Chapter

Intradural Extramedullary Spinal Tumors

Saleh Rasras and Arash Kiani

Abstract

Intradural extramedullary (IDEM) spinal tumors are common pathologies, and despite their name, they can extend beyond dural confinements. IDEMs can have both sporadic and syndromic patterns, and various genetic abnormalities are believed to be responsible for these mainly benign pathologies. Meningiomas, nerve sheath tumors (NST), and ependymomas are the three most common subtypes, and due to their pathologically benign nature, surgical total resection plays the most important role in their management. These tumors have always been challenging entities to neurosurgeons, and many surgical techniques have been described in order to achieve gross total resection, and these techniques have continued to evolve over time. Adjuvant therapies such as radiotherapy or radiosurgery are usually considered when total resection is not possible or sometimes in syndromic patients in order to avoid multiple surgical procedures in a short period of time.

Keywords: intradural extramedullary (IDEM), spinal cord, tumor, nerve sheath tumors (NST), meningioma, ependymoma

1. Introduction

A wide variety of tumors can affect spinal column and cord causing functional or neurological impairment. Axial skeleton tumors can be either primary or secondary with metastatic lesions being the most common and are classified as secondary malignant tumors. On the other hand, primary tumors of the axial skeletons are the ones arising from vertebral bony structures and can also be benign or malignant.

The skeletal system is one the most common sites for metastasis with spinal part being the most frequent site [1] due to its cancellous structure and extensive arterial and venous supplies [2]. Cancers with tendency to affect the spinal column are in descending order: prostate, breast, kidney, lung, and thyroid [3] (**Figure 1**).

Benign tumors of the spinal column can be diagnosed in both children and adults; in children they could be similar to the tumors of other skeletal areas like giant cell tumors (GCT) or osteoblastomas. Regarding the autopsy studies, vertebral hemangiomas are the most common benign primary lesions of the spinal column in adults and could be seen in up to 20% of the population. Other common benign primary tumors are aneurysmal bone cyst, osteoblastoma, osteoid osteoma, GCT, osteochondroma, and enchondroma (**Figure 1**) [4].

Malignant primary spinal column tumors tend to occur in older patients than primary ones, and the most commonly occurring tumors are multiple myeloma and plasmacytoma, chordoma, and osteosarcoma in order of frequency (**Figure 1**).

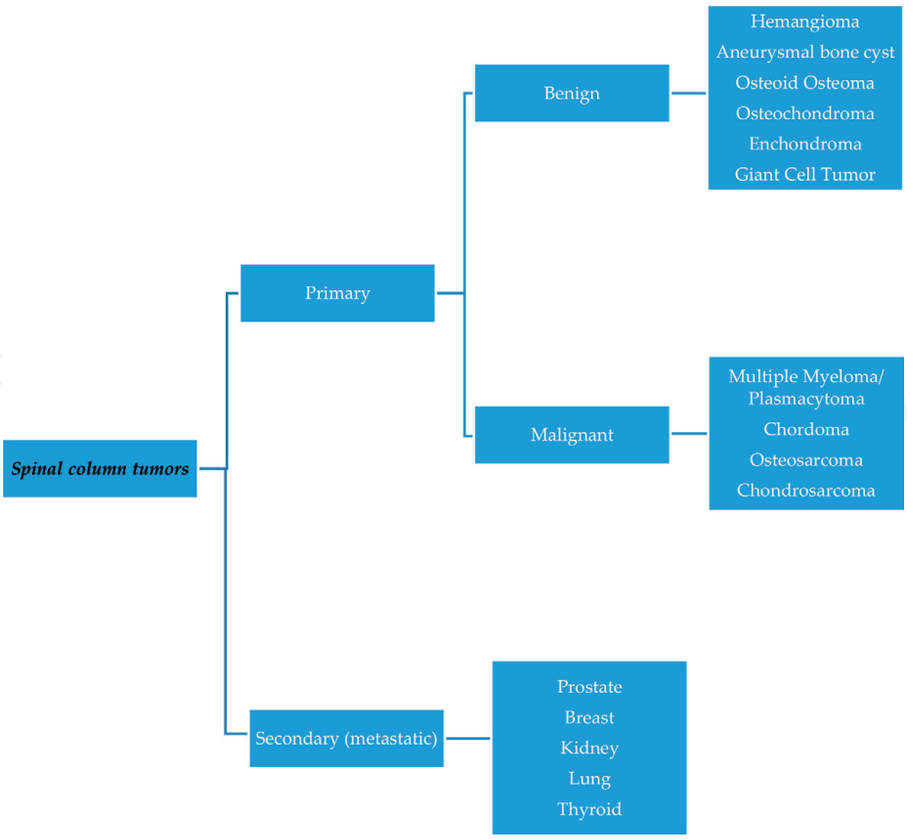

Figure 1.
Spinal column tumors.

