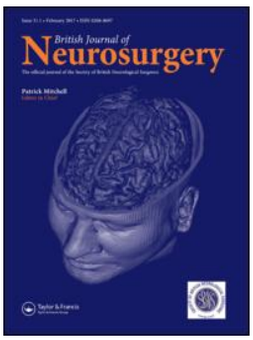

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ORIGINAL ARTICLE

Trans-thoracic versus retropleural approach for symptomatic thoracic disc herniations: comparative analysis of 94 consecutive cases

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ABSTRACT

Purpose: The authors illustrate their results in the surgical treatment of symptomatic thoracic disc herniations (TDHs) by comparing the traditional open to the less invasive retropleural lateral approaches.

Methods: Retrospective review of 94 consecutive cases treated at a single Institution between 1988 and 2014. Fifty-two patients were males, 42 females, mean age was 53.9 years. Mean follow-up was 46.9 months (12–79 months). 33 patients were diagnosed with a giant thoracic disc herniation (GTDH). Upon admission, the most common symptoms were: motor impairment (91.4%, $n = 86$), neuropathic radicular pain with VAS > 4 (50%), bladder and bowel dysfunction (57.4% and 41.4% respectively) and sensory disturbances (29.7%). The surgical approach was based upon level, laterality and presence or absence of calcified lesions.

Results: Decompression was performed in 7 cases via a thoraco-laparo-phrenotomy and in 87 cases via an antero-lateral thoracotomy. Out of the latter cases, 49 (56%) were trans-thoracic trans-pleural approaches (TTA) and 38 (44%) were less invasive retropleural approaches (MIRA). At follow-up, there were 59.5% neurologically intact patients according to the McCormick Scale, while 64.8% and 67% had no bladder or bowel dysfunction respectively. Complications occurred in 24 patients (25.5%). Pulmonary complications were the commonest (12.7%) with pleural effusion being significantly more common in patients treated with TTA compared to MIRA (20% vs 5.2%: X^2 4.13 P:0.042). Severe post-operative neuralgia (VAS 7–10) was also significantly more frequent in the TTA group (22.4% vs 2.6% X^2 7.07 p 0.0078).

Conclusions: MIRA is a safe and effective technique to obtain adequate TDH decompression and is associated with lower morbidity compared to TTA.

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Thoracic disc herniation; myelopathy; thoracotomy; minimally invasive surgery

Introduction

Thoracic disc herniations (TDHs) can be incidentally found in MRIs of asymptomatic subjects.[1] Symptomatic TDHs represent a rarity in the daily practice of spinal surgeons (0.5% to 1.4% of all disc surgical procedures[2]). Compared to disc herniations in the cervical and lumbar spine, TDHs are less frequent probably due to the anatomy, physiology and biomechanics of the thoracic spine[3]. The overall prevalence of symptomatic TDHs is $1/10^3$ to $1/10^5$ in the general population; males are affected more frequently than females, the highest incidence is between 40 and 50 years of age and the site most commonly involved is the caudal thoracic spine.[2] Only a small percentage of TDHs becomes symptomatic. Symptoms are thought to be caused either by direct compression of the spinal cord and/or thoracic nerves, or by chronic ischaemia.[4–11] Upper motor neuron symptoms typical of TDHs include lower limbs weakness or paralysis, sphincter disorders, alteration of balance and proprioception and dorsal root pain. Occasionally, an acute ischaemic injury can occur and patients can present with acute paraplegia.[12–14]

The diagnosis of TDH is confirmed by T1, T2 sagittal and axial MRI sequences, which should also include the cervical and lumbar spine to exclude concurrent disease at these levels. A CT scan can be useful to detail the potentially calcific nature of the TDH if the sagittal T1 weighted MRI images suggest so. A preoperative spinal angiogram is recommended to evaluate the topography of the Adamkiewicz artery[15] if an anterior approach is contemplated.

Different surgical approaches are described for the treatment of TDHs and include posterior, posterolateral and anterior techniques. The type of approach should be individualised for each patient and should be tailored to the location (median or lateral) volume (small or giant) and morphology (calcification or not) of the herniation.

In this paper we aim to report on our experience in the treatment of TDH in 94 consecutive cases operated from 1988 to 2014 at a single Institution with a lateral approach. Ten further cases were excluded from this analysis following surgery via a posterior approach. We reviewed these cases' demographical, radiological and clinical data and examined clinical outcomes and complications stratified by surgical approach: open transthoracic (TTA) versus minimally invasive retropleural (MIRA).

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Materials and methods

Study design

Data were retrospectively collected and evaluated from medical records, outpatients' consultations and clinical examinations. When any significant information was missing, the records were supplemented by telephone interviews. Only patients with a single-level TDH were included. A history of spinal fracture, previous surgery at the same site, deformity, tumour or infection were exclusion criteria. Radiological findings (CT, MRI, Spinal Angiography) were retrospectively reviewed by a Consultant Neuroradiologist.

Table 1. Modified McCormick scale I–V.

McCormick scale	
I	Intact neurologically, normal ambulation, minimal dysesthesia
II	Mild motor or sensory deficit, functional indipendence
III	Moderate deficit, limitation of function, dependent
IV	Severe motor or sensory deficit, limited function, dependent
V	Paraplegia or quadriplegia, even w/flickering movement

Table 2. Frankel classification A–E.

Frankel classification	
A	Absence of motor or sensory function below the level of the lesion
B	Absence of motor function, but with some degree of sensitivity preserved below the level of the lesion
C	Some degree of motor function but without practical usefulness
D	Useful motor function below the level of the lesion
E	Normal sensory and motor function, althought there may be some abnormality of reflexes

Table 3. Barthel index activity, grade of dependence (0–24 = total, 25–49 = severe, 50–74 = moderate, 75–90 = mild, 91–100 minimal).

Barthel index activity	
Feeding	0 = unable 5 = needs help 10 = independent
Bathing	0 = dependend 5 = independent
Grooming	0 = needs help with personal care 5 = independent face/hair/teeth/shaving
Dressing	0 = dependent 5 = needs help but can do about half unaided 10 = independent
Bowels	0 = incontinent 5 = occasional accident 10 = continent
Bladder	0 = incontinent or catheterised and unable to manage alone 5 = occasional accident 10 = continent
Toilet use	0 = dependent 5 = needs some help but can do something alone 10 = independent
Transfers	0 = unable, no sitting balance 5 = major help (one or two people, physical), can sit 10 = minor help (verbal or physical) 15 = independent
Mobility	0 = immobile or <50 yards 5 = wheelchair independent, >50 yards 10 = walks with help of one person >50 yards 15 = independent >50 yards
Stairs	0 = unable 5 = needs help 10 = independent

Clinical and radiological assessment

Patients' neurological status was graded using the Frankel and the modified McCormick scales (Tables 1 and 2). The Barthel index was used to measure performance in activities of daily living (Table 3). We measured urinary and bowel dysfunction using the Kesselring scale[16] (Table 4). A visual analogue scale (VAS) rating from 0 to 10 was used to grade radicular pain (0–3 = mild, 4–6 = moderate, 7–10 severe).

TDHs were classified as central, centro-lateral and lateral based on their location compared to the lateral margin of the dural sac as seen on MRI. Any calcification of the TDH was confirmed by CT scanning and intraoperative inspection. We classified Giant Thoracic Disc Herniations (GTDHs) as those lesions occupying more than 40% of the canal on CT or MRI.[17]

Indications for surgery and approaches

Surgical treatment was discussed with patients showing progressive and/or persistent signs or symptoms of spinal cord and/or radicular compression. These included motor or sensory impairment, hyperreflexia/spasticity, bladder/bowel dysfunction, alteration of balance and proprioception. Patients with only radiated pain were offered surgery if the side and level were concordant with symptoms.

The surgical approach was chosen depending on the following features of the herniated disc: size, consistency and location. All central, calcified, GTDHs and herniations determining a posterior dislocation of the spinal cord were removed antero-laterally via a thoraco-abdominal, trans-thoracic trans-pleural (TTA) or minimally invasive retropleural (MIRA) approach.

Initially all patients were operated by TTA. We evolved our practice to a less invasive approach, MIRA, in order to avoid lung desufflation and its related complications. Overall, 49 patient were treated by TTA and 38 by MIRA (56% and 44% respectively). In both procedures, after induction of general endotracheal anaesthesia with dual-lumen intubation, patients were placed in the lateral decubitus position (Figure 1(A)). The side of the approach was contralateral to the dislocation of the spinal cord. Similarly, the approach was opposite to the Adamkievicz artery when the vessel was identified at the level of the TDH.

The level of surgery was identified under intraoperative fluoroscopic guidance. With the patient in lateral decubitus

Table 4. Kesselring scale for bladder and bowel dysfunction (0–4).

