

MRI of Conus Medullaris, Cauda Equina, and Filum Terminale Lesions

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After participating in this educational activity, the radiologist should be better able to diagnose conus medullaris, cauda equina, and filum terminale lesions on MRI.

Category: Neuroradiology
Modality: MRI

Key Words: Cauda Equina, Filum Terminale, Spinal Nerve Roots, Conus Medullaris

Cauda equina is the Latin name for horse's tail because the cauda equina resembles a horse tail. The cauda equina is a set of 10 paired dorsal and ventral nerve roots (20 nerve roots in total), corresponding to four lumbar (second to fifth), five sacral, and one coccygeal segments that originate from the conus medullaris. These nerve roots are contained by the thecal sac, which is an enclosed space formed by dura mater and arachnoid extending from the head to the sacrum. The conus medullaris is an expansion of the terminating distal thoracic spinal cord, typically located at the T12-L1 level.

As the cauda equina nerve roots exit the thecal sac at each level, they move in pairs to the lateral recess, which is a tubular reflection of meninges located at the anterolateral portion of the thecal sac, and decline in number as they extend caudally from 20 nerve root pairs at L2-L3 to 11 nerve root pairs at L5-S1 and one coccygeal nerve root pair at S5-C1.

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Finally, the filum terminale, which is a fine strand of fibrous tissue embedded in the cauda equina, is formed by a prolongation of the pia, and it extends from the conus medullaris to the termination of the thecal sac at the inferior border of S2.

Imaging Consideration

The best way to assess the cauda equina is with MRI of the lumbar spine with and without contrast medium. High-field strength MR magnets (≥ 1.5 T) allow evaluation of the nerves, their size, enhancement, and involvement by a pathologic process.

Pathology of the cauda equina can arise from a nerve root, pia mater, or arachnoid space. The etiology can be primary or secondary via direct or hematogenous spread of disease. Pathology can be classified in multiple ways. A simple classification into malignant, inflammatory, vascular, infectious, and congenital is considered in this article. The purpose of this article is to review the most common pathologies of the conus medullaris, cauda equina, and filum terminale with emphasis on MRI findings.

Neoplastic

Ependymoma. Ependymoma is the most common spinal intramedullary neoplasm in adults.¹ The most common location is the cervical region, and only about 6.5% involves the distal spinal cord or the conus medullaris. Typically, patients initially present with mild symptoms that often lead to a delay in diagnosis. Spinal cord ependymomas arise from ependymal cells that line the central canal, which explains the central location and symmetrical appearance of ependymomas. Most spinal cord ependymomas



Figure 1. Ependymoma in a 26-year-old woman with paresthesia. Sagittal, contrast enhanced, T1-weighted MR image demonstrates intense enhancing mass with enlargement and infiltration of the conus medullaris and cauda equina filling and distending the thecal sac at the upper lumbar spine (arrow). Given location, appearance, and age of patient, myxopapillary ependymoma should be the primary consideration. Findings were confirmed at surgery.



Figure 2. Schwannoma in a 43-year-old woman who presented with chronic lower back pain. Sagittal, contrast enhanced, T1-weighted MR image demonstrates an intradural, extramedullary, peripherally enhancing cystic mass (arrow) without evidence of a dural tail. Given location, cystic appearance, and lack of dural tail, schwannoma was suggested and confirmed at surgery.

are iso- or hypointense relative to the spinal cord on T1-weighted sequences and iso- to hyperintense on T2-weighted sequences. About 20% to 33% demonstrate the “cap sign,” a hypointense rim (hemosiderin) seen at the poles of the tumor on T2-weighted sequences. The cap sign is thought to be secondary to hemorrhage. Most ependymomas exhibit enhancement on MR images. A special variant of ependymoma, the myxopapillary ependymoma (Figure 1), constitutes about 13% of all spinal ependymomas,¹ and it has been reported at all ages, with peak age at 30 to 40 years. These mucoid tumors arise from the ependymal glia of the filum terminale, and constitute the most common neoplasm in this region. Myxopapillary ependymomas are typically isointense relative to the spinal cord on T1-weighted images and hyperintense on T2-weighted images. Enhancement always is present on MR images.

The cervical spinal cord is the most common site of spinal intramedullary ependymomas.

Schwannoma. Schwannoma is the most common intradural, extramedullary spinal mass. It can present as an intradural, extramedullary mass (70%); transforaminal mass (15%); or extradural mass (15%). Most schwannomas are solitary (90%) and present within the fifth or sixth decade. However, when schwannomas are associated with neurofibromatosis type 2 (NF-2), they tend to present at a younger age. Imaging depends on the cellular content of Antoni A (densely packed and arranged in fascicles) and Antoni B (loosely packed and more prone to cystic degeneration)² (Figure 2). On T1-weighted images, schwannomas are typically iso- to hypointense relative to the spinal cord and nerve root. Typically, schwannomas are hyperintense on T2-weighted sequences, and they can be cystic and can contain blood products.

