

Original Article

Single-stage posterior midline approach for dumbbell tumors of the thoracic spine, with intraoperative CT guidance

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Abstract

Background: Several different procedures have been advocated for thoracic spine dumbbell tumor resection, combining thoracic and neurosurgical approaches, in single and multiple stages, using various incisions and positions. These have led to controversies in the ideal management. The authors report their analysis of a series of 11 patients successfully treated through a one-step midline approach for complete resection and instrumentation when indicated under intraoperative CT (ICT) guidance.

Methods: The patients' clinical presentations, imaging results, operative findings and follow-up were reviewed in 11 patients (age ranged from 11 to 62 years), over the period from August 2007 to May 2010. A single-stage, posterior midline incision approach with laminectomy, facetectomy, costotransversectomy, for complete resection of intraspinal and paraspinal components of tumor was used. Spinal instrumentation under ICT guidance was also carried out in relevant (six) cases with tumors involving junctional spinal regions such the cervico-thoracic or thoraco-lumbar region.

Results: The initial clinical presenting symptom was pain in eight patients and paresthesia in one, while two patients were detected incidentally on routine chest X-rays. Total excision was achieved in 10 patients (9 schwannomas, 1 neurofibroma) with the exception of one patient who had a recurrent malignant peripheral nerve sheath tumor adherent to the vertebral artery. No significant postoperative complications occurred and an early mobilization/discharge was achieved in all patients with an average hospital stay of 5 days.

Conclusions: A one-step approach through a posterior midline incision is feasible, safe and efficient for complete excision of thoracic dumbbell tumors. This approach facilitates laminectomy, facetectomy, costotransversectomy and instrumentation under ICT guidance, while limiting muscle damage, blood loss, operative time, postoperative pain, thus enabling early mobilization with a reduced hospital stay.

Key Words: Neuronavigation, schwannoma, spinal fusion, spinal tumor

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INTRODUCTION

Spinal dumbbell tumors, previously defined by Heuer, were so named due to their shape.^[13] However, currently, the term “dumbbell tumors” connote not only their shape, but more importantly imply their extent across two anatomical distinct compartments, i.e. intraspinal and extraspinal formed by a connection through the narrow intervertebral foramen. Although most of these are benign neurogenic tumors (schwannomas, neurofibromas, ganglioneuromas), rare malignant tumors such as neuroblastomas can occur. These tumors can enlarge and compress neural structures, causing pain or neurological deficits. Evaluation by plain X-rays in the past has been superseded by magnetic resonance imaging (MRI) and computed tomography (CT) scans in the recent decades. Despite these advances, they pose a formidable surgical challenge due to difficulties inherent in accessing these multi-compartment lesions lying adjacent to critical neurovascular and visceral structures. Due to the controversies in managing them, several approaches have been described in single or multiple stages combining laminectomy and thoracotomy in the same or separate incisions.^[2,15,17,21,23]

There are few standardized procedures described in literature which address specific concerns related to thoracic dumbbell tumors. Extensive surgery with associated morbidities should be avoided; but at the same time, subtotal resection could result in late recurrence with its attendant reoperative risks.^[3] Therefore, unlike previously reported approaches, we standardized a one-step midline approach for complete tumor excision, avoiding an open thoracotomy, additional incisions or repositioning as well as addressing the issue of stability.^[2,15,17,21,23] We have described a simple straightforward single midline (one-stage) approach for these complex tumors, establishing the basic principles outlining our strategy, i.e. complete safe resection, providing foremost cord decompression as well as addressing the long-term effect of instability at transitional spinal regions. This surgical exposure allows for laminectomy, facetectomy, costotransversectomy, with rib resection and complete tumor excision. This approach preserves paraspinal muscle viability, bulk and innervation, and reduces overall morbidity while ensuring safe spinal instrumentation under intraoperative CT (ICT) neuronavigation in relevant cases. We have successfully employed a one-stage posterior midline approach in 11 patients, with instrumentation (6 patients) when indicated, and present our technique and results.

MATERIALS AND METHODS

A prospective analysis of 11 patients with thoracic spine dumbbell tumors, surgically treated by this approach

between August 2007 and May 2010, was done. The patients had undergone a thorough neurological examination before and after operations as well as on follow-up. Patients were often referred from other departments after initial CT scans or X-rays. Diagnosis and preoperative evaluation were achieved with relevant regional X-rays, MRI and/or CT. All patients (6 women and 5 men) underwent surgery in prone position, in an operating theater equipped with an image intensifier and ICT. Although all patients underwent laminectomy, costotransversectomy, and facetectomy, indications for spinal instrumentation were reserved for patients with tumors at transitional/junctional spinal regions (cervico-thoracic and or thoraco-lumbar regions) or in presence of extensive vertebral body erosion from large tumors affecting curvature/stability on preoperative imaging or for expected postoperative radiation. Spinal instrumentation systems used were all of MRI compatible (titanium) materials. A combined team approach consisting of neurosurgical and thoracic surgeons was employed. Intraoperative nerve monitoring was used selectively for tumors involving C7, T1, or L1, L2 spinal segments. Clinical presentations, spinal level with tumor types (Eden and Toyama classifications), and surgical treatments are outlined in Table 1.^[6,25]