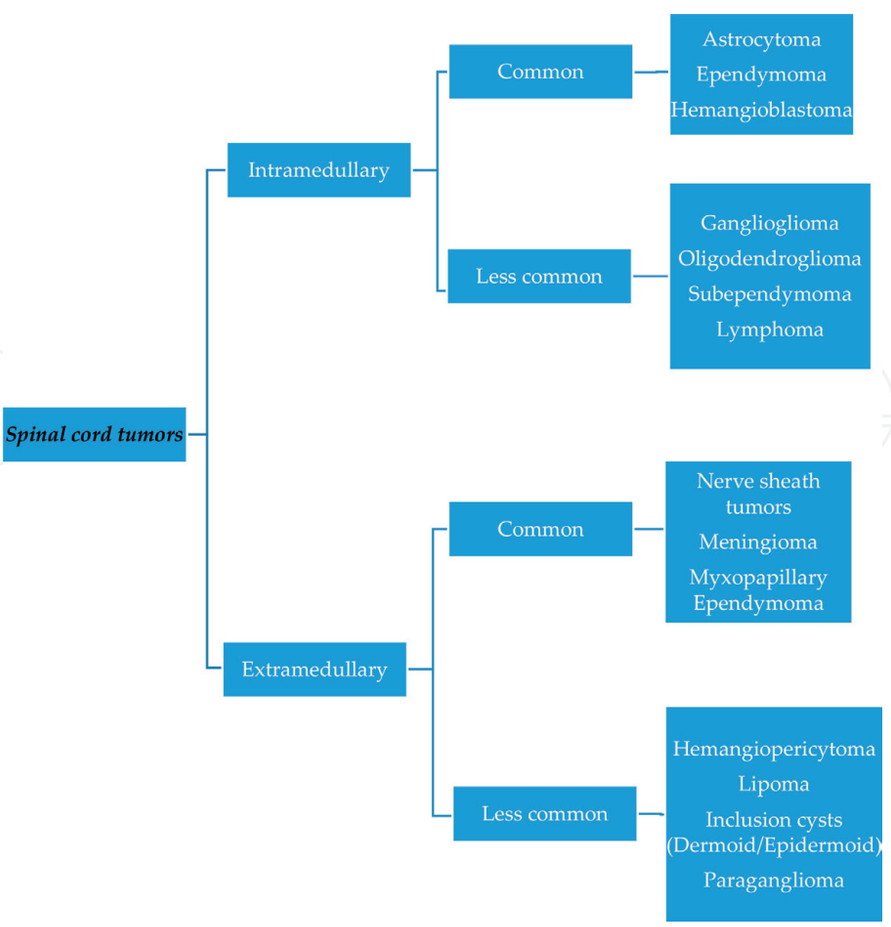

Figure 2.
Intradural spinal cord tumors.

Tumors that arise within the dural sac are termed as intradural tumors and can be within the substance of the spinal cord (intramedullary) or outside of it (extramedullary); however, a small portion of tumors can be both intra- and extramedullary and usually are seen at the conus medullaris transition site to filum terminale or at the nerve root entry zone areas.

Intramedullary tumors are usually benign but can also be malignant, and the most common pathologies are astrocytoma, ependymoma, and hemangioblastoma (**Figure 2**); other less common tumors are gangliogliomas, oligodendrogliomas, subependymomas, and in very rare cases lymphomas.

Intradural extramedullary (IDEM) tumors consist almost 70% of all intradural lesions [5], and the most frequent types are nerve sheath tumors, meningiomas, and myxopapillary ependymomas. Other less common tumors include hemangiopericytomas, lipomas, paragangliomas, and inclusion cysts such as dermoid and epidermoid cysts (**Figure 2**).

In this chapter we focus on fundamentals of assessment, diagnosis, and treatment of intradural extramedullary tumors.

