Transthoracic approach for the treatment of calcified giant herniated thoracic discs

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Received: 16 July 2012/Revised: 26 January 2013/Accepted: 1 April 2013/Published online: 16 June 2013
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Abstract

Objective This study aimed at reporting the results of a transthoracic approach in the treatment of patients with calcified giant herniated thoracic discs (HTDs).

Methods Fifteen consecutive patients, 11 males and 4 females with a mean age of 46 years (range 33–61), with calcified giant HTDs underwent transthoracic decompression and segmental instrumentation with interbody fusion from November 2004 to September 2010. Clinical data retrospectively examined and compared were levels and types of disc herniation, operative time, blood loss, pre- and postoperative Frankel grades and Japanese Orthopedic Association (JOA) score, and complications.

Results Of the 15 patients, 2 had HTDs at two levels and affected discs were primarily at the T11/12 level (60 %). Presenting symptoms included myelopathy, axial back pain, urinary symptoms, and radiculopathy. Disc herniations were classified as central (40 %) or paracentral (60 %). All discs were successfully removed without dural

tears or cerebral spinal fluid leakage. The mean operation time was 179 ± 27 min (range 140–210 min), and the mean estimated blood loss was 840 ± 470 ml (range 300–2,000 ml). Frankel grades improved in 9 patients postoperatively and 12 patients at the last follow-up. The mean JOA score improved from 4.9 to 7.7. All patients reported improvement in symptoms. The average duration of follow-up was 45 ± 24 months (range 7–77 months).

Conclusions Transthoracic decompression combined with reconstruction, fusion, and fixation is an effective method for the treatment of these lesions and is associated with a low rate of complications, morbidity, and neurological impairment.

Keywords Transthoracic approach · Thoracic disc herniation · Herniated thoracic disc · Thoracic stenosis

Introduction

Thoracic disc herniations (TDHs) comprise 0.1–4 % of all disc herniations [1, 26] and are rare in comparison with cervical and lumbar counterparts. The incidence of TDH is reported to be approximately 1 case per million population per year [4]. Because patients with herniated thoracic discs (HTDs) present with variety of symptoms, the diagnosis of TDH is often unexpected or delayed [2]. Patients with TDH may be mistakenly diagnosed with cholecystitis, pancreatitis, or cardiac or intrathoracic disorders [35]. For this reason, patients are often diagnosed with a TDH at an advanced stage of the disease, and the herniated disc may be giant and/or calcified.

Because of the unacceptable morbidity and poor results of posterior decompression via laminectomy [17, 18, 34] in the treatment of TDH [17], a number of alternative surgical approaches have been developed including posterior

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transdural [21], tailored posterior [3], oblique paraspinal [5], posterolateral (transpedicular [14, 16, 24], transfacet pedicle sparing [25, 32], transcostovertebral [7], costovertebral [11, 29]), lateral (lateral extracavitary [19]), anterolateral (transthoracic [2, 6, 8, 22, 23], thoracoscopic [12, 27]), and anterior (transsternal [33], mini-thoracotomy [28]), as well as other transthoracic approaches [20].

Because of the familiar anatomy to spine surgeons and the perception that thoracotomy is associated with a high morbidity rate, posterolateral approaches have grown in popularity over the past years. However, for patients with calcified giant HTDs, especially for those with centrally located herniations, we prefer a transthoracic approach which exposes the ventral aspect of the spinal canal without the need for manipulation of the dura mater.

In this study, we report the outcomes of a transthoracic approach in 15 patients with calcified giant HTDs.

Materials and methods

Patients

In this retrospective study, the medical records of consecutive patients with giant, calcified HTDs who were treated with transthoracic anterior decompression, segmental

reconstruction, and fusion using an autogenous rib graft performed by the corresponding author between November 2004 and September 2010 were reviewed. Patients with calcified but not enlarged thoracic discs were excluded from the analysis. A giant herniated thoracic disc was defined as occupying more than 40 % of the diameter of the spinal cord based on computerized tomography (CT) and/or magnetic resonance imaging (MRI). Herniated discs were classified as central if the bulk of the herniation was against the midline of the thecal sac and as paracentral if more than half of the disc was located lateral to the midline.