Operative technique

After intubation and appropriate arterial and venous access, the patient is turned prone on bolsters. The hands are tucked by side to allow CT scanner to move in over the OT table. Initial X-ray, image intensifier or CT scout film/scannogram is employed for localizing the target level. A midline incision is made with subperiosteal muscle elevation, providing exposure for laminectomy/laminotomy and posterior instrumentation. The tips of spinous processes, with their attached supraspinatus ligaments intact, are initially cut dorsal to junction with laminae. Then, the supraspinatus ligament is transected at the highest level to be turned down with spinous process tips and wrapped in saline soaked gauze to preserve its viability. This transected supraspinatus is later reapproximated, after complete tumor removal at the end of stage 2, using a strong suture.

Following a laminectomy, extradural tumor is resected with the originating nerve root sectioned just outside the dura. The ipsilateral facet and transverse process are removed using Kerrison's punch or drilled as required to expose intraforaminal tumor. Then, the dura is opened in midline for intradural tumor excision. Ventral rootlets are preserved as most tumors arise from dorsal rootlets. Even if the tumor arises from the ventral rootlets, the nerve root is usually not functional. The watertight dural repair is carried out after the intradural tumor resection. The dura is not opened if tumor is found on inspection to be purely extradural (intraspinous) with a normal nerve segment proximal to it. The extradural–intraspinous spinal

Table 1: Clinical and surgical data of patients

Age/sex	Clinical presentation	Tumor location	Operation/instrumentation (tumor excision)	Postoperative outcome /follow-up	Eden type	Toyama type
42/M	Left chest pain	Left T3–T4 (extradural)	T3–4 laminectomy, facetectomy, costotransversectomy	Small (insignificant) pneumothorax (chest tube)	III	VI
43/M	Left hypochondrial pain	Left T8–T9 (extradural)	T8–9 hemilaminectomy, facetectomy, costotransversectomy, partial resection of T8–9 ribs	Normal	III	IIC
32/F	Back pain	Left T4–T5 (extradural)	Left T4–5 laminotomy, facetectomy, costotransversectomy	Normal	III	IIB
61/F	Back pain	Right T12–L1 (extradural)	T12–L1 laminectomy, facetectomy, costotransversectomy, instrumentation T11–L2 (pedicle screw)	Normal	III	IIB
30/F	Incidental finding	Right T3–T4 (extradural)	T3–4 laminectomy, facetectomy, costotransversectomy	Small pneumothorax (chest tube)	IV	VI
11/M	Back pain	Right T3–T4 (extradural)	T3–4 laminectomy, facetectomy, costotransversectomy	Slight scoliosis postoperatively	III	IIB
31/F	Incidental finding	Right T1–T2 (extradural)	T1/2 laminectomy, facetectomy, costotransversectomy, C6–T3 instrumentation (pedicle screw fixation)	Normal	III	11C
34/F	Right hypochondrial pain	Right T12–L1 (extradural)	T12–L1 laminectomy and facetectomy, T11–L2 instrumentation (pedicle screw)	Normal	III	IIB
53/F	Neurologic symptoms (paresthesias)	Left C7–T1 (intradural)	Left C7–T1 laminectomy, facetectomy, C5–T2 instrumentation	For radiation therapy*	IV	VI
25/M	Neurologic + radicular pain	Left L1–L2 (intradural)	L1 laminectomy, left L1 facetectomy, T12–L2 instrumentation (pedicle screw)	Mild sensory deficit	II	IIIA
33/M	NF1 with left-sided back pain	Left T11–12 (extradural)	T11–T12 laminectomy, left T12 facetectomy, costotransversectomy, instrumentation T10–L1 (pedicle screw)	Mild sensory deficit	III	IIB

*= Recurrent malignant sarcoma

tumor component is excised along with the distal nerve root stump. However, this part may be in some cases better delineated after costotransversectomy. Tissue for frozen section histology is routinely sent to confirm benign nature of lesion. The intraspinal phase of tumor removal is conducted first as it prevents traction on spinal cord during the second phase of paraspinal tumor component excision.

