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Once a nerve leaves the spinal column and ventures to the periphery as part of a large nerve plexus, it faces the same hazards as other soft tissues. These include trauma, traction, entrapment, compression, and impingement by tumors, leading to neuropathies such as pain, tingling, inflammation, numbness and motor deficits. Oak Tree Medical Center (Pasadena, Calif. USA) is building a reputation in peripheral nerve MRI, an exceptionally demanding application due to the complexity and compactness of nerve plexus anatomy and the challenges in discerning normal and abnormal nerve conditions, says Director of MRI, Jay Tsuruda, M.D.

Many patients referred to Oak Tree Medical Center have had at least one other MRI that failed to identify a biomechanical cause for their chronic pain or motor/sensory deficit.

“If a patient presents with a nerve deficit – particularly a combination motor-sensory deficit – and the routine spine study is negative, then invariably we will find peripheral nerve abnormalities,” Dr. Tsuruda says.

Established in 2005, Oak Tree Medical Center is building a reputation for peripheral nerve imaging. While Dr. Tsuruda co-authored his first paper on 3D nerve imaging in 1993 and the scientific literature is replete with similar works, the imaging study still is not widespread clinically, he maintains.

“It takes a lot of interest to do peripheral nerve imaging,” he says. “Specialized training is required to understand normal and abnormal anatomy and a good scanner using the right protocols is critical. The Achieva 1.5T combines excellent gradient performance, scan flexibility, SENSE coils and SNR for optimal contrast and spatial resolution. It also affords a robust RF chain and extremely fast reconstructions, so we can monitor images on-the-fly. The operating front end of Achieva 1.5T has been phenomenal for nerve imaging.”

Principle plexuses

The peripheral nervous system connects all body regions with the CNS (brain and spinal cord). A great many nerves below C4 originate from two major nerve plexuses, the brachial plexus and the sacral plexus. The nerves that comprise the plexuses have a cross-sectional architecture consisting of sensory and motor neurons bundled into several discrete fascicles. The ability to resolve fascicular anatomy is the basis of peripheral nerve MRI.

Though Oak Tree clinicians regularly encounter distal neuropathies (e.g., nerve entrapments at elbow, wrist, knee), brachial and sacral plexus studies are most common.

Brachial plexus

The brachial plexus is the confluence of nerves arising from the cervical spine (C5-T1) and running through the neck, the axilla and into the arm. The most common reason to image the brachial plexus is to search for the cause of symptoms consistent with thoracic outlet syndrome (TOS), a symptom complex caused by nerve or vessel compression in the neck or armpit. The challenge is identifying the source of the compression. Standard MRI can aid in the
detection of a number of low-probability causes of TOS, such as compression by soft tissue masses (e.g., Pancoast tumor) and primary neoplasms within or near the plexus. Not locating a mass with traditional MRI does not exclude TOS.

“Because masses in the plexus are rare, we evaluate the health of the entire plexus itself,” he says.

In a recent case, a patient presented with diffuse neck, shoulder and arm pain and paresthesia, in addition to generalized tenderness to palpation in the supraclavicular region.

“The MRI depicted mild edema in the supraclavicular plexus and a prominent vein, which probably caused some vascular impingement,” Dr. Tsuruda recalls. “Some of the edema even tracked into the brachial plexus roots. The MRI results correlated with the patient’s symptom complex and supported the TOS diagnosis.”

Often, many patients presenting with diffuse radiculopathy in the upper torso and arms will have a normal cervical spine, which should prompt a look at the brachial plexus for TOS and other neural pathology, such as diffuse brachial neuritis or a traction type injury, he adds.

“A patient history may include a vehicular accident or fall in which the neck and shoulder strike a hard object or the shoulder is severely wrenched,” Dr. Tsuruda says. “A traction injury of the plexus often occurs with shoulder injuries. The musculoskeletal derangement can be repaired, but patients often return with problems because they probably stretched or damaged the nerves. This is a very common yet under-recognized problem.”

**Imaging approach for brachial plexus**

The brachial plexus runs obliquely from mid/lower neck to the axilla in a mainly longitudinal vector. For in-plane imaging, oblique coronal slice positioning is necessary and coverage runs through the supra-, mid- and infraclavicular plexus.

“Presently, we use the SENSE Body coil positioned tightly against the skin,” he says. “Then we run just four sequences after the localizers, an oblique coronal T1-weighted TSE sequence and an oblique coronal T2-weighted sequence using STIR for fat..."
suppression. Next, we use the same sequences with oblique sagittal slice positioning [and A-P phase direction] to provide cross-sectional views. We suppress respiratory artifact using saturation bands (REST). The FOVs are adjusted to the minimum, say 16 to 18 cm, in the oblique sagittal acquisitions to deliver high spatial resolution.”

