Intradural spinal tumors: current classification and MRI features

Kasim Abul-Kasim · Majda M. Thurnher · Paul McKeever · Pia C. Sundgren

Abstract The differential diagnosis of intradural spinal tumors is primarily based on location, but the clinical presentation, age, and gender of the patient are also important factors in determining the diagnosis. This comprehensive review focuses on the current classification, clinical symptoms, and MRI features of the more common intradural extramedullary and intramedullary neoplastic lesions. This review does not include extradural lesions.

Keywords Intradural extramedullary tumors · Intramedullary tumors · MRI

Introduction

Intradural spinal tumors are relatively uncommon lesions that may result in serious morbidity. Their clinical symptoms are often nonspecific and include back pain, radicular symptoms, and slowly progressive neurological deficits such as weakness, paresthesia, gait problems, impotence, and bowel and bladder dysfunctions, to mention the most common. Also Brown-Séquard syndrome and signs of long tract involvement, such as clonus, hyperreflexia and Babinski sign are common but likewise nonpathognomonic. A less common clinical presentation in addition to neurological deficits is acute headache due to subarachnoid hemorrhage (SAH). A patient with such a clinical presentation with predominantly prepontine blood should always undergo MRI of the spine to exclude neoplasm or vascular malformation. Predominantly in children, intradural tumors may be associated with skeletal deformities such as kyphoscoliosis or scalloping of the vertebral bodies, nonspecific findings as well. Since the symptoms often are nonspecific and may occur first in the late stage of the disease, the diagnosis of intradural spinal neoplasms often is delayed.

The method of choice for the detection and evaluation of intradural spinal lesions is MRI. When there is suspicion of tumor, based on clinical history or any positive appropriate neurological sign, MRI should be performed, unless contraindicated. Any other examination merely causes delay. Neither the presence nor the absence of abnormal findings on plain film imaging, CT or CT myelography can exclude or sufficiently delineate and characterize an intradural tumor. In patients in whom MRI is contraindicated or when MRI or the spinal canal is impaired by metal hardware artifacts, myelography and/or CT myelography are the suboptimal methods of choice. While plain films play no role in the evaluation of suspected spinal cord tumors, CT of the spine with three-dimensional or high-quality multiplanar reformatted images might be helpful for presurgical planning [1]. Conventional angiography can be used for evaluation of the relationship among feeding and draining vessels in hemangioblastoma, for evaluation of vascular malformations, and for presurgical

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interventions such as embolization of hypervascular lesions or large feeding arteries [2, 3].

Analysis of the CSF may help to increase the level of suspicion of tumor before the MRI examination and may be useful chiefly in the deciding among differential diagnoses with an inflammatory etiology.

The current comprehensive classification and grading of spinal tumors by the World Health Organization (WHO) in the year 2007, as well as the imaging features of the most common intradural spinal tumors, are the focus of this review.

Classification of spinal cord tumors

The 2007 comprehensive WHO classification of CNS neoplasms is based on the assumption that the tumor type results from the abnormal growth of a specific cell type. The WHO classification also provides a grading system for tumors of each cell type and allows the classification of tumors to guide the choice of therapy and predict prognosis. Based on the grading system, most tumors are of a single defined grade [4]. The latest classification includes additional tumors of the CNS and histological variants. Although the updated WHO classification does not have a direct impact on the daily

practice of the neuroradiologist or in the interpretation of images, it is valuable in the communication between clinicians, radiologists and pathologists. The WHO classification provides the standard for communication between medical centers worldwide.

Table 1 presents an abbreviated version of the present classification of spinal cord tumors [5] and of the recent WHO classification of tumors of the central nervous system [6]. The table includes the most common intradural spinal neoplasms and does not include extradural tumors or vascular malformations as these lesions are not the topic of this review.

Characterization of intradural spinal tumors and differential diagnosis by location

Intradural spinal tumors can be divided into extramedullary and intramedullary tumors. The four most common intradural spinal tumors are the following:

– Intradural extramedullary (80% of intraspinal tumors in adults, 65–70% of intraspinal tumors in children):

Schwannoma (30%).
Meningioma (25%).

Table 1 Abbreviated WHO grading system for spinal cord tumors

			Grade
Neuroepithelial tumors	Astrocytic tumors (glial tumors)	Pilocytic astrocytoma	I
		Pleomorphic xanthoastrocytoma	II
		Fibrillary astrocytomas	II
		Anaplastic astrocytomas	III
		Glioblastoma multiforme	IV
	Oligodendroglial tumors	Oligodendroglioma	II
		Anaplastic oligodendroglioma	III
	Ependymal cell tumors	Ependymoma	II
		Myxopapillary ependymoma	I
		Subependymoma	I
	Mixed gliomas	Mixed oligoastrocytoma	II
		Anaplastic oligoastrocytoma	III
	Neuronal and mixed neuronal/glial tumors	Gangliocytoma	I
		Ganglioglioma	I/II
		Anaplastic ganglioglioma	III
		Desmoplastic infantile ganglioglioma	I
		DNT (dysembryoplastic neuroepithelial tumor)	I
		Paraganglioma	I
Peripheral nerve tumors		Schwannoma	I
		Neurofibroma	I
		Malignant peripheral nerve tumor	II/IV
Hematopoietic tumors		Primary malignant lymphoma	
Tumors of the meninges		Meningiothelial tumors	
		Meningioma	I
		Atypical meningioma	II
		Anaplastic meningioma	III
Other tumors related to the meninges		Hemangioblastoma	I

– Intradural intramedullary (20% of intraspinal tumors in adults, 30–35% of intraspinal tumors in children), of which about 90% are glial tumors:

Ependymoma (60%), of which 10–15% are myxopapillary ependymoma.
Astrocytoma (30%).

Intradural extramedullary tumors

The most common intradural extramedullary lesions are schwannomas, meningiomas, and neurofibromas. Less common lesions include paragangliomas, metastases, lipomas, spinal nerve sheath myxomas (neurothekeoma), sarcomas, and vascular tumors [7].

Schwannomas Schwannomas, which are considered benign tumors (WHO grade I), are the most common intradural extramedullary spinal lesions, followed by meningiomas [8]. Schwannomas are more commonly seen in adults and often in association with neurofibromatosis type II (NF-II). Although far less common in children, in general, multiple schwannomas occur in children with NF-II (where the risk of malignant transformation is higher). The tumor commonly arises from the dorsal sensory roots of the cervical and lumbar spine with less frequent involvement of the thoracic region. Of schwannomas, 70% are intradural while 30% can be extradural. "Dumbbell" tumors are usually located both intradurally and extradurally. Intramedullary schwannomas are very rare.

