REMOVAL OF THE INTERVERTEBRAL THORACIC DISC HERNIA UNDER INTRAOPERATIVE NEUROMONITORING: CASE SERIES

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Objective. To analyze the results of the removal of thoracic intervertebral disc hernia through posterior surgical approach using intraoperative neuromonitoring.
Material and Methods. A total of 14 patients aged 43–64 years (M = 53.9) were operated on through posterior approach for symptomatic hernia of the thoracic intervertebral discs, with myelopathy (isolated or in combination with radiculopathy) in seven cases, and with isolated radiculopathy in another seven cases. Hernia were ossified in 6 cases. Operations were performed using intraoperative neuromonitoring. In 11 cases, unilateral or bilateral laminectomy and facetectomy were performed to remove a hernia; in three cases - laminectomy with resection of the facet joints and pedicles (in two of them, with ossified large and giant hernias, radiculotomy was performed to mobilize the dural sac).
Results. The long-term clinical results of surgical interventions were evaluated 1–4 years after the surgery using VAS-10, ODI, and Frankel scales. VAS scores decreased by 2–6 points In 11 patients, and remained at the same low level characterized by mild pain (1–2 points) in three patients. In patients with myelopathy, the Frankel scale showed a positive trend in six out of seven cases. Two patients showed an increase in neurological deficit in the postoperative period. In one case, neurological disorders regressed within a short period of time, in the other one, they became permanent. Damage to the dura mater was observed in two cases.
Conclusion. Intraoperative neuromonitoring allows the surgeon to act more actively and confidently in the area of disco-medullar conflict and thereby avoid excessive expansion of surgical approach without compromising the surgical result. A small number of observations does not allow making evidence-based conclusion.
Key Words: intervertebral disc herniation, posterior surgical approach, intraoperative neuromonitoring.
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Thoracic disc herniation accounts for no more than 5% of all symptomatic disc herniations [1]. Despite relative rarity of this pathology, the problem of thoracic disc herniation surgery has attracted attention of orthopedists and neurosurgeons. In particular, the choice of optimal surgical techniques, which are in detail described in the literature [2–5], has been a matter of debate. Various anterior, posterior, and posterolateral surgical approaches as well as minimally invasive microsurgical and endoscopic technologies have been developed and used, but none of them has become the gold standard [6]. The choice of an approach is based not only on the structure and localization of disc herniation but also on the neurosurgeon's skills and preferences. One of the serious complications of thoracic disc herniation surgery is injury to the spinal cord with development of serious neurological disorders. In this regard, it seems reasonable to use intraoperative neuromonitoring for assessing the spinal cord condition and for expanding technical capabilities of discectomy, in particular through a posterior approach.

The study objective was to analyze the technical capabilities and results of thoracic disc herniation removal through a posterior surgical approach under intraoperative neuromonitoring control.

Design: a retrospective descriptive study.

Material and Methods

We analyzed the results of surgical treatment of 14 patients with single level symptomatic thoracic disc herniation, who were operated on through a posterior approach. There were 5 males and 9 females aged from 43 to 64 years (M = 53.9).

The inclusion criteria and indications for surgery were as follows: isolated and combined myelopathy and radiculopathy syndromes caused by thoracic disc herniations verified by neuroimaging techniques.

Disc herniations were located in the lower thoracic spine in most cases and at the T1–T2 level only in one case. We classified disc herniations into soft and ossified ones, based on their morphological features, and into median/paramedian and lateral ones, based on their location in the spinal canal (Table 1). Preoperative investigation included clinical and neurological examination, MRI, and SCT.

Surgical technique. A linear incision of soft tissues was made along the spinous process line, one segment above and one segment below the intended level of discectomy. Laminaes, interlaminar spaces, and facet joints were exposed. When accessing the disc, we tried to minimize invasiveness of the approach and the amount of resection of the posterior support complex structures. In all cases, the intervertebral disc was accessed through unilateral or bilateral, partial or complete resection of the laminae and articular processes. The bone structures were resected as much as necessary to expose the disc portion not covered with the dural sac; we started disc herniation removal from this site, trying to minimize contact with the spinal cord. A unilateral approach was used for small and medium lateral disc herniations (15–25 % of the transverse spinal canal size) with soft consistency or partial calcification. A 61-year-old female patient 1 with small lateral disc herniation combined with degenerative spinal canal stenosis associated with degenerative spondyloarthrosis underwent bilateral resection of the facet joints and lamina of the T10 vertebra for decompression purpose. We used a bilateral approach for median disc herniations, including large and giant ossified lesions.