2. Epidemiology and histology

IDEM tumors are mostly consisted of meningiomas, nerve sheath tumors (schwannomas and neurofibromas), and at the filum terminale myxopapillary ependymomas.

Meningiomas are the most frequent intradural tumors and usually happen at the thoracic region. Psammomatous subtype is the most common histologic subtype, and they resemble the intracranial ones in which numerous psammoma bodies can be observed [6, 7]. Meningiomas have female preponderance with female to male ratio of 3–4:1 and tend to affect the elder population of 50–70 years of age [8].

Nerve sheath tumors affect both sexes equally with the peak incidence in the fourth and fifth decade of life. Schwannomas are the far more common subtype in this category and usually happen sporadically but also can be seen in neurofibromatosis type 2 [9]. Spinal NSTs arise from ventral or dorsal nerve rootlets with the dorsal nerve rootlet being more common. These tumors can be purely extradural especially at the cervical regions or purely intradural; they also can have both intra- and extradural components and present in dumbbell shape pattern.

The transition zone of the myelin-producing cells from oligodendrocytes to Schwann cell is believed to be where schwannomas arise from a nonfunctional nerve fascicle, and as they grow, these well-capsulated lesions can cause compression on adjacent functional fascicles [10]. Schwannomas can be seen in a compact cellular pattern with palisading verocay bodies (Antoni A) or in a less cellular pattern (Antoni B) [11].

Neurofibromas primarily are seen in patients with neurofibromatosis type 2 but can also happen sporadically. Unlike schwannomas these tumors can involve multiple nerve fascicles and expand the whole nerve which makes it sometimes impossible to totally resect the tumor without sacrificing the nerve of origin. The presence of axons in gross pathology can help in distinguishing these lesions from schwannomas.

Filum terminale ependymomas are well-capsulated tumors with slight male preponderance with peak incidence at 36 years of age [12]. Histologic smears reveal well-differentiated radially arranged cuboidal or columnar cells around vascularized myxoid cores with a myxopapillary appearance.

3. Genetic considerations

Genetic syndromes such as neurofibromatosis can be associated with IDEMs. Spinal neurofibromas can be associated with NF1 and NF2 in which NF1 is far more common than NF2.

Neurofibromatosis type 1 (NF1) caused by a mutation in the NF1 gene on chromosome 17 that codes neurofibromin is an autosomal dominant inherited syndrome that can be associated with multiple spinal neurofibromas.

Schwannomas, neurofibromas, and meningiomas are associated with NF2 which is inherited as an autosomal dominant syndrome and caused by mutation at chromosome 22 (NF2 gene) that codes merlin protein which is the responsible etiology [13]. Schwannomatosis a syndrome which is characterized by multiple schwannomas without defining other features of NF1 or NF2 is also another syndrome that may cause spinal schwannomas.

Spinal irradiation and NF2 are two main predisposing factors that cause spinal meningiomas. Intramedullary ependymomas are associated with NF2, but myxopapillary ependymoma is believed to be a distinct entity and is not related to NF2.

4. Sign and symptoms

IDEM tumors are usually benign slow-growing tumors, and there can be a long period of time between the initiation of symptoms and the diagnosis. Axial back pain can be present for a long time before diagnosis and can be the only symptom. Radicular pain is another symptom especially in patients with NSTs. Spinal cord compression can cause myelopathy or cauda equina syndrome.

Syndromic patients may reveal symptoms at younger age with more rapid progression of functional or neural impairment.

5. Imaging

Plain X-ray is not usually indicated in evaluation of patients with IDEM tumors, but due to the slow-growing nature of these tumors, reactive bony responses such as foraminal widening, vertebral body scalloping, laminar thinning, and increased inter-pedicular space can be seen.

Computed tomographic studies are quite helpful regarding the evaluation of bony structures, spinal stability, and tumoral calcification and are also helpful in surgical planning.

Magnetic resonance imaging is the modality of choice for the diagnosis of these lesions and delineating their relative anatomy regarding the spinal cord and nerve rootlets.

Schwannomas and neurofibromas have decreased or equal signals in T1W imaging and increased signal in T2W imaging, and they show avid heterogeneous or homogeneous enhancement in contrast studies (**Figure 3**).

Meningiomas have more homogeneous imaging patterns than NSTs and show equal to decreased signals in T1WI and equal to slightly increased signals in T2WI; they show more homogeneous contrast enhancement, and dural enhancement (dural tail) can also be observed (**Figure 4**).

Myxopapillary ependymomas usually represent themselves as isointense lesions in T1W imaging, but the mucinous component can show hypersignality in T1WI. Ependymomas are usually hypersignal in T2W imaging studies and

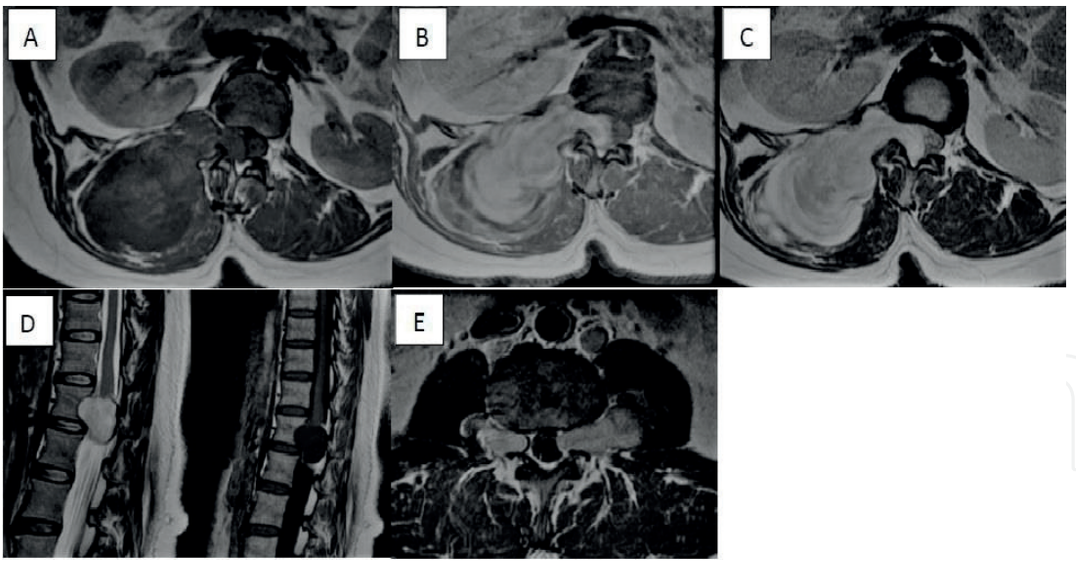

Figure 3.
T1W non-contrast-enhanced (A), T1W contrast-enhanced (B), and T2W (C) axial images of a thoracic schwannoma showing cord compression and massive retroperitoneal and paraspinal component. Midsagittal T1W and T2W MR images of a patient with thoracic schwannoma (D). Axial T2W MR image of a syndromic patient with NF1 showing bilateral spinal neurofibroma (E).

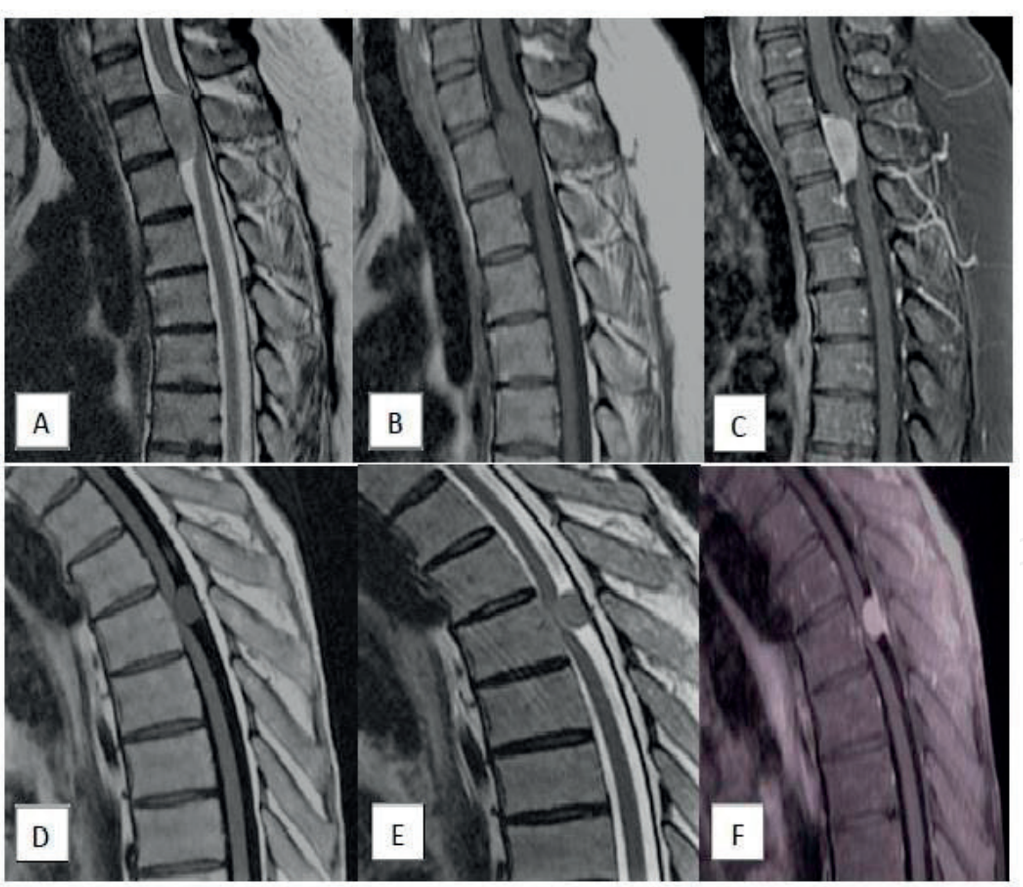

Figure 4.
Sagittal T2W (A), T1 non-contrast, (B) and contrast-enhanced (C) images of a patient with ventral thoracic meningioma. Sagittal T1W (D), T2W (E), and (F) T1 contrast-enhanced images of a patient with dorsal thoracic meningioma.

are enhanced in contrast studies. Myxopapillary ependymomas are most prone to hemorrhage, and when present, MR images show heterogeneous signals and heterogeneous enhancement pattern (**Figure 5**).

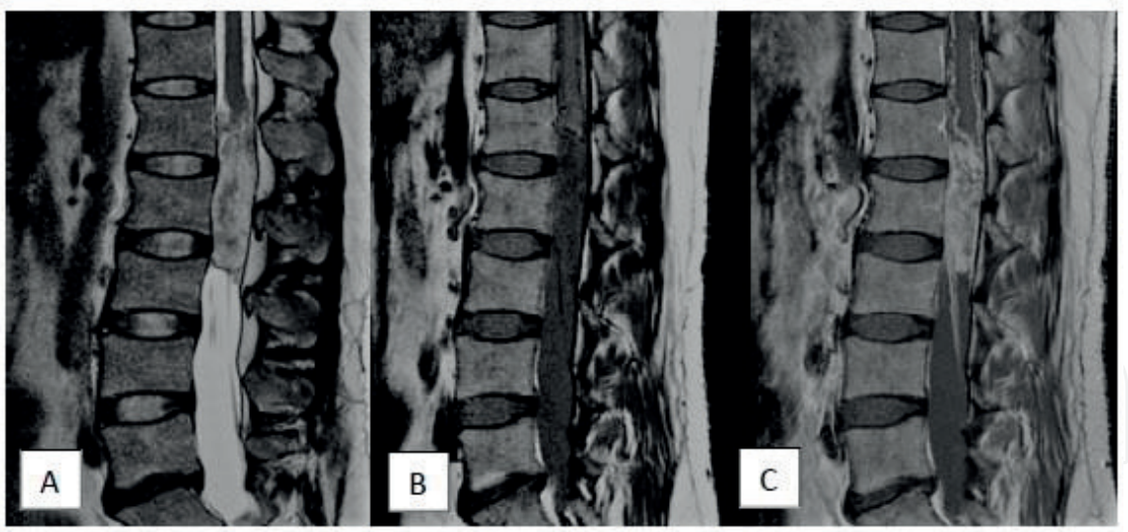

Figure 5.
Sagittal T2W (A), T1 non-contrast, (B) and contrast-enhanced (C) images of a patient with filum terminale ependymoma.

6. Indications for surgery and surgical routes

Surgical intervention is required in almost all symptomatic patients, but in syndromic patients with mild symptoms, due to higher chance of regrowth and multiple lesions, surgery might not be performed in order to avoid multiple surgeries in a short period of time.

All patients with progressive neural or functional impairment and those with rapid tumor growth in serial MR studies should undergo surgery.