Kesselring scale (bladder)		Kesselring (bowel
0	Normal	Normal
1	Occasional urinary retention or urgency, occasional use of medications	Stipsis treated with fiber-rich foods, self-administered laxatives
2	Frequent urinary retention or urgency, autocatatherisation, frequent use of medications	Stipsis, regular self administering of laxatives
3	Occasional urinary incontinence, catetherisation	Stipsis, regular use of laxatives administered by third persons, needs help for hygiene, occasional incontinence
4	Frequent incontinence	Fecal incontinence

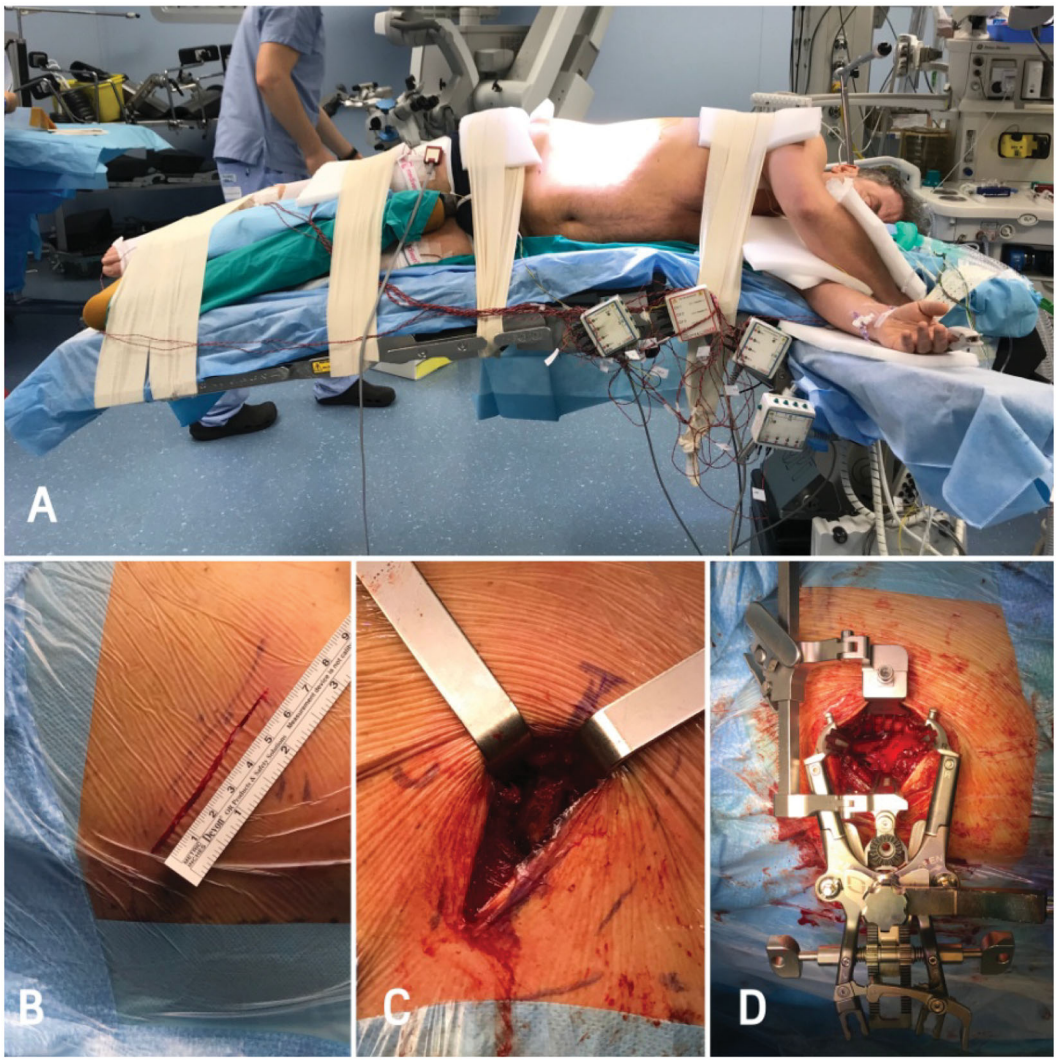

Figure 1. Main steps in the surgical preparation of patients treated by a MIRA approach (giant TDH T7–T8). Patients are placed in the lateral decubitus position (A); after the setup of a sterile surgical field, a 5–6 cm incision is made along the corresponding rib (B); the rib of the level above (T7 rib) is partially resected (4–5 cm) and the parietal pleural is deflected from the inner thoracic wall (C); the lung is shifted anteriorly and 3 sequential dilators on the disc level are placed. An expandable split-blade retractor is finally docked over the dilators (D) and then the T8 rib head is removed.

position, a lateral fluoroscopic image was obtained and the affected level was marked on the skin with the aid of a K wire (Figure 1(A)).