The second phase of operation (paraspinal approach) consisting of transversectomy, facetectomy and proximal rib resection is now done [Figure 1]. Keeping large, self-retaining retractors *in situ*, the ipsilateral skin and subcutaneous tissue are elevated with hand-held retractor on the ipsilateral side. Then, the underlying deeper layer of paraspinal muscle with its fascia is exposed for a transverse incision. After cutting the required length down to the rib with electrocautery, a smaller, self-retaining retractor is placed perpendicular to the divided longitudinal muscle fibers, easily exposing the transverse processes and the ribs which overlie the paraspinal tumor. This type of lateral paraspinal muscle incision is parallel to the rib which is resected. This minimizes muscle denervation and preserves viability while allowing easy re-approximation. The transverse process

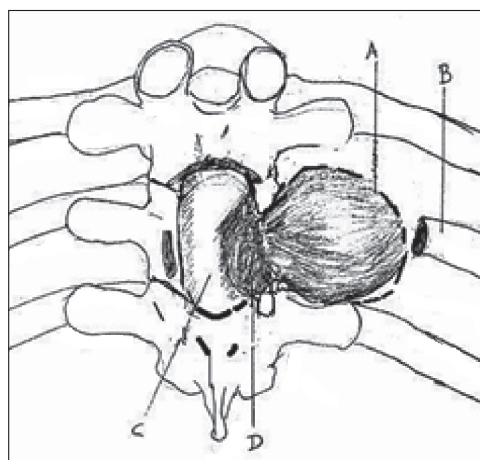


Figure 1: Schematic view after typical thoracic laminectomy, right facetectomy and costotransversectomy. A = paraspinal tumor; B = cut end of rib; C = compressed thecal sac; D = intraspinal tumor

and medial part of rib of adequate length is rongeured off after a subperiosteal dissection widely exposing the paraspinal tumor. Using blunt dissection techniques, the thoracic surgeon progressively dissects away the pleura/peritoneum, defining the tumor boundaries. With this method, the tumor is excised *en bloc*, if feasible, but large

tumors are initially debulked with an ultrasonic aspirator within their capsule before complete removal. We prefer to sacrifice the involved nerve root as it rarely results in significant neurological deficit other than mild sensory loss (numbness) in the affected dermatome. Leaving the affected nerve root behind can result in a potential recurrence with the attendant difficult problems of reoperation. A Valsalva maneuver to check for pleural breach is performed, and where necessary, a temporary chest tube is inserted. The transverse muscle incision is closed using interrupted sutures. Then, the spinal incision and usual muscle and fascia are closed meticulously in layers over a drain (kept for 24 hours).

In patients with junctional (cervico-thoracic or thoracolumbar spine) spinal tumors, initial instrumentation is carried out to stabilize the spine in the first phase of operation after a midline exposure. ICT and autoregistration are performed after bone exposure. ICT neuronavigation adds safety and accuracy to pedicle screw insertion, thus reducing the need for repeated fluoroscopy, irradiation or extensive muscle dissection for visual identification of pedicle entry sites. Errors in identifying the correct spinal level or accurate pedicle entry sites may occur with fluoroscopy. Additional ICT also confirms the extent of paraspinal tumor, if required.

The transpedicular screws are inserted bilaterally above and below the involved spinal level under image guidance. This sequence ensures stability of spine before any bony resection commences. Morcellated bone autografts are laid alongside facet joints/rods. Only after tumor resection is the second ipsilateral rod inserted, followed by cross links and locking screws and final tightening. For straightforward cases not requiring instrumentation, a similar two-phase sequence was performed with a CT scout film only to localize the tumor, thus avoiding unnecessary radiation exposure.

Postoperatively, patients are put on a patient controlled analgesia (PCA) pump for 2–3 days and mobilized within the next 24–36 hours by the physiotherapist. After discharge, patients are followed up in our outpatient clinic every 3 months in the first year with X-rays and then annually with MRI scans to look for recurrence.

RESULTS

Patient characteristics and clinical presentations

There were 11 patients (5 males and 6 females) with age ranging from 11 to 62 years. The most common presenting symptom was pain (eight patients) which was either radicular or localized to the midline posteriorly. One patient presented with neurologic (painless) symptoms (paresthesias), while two others were detected incidentally on routine chest X-ray performed as part of their pre-employment screen. All patients had plain

X-rays as well as either CT spine or additional MRI scans done.

Surgical management

All patients underwent a standard midline incision with laminectomy and removal of spinal tumor component in the first (spinal) phase. This was followed by costotransversectomy, rib resection in the second phase for paraspinal tumor excision [Figure 1]. Spinal instrumentation (pedicle screw rod system) was completed uneventfully in the six patients. Most tumors, being completely extradural, did not require dural opening except for two patients (patients 9 and 10). Two patients (1 and 5) required a chest tube after a small pleural opening was made during resection. The chest tube was removed after a day. Operative blood loss was not significant and all patients were successfully extubated postoperatively.