Meningiomas More than 95% of meningiomas are benign tumors (WHO grade I). They are the second most common intraspinal tumors, occurring most frequently in older patients (peak age in the fifth and sixth decades) [9]. However, when occurring in younger patients spinal meningiomas may be more aggressive, with a worse prognosis [10]. Of meningiomas, 90% are intradural and only 10% are extradural or dumbbell tumors. Most meningiomas (80%) affect females and 80% arise in the thoracic region, with less common involvement of the cervical (15%) or lumbar (5%) regions [10]. Several subtypes exist and the surgical outcome may differ depending on subtype [11]. Meningiomas are often located posterolaterally in the thoracic region and anteriorly in the cervical region [10]. They are often solitary tumors, but multiple meningiomas, which occur in 2% of affected patients, are most often associated with NF-II.

Neurofibromas Neurofibromas are benign tumors (WHO grade I) of the peripheral nerves. The tumor encases the nerve roots in contrast to schwannomas (neurinomas), which commonly displace the nerve root due to their asymmetric growth. Neurofibromas are rare intraspinal tumors except in patients with NF II in whom multiple tumors are typical. Intraspinal neurofibromas are usually localized tumors whereas a peripheral nerve neurofibroma can be localized, diffuse, or plexiform.

Paragangliomas Paragangliomas are rare intradural spinal tumors that are considered benign but can present with a more aggressive growth pattern and even metastasis [12]. They are usually found in the conus medullaris, cauda equina, and filum terminale [12, 13]. Like other extraadrenal chemodectoma, the spinal paragangliomas are endocrinologically inactive.

Leptomeningeal metastases Leptomeningeal metastases are a secondary neoplasm that may arise from a malignant primary neoplasm outside the CNS, such as a breast or lung neoplasm, or from the spread of a CNS tumor, i.e. the so-called "drop metastasis" [14]. Common primary CNS tumors that may spread to the leptomeninges are anaplastic astrocytomas, ependymomas, or medulloblastomas [15]. Leptomeningeal dissemination from CNS neoplasms occurs in younger patients, whereas metastases from lung or breast carcinomas occur in older patients [16]. In children, leptomeningeal spread from medulloblastoma and ependyma is common.

Intramedullary tumors

Intramedullary lesions are most commonly ependymomas, astrocytomas, gangliogliomas, and, less often, hemangioblastomas or a secondary neoplasm such as metastases [17, 18].

Ependymomas Ependymomas are the most common spinal cord tumors in adults, with a peak incidence in the fourth and fifth decades [19], and account for 60% of all intramedullary tumors [5, 20, 21]. The majority of ependymomas arise in the cervical spinal cord, with 44% in the cervical cord alone and 23% involving the upper thoracic spinal cord as well. In contrast to *cellular* ependymomas, which are located in the cervical spine, the *myxopapillary* ependymomas are commonly present in the conus medullaris and the filum terminale [22, 23]. This tumor occurs predominantly in young men, who present with chronic back pain.

Astrocytomas Spinal cord astrocytomas are the most commonly occurring intramedullary tumors in children and the second most common spinal cord tumor in adults, with an average age of 30 years at the time of presentation. Similar to cellular ependymomas, these tumors are more common in the cervical region, followed by the upper thoracic spinal cord.

Fig. 1 Meningioma. Sagittal unenhanced T1-weighted (**a**) and T2-weighted (**b**) images, and contrast-enhanced T1-weighted image (**c**) demonstrate a well-circumscribed, homogeneously enhancing intradural extramedullary lesion in the posterolateral aspect of the spinal canal
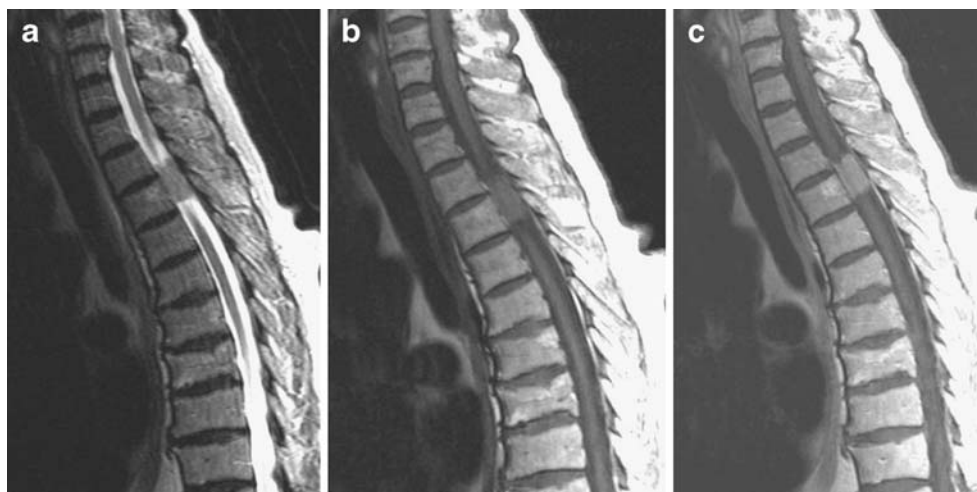
Gangliogliomas Gangliogliomas are rare tumors (grade I or grade II) accounting for only 1–2% of all spinal cord tumors [24, 25]. The tumor is more frequently seen in children than in adults.

Hemangioblastomas Hemangioblastomas, which are rare benign tumors, are seen more commonly in adults, with a peak incidence in the fourth decade [26]. The tumor primarily affects the thoracic cord (50%) and the cervical cord (40%). They present in 80% of patients as a solitary lesion, with multiple lesions seen in only 20% of affected patients. The majority (75%) of the tumors are intramedullary. One-third of the patients have von Hippel-Lindau syndrome [27]. The majority of hemangioblastomas are intramedullary, usually subpial in location and often have enlarged feeding arteries and draining veins. Conventional angiography might be indicated in the presurgical planning for these tumors to evaluate the relationship

among feeding arteries and the relationship to the artery of Adamkiewicz. Diagnostic features of spinal angiography in spinal hemangioblastoma include enlarged feeding arteries, intense nodular tumor stains and early draining veins [2].

Intramedullary metastases Intramedullary metastases are rare, accounting for only 5% of all intramedullary lesions [15]. They are less common than leptomeningeal metastases [8]. The lung and breast are the most common sites of primary malignancies for intramedullary spread [28].

