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ORIGINAL ARTICLE

Giant central thoracic disc herniations: surgical outcome in 17 consecutive patients treated by mini-thoracotomy

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Abstract
Purpose Safe treatment of giant central thoracic disc herniations (cTDHs) remains a surgical challenge due to frequent calcifications, intradural extension and, importantly, the rare exposure of spine surgeons to these lesions. We report our 10-year experience in the management of giant cTDH by mini-thoracotomy and offer a detailed description of the technique.
Methods 17 patients harboring 17 giant cTDH operated on via a mini-thoracotomy at the authors' institution between 2004 and 2014 were reviewed. All patients presented with myelopathy of varying magnitude. Mean patient age was 47 years. The mean follow-up period was 5.5 years. Median canal compromise of the cTDH was 66 %. cTDH were densely calcified in 7 (41 %), partially calcified in 6 (35 %) and soft in 4 (24 %) patients. Intradural extension of cTDH was noted in six patients (35 %). Benzels' modified myelopathy score of the Japanese Orthopedic Association was adjusted for the evaluation of thoracic myelopathy (mJOA) to assess functional outcomes.
Results Successful removal of the offending cTDH was achieved in all patients. The overall mJOA Score improved from 7.9/13 to 11.1/13. Two patients with giant and densely calcified cTDH experienced a transient post-operative neurological decline. There was a statistically significant correlation between size of cTDH and intradural extension.
Conclusion Patients with myelopathy due to giant cTDH can be safely treated by the mini-thoracotomy approach. Postoperative neurological worsening and severe complications or incisional pain are rare. In contrast to complex posterior or thoracoscopic approaches, the mini-thoracotomy is technically straightforward and thus easy to learn for experienced spine surgeons.

Keywords Thoracic disc herniation · Myelopathy · Transthoracic approach · Thoracic spine

Introduction

Thoracic disc herniations are frequently encountered as incidental findings in spinal magnetic resonance imaging (MRI) [1]. However, symptomatic disc herniations at the thoracic spine are very rare compared to their cervical and lumbar counterparts and account for only a small percentage of disc surgeries [2–5]. The incidence of symptomatic TDH is thought to be as low as 1:1,000,000 patient years [6, 7].

A diversified armamentarium of surgical techniques has been developed to address any given type of disc herniation in any patient by the least invasive and safest way. Among them are transpedicular [8–10] and transfacet pedicle-sparing [11, 12] approaches, costotransversectomy [5, 15], lateral extracavitary [13], transthoracic [14–24] and thoracoscopic [25–27], and, finally transsternal [28] approaches.

Giant thoracic disc herniations—defined as compromising more than 40 % of the spinal canal as measured on axial computed tomography (CT) by Hott et al. [19]—are a subset of thoracic disc herniations typically presenting with myelopathy, high amount of calcification and frequent intradural extension. They expose the patient to a considerable risk of neurological injury and the surgeon to

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specific challenges. Here, we report our experience in the management of this exceptionally rare condition in 17 consecutive patients treated between 2004 and 2014 using a mini-thoracotomy approach.

Methods

Patient population

The study was approved by the Institutional Review Board (618/14).

Clinical, radiographic and surgical characteristics of all patients who underwent a transthoracic resection of a giant TDH were retrospectively retrieved. Seventeen patients harboring 17 cTDH were operated on via a mini transthoracic approach in the authors' department between January 2004 and May 2014. The patient population consisted of 12 women and 5 men with a median age of 47 years (range 31–74). Four patients (22 %) had a history of a previous severe trauma (three motor vehicle accidents, one fall from a stair case). Patient, disc, treatment and outcome characteristics are summarized in Table 1. The median follow-up was 5.5 years (range 0.2–9.3 years).

Surgical technique: the mini-transthoracic approach

All patients are positioned in the lateral position after induction of general anesthesia. Care is taken to attain an as true as possible lateral position. The side of the approach is chosen according to the laterality of the prolapse. In this series, 10 right-sided and 7 left-sided mini-thoracotomies were performed. As the approach is directed to the posterior aspect of the vertebral bodies, anatomical obstacles related to the side of exposure (i.e. vena cava, aorta, thoracic duct) are not encountered. Both lungs are ventilated throughout the procedure. Intraoperative SSEP and MEP monitoring are routinely performed. Localization of the disc space of interest is performed by fluoroscopic C-arm imaging counting up from the sacrum. A radio-opaque plumb line that intersects the target disk space is dropped to the thoracic skin level under anterior-posterior fluoroscopy. A skin incision of approximately 6–8 cm is carried out parallel to the rib that is perpendicular to the affected level. Of note, this is frequently not the rib corresponding to the vertebral bodies of the segment affected by the cTDH. The rib is displayed and the intercostal muscles incised. Resection of the rib is not necessary as long as the intercostal muscle is incised long enough. The pleura is incised, the lung is retracted manually and the blades of the retractor system (SynFrame, Synthes Spine, Paoli, PA, USA) are introduced into the thoracic cavity gently and progressively retracting the lung. The head of the rib and the lateral aspect of the vertebral body are visualized. The retractor blades are centered over the disc space of interest and secured. The level is fluoroscopically confirmed. All following steps are performed under microscopic view. The parietal pleura is incised in a door-shaped fashion. Resection of the rib head is done using the chisel. This exposes the pedicle and neuroforamen. In select cases, the rib head only needs to be partially removed. A box-shaped cavity is created—opening the spinal canal ventrally of the TDH—by drilling of the bone and partial resection of the disc (usually 1×1 cm) on the posterior aspect of the adjacent upper and lower vertebral bodies. The dimensions of the cavity must at least be large enough to allow visualization of the entire ventral dura and are further determined by the size of the disc pathology which has to be retracted anteriorly into the cavity before removing it through the lateral approach (Fig. 1). Decompression of the dura is now performed by gently manipulating herniated disc fragments into the cavity. As the disc material and the posterior longitudinal ligament are tightly adherent in most of the cases the ligament is cut cranial and caudal of the disc space after coagulating and cutting the epidural veins. In case of intradural extension of the herniated disc the tight adhesion mostly includes the dura. In those cases it is often possible to dissect large amount of the adhered dura from the ligament. In most cases it is still necessary to resect parts of the dura around the intradural part of the prolapse. Dural closure is performed by tissue patch graft as there is usually no remnant anterior dura allowing suture. The osteotomy defect can be filled with autograft collected from the rib head and the vertebral bodies. A chest tube is inserted, the dissected ribs are "narrowed" by tight sutures around the two neighboring ribs and the wound is closed in layers.

Outcome measures

The Japanese Orthopeadic Association Scale as modified by Benzel et al. [29] was used to assess patient outcome. It was further modified for the specific evaluation of thoracic myelopathy by omitting the score for the upper extremity. The final scoring system, hereafter termed mJOA, is shown in Table 2. Bowel and sexual dysfunction, despite its well-recognized and self-explanatory relevance in patients suffering from myelopathy, is not integrated in commonly used spine scales [30]. We therefore set up an additional scoring for both bowel and sexual dysfunction (Table 2b, lower row). To allow for comparison with other studies, we did not include these measures into the mJOA score.

Table 1 Patient, disc and outcome characteristics of patients included in the study

Pat. no.	Age, sex	Time to diagnosis (months)	Follow-up (months)	History of severe trauma	Level	Type of calcification	Canal compromise (%)	Intradural extension	Pre-OP mJOA	Post-OP mJOA	Last follow-up mJOA	Complications/post-OP deficit (transient/permanent)	Post thoracotomy Syndrome	Return to work
1	41, f	0	113	+	11/12	soft	70	–	6	8	11		No	Yes
2	44, f	1	110	–	9/10	Partial	63	–	12	12	13		No	Yes
3	74, m	24	64	–	7/8	Partial	56	–	6	6	9		No	N/A
4	45, f	24	100	–	9/10	Partial	94	+	6	7	9		No	Yes
5	41, f	30	86	+	7/8	Dense	40	–	4	7	12		Intercostal neuralgia persisting for 12 months post OP	Yes
6	65, f	9	78	–	7/8	Soft	45	–	11	11	11		Mild intercostal neuralgia	N/A
7	40, m	6	19	+	10/11	Dense	90	+	12	2	11	Paraplegia immediately post-OP (transient)	Mild intercostal neuralgia	No
8	65, f	66	4	–	11/12	Dense	58	–	9	9	12		No	Yes
9	51, f	4	71	–	9/10	Dense	80	+	10	4	8	CSF fistula requiring surgical revision Severe paraparesis immediately post-OP (transient)	No	No
10	44, f	3	68	–	7/8	Dense	66	+	7	7	13	Pleural effusion requiring drainage	Mild intercostal neuralgia	Yes
11	50, m	2	63	–	9/10	Partial	71	–	6	6	10		Very mild intercostal neuralgia	No
12	51, m	10	58	–	7/8	Partial	75	–	10	11	13		No	Yes
13	31, m	1	28	+	10/11	Partial	47	–	7	10	13		No	Yes
14	49, f	6	10	–	7/8	Soft	59	–	11	12	13		Mild intercostal neuralgia	Yes
15	41, f	0	4	–	11/12	Soft	36	–	6	9	10		No	Yes
16	47, f	2	4	–	10/11	Dense	71	+	6	5	11	Mildly worsened paraparesis (transient)	Mild thoracic hypaesthesia	Yes
17	50, f	16	3	–	8/9	Dense	91	+	6	5	9	Mildly worsened paraparesis (transient)	No	Yes

