezius, rhomboid major, rhomboid minor, and latissimus dorsi) and retraction of the scapula, resulting in a significant pain and compromise of shoulder range of motion postoperatively [2–5, 15, 16]. Additionally, cases necessitating posterior spinal fusion and instrumentation require an additional staged procedure, which furthers the surgical morbidity.

Dorsal approaches to the upper thoracic spine may be performed as well through a posterior midline incision, including the lateral extracavitary and transpedicular approaches [17]. A laminectomy with removal of the facets and pedicles, with or without rib resection, is performed to access anterior structures for removal of the vertebral body. However, these dorsal approaches do not allow direct visualization of the anterolateral aspect of the vertebral body, which impedes the removal of tumors with large soft tissue masses, tumors that originate from the lung, and tumors that require en bloc excision. Moreover, these approaches complicate anterior column reconstruction and instrumentation as they only afford limited exposure and poor visualization. To overcome this, surgeons have traditionally combined this approach with the aforementioned standard high thoracotomy ventrally, which greatly magnifies surgical morbidity.

Given these challenges, the ideal technique would afford adequate visualization while minimizing morbidity, and thus

preserving shoulder girdle function. In 1991, Fessler et al. developed a lateral parascapular extrapleural approach to the upper thoracic spine, which spares the trapezius and rhomboid muscles; however, it requires that the patient be placed in a prone position, which limits direct visualization of the anterior column and, therefore, extensive anterior resection and reconstruction. While this technique preserves function to the shoulder girdle, the reported cohort did not require resection of large soft tissue components or placement of anterior spinal instrumentation, which limits its application [18].

The muscle-sparing, high thoracotomy described is advantageous as it overcomes many of the pitfalls associated with the aforementioned techniques. It includes an extensible approach to the cervicothoracic, upper, and middle thoracic spine, which allows the simultaneous exposure and reconstruction of the anterior and posterior spine without the need to transect the trapezius, latissimus, and rhomboid muscles. Additionally, it only minimally disrupts the anterior bony, visceral, and vascular structures; preserves the muscles of the shoulder girdle; preserves postoperative shoulder function; affords improved exposure and direct access to the vertebral bodies and any associated soft tissue masses without the need to retract on the scapula; and allows the resection and reconstruction of the anterior and posterior spine all in one session. This approach should be considered as one surgical option for any patient with a lesion that requires a high thoracotomy for removal and is especially useful and beneficial for the removal of benign and malignant vertebral bone tumors requiring en bloc excision, metastatic tumors with large soft tissue masses, and lung cancer with direct invasion into the spine. The cases described in this report are representative of the variety of situations in which this muscle-sparing, high thoracotomy technique could be used to excellent effect.

Compliance with ethical standards

Conflict of interest Author RAWM is a paid presenter or speaker for DePuy, a Johnson & Johnson Company and Globus Medical. Author RAWM is a board or committee member for the Musculoskeletal Tumor Society.

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