Primary intramedullary lymphomas Primary intramedullary lymphomas of the spine are very rare—only 3.3% of primary intramedullary lymphomas are estimated to occur in the spine [29]. They are most often predominantly histiocytic or mixed histiocytic and lymphocytic [30]. They can present as a single or as multiple lesions throughout the

Fig. 2 Schwannoma. Sagittal T2-weighted (**a**) and contrast-enhanced T1-weighted (**b**) images demonstrate a small lobular contrast-enhancing intraspinal schwannoma at the L2–L3 level
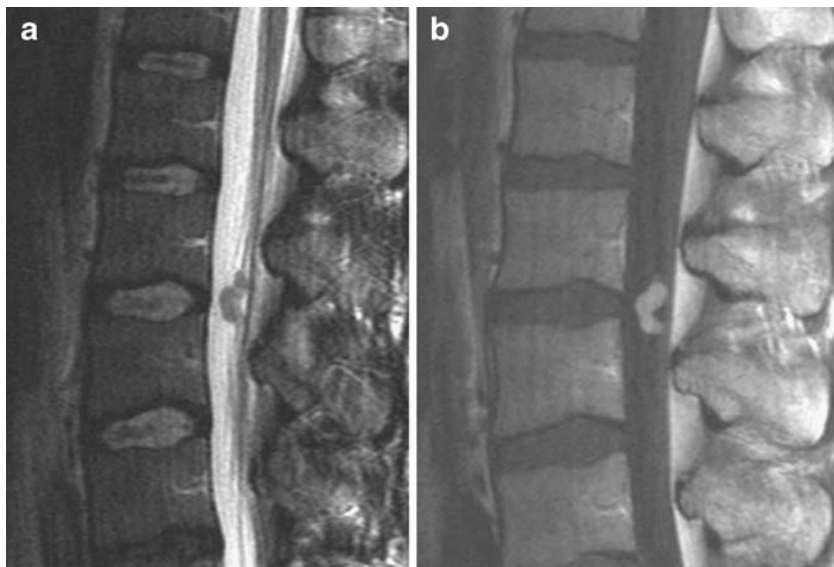
spinal cord, most commonly in the cervical region followed by thoracic and lumbar regions [30–32]. The majority (85%) are non-Hodgkin lymphomas [31].

MRI findings of intradural spinal tumors

The imaging modality of choice for the evaluation of intradural spinal tumors is MRI. The MRI protocol for examination of the spine and spinal cord may vary slightly between institutions depending on the type of MR scanner (manufacturer and field system), but in general several phased-array spine coils should be used simultaneously to obtain a large field of view. The imaging protocol should include sagittal and axial T1-weighted and T2-weighted sequences including contrast-enhanced sagittal and axial T1-weighted sequences [33, 34] and if needed also coronal images. The short-time inversion recovery (STIR) sequence is excellent for evaluating intramedullary cord lesions as well as marrow and soft tissue edema. The fluid-attenuated inversion-recovery (FLAIR) sequence has been recently

Fig. 3 Schwannoma. **a–d** Sagittal T2-weighted image (**a**), and sagittal (**b**), coronal (**c**) and axial (**d**) contrast enhanced T1-weighted images demonstrate a large right-side intense but mildly heterogeneously enhancing "dumbbell" shaped intra- and extradural tumor at the L3–L4 level with associated cord edema. **e** Sagittal 2-D reconstructed CT image of the spine demonstrates enlargement of the neural foramen and scalloping of the posterior aspect of the L3 vertebral body
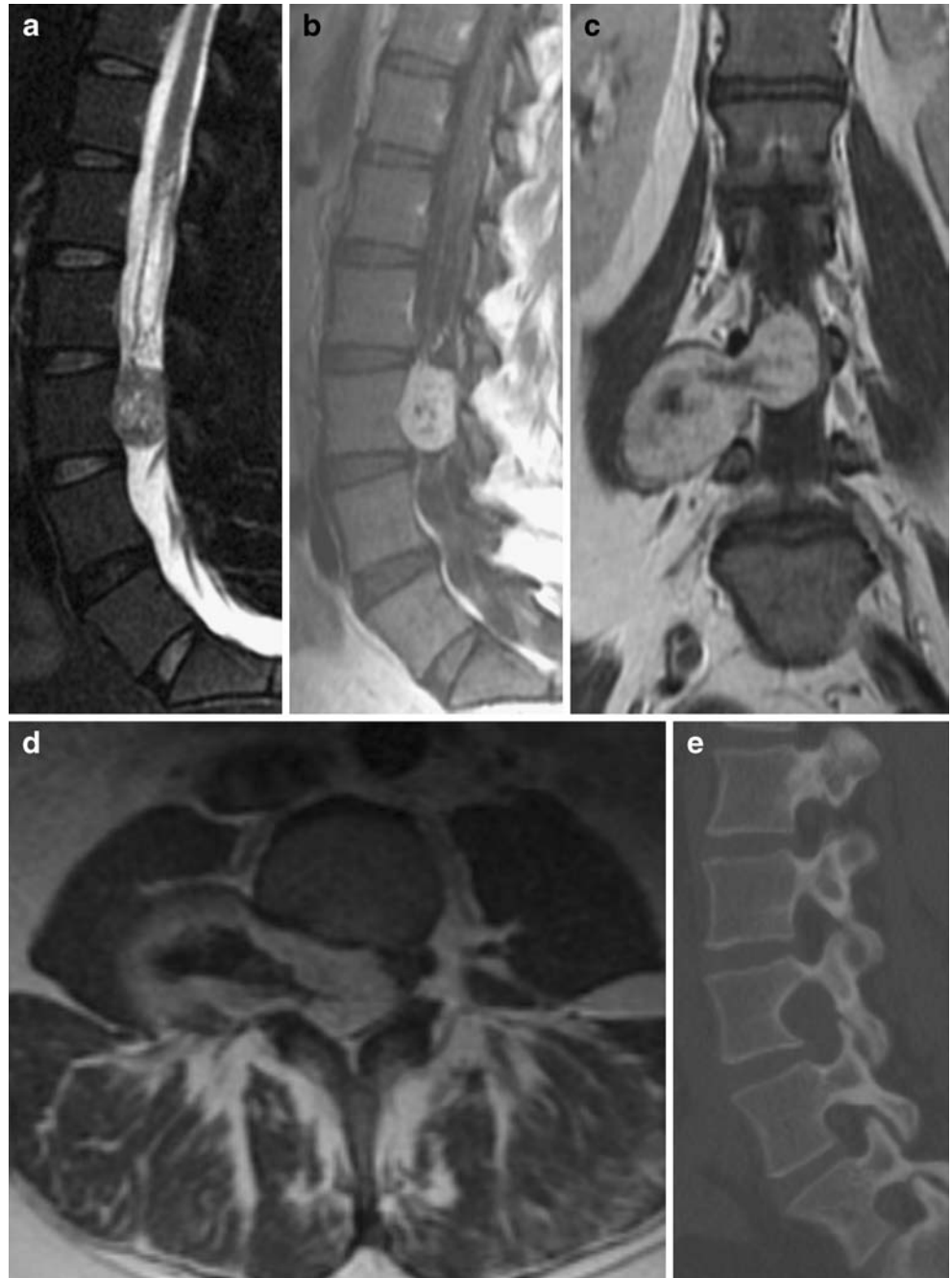
introduced into spinal imaging and has been rated superior to conventional T2-weighted MR sequences for the detection of leptomeningeal pathologies in the brain [35], and is considered helpful in the detection of subtle intramedullary lesions [5, 36]. However, the use of FLAIR for imaging spinal cord lesions remains controversial [37]. Contrast-enhanced images are important to define the extent of the lesion and are useful in distinguishing associated cysts or syrinx from neoplastic involvement and are important in postoperative follow-up [1]. The imaging protocol for the work-up of suspected intradural spinal tumors may slightly vary depending on the degree of clinical suspicion, suspected location, field-strength of the MR scanner, and institution. A basic routine MR protocol should include the following sequences: sagittal and axial unenhanced and contrast-enhanced T1-weighted imaging, and sagittal and axial fast spin echo T2-weighted imaging with a slice thickness of 3–4 mm and an interscan spacing of 0.5–1 mm. Diffusion-weighted MR imaging (DWI) can be added if clinically warranted (in patients in whom spinal cord ischemia is suspected). At our institution we have found sagittal T1-weighted FLAIR images helpful, especially in detection of meningeal metastases.