Asymptomatic patients can be followed by serial clinical and radiological examinations, and surgery is not advised for diagnostic purposes only; the only exception would be myxopapillary ependymoma in which asymptomatic patients may be advised to undergo surgical evacuation for CSF seeding prevention [14, 15].

Most of IDEM tumors can be approached via simple posterior standard laminectomy, though the tumor location in the spinal axis and its relation to the spinal cord are the major factors determining the surgical route.

Cervical lesions can be addressed via both anterior and posterior approaches. Tumors located posteriorly, laterally, and ventrolaterally can be approached by posterior laminectomy procedure.

For the lesions above C2 when located ventrally, an extensive lateral approach to the foramen magnum can be used which needs vertebral artery transposition and sigmoid sinus skeletonization; on the other hand, ventral subaxial lesions can be addressed via standard anterior cervical procedure.

Thoracic IDEM tumors are generally operated via posterior approaches due to complications and difficulties of the transthoracic technique described by Bohlman which needs significant lung retraction and may cause serious vascular injuries [16]. Various posterior techniques have been described for ventral thoracic lesion removal including the traditional extracavitary technique described by Larson which is suitable for both ventrally located tumors and tumors with large extraforaminal component and costotransversectomy technique which is also suitable for lateral and ventrolateral lesions but not for tumors located ventrally due to limited surgical view of the contralateral side passing the midline [17].

Most of lumbar and sacral IDEM tumors are operated via posterior approach or its modifications; anterior trans- or retroperitoneal approaches are barely used now.

The key to a successful surgery is minimal cord or nerve root retraction, and for this purpose extensive resection of bony structures may be necessary, and this might lead to spinal instability. There are multiple reports of successful spinal instrumented fusion surgeries in treated patients with IDEM [18].

Bilateral laminectomy and medial facetectomies usually do not cause spinal instability, while total unilateral facetectomy especially at cervical or lumbar area makes spinal column unstable [19].

7. Surgical treatment of nerve sheath tumors

Patients undergoing standard posterior approach are placed in prone position with head fixed in Mayfield head holder for cervical tumors or placed at the headrest frame. Arms are placed along side of the trunk in upper thoracic lesions or are abducted by 90° in lower thoracic or lumbosacral lesions.

Motor and sensory evoked potential monitoring system is applied, and for cervical and lumbosacral lesions, continuous nerve root EMG monitoring should also be performed.

Midline skin and fascia incisions are made, and classic subperiosteal dissection of the paravertebral muscles is performed. Small laterally located lesions can be reached by a simple hemilaminectomy, but bilateral laminectomy widens the surgical view and may be preferred in most surgeries. Laminectomy length should exceed the whole length of the tumor, and regarding the tumor size and location, unilateral facetectomy may also be performed; intraoperative ultrasonography is helpful in determining the adequacy of the laminectomy extension.

Dura is usually opened posteriorly in a linear fashion which makes duraplasty much easier but also can be opened in a T-shaped fashion or at the paramedian site. Dural opening length should exceed the tumors' length, and when opened, it is sutured to the paraspinal musculature, and then the arachnoid layer is opened. Surgical microscope is mandatory in intradural tumor resection surgeries, and under microscopic view careful dissection of the arachnoid layer, cord, and nerve roots from the tumor is carried out. NSTs are usually originated from dorsal nerve rootlets, but the normal anatomy might be distorted; careful identification of the afferent and efferent origin nerve roots should be performed before tumor resection. Large tumors obstructing the surgical view should be entered and debulked by an ultrasonic aspirator, and then careful identification of the origin roots is carried out. Sensory origin nerve roots are usually bulge and vascular, but motor ones can appear totally normal, and motor evoked potential monitoring can be helpful in distinguishing the motor nerve of origin.

NSTs might extend into the pial surface of the spinal cord, and so, no obvious sensory afferent root might be distinguishable; in these cases, careful dissection of the tumor from the cord substance should be performed. At the cervical and lumbar spine, preservation of the functional motor roots is important, and only those confirmed to be nonfunctional by motor evoked potential studies can be sacrificed. After identification and ligation of the origin afferent and efferent roots with preservation of all functional ones, the tumor is carefully dissected and resected. Subarachnoid space is irrigated vigorously until the blood is cleared. Dural closure is performed with running sutures in a watertight fashion, and then multilayer suturing of the paraspinal muscles, fascia, subcutaneous layer, and skin is carried out. Some surgeons advocate the use of lumbar drain post-op for 48–72 hours to avoid CSF leakage from the incision site.