Spinal schwannomas present as an intradural, extramedullary mass (70%); transforaminal mass (15%); or extradural mass (15%).

Neurofibroma/Neurofibromatosis Type 1

Commonly related to neurofibromatosis type 1 (NF-1), von Recklinghausen disease is an autosomal dominant

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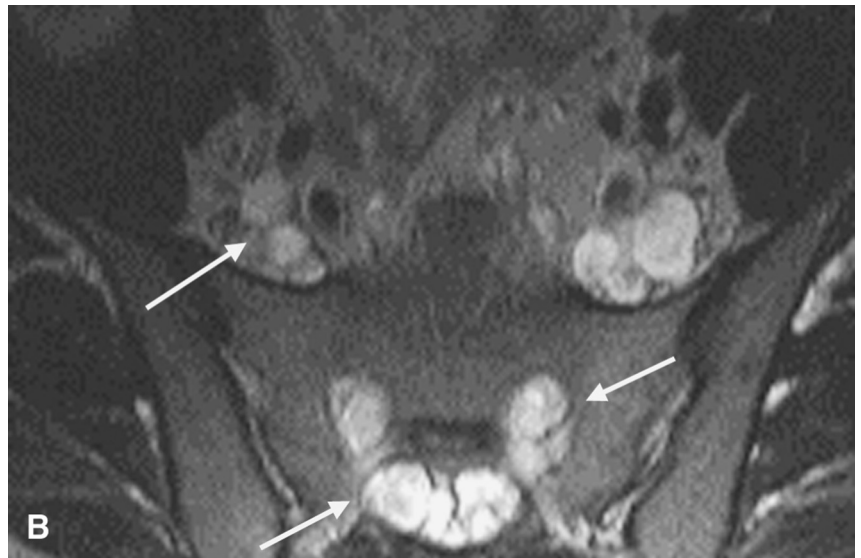
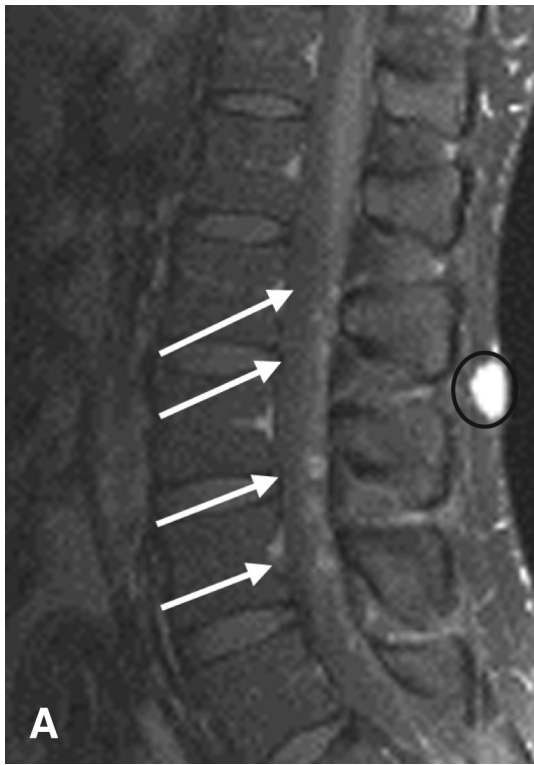


Figure 3. NF-1 that had been clinically diagnosed in a 24-year-old man with lower extremity neuropathy. *A:* Sagittal, contrast enhanced, T1-weighted MR image demonstrates nodular enhancement of the enlarged nerve roots (*arrows*) at the cauda equina and the subcutaneous neurofibroma (*circle*). *B:* Axial, T2-weighted MR image at the level of the pelvis demonstrates plexiform neurofibromatosis (*arrows*), a pathognomonic finding, with multiple hyperintense lesions with central hypointensity (the classic target sign).

disease resulting from a mutation of the neurofibromin gene 1. Hypoplastic posterior spinal elements and dural ectasia may be present. The cauda equina may be involved by neurofibromas that can be focal or plexiform. Plexiform neurofibromatosis (Figure 3) has a pathognomonic MRI finding and presents as large, bilateral, multilevel lesions with predilection for sciatic nerves and the brachial plexus.³ Nerve root neurofibromas typically are T1-isointense and T2-hyperintense with variable postcontrast enhancement.

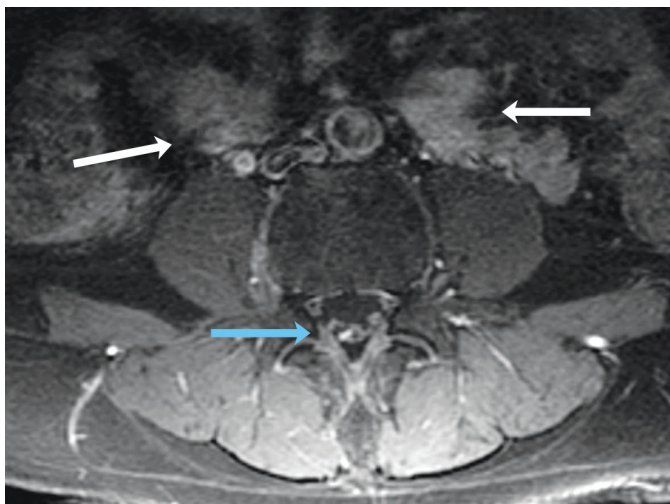


Figure 4. Lymphoma in a 65-year-old man with right lower extremity motor deficits. Axial, T1-weighted, contrast enhanced MR image demonstrates thickening and enhancement of a right nerve root, likely L5 (*blue arrow*). Also present are retroperitoneal, enlarged, enhancing lymph nodes (*white arrows*). Further imaging (*not shown*) demonstrated diffuse systemic lymphadenopathy without evidence of a dominant mass. Lymphoma was suggested and confirmed at biopsy.

Plexiform neurofibromatosis presents as large, bilateral, multilevel lesions with predilection for sciatic nerves and the brachial plexus.

Lymphoma. Involvement of the spinal cord is an uncommon manifestation of lymphoma. Primary spinal lymphoma is less common than secondary lymphoma (hematogenous or direct extension), and non-Hodgkin lymphoma is the most common subtype. Although lymphoma more commonly involves the vertebral bodies or epidural compartment and leptomeninges, intramedullary lymphoma may rarely occur [3.3% of central nervous system (CNS) lymphoma]. Leptomeningeal disease

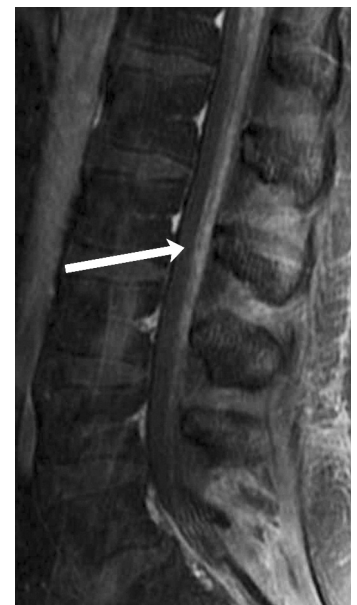


Figure 5. Pineal mass in a 17-year-old man with nausea and vomiting. MRI demonstrated a pineal mass resulting in obstructive hydrocephalus (*not shown*). Sagittal, T1-weighted, contrast enhanced MR image demonstrates leptomeningeal enhancement along the nerve roots (sugar-coating appearance) (*arrow*). These findings are consistent with drop metastases from a pineal germinoma.

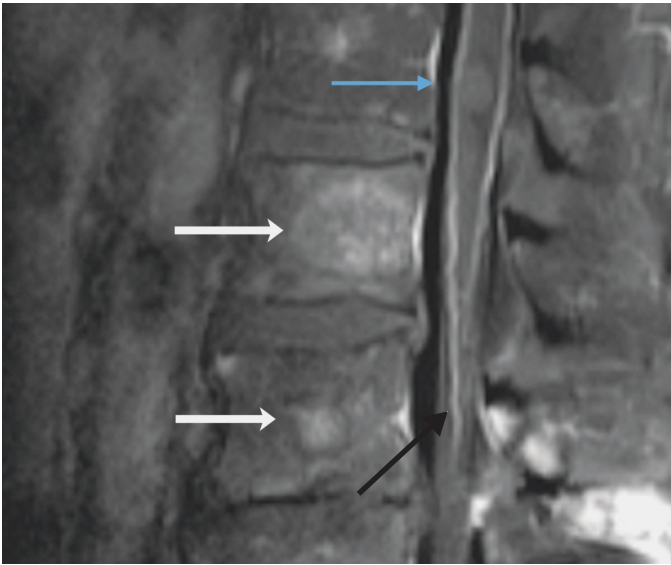


Figure 6. A 57-year-old woman with Stage IV breast cancer and lower extremity neuropathy. Sagittal, contrast enhanced, T1-weighted MR image demonstrates diffuse leptomenigeal enhancement affecting the distal cord (*blue arrow*) and cauda equina (*black arrow*), giving the appearance of sugar coating. There are also multiple lumbar spine osseous metastases (*white arrows*).

(Figure 4) typically presents with thickening of the nerve roots and smooth and/or nodular leptomenigeal enhancing lesions. Involvement of other organs and/or lymph nodes typically is present and aids in the diagnosis.