This study was approved by the Institutional Review Board of our hospital, and all patients provided written informed consent for the surgical procedures.

Surgical technique

The level of the thoracotomy was decided pre-operatively. Patients were placed in the lateral decubitus position with the lesion convex in the center. After thoracotomy, the herniated discs and related vertebral bodies were exposed. In order to resect the calcified herniated discs safely, relevant posterior vertebral bodies must be resected. First, a trough at the middle and posterior third of the vertebra, stretching over the longitudinal length of the calcified giant herniated disc (Fig. 1a), was prepared. The trough must be

Fig. 1 a Range of the trough determined on MRI. b Intraoperative photo illustrating the preparation of the trough. c Removal of the herniated disc ventrally

deep till the opposite side of the column (Fig. 1b). After preparation of the trough, the calcified giant herniated disc was removed ventrally, without over-manipulation of the dura mater (Fig. 1c). The calcified disc was removed as a whole. Other calcifications, if presented, were dissected. Decompression was performed until the dura mater could be seen and no residual compression was noted. If adhesions to the dura mater were noted, dissection was performed with the aid of an operating microscope when necessary. If adhesions to the dura mater were difficult to separate, the trough was increased in width and depth rather than performing a difficult dissection.

Spinal instrumentations with the Johnson (Depuy) Kaneda internal fixation system was used in all cases. After surgery, a drain was placed and the wound was closed. When the pleural effusion decreased to less than 100 ml per day, the drain was removed and the patient was allowed to walk. Postoperative pain management consisted of patient-controlled analgesia and non-steroidal anti-inflammatory drugs (NSAIDs). If the patient had clear signs of intercostal neuralgia that was not relieved by the above methods, oral carbamazepine was administered.

Assessment of clinical outcomes

Operating time and blood loss were recorded. Pre- and post-operative symptoms were assessed by the Frankel neurological classification [9] and JOA score [10, 36] for thoracic myelopathy. The JOA score measures three functions: motor function in the lower limbs, sensory in the lower limbs and trunk, and bladder function. The JOA score recovery rate was calculated using the method of Hirabayashi et al. [13]. The recovery rate and the final results were classified into five groups: excellent (75–100 %), good (50–74 %), fair (25–49 %), unchanged (0–24 %), and worse (less than 0 %).

Results

A total of 15 patients with 17 herniated discs, 15 calcified giant HTDs, and 2 small HTDs were included in the study. The levels of herniation ranged from T-6 to L-1. Thirteen patients had single-level herniations, and two patients were found to have significant herniations at more than one thoracic level. Patient data are summarized in Table 1.

All 15 patients presented with objective signs or symptoms of myelopathy, including 10 patients with radicular pain. The duration between onset of myelopathic symptoms to final diagnose ranged from 2 to 48 months, with a mean time of 19 months. Ambulation was impaired in all 15 patients, with 4 patients (27 %) unable to ambulate, and 11 patients (73 %) requiring the aid of a walker or

cane. Six patients were Frankel grade C, and nine patients were grade D. The mean Japanese Orthopedic Association (JOA) score was 4.87 ± 0.92 (range 4–6).

Evidence of at least partial calcification on radiographs, CT, or MRI was present in 16 of 17 discs. Nine of the 15 calcified giant discs (60 %) were paracentral in location, while the other six discs (40 %) located centrally (Table 1). There was no obvious intradural penetration found in this series, while 4 discs were adhered to dura mater, with one combined with dura calcifications.

The mean operative time was 179 ± 27 min (range 140–210 min). The average estimated blood loss was 840 ± 470 ml (range 300–2,000 ml). We encountered no dural tears or cerebrospinal fluid (CSF) leaks in any patients. No postoperative neurological deterioration was noted in any patient.

Follow-up was obtained in all the 15 patients, with a mean follow-up duration of 45 ± 24 months (range 7–77 months). Nine patients (60 %) improved by one Frankel grade postoperatively, while six patients (40 %) remained stable (Table 2). At the last follow-up, there were three patients (20 %) without improvement in Frankel grade; however, they were satisfied with the results of the operations as no further neurological deterioration had occurred and they experienced relief of their back pain. In all patients the total JOA score increased after surgery, with the mean total JOA score increasing from 4.87 ± 0.92 (range 3–6) preoperatively to 7.67 ± 1.59 (range 5–10) postoperatively (Table 3). The mean recovery rate for lower limb motor function was 45.47 ± 32.92 % (range 0–100 %), for sensory function was 45.53 ± 31.22 % (range 0–100 %), and for bladder function 55 ± 43.48 % (range 0–100 %). The mean recovery rate for the total JOA score was 46.8 ± 21.41 % (range 14–83 %). The overall results were excellent in two patients, good in six, fair in five, and unchanged in two. No patient was classified as worse.

Serial radiographs were obtained in each case to confirm stability of instrumentation. No measurable change in spinal alignment was noted between the preoperative and final postoperative status. None of the patients showed any signs of instrument migration or failure during follow-up.

Eleven of the 15 patients had an uncomplicated postoperative course. Postoperatively, one patient developed pneumonia, one had a cardiac event, and two complained of pain at the site of the skin incision. The patient with pneumonia recovered with conservative treatment. The patient with the cardiac event was transferred to the department of cardiology for further treatment and recovered. One of the patients with pain at the skin incision recovered with conservative treatment, while the other patient required an intercostal nerve block to resolve the pain.

Table 1 Patient data

Case	Age (years)	Gender	Level of HTD	Location of HTD	Calcification/ adhesion of HTD	Neurological impairment	Operative time (min)	Blood loss (ml)	Follow-up (mo)
1	45	M	T11/12	Central	Dense/–	Myelopathy	210	1,300	57
2	40	M	T11/12	Paracentral	Partial/–	Myelopathy, radiculopathy	150	500	7
3	34	M	T9/10	Central	Dense/+ ^b	Myelopathy	160	2,000	21
4	49	F	T7/8	Paracentral	Dense/+	Myelopathy, radiculopathy	160	300	8
5	61	M	T11/12	Paracentral	Partial/–	Myelopathy, radiculopathy	180	1,000	77
6	39	M	T12/L1	Paracentral	Dense/–	Myelopathy, radiculopathy	180	400	33
7	42	M	T11/12/L1 ^a	Paracentral	Dense/+	Myelopathy, radiculopathy	200	1,500	54
8	48	F	T11/12	Central	Dense/–	Myelopathy, radiculopathy	210	800	71
9	52	M	T6/7	Paracentral	Dense/–	Myelopathy	240	1,100	55
10	33	M	T7/8	Central	Dense/–	Myelopathy	170	700	38
11	35	M	T11/12	Central	Dense/–	Myelopathy, radiculopathy	180	500	51
12	60	F	T10/11	Paracentral	Dense/–	Myelopathy, radiculopathy	150	800	52
13	59	M	T11/12	Central	Dense/–	Myelopathy	160	400	77
14	51	F	T11/12	Paracentral	Dense/–	Myelopathy, radiculopathy	140	600	11
15	50	M	T11/12/L1 ^a	Paracentral	Dense/+	Myelopathy, radiculopathy	190	700	66
Mean	46 ± 9	–	–	–	–	–	179 ± 27	840 ± 470	45 ± 24

HTD herniated thoracic disc

^a The T11/12 disc is the calcified giant HTD^b The HTD was found adhering to the dura mater, combined with dura calcification

Table 2 Outcomes

Case	Duration of symptoms	Back pain	Complications	Frankel neurological classification		
				Preoperative	Postoperative	Last follow-up
1	2 months	–	–	D	E	E
2	18 months	Relieved	–	D	E	E
3	16 months	–	Pneumonia	C	C	C
4	3 months	No change	Pain of intercostal nerve	C	D	D
5	11 months	Relieved	–	D	D	E
6	24 months	Relieved	–	C	D	D
7	30 months	Relieved	–	D	D	E
8	5 months	Relieved	–	D	D	E
9	12 months	Relieved	–	C	D	D
10	5 months	Relieved	–	D	E	E
11	48 months	Relieved	–	D	D	D
12	3 months	Relieved	–	D	E	E
13	48 months	–	Pain of intercostal nerve ^a	D	E	E
14	40 months	Relieved	–	C	D	D
15	20 months	Relieved	Cardiac accident	C	C	C

^a The patient received an intercostal nerve block

Representative case

Case 10 A 33-year-old male presented with a 5-month history of progressive paralysis of the lower extremities, mid-back pain, and a buzzing sensation along his flank in a band-like distribution. Physical examination revealed the patient could not ambulate by himself. Hyperreflexia in the ankle tendon reflex and decreased sensation below the T-8 distribution with a positive Babinski sign were noted. MRI and CT demonstrated T7/8 disc herniation centrally with spinal cord compression (Fig. 2a, b). The calcified herniated disc occupied almost the entire spinal canal. The patient underwent transthoracic decompression, instrumentation, and fusion with autogenous rib graft. Postoperatively, the patient experienced relief of his symptoms and began to walk by himself on the 7th day postoperatively. His Frankel grade improved from D to E, and the JOA score improved from 6 to 10 with a recovery rate of 80 %. The patient returned to work 6 months after the operation, reporting complete pain relief with no axial back pain. The MRI showed that there was no spinal cord compression (Fig. 2c).

Discussion

Because of the low incidence relative to herniations in the cervical or lumbar spine, the variety of clinical presentations, divergent definitions of what constitutes a symptomatic TDH, and uncertainty of the natural history of this disorder, treatment of THDs remains controversial. The

initial symptoms are often mild and easily confused with other diseases, and thus most patients fail to have timely treatment. When the symptoms become more serious, patients eventually seek treatment; however, the disease is typically at an advanced stage. Definite indications for surgical treatment include myelopathy, intractable radiculopathy, and persistent unbearable axial pain [16, 19, 31].

Due to the poor results of posterior decompression via laminectomy [17, 18, 34], many other approaches have been proposed [2, 5–8, 11, 12, 14, 16, 17, 19, 21–25, 27–29, 32, 33]. The choice of surgical approach is predicated on several factors which include the training and experience of the surgeon, neurological symptoms, localization and consistency of the herniated disc, presence of spinal deformity, and presence of osteophytes [25]. Patient-related factors such as body habitus and other medical comorbidities may also influence the choice of approach.

Of all TDHs, calcified giant HTDs, which are somewhat uncommon, tend to drape and erode the dura mater and are the most challenging. Most of patients suffer from progressive neurological deficits, especially myelopathy. Furthermore, the neurological conditions of the patients with calcified giant HTDs are more likely to worsen, and the severely impaired spinal cord can bear no further disturbance. Therefore, choosing an appropriate safe surgical approach is of great importance for the patients with calcified giant HTDs. Clinical reports have indicated that video-assisted thoracoscopic surgery is not suitable for such disc herniations with significant calcifications. The potential for nerve damage is greater with a thoracoscopic approach, and thus thoracoscopic surgery is not

Table 3 Japanese Orthopedic Association (JOA) scores

Case	JOA scores														
	Lower limb motor function						Sensory function			Bladder function			Total		Final results
	Pre-operative	Post-operative	Recovery rate (%)	Pre-operative	Post-operative	Recovery rate (%)	Pre-operative	Post-operative	Recovery rate (%)	Pre-operative	Post-operative	Recovery rate (%)	Pre-operative	Post-operative	
1	2	4	100	2	3	50	1	2	50	5	9	67			
2	2	3	50	2	4	100	1	3	100	5	10	83			Excellent
3	0	0	0	1	2	33	3	3	–	4	5	14			Unchanged
4	0	2	50	1	3	67	3	3	–	4	8	57			Good
5	1	2	33	1	2	33	2	2	0	4	6	28			Fair
6	1	2	33	2	3	50	2	3	100	5	8	50			Good
7	2	2	0	3	4	100	1	2	50	6	8	40			Fair
8	1	2	33	2	3	50	2	2	0	5	7	33			Fair
9	1	2	33	1	2	33	3	3	–	5	7	33			Fair
10	1	4	100	2	3	50	3	3	–	6	10	80			Excellent
11	1	2	33	2	2	0	2	3	100	5	7	33			Fair
12	1	3	67	2	3	50	3	3	–	6	9	60			Good
13	2	4	100	3	3	0	1	2	50	6	9	60			Good
14	0	1	25	1	3	67	2	3	100	3	7	50			Good
15	0	1	25	2	2	0	2	2	0	4	5	14			Unchanged
Mean	1.00 ± 0.76	2.27 ± 1.16	45.47 ± 32.92	1.80 ± 0.68	2.80 ± 0.68	45.53 ± 31.22	2.07 ± 0.80	2.60 ± 0.51	55.00 ± 43.78	4.87 ± 0.92	7.67 ± 1.59	46.80 ± 21.41			–

Fig. 2 Case 10. A 33-year-old male presented with a 5-month history of progressive paralysis of the lower extremities, mid-back pain, and a buzzing sensation along his flank in a band-like distribution. **a, b** MRI

showed that the calcified herniated disc occupied almost the entire spinal canal. **c** MRI at 6 months postoperatively showed that there was no spinal cord compression

recommended even though it is less traumatic [27]. Jonathan et al. [15] reported the surgical results of 20 patients with giant HTDs, most of which were ossified and concluded that the best approach for giant HTDs is open thoracotomy.

In contrast to the cervical and lumbar canal, the thoracic canal is smaller and more difficult to enter and explore. Of all the surgical approaches, the anterolateral transthoracic approach provides the best exposure allowing for the safest and most complete decompression of the spinal cord despite the potential for pulmonary complications such as pneumothorax, pleura effusion, chylothorax, atelectasis, and prolonged mechanical ventilation [30]. However, because of the complications related to thoracotomy, new forms of posterolateral approaches for the treatment of TDHs are being adopted by surgeons [7, 11, 14, 16, 24, 25, 29, 32], with results for some types of TDHs comparable to those of the transthoracic approach [25]. However, there have been no comparisons between different approaches in the treatment of calcified giant HTDs, which are more complicated and risky, and for this situation most surgeons would choose the transthoracic approach [15, 25, 31].

Because of the solid calcified nature, the herniated discs should be resected as a whole. At the same time, there should be no over-manipulation to the dura mater, for large herniated discs make the spinal cord vulnerable to any disturbance. Furthermore, the decompression should be comprehensive enough for continued spinal cord irrigation. For this reason, we create a trough that is long and wide enough to resect the herniated disc as a whole without over-traction of the dura mater, leaving spacious room for the continued spinal cord irrigation. To ensure an entire decompression, a large space must be created which can damage upper and lower adjacent vertebral bodies in the spine. Though we have no experimental evidence, we believe that this can affect the stability of the spine. For this reason, we use instrumentation and fusion to reconstruct the integrity of the spine.

Calcified giant HTDs may have transdural migration and adherence to the dura mater. Fortunately, no intradural penetration of the discs was present in the patients reported herein. However, four HTDs were found adhering to the dura mater, one of which was combined with dura calcification. In the course of decompression, there was an adequate angle of approach and enough room to dissect the herniated disc from the dura and no neurological compromise of dural tears occurred. Although calcified discs can be left “floating” in the posterolateral approach, which can achieve an indirect decompression without risk of CSF leakage or dural tear [25], the surgical technique and risk are relatively higher. In addition, the “floating” model can also be achieved by the anterolateral approach, as we did for the patient with dura adhesions and calcifications.

