AJNR

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AJNR Am J Neuroradiol 2008, 29 (2) 400-402
http://www.ajnr.org/content/29/2/400

ACR APPROPRIATENESS CRITERIA

Plexopathy

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for the Expert Panel on
Neurologic Imaging

Brachial plexopathy causes weakness, sensory loss, and loss of tendon reflexes in body regions innervated by nerves in the C5-T1 segmental distribution. The clinical diagnosis is confirmed by electrodiagnostic studies (EMG). Lumbar plexopathy produces weakness, sensory loss, and reflex changes in the distribution of spinal segments L1-L4, resulting in weakness and sensory loss in obturator- and femoral-innervated territories. Sacral plexopathy causes the same abnormalities in segments L5-S3, causing weakness and sensory loss in the gluteal (motor only), and peroneal, and tibial nerve territories.

Typical findings include mass lesion infiltrating perineural fat and abnormal MR imaging features of nerves on short tau inversion recovery (STIR) or fat-saturated T2-weighted fast-spin-echo (FSE) images, abnormal appearance of the intraneural fascicular pattern, and/or abnormal contrast enhancement on fat-saturated T1-weighted images.[1] If MR imaging is of diagnostic quality, an accompanying CT study or positron emission tomography (PET) study is only rarely necessary, except in post-traumatic brachial plexopathy, for which MR imaging and postmyelographic CT are complementary.

MR Techniques and Image Contrast

For brachial plexus imaging (Table 1), high resolution unilateral imaging in two or three planes is preferred, though bilateral examination may also be employed. MR imaging includes the roots, located in the supraclavicular region, to the cords, located in the infraclavicular region.

The lumbosacral plexus[2] is formed from the lumbar plexus [L1-L3 ventral rami, with contributions from T12 and L4] (Table 2) and the sacral plexus [ventral rami of L4/L5 (lumbosacral trunk) and S1-S4] (Table 3). A unilateral or bilateral study may be performed.

Pulse Sequences

T1-weighted images display regional anatomy best.[2,3] T2-weighted images usually FSE are useful to detect pathologic changes within components of the plexus. Fat suppression is used because abnormal intraneural signal intensity may be obscured by adjacent fat signal intensity.

Gadolinium contrast is useful for suspected neoplasm, radiation injury, inflammation, or abscess, and following peripheral nerve surgery. Gadolinium is useful in nerve entrapment and stretch injury.

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MR Imaging: Normal versus Abnormal Plexus

Abnormal findings include loss of fat planes around all or part of a plexus component, diffuse or focal enlargement of a component (especially, the presence of an eccentric or nodular mass), marked hyperintensity on T2-weighted images and/or enhancement on T1-weighted images with fat suppression. An altered fascicular pattern is also abnormal.[1]

Indications for MR Imaging of the Brachial Plexus

Bilbey et al[4] found SE MR imaging without gadolinium to be 63% sensitive, 100% specific, and 77% accurate compared with clinicopathologic results in 43 patients with suspected brachial plexopathy. