Diagnostic approach, therapeutic strategies and surgical indications in Intradural Thoracic Disc Herniation associated with CSF Leak, Intracranial Hypotension and CNS Superficial Siderosis

ABSTRACT

Background and purpose: Intradural disc herniation (IDH) can manifest with radicular or medullary syndrome. In about 15% of cases, IDH may be responsible, through a dural laceration, for a CSF leak, determining spontaneous intracranial hypotension (SIH) and CNS superficial siderosis (CNSss). This paper attempts to present an overview on IDH as the cause for both CSF leak, and subsequent SIH, and CNSss, and to describe a peculiar clinical and neuroradiological scenario related to this condition.

Methods: Clinical examination, brain and spinal imaging and lumbar puncture were performed. IDH was treated through a posterior transdural herniectomy via a monolateral laminectomy and the placement of muscle and fibrin glue to repair the anterior dural fistula

Results: A 69-year-old woman was referred to our hospital for slowly progressive gait disturbances and hearing impairment. Brain imaging revealed diffuse bilateral supratentorial and infratentorial superficial siderosis, mostly of the cerebellum, the eighth cranial nerves and the brainstem. Spinal imaging disclosed a posterior disc herniation determining a dural tear at D6-D7. Lumbar puncture revealed low opening pressure and hemorrhagic CSF with siderophages. Herniectomy and dural sealing determined a stabilization of hearing and a significant improvement in both gait and balance.

Conclusions: The diagnostic workup of IDH associated with CNS leak demands whole neuraxis imaging, especially in cases presenting brain radiological signs of CNSss. This may avoid delays in detection and treatment of spinal dural leaks. The different forms of treatment available depend on the type and severity of the clinical picture.

INTRODUCTION

An intradural disc herniation (IDH) consists of a nucleus pulposus fragment of the intervertebral disc violating the dural sheath and penetrating the thecal space. The first report of an IDH was made by Dandy in 1942. [1] IDH has an incidence rate of about 0.27% to 0.33% of all cases of disc herniation, and its incidence peaks in the fifth and sixth decades of life. [2] Approximately 92% of IDHs occur in the lumbar region, most commonly in the L4-L5 segment (55%), followed by L3-L4 segment (16%), and L5-S1 segment (10%). [3] By contrast, less than 5% occur in either the cervical or thoracic segments [4]. The main clinical sign of thoracic IDH is represented by radicular pain. [4] Thoracic IDH may also manifest with walking ataxia or pyramidal tract syndrome, raising the suspect of medullary compression. Other less common signs include axial pain (cervical above T5 level and lumbar below T10 level), scapulalgia for T1–T2 locations, radiating pain in the T1 territory and Bernard Horner's syndrome due to T1 root's sympathetic component compression. IDH may also result in a dural laceration, which, in turn, can promote a CSF leak, whose incidence has been reported to be up to 15%. [5] CSF leak may be easily responsible for spontaneous intracranial hypotension (SIH) and CNS superficial siderosis (CNSss). While SIH mainly manifests primarily with headache, CNSss becomes explicit with hearing and gait impairments. Both SIH and CNSss are also characterized by typical radiological findings.

In this paper, we review the literature concerning thoracic IDH as the cause for both CSF leak, and subsequent SIH, and CNSss. We also present a case exposing the peculiar clinical picture, discussing the possible underlying pathophysiological mechanisms and examining the therapeutic strategies that were implemented.

CASE PRESENTATION

We present the case of a 69-year-old, right-handed, woman who suffered from a 1-year history of slowly progressive gait disturbances and hearing impairment. Neurological examination revealed an ataxic gait and bilateral sensorineural auditory alteration. No previous history of surgery or trauma of

the CNS were present, and no major comorbidities were reported. Therefore, the patient underwent brain magnetic resonance imaging (MRI) (**Fig.1**) which disclosed diffuse bilateral supratentorial and infratentorial superficial siderosis, mostly of the cerebellum, the eighth cranial nerves and the brainstem. Hemosiderin coating was specifically accentuated at the level of the cerebellar folia. This appearance was combined with a prominent and symmetrical secondary degenerative atrophy of the vermis and superior cerebellar peduncles. Spinal MRI and computed tomography (CT) (**Fig.1**) showed an anterior dural detachment with a ventral epidural fluid collection extending from D6-D7 up to D1. There was also an osteoporotic fracture with anterior wedge deformation of the D6 and D7 somae with superimposed posterior marginal-somatic osteophytosis and herniation of disc material with osteocalcific signal that determined a dural tear at D6-D7. Moreover, fibrotic reactive tissue was recognizable at the level of dural defect. Lumbar puncture showed a low opening pressure (3 cm H2O) and hemorrhagic CSF with 40/mm3 red blood cells and siderophages. In October 2021, the case was discussed by a multidisciplinary committee which set the indication for surgical repair of the dural fistula. The patient gave written informed consent for the procedure. The day of surgery, the patient was positioned prone and, under microscopic guidance, a D6-D7 herniectomy through a right hemilaminectomy combined with an intradural approach was performed (**Fig.2**). A muscle patch and fibrin glue were used to seal the ventral dural defect. Histology confirmed degenerative disc material. Postoperative course was uneventful and characterized by early autonomous mobilization. The patient was discharged from our Institute two days after the surgical procedure. She exhibited no signs or symptoms of intracranial hypotension at the time of the discharge and at two months follow-up. In addition, she reported a stabilization of the hearing impairment but also a significant improvement in both gait and balance in the following two months after surgery.

LITERATURE REVIEW

In 2014, Toro et al. described the case of a patient with a four-year history of leg weakness and progressive gait impairment, besides other symptoms such as bilateral hearing loss and urinary

incontinence. T2-weighted brain MRI showed extensive hemosiderin deposits around the brainstem and along the cerebellar folia, while spinal MRI demonstrated a disc herniation at the T8-T9 level, located where a previous dynamic CT myelogram highlighted a ventral dural defect. A surgical dural repair was offered but declined by the patient. [6] Reviewing this case, we believe that in cases of thoracic IDH with progressive myelopathy and/or CNSss, a more invasive treatment is needed through a total microdiscectomy.

In 2018, Wipplinger et al. described a case of CNSss secondary to a thoracic IDH causing CSF leak. Their patient was successfully treated with lateral T6-T8 transpedicular partial corpectomy, as well as diskectomy with decompression and fusion, followed by watertight closure of the CSF leak. No postoperative complications occurred, and, at three months' follow-up, the patient displayed stability of preoperative symptoms, such as mild bilateral hypoacusis and mild difficulty in tandem gait [7].

In 2020, Cornips et al. presented two patients with a thoracic IDH, secondary SIH and, in one of them, CNSss [8]. The first patient, without CNSss, presented with frontal headache, mild cognitive disfunction and gait impairment. Cranial MRI showed bilateral subdural effusions and sagging of the midbrain. On the suspicion of a spinal CSF leak, MRI of the entire neuraxis was also performed, demonstrating a left paramedian thoracic IDH at the T9-T10 level. After refractoriness to both thoracic and lumbar EBP, a left-sided thoracoscopic microdiscectomy was performed, resulting in clinical improvement [8]. The second patient, with CNSss, presented with a two-year history of pain in the occipital region. Cranial MRI indicated subarachnoid susceptibility artifacts, particularly in the posterior fossa. As both history and MR angiography were not indicative for subarachnoid bleeding, a diagnosis of CNSss was formulated. Spinal MRI revealed a large central thoracic IDH at the T7-T8 level. Hence, a left-sided tubular microscopic discectomy was performed. A few days after surgery, the patient became dyspneic and a CT-thorax demonstrated a large fluid collection in the left hemithorax, thus posing an indication for an external lumbar drainage, which allowed significant improvement of the clinical picture [8]. In our opinion, in the presence of a thoracic IDH with symptomatic SIH and CNSss, the conservative EBP does not represent the most effective therapeutic

strategy. At the same time, in the presence of mild SIH and/or CNSss symptoms, a thoracoscopic approach for microdiscectomy represents a far too invasive procedure.