Stefaan and Debois [30] reported that the nature of the neurological impairment (myelopathy versus radiculopathy) is a strong predictor for the prognosis of TDHs. Cord damage seems to be more permanent than root injury, with less severe paresis and is more reversible than severe plegia. Almost all patients (95 %) in the study of Jonathan et al. [15] and 100 % of the patients reported herein had myelopathy. Of the 19 patients in Jonathan’s cohort presenting with myelopathy, the status improved in 42 % (an increase of one Frankel grade), stabilized in 42 %, and worsened (decrease of one grade) in 16 % postoperatively. Of patients in whom neurological status improved, the Frankel grade changed from C to D in 16 % and from grade D to E in 37 %. Of the three patients in whom neurological status worsened, two underwent endoscopic and one posterolateral surgery. However, there were no neurological complications associated with open thoracotomy in Jonathan’s cohort, which is consistent with our results. Stefaan and Debois [30] also concluded that patients with longer duration of symptoms had a worse prognosis. In our cohort, patients who had no neurological improvement did appear to have a longer duration of symptoms; however, because of the small sample size a statistical analysis was not performed.

There are limitations to this study that should be considered. These include the retrospective nature of the study and the small number of patients. In addition, spinal cord monitoring was not used; its use would have provided valuable evidence to assess the immediate effect of anterior decompression. Spinal cord monitoring facility was not available on a regular basis in our hospital until 2010. Last, pain scores and Oswestry scores were not used.

Conclusions

Calcified giant HTDs, which may have transdural migration, and adherence to the dura mater are challenging and high-risk surgical lesions. Our results indicate that trans-thoracic decompression combined with reconstruction, fusion, and fixation is an effective method for the treatment of these lesions and is associated with a low rate of complications, morbidity, and neurological impairment.

Conflict of interest None.