In TTA, a wide incision along the rib overlying the affected disc space was made; the rib was then resected 10–15 cm laterally to the tip of the transverse process. The parietal pleura was incised, the wound retracted using a Finochietto rib spreader and the lung collapsed and packed. Care was taken to preserve the intercostal nerve and vessels. To confirm the correct level a needle was inserted into the target disc space under fluoroscopy and the level counted in a cranio-caudal or caudo-cranial sequence. A wedge-trench osteotomy allowed access to the spinal canal above and below the area of cord compression. The osteotomy was limited to one quadrant of both adjacent vertebrae to reduce the risk of subsequent instability. Partial or complete drilling of the caudal pedicle was occasionally necessary. The posterior annulus and posterior longitudinal ligament were dissected off the dura under microscopic vision and the TDH removed to obtain a central decompression, up to the level of the contralateral pedicle.

In MIRA, a lesser invasive technique compared to TTA, the aim was to approach the disc space antero-laterally without violation of the pleura and without exclusion of the lung from ventilation. With the aid of fluoroscopy and with the patient in the same position as for a TTA, the junction of the posterior and middle third of the affected disc space was marked over the skin. In our technique, a 5–6 cm incision was made along the rib overlying the affected disc space and the rib was partially resected (4–5 cm) to avoid the subsequent retractors exerting undue pressure on the neurovascular bundle (Figure 1(B)). Next, the parietal pleural was reflected from the inner thoracic wall (Figure 1(C)), the lung shifted anteriorly and sequential dilators on the disc level positioned. An expandable split-blade retractor was then docked over the dilators. The rib head caudal to the affected level was removed to allow access to the offending disc and foramen (Figure 1(D)). Wedge osteotomies of the posterior part of the vertebral bodies and pedicle were usually performed to expose the dura adjacent to the disc herniation. The pathology was then addressed using the same technique as TTA.

A post-operative pleural drain was routinely positioned in all TTA patients and removed after 48 hours if no persistent effusion occurred. No pleural drain was positioned in patients following MIRA.

Statistical evaluation

Analyses were performed using a Microsoft SPSS software and evaluated by an academic mathematician. The methodology was considered appropriate for the proposed study. To compare mean pain values we performed a *t*-student analysis and considered $\alpha < 0.05$ to indicate statistical significance. We used the $\chi 2$ test to assess the difference between groups in the persistence of post-operative radicular pain, complications and neurological outcome, with $\alpha < 0.05$ to indicate statistical significance.

Results

Patient population

Between January 1988 and December 2014, 104 patients underwent surgery at our Institution for removal of a symptomatic TDH. There were 55 males and 49 females with an average age of 54.5 years (range, 27–84). Mean follow-up was 46 months (range, 12–79). Ninety four patients (90.3%) underwent surgery with a lateral approach and constitute the study cohort. Out of these patients, 52 were males and 42 females, with an average age of 53.9 years (range, 25–76) and mean follow-up of 46.9 months (range, 12–79).

Neurological status and radiographic findings

The most common presenting symptom was pain (55 patients; 58.5%), followed by sensory disturbance (25; 26.5%) and paraparesis (14; 14.8%). Of these 14 cases who presented with motor impairment as their primary symptom, 10 (58.8%) were unilateral and 6 (41.2%) bilateral. Eighty six patients (91.4%) had motor impairment prior to surgery according to the McCormick scale (Table 1). In 47 of these cases the motor impairment was graded as McCormick II, while 23 (24.4%) presented with grade IV or V functional impairment. On a Frankel scale (Table 2), 49 cases (52.1%) were classified as D and 37 (39.3%) presented with severe impairment (A, B or C type). Forty nine (52.1%) cases had mild disability according to the Barthel disability index (Barthel 75–90) (Table 3).

At follow-up, 67 patients (71.2%) were functionally independent (McCormick I or II). Seventy seven (82%) had none or a mild grade of dependence according to the Barthel scale, and 75 patients (79.7%) scored no or mild disability at Frankel scale (E or D). Among patients showing a motor impairment before surgery, 70 (74.4%) improved by one class of disability at follow-up in both the McCormick and Barthel Index scale. Two patients suffered post-operative neurological deterioration (TTA), both had been diagnosed with a giant calcified herniation infiltrating the dural sac. Their motor function remained unchanged at the last evaluation.