DWI and diffusion tensor MR imaging (DTI) have been proven useful in brain tumors and may also be an additional tool for the evaluation of spinal tumors [38]. DTI was used to successfully characterize five spinal cord astrocytomas [39]. Fractional anisotropy (FA) values have been shown to be similar for astrocytomas, ependymomas, and metastases (0.48, 0.5, 0.46, respectively), but are different for hemangioblastomas (0.59) [40]. The lowest FA values are seen in metastases and the highest in hemangioblastomas. Furthermore, surrounding edema may be separated from tumor using FA maps, and fiber-tracking may show warped fibers or fibers destroyed by tumor [40].

Intradural extramedullary tumors

Meningiomas Meningiomas are often solid, well-circumscribed lesions with broad attachment to the dura. The dura tail and calcification may be seen, but they are less common than in the intracranial meningiomas. Meningiomas are iso- to hypointense on T1-weighted images and slightly hyperintense on T2-weighted images. In general, meningiomas demonstrate strong homogeneous enhancement after gadolinium administration, except for calcified areas [41]. Meningiomas cause compression and displacement of the spinal cord. Signal changes in the spinal cord secondary to compression can be seen, but are usually rare (Fig. 1).

Schwannomas Schwannomas are usually solid tumors typically seen in the dorsal sensory roots in the lumbar region. They displace the spinal cord, conus medullaris, or filum terminale to the contralateral side as they arise from the nerve roots. The schwannomas are commonly iso-intense on T1-weighted images and markedly hyperintense on T2-weighted images. Based on imaging findings, it is difficult to distinguish schwannomas from neurofibromas in patients with NF-II. Hemorrhage and calcifications are uncommon. Contrast enhancement may vary and can be intense and homogeneous or only show faint peripheral enhancement [41] (Fig. 2). When the contrast enhancement is faint or absent, it can be difficult to distinguish the tumor from perineural cysts, which are a common incidental radiological finding. When large they extend into the neural foramina and prevertebral space in a "dumbbell" fashion,

Fig. 4 Paraganglioma. Sagittal T2-weighted (**a**), unenhanced T1-weighted (**b**), and contrast-enhanced T1-weighted (**c**) images demonstrate a well-circumscribed, intradural extramedullary tumor filling the anterior spinal canal at the craniocervical junction, causing compression of the anterior aspect of the cervical cord. The tumor shows intense homogeneous enhancement after injection of gadolinium DTPA (Sundgren P et al, *Neuroradiology* 1999;41;788–794: Paraganglioma of the spinal canal; Fig. 3. Reprinted with the kind permission of Springer Science and Business Media)
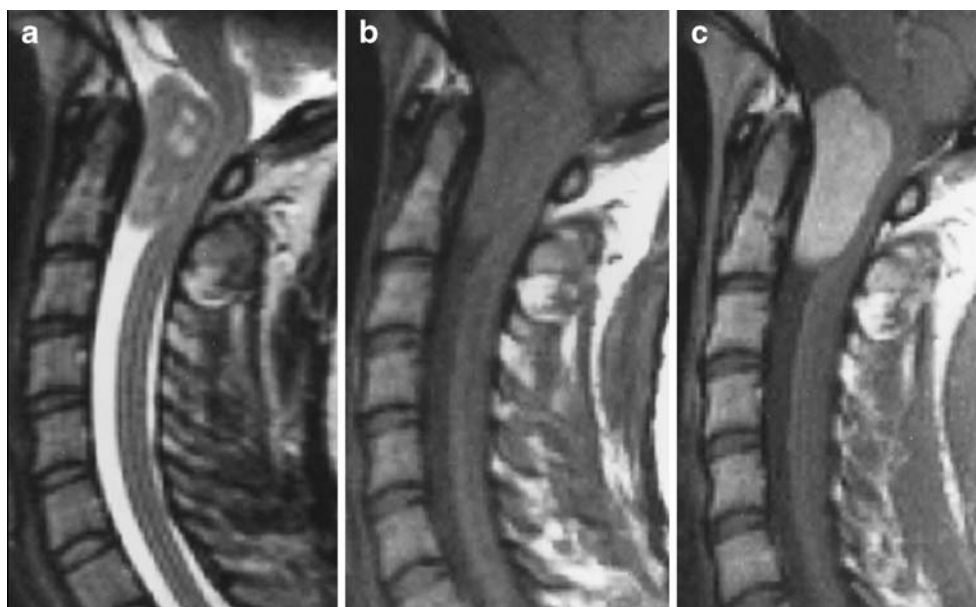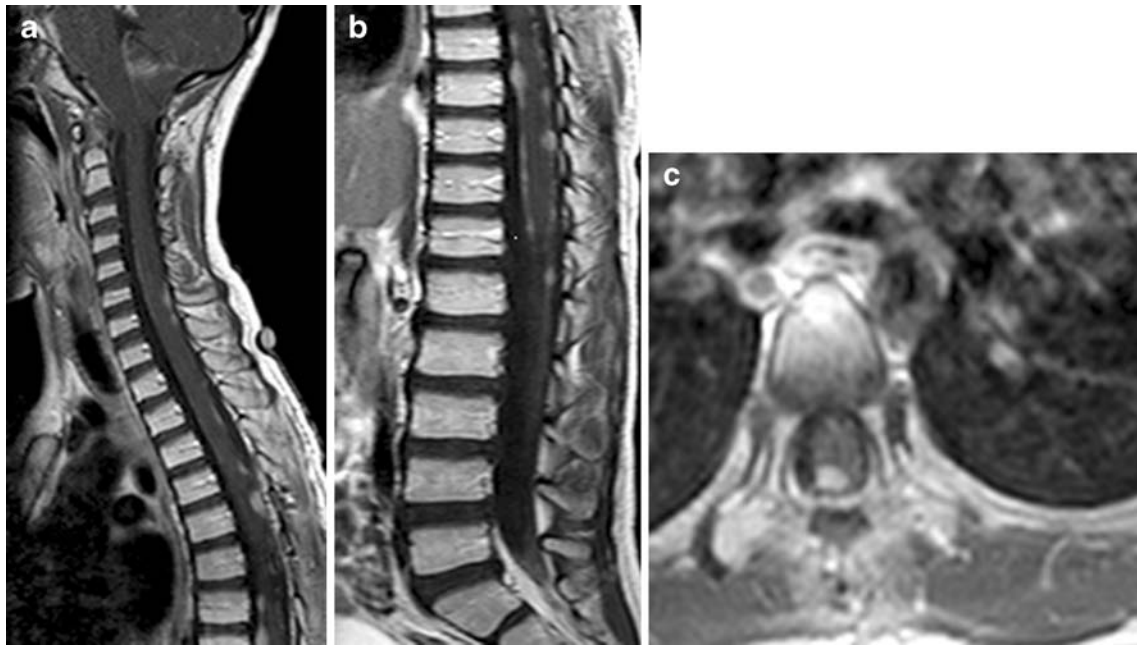
Fig. 5 Leptomeningeal metastases in an 8-year-old boy with primary medulloblastoma/PNET. Sagittal (**a**, **b**) and axial (**c**) contrast-enhanced T1-weighted images demonstrate multiple nodular and diffuse leptomeningeal enhancement throughout the entire spine