Removal of large and giant ossified disc herniations was most technically difficult because attempts to displace the dural sac spread over disc herniation and fixed by a stretched spinal root would inevitably lead to injury to the spinal cord. In two such cases (patients 12 and 13), we used, along with laminectomy and facetectomy, resection of the pedicles restricting the space for the dural sac as well as transection of the spinal nerve root. Radiculotomy and pedicle resection greatly facilitated mobilization of the dural sac, which enabled displacement of the sac to expose lateral portions of disc herniation, i.e. within the space ensuring herniation removal.

Given the risk of injury to the Adamkiewicz artery and displacement of the dural sac for accessing disc herniation, the spinal root was transected under neuromonitoring control. Before radiculotomy, we recorded evoked muscle responses caused by compression of the root with a swab and placement of a temporary ligature on it. If the muscle potential amplitude did not decrease, the root was ligated and transected close to the dural sac, proximal to the sensory spinal ganglion. Disc herniation was removed starting with its lateral portions, gradually going in the medial direction through the space between the dural sac squeezed by disc herniation and the posterior surface of the vertebrae. The main surgical stages were performed using a surgical microscope or binocular loupes.

In all cases, surgery, including exposure and removal of disc herniation, was accompanied by monitoring of the corticospinal tract function (transcranial electrical stimulation of the motor cortex). Cadwell Cascade Elite (USA) and ISIS Inomed (Germany) systems were used for neurophysiological monitoring. Stimulating electrodes were mounted on the head at points C3 and C4 (10–20 system), and recording electrodes were placed on *m. abductor pollicis brevis* (C5–T1), *m. quadriceps femoris* (L2–L4), *m. tibialis anterior* et gastrocnemius (L5–S1), and *m. abductor hallucis* (S1–S2). Stimulation was performed with a series of 5–9 pulses at a frequency of 500 Hz and a voltage of 200 to 800 V. Evoked muscle responses (EMRs) were recorded bilaterally from all target muscles before the start of surgery (before skin incision), during the main surgical stage, and before closure of the surgical wound. EMRs were recorded on a monitor with visual assessment by a neurophysiologist every 2–10 min, depending on the course of surgery and situation in the wound. If a significant (more than 50 % of the baseline value) decrease in the EMR amplitude was detected, surgical manipulations were stopped, and registration was repeated after a 10–15-minute pause. Further manipulations in the wound were performed under neuromonitoring control, but more delicately, limiting contact with the dural sac.

The surgical treatment outcomes were assessed 1–4 years after surgery, based on the pain intensity (VAS-10), Oswestry index (ODI), and neurological disorders (Frankel scale).

Results

The clinical outcomes of surgical treatment are presented in Table 2. In 11 patients, VAS scores decreased by 2–6 points; in 3 patients, VAS scores remained at a low baseline level of 1 or 2 points (mild pain). All operated patients had an improvement in the ODI; however, the differences between the preoperative and postoperative parameters varied widely, from minor 2 % to pronounced 64 %. These differences were more noticeable in patients with radicular pain and, accordingly, with high preoperative VAS and ODI values, which decreased after elimination of a disco-radicular conflict. Six of seven patients with myelopathy had one-grade improvement (C–D and D–E) on the Frankel scale, and one patient had one-grade worsening (D–C).