DISCUSSION

The migration of a disc into the intradural region requires perforation of the annulus fibrosus, and then the laceration of both the posterior longitudinal ligament and the dura mater. Various predisposing anatomical factors have been proposed, of which the most relevant one is the presence of adhesions between the annulus fibrosus, the posterior longitudinal ligament and the dura mater. These adhesions are likely to be congenitally present or occur secondary to chronic disc protrusion [9]. In this regard, over the long term, a herniated disc does not represent an inert tissue, but rather an active area of proliferation, neovascularisation, and inflammation. The inflammatory response (expressed by the production of proinflammatory cytokines) leads to calcification of the disc, which, in turn, causes intradural erosion, and subsequently, tears [10]. Lesions of the dura mater, in turn, may lead to SIH [11]. CSF leak is also associated with CNSss [12, 13], a rare disorder characterized by the deposition of hemosiderin in the leptomeninges and the subpial layer of the cerebellum, VIII cranial nerve, brainstem and spinal cord, resulting in severe neurological deficits, such as ataxia and hearing impairment [14].

MRI yields pathognomonic findings, which may be revealed in the pre-symptomatic phase of the disease. They result from the deposits of hemosiderin, ferritin and ionic iron. In gradient-echo T2-weighted images, the hallmark is a dark band surrounding the intracranial structures, such as the cerebellar hemispheres and the VIII cranial nerve, while other cranial nerves are less frequently affected. Following gadolinium administration, the leptomeninges are enhanced. On the other hand, CT imaging is not sufficient for the diagnosis of CNSss [15].

The main differential diagnosis of CNSss are neoplasms (21%), cranial or spine trauma (13%), and vascular malformations (9%), neurosurgical procedures, (7%), brachial plexus injury (6%), and cerebral amyloid angiopathy (3%). Nevertheless, most cases remain idiopathic (35%) [16].

The association between CSF leak and CNSss has been explained by two theories. The first theory states that brain sagging due to intracranial hypotension may lead to bleeding from bridging veins on the surface of the cerebellum [17]. While the second theory affirms that the bleeding source may be localised around the dural defect [13, 18, 19]. In fact, regarding the latter theory, when CSF leaks through a dural defect, the epidural space enlarges, stretching the epidural venous plexus and making it more prone to laceration. Therefore, when bleeding from this plexus occurs, it may not stop spontaneously because of CSF's continuous flow. This, in turn, can lead to subarachnoid bleeding.

Preoperative imaging-based diagnosis of thoracic IDH is challenging. Considering the literature [20-30], in only a few cases the presence of thoracic IDH was suspected following preoperative investigation with CT myelography. In our case, preoperative diagnosis through spine MRI was possible by understanding the underlying pathophysiological mechanism that binds CNSss, SIH and IDH. However, when preoperative imaging-based diagnosis of IDH is non-discerning, an alternative route must be undertaken and therefore diagnostic workup for SIH should be implemented. SIH can be identified through neuroradiological exams such as brain MRI. Through brain MRI, five typical features can be identified: subdural fluid collections (50%), diffuse non-nodular enhancement of the pachymeninges (due to dilated blood vessels in the subdural area), engorgement of venous structures, pituitary hyperemia, to the point of mimicking a pituitary tumor [31] and sagging of the brain [32]. Both the dural enhancement and pituitary enlargement are consistent with the Monro–Kellie doctrine: in the presence of a significant decline in CSF flow, intracranial blood volume must increase to keep the total intracranial volume constant. In line with this theory, subdural hematomas, could be the expression of an underlying CSF leakage and they usually can be managed by treating the spinal CSF leak. [33] In addition to MRI imaging, brain CT scan can suggest the diagnosis by highlighting subdural fluid collections or obliteration of subarachnoid cisterns. [34] Even myelography with iodinated contrast followed by spine CT can accurately define the location of a CSF leak. [35]

Surgical treatment of thoracic IDH is needed in the presence of radicular symptoms, myelopathy clinical and radiological signs (highlighted by a medullary T2 hyperintensity area on spine MRI) and

