Imaging of the Lumbosacral Plexus

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Introduction

Imaging of the lumbosacral plexus remains one of the more challenging areas of peripheral nerve imaging. The plexus is anatomically complex, extends over a large field of view, and lies deep within the pelvis in close relationship with bone, muscles, vessels and pelvic organs. Furthermore, symptoms of plexopathy frequently overlap with those of lumbar radiculopathy, hip disease and peripheral mononeuropathy.

MRI is the principal imaging modality for direct assessment of the lumbosacral plexus. Modern high-resolution MRI and MR neurography can demonstrate nerve morphology and signal abnormalities, identify denervation changes in muscles, and reveal an underlying structural cause such as tumor, inflammation, trauma, hematoma or fibrosis.

Anatomy of the lumbo-sacral plexus

The lumbosacral plexus is formed by the ventral rami of the lumbar and sacral spinal nerves. The lumbar plexus arises predominantly from L1–L4 and lies within and around the psoas major muscle. The lumbosacral trunk, predominantly formed by L4 and L5 fibers, descends across the pelvic brim to join the sacral plexus. The sacral plexus is formed predominantly by L4–S4 and is located along the posterolateral pelvic wall, anterior to the piriformis muscle. Its largest branch, the sciatic nerve, exits the pelvis through the greater sciatic foramen, usually below the piriformis.

Several major nerves should be identified systematically. These include the femoral and obturator nerves from the lumbar plexus and the sciatic, superior and inferior gluteal and pudendal nerves from the sacral plexus. Rather than attempting to memorize the entire plexus as a complicated network, it is useful to conceptualize three anatomical levels:

roots → plexus → major peripheral nerves.

This approach is particularly helpful when attempting to determine whether symptoms originate from the spine, plexus or peripheral nerve.

MRI technique: cover enough anatomy

One of the most frequent technical problems in lumbosacral plexus imaging is inadequate anatomical coverage. A dedicated examination should generally extend from the lumbar spine and iliac crests through the pelvis to include the sciatic foramina and proximal thighs when clinically appropriate. The exact field of view should be adapted to the suspected pathology.

High-resolution T1-weighted images are essential. They provide excellent anatomical information, demonstrate perineural fat and allow evaluation of muscle volume and fatty replacement. Fluid-sensitive fat-suppressed sequences—typically T2-weighted or proton-density-weighted sequences with robust fat suppression—are fundamental for detecting increased intraneural signal and acute or subacute muscle denervation. Three-dimensional isotropic sequences may be particularly valuable because they allow multiplanar and curved reformations along the expected course of nerves. MR neurography techniques attempt to increase nerve conspicuity by suppressing surrounding fat and vascular signal. Diffusion-weighted approaches may provide additional information in selected situations, although they remain technically demanding in the pelvis. Intravenous gadolinium is not required for every examination. It becomes particularly valuable when tumor, infection, inflammatory neuropathy, postoperative disease or radiation-related pathology is suspected.

What does an abnormal nerve look like?

The radiologist should systematically evaluate several characteristics. A pathological nerve may demonstrate increased caliber, increased T2-weighted signal, loss or distortion of the normal fascicular architecture, abnormal enhancement, or discontinuity in traumatic injury.

Signal intensity alone must be interpreted cautiously. Peripheral nerves normally have moderately high signal on fluid-sensitive sequences, and apparent signal can vary with technical factors and orientation. The most convincing abnormality is therefore usually not simply a bright nerve but a combination of: abnormal signal + abnormal caliber + abnormal course or morphology + compatible muscle denervation. Comparison with the contralateral side is extremely useful, particularly when symptoms are unilateral.

Muscle denervation: the radiologist's anatomical map

One of the most useful clues to plexus pathology is frequently found not in the nerve itself but in the muscles it supplies. Acute and subacute denervation produces increased

muscle signal on fluid-sensitive sequences. Importantly, this can occur before substantial muscle atrophy develops. Chronic denervation produces muscle volume loss and fatty replacement, readily demonstrated on T1-weighted images.

The distribution of denervated muscles can help localize the lesion.

For example, abnormalities involving multiple muscles supplied by different peripheral nerves but sharing proximal plexus contributions suggest a plexopathy rather than an isolated mononeuropathy. Conversely, abnormalities restricted to the territory of one peripheral nerve favor a lesion distal to the plexus. This leads to one of the most useful principles of MR neurography: When the nerve is difficult to see, follow the muscles.

Muscle denervation can provide a biological map of the affected neural territory.

Radiculopathy or plexopathy?

This is often the central diagnostic question. Lumbar degenerative disease is extremely common, and the presence of disc protrusions or foraminal stenosis does not prove that they explain the patient's symptoms. A plexopathy should be considered when the clinical deficit involves several peripheral nerves or does not correspond convincingly to a single nerve root. MRI should therefore not be limited to the pelvis. Review of the lumbar spine is often necessary to exclude a proximal cause.

Muscle distribution can again be helpful. Radiculopathy follows a myotomal distribution, whereas plexopathy may involve muscles supplied by several roots and peripheral nerves in a pattern corresponding to a plexus segment. Electromyography and imaging are highly complementary in this setting.