Outcome and follow-up

Nerve monitoring was performed in patients 7 (C7, T1 motor), 9 (C7, T1 motor), and 10 (L1, L2 motor), and was uneventful. No significant neurological deficits were seen other than a mild dermatomal sensory loss in patients 10 and 11. Patients with tumors at spine junctions such as patients 4, 7, and 8–11 underwent successful spinal instrumentation. The youngest patient 6 had mild scoliosis postoperatively although the level of tumor was T3–4 only. This has been stable since. In pediatric patients, close follow-up for spinal deformity is needed. Patient 5, who developed slight scoliosis on follow-up X-ray, is being monitored long term. Interestingly, Patient 2 had been previously investigated for left hypochondrial pain and had undergone negative emergency laparotomy for suspected duodenal perforation at another hospital. Thereafter, he had also undergone esophago-gastro-duodenoscopy which was normal. Subsequent CT abdomen scan picked up the incriminating left T8–9 dumbbell tumor, which was undoubtedly the source of patient's symptoms. Patients 10 and 11 had slight dermatomal sensory loss due to the dorsal nerve root resection; however, this was not disabling enough to impede patients' activities of daily living. Patient 5 had a small capsule left behind as it was attached anteriorly to inferior vena cava. However, no deficit or recurrence was seen at 6 months follow-up. Total resection was achieved in 10 patients, with near total resection in one patient. Median (postoperative) hospital stay was 5.3 days (range 4–11 days). There were no infections in our series. Postoperative follow-up ranged from 7 to 40 months with an average of 20 months follow-up. There were no recurrences or spinal deformities or pain symptoms.

There were no pedicle screws breakouts, pull outs in any of the 51 screws or any implant failures on follow-up.

Pathology

All patients had benign tumors (nine schwannomas

and one neurofibroma), except for one (patient 9) who had presented with recurrent malignant sarcoma tumor following two previous operations at another hospital 2 years ago. She required radiation therapy postoperatively.

Example 1

A young, 29-year-old lady was found to have a right apical lung lesion on a routine chest X-ray (as part of her pre-employment screen). The CT thorax confirmed dumbbell, a right-sided tumor at T1/T2 vertebral level [Figure 2]. MRI thoracic spine [Figure 3] showed this lesion to be closely related to the thecal sac (intraspinal extension). She underwent T1/2 laminectomy, right-sided facetectomy, costotransversectomy, excision of dumbbell tumor and C6–T3 spinal stabilization (C6 lateral mass, C7–T3 pedicle rod–screw fixation). Spinal instrumentation was required as the tumor involvement at junctional spinal region (cervico-thoracic) and the extent of bony resection (costotransversectomy) would have destabilized the spine predisposing her to postoperative

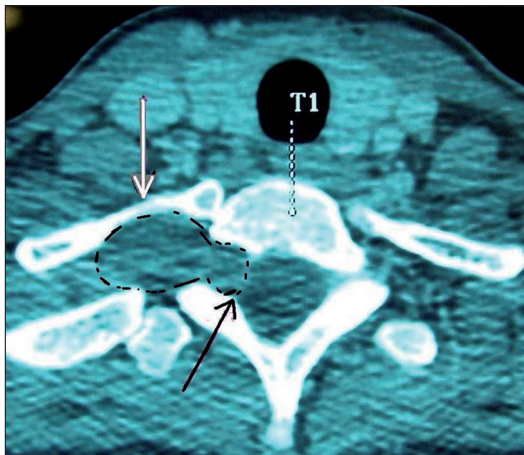


Figure 2: Right T1 dumbbell tumor (dashed outline) showing paraspinal tumor eroding the rib (white arrow) and intraspinal tumor component (black arrow) (example 1)

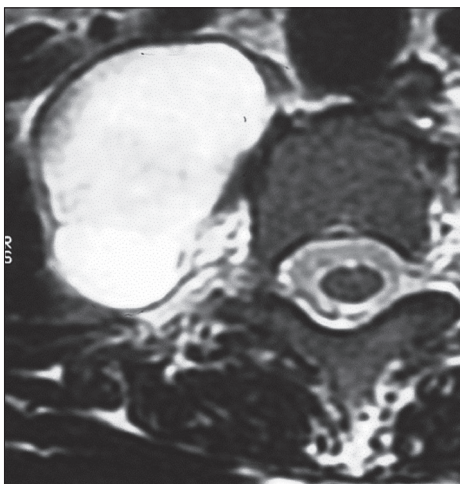


Figure 3: MRI (T2 weighted) axial view of same tumor as in Figure 2 (example 1)

