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Mini Review

Surgical Resection of Spinal Intradural Extramedullary Neoplasms: Policy According to the Lesion Location

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Abstract

Background: Intradural extramedullary (IDEM) tumors account for two thirds of all primary intraspinal neoplasms. They mostly include schwannomas, meningiomas and ependymomas which are located circumferentially anywhere by the spinal cord. Since the clinical symptoms and histology of these tumors are mostly benign in nature, the primary goal of the treatment should be gross total resection without any functional deterioration.

Objective: In cases of intradural extramedullary tumors, surgery should be planned with respect to preservation of the stability and the anatomy of the spine without giving any harm to surrounding vital structures. Therefore, surgical policy should be planned thoroughly for the best outcome.

Methods: The authors shall discuss the surgical policy according to the localization of these neoplasms, especially the minimally invasive attempts in accordance with the most recent literature.

Results: IDEM spinal tumors is classified according to their relation with spinal cord and the denticulate ligament; posterior, posterolateral, lateral, anterolateral, and anterior. The trajectory and surgical techniques are discussed in detail in each group with cases of our own experience.

Conclusion: Surgical excision of these benign lesions should be planned according to the localization of the tumor in order to achieve gross total resection with minimal harm to vital structures.

Keywords: Approach; Intradural Extramedullary; Tumor; Laminectomy; Minimally Invasive

Introduction

Intradural extramedullary (IDEM) tumors account for two thirds of all primary intraspinal neoplasms which are mostly benign in histology [1]. Schwannomas and menengiomas represent 90% of IDEM tumors whereas ependymomas, dermoid and epidermoid tumors, lipomas, metastasis, arachnoid cysts, chordomas, melanomas, myxomas and sarcomas present the rest [2]. The first successful intradural spinal tumor surgery was performed by Sir Victor Horsley in 1887, and the patient Captain G. was free of symptoms at the end of first year after surgery [3]. A century later, despite vast improvements in imaging studies, anesthetic care, and surgical instruments; the surgical technique remains basically the same, a traditional open procedure consisting of a midline incision, bilateral muscle stripping and multilevel laminectomies with intradural tumor resection [4]. Such technique has been used for most of the IDEM tumors regardless of the location, and has documented

to indicate excellent outcomes while providing adequate exposure for tumor excision in a number of large series [5-7]. However, it has been recognized that the incidence of chronic back pain and acquired deformity increases after laminectomy only procedures, particularly for multilevel surgery [8-10]. Advances in neuroimaging and intraoperative technologies have improved the likelihood of complete and safe removal of IDEM tumors with an emphasis on minimizing surrounding tissue damage and blood loss.

Minimally invasive spinal surgery techniques previously used for disc herniations and degenerative spine conditions [11,12], are also suitable for some of the spinal IDEM tumors [13]. Such techniques aim to limit the extent of tissue dissection and resection required while achieving the same surgical goal, thus avoiding or reducing the incidence of iatrogenic instability. Moreover, they also reduce intraoperative blood loss, length of hospitalization and postoperative pain; and speed up recovery along with ensuring the long term spinal structural integrity [14]. Here, the authors review the surgical policies depending on the location of IDEM tumors in accordance with their own experience as well as the most recent literature paying special attention to minimally invasive approaches.

Methods

A detailed planning of surgical approach to IDEM spinal neoplasms, according to their localization in the entire spinal column, is presented with respect to the authors' experience. Preoperative evaluation, classification of the tumors according to localization, surgical nuances and comparison of such approaches are described and discussed with respect to the current available literature, in step by step fashion.

Preoperative evaluation

A thorough radiological study should be done in order to plan the right surgical approach to the IDEM spinal neoplasm. The relationship of the lesion to the spinal cord is of primary importance. If an intradural spinal tumor is identified, the following features should be described in magnetic resonance imaging (MRI) scan; the size, the signal intensity on T1 and T2 weighted images and/or the appearance on other sequences, the presence and pattern of contrast enhancement, single vs multiple lesions, the presence of heamorrhage, calcification, necrosis, associated cysts (tumoral /non-tumoral) or syringomyelia, compression of the spinal cord or displacement of nerve roots [15]. These lesions may also be related to nerve roots and may extend into the neural foramina (e.g. schwannomas and neurofibromas) or they may have a broad dural attachment (e.g. meningiomas) or be directly attached to the spinal cord (leptomeningeal metastases).