References

- Arce CA, Dohrmann GJ (1985) Herniated thoracic disks. *Neurol Clin* 3:383–392
- Bohlman HH, Zdeblick TA (1988) Anterior excision of herniated thoracic discs. *J Bone Joint Surg (Am)* 70:1038–1047
- Börm W, Bazner U, König RW, Kretschmer T, Antoniadis G, Kandenwein J (2011) Surgical treatment of thoracic disc herniations via tailored posterior approaches. *Eur Spine J* 20:1684–1690
- Carson J, Gumpert J, Jefferson A (1971) Diagnosis and treatment of thoracic intervertebral disc protrusions. *J Neurol Neurosurg Psychiatry* 34:68–77
- Cho JY, Lee SH, Jang SH, Lee HY (2012) Oblique paraspinous approach for thoracic disc herniations using tubular retractor with robotic holder: a technical note. *Eur Spine J* 21:2620–2625
- Currier BL, Eismont FJ, Green BA (1994) Transthoracic disc excision and fusion for herniated thoracic discs. *Spine* 19:323–328
- Dzung HD, John T, Shawn BC (2001) Transcostovertebral approach for thoracic disc herniations. *J Neurosurg* 94:38–44
- Fidler MW, Goedhart ZD (1984) Excision of prolapse of thoracic intervertebral disc. A transthoracic technique. *J Bone Joint Surg (Br)* 66:518–522
- Frankel HL, Hancock DO, Hyslop G et al (1962) The value of postural reduction in the initial management of the closed injuries of the spine with paraplegia and tetraplegia. *Paraplegia* 7:179–192
- Fujimura Y, Nishi Y, Nakamura M et al (1997) Long-term follow-up study of anterior decompression and fusion for thoracic myelopathy resulting from ossification of the posterior longitudinal ligament. *Spine* 22:305–311
- Garrido E (1980) Modified costotransversectomy. A surgical approach to ventrally placed lesions in the thoracic spinal canal. *Surg Neurol* 13:109–113
- Gille O, Soderlund C, Razafimahandri HJ, Mangione P, Vital JM (2006) Analysis of hard thoracic herniated discs: review of 18 cases operated by thoracoscopy. *Eur Spine J* 15:537–542
- Hirabayashi K, Watanabe K, Wakano K et al (1983) Expansive-door laminoplasty for cervical stenotic myelopathy. *Spine* 8:693–699
- Jho HD (1997) Endoscopic microscopic transpedicular thoracic discectomy. Technical note. *J Neurosurg* 87:125–129
- Jonathan SH, Iman FE, Kathy K et al (2005) Surgical management of giant herniated thoracic discs: analysis of 20 cases. *J Neurosurg* 3:191–197
- Le Roux PD, Haglund MM, Harris AB (1993) Thoracic disc disease: experience with the transpedicular approach in twenty consecutive patients. *J Neurosurg* 33:58–66
- Logue V (1960) Thoracic intervertebral disc prolapse with spinal cord compression. *J Neurol Neurosurg Psychiatry* 23:133–137
- Love JG, Kiefer EJ (1950) Root pain and paraplegia due to protrusions of thoracic intervertebral disks. *J Neurosurg* 7:62–69
- Maiman DJ, Larson SJ, Luck E et al (1984) Lateral extracavitary approach to the spine for thoracic disc herniation: report of 23 cases. *Neurosurgery* 14:178–182
- McCormick WE, Will SF, Benzel EC (2000) Surgery for thoracic disc disease. Complication avoidance: overview and management. *Neurosurg Focus* 9(4):e13
- Moon SJ, Lee JK, Jang JW, Hur H, Lee JH, Kim SH (2010) The transdural approach for thoracic disc herniations: a technical note. *Eur Spine J* 19:1206–1211
- Otani K, Manzoku S, Shibasaki K et al (1977) The surgical treatment of thoracic and thoracolumbar disc lesions using the anterior approach: report of six cases. *Spine* 2:266–275
- Otani K, Yoshida M, Fujii E et al (1988) Thoracic disc herniation. Surgical treatment in 23 patients. *Spine* 13:1262–1267
- Patterson RH Jr, Arbit E (1978) A surgical approach through the pedicle to protruded thoracic discs. *J Neurosurg* 48:768–772
- Richard B, Fangyi Z, Carlo B et al (2010) Early experience treating thoracic disc herniations using a modified transfacet pedicle-sparing decompression and fusion. *J Neurosurg* 12:221–231
- Ridenour TR, Haddad SF, Hitchon PW et al (1993) Herniated thoracic discs: treatment and outcome. *J Spinal Disord* 6:218–224
- Rosenthal D, Dickman CA (1998) Thoracoscopic microsurgical excision of thoracic discs. *J Neurosurg* 89:224–235
- Russo A, Balamurali G, Nowicki R, Boszczyk BM (2012) Anterior thoracic foraminotomy through mini-thoracotomy for the treatment of giant thoracic disc herniations. *Eur Spine J* 21(Suppl 2):S212–S220
- Simpson JM, Silveri CP, Simeone FA et al (1993) Thoracic disc herniation. Re-evaluation of the posterior approach using a modified costotransversectomy. *Spine* 18:1872–1877
- Stefaan M, Debois V (1998) Thoracic disc herniations: trans-thoracic, lateral, or posterolateral approach? A review. *Surg Neurol* 49:599–608
- Stillerman CB, Chen TC, Couldwell WT et al (1998) Experience in the surgical management of 82 symptomatic herniated thoracic discs and review of the literature. *J Neurosurg* 88:623–633
- Stillerman CB, Chen TC, Day JD et al (1995) The transfacet pedicle-sparing approach for thoracic disc removal: cadaveric morphometric analysis and preliminary clinical experience. *J Neurosurg* 83:971–976
- Sundaresan N, Shah J, Feghali JG (1984) A transsternal approach to the upper thoracic vertebrae. *Am J Surg* 148:473–477
- Tovi D, Strang RR (1960) Thoracic intervertebral disk protrusions. *Acta Chir Scand Suppl* 267:1–41
- Whitcomb DC, Martin SP, Schoen RE et al (1995) Chronic abdominal pain caused by thoracic disc herniation. *Am J Gastroenterol* 90:835–837
- Yonenobu K, Ebara S, Fujiwara K et al (1987) Thoracic myelopathy secondary to ossification of the spinal ligament. *J Neurosurg* 66:511–518