Seventy-two TDHs were central (76.5%), 16 centro-lateral (17%) and 6 were lateral (6.3%). Evidence of calcification was seen in 79 discs (84%). Thirty-three (35.1%) TDHs were classified as GTDHs. In 5 (5.3%) an intradural calcified extension was noted during surgery. The levels treated ranged from T6 to L1, with the most common being T8–T9 (23 discs, 24.4%).

Table 5 summarises the mean preoperative and follow-up neurological status in this cohort.

No patients required revision surgery; however one was re-admitted due to surgical complications described below.

Table 5. Number and % of patients as classified by McCormick, Frankel and Barthel scales.

McCormick			Frankel			Barthel		
	Pre-op	F-up		Pre-op	F-up		Pre-op	F-up
I	8 (8.5)	56 (59.5)	A	7 (7.4)	6 (6.3)	0–24	13 (13.8)	11 (11.7)
II	47 (50)	11 (11.7)	B	10 (10.6)	7 (7.4)	25–49	7 (7.4)	2 (2.1)
III	16 (17.)	13 (13.8)	C	20 (21.2)	6 (6.3)	50–74	18 (19.1)	4 (4.2)
IV	17 (18)	9 (9.5)	D	49 (52.1)	17 (18.1)	75–90	49 (52.1)	22 (23.4)
V	6 (6.4)	5 (5.3)	E	8 (8.5)	58 (61.7)	91–100	7 (7.4)	55 (58.5)

Table 6. Number and % of patients with bladder and/or bowel dysfunction before surgery and at follow-up.

	Kesselring bladder		Kesselring bowel	
	Pre-op	F-up	Pre-op	F-up
0	40 (42.5)	61 (64.8)	55 (58.5)	62 (67)
1	26 (27.6)	20 (21.2)	20 (21.2)	21 (22.3)
2	18 (19.1)	3 (3.1)	14 (14.8)	5 (5.3)
3	10 (10.6)	10 (15.6)	5 (5.3)	5 (5.3)
4	0 (0)	0 (0)	0 (0)	0 (0)

Table 7. Mean radicular pain as measured by VAS for trans-thoracic and retro-pleural technique.

	TTA		MIRA	
	Pre-op	F-up	Pre-op	F-up
0–3	17 (34.7)	35 (71.4)	23 (60.5)	32 (84.2)
4–6	18 (36.8)	3 (6.2)	5 (13.2)	5 (13.2)
7–10	14 (28.5)	11 (22.4)	10 (26.3)	1 (2.6)

Urinary/bowel dysfunction

Urinary and bowel function were graded according to the Kesselring scale (Table 4). Before surgery, bladder and bowel disorders were observed in 54 (57.4%) and 39 (41.4%) patients respectively. Urinary disturbances were mild (grade 1 or 2) (44; 46.8%). At follow-up, improvement was seen in 37 patients (39.3%); 57 (60.6%) remained unchanged. Bowel dysfunction was also most commonly mild (Grade 1 or 2) (34; 36.1%). There was no post-operative change in 71patients (75.5%). Twenty one (22.3%) improved and 2 (2.1%) deteriorated (Table 6).

Pain control in TTA Vs MIRA

The mean preoperative radicular pain was 4.7 and 5 for patients treated by TTA and MIRA on a VAS scale respectively. Pain at follow-up was significantly better controlled both in the MIRA (1.39, $p < 0.05$) and TTA group: (3.2, p 0.0019) compared to the preoperative status. When comparing the absolute mean value of post-operative radicular pain, the MIRA group scored significantly better than TTA. (1.39 vs 3.2; p 0.0426 $p < 0.05$). Furthermore, only one patient (2.6%) of the MIRA group who presented with severe radiculopathy (10, 26:3%) had persistent severe pain at follow-up. Conversely, within the TTA group 28.5% (14) patients had severe preoperative pain that persisted and was disabling in 11 patients (22.4%) at follow-up. The MIRA approach therefore seems to have a statistically significant advantage on reducing radicular pain (X^2: 7.07, p 0.0078) when compared to TTA (Table 7).

Complications

Post-operative complications are listed in Table 8. Pneumonia, pleural effusion and respiratory distress were the most commonly

encountered pulmonary complications (12; 11.5%) and were significantly more frequent in patients operated by TTA than MIRA (10 vs 2; X ^{2}: 4.13, p 0.042). In two MIRA cases where an intraoperative pleural breach was identified, a post-operative pleural effusion occurred. In one patient the effusion manifested after discharge and was successfully treated with a chest drain following readmission. In the second patient the effusion was evident during their hospital stay and was successfully managed with a chest drain. During MIRA if a small parietal pleural violation is encountered intraoperatively, a piece of haemostatic gelatine foam can be positioned under the defect to protect the lung and prevent the expansion of the pleural defect itself.

Table 8 Surgical complications in our 94 cases series. Number of patients and (%).

	TTA	MIRA	Total	P
Transient liquoral fistula	5 (10.2)	4 (10.5)	9 (8.6)	
Pulmonary complications	10 (20)	2 (5.2)	12 (13.7)	X^2 : 4.13 P: 0.042
Infections	1		1 (0.9)	
Neurological worsening			2 (1.9)	

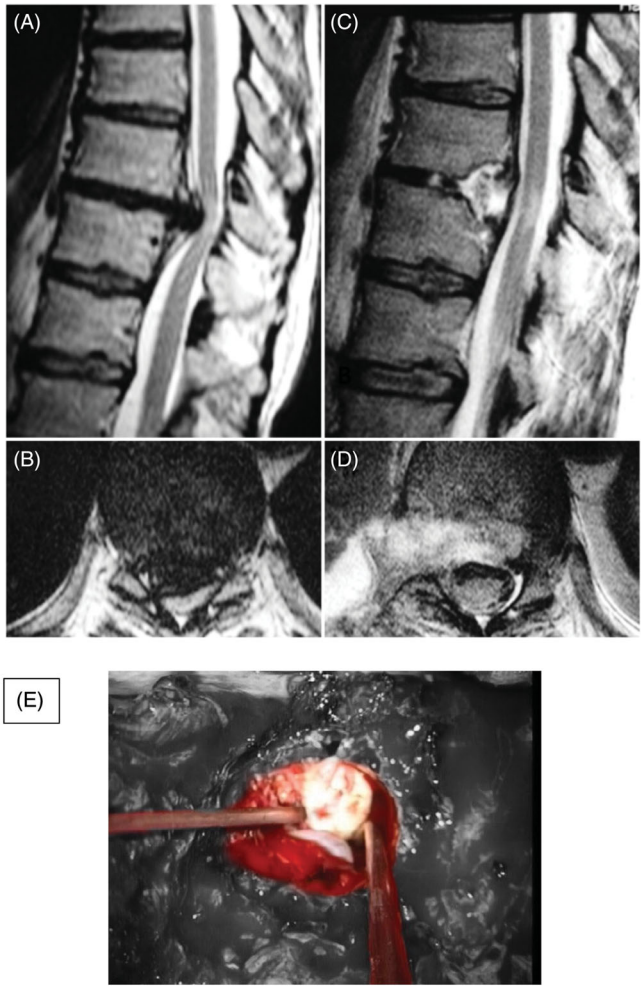

Figure 2. T2 MRI sequences showing a T7–T8 a giant TDH. The herniation appears mostly calcified, occupies >40% of the spinal canal, compresses and dislocates posteriorly the spinal cord that shows signs of myelopathy (A, B); The TDH was removed by MIRA and MRI shows decompression of the spinal canal and signs of partial drilling of T7 and T8 vertebral bodies (C, D). (E) Surgical steps: (a) patient position in lateral decubitus (b) skin marking level overlying the affected disc space (c) after the split-blade retractor is docked over the dilators the GTDH is removed with microsurgical technique.

In 9 patients (8.6%) a spinal fluid leakage was seen: all cases resolved after positioning of a lumbar drain. None of our patients required a permanent shunt. One patient developed a superficial wound infection that was successfully treated with antibiotics.

Post-operative neurological deterioration occurred in two patients (2%) as measured by Frankel's grading. Both had a giant calcified TDH penetrating the dural sac and were operated by TTA (2 of 33, 6%).

Discussion

The thoracic spine hosts the narrowest section of the spinal canal. At this level the spinal cord runs close to the posterior surface of the thoracic vertebrae, making it vulnerable to anterior compression. The vascularisation of the thoracic spinal cord has unique characteristics ('watershed zone'[18]) that expose the spinal cord to a high risk of compression or ischaemic injury.[4] The relatively long time between the first presenting symptoms and signs of TDH and the final diagnosis (around 30 months) in our cohort confirms the existence of compensatory and protective mechanisms at this level.[5–11]

TDHs most commonly present with symptoms of progressive myelopathy accompanied by radicular or axial pain. Less frequently they can present with acute symptoms.[12,13,19] Patients with TDHs may occasionally report extra-axial symptoms mimicking other commoner conditions, thus creating diagnostic delays.[20] Arce and Dohrman reported back or radicular pain was the first symptom in 57% of cases, sensory disturbance in 24%, motor weakness in 17%, and sphincter dysfunction in 2%.[21] In accordance with these findings, in our series the first presenting symptom was pain (55.7%), while upper motor neuron signs were less commonly encountered (16.3%).

With the availability of CT and MRI techniques, TDHs are often incidentally diagnosed in asymptomatic subjects (with an incidence of around 37%.[22]) Cases of spontaneous regression of asymptomatic and symptomatic disc herniations are described.[23–25] The history of the disease is nonetheless most commonly evolutive. The diagnosis of TDH is usually confirmed by MRI. A CT scan can be useful to better describe the calcific nature of the TDH. Both imaging modalities provide valuable information and should be part of routine investigations when evaluating a patient with suspected TDH.[13] As described above, when an anterior approach was planned we performed a preoperative spinal angiography to detect the topography of the Adamkiewicz artery;[15] if surgery was required at this level, a contralateral approach or a selective surgical technique without

Table 9. Neurological status pre and post-operatively.

	Frankel scale		Mccormick scale		Kesselring bladder		Kesselring bowel	
	Improved	Not improved	Improved	Not improved	Improved	Not improved	Improved	Not improved
MIRA	25	13	25	13	13	25	6	32
TTA	38	11	39	10	20	29	13	36

vessel ligation could lower the risk of damage to the anterior vascular axis.

No clear consensus regarding the best approach to treat TDHs exists. Different approaches offer different exposure of the ventral spinal canal and the choice should be based on the location, consistency and size of the herniated disc. The biomechanics of the thoracic spine should also be considered.[26–28] Each approach should attempt to minimise manipulation of the thoracic spinal cord. Several surgical strategies are described: posterior (laminectomy and its variants), posterolateral (transpedicular, costo-trasversectomy), lateral (extra-cavitary) trans-facet pedicle sparing,[29,30] antero-lateral trans-thoracic (TTA, MIRA, thoracoscopic) and ventral (trans-sternal).[31]

Posterior approaches allow an indirect decompression of the spinal cord unless the disc herniation is posterolateral. They are seldom used due to the risk of manipulative injury to the spinal cord[32].

Posterolateral approaches reduce the need for cord retraction but allow for a limited working field. Some authors suggest posterolateral approaches for laterally located TDHs.[8,10,27,33] We adopted these techniques when the TDH laterally displaced the spinal cord creating a natural surgical corridor to the cord itself.[15] In the last 20 years, at our Institution we have used a posterolateral approach in 7 patients who are not included in this study.

Antero-lateral approaches provide the best exposure and the safest and most complete decompression of the spinal cord.[34,35] We have adopted antero-lateral approaches for centrally located and large ossified TDHs causing posterior displacement of the spinal cord. The interface between the herniation and the spinal cord is under visual control avoiding any blind manipulation. In our series, antero-lateral approaches, either TTA or MIRA were most commonly adopted (87; 92.5%).

TTA carries a significant risk of perioperative morbidity and approach-related complications (mainly pulmonary and persistent intercostal neuralgia[7,16,36,37]). MIRA has been developed to reduce complication rates.[36,38] We believe this is due to a smaller incision, smaller rib resection, pleural preservation and lack of lung desufflation. Thoracoscopic approaches are less invasive but their learning curve may cause prolonged operative time and occasional conversion to open thoracotomy.[39] The risk of pulmonary complications (pleural effusion, atelectasis, pneumonia, and pneumothorax) ranges from 3.6% to 21%[5,11,40] and is linked to the need to deflate the ipsilateral lung during the procedure.

In our series, complications occurred in 25.5% of cases (24 overall) treated with an antero-lateral approach. This is comparable to other recent studies.[33,39] Pulmonary complications (pleural effusion with pneumonia) occurred in 12 patients (13.7%) and were successfully treated with antibiotics. They were significantly more frequent in TTA than MIRA (10; 20% vs 2; 5.2% X^2: 4.13; p 0.042), while in the two MIRA patients that developed pleural effusion, the pleura was accidentally violated during surgery. Post-operative persistent intercostal neuralgia is a disabling complication. It occurs in 3% to 15% of cases operated by an antero-lateral approach.[16,36–38,41] Pain usually decreases with time, but never disappears: 30% of patients still have pain 4 years after surgery.[42] In thoracoscopic surgery, persistent intercostal neuralgia is described as transitory in 8% of cases[40] and resolving in 6 weeks in 5.6%.[5] In our series, persistent post-operative neuralgia was significantly more frequent in patients treated with TTA than MIRA (22.4% vs 2.6%, X^2 7.07, p 0.0078).