In one case (female patient 1), small lateral soft disc herniation at T10–T11 combined with degenerative spinal canal stenosis required decompressive laminectomy and facetectomy. Clinically, before surgery, there was lower central paraparesis: Frankel grade D, VAS score of 2, and ODI of 36 %. Immediately after laminectomy and facetectomy, there was a decrease in the EMR amplitude to 50–60 % of the baseline level. It should be noted that this decrease occurred before disc herniation removal and remained unchanged until the end of surgery. This effect suggested that the causes for the EMR amplitude decrease were insufficiently delicate laminectomy and facetectomy. Removal of the disc herniation, given its lateral location, was

Table 1

Characterization of patients included in the study

Patient	Gender	Age, years	Herniation level	Clinical syndrome	Disease duration, months	Herniation location	Ossification	Surgical approach	Herniation size*
1	F	61	T10–T11	Myelopathy	>60	Lateral	–	Bilateral transfacet	Small
2	F	50	T10–T11	Myelopathy	8	Lateral	–	Unilateral transfacet	Medium
3	M	60	T1–T2	Radiculopathy	>36	Lateral	–	Unilateral transfacet	Medium
4	F	50	T10–T11	Radiculopathy	>36	Paramedian	–	Unilateral transfacet	Medium
5	F	59	T4–T5	Radiculopathy	6	Lateral	+	Unilateral transfacet	Medium
6	M	48	T9–T10	Radiculopathy	12	Lateral	+	Unilateral transfacet	Medium
7	M	51	T7–T8	Radiculopathy	9	Lateral	+	Unilateral transfacet	Medium
8	M	63	T11–T12	Myelopathy	24	Lateral	–	Unilateral transfacet	Medium
9	F	63	T8–T9	Myeloradiculopathy	5	Lateral	–	Unilateral transfacet	Medium
10	F	50	T9–T10	Myelopathy	24	Paramedian	+	Unilateral transfacet	Small
11	F	64	T6–T7	Radiculopathy	24	Lateral	–	Unilateral transfacet	Medium
12	F	46	T9–T10	Radiculopathy	6	Central	+	Bilateral transfacet with pedicle resection and radiculotomy	Giant
13	M	47	T9–T10	Myeloradiculopathy	12	Lateral	+	Bilateral transfacet with pedicle resection and radiculotomy	Large
14	F	43	T12–L1	Myeloradiculopathy	10	Lateral	–	Bilateral transfacet with pedicle resection	Large

* Small, medium, large, and giant disc herniation of up to 15 %, 25 %, 40 %, and over 40 % of the transverse spinal canal size, respectively.

started from the lateral portions of the disc, with minimal impact on the dural sac. After surgery, aggravation of lower central paraparesis was observed. At a follow-up examination, the patient presented with a VAS score of 2, an ODI of 32 %, and Frankel grade C.

Below, we describe clinical cases of surgery for giant (patient 12) and large (patient 13) ossified disc herniations at T9–T10.

Case 1. A 46-year-old female patient 12 presented to the department with complaints of intense thoracic spine pain radiating to the left half of the chest. The pain developed 6 months ago and significantly increased by the time of admission to the department. Conservative treatment failed. Neurological status: strength in the lower extremities was sufficient; the tone was not changed. The knee reflexes were brisk, S > D; the Achilles reflexes were moderately brisk, D = S. There were no sensory disorders and pelvic dysfunctions. SCT revealed a giant ossified disc herniation at T9–T10. Before surgery, the pain intensity was scored 10 (VAS); ODI was 96 %; Frankel grade E.

Diagnosis: degenerative disc disease of the thoracic and lumbar spine, a giant ossified disc herniation at T9–T10, discogenic radiculopathy, and thoracalgia on the left. Surgery: laminectomy, bilateral facetectomy at T9, resection of the T10 pedicles, radiculotomy of the T10 on the left, removal of the disc herniation at T9–T10, transpedicular fixation at T8–T9–T11–T12, and T9 and T10 laminectomy.

Severe anterior compression of the dural sac at the T9–T10 level was revealed. The left T10 pedicle was resected to improve access to the intervertebral disc. A delicate attempt to displace the dural sac from left to right failed. To mobilize the dural sac, the left T10 root was ligated and transected 7 mm from the dural sac under neuromonitoring control. Before transecting, the root was tested by its compression and temporary ligation; no changes in the muscle response amplitude were observed. Adhesions between the dura mater and the ossified disc herniation were resected. The right pedicle was resected; the dural sac was effortlessly displaced to the right until the disc herniation was exposed. After the displacement, the muscle response amplitude decreased to 60 % of the baseline value. Surgical manipulations were discontinued; EMR parameters recovered after a 15-minute pause.