Metastasis. Intrathecal spinal metastases are rare and only 8% affect the lumbar region. When intrathecal spinal metastases affect the cauda equina, the leptomeninges are involved. Leptomenigeal routes of spread include hematogenous (arterial, Batson plexuses) and cerebrospinal fluid (CSF) drop metastases from intracranial malignancies.⁴ CNS tumors that can have leptomenigeal spread are in close proximity to or in contact with CSF and include glioblastoma, pineal masses (Figure 5), medulloblastoma, choroid plexus papilloma, and ependymoma among others. The most common extracranial

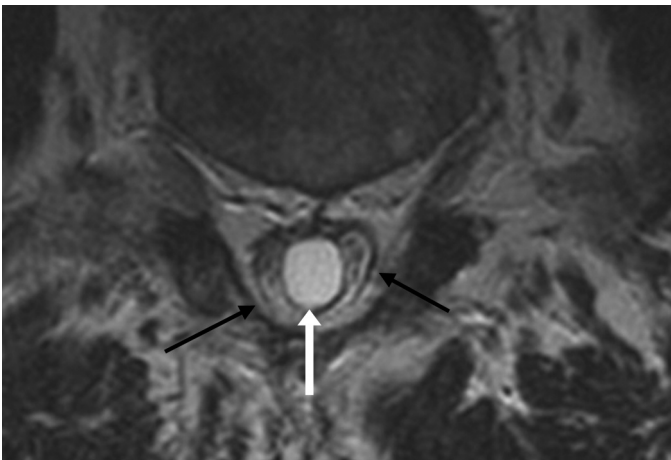


Figure 7. Arachnoiditis in a 49-year-old woman with prior back surgery. Axial, T2-weighted MR image demonstrates peripheral displacement and clumping of the cauda equina nerve roots (*black arrows*). There is also central CSF without visualization of nerve roots centrally (*white arrow*). This is known as the empty sac sign, and it is consistent with type 2 arachnoiditis.

malignancies to cause leptomenigeal spread are breast cancer (Figure 6) and lung cancer. Most patients tend to have rapid onset of significant symptoms. Prognosis is typically poor. Imaging appearance can vary with four common patterns: (1) solitary focal mass at the bottom of the thecal sac or along the spinal cord surface; (2) diffuse, thin, sheet-like coating of spinal cord/roots (carcinomatous meningitis); (3) rope-like thickening of the cauda equina; or (4) multifocal, discrete nodules along spinal cord/roots.

The most common extracranial malignancies to cause leptomenigeal metastasis are breast cancer and lung cancer.

Inflammatory

Arachnoiditis. Arachnoiditis is a postinflammatory process of the arachnoid affecting the thecal sac and cauda equina. Arachnoiditis is not a disease entity but rather a potential presentation of multiple etiologies including postoperative back, infectious spinal meningitis, hemorrhage,

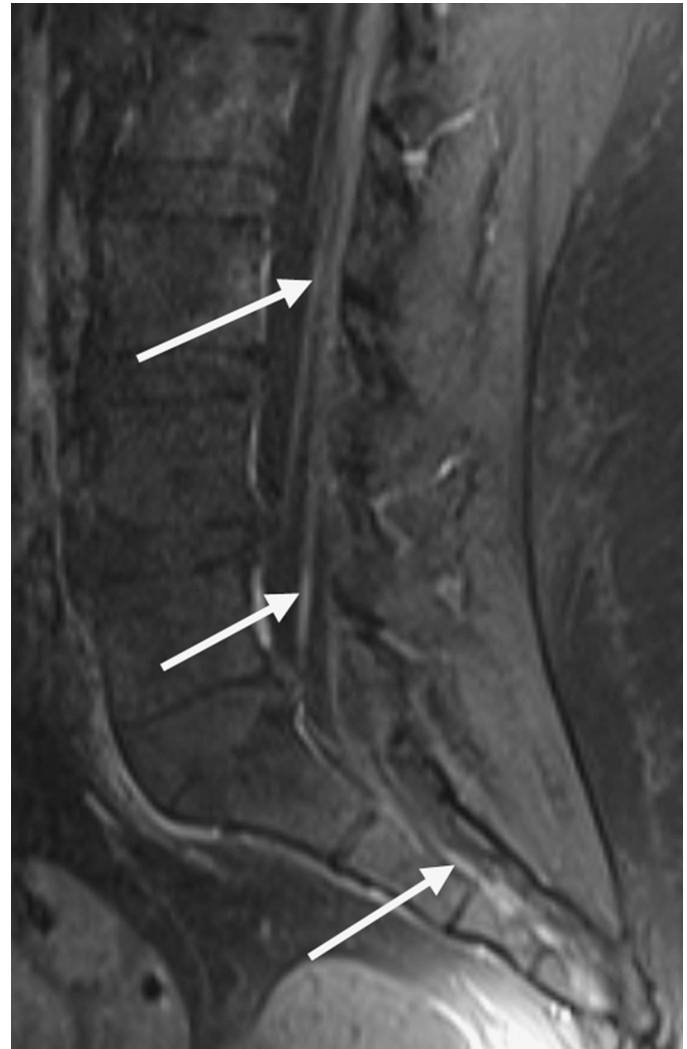


Figure 8. Guillain-Barre syndrome in a 34-year-old woman who presented with paralysis and acute respiratory failure after a history of recent viral infection. Sagittal, contrast enhanced, T1-weighted MR image of the lumbar spine demonstrates enhancement of the cauda equina nerve roots (*arrows*), which is consistent with peripheral polyneuropathy.

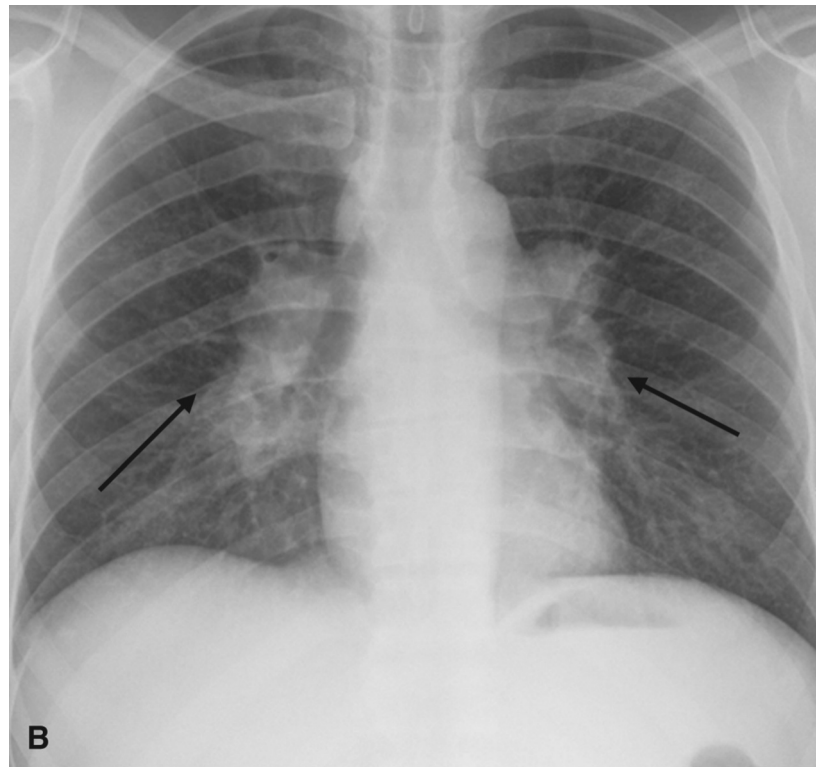
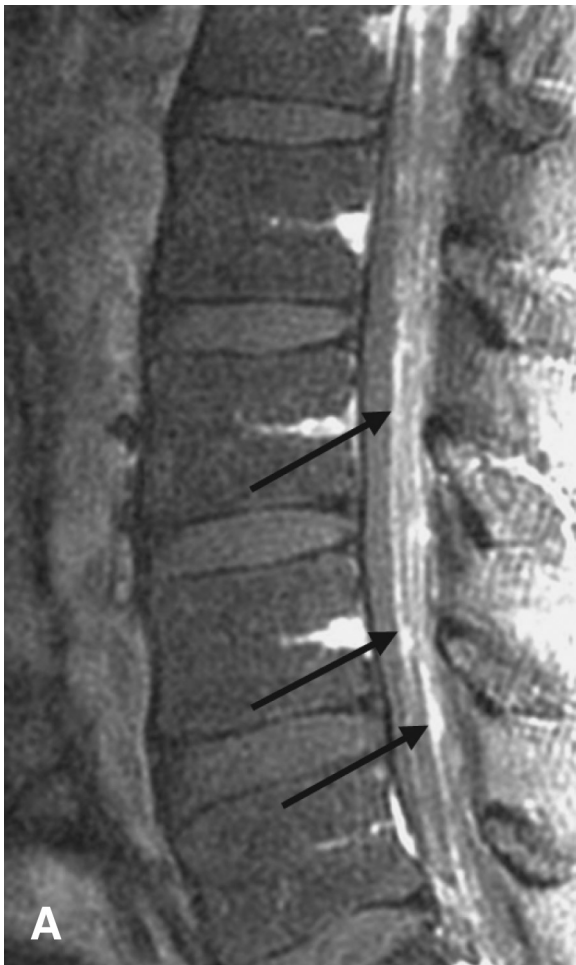


Figure 9. Sarcoidosis in a 29-year-old woman with initial presentation of paresthesia and neuropathy. *A:* Sagittal, T1-weighted, contrast-enhanced MR image demonstrates fine nodular leptomeningeal enhancement (arrows) with sugar-coating appearance. *B:* The leptomeningeal imaging findings are not specific, but further imaging demonstrated bilateral hilar adenopathy (arrows). Blood work demonstrated elevation of angiotensin-converting enzyme. These findings were consistent with the diagnosis of sarcoidosis.