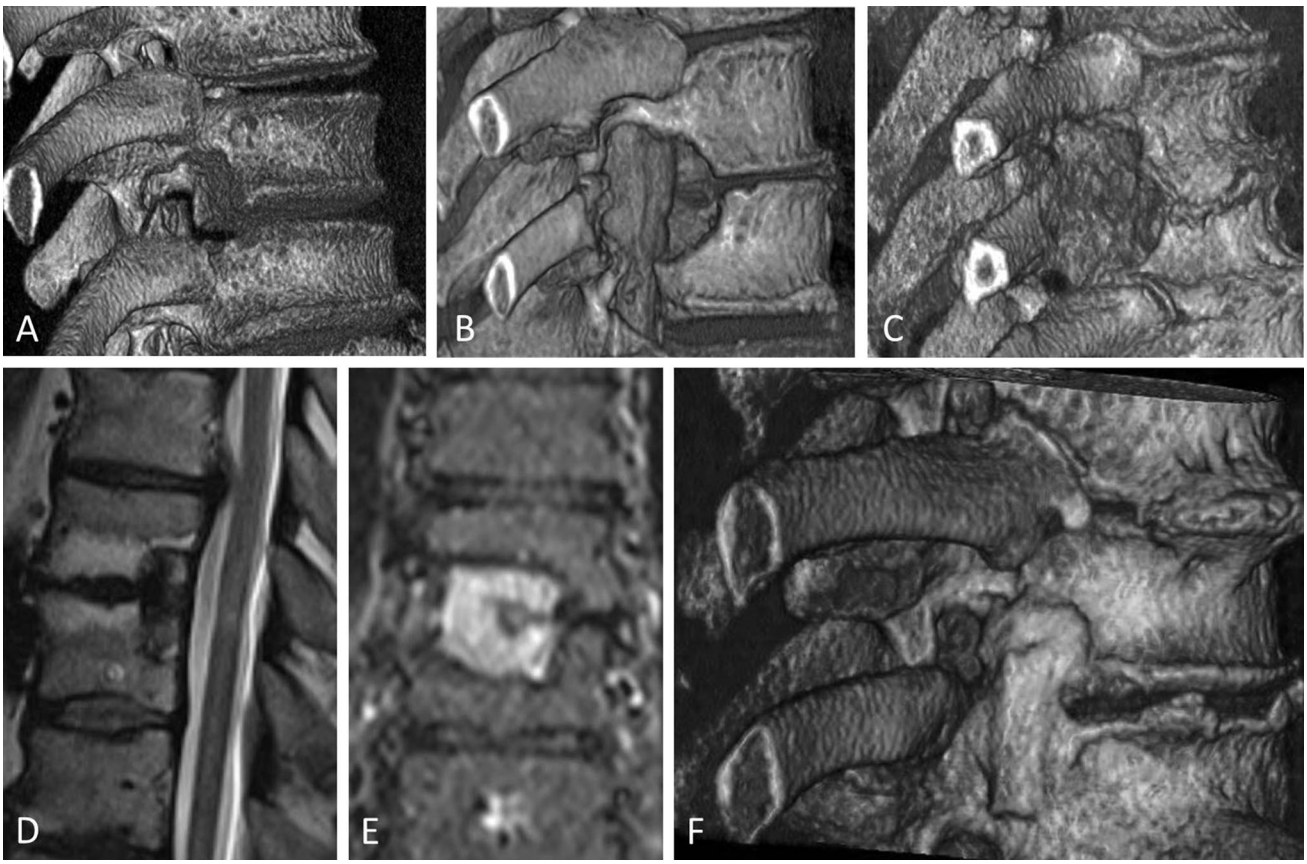

Fig. 1 Post-operative imaging demonstrating the anterior surgical access to the spinal canal by drilling a box-shaped cavity within the posterior part of the upper and lower vertebral body and partial removal of the disc itself. The size of the cavity is adjusted to the size, features and location of the herniated disc. Usually, resection of the rib head is required to obtain enough space for safe manipulation (**b**, **c**). In select cases, the rib head can be spared (**a**). Segmental fusion can be induced by filling the cavity with autologous bone obtain during the access—usually the rib head, which can be harvested in total by using a chisel (**f**)

Statistical analysis

Unpaired Students *t* test or Kruskal–Wallis non-parametric ANOVA was used for comparison of differences between groups for parametric data. Non-parametric data were analyzed by Fisher exact or Mann–Whitney *U* test. All tests were two-sided. A p value <0.05 was considered statistically significant. All statistics were performed using GraphPad Prism version 5 Statistical Software (GraphPad Software, San Diego, USA).

Results

Clinical presentation

The clinical presentation of the 17 patients operated on via the described approach is presented in Fig. 2. The time between onset of symptoms and establishment of the diagnosis was highly variable and ranged from an immediate diagnosis due to an acute onset of paraparesis and 5.5 years (median, 6 months). All patients presented with myelopathy. Sensory deficits were present in 16 (94 %) and paraparesis of varying severity was present in 8 (47 %). Three patients (18 %) presented with monoparesis. Upon admission, three patients were unable to walk. Spastic gait or hyperreflexia of the lower limbs was found in nine patients (53 %). Urinary symptoms were reported by six patients (35 %) and consisted of partial or severe incontinence. Voiding difficulty was not observed. Partial fecal incontinence was present in three patients (18 %) and one patient reported marked constipation. Fourteen patients were willing to respond to questions about their sexual function throughout the disease course (10 women and 4 men). Three of them reported severe impairment (e.g. complete loss of potency/sexual dysfunction), five reported mild impairment (potency disturbance/sexual dysfunction) and six normal sexual function. Pain was a leading symptom in 13 patients. Axial back pain was present in 12 patients, accompanied by radicular pain in six of them. Only one patient presented with radicular pain in the absence of axial back pain.