A gradual displacement of the dural sac but within a smaller range, only until the lateral disc herniation was exposed, did not affect EMRs, which enabled removal of the disc herniation. The disc herniation was removed by fragments, from the lateral portions towards the medial ones. During resection of the adhesions between the disc herniation and the dural sac and removal of the disc herniation, short-term CSF leakage from the ventral surface of the dural sac was noted. No dura mater defect was visually detected. Hemostatic material treated with glue was placed on the ventral surface of the dural sac. CSF did not enter the wound. Placement of transpedicular instrumentation was completed. During surgery, the muscle response amplitude was at the baseline level. Because of intraoperative CSF leakage, a tubular drain was placed in the wound, which was connected to a system for active drainage of the wound. On the 2nd postoperative day, an additional lumbar CSF drain was placed due to a suspicion of CSF presence in discharge from the wound drain. After another day, there was no discharge in the wound drain, and the drain was removed. The wound healed by primary intention; on the 9th day after surgery, the sutures and lumbar drain were removed.

After surgery, there was urinary retention for one day and a slight decrease in strength in the left lower extremity to 4 points, which completely regressed in the postoperative period. There were no other neurological disorders. At the follow-up examination after 4 years, the patient had no complaints. There were no neurological symptoms; strength in the left lower extremity fully recovered to 5 points. The indicators were as follows: a VAS score of 4, an ODI of 32%, and Frankel grade E.

Figure 1 shows CT scans of the thoracic spine before and after surgery.

Case 2. A 47-year-old male patient 13 presented to the department with complaints of numbness in the left half of the trunk below the left hypochondrium as well as weakness and burning in the right lower extremity. The disease developed about a year ago and gradually worsened. Conservative treatment for vertebrogenic myelopathy failed. Neurological status: reduced strength in all muscle groups of the left lower extremity to 4 points; increased pyramidal tone in the left lower extremity. There were no abdominal reflexes on the left. The knee and Achilles reflexes were high, S > D. There was tactile hypesthesia on the left, from the T10 level to the end, as well as a decrease in temperature sensitivity at the L4–S1 level on the right. There were clonus-like movements of the left foot and patella. Positive Babinski symptom on the left. No pelvic dysfunctions were detected. Preoperative indicators were as follows: a VAS score of 7, an ODI of 86 %, and Frankel grade D.

Diagnosis: degenerative disc disease of the thoracic spine, ossified disc herniation at T9–T10 on the left, vertebrogenic compressive-ischemic thoracic myeloradiculopathy, and lower left-sided central monoparesis.

Surgery included T9 and T10 laminectomy, resection of the cranial portion of the left T10 pedicle, spinal cord decompression, and transpedicular fixation at T8–T9–T11–T12.

A linear incision of soft tissue was made along the T7–T12 spinous pro-

Table 2

Preoperative and postoperative VAS-10, ODI, and Frankel values

Patient	VAS-10 score		ODI, %		Frankel grade	
	before surgery	after surgery	before surgery	after surgery	before surgery	after surgery
1	2	2	36	32	D	C
2	3	1	18	12	C	D
3	3	2	54	14	E	E
4	2	2	10	8	E	E
5	4	2	24	22	E	E
6	2	0	26	12	E	E
7	6	3	56	10	E	E
8	1	1	8	6	C	D
9	5	1	44	12	D	E
10	5	1	52	18	D	E
11	6	1	62	14	E	E
12	10	4	96	32	E	E
13	7	4	86	22	D	E
14	8	4	82	34	C	D

cess line. The T8–T9–T11–T12 laminae and interlaminar spaces were exposed on both sides. T9 and T10 laminectomy and resection of the cranial portion of the left T10 pedicle were performed. To facilitate dural sac mobilization, the left T10 root was ligated and transected. Before transecting, the root was tested by its compression and temporary ligation; no changes in the muscle response amplitude were observed. The dural sac was displaced to the right under neuromonitoring control. After displacement, a decrease in the muscle response amplitude to 50–60 % of the baseline value occurred. Surgical manipulations were stopped; EMR parameters recovered after a 15-minute pause. Fragmentary removal of the disc herniation was started from the lateral portions. Transpedicular instrumentation was applied. A tubular drain was placed. The wound was closed in layers.