157 symptomatic SIH. [36] In our case, symptoms were ascribed to CNSss, thus posing a new and rare
158 surgical indication in the case of an IDH. Three types of surgical approaches are now used in the
159 treatment of thoracic IDH: 1) posterolateral with pedicular-transfacet and transfacet variations that
160 spare the pedicle; 2) lateral such as costotransversectomy; 3) anterior such as transpleural
161 thoracotomy, thoracoscopy and mini-thoracotomy. The choice of approach depends on patient's
162 characteristics (weight) and on the location (central or lateral), size and type (soft or calcified) of
163 herniation. On the other hand, treatment of SIH begins with conservative management, including bed
164 rest, intravenous administration of fluids and steroids. If the patient fails to respond to medical
165 therapy, epidural blood patch (EBP) is adopted [37], either by percutaneous or open surgical
166 approaches. The mechanism of action of EBP is based on its initial tamponade effect over the dural
167 tear and subsequent scar formation. [38]
168 In our case, the clinical picture was mainly ascribed to CNSss, which, undoubtedly, set the indication
169 to invasive treatment as to resolve both the CSF fistula and the SIH. Given the absence of myelopathy
170 and significant SIH symptoms, our surgical strategy was primarily based solely on repairing the
171 ventral dural defect to handle the progression of frank CNSss. Therefore, we proceeded with a
172 posterior transdural herniectomy through a monolateral laminectomy and the placement of muscle
173 and fibrin glue to repair the anterior dural fistula, rather than performing a more invasive total
174 microdiscectomy.
175
176 **CONCLUSIONS**
177 In the case of thoracic IDH associated with suspected CSF leak, diagnostic workup should include
178 MRI of the whole spine, particularly in patients having radiological signs of CNSss. This may avoid
179 delays in detection and treatment of spinal dural CSF leaks. With no apparent myelopathy, a less
180 demolitive surgery is recommended, proceeding with the repair of the fistula with sealants and the
181 excision of the intradural herniated disc material.
182

REFERENCES

1. Dandy WE. Serious complications of ruptured intervertebral disks (1942). JAMA. 119(6):474–477. doi:10.1001/jama.1942.02830230008002
2. Kataoka, O., Nishibayashi, Y., & Sho, T. (1989). Intradural lumbar disc herniation. Report of three cases with a review of the literature. Spine, 14(5), 529–533.
3. Baudracco, I., Grahovac, G., & Russo, V. M. (2017). Spontaneous cervical intradural disc herniation presenting with Brown-Séquard and Horner's syndrome: lesson learned from a very unique case. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 26(Suppl 1), 218–221. https://doi.org/10.1007/s00586-017-5044-4
4. Guan, Q., Xing, F., Long, Y., & Xiang, Z. (2018). Cervical intradural disc herniation: A systematic review. Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia, 48, 1–6. https://doi.org/10.1016/j.jocn.2017.10.024
5. Bouthors, C., Benzakour, A., & Court, C. (2019). Surgical treatment of thoracic disc herniation: an overview. International orthopaedics, 43(4), 807–816. https://doi.org/10.1007/s00264-018-4224-0
6. Toro, J., Díaz, C., Reyes, S., Jeanneret, V., & Burbano, L. E. (2014). Superficial siderosis related to a thoracic disc herniation with associated dural injury. CNS neuroscience & therapeutics, 20(5), 469–472. https://doi.org/10.1111/cns.12253
7. Wipplinger, C., Simian, A., Hernandez, R. N., Navarro-Ramirez, R., Kim, E., Kirnaz, S., Schmidt, F. A., Fink, M. E., & Härtl, R. (2018). Superficial Siderosis of Central Nervous System as Primary Clinical Manifestation Secondary to Intradural Thoracic Disk Herniation. World neurosurgery, 119, 40–44. https://doi.org/10.1016/j.wneu.2018.07.117
8. Cornips, E., Grouls, M., & Bekelaar, K. (2020). Transdural Thoracic Disk Herniation with Longitudinal Slitlike Dural Defect Causing Intracranial Hypotension: Report of 2 Cases. World neurosurgery, 140, e311–e319. https://doi.org/10.1016/j.wneu.2020.05.077