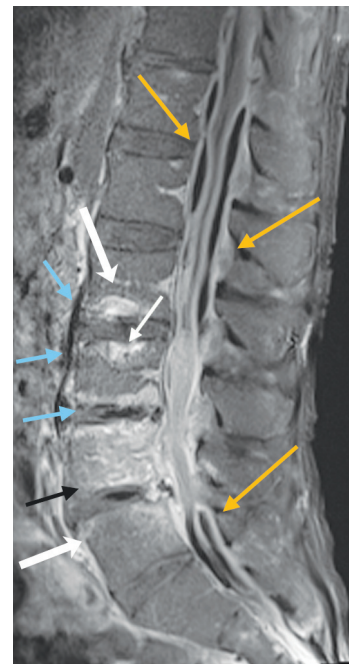
trauma, or degenerative disc disease. Arachnoiditis can be asymptomatic or symptomatic, and if symptomatic, it most commonly presents as chronic back pain with or without radiculopathy. Arachnoiditis involving the cauda equina is classified in three types based on the different MR appearances of the nerve root clumping pattern: Type 1, central clumping; Type 2, peripheral clumping without visualization of nerve roots centrally (“empty sac sign,” Figure 7); and Type 3, central, mass-like clumping with decreased thecal sac diameter and loss of subarachnoid space.

Guillain-Barre Syndrome. Guillain-Barre syndrome, an acute inflammatory demyelinating polyradiculoneuropathy, is an autoimmune postinfectious or postvaccinal acute inflammatory demyelination of peripheral nerves, nerve roots, and occasionally cranial nerves, presenting as an ascending neuropathy with rapidly progressive paralysis, with 20% to 25% of patients requiring assisted ventilation. It typically involves the cauda equina with predilection to the ventral nerve roots (Figure 8). T1- and T2-weighted MR images are mostly normal, with the imaging diagnosis made on the basis of postcontrast MR images. Postcontrast MR images demonstrate smooth pial enhancement of the cauda equina and conus medullaris.⁵

In patients with Guillain-Barre syndrome, affected spinal nerve roots in the cauda equina usually are normal on T1- and T2-weighted MR images but enhance with contrast.

Sarcoidosis. Sarcoidosis is a systemic granulomatous disease of unknown origin, characterized by the presence of noncaseating granulomas in affected organs. Sarcoidosis can affect most organ systems in the body, including the CNS. Imaging detects neurosarcoidosis in 10% of patients who have systemic sarcoidosis. Symptomatic neurosarcoidosis is less common, affecting 5% of patients, suggesting nonoverlap

Figure 10. Spinal infection in a 46-year-old man with subacute back pain but more acute neuropathy. Sagittal, T1-weighted, contrast-enhanced MR image demonstrates osteomyelitis of L4 (black arrow) as suggested by diffuse enhancement of the vertebral body. End plates of L2, L3, and L5 are involved (white arrows), with relative sparing of the disc spaces and abnormal signal along the anterior longitudinal ligament (blue arrows). These findings are suggestive of tuberculosis infection. Multiple epidural abscesses are present (orange arrows), resulting in mass effect on the thecal sac. Note multiple cauda equina enhancing nerve roots suggestive of leptomeningeal meningitis.



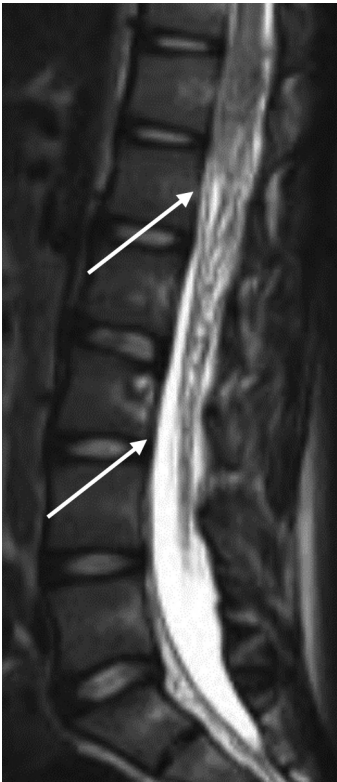


Figure 11. Spinal dural arteriovenous fistula Type 1 in a 41-year-old woman with paresthesia and back pain. Sagittal, T2-weighted MR image demonstrates multiple, serpentine T2-hyperintense structures consistent with multiple veins with slow flow (arrows).

between imaging findings and clinical symptoms.⁶ Spinal neurosarcoidosis can cause an array of imaging findings, which include intramedullary; intradural, extramedullary; extradural; vertebral; and disc space lesions. Extradural, intradural lesions manifested by leptomeningeal sarcoidosis infiltration (Figure 9) are the most common spinal