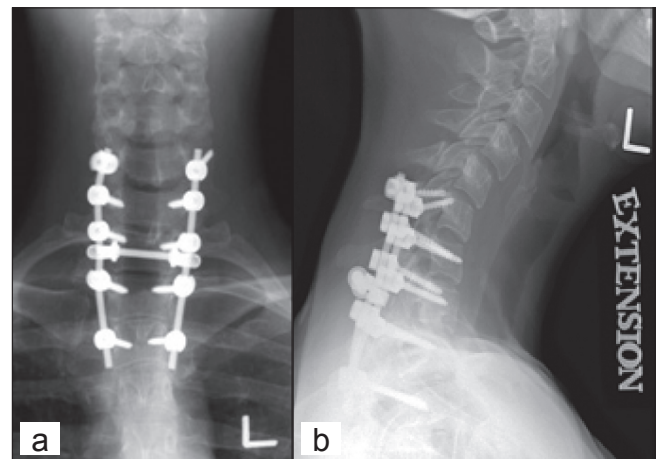
kyphosis [Figure 4a and b]. Motor nerve monitoring of the right C8, T1, T2 was normal and the nerve root was sacrificed as there was no response in the right T1 myotomes (flexor pollicis longus, abductor pollicis brevis) on stimulation. Postoperatively, the patient recovered without any deficits (e.g. Horner's syndrome) and was discharged on 5th postoperative day.

Example 2

A 36-year-old lady presented with history of right-sided flank pain for a few years. She was treated symptomatically by a family physician and was investigated for suspected gall bladder disease. A CT abdomen revealed right side dumbbell neurogenic tumor [Figure 5a and b]. She also had by this time developed progressive numbness of the lower limbs for a year. On physical examination, she had no weakness, but had a sensory level at T12. An MRI thoracic spine confirmed a right T12–L1 dumbbell (extradural) tumor [Figure 6]. She underwent a T12–L1 laminectomy, right facetectomy, transversectomy, partial removal of 12th rib, tumor excision and T11–L2 fusion [Figures 7, 8]. She was well and her follow-up X-rays showed good alignment [Figure 9].

DISCUSSION

Approximately 10% of all neurogenic tumors located in the posterior mediastinum are dumbbell tumors having intraspinal extensions via intervertebral foramen.^[3,8] Although mostly benign, dumbbell tumors are particularly challenging, as they may lie across two or more anatomically distinct regions, grow to a large size, erode the pedicle or lie adjacent to critical structures such as pleura, peritoneum and major blood vessels. Important surgical factors to consider are tumor size, tumor lie or axis, tumor relationship to the neural, vascular pleural structures, and the spinal level involved. The last parameter is an important consideration for long-term



Figures 4: (a and b) Postoperative lateral and anteroposterior X-ray views showing C6 lateral mass, C7–T3 pedicle rod-screw instrumentation (same patient as in Figures 2 and 3; example 1)

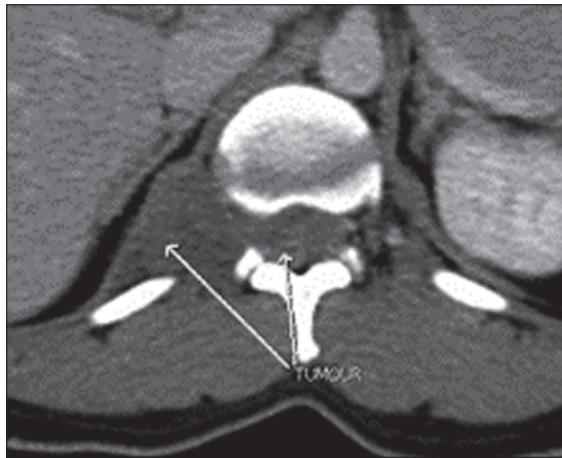


Figure 5a: Axial view on CT scan showing spinal and paraspinous components (arrows) (example 2)



Figure 5b: Coronal view on CT scan of the same tumor (example 2)

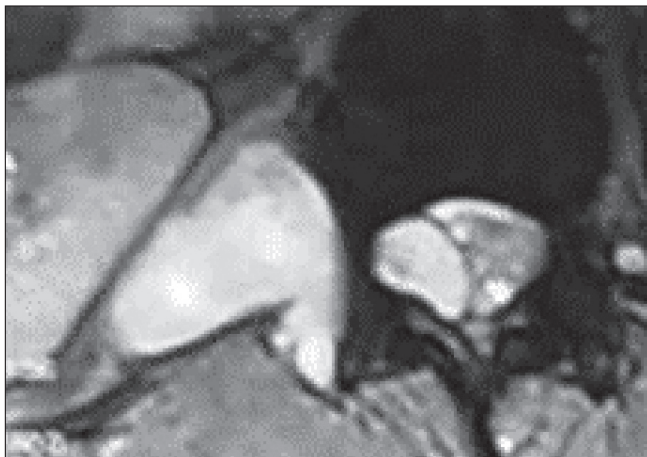


Figure 6: Multicompartiment dumbbell tumor on MRI (axial T2W image) (example 2)



Figure 7: Intraoperative CT showing right pedicle blunt pin *in situ* which was replaced with screw after tumor removal (arrow) (example 2)