Neoplastic plexopathy

Tumor is one of the most important indications for imaging the lumbosacral plexus. Direct extension of pelvic malignancies, metastatic disease, lymphoma and peripheral nerve sheath tumors may involve the plexus. The radiologist should search for focal or diffuse nerve enlargement, abnormal T2 signal, enhancement, loss of surrounding fat planes and an adjacent mass. Cancer-related plexopathy can be particularly difficult in patients previously treated with surgery or radiotherapy. Recurrent tumor must be distinguished from treatment-related fibrosis or radiation-induced plexopathy.

A focal enlarging mass, nodular nerve thickening and aggressive enhancement favor tumor recurrence, whereas diffuse fibrotic change may favor treatment-related disease, although substantial overlap exists. FDG PET/CT can provide valuable complementary information when recurrent malignancy is suspected.

Radiation-induced plexopathy

Radiation-induced lumbosacral plexopathy may occur months or years after pelvic radiotherapy. MRI findings can be subtle and may include smooth diffuse thickening of plexus structures and variable T2 signal or enhancement. The surrounding tissues often demonstrate additional post-radiation changes. The major clinical and imaging challenge is distinguishing radiation injury from recurrent tumor. No isolated MRI finding is completely reliable. Morphology, time course, clinical history, serial imaging and metabolic imaging may all be necessary.

Inflammatory and diabetic plexopathy

Inflammatory neuropathies may produce diffuse or multifocal nerve enlargement, increased T2 signal and enhancement. Diabetic lumbosacral radiculoplexus neuropathy is an important clinical entity, typically presenting with acute or subacute severe pain followed by weakness and muscle wasting. MRI may demonstrate increased signal and enlargement of affected nerves together with muscle denervation. Findings may be bilateral but asymmetric. Imaging is particularly useful for excluding alternative structural causes such as tumor, hematoma or severe spinal disease. The radiologist should avoid interpreting every abnormal nerve signal as compression. Not all neuropathies are entrapment neuropathies.

Trauma and postoperative injury

Pelvic fractures, hip trauma and surgery can injure components of the lumbosacral plexus. MRI may demonstrate nerve edema, enlargement, discontinuity or surrounding hematoma. In chronic cases, fibrosis and muscle denervation may dominate the imaging appearance.

Metallic implants can considerably degrade image quality. Metal-artifact-reduction techniques and careful sequence optimization may therefore be required after hip arthroplasty or pelvic fixation.CT remains complementary when detailed assessment of fractures or hardware is necessary.

The piriformis and the sciatic nerve

The sciatic nerve is usually readily identified as it exits the pelvis through the greater sciatic foramen. Attention should be paid to its relationship with the piriformis muscle. Anatomical variations are relatively common, and components of the sciatic nerve may pass through or around the muscle. However, anatomical variation alone does not establish piriformis syndrome. A convincing diagnosis requires concordant abnormalities such as sciatic nerve signal alteration or enlargement, muscle asymmetry, an adjacent mass, fibrous bands, or other evidence of nerve compromise. This illustrates another important principle: Anatomical variants should be reported when relevant, but should not automatically be converted into diagnoses.

Do not forget the surrounding structures

A dedicated plexus MRI should never become so focused on nerves that the rest of the pelvis is ignored. The radiologist should systematically evaluate the lumbar spine, sacrum, sacroiliac joints, hip joints, pelvic bones, muscles, vessels and pelvic organs. An apparent neuropathy may ultimately be caused by a pelvic tumor, iliopsoas hematoma, inflammatory collection, vascular abnormality, endometriosis, fracture or postoperative complication.

The psoas and iliacus muscles deserve particular attention because abnormalities in this compartment may affect the femoral nerve. Similarly, disease along the obturator internus and pelvic sidewall may involve the obturator or pudendal nerves. In many cases, the most important finding on a plexus examination is therefore not located within the plexus itself.

A practical reading strategy

A systematic approach reduces the risk of overlooking subtle abnormalities.

- First, determine whether the abnormality is likely to arise from a root, the plexus or a distal peripheral nerve. Review the lumbar spine when necessary.
- Second, follow the major nerves from proximal to distal, preferably comparing both sides simultaneously. Look for asymmetry in caliber, signal, fascicular architecture and enhancement.
- Third, inspect the muscles systematically for acute denervation edema and chronic fatty atrophy.

- Fourth, search for an underlying cause along the entire course of the abnormal nerve: tumor, fibrosis, inflammation, trauma, hematoma or vascular disease.
- Finally, verify whether the imaging distribution corresponds to the clinical and electrophysiological findings.

Conclusion

Imaging of the lumbosacral plexus is challenging because the plexus cannot be interpreted as an isolated anatomical structure. Successful diagnosis requires integration of the lumbar roots, plexus, peripheral nerves and muscles.

MRI and MR neurography provide direct visualization of nerve morphology and signal, but some of the most useful diagnostic information comes from secondary muscle denervation and from identification of the underlying disease process.