In MIRA, tubular retractor blades are strong enough to widen the intercostal space without rib resection. Nevertheless, a significant force can be generated as rigid blades are expanded and rib fractures or nerve compressions can occur.[35,36] Therefore, we prefer to resect approximately 5 cm of the rib projecting above the disc space as described above.

Cerebrospinal fluid leakage is reported more frequently in series including GTDHs (1.2% to 18%), probably due to their central location, consistency and infiltrating nature.[5,7,16,35–37,43] Repeat surgery is seldom required to repair the dural defect.[5,7] Dural tears were identified intraoperatively in 9 of our cases (8.6%): all were GTDHs. The resulting dural defects were repaired with muscle patches, fibrin sealants, bed rest and placement of lumbar drains. A persistent self-limiting pleural fluid fistula was seen in one patient and a they were treated conservatively in view of the absence of clinical signs/symptoms. Dural tears are also described with thoracoscopic approaches.[7,9,44] In these, the interface between disc herniation and theca can be difficult to visualise, complicating dural repair.[44]

Other complications in our series, namely one wound infection and one non-fatal pulmonary embolism, were comparable in number to those reported in the literature.

In our series, 33 TDHs (35.1%) were classified as GTDHs, all were calcified and 5 (15%) eroded the dura and became transdural. Other series report a trans-dural extension ranging from 42% to 70%.[7,16,37] Only a few series report no trans-dural extension.[41] In our cohort, 24 GTDHs (72.7%) were treated by a MIRA and 8 (24%) by TTA. Both techniques allowed exposure of the normal dural surface around the margins of the GTDHs; in one case a thoraco-abdominal approach was used for a GTDH located at the junction. When addressing a GTDH case, corpectomies in our series were not necessary, contrary to other authors' opinion.[7,16,39] In fact, a wedge-shaped osteotomy of the postero-superior corner of the vertebra below and postero-inferior corner of the vertebra above is sufficient to achieve exposure of the pathology (Figure 2(A–E)). Dural adhesions can be resolved and dural tears repaired if necessary with this type of conservative osteotomy. Although we avoided spinal instrumentation in our cases, contrary to other authors,[29,35,36] none of the patients in this series developed mechanical complications or spinal malalignment at follow-up. Some authors of large case series who successfully managed GTDHs without the need for instrumentation share this view.[12,13,23,24,37,43,45–47] Finally, good anesthesthetic support (volume status optimisation, maintenance of mean arterial pressure above 90 mmHg among others) is a fundamental aspect of thoracic spine surgery for cord compression.[48]

The high prevalence of patients presenting with motor impairment (91.4%) in this cohort correlates well with other reports including a large number of GTDHs.[7] Most of our patients improved their neurological status after surgery in accordance with other reports (70–91%).[5–11] Seventy patients (74.4%) improved by one class of disability at the clinical evaluation by McCormick and Barthel Index Scale and 69 (73.4%) at Frankel scale. In our series, the greater the size of the TDH the greater was the probability to have a post-operative clinical deterioration as measured by the Frankel scale. Post-operative neurological deterioration occurred in two patients (2.1%), and both had a GTDH with intradural extension (6% of GTDHs). MIRA can be effectively utilised to address GTDHs since no extensive osteotomy is necessary for its removal[17] as confirmed in this cohort.

In our study, bladder and bowel disturbance were more frequently reported than other studies, probably due to the large number of GTDHs.[6] A meaningful clinical recovery of these symptoms at follow-up was found only in 39.3% (37) and 22.3%

(21) of our patients, respectively. Neurological outcomes did not differ among patients treated with either MIRA or TTA (Table 9) at follow-up. Finally, only the last 15 patients in our cohort were operated with the support of neuromonitoring. We found no differences in outcomes for patients treated with or without neuromonitoring, although we recognise its merits especially in difficult cases of TDH removal.[49]

Conclusions

TDHs can be an incidental neuroradiological finding and cause no symptoms. Symptomatic TDHs are uncommon, but when signs and/or symptoms of spinal cord compression appear, surgical treatment should be considered .

Several approaches can be adopted to access the thoracic disc herniation. The technique depends on location, size and consistency of the TDH.

Minimally invasive techniques including MIRA may reduce the incidence of surgical complications. Our series confirms the success of MIRA even in cases of GTDHs, and we demonstrated that extensive vertebral body resection and instrumented fusions can be avoided. Neurological outcomes do not seem to be influenced by the choice of approach, whether TTA or MIRA, although MIRA seems to provide better control of radicular pain at follow-up.

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