The determination of the level, especially in middle and upper thoracic levels, is vital in preoperative planning. Since the incidence of the exposure of wrong level is high in minimally invasive surgery[16], preoperative marking and detection of level via repeated MRI scans that has to be obtained in the surgical position, is of great importance [17]. Besides MRI, computerized tomography (CT) scans and direct radiographs are also crucial in evaluation of the bony structures, such as widening of the spinal canal, scalloping of the posterior vertebral bodies, foraminal enlargement, as well as scoliosis.

Approach related to localization of the tumor

IDEM spinal tumors can be classified according to their relation with spinal cord and the denticulate ligament. The lesions located posterior to denticulate ligaments are classified as posterior and posterolateral; those located anterior to dentate ligament are classified as anterior and anterolateral.

Posterior lesions

These lesions are located posterior to spinal cord in the midline, and some occupying several vertebral levels. Posterior laminectomy, also known to be the traditional approach to intraspinal lesions is usually the procedure chosen for pure posteriorly located lesions, especially more than two vertebral levels. The spinous processes, the interspinous and supraspinous ligaments, the ligamentum flavum and medial 2/3 of the laminae are the anatomical structures that have to be removed. In this conventional intervention, one level above and one level below the lesion should be included to surgery to achieve an advanced exposure of the lesion as well as the surrounding spinal cord. However, this approach may lead to unnecessary removal of bony structures and blood loss with gradually-increasing instability or deformity of the vertebral column caused by the removal of interspinous ligaments and the majority of laminae [6,18,19]. To reduce the post-laminectomy problems, less invasive procedures such as hemilaminectomy [20,21], and osteoplastic laminotomy [22] have been proposed. In the setting of pure posteriorly located lesions, we choose interlaminar approach by performing bilateral 1/3 hemilaminectomies with midline skin incision (Figure 1). Recently, minimally invasive attempts with expandable tubular retractors via muscle splitting technique have been found to be favorable [23]. The bony removal is carried out

by high speed drill or Kerrison rongeurs through the retractor, the dura is often closed primarily and a dural sealent is preferred in most of the cases where this technique has been applied [23-25].

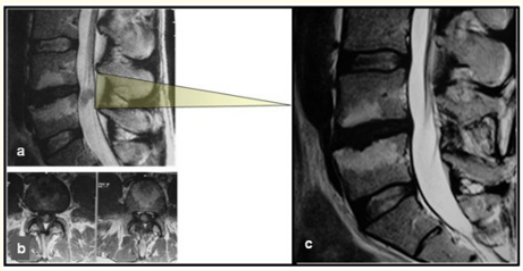

Figure 1: Sagittal (a) and axial T2 weighted (b) MRI images of posteriorly located lesion. The interlaminar triangle depicts the surgical corridor that could potentially be the safer, easier, more reachable and minimally invasive attempt. Postoperative sagittal T2 weighted MRI image is seen (c).

Posterolateral lesions

These lesions are mainly schwannomas and meningiomas and this is the most common localization of the IDEM neoplasms. Posterior approach by performing a unilateral hemilaminectomy intervention is the most common method used to excise such lesions.

In a routine posterior hemilaminectomy; the spinous process and the contralateral lamina is not excised. After a midline incision and completion of ipsilateral paraspinal muscle dissection and retraction, hemilaminectomy is performed. In a modified hemilaminectomy presented by Sun., *et al*. [16], the inner parts of the medial and lateral laminae have mostly been drilled for wider view, and a 3.3cm in mean length (range: 2.0–6.5 cm) and a 1.2cm in mean width (range: 0.6–1.5 cm) bone window have been obtained. In the setting of extremely narrow lamina, such as in the management of thoracic tumors, the base of the spinous processes and parts of the articular processes as well as the pedicles (in combination with facetectomy) must be removed for a wider surgical vision [26]. Recently, in an attempt to further reduce the need for bone removal, Koch-Wiewrodt., *et al*. have used multilevel interlaminar fenestration, also called "multiple spinal keyhole surgery", to remove small posterior or posterolateral lumbar seated lesions [27].

Similar to pure posterior located tumors, we prefer posterior interlaminar approach and unilateral hemilaminectomy with the aid of surgical microscope. After hemilaminectomy, the ligamentum flavum is removed with a Kerrison rongeur and the dura mater is exposed. A midline durotomy is then performed by using a blade scalpel and a nerve hook. The nerve roots and tumor is identified, and the tumor is removed by using standard microsurgical techniques. After removal of the tumor, hemostasis is obtained and, the dura is primarily closed with running sutures. Then the anatomical structures are closed in standard fashion (Figure 2).