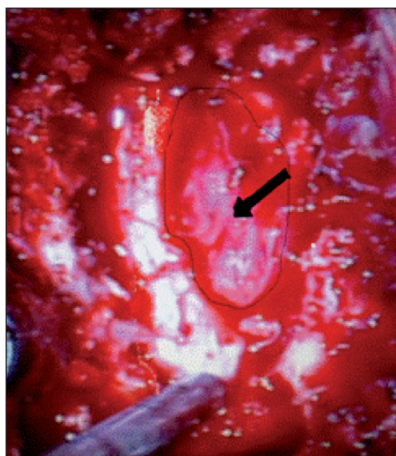
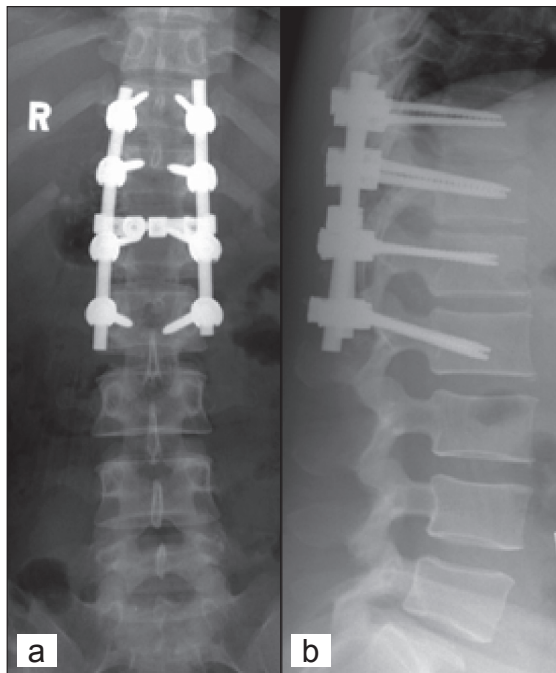


Figure 8: Postlaminectomy, costotransversectomy view (black arrow) of spinal extradural tumor (black outline) (example 2)

postoperative spinal stability. A thorough knowledge of relevant anatomical compartments and surgical principles is without doubt an important prerequisite to optimize

operative exposure for a safe and complete resection of these benign lesions. We were able to accomplish these goals through a single posterior midline approach. Most patients present with pain, while some may be diagnosed incidentally on X-rays or with neurological deficits. Up to two thirds may present with neurological symptoms^[3,9] such as radiating pain or deficit. In our series, most (8/11) presented with pain (either of the radiating or localized type), one with neurological deficits and two were discovered incidentally. However, isolated presentation with pain can often be mistaken for an abdominal or a lung pathology. This was the case in Patient 2 [Table 1] who was initially misdiagnosed and underwent a negative laparotomy and gastroscopy. Therefore, clinicians should maintain high index of suspicion for these tumors in patients with long-standing pain.

The surgical objective besides adequate neural decompression and complete tumor resection is preservation of spinal stability while minimizing paraspinous tissue damage. Eden or Toyama tumor classifications based on intradural, foraminal and



Figures 9: (a and b) Postoperative follow-up X-ray AP and lateral views showing T11, T12, L1, L2 spinal instrumentation with normal alignment (example 2)

paravertebral extensions were meant to enable selection of procedure for appropriate tumor type. Controversies exist with regards to the operative approaches, as neither MRI nor CT scan conclusively rules out intradural involvement preoperatively. We preferred to rely on direct intraoperative inspection. The use of two stages and/or two surgical approaches includes an open thoracotomy and increased morbidity (blood loss, coagulopathy, paralytic ileus, respiratory complications, and infection), prolonged postoperative stay and postoperative pain.^[2,15,17,21,23] Akwari *et al*,^[3] performed single-stage operation consisting of two approaches and repositioning (posterior midline for laminectomy and then a posterolateral thoracotomy). Grillo *et al*,^[9] in 1983, similarly demonstrated laminectomy and thoracotomy approaches in prone position via “L” shaped incision in a one-stage technique.

As multiplicity of surgical approaches, positions and/or incisions does not add safety or simplicity to the operation, we preferred a one-stage posterior midline approach. McCormick had described single-stage procedure lateral extracavitary (extrapleural) approach (LECA).^[15] In LECA, the incision is either paramedian or T shaped. Secondly, the paraspinal muscle is dissected circumferentially and long vertical length of muscle is mobilized for access for costotransversectomy. These result in denervation of paraspinal muscle (dorsal spinal nerve branches to paraspinal muscles) and could also result in devascularizing mobilized length of this muscle segment. As described therein, the paraspinal muscle

belly was circumferentially mobilized by dissection and was also subjected to a transverse incision. Route taken was lateral to the paramedian muscle length, requiring an additional surgical corridor with its attendant morbidity. Understandably, LECA approach therefore requires more extensive length of muscle exposure and therefore longer incisions. Long-term results of this muscle segment denervation and scarring from ischemic insult could result in pain, stiffness, scoliosis or instability at critical junctional regions. Also, retracting muscle belly over intact spine may be feasible in operations addressing purely paraspinal pathologies such as tuberculosis or mediastinal tumors, but doing so over the exposed thoracic dural sac warrants caution.^[15]

