Lumbosacral MR neurography: A pictorial review of magnetic resonance imaging of the lumbosacral plexus and its branches

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Learning objectives

- To review general imaging techniques and anatomy relevant to lumbosacral MR neurography.
- To illustrate application of lumbosacral MR neurography in a variety of clinical cases of lumbosacral plexopathy, piriformis syndrome, and sciatica.
Background

MRI has increasingly been used to evaluate lumbosacral plexus pathology and can detect both intrinsic abnormalities of the lumbosacral plexus and extrinsic disease involving the lumbar spine, pelvis, psoas and piriformis muscles, and adjacent structures [1].

Clinical indications for lumbosacral MR neurography include

- Assessment of neural involvement by tumor.
- Assessment of extent of traumatic injury.
- Excluding a mass lesion in patients with unilateral EMG abnormalities.
- Confirmation of lumbosacral plexitis or plexopathy in the setting of inconclusive clinical findings and known systemic disease.

Image acquisition protocol

Lumbosacral MR neurography is typically performed using an imaging protocol that includes high-resolution T1-weighted (T1W), STIR, and fat-suppressed T2-weighted (T2WFS) sequences in the axial and coronal planes [3]. 3D isotropic imaging sequences (e.g., SPACE) are often used in addition to 2D imaging. Post-contrast T1-weighted imaging (T1W+C), with fat suppression, is typically performed for various indications that include suspected neoplastic or inflammatory disease or diffuse polyneuropathy. Images are typically acquired at 3 T, which offers better signal-to-noise ratios than 1.5 T. Particular advantages of the various sequences are listed below.

- T1W imaging allows excellent depiction of anatomy and fascicular morphology, visualization of fat planes and perineural fat, and fatty atrophy in the musculature.
- T2-weighted (T2W) and STIR imaging allows detection of a variety of pathological changes in the nerves and is also sensitive for early changes of muscle denervation. Fat suppression is crucial for differentiating pathological T2W changes from perineural and intraneural fat.
- Isotropic 3D imaging permits multiplanar and curved planar reconstructions and maximum-intensity projections to facilitate visualization of normal anatomy and pathology.

Approach to interpretation

The lumbosacral plexus and its nerve branches can be evaluated on MR neurography based on intrinsic imaging characteristics of the nerves, such as size, signal intensity, fascicular morphology, and course [4]. Pathology can also manifest as changes in
adjacent anatomic structures, including presence of mass lesions or areas of fibrosis, effacement of adjacent fat planes, or sequelae of muscle denervation.

- Normal nerves are usually similar in size to adjacent arteries, with gradual tapering as they course distally. Focal or diffuse enlargement of a nerve to a size larger than the adjacent arteries may indicate pathology.
- Nerves typically have intermediate signal on T1W images, similar to skeletal muscle, and appear isointense or minimally hyperintense on STIR and T2WFS sequences. Increases in T2W signal intensity approaching that of adjacent vessels would indicate abnormal nerve signal. Assessment for asymmetry relative to the contralateral side can be useful. It should be noted that minimally elevated T2W signal could be artifactual due to a magic angle effect when a nerve is oriented at a certain angle (55 degrees) relative to the direction of the main magnetic field. Higher signal intensity can be seen in normal nerves on 3D SPACE imaging but should be uniform and symmetric.
- Large nerves, such as the femoral and sciatic nerves, should have a characteristic fascicular pattern on T1W images. Abnormal findings may include loss of the normal fascicular architecture or enlargement of the fascicles.
- Normal nerves typically demonstrate a smooth course, without focal deviations, and are surrounded by intact fat planes, without fat stranding or nerve encasement.
- Enhancement is not observed in the absence of pathology except at locations that normally lack a blood-nerve barrier, such as the dorsal root ganglia. Pathological process that disrupt the blood-nerve barrier, such as neoplastic or infectious etiologies, may result in abnormal nerve enhancement.
- Denervation changes in muscle may represent indirect evidence of lumbosacral plexus pathology and can have varying appearances depending on duration [4]. Acute denervation (< 1 month) is hyperintense on T2W sequences due to edema. Subacute denervation (1-3 months) is hyperintense on T1W and T2W sequences due to edema and fatty infiltration. Chronic denervation (>3 months) is hyperintense on T1W sequences and shows decreased muscle volume due to fatty atrophy.
Findings and procedure details

Anatomy of the lumbosacral plexus

The lumbosacral plexus (Fig. 1 on page 9) consists of a lumbar plexus and a sacral plexus formed from ventral rami of the lumbosacral nerve roots [5]. The lumbar plexus is formed in or along the posterior aspect of the psoas muscle and consists of the ventral rami of the L1 through L4 nerve roots, often with a minor contribution from T12. The following branches of the lumbar plexus arise laterally from the psoas:

- Iliohypogastric nerve.
- Ilioinguinal nerve.
- Genitofemoral nerve.
- Lateral femoral cutaneous nerve.
- Femoral nerve. As the largest branch of the lumbar plexus, the femoral nerve (Fig. 2 on page 9) is consistently visible on MR neurography. Derived from the posterior divisions of the ventral rami of the L2 through L4 nerve roots, the femoral nerve courses inferiorly through the psoas muscle to exit from the lower lateral aspect of the muscle, subsequently descends between the psoas and iliacus muscles, and courses under the inguinal ligament to enter the thigh.

The medial branches are the following:

- Obturator nerve. The obturator nerves are consistently visible on MR neurography and can often be identified by their longitudinal course along the pelvic sidewall (Fig. 3 on page 10). The obturator nerve, arising from the ventral rami of the L2 through L4 nerve roots, exits the medial aspect of the psoas muscle to descend into the pelvis along the ilipectineal line. It exits the pelvis through the obturator canal in the upper part of the obturator foramen (Fig. 4 on page 11).
- Lumbosacral trunk. The lumbosacral trunk is formed from a minor branch of L4 and the ventral ramus of L5 (Fig. 5 on page 12) and descends along the anterior aspect of the sacral ala prior to joining with sacral S1 through S3 nerve roots along the ventral aspect of the piriformis muscle to form the sacral plexus.

Branches of the sacral plexus are as follows:

- Superior gluteal nerve.
- Inferior gluteal nerve.
- Pudendal nerve.
- Posterior femoral cutaneous nerve.
- Sciatic nerve. As the largest peripheral nerve in the body, the sciatic nerve (Fig. 6 on page 13) is reliably detected on MR neurography. It consists
of components from the L4 through S3 nerve roots. It descends anterior to, superior to, or within the piriformis muscle and exits the pelvis through the greater sciatic foramen. It then courses between the ischial tuberosity and the greater trochanter of the femur to descend in the posterior compartment of the thigh between the gluteus maximus and adductor magnus muscles. In the distal third of the thigh, it divides into the tibial and common peroneal trunks.

**Pathological conditions and case examples**

**Degenerative**

Degenerative lumbar spine osteoarthritis may result in a lumbar plexopathy and neuropathy, as illustrated in Fig. 7 on page 14, which depicts MR neurography findings in a 55-year-old man who presented with low back pain and right lower extremity radiculopathy. In this case, abnormalities of the right L4 nerve are seen adjacent to asymmetric right-sided degenerative disc disease at L4-5, extending into the right lumbar plexus and lumbosacral trunk. In a different patient with right leg weakness, abnormal edema and enhancement are seen at the right L3 nerve root (Fig. 8 on page 15), extending into the right lumbar plexus and right femoral nerve.

**Diffuse plexopathy from systemic disease, inflammation, or radiation**

Diffuse or bilateral plexopathy can be seen with several systemic disease processes such as amyloidosis, diabetes, and vascular disease (ischemia or vasculitis). For instance, Fig. 9 on page 16 shows fatty atrophy of multiple muscle groups bilaterally, along with asymmetric edema and enhancement within several left-sided muscles consistent with subacute to chronic denervation. As this patient had long-standing hypertension and poorly controlled diabetes and no focal lumbosacral plexus lesions were identified, diabetic polyneuropathy was the presumed cause of the patient's progressive lower extremity weakness. Radiation neuropathy can also produce a diffuse pattern of enhancement and T2W signal hyperintensity in the portions of the lumbosacral plexus within the radiation field in acute or subacute stages (Fig. 10 on page 17). Vasculitis may demonstrate long-segment neural abnormalities, including T2W signal hyperintensity and enhancement (Fig. 11 on page 18). Various inflammatory or hereditary disorders that may affect peripheral nerves, such as Guillain-Barre syndrome, Charcot-Marie-Tooth disease, or chronic inflammatory demyelinating polyneuropathy, may also involve the lumbosacral plexus, typically with enlargement of multiple plexus branches.
Trauma

Findings on MR neurography following trauma depend on the severity of the nerve injury. It is important to ascertain whether abnormalities represent stretch injury in an otherwise intact nerve or whether there are findings that may need surgical intervention, such as nerve root avulsion, loss of nerve continuity, or neuromas. Acute trauma to a nerve may manifest as enlargement, enhancement, and T2W signal hyperintensity (Fig. 12 on page 19). In addition to intrinsic nerve abnormalities following trauma, MR may also demonstrate additional posttraumatic findings in the adjacent musculature, such as tendon tears or muscle strains (Fig. 13 on page 19). Effects of denervation may also be seen in visualized muscles. In the setting of acute trauma, hemorrhage or edema may hinder assessment of nerve continuity. Large hematomas may also result in compressive injury to the lumbosacral plexus or its branches due to mass effect, as seen on the right sciatic nerve in Fig. 14 on page 20 due to a hematoma in the right piriformis muscle. Neuropathy may persist well after mass effect has resolved, as illustrated in Fig. 15 on page 21, which shows persistent signal abnormality in the same sciatic nerve a month after hematoma evacuation.

Neoplasms

Peripheral nerve sheath tumors (neurofibromas and schwannomas) can involve the lumbosacral plexus and manifest as areas of focal or fusiform nerve enlargement. Nerve sheath tumors can be seen along peripheral nerves or in the spine (Fig. 16 on page 22). Neurofibromas can be seen sporadically or in patients with neurofibromatosis type 1 (NF1). On MRI, neurofibromas are typically T2-hyperintense with heterogeneous enhancement; occasionally they may demonstrate classic imaging features, such as the target sign or fascicular sign. Involvement of the lumbosacral plexus in NF1 can manifest as diffuse enlargement of neural structures (Fig. 17 on page 23) or multiple discrete intraneural lesions (Fig. 18 on page 24). Although neurofibromas commonly involve superficial cutaneous nerves, they occasionally affect larger nerves (Fig. 19 on page 25). It is sometimes difficult to differentiate between benign and malignant variants on imaging, but size over 5 mm in largest diameter, ill-defined or infiltrative margins, rim enhancement or edema, cystic or necrotic intralesional changes, or substantial growth raise suspicion for malignancy. Metastases may also involve the lumbosacral plexus and associated peripheral nerves (Fig. 20 on page 26).

Piriformis syndrome and other compressive neuropathies
Piriformis syndrome, an entrapment neuropathy of the sciatic nerve secondary to an abnormal piriformis muscle, can mimic other common conditions such as lumbar degenerative disc disease, sacroiliitis, or trochanteric bursitis. Piriformis syndrome can be classified as primary or secondary.

- Primary: due to an anatomic cause such as split piriformis muscle, split sciatic nerve, or an aberrant course of the sciatic nerve
- Secondary: precipitated by another disease process such as trauma, ischemia, or mass effect from adjacent lesions

Neuropathy can be due to hypertrophy of the piriformis (Fig. 21 on page 27) or to anatomical variants such as bifid piriformis (Fig. 22 on page 28). Occasionally the piriformis on the symptomatic side is smaller due to denervation atrophy (Fig. 23 on page 29).

An example of secondary compressive neuropathy is postpartum neuropathy, as shown in Fig. 24 on page 30 in a 31-year-old female who presented with sustained left lower extremity numbness and weakness following vaginal delivery, with persistent flail foot. At the time of labor, she had experienced bilateral leg numbness, greater on the left. MR neurography showed an enlarged, edematous, and enhancing left sciatic nerve at and beyond the greater sciatic foramen. Findings are consistent with compressive sciatic neuropathy.
Fig. 1: Schematic illustration of the lumbar plexus and sacral plexus.

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Fig. 2: Coronal T1W and STIR and axial T1W and T2WFS sequences demonstrate a normal appearance of the left femoral nerve (yellow arrow) coursing between the psoas and iliacus muscles. The abnormal right femoral nerve (red arrow) shows asymmetrically higher signal on fluid-sensitive sequences.

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**Fig. 3:** Coronal T1W imaging shows a normal appearance of the obturator nerves (yellow arrows). After emerging from the medial aspects of the psoas muscles, the obturator nerves descend longitudinally in the lateral portions of the pelvis.

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Fig. 4: Obturator nerves (yellow arrows) exit the pelvis through the obturator canal and enter the medial thigh between the adductor muscles and subjacent to the pectineus.

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**Fig. 5:** Coronal SPACE STIR and axial T2WFS images show a normal appearance of the lumbosacral trunk (green arrows) and its relationship to the L4 (yellow arrows) and L5 (red arrows) nerve roots. A minor branch of the L4 nerve root combines with the ventral ramus of L5 to form the lumbosacral trunk, which descends along the anterior aspect of the sacral ala.

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**Fig. 6:** Coronal T1W and STIR images show a normal appearance of the bilateral sciatic nerves (yellow arrows) as they pass through the greater sciatic foramina.

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**Fig. 7:** Axial T2WFS and coronal STIR images show asymmetric degenerative disc disease at L4-5 on the right (blue arrows), with asymmetric loss of disc height and reactive endplate changes. Abnormally elevated T2W signal in the right L4 nerve and right lumbar plexus (yellow arrows) extends into the right femoral nerve (red arrows) and lumbosacral trunk (green arrow).

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**Fig. 8:** Coronal T1W+C and STIR and axial T1W+C images show edema and enhancement along the right L3 nerve root extending into the right lumbar plexus and right femoral nerve (yellow arrows). There is also edema and asymmetric enhancement involving the right psoas muscle (red arrows).

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Fig. 9: Axial T1W, T2WFS, and T1W+C and coronal T1W images show multifocal fatty atrophy of the hip and thigh musculature bilaterally (red arrows), including the bilateral piriformis and gluteal muscles. Asymmetrically elevated T2W signal and enhancement in several left-sided muscles (green arrows) are consistent with subacute to chronic denervation. No focal abnormality of the lumbosacral plexus was identified in this study. As this patient had long-standing hypertension and poorly controlled diabetes, diabetic polyneuropathy was the presumed cause of the patient's progressive lower extremity weakness.

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Fig. 10: Coronal T1W, STIR, and T1W+C images show extensive subacute denervation changes involving multiple muscles (red arrows), including the gluteal and obturator muscles, in a patient who previously received radiation therapy. Diffuse enhancement and elevated STIR signal in the lumbosacral plexus bilaterally (yellow arrows) is consistent with radiation-induced neuropathy.

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**Fig. 11:** Coronal STIR and T1W+C images and axial T2WFS and T1W images show enlargement, edema, and enhancement of the right lumbosacral plexus (yellow arrows) and its branches, including the right femoral nerve (red arrows) and right sciatic nerve (green arrow). Denervation changes, including atrophy, edema, and enhancement, are seen in multiple muscles in the region of the right hip (blue arrows). A right sciatic nerve biopsy was positive for inflammation, and the plexopathy is believed to be vasculitic in etiology.

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**Fig. 12:** Axial T1W, T2WFS, and T1W+C and coronal STIR and T1W+C images show an enlarged, edematous, and enhancing left sciatic nerve (yellow arrows) following trauma. Also present is edema of multiple muscles in the region of the left hip, including the left gluteus medius, obturator internus and externus, and tensor fasciae latae (red arrows).

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Fig. 13: Coronal STIR, axial T2WFS, and axial T1W+C images demonstrate an enlarged, T2-hyperintense, enhancing left sciatic nerve (yellow arrows) in the setting of trauma. Also noted are a partial left hamstring tear and strains of the left adductor and gluteus maximus muscles (red arrows).

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**Fig. 14:** Coronal T1W, STIR, and T1W+C and axial T1W and STIR images in a hemophiliac patient show a hematoma (red arrows) within and expanding the right piriformis muscle. There is rim enhancement of the hematoma, with mild enhancement also seen in the adjacent muscle. The right sciatic nerve (yellow arrows) is displaced and compressed at the greater sciatic foramen due to mass effect from the hematoma. Abnormal STIR signal is seen in the right sciatic nerve more inferiorly (green arrow), within the posterior thigh.

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Fig. 15: Coronal and axial T1W, STIR, and T1W+C images one month following evacuation of the right piriformis muscle hematoma show that mass effect on the right sciatic nerve (yellow arrows) has resolved, but there is persistent enhancement and STIR signal abnormality compatible with sciatic neuropathy.

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**Fig. 16:** Axial T2WFS and T1W+C and coronal STIR and T1W+C images show a T2-hyperintense, avidly enhancing rounded mass (yellow arrows) between the left psoas and iliacus muscles, likely along the left lumbar plexus or left femoral nerve, compatible with a nerve sheath tumor. A thoracic intradural extramedullary enhancing lesion (green arrows), as shown on the sagittal T2W and T1W+C images of the thoracic spine, may also represent a nerve sheath tumor.

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Fig. 17: Axial T2WFS and coronal STIR images in a patient with NF1 show numerous hyperintense peripheral nerve sheath tumors (yellow arrows) diffusely involving the lumbosacral neural foramina, lumbosacral plexus, and sciatic nerves, with some lesions demonstrating a characteristic target sign. Note the diffuse enlargement of the sciatic nerves.

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**Fig. 18:** Coronal STIR imaging in a patient with NF1 shows multiple nerve sheath tumors involving the lumbosacral plexus bilaterally (yellow arrows), including a 2 cm probable neurofibroma in the left psoas muscle (green arrows) that enhances as shown in the axial T1W+C image. Denervation atrophy of the left piriformis muscle (red arrow) is suspected based on asymmetrically decreased size on axial T1W imaging.

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Fig. 19: Coronal T1W and T2W, axial proton density and T1W+C, and sagittal T1W+C images demonstrate a T1-isointense, predominantly T2-hyperintense, smoothly marginated, intensely enhancing ovoid mass (yellow arrows) involving the right sciatic nerve posterior to the right hip, compatible with a neurofibroma.

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Fig. 20: Coronal T1W and T2W images and axial proton density and T1W+C images demonstrate extensive metastatic involvement of the bilateral sciatic nerves (yellow arrows). There is complete encasement and obliteration of the right sciatic nerve at the sciatic notch. Axial images demonstrate metastatic deposits infiltrating and enlarging the left sciatic nerve.

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**Fig. 21:** Coronal and axial T1W images show a hypertrophied right piriformis muscle, with the right S2 nerve root (yellow arrows) coursing between hypertrophied components of the muscle. This could potentially represent a site of nerve entrapment.

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Fig. 22: Axial and coronal T1W images show a bifid left piriformis muscle, with the left sciatic nerve (yellow arrows) coursing through the muscle.

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**Fig. 23:** Coronal T1W and STIR and axial T1W images show relative decrease in size and mild STIR signal hyperintensity of the right piriformis muscle (red arrows) in a patient with right buttock pain, suggestive of denervation edema and atrophy.

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**Fig. 24:** Axial T1W, T2WFS, and T1W+C and coronal STIR images in a patient with persistent left lower extremity numbness and weakness following vaginal delivery demonstrate an enlarged, edematous, and enhancing left sciatic nerve (red arrows) at and beyond the left greater sciatic foramen, consistent with compressive sciatic neuropathy. A normal sciatic nerve is seen on the right (yellow arrows).

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Conclusion

Lumbosacral MR neurography is a valuable imaging tool to supplement clinical and electrodiagnostic assessment of lumbosacral plexus pathology.
References