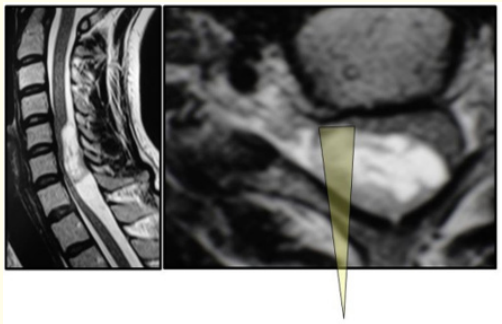

Figure 2: Sagittal (left) and axial (right) T2 weighted MR images of the posterior cervical lesion are seen. The posterolateral triangle represents the possible safe trajectory for surgical exposure of the tumor.

Lateral –Anterolateral lesions

Lateral and anterolateral lesions are mostly schwannomas or neuromas with an intraforaminal component. The symptoms are related to ventral or dorsal nerve root involvement or thecal sac compression.

Laterally-anterolaterally situated thoracic lesions may be directly exposed using posterolateral approaches, including hemilaminectomy (Figure 3), costotransversectomy, lateral extracavitary, and/or lateral extrapleural parascapular interventions. For larger lesions extending into foramen or more to anterolateral region; medial facetectomy, anterolateral pediculotomy, even costotransversectomy should be performed for adequate exposure [28].

For laterally situated cervical lesions; hemi-semi-laminectomy combined with the supraforaminal burr hole technique can be used. This technique allows an enhanced visualization of the foramen [29].

For laterally located lumbar lesions; posterolateral approach with total laminectomy, facetectomy, and even pediculotomy have

been done in which postoperative instability occurred in most of the cases [20,30-32]. Pure lateral- retroperitoneal approach is preferred in larger tumors however with a high morbidity rate [31]. Recently, for lateral-anterolateral lesions, minimally invasive techniques with tubular retractors are introduced via a posterior interlaminar approach [24] or an anterolateral approach [28].

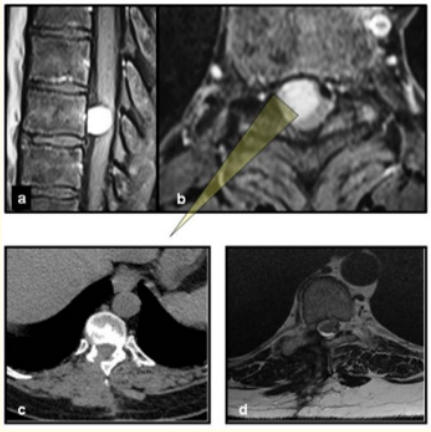

Figure 3: Sagittal (a) and axial (b) contrast enhanced T1 weighted MRI images demonstrate anterolateral located meningioma with contrast enhancement and spinal cord compression. The posterolateral triangle represents the possible safe trajectory for surgical exposure of the tumor. Postoperative axial computed tomography section (c) and axial T2 weighted MR image (d) show the hemilaminectomy defect and totally resected tumor with decompression of the spinal cord, respectively.

Anterior lesions

They are mostly situated in upper cervical and thoracic spinal segments. Two main approaches have been described to access the ventral cervical and cervicothoracic spinal column; anterior (cervical or transthoracic) and posterolateral approaches [33]. Among the anterior approaches, corpectomy is a traditional technique for ventral neoplasms, especially for cervical and upper thoracic lesions. The authors recommend performing a corpectomy (Figure 4) or anterolateral pediculotomy (Figure 5) for upper thoracic lesions. Pedicle may be excised via transpleural as well as extracavitary approaches and a wider view is gained for achieving a possible gross total tumor resection.

Posterolateral interventions for anterior lesions are classified as paramedian transpedicular and posterolateral hemilaminectomy approaches [34-36]. In paramedian transpedicular technique [34], unilateral facetectomies and pedicle resection to the base of the spinal canal should be performed. After repositioning of the vertebral artery and the nerve roots, dorsal partial corpectomy should be done to expose the ventral spinal canal. On the other hand, after having a facetectomy that is combined with hemilaminectomy [35,36], dentate ligament division and spinal cord rotation is needed in posterolateral hemilaminectomy technique.

Figure 4: Sagittal T1 weighted MRI sections (a) of an anteriorly located thoracic lesion. The anterior triangle represents the possible safe trajectory for the removal of the IDEM tumor. Postoperative antero-posterior plain x-ray (b) and sagittal T1 weighted MRimage (c) show the reconstructed upper thoracic spine with a plate and totally excised tumor as well as the decompression, respectively.

Minimally invasive approaches, such as retropleural or paramedian transpedicular interventions via tubular retractor systems, may also be used in anteriorly situated lesions [4,37].

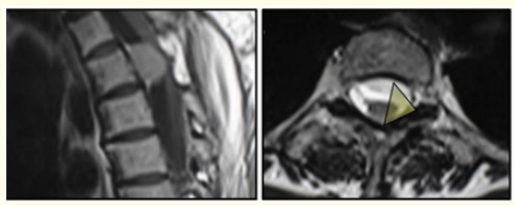

Figure 5: Sagittal contrast enhanced T1 (left) and axial T2 (right) weighted MRI sections show a ventral meningioma with contrast enhancement. The anterolateral triangle represents the possible safe trajectory for surgical exposure of the tumor.

Discussion

Spinal IDEM tumors, although being benign in nature, may have high morbidity rates in the postoperative period depending on the selected approach as well as the surgical planning. Many surgically treated case series either minimally invasive or conventional have been presented in the literature [13,28,31,34,36,37].

There is not yet randomized prospective clinical studies presenting the superiority of any of the surgical approaches for treating spinal IDEM tumors at the time of this manuscript has been written. The main purpose of all these surgical strategies is to perform as much gross total resection as possible with the lowest morbidity rate. Therefore, with this manuscript, we would like to draw attention to planning the surgery according to the location of tumor through the possible shortest corridor. We have classified the approaches as posterior-posterolateral and anterior-anterolateral, and discuss them accordingly (Table 1).

Localization of tumor	Approach	
Posterior	Hemilaminectomy via interlaminar approach (Minimally invasive approach)	Gandhi., *et al*. 2013 [23], Nzokou., *et al*. 2013 [24], Tan., *et al*. 2014 [25]
	Hemilaminectomy via interlaminar approach	Hazer., *et al.* (present study)
Posterolateral	Unilateral Hemilaminectomy	Sun., *et al*. 2011 [16]
	Key hole surgery (Multiple interlaminar fenestration)	Koch-Wiewrodt., *et al*. 2007 [27]
	Hemilaminectomy via interlaminar approach (Minimally invasive approach)	Gandhi., *et al*. 2013 [23], Nzokou., *et al*. 2013 [24], Tan., *et al*. 2014 [25]
	Hemilaminectomy via interlaminar approach	Hazer., *et al*. (present study)
Lateral	Hemilaminectomy with costatransversectomy-facetectomy-antrolateral pediculotomy (depending on the size of the lesion)	Park *et al*, 2014 [28]
	Hemi-semi laminectomy with supraforaminal burr hole	Banczerowski., *et al*. 2009 [29]
	Hemilaminectomy via interlaminar approach	Nzokou., *et al*. 2013 [24]
	Hemilaminectomy with costatransversectomy-	Hazer., *et al*. (present study)
Anterolateral	Hemilaminectomy with costatransversectomy-facetectomy-antrolateral pediculotomy (depending on the size of the lesion)	Park., *et al.* 2014 [35]
	Hemi-semi laminectomy with supraforaminal burr hole	Banczerowski., *et al*. 2009 [29]
	Hemilaminectomy via interlaminar approach	Nzokou., *et al*. 2013 [24]
	Hemilaminectomy with costatransversectomy-	Hazer., *et al*. (present study)
Anterior	Posterolateral hemilaminectomy and facetectomy via dentate ligament division	Voulgaris., *et al*. 2010(45) , Yu., *et al*. 2011 [35]
	Paramedian transpedicular approach	Acosta., *et al*. 2007 [34]
	Retropleural or paramedian transpedicular approach (Minimally invasive approach)	Angevine., *et al*. 2011 [37], Tredway., *et al*. 2006 [4]
	Corpectomy +/- anterolateral pediculotomy	Hazer., *et al*. (present study)

Table 1: Summary of the surgical approach related to the localization of the tumor.