The approach as described by us avoids mostly unnecessary paraspinal circumferential dissection. Our approach reduces the incision length as it allows more than adequate exposure through a precise but limited muscle elevation over concerned rib while avoiding long length of muscle mobilization. This transected muscle is separated by self-retaining retractor and this approach limits injury to segmental dorsal spinal nerves and preserves its vascularity. Also, the surgical corridor is the same as for laminectomy, and therefore, orientation during surgery is easy and directed to paraspinal tumor. Thus, overall, blood loss and muscle-related morbidities such as pain and scarring are significantly reduced.

Tumors in spinal component should be adequately exposed for complete excision. The single midline incision approach achieves three primary goals for any spinal surgery: decompression, stabilization, and prevention/correction of deformity. This can be performed even in emergent situation as no repositioning or reintubation is required.

Midline approach without costotransversectomy, with only a foraminotomy, can only address a small paraspinal/paravertebral tumor mass. Thus, large paravertebral tumors, more than 3 cm across, as seen in our series, would be difficult to remove completely and such a blind procedure for these tumors could risk injury to pleura, peritoneum or critical vascular structures.^[1,4] Alternatively, leaving a remnant for later would risk bleeding, tumor edema or extension to spinal compartment and result in neurological deficit. A second thoracotomy and its attendant morbidity, anesthesia risks, prolonged stay, etc. are therefore best avoided. In contrast, our patients could return to normalcy sooner as evidenced by their short stay, reduced pain control medication and early mobilization.

A wide access to paraspinal tumor following costotransversectomy, facetectomy medial rib resection was demonstrated. This technique preserves the integrity of the paraspinal muscle, overlying skin and subcutaneous tissue, and reduces blood loss, risks of

infection, pain, immobility and optimizes cosmesis. The single midline incision also reduces risk of infection especially in patients requiring instrumentation and when dura has been opened. Subsequent to bony resection, we had no difficulty in completely excising large tumors. In our series, Eden type III tumor was the commonest (8/11) similar to those reported by Ozawa *et al.*^[22] The largest tumors in our series were 7 cm across, vertically involving two vertebral body lengths (Patient 1), and the other was 6 cm across and vertically 6 cm (Patient 8), and they were completely removed with good results. Rare tumors, 20 cm or more across, spreading extensively to the subcutaneous tissues of chest wall, may require a staged procedure.^[5,10,16] Lately, a combined approach involving laminectomy by a neurosurgeon followed by a videothoracoscopic removal of the intrathoracic part has been described for small tumors. However, this involves two incisions, repositioning and reintubation.^[4,27] By avoiding a laminectomy–facetectomy, some have suggested that these patients would not be at risk of spinal destabilization after laminectomy and resection of the facet joints and therefore advocated thoracoscopic approach before neurosurgical procedure.^[23] However, we would advice caution, as although some thoracic approaches may have successfully dealt with total resection of purely paraspinal tumors,^[22] dumbbell lesions deserve special attention to spinal component first. Critical points which uphold our views are that MRI images cannot be relied upon to conclusively exclude dural involvement with obvious implications. Secondly, attempted resection of the foraminal component through thoracic approach (without spinal decompression) could result in a number of complications such as cord contusion, epidural hematoma or pseudomeningocele formation.^[3] Leaving behind the intraforaminal spinal component for the second delayed stage, risks spinal cord compression from bleeding or due to edema of the remnant portion.^[3,11,16] Shamji *et al*, concluded that most of tumors may have a silent connection through the foramen not detected even on MRI scan.^[24] Therefore, it is critical to deal with the spinal component first by direct intraoperative inspection after laminectomy, regardless of any large paraspinal component. The sacrifice of the spinal root is usually required once the tumor extends distal to the dorsal root ganglia.^[14] This did not result in significant motor deficit in suspected eloquent nerve root levels, such as in Patient 11, where nerve monitoring was also employed.