“Occasionally we will add a T1-weighted axial sequence at the end,” he continues, “if we want to determine if there has been a resection or atrophy of the scalene muscle or if we’re considering a steroid injection. In all sequences, no contrast agent is given unless we see a tumor or mass.”

A critical goal in peripheral nerve imaging is to obtain enough resolution to both resolve the fascicular anatomy and separate nerve structures from blood vessels, which run together in the neurovascular bundle. The time slot for peripheral nerve imaging cases is 45 minutes.

**Nerve pathology visualized**

In addition to noting whether nerve trajectory is normal or abnormal on MRI images, physicians examine the fascicular anatomy for signal and morphological changes. “An understanding of normal nerve anatomy is critical,” Dr. Tsuruda says. “Abnormal nerves often have increased intraneural fluid and fascicles can become swollen and displaced. Damaged nerves typically appear quite hyperintense, whereas normal nerves look isointense compared with surrounding tissues. Interestingly, normal nerves can be contiguous with or adjacent to pathological nerves, providing a direct comparison.”

Before the MRI study, clinicians need the patient’s complete clinical history to help focus the examination on a precise region-of-interest. “All physical exams and electrodiagnostics are needed,” he says. “You shouldn’t scan without knowing the highest probability anatomical level of pathology. The histories can be very complicated and patients may have been shunted around to many places with incorrect diagnoses.”

**Straightforward therapy**

Therapy for brachial plexus neuropathies varies. If the determination is thoracic outlet syndrome possibly caused by scalene muscle compression, scalenectomy and/or rib resection are two aggressive solutions. “From a radiologist’s standpoint, however, we could inject the scalene muscles under image guidance with anesthetics and steroids for a diagnostic and therapeutic block, or Botox in selected patients,” Dr. Tsuruda says.

Traumatic injuries of either the brachial or sacral plexus – involving nerve contusion, transection and subsequent fibrous remodeling (neuromas) – could require surgical remedies such as neurolysis to remove the adhesions around the nerve or resection and regrafting of the nerve.

**Sacral plexus**

The sacral plexus, the nerve network emanating from L4-5 to S1-4, provides nerves for the pelvis and lower limbs and includes the sciatic nerve.

“We’re looking for sacral plexopathy that is unexplained by the lumbar spine MR, which often is conducted to exclude sciatica,” Dr. Tsuruda says. “The major pathology to scan for are intrinsic abnormalities within the sacral plexus, such as tumor or piriformis syndrome or compression/injury of the proximal sciatic nerve within the ischial tunnel.”

**Sacral plexus imaging strategy**

Scanning requirements for the sacral plexus are similar to those of the brachial plexus, a combination of T1- and T2-weighted, fat-suppressed in-plane and cross-sectional acquisitions.

“We use a coronal T1-weighted sequence and a T2-weighted SPIR sequence,” he says. “Then, we conduct oblique axial T1-weighted and T2-weighted SPIR acquisitions along the long axis of the plexus. We use STIR if there is any metal, such as a hip prosthesis, in the region.”

When viewing the images, clinicians trace the sacral and lumbar nerve courses from the roots to the cords, carefully noting nerve morphology and the sciatic nerve.
If imaging findings are compatible with edema and compression of the sciatic nerve and the regional piriformis muscle, radiologists then may perform a diagnostic/therapeutic nerve block [steroid and anesthetic and/or Botox] of the piriformis muscle, after consulting with the referring physician.

**Added nerve sequence with routine lumbar spine imaging to cover lumbar plexus**

For all routine lumbar spine studies, Oak Tree clinicians add a coronal T2-weighted SPIR sequence with a long TR (>4500 ms), aimed at visualizing the peripheral nerve roots in the lumbar plexus.

“With acute herniated disks, there typically is edema around the nerves,” Dr. Tsuruda says. “This single scan may identify the problem and is an underutilized strategy. Injections in the nerve area with steroids and anesthetic can help these patients significantly because they reduce the inflammation caused by the periradicular and intraroot edema.”

**Getting the word out**

The neuroradiologic specialty of peripheral nerve imaging is a valuable adjunct to traditional MRI, particularly when standard work-ups don’t completely account for the scope of the patient’s symptoms. With an earnest desire to provide peripheral nerve imaging and equipped with a state-of-the-art scanner and techniques, imaging centers can offer patients another avenue for symptomatic relief.

“We’re trying to get the word out,” he says. •