Table 2 Outcome Scale: modified Japanese Orthopaedic Association Score

Score	Definition
A: mJOA Scale for thoracic myelopathy as used in the present study (referred to as mJOA)	
Motor dysfunction (lower extremities)	
0	Complete loss of motor and sensory function
1	Sensory preservation without ability to move legs
2	Able to move legs but unable to walk
3	Able to wlk on flat floor with a walking aid
4	Able to walk up and/or down stairs with hand rail
5	Moderate to significant lack of stability but able to walk up and/or down stairs without hand rail
6	Mild lack of stability but walk unaided with smooth reciprocation
7	No dysfunction
Sensation (lower extremities)	
0	Complete loss of sensation
1	Severe sensory loss or pain
2	Mild sensory loss
3	No sensory loss
Sphincter function	
0	Inability to micturate voluntarily or complete incontinence
1	Marked difficulty with micturition or partial incontinence
2	Mild to moderate difficulty with micturition or mild incontinence
3	Normal micturition
B: Additional scale to assess bowel and sexual dysfunction (not included in the mJOA)	
Bowel function	
0	Incontinence for solid stool
1	Incontinence for liquid stool
2	Incontinence for gas
3	Normal function
Sexual function	
0	Severe impairment of sexual function (e.g. loss of potency, loss of sexual activity)
1	Mild impairment of sexual function (e.g. potency disturbances, reduced sexual activity)
2	Normal sexual function

Disc characteristics

Median compromise of the spinal canal by the cTDH was 66 % (range 42–94 %). The size of the cTDH was positively correlated to intradural extension (Fig. 3a). We found three subtypes of cTDH with respect to calcification: cTDH occurred as either densely calcified, partially calcified or without calcification (termed soft cTDH) (Fig. 3b). Although there was a tendency towards calcification with increasing size of the herniated disc, this difference was not statistically significant (Fig. 3c). The number of cases included in this study is too small to allow for a valid statistical analysis but there was an obvious correlation between dense calcification and intradural extension of the disc herniation (Fig. 3d). Intradural extension was noted in 5 of 7 densely calcified disc herniations compared to only 1 of 6 partially and 0 of 4 soft cTDH. Of note, a non-significant trend towards a longer time-to-diagnosis with increasing calcification was found.

Surgical characteristics and outcome

Median operative time was 245 min (range 130–363 min). No blood transfusions were required. Surgical complications occurred in two patients. One patient suffered from a pleural CSF fistula. Surgical revision and sealing of the dural leak with fibrin glue successfully resolved the fistula. Another patient suffered from a pleural effusion and required drainage by reinsertion of a chest tube for several days.

The neurological outcome is summarized in Fig. 4. The pre-operative mJOA was 7.9/13. There was a non-significant decline in overall mJOA immediately after surgery to 7.7/13, a non-significant improvement to 8.4/13 at

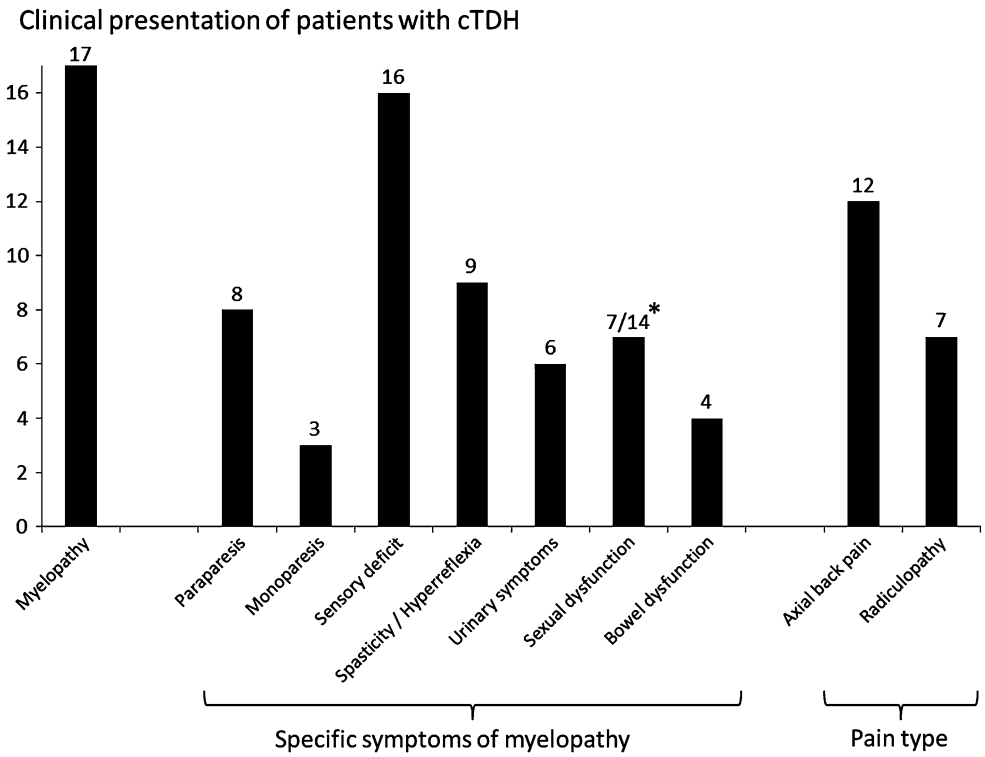

Fig. 2 All 17 patients operated on for a centrally located giant TDH presented with myelopathy. Pain, either as axial back pain, radiculopathy or both was present in 13 patients. *14 patients were willing to comment on sexual functions and 7 (50 %) of those reported sexual dysfunction

discharge and a significant and marked improvement to 10.4/13 after 3 months. A slight further increase to a final mJOA of 11.1/13 was noted at the last available follow-up (Fig. 4a). Sensory deficits improved significantly in all patients and the recovery was faster compared to the motor deficits (Fig. 4b, c). Urinary, bowel and sexual dysfunctions also improved following surgery but the recovery measured did not attain statistical significance. No patient remained with a urinary or fecal incontinence (Fig. 4d, e). Severe sexual dysfunction in 1 of 3 patients presenting with this condition.