Osada *et al*, had described a single staged approach for small series of four patients, adding a transverse limb to the midline skin incision for better exposure, but did not address spinal stability at junctional region.^[19] In a large number of cases, by Ozawa *et al*, the dumbbell tumors were excised through a hemilaminectomy and a facetectomy with the spinal stabilization/reconstruction

by Rogers wiring and contralateral facet fusion, leaving the spinous process, supra- and intraspinal ligaments, and contralateral facet joint intact.^[20] However, we are of the opinion that in large intradural/intraspinal tumors with cord compression and displacement, full laminectomy is safer over hemilaminectomy and protects the cord from trauma.^[20] Hooks or sub laminar wires are risky and may cause cord compression if breakages occur. Indications for instrumentation are extensive bony resection involving two or more spinal columns (Denis) at junctional regions. In our approach, bony removal involves laminectomy, facetectomy as well as transversotomy with rib resection. Costotransversotomy with facetectomy and rib resection at midthoracic region does not lead to instability or deformity. However, such problems can occur at transitional spinal regions and would certainly destabilize spine in the long term or lead to pain or scoliosis. This is an important consideration for pedicle screw instrumentation. Therefore, instrumentation was safely performed in six such patients under ICT guidance, conferring three-column stability. The Intraop-CT (non-contrast) and Brain Lab® registration takes an additional 10 minutes of operative time, and unlike conventional fluoroscopy, helps select screw dimensions, appropriate screw pedicle trajectory as well as provides necessary accuracy for a speedy instrumentation. Pedicle screw instrumentation was quick, precise and smoothly performed with help of ICT neuronavigation (Brain Lab). ICT guidance is not only crucial in order to prevent malposition of pedicle screw but also to decrease the amount of radiation. A Check Tomogram confirmed accurate placement. Despite a significant number of pedicle (51) screws, there were no pedicle screw insertion related problems such as pedicle wall breach. Pedicle screw breach rates in literature range from about 2 to 28% with a 14–55% misplacement rate for pedicle screws using standard techniques.^[7,13,18,26] Using image guidance system, Nottmeier *et al*, reported 7.5% pedicle breach rate (less than 2 mm breach).^[18]

Although traditionally speaking, thoracic spine is considered to be biomechanically stable, patients (patients 2 and 6) did develop mild scoliosis on follow-up. This could be either due to ipsilateral segmental muscle denervation, splinting due to pain or an immature bony spine such as in Patient 6. Therefore, these patients with midthoracic spine dumbbell tumors, especially if younger than 12 years, should be followed up closely especially during puberty growth spurts as they may need delayed corrective instrumentation.

The median postoperative stay was 5 days compared to an average stay of 7–10 days for open thoracotomy. Riquet *et al*, reported average postoperative stay after a videothoracoscopic procedure for neurogenic tumors to be 5.3 days.^[22] However, their procedure involving making three ports did not include the second stage spinal

procedure or the fact that one in six required conversion to an open thoracotomy.

Our single-stage midline approach with instrumentation under ICT guidance, although in a small series, provided ease and familiarity of access, enabled complete tumor resection, and addressed spinal stability in one sitting while avoiding thoracotomy. This procedure facilitated an early patient mobilization and reduced hospital stay without compromising on tumor excision or spinal stabilization.

CONCLUSIONS

A single-stage approach through posterior midline incision is simple, elegant and optimizes exposure regardless of tumor size and extent. This method enables adequate visualization of critical structures, while minimizing tissue damage, blood loss and operative time. A complete tumor resection is easily achievable, and along with ICT guidance, provides a safe and precise spinal instrumentation, allowing early mobilization, reduced pain and shortened hospital stay.

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Commentary

The surgical management of spinal dumbbell tumors may be challenging both due to the size these tumors can reach and to the extent of their location. Indeed, they may be intraspinal (intra- and/or extradural), foraminal, and/or paraspinal that lead their classification into 4 categories.^[1] Several approaches have been described and historically combined approaches were performed for large dumbbell tumors, and especially in the thoracic region.

In this article, the authors describe a single posterior midline approach in the treatment of 11 large thoracic spinal dumbbell tumors and achieved a complete resection with minimal morbidity rate in 10 patients. Their surgical technique consists of removing the intraspinal portion (intra- and/or extradural) of the tumor after a simple laminectomy followed by the resection of the paraspinal portion after facetectomy and costotransversectomy. It is a variation of the lateral extracavitary approach described by McCormick,^[2] whose incision is usually paramedian

and where the exposure necessitates the mobilization of the paraspinal muscles.

This article is interesting in 2 aspects. At first, it shows that a classical posterior approach that is widely used by the neurosurgical community allows the safe resection of multicompartmental voluminous dumbbell spinal tumors without the need of a second operation or patient repositioning. By minimizing the surgical morbidity and the time procedure, the surgical technique described in this article illustrates what I consider as the standard of care.

Second, even if the use of instrumentation after facet resection and costotransversectomy in the thoracic spine may be controversial, the use of Intraoperative Computed Tomography (ICT) or 3D fluoroscopy that enables straightforward and accurate spinal neuronavigation is promising. Based on my experience and the literature, it minimizes the radiation exposure to the surgeon and to the patient and increases the accuracy and safety of the

pedicle screw placement by allowing a 3D peroperative control of screw positioning.^[3] The cost effectiveness of this technique needs obviously to be assessed, but in my opinion this technique will replace the use of the classical single-arm fluoroscopy in the next few years.

I congratulate the authors for their work and encourage them to pursue in this direction.

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