and may, if longstanding, result in enlargement and remodeling of the foramina and erode or cause scalloping of the posterior aspect of the vertebral body (Fig. 3).

Neurofibromas Neurofibromas encase rather than displace the nerve roots. They commonly tend to be relatively small and scattered. They are typically rounded or fusiform tumors that are isointense on T1-weighted images and markedly hyperintense on T2-weighted images. After injection of gadolinium, intense and homogeneous enhancement is seen. Some neurofibromas show only peripheral enhancement. Multiple and plexiform neurofibromas are often seen in patients with neurofibromatosis type I (NF-I) [42–45]. An important differential diagnosis in multiple neurofibromas is intradural extramedullary metastasis, especially in patients who do not have NF-II. Scalloping of the posterior vertebral bodies can be present in longstanding, slow-growing tumors.

Paragangliomas Spinal paragangliomas are heterogeneous tumors commonly found in the conus medullaris, cauda equina, and filum terminale. They are isointense on T1-weighted images, hyperintense on T2-weighted images, and demonstrate marked contrast enhancement. Hemorrhage and intratumoral vessels with flow voids are common features of this tumor [12, 13] (Fig. 4).

Leptomeningeal metastases Leptomeningeal metastases may present with three different imaging patterns: (1) diffuse, thin, enhancing coating of the surface of the spinal cord and nerve roots; (2) multiple small enhancing nodules on the surface of the cord and/or nerve roots; and (3) as a single mass in the lowest part of the thecal sac [5, 13, 46] (Fig. 5). A unenhanced MR T1-weighted images might be normal or demonstrate nodular lesions that are isointense to the spinal cord. Whereas the contrast-enhanced images of intradural extramedullary lesions demonstrate significant enhancement.

Fig. 6 Cellular ependymoma in a 40-year-old woman. Sagittal T2-weighted (**a**) and unenhanced T1-weighted (**b**) images demonstrate a focal mass, small cyst formation and an associated syrinx in the lower thoracic cord. The focal lesion demonstrates hemorrhagic components with hemosiderin deposits peripherally which is a common finding in ependymomas

Fig. 7 Myxopapillary ependymoma in a 40-year-old male with a history of back pain and numbness in the lower extremities. Sagittal T2-weighted image (**a**), and unenhanced (**b**) and contrast-enhanced (**c**) T1-weighted images, demonstrate a well-defined homogeneously enhancing mass in the conus at the level of the T12–L1 intervertebral disc space
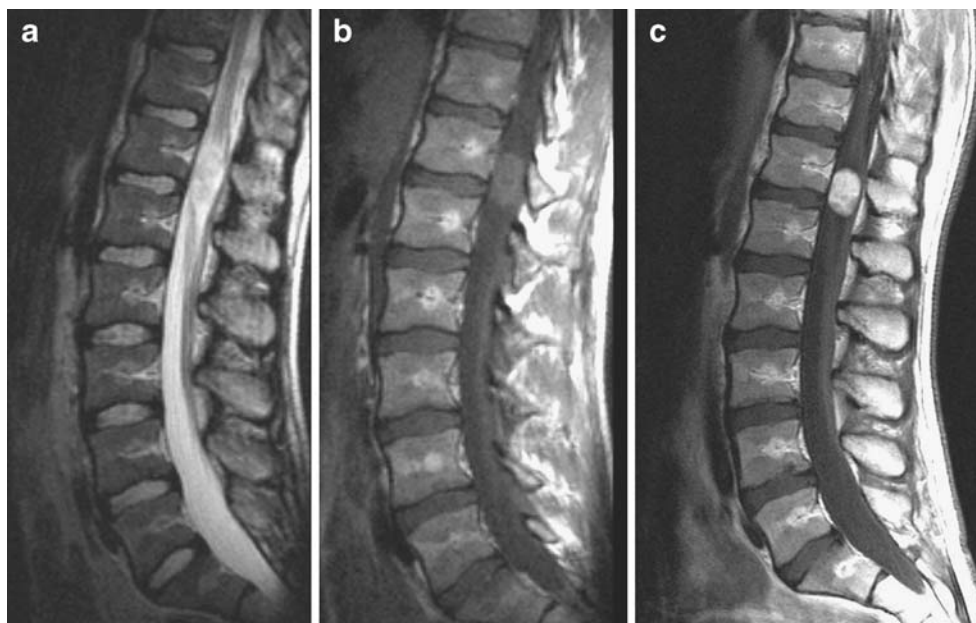
Meningeal lymphomas Meningeal lymphomas (lymphomatous meningitis) is seen on MR images as diffuse thickening of the nerve roots and/or multiple enhancing nodules.