A relevant post-operative neurological deterioration occurred in two patients (11.8 %). Both had a good pre-operative neurological status (mJOA 10 and 11 respectively) and had large (canal compromise of 80 and 90 % respectively) and densely calcified herniated discs with intradural extension. They suffered from severe paraparesis immediately after the operation. The course of their neurological decline and recuperation is shown by the arrows in Fig. 4a. One of them was not able to walk upon discharged but returned to a good functional status within 3 months and regained the pre-operative level (mJOA 11/13) after 6 months (black arrow, Fig. 4a). The second patient had a delayed recovery. She regained ambulation after 6 months following the operation and recovered to a mJOA of 8/13 (dotted arrow, Fig. 4a).

Discussion

Today, the history of surgery for TDH overlooks more than 100 years. The path to the successful management of this rare condition is characterized by unacceptable results of early dorsal approaches followed—decades later—by pioneering innovations. Surgery evolved from dorsal strategies towards posterolateral, lateral and anterior (e.g. transthoracic) approaches to reach the good outcomes reported throughout the world today.

The continuous refinement of the surgical strategies by specialists in the field has given birth to a highly differentiated armamentarium of surgical solutions tailored to any type of disc herniation and affected individual. This way, paracentral and lateral disc herniations, and potentially smaller non-calcified cTDH can now be safely managed by posterior pedicle-sparing approaches avoiding the potential morbidity of a transthoracic approach [31]. For giant cTDH in turn, especially when densely calcified, the transthoracic route remains the optimal approach as only this allows a true anterior spinal cord decompression [32].

The last decade has seen an increasing popularity of thoracoscopic approaches for TDH. The appealing theoretical benefits of thoracoscopy over thoracotomy (e.g. becoming less invasive causing less incisional pain and