NSTs can grow extradurally and into neural foramina and even beyond that and get to a significant size at the paraspinal regions; in these cases, we prefer to operate the

intradural part first and decompress the spinal canal; the extradural part can be evacuated at the same procedure or may be addressed to in a staged surgery via the same route or in another surgical route depending on the size of the extra-foraminal part.

8. Surgical treatment of spinal meningiomas

In order to approach a spinal meningioma, a surgeon must consider the site and the location of the tumor regarding the cord and boney structures. Meningiomas barely have extradural components and are commonly ventral to the cord.

Cervical meningiomas are addressed by a posterior standard technique if located dorsally or by an anterior approach if located ventrally. Thoracic meningiomas are usually reached via posterior routes, and if located ventrally, extracavitary or costotransversectomy techniques might be used; sectioning and suture rotating the dentate ligament may be helpful for a better and wider surgical view. Lumbar meningiomas are usually operated via posterior approaches because the surgeon is able to safely retract the nerve roots.

Patients are positioned in the same way as patients with NSTs, and motor and sensory evoked potentials are monitored before and during the surgery.

Meningiomas are dural-based lesions, and the extent of dural involvement may be greater than the amount shown in MR studies so the laminectomy length should exceed the cephalad and caudal poles of the tumor, and intraoperative sonography is very helpful in this regard. Durotomy should be performed in an ellipsoid fashion in dorsally located tumors so that the tumor and the involved dura matter could be resected totally.

Ventrally located meningiomas are more challenging both in surgical resection and dural reconstitution which the latter might even be impossible; hence, many prefer dural coagulation instead of resection. Dural coagulation at the tumor base reduces intraoperative bleeding.

When the tumor poles are exposed, the dentate ligament can be sectioned and rotated by a suture for surgical view improvement. Large tumors compressing the cord should be debulked by an ultrasonic aspirator before resection so that spinal cord gets decompressed and a better view of the tumor margins could be achieved.

9. Surgical treatment of filum terminale ependymomas

Myxopapillary ependymomas are solid fleshy lesions originating from filum terminale and can have a large size at the time of diagnosis. These lesions are exclusively approached via posterior surgical procedure, and care must be taken to resect these tumors in an en bloc fashion so that CSF seeding and metastasis would not occur [20, 21].

Standard posterior approach in a prone position is performed under electrophysiologic monitoring evaluation, and when laminectomy is completed, dura is opened dorsally in a linear fashion and then sutured to paraspinal musculature. Arachnoid layer is opened, and careful microdissection of the neural roots from tumor is performed, and filum is identified proximal and distal to the tumor and tested by a neurostimulator.

Filum is cauterized and sectioned at both ends of the tumor, and then en bloc tumor resection is achieved with caution not to retract adjacent nerve roots excessively.

In some cases, en bloc resection of the tumor cannot be obtained especially when the tumor is too fragile and falls apart even with most careful microdissection or

when it's too large, and safe en bloc resection is impossible. The presence of functional nerve roots in the tumor substance also makes en bloc resection impossible, and subtotal resection would be the only option.

Dura is approximated by running sutures in a watertight fashion, and multilayer closure of the overlying compartments is carried out.

10. Adjuvant therapies

Adjuvant therapies do not play a major role in treatment of IDEM tumors, and microsurgical gross total resection still is the gold standard modality of treatment.

Radiotherapy has a defined role in patients with myxopapillary ependymoma and improves their progression-free survival when administered postsurgery [21].

Radiotherapy is administered in multiple recurrent meningiomas or the ones with atypical or malignant histology [22]. Stereotactic radiosurgery has been shown to be beneficial in patients with NSTs or meningiomas as the primary modality of treatment or as an adjuvant therapy in patients with post-operation radiologic tumor growth [23, 24].

Stereotactic radiosurgery is of more importance in syndromic patients who might have multiple lesions and also a higher tumor progression rate and helps them to face less surgical procedures in their lifetime.

Author details

Saleh Rasras* and Arash Kiani
Ahvaz Jundishapour University of Medical Sciences, Ahvaz, Iran

*Address all correspondence to: dr.rasras@gmail.com

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