Intramedullary tumors

Cellular ependymomas Cellular ependymomas (cellular or mixed) are commonly present in the cervical or upper thoracic region as a focal enlargement of the cord. They arise from the ependyma-lined central canal and are therefore often concentric in location. The intramedullary ependymomas are fairly well-circumscribed masses, commonly hyperintense on T2-weighted images and hypointense or isointense to cord on T1-weighted images [10, 23, 47–49]. They demonstrate marked but often heterogeneous enhancement, and polar cyst formations and hemorrhage are common as illustrated in Fig. 6, whereas calcification is rare. Syrinx is also a characteristic finding especially with cervical ependymomas. Spinal cord edema on either side of the tumor is variable, but often seen in the large multi-segmental tumors.

Myxopapillary ependymomas Myxopapillary ependymomas are by far the most common tumors of the conus medullaris and filum terminale. They may vary in size and, if very large, are associated with scalloping of the vertebral

Fig. 8 Pilocytic astrocytoma in a 3-year-old girl. Sagittal T2-weighted (**a**), T1-weighted FLAIR (**b**) and contrast-enhanced T1-weighted (**c**) images of the cervical spine demonstrate an expanded cord with a large, heterogeneously enhancing cervicomedullary tumor with surrounding cord edema. The findings are consistent with a pilocytic astrocytoma
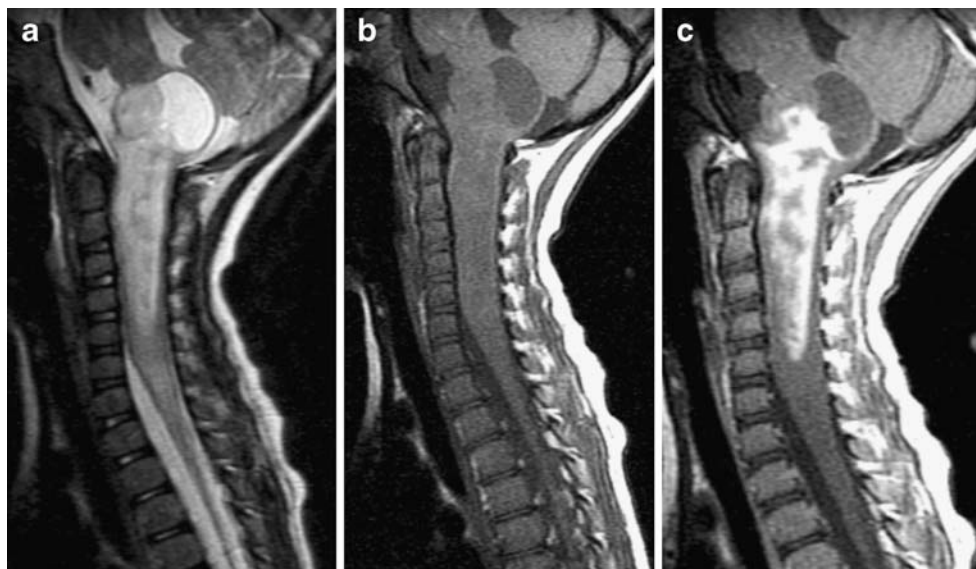
Fig. 9 Fibrillary astrocytoma. **a** Sagittal T2-weighted image demonstrates a heterogeneously hyperintense lesion in the cervical cord. **b** Unenhanced T1-weighted image shows an isointense lesion with mild heterogeneous hyperintensity in the periphery that may represent blood products. **c** Contrast-enhanced T1-weighted image shows marked heterogeneous enhancement. Histopathology confirmed fibrillary astrocytoma
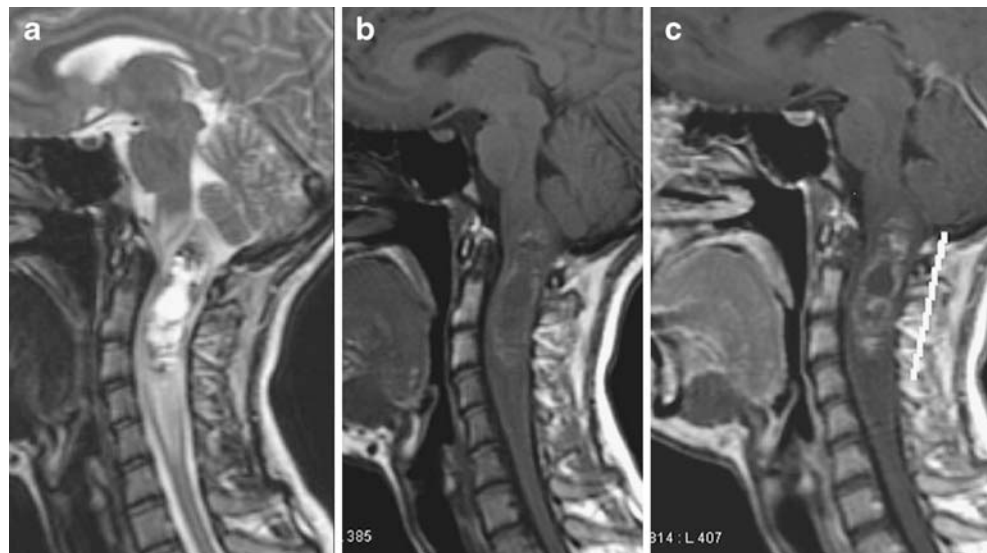
body, scoliosis, and enlargement of the neural foramina. They present usually as a hyperintense mass on T2-weighted images and are iso/hyperintense on T1-weighted images. They can be hyperintense on T1-weighted images because of their mucin content or hemorrhage and demonstrate strong somewhat inhomogeneous enhancement. Hemorrhage and cyst formations are common features that contribute to signal inhomogeneity (Fig. 7).