In the postoperative period, there was no worsening of neurological symptoms. The wound healed by primary intention. There were no complaints at the follow-up examination after 4 years. In the neurological status, there remained impaired tactile sensitivity from the T10 on the left. Strength in the lower extremity recovered. VAS – 4; ODI – 22%; Frankel grade E. SCT scans of the thoracic spine before and after removal of the disc herniation are shown in Figure 2.

Complications. In the postoperative period, neurological deficit worsening occurred in two cases. In female patient 12, who underwent removal of the giant ossified disc herniation at T9–T10, pedicle resection, and radiculotomy, there was short reflex urinary retention and mild paresis in the lower extremity on the intervention side after surgery, which regressed completely in the postoperative period. Female patient 1, who underwent decompressive laminectomy and removal of the disc herniation at T10–T11 using a transfacet approach, had worsening of lower extremity paresis (from Frankel grade D to grade C). In both cases, intraoperative neuromonitoring revealed a significant (over 50 % of the baseline value) decrease in the EMR amplitude: in patient 12, it was reversible and caused by a significant displacement of the dural sac, followed by recovery to the baseline level upon more delicate manipulations; in patient 1, it remained until the end of surgery.

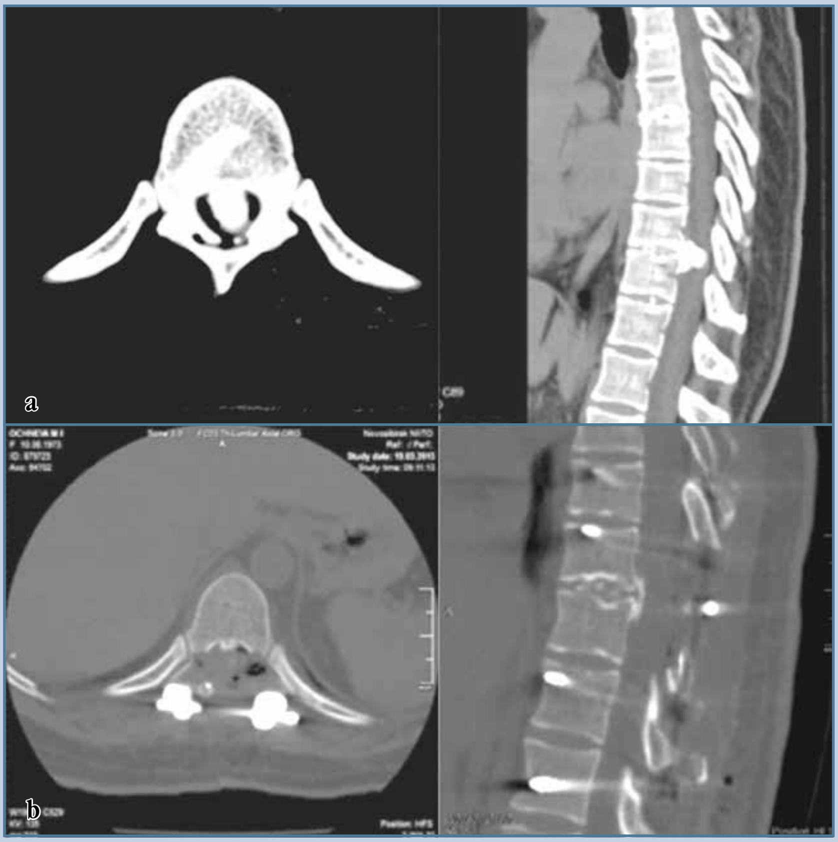

Fig. 1
SCT scans of the thoracic spine of a 46-year-old female patient 12: giant median ossified disc herniation at T9–T10 before surgery **(a)** and after disc herniation removal **(b)**

In two cases, exposure of the disc herniation resulted in dura mater injury, which was sealed with hemostatic sponge and medical glue. There was no CSF leakage in the postoperative period; the wounds healed by primary intention.