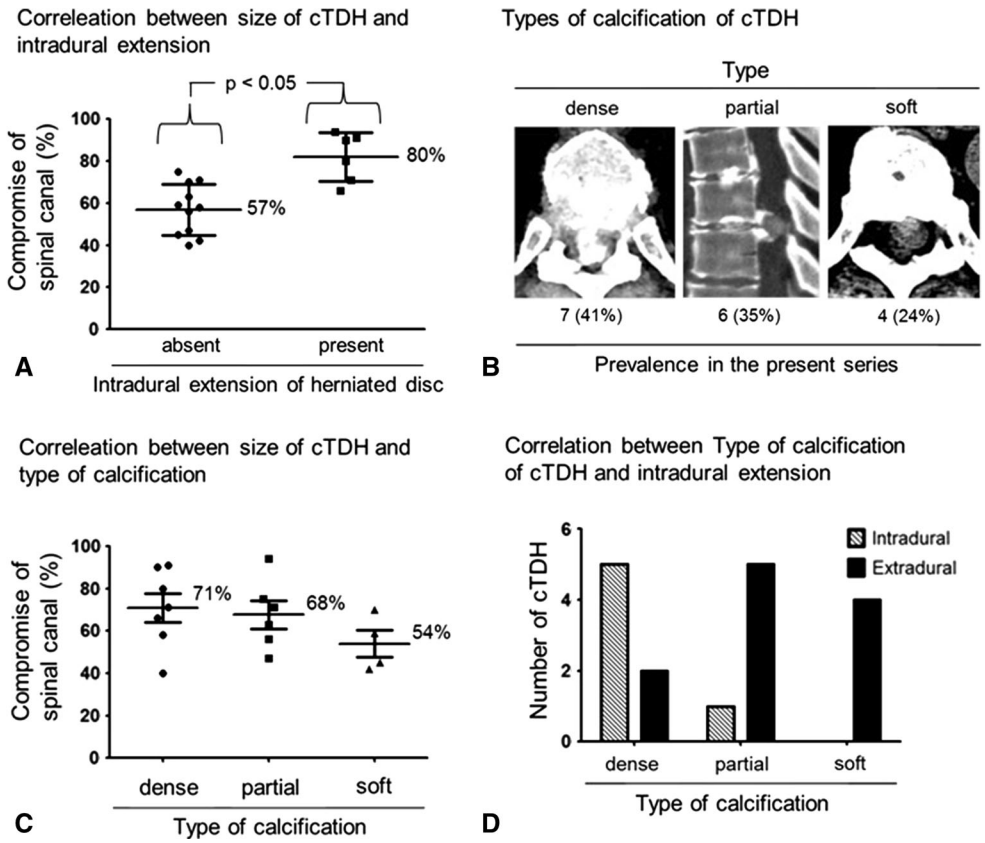

Fig. 3 Intradural extension of TDH was significantly associated to larger size of TDH (**a**). TDH were classified according to the type of calcification—dense, partial or soft (**b**). There was a trend (statistically not significant) towards increasing calcification with larger size of the TDH (**c**). Intradural extension is a feature typical of densely calcified TDH (**d**)

allowing faster recovery) have not been met in practice [14, 19]. However, thoracoscopic procedures are difficult to learn and regular exposure to this technique is required to preserve the skill. As symptomatic TDH are extremely rare training a team of staff surgeons is not realistic in most spine centers around the world. This is highly relevant since rapid neurological decline is not uncommon in patients with cTDH requiring emergent surgery. We therefore believe that the benefits of the mini-thoracotomy and its variations [20, 23]—microscopic view with ideal visualization of the pathology and application of classic microsurgical skills—turn it into the ideal instrument for the management of cTDH and outweigh the questionable advantages of thoracoscopy.

Previously reported series of surgical management of TDH typically mix all types of disc herniations. Commonly, the size of the disc herniations is not reported but absence of myelopathy in the majority of these cases and the focus being on pain improvement suggests that the number of giant TDH included was usually small.

Hott et al. [19] were the first to address the specific clinical features and surgical challenges of giant TDH. In line with their series of 20 giant TDH (16 were centrally located), further 15 cases of giant TDH reported by Zhao et al. [24], 17 giant TDH reported by Russo et al. [33] and a series of seven TDH by Moran et al. [34] myelopathy was the leading symptom in all patients from the present series. Calcifications and intradural extension are highly prevalent in giant TDH. Hott et al. changed their strategy from a thoracoscopic approach to thoracotomy after neurological complications were encountered in patients managed thoracoscopically. Hott et al. further describe that "most cases require a two level corpectomy". Our own experience is that even with densely calcified cTDH of large sizes a box-shaped osteotomy of about 1×1 cm as described above is sufficient to remove the pathology and decompress the spinal cord. While Hott et al. and Zhao et al. performed lateral plate osteosynthesis (and—in part—vertebral body replacement) in all of their reported cases of giant cTDH, instability does not seem to be an issue using the technique presented here as no patient in our series required a subsequent instrumentation.

The pathophysiology of TDH is poorly understood [35, 36]. Particularly conflicting data exist on the association between preceding accidents and TDH. Taken together, 14