9. Guan, Q., Xing, F., Long, Y., & Xiang, Z. (2018). Cervical intradural disc herniation: A systematic review. Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia, 48, 1–6. https://doi.org/10.1016/j.jocn.2017.10.024
10. Cosamalón-Gan, I., Cosamalón-Gan, T., Mattos-Piaggio, G., Villar-Suárez, V., García-Cosamalón, J., & Vega-Álvarez, J. A. (2021). Inflammation in the intervertebral disc herniation. Inflamación en la hernia del disco intervertebral. Neurocirugia (English Edition), 32(1), 21–35. https://doi.org/10.1016/j.neucir.2020.01.001
11. Headache Classification Subcommittee of the International Headache Society (2004). The International Classification of Headache Disorders: 2nd edition. Cephalalgia : an international journal of headache, 24 Suppl 1, 9–160. https://doi.org/10.1111/j.1468-2982.2003.00824.x
12. Hoxworth, J. M., Patel, A. C., Bosch, E. P., & Nelson, K. D. (2009). Localization of a rapid CSF leak with digital subtraction myelography. AJNR. American journal of neuroradiology, 30(3), 516–519. https://doi.org/10.3174/ajnr.A1294
13. Kumar N. (2012). Beyond superficial siderosis: introducing "duropathies". Neurology, 78(24), 1992–1999. https://doi.org/10.1212/WNL.0b013e318259e272
14. Kumar, N., Cohen-Gadol, A. A., Wright, R. A., Miller, G. M., Piepgras, D. G., & Ahlskog, J. E. (2006). Superficial siderosis. Neurology, 66(8), 1144–1152. https://doi.org/10.1212/01.wnl.0000208510.76323.5b
15. Miliaras, G., Bostantjopoulou, S., Argyropoulou, M., Kyritsis, A., & Polyzoidis, K. (2006). Superficial siderosis of the CNS: report of three cases and review of the literature. Clinical neurology and neurosurgery, 108(5), 499–502. https://doi.org/10.1016/j.clineuro.2005.01.014
16. Levy, M., Turtzo, C., & Llinas, R. H. (2007). Superficial siderosis: a case report and review of the literature. Nature clinical practice. Neurology, 3(1), 54–59. https://doi.org/10.1038/ncpneuro0356
17. Schievink, W. I., Maya, M. M., & Nuño, M. (2011). Chronic cerebellar hemorrhage in spontaneous intracranial hypotension: association with ventral spinal cerebrospinal fluid leaks:

clinical article. Journal of neurosurgery. Spine, 15(4), 433–440. https://doi.org/10.3171/2011.5.SPINE10890

18. Schievink, W. I., Wasserstein, P., & Maya, M. M. (2016). Intraspinal hemorrhage in spontaneous intracranial hypotension: link to superficial siderosis? Report of 2 cases. Journal of neurosurgery. Spine, 24(3), 454–456. https://doi.org/10.3171/2015.6.SPINE15428
19. Yokosuka, J., Takai, K., Komori, T., & Taniguchi, M. (2014). Superficial siderosis: bleeding from the bone marrow after laminectomy for spinal tumor removal. Journal of neurosurgery. Spine, 21(6), 905–908. https://doi.org/10.3171/2014.8.SPINE13328
20. Epstein, N. E., Syrquin, M. S., Epstein, J. A., & Decker, R. E. (1990). Intradural disc herniations in the cervical, thoracic, and lumbar spine: report of three cases and review of the literature. Journal of spinal disorders, 3(4), 396–403.
21. Stone, J. L., Lichtor, T., & Banerjee, S. (1994). Intradural thoracic disc herniation. Spine, 19(11), 1281–1284. https://doi.org/10.1097/00007632-199405310-00016
22. Hamilton, M. G., & Thomas, H. G. (1990). Intradural herniation of a thoracic disc presenting as flaccid paraplegia: case report. Neurosurgery, 27(3), 482–484. https://doi.org/10.1097/00006123-199009000-00027
23. Wang, A. M., & Zamani, A. A. (1986). Intradural herniation of thoracic disc: CT metrizamide myelography. Computerized radiology : official journal of the Computerized Tomography Society, 10(2-3), 115–118. https://doi.org/10.1016/0730-4862(86)90054-5
24. TOVI, D., & STRANG, R. R. (1960). Thoracic intervertebral disk protrusions. Acta chirurgica Scandinavica. Supplementum, Suppl 267, 1–41.
25. Fisher R. G. (1965). Protrusions of thoracic disc. The factor of herniation through the dura mater. Journal of neurosurgery, 22(6), 591–593. https://doi.org/10.3171/jns.1965.22.6.0591
26. Isla, A., Roda, J. M., Bencosme, J., Alvarez, M. P., & Blázquez, M. G. (1988). Intradural herniated dorsal disc: case report and review of the literature. Neurosurgery, 22(4), 737–739. https://doi.org/10.1227/00006123-198804000-00020

27. Reeves, D. L., & Brown, H. A. (1968). Thoracic intervertebral disc protrusion with spinal cord compression. Journal of neurosurgery, 28(1), 24–28. https://doi.org/10.3171/jns.1968.28.1.0024
28. Jefferson A. (1975). The treatment of thoracic intervertebral disc protrusions. Clinical neurology and neurosurgery, 78(1), 1–9. https://doi.org/10.1016/s0303-8467(75)80002-3
29. D'Andrea, G., Trillò, G., Roperto, R., Celli, P., Orlando, E. R., & Ferrante, L. (2004). Intradural lumbar disc herniations: the role of MRI in preoperative diagnosis and review of the literature. Neurosurgical review, 27(2), 75–82. https://doi.org/10.1007/s10143-003-0296-3
30. Negovetić, L., Cerina, V., Sajko, T., & Glavić, Z. (2001). Intradural disc herniation at the T1-T2 level. Croatian medical journal, 42(2), 193–195.
31. Mokri, B., & Atkinson, J. L. (2000). False pituitary tumor in CSF leaks. Neurology, 55(4), 573–575. https://doi.org/10.1212/wnl.55.4.573
32. Schievink W. I. (2008). Spontaneous spinal cerebrospinal fluid leaks. Cephalalgia : an international journal of headache, 28(12), 1345–1356. https://doi.org/10.1111/j.1468-2982.2008.01776.x
33. Schievink, W. I., Maya, M. M., Moser, F. G., & Tourje, J. (2005). Spectrum of subdural fluid collections in spontaneous intracranial hypotension. Journal of neurosurgery, 103(4), 608–613. https://doi.org/10.3171/jns.2005.103.4.0608
34. Schievink, W. I., Maya, M. M., Tourje, J., & Moser, F. G. (2005). Pseudo-subarachnoid hemorrhage: a CT-finding in spontaneous intracranial hypotension. Neurology, 65(1), 135–137. https://doi.org/10.1212/01.wnl.0000167192.86419.15
35. Schievink W. I. (2006). Spontaneous spinal cerebrospinal fluid leaks and intracranial hypotension. JAMA, 295(19), 2286–2296. https://doi.org/10.1001/jama.295.19.2286
36. Court, C., Mansour, E., & Bouthors, C. (2018). Thoracic disc herniation: Surgical treatment. Orthopaedics & traumatology, surgery & research : OTSR, 104(1S), S31–S40. https://doi.org/10.1016/j.otsr.2017.04.022

37. Agarwal, V., Sreedher, G., & Rothfus, W. E. (2013). Targeted CT-guided epidural blood patch for treatment of spontaneous intracranial hypotension due to calcified intradural thoracic disc herniation. Interventional neuroradiology : journal of peritherapeutic neuroradiology, surgical procedures and related neurosciences, 19(1), 121–126. https://doi.org/10.1177/159101991301900118

38. Levi, V., Di Laurenzio, N. E., Franzini, A., Tramacere, I., Erbetta, A., Chiapparini, L., D'Amico, D., Franzini, A., & Messina, G. (2019). Lumbar epidural blood patch: effectiveness on orthostatic headache and MRI predictive factors in 101 consecutive patients affected by spontaneous intracranial hypotension. Journal of neurosurgery, 132(3), 809–817. https://doi.org/10.3171/2018.10.JNS181597

FIGURE LEGEND

Fig. 1 (a) Axial T2-weighted Brain Magnetic Resonance imaging (MRI), **(b)** Axial Constructive Interference in Steady State (CISS) sequences of Brain Magnetic Resonance imaging (MRI) and **(c)** Axial Gradient-echo T2-weighted Brain Magnetic Resonance imaging (MRI) showing infratentorial superficial siderosis mostly of the cerebellum (specifically at the level of the folia), the eighth cranial nerves and the brainstem; (**d)** Axial T2-weighted Spinal Magnetic Resonance imaging (MRI), (**e**) Sagittal T2-weighted Spinal Magnetic Resonance imaging (MRI) and (**f)** Non-contrast sagittal Spinal Computed Tomography (CT) images demonstrating an anterior wedge deformation of the D6 and D7 somae with superimposed posterior herniation of disc material (white arrow) with osteocalcific signal that determined a dural tear at D6-D7

Fig. 2 Intraoperative picture illustrating the ventral intradural disc herniation after posterior durotomy