Astrocytomas Astrocytomas present as focal fusiform expansions of the cord with irregular tumor margins and with cystic components and associated edema and syrinx. They are asymmetrical and located off-center [10, 50], and are usually hypo- to isointense on T1-weighted images and hyperintense on T2-weighted images [10]. On MRI

astrocytomas may be indistinguishable from ependymomas [1]. Pilocytic astrocytomas (WHO grade I) may enhance homogeneously or have patchy enhancement or no enhancement at all [50, 51] (Figs. 8 and 9). Nearly all spinal astrocytomas enhance with a uniform or heterogeneous enhancement pattern [5, 51] but it has been reported that diffuse astrocytomas (WHO II) might not enhance at all or only demonstrate faint enhancement [52]. Astrocytomas occur most commonly in the cervical and thoracic cord. Typically, the tumor affects fewer than four segments of the spinal cord, but multisegmental, even holocord, tumors occur, especially with pilocytic astrocytoma [8, 53].

Spinal gangliogliomas Spinal gangliogliomas are most commonly present in the cervical and upper thoracic cord.

Fig. 10 Hemangioblastoma. **a**, **b** Sagittal T2-weighted image (**a**) demonstrates a hyperintense lesion in the lower cervical cord that is isointense on the unenhanced T1-weighted image (**b**). **c** After contrast enhancement, there is a small homogeneously enhancing nodulus, which is a classic finding in spinal cord hemangioblastoma
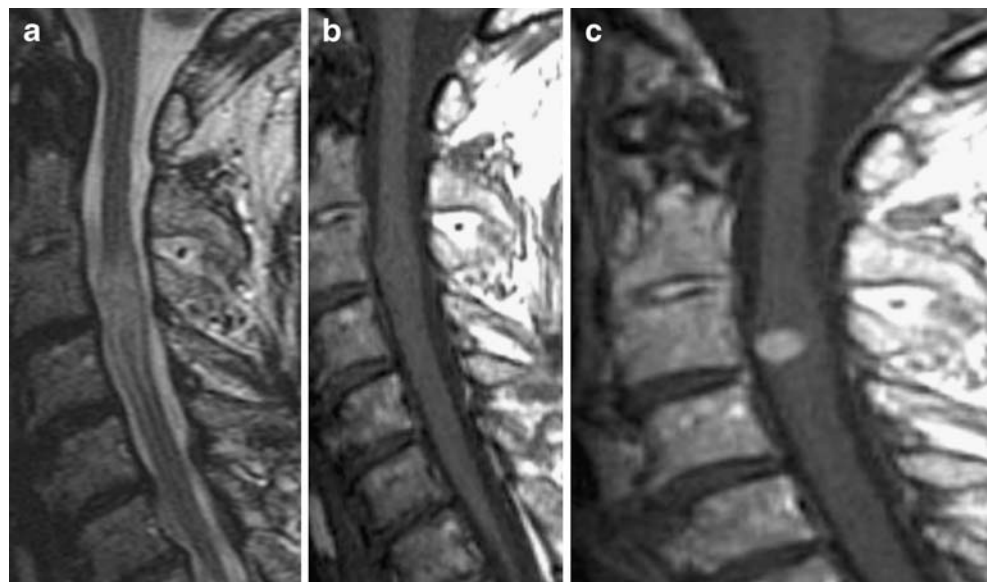
Fig. 11 Leptomeningeal and intramedullary metastases. **a** Sagittal T2-weighted image of the cervicothoracic spine shows an oval intramedullary lesion at T1 with cord expansion and associated edema of the spinal cord. **b** Contrast-enhanced T1-weighted image shows a homogeneously enhancing lesion . **c** Contrast-enhanced T1-weighted FLAIR image of the lumbar spine also shows a small, enhancing, nodular lesion at L4, which represents leptomeningeal metastasis. Note the improved contrast between CSF and the lesion on the T1-weighted FLAIR image


The tumor is typically eccentric in location and often involves long segments of the spinal cord. The tumor is associated with bone erosion or scalloping, and demonstrates areas of mixed signal on T1-weighted images, prominent tumoral cyst, and patchy enhancement extending to the surface of the cord. A lack of edema, and the absence of hemosiderin are other features of spinal gangliogliomas [24, 25].

Hemangioblastomas Most hemangioblastomas (75%) present as a focal spinal cord mass. Small hemangioblastomas are often isointense on T1-weighted images and hyperintense on T2-weighted images, and demonstrate homogeneous contrast enhancement. Larger tumors have a tendency to be iso- to hypointense on T1-weighted images, with a heterogeneous signal on T2-weighted images, and heterogeneous enhancement [54, 55]. Hemorrhage, mural noduli, as well as flow void caused by enlarged feeding/draining vessels, contribute to signal inhomogeneity and heterogeneity of the contrast enhancement in large tumors. Syrinx and spinal cord edema are characteristic findings even in small tumors (Fig. 10).

Intramedullary metastases Intramedullary metastases have a nonspecific MRI appearance, with cord swelling, edema, and an enhancing lesion. The edema is often disproportionately extensive compared with the small enhancing lesion [5, 14, 28]. However diagnostic difficulties in distinguishing intramedullary metastases from other nonneoplastic lesions of the spinal cord might arise, especially with multiple sclerosis, and some infectious lesions (Fig. 11).

Intramedullary lymphomas Intramedullary lymphomas have a nonspecific MR appearance with slightly ill-defined T2 hyperintensity and marked solid contrast enhancement on T1-weighted images. They may present as a focal or
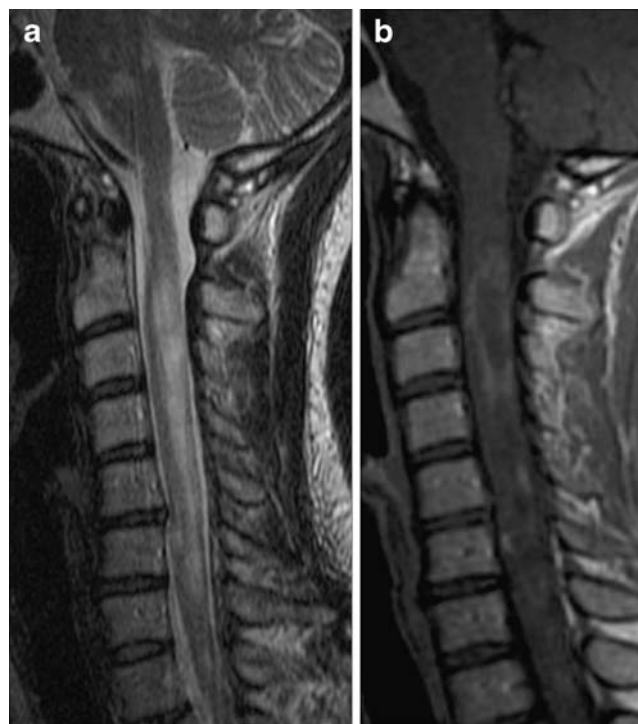
Fig. 12 Acute multiple sclerosis plaque in the spinal cord in a 25 -year-old male with radiculopathy and myelopathy. **a** Sagittal T2-weighted image of the cervical spine shows increased signal in a mildly expanded cord extending from C2 to C7. **b** Contrast-enhanced T1-weighted image shows extensive heterogeneous enhancement consistent with a large acute multiple sclerosis plaque

Fig. 13 Transverse myelitis in a 45-year-old male with myelopathy. **a** Sagittal T2-weighted image shows a focal lesion with increased signal in the thoracic cord. **b, c** Contrast-enhanced sagittal (**b**) and axial (**c**) T1-weighted images show mild homogeneous contrast enhancement of the right laterally located lesion consistent with transverse myelitis

multifocal lesions in the spinal cord and with less severe cord enlargement as with other intramedullary tumors [29–32, 56].

## The main differential diagnoses of intradural spinal tumors

There are several lesions that can mimic intradural neoplasms such as vascular malformation (i.e. cavernous hemangioma and dural arteriovenous fistula), tumefactive multiple sclerosis (MS) (Fig. 12), transverse myelitis (Fig. 13), cord contusion and cord infarction, to mention just a few. Among the vascular malformations spinal cord cavernous hemangiomas especially may mimic an intradural spinal cord tumor. Cavernous hemangiomas accounts

for 5–12% of all vascular spinal abnormalities [57–60]. The cavernous malformation is commonly hyperintense on T2-weighted images and isointense on T1-weighted images, and demonstrates fairly homogeneous contrast enhancement on MR imaging [57–60] (Fig. 14). Because of the risk of bleeding of these lesions, MRI with T2* weighting is helpful to detect blood or its breakdown products within the lesion.

The differential diagnoses of intradural extramedullary tumors also include the following:

1. Cysts and cyst-like lesions:

    Arachnoid cyst
    Perineural cyst
    Epidermoid, dermoid, and teratoma
    Neuroenteric cyst
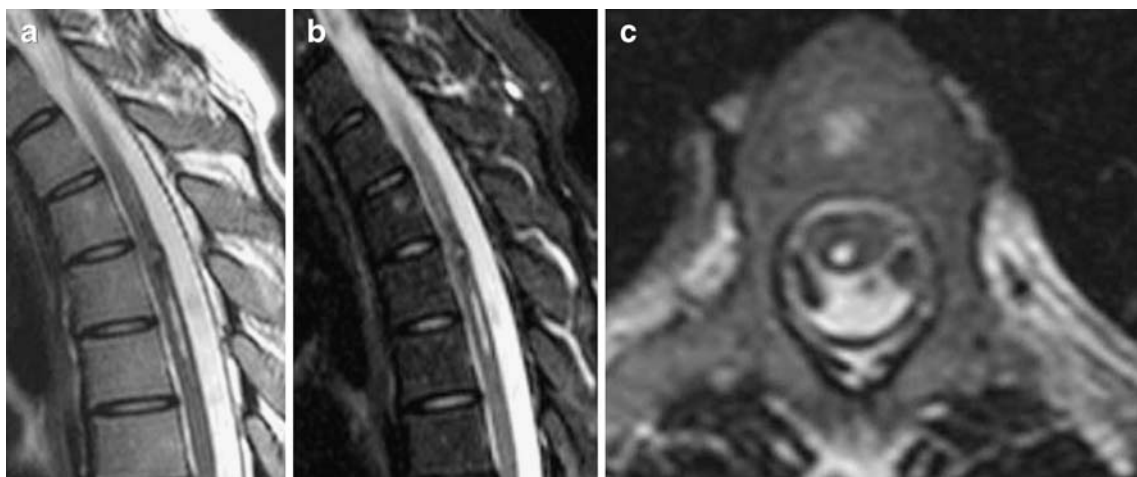
Fig. 14 Cavernous hemangioma. Sagittal T2-weighted (**a**) and STIR (**b**) images and axial T2-weighted image (**c**) show a "pop-corn-like" lesion with central high signal intensity and a hypointense surrounding rim (hemorrhage) in the right posterior aspect of the upper thoracic cord

2. Degenerative:

>   Disc extrusion
>   Synovial cyst

3. Inflammatory conditions affecting the nerve roots:

>   Guillain-Barré syndrome
>   Arachnoiditis
>   HIV-related neuritis
>   Chronic interstitial demyelinating polyneuropathy (CIDP)

4. Infectious:

>   Viral
>   Bacterial
>   Parasitic

5. Granulomatous:

>   Sarcoidosis
>   Wegener's granulomatosis

The differential diagnoses of intramedullary tumors also include the following:

1. Multiple sclerosis (MS)
2. Transverse myelitis
3. Acute disseminated encephalomyelitis (ADEM)
4. Cord infarction
5. Syringohydromyelia
6. Cord contusion
7. Abscess
8. Tuberculosis
9. Arteriovenous malformation and dural fistulae
10. Sarcoidosis
11. Myelopathy secondary to cord compression due to degenerative changes

One should bear in mind that the clinical presentation of many of these differential diagnoses is more acute with a more abrupt onset of neurological deficits or symptoms than the clinical presentation of most intradural spinal tumors. The differential diagnoses are also commonly associated with other clinical symptoms or causes such as viral or bacterial infection, or trauma, or with known underlying disease such as multiple sclerosis, diabetes, sarcoidosis or known drug abuse, to mention just a few examples.

Conclusion

In conclusion, intradural spinal tumors may be difficult to distinguish based on imaging alone and additional information and clinical features, such as symptoms, age, gender, and location, are helpful in the final diagnosis.

MRI is the imaging modality of choice for the evaluation of spinal tumors, and particularly for spinal cord tumors. MRI is the only method that has a sensitivity high enough to depict intraspinal and spinal cord abnormalities. Therefore, all patients with any neurological deficits, prepontine SAH or clinical symptoms suggestive of spinal infection or demyelinating disease should have a scheduled unenhanced and contrast-enhanced MRI of the spine as part of their work-up. Also patients with skeletal abnormalities such as scalloping of vertebral bodies or enlarged neural foramina seen on plain films or CT images should undergo MRI of the spine. The imaging protocol may vary from institution to institution, but any imaging protocol for work-up of suggested intradural spinal tumor should include T2-weighted and both unenhanced and contrast-enhanced T1-weighted images in the sagittal and axial projections. Images in the coronal projection can also be helpful for delineating the extent of the tumor prior to surgery. Also, T2* images might be helpful to detect blood or its breakdown products in, for example, ependymomas or cavernous malformations. Patients in whom MRI is contraindicated should be examined with CT or CT myelography.

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