Traditional approach for IDEM tumors is stated as a posterior midline incision with stripping of muscles and ligaments off the underlying lamina and spinous processes. It is followed by a bilateral laminectomy from one level above and to one level below the lesion to facilitate access and visualization. In the past century, surgeons have reported excellent results in resecting IDEM spinal neoplasms. Sepalla., *et al*. reported a series of 187 patients that underwent surgical resection for spinal schwannomas. In this large series, 90% were completely resected with a 10% surgical complication rate and 1.5% surgical fatality rate [7]. Levy., *et al*. also demonstrated similar results on 66 patients with a 9% surgical complication rate and a 1.5% mortality rate [5]. Potential complications (aside from

neurological injury during resection) include pain, spinal instability, and cerebrospinal fluid leak. Biomechanical failures following multilevel laminectomies can be listed as spondylolisthesis in the lumbar spine [38], and kyphotic deformity in the cervical spine, particularly in young patients with intradural pathology [39,40]. While permitting the replacement of bone and partial posterior tension band restoration, the risk of postoperative deformity has found to be similar between osteoplastic laminotomy and laminectomy regardless of the localization of the tumor, age of the patient, the presence of preoperative malalignment in coronal and/or sagittal planes [39].

However laminoplasty is shown to be associated with reduction in incisional cerebrospinal fluid leak [39]. By the evolution of less invasive approaches, structural integrity is more spared and the complication rate is decreased [41]. So, the minimally invasive approaches, which were previously popularized in other spine pathologies such as herniated discs or degenerative diseases [11,12], have also been introduced to the surgical treatment of spinal tumors [13,42]. One of the most popular techniques used as minimally invasive attempt is posterior unilateral hemilaminectomy. It has been frequently introduced with extradural, intradural and even intramedullary spinal tumors in the literature [14,16,26,43-45]. Biomechanical studies have demonstrated that a minimally-invasive exposure by means of hemilaminectomy preserves the structural integrity of the lumbar spine and minimizes alterations to segmental motion postoperatively [19,42]. Additionally, recent studies have indicated that minimally invasive surgical interventions have lower complication rates mainly in thoracic and lumbar intradural lesions when compared to conventional surgeries [23,24]. Furthermore, many reports have stated that minimally invasive approach is the most effective surgical technique for IDEM tumors, which are dorsally or laterally located and those occupying two or less vertebral segments [14,24].

Although minimally invasive techniques are very popular and suggested to be used in IDEM tumors, they may not be appropriate for all lesions. The relative contraindications to this approach including; very extensive ventrally located or extraforaminal tumors, tumors involving 2 or more levels, certain types of tumors that are haemorrhagic, such as paragangliomas or certain metastasis, and morbid obesity because sometimes the height of the tube may not be appropriate. There are also a number of technical challenges that surgeons should be aware of the minimally invasive approaches. Working corridor is very narrow therefore, hemostasis should be done meticulously. Also dural closure through the tube is challenging and special instruments are often needed [14]. Moreover, there is a steep learning curve for unexperienced surgeons [23,25].

For anterior or anterolateral multilevel tumors which are not suitable for minimally invasive attempt, a thorough preoperative planning for the choice of surgical corridor is essential. The aim of the surgery should be to sacrifice a significant amount of bone from the vertebral column to achieve a wider and more direct visualization with minimal, if any, neural manipulation. There are several reports presenting successful removal of such cases via transthoracic, transvertebral or anterior thoracoscopic approaches [46-48]; however these are usually associated with a significant amount of morbidity. Challenges and limitations to these approaches include their unfamiliarity, a deep-less secure surgical field, problematic ventral epidural bleeding, limited lateral access, risk and consequences of cerebrospinal fluid fistulas, and the usual requirement for spinal stabilization and reconstruction.

Posterior unilateral hemilaminectomy may also be chosen for ventrally located intradural cervical [34] and thoracic tumors [36]. Posterolateral approach with hemilaminectomy allows direct visualization of the ventral and dorsal boundaries of the tumor with minimal manipulation of the spinal cord. It was also mentioned that most ventral IDEM pathologies present eccentrically with some degree of cord rotation and lateral displacement. Therefore, with sufficient bone removal, adequate exposure is gained without the need for harmful spinal cord rotation [33,37]. Besides unilateral hemilaminectomy, Acosta., *et al*. have described another approach for the anterolateral cervical or cervicothoracic lesions defined as a modified paramedian transpedicular approach, in which a partial dorsal corpectomy is added to fasetectomy and pedicle resection [34]. However with these posterolateral approaches for anterior lesions, there is an increased risk of instability. Therefore in the setting of such circumstances, the fixation as well as the reconstruction of the involved spinal segment is inevitable.

Conclusions

The main goal of all the techniques is to achieve a gross total resection with the lowest complication rates. One necessity to reach such aim is a thorough preoperative planning of the trajectory to identify the right approach on the basis of "location" of the individual tumor. Nowadays, although minimally invasive techniques are more popularized, the drawbacks of these approaches, especially for the unexperienced surgeons, should be kept in mind.

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