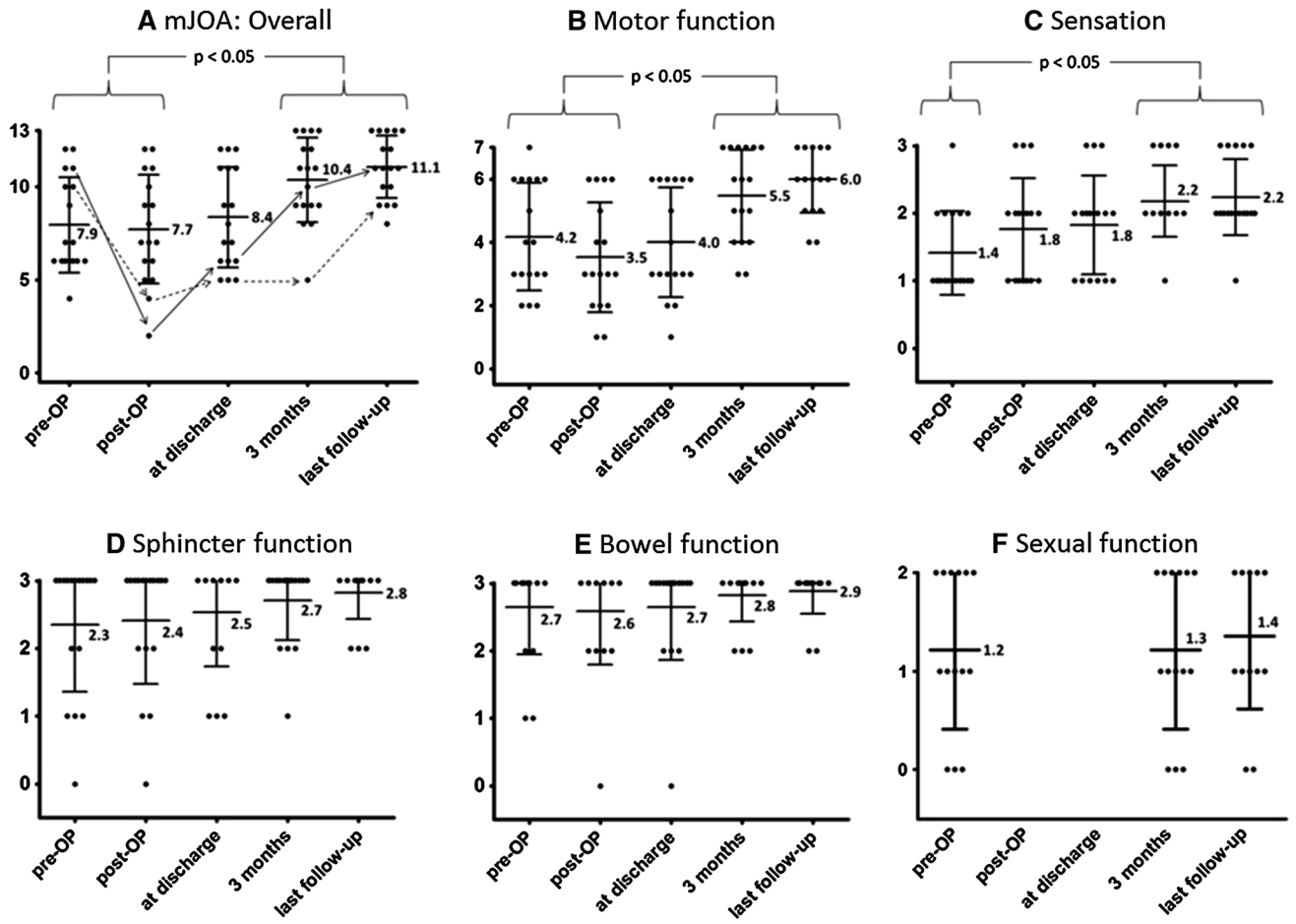

Fig. 4 Neurological patient outcome was assessed by the modified JOA Scale as described in the methods section. Overall, a solid improvement following surgery was reached (**a**). Two patients worsened significantly immediately after surgery. Their deterioration and subsequent recovery is marked by the *arrows* in **a**. Two patients had a slight and transient decline of motor functions immediately after surgery. Three months after surgery all patients were ambulating. The last follow-up revealed an excellent mean motor score of 6/7 (**b**). Sensory deficits were more rapidly relieved compared to motor dysfunctions (**c**). Improvement in bladder and bowel and sexual dysfunction did not attain statistical significance (**d**–**f**)

older series reported an antecedent trauma in 37 % of patients [12, 36]. Contrarily, Cornips et al. [37] reported an associated trauma in only 3 % of patients in a large series of TDH. Four of 17 patients (24 %) in the present series had a history of a severe trauma, mostly motor vehicle accidents, supporting the hypothesis that TDH can be associated to trauma.

Conclusion

Giant cTDH occupy a special rank in the field of TDH. While pain is a common reason to indicate surgery for smaller and paracentral TDH, myelopathy is the leading symptom in patients with giant cTDH making surgical intervention mandatory. The likelihood of intradural extension and calcification complicating the surgical removal increases with the size of the cTDH. While representing a particular surgical challenge, these pathologies can still be safely managed using the mini-thoracotomy approach. Postoperative worsening is rare and mostly temporary. The obvious advantages of this procedure—the optimal anterior exposure and the applicability of common microsurgical skills—outweigh the potential benefits of less invasive approaches (e.g. thoracoscopy or dorso-lateral approaches). Furthermore, the straightforward nature of this procedure makes it easier to learn and apply for experienced spine surgeons which is essential to provide this surgical technique as an emergency service.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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