Discussion

Until the 1960s, laminectomy, which has a bad reputation due to a large number of neurological complications, was the only posterior approach for removal of thoracic disc herniations. Currently, the main approaches used for thoracic disc herniation removal are posterolateral (transpedicular and transfacet), lateral (costotransversectomy), and anterior (transpleural thoracotomy, thoracoscopy, and retropleural mini-thoracoscopy) ones. Anterior transthoracic approaches provide a good view of the ventral portions of the dural sac and the opportunity to effectively remove disc herniations, including large ossified ones located medially. But compared to the posterior approaches, the anterior approaches are more traumatic and associated with serious pulmonary complications, formation of CSF-pleural fistulas upon injury to the dura mater, and post-thoracotomy intercostal neuralgia.

Yoshihara et al. [7] compared surgical complications of anterior and other approaches and determined their rate as 26.8 and 9.6 %, respectively. According to Wait et al. [8], the rate of complications associated with thoracotomy and thoracoscopy was 34.4 and 16.7 %, respectively. Transthoracic approaches, in particular upon exposure of ossified disc herniations, are often accompanied by dura mater injury with subsequent formation of CSF fistulas, which requires pleural drainage or re-operation [9, 10]. According to Moran et al. [10], removal of ossified disc herniations through the transthoracic retropleural approach led to injury to the pleura in 5 of 17 cases; pleural drainage was required in one case, and pleural CSF hygroma formed in another case. Arts et al. reported [11] that out of 56 cases of successful disc herniation removal through the transthoracic mini-approach, there were 10 cases of postoperative pneumonia and pleural effusion, two cases of dura mater injury, and two cases of neurological deficit aggravation.

According to Quint et al. [12], the overall rate of surgical complications of the thoracoscopic approach was 15 %. Similar complications, including pulmonary ones in the case of pleural damage, may accompany cosotransversectomy – a lateral approach that is rarely used now because of its morbidity. The posterior surgical approach is not versatile for removal of herniations of all types and localizations because it is associated with the risk of serious neurological complications. The use of posterior approaches is mainly limited to soft lateral and paramedian disc herniations; however, some modified posterior approaches, in particular removal of disc herniation using an eggshell procedure, enable successful removal of thoracic ossified disc herniations [13].

We used the posterior approach in 14 patients with thoracic disc herniations, including ossified, large, and giant ones. Removal was performed through a unilateral or bilateral transfacet approach, with partial or complete resection of laminae; in the case of large and ossified disc herniations, the approach was extended by pedicle resection and combined with radiculotomy. Intraoperative monitoring with EMR registration was performed at all surgical stages, which should be considered as a necessary option when removing thoracic disc herniations [6, 14].

Court et al. [6] believe that spinal angiography is appropriate for preoperative assessment of the Adamkiewicz artery condition. The Adamkiewicz artery, which supplies blood to the lumbar enlargement, enters together with the spinal root, more often with the left one, the spinal canal at the lower thoracic and upper lumbar level. Injury to the artery entails the development of a gross neurological deficit in the form of lower paraplegia. In our two cases where radiculotomy at the lower thoracic level on the left was performed to remove a giant median ossified disc herniation, it was especially important to take this fact into account. In these cases, before making a decision on radiculotomy, we performed a test with compression and temporary ligation of the root under neuromonitoring control. No changes in EMR parameters were observed, and the roots were transected without any effect on the spinal cord. Radiculotomy enabled mobilization of the dural sac and, after resection of a heterolateral pedicle, its easy displacement as much as necessary for disc herniation removal. During exposure of the disc herniation, neuromonitoring was used to assess the allowable limits of dural sac traction, which were identified when the EMR amplitude decreased to significant values (50–60 % of the baseline level).