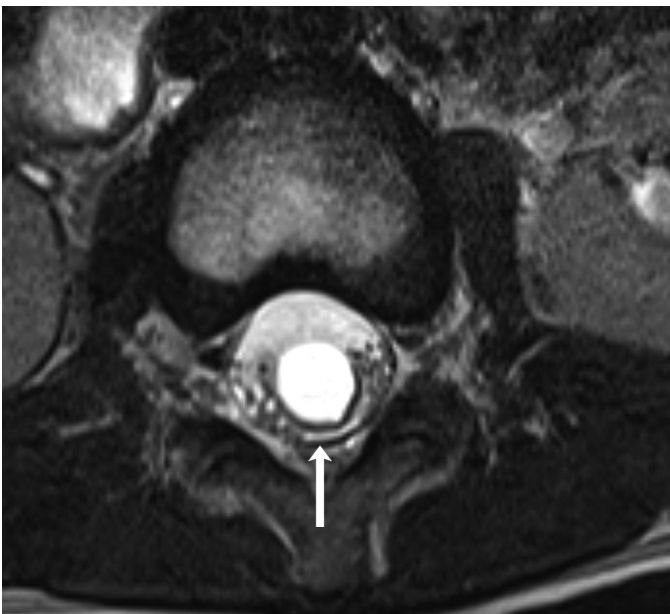


Figure 12. Ventriculus terminalis in a 13-year-old boy, an incidental finding on posttraumatic MRI. Axial, T2-weighted MR image at the conus medullaris demonstrates a cystic lesion (arrow) at the transition from the tip of the conus medullaris to the origin of the filum terminale. The cystic lesion did not enhance (*not shown*). Given location, findings are very suggestive of the diagnosis of ventriculus terminalis, and no intervention was indicated.

manifestations and are present in up to 60% of spinal cord lesions. This is the reason neurosarcoidosis should be included in the differential diagnosis of cauda equina leptomeningeal enhancement. Careful history, systemic imaging findings, and elevated angiotensin-converting enzyme should help secure the diagnosis of sarcoidosis.

Multiple Sclerosis. Multiple sclerosis is the most disabling CNS disease of young adults. It is an immune-mediated demyelinating disease of the CNS with multiple lesions disseminated over time and space. Diagnosis is based on the McDonald criteria where imaging is markedly implemented. Multiple sclerosis involving the spine is rarely isolated. Isolated spinal disease constitutes only 10% of the cases. The cervical spinal cord is the most common involved segment in the spine. Isolated conus medullaris involvement is exceedingly rare, with almost all conus medullaris lesions presenting as part of diffuse spine disease with or without brain involvement. On T1-weighted images, the conus medullaris is typically normal. T2-weighted images exhibit hyperintense signal with or without expansion of the conus medullaris. Enhancement on postcontrast MR images can be present and typically indicates active disease.

Infectious

Spinal infection is a life-threatening disease, in particular bacterial spinal infection with spinal bacterial meningitis mortality ranging from 20% to 90%. Spinal meningitis can be bacterial (typically acute), viral (typically subacute), and granulomatous (typically chronic) (Figure 10). Spinal meningitis can result from hematogenous spread, contiguous spread from adjacent spondylodiscitis, or direct inoculation from trauma or procedures. Spondylodiscitis can occur at any location in the spine but is more common within the

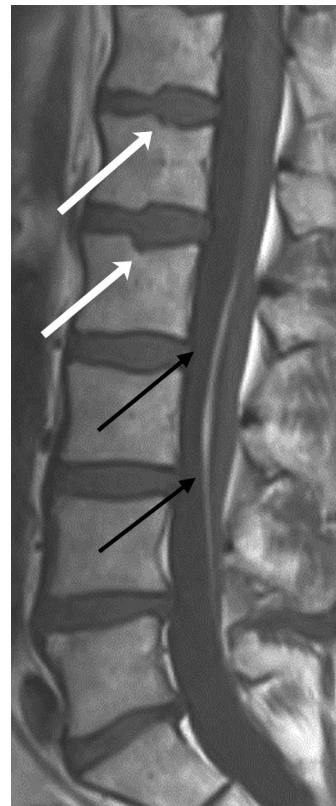


Figure 13. Filum terminale fibrolipoma, an incidental finding in a 21-year-old man with chronic back pain. Sagittal, T1-weighted MR image demonstrates a thin (transverse diameter less than 2 mm) lesion within the filum terminale (black arrows) that exhibits fat signal intensity consistent with fibrolipoma of the filum terminale. Incidental note is made of multiple Schmorl nodes (white arrows), which suggest chronic axial loading in an active patient.

lower lumbar spine, with common involvement of the cauda equina. Cauda equina involvement presents as leptomeningeal enhancement on MR images. Although this imaging feature is not unique, the toxic clinical presentation typically aids in making the correct diagnosis. Systemic symptoms, positive blood cultures, and CSF sampling aid in making the diagnosis in challenging cases.