In the case of transient changes in the EMR parameters, which disappeared after termination of surgical manipulations, favorable surgical outcomes were observed: in one case, there were no postoperative neurological disorders; in the other, mild paresis developed in the lower extremity on the intervention side, which completely regressed in the postoperative period. In one case, decompressive laminectomy and bilateral resection of the facet joints were used for removal of lateral soft disc

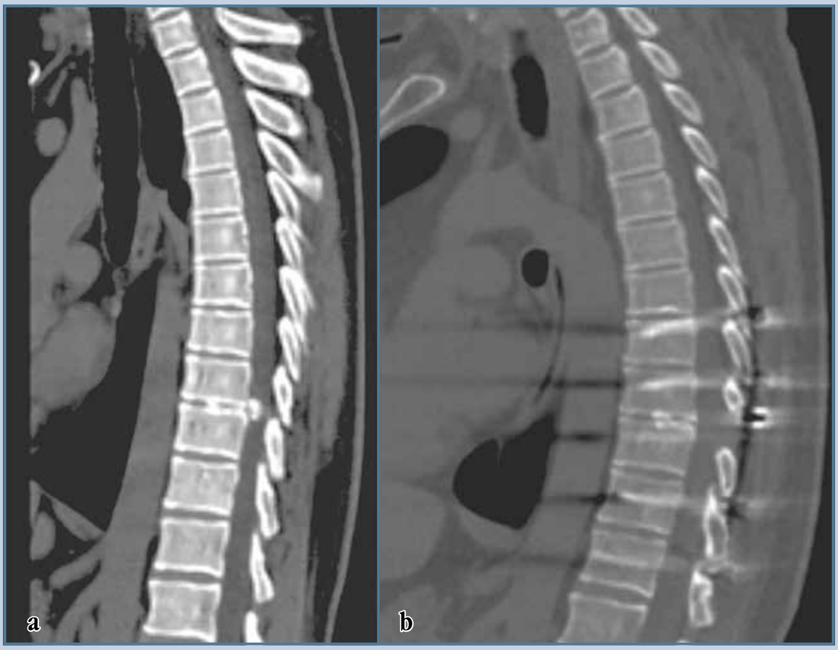

Fig. 2
SCT scans of the thoracic spine of a 47-year-old male patient 13: large lateral ossified disc herniation at T9–T10 before **(a)** and after **(b)** surgery

herniation and decompression of the dural sac due to degenerative stenosis. A decrease in the EMR amplitude of over 50 % occurred immediately after laminectomy, before the start of disc herniation removal, and remained unchanged throughout the operation. It may be supposed that these changes were of angiodiscirculatory origin upon long-existing compression myelopathy or were due to insufficiently delicate manipulations with the spinal cord during resection of the posterior vertebral structures. The disc herniation was removed without technical difficulties and traction of the dural sac; however, there was postoperative aggravation of lower paraparesis, which was present before surgery.

Comparison of the neuromonitoring data with the clinical outcomes of interventions in our series is consistent with the opinion of Kapoor et al. [14] that reversible intraoperative changes in EMR parameters indicate close mechanical contact with the spinal cord, while persistent changes are associated with the development of a neurological deficit. Therefore, worsening of the neurological deficit after our surgical interventions for both soft and ossified thoracic disc herniations was found only in one patient in the late period. Of great importance is the fact that there was no neurological deficit worsening, clinical outcomes were good, and neurological disorders regressed in patients after removal of large and giant disc herniations, including ossified ones. There were no serious surgical complications.

Stabilization of the operated segments was not the subject of our special interest and was performed according to a standard procedure using transpedicular instrumentation in the case of total facetectomy, pedicle resection, and interventions at the T12–L1 thoracolumbar level. The length of fixation was not regulated by any hard rules and was determined by the operating surgeon.

Conclusion

Intraoperative neuromonitoring allows the surgeon to more actively and confidently manipulate in the area of a disc-spinal cord conflict. This enables successful removal, without excessive extension of the posterior surgical approach, of not only soft lateral disc herniations but also large and giant disc herniations, including ossified median ones. However, the small number of cases in the presented series prevents making evidence-based conclusions. Accumulation of clinical material and research in this direction will be continued.

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