Vascular

Spinal Vascular Malformations. Spinal vascular malformations represent a heterogeneous group of vascular anomalies that include malformations and arteriovenous fistulas. The most common classification is the scheme of Anson and Spetzler, which subdivides the vascular malformations into four types.⁷ Type I, spinal dural arteriovenous fistula, is an abnormal communication between a dural branch of the spinal ramus of a radicular artery and an intradural medullary vein. It is the most common type, constituting approximately 80% of spinal vascular malformations (Figure 11). Type II, intramedullary glomus malformation, is similar to brain arteriovenous malformation. Type III, extensive juvenile malformation, often extends to involve surrounding paraspinous tissues. Finally, Type IV, arteriovenous fistula between an intradural, extramedullary artery and a dilated perimedullary vein, commonly is called perimedullary spinal cord arteriovenous fistula. Digital subtraction angiography is considered the standard of care for evaluation of spinal vascular malformations, given its superior capability for exact localization of the level of the vascular abnormality, pretreatment planning, and therapeutic intervention if indicated. However, with recent advances in MRI and MRA, both have gained popularity in assessment and diagnosis of spinal vascular malformations. MRI adds the benefit of evaluating the spinal cord for complications, such as myelomalacia and spinal venous congestion/venous infarction.

Congenital

Ventriculus Terminalis. The ventriculus terminalis (Figure 12), also known as the “fifth ventricle,” is a small, ependyma-lined cavity in the conus medullaris/proximal filum terminale, which is usually in continuity with the central spinal canal of the rostral spinal cord. Typically, it is identified in childhood, with some reported series demonstrating prevalence of 2.6% in young children. The lesion regresses in size with aging and is smallest in adulthood. It might increase in size in older patients.⁸ Ventriculus terminalis is an incidental finding and almost never is symptomatic, with very few case reports of symptomatic lesions

requiring surgery. The lesion follows CSF signal on all MR sequences and exhibits no enhancement.

Filum Terminale Lipomatous Lesions

The filum terminale is a long, slender strand of fibrous tissue extending from the conus medullaris extremity to the coccyx. Fatty lesions of the filum terminale are relatively common and are detected in up to 5% of autopsies.⁹ Filum terminale lipomatous lesions are classified as fibrolipoma or lipoma of the filum terminale based on size and symptoms. Fibrolipoma of the filum terminale (Figure 13) represents an incidental asymptomatic lesion that is typically smaller than 5 mm in transverse diameter. Filum terminale lipomas are larger than 5 mm in transverse diameter. Filum terminale lipomas can be incidental or symptomatic.

Lipomas of the filum terminalis are larger than fibrolipomas of the filum and may be either an incidental or symptomatic finding.

Conclusion

This CME activity emphasizes that the cauda equina is a significant part of the CNS and should always be assessed. Look for normal size, smooth, and organized cauda equina nerve roots. When this checklist is not fulfilled, it may represent a manifestation of systemic, intracranial, or spinal process. An abnormal appearance may prompt MRI of the entire neuroaxis or a search for an unknown systemic pathologic process.

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- All of the following are MR features of spinal cord ependymomas, *except*
 - iso- or hypointense mass on T1-weighted images
 - central location
 - the majority do not enhance
 - "cap sign" on T2-weighted images
 - iso- to hyperintense mass on T2-weighted images
- The *most* common site of multiple sclerosis lesions in the spinal canal is the
 - cervical spinal cord
 - upper thoracic spinal cord
 - mid thoracic spinal cord
 - conus medullaris
 - cauda equina nerve root
- All of the following intracranial neoplasms are associated with drop leptomeningeal metastases, *except*
 - pineal germinoma
 - ependymoma
 - meningioma
 - choroid plexus papilloma
 - medulloblastoma
- Which one of the following is the *most* common spinal vascular malformation?
 - Type II, intramedullary glomus malformation
 - Type IV, perimedullary spinal cord arteriovenous fistula
 - Type I, spinal dural arteriovenous fistula
 - Type III, extensive juvenile malformation
- Which one of the following is the *most* common intradural, extramedullary neoplasm in the cauda equina?
 - Meningioma
 - Schwannoma
 - Astrocytoma
 - Lymphoma
 - Neurofibroma
- Plexiform neurofibromatosis has a predilection for which of the following nerves?
 - Brachial plexus and thoracic
 - Thoracic and sciatic
 - Brachial plexus and lumbar
 - Brachial plexus and sciatic
 - Sciatic and lumbar
- All of the following are MR features of a spinal nerve schwannoma in the cauda equina, *except*
 - intradural, extramedullary mass
 - peripherally enhancing mass
 - solitary mass
 - mass with a dural tail
 - cystic mass
- In patients with Guillain-Barre syndrome, MR features seen predominantly in affected ventral nerve roots in the cauda equina are
 - T1-hyperintensity, T2-hypointensity, no enhancement
 - normal T1 and T2, enhancement
 - T1-hypointensity, T2-hyperintensity, enhancement
 - T1- and T2-hyperintensity, enhancement
 - T1- and T2-hypointensity, no enhancement
- Which one of the following is the *most* common primary spinal intramedullary neoplasm in adults?
 - Glioblastoma multiforme
 - Ependymoma
 - Meningioma
 - Schwannoma
 - Lymphoma
- The origin of the filum terminale is
 - the distal aspect of conus medullaris
 - L3
 - L5
 - S2
 - the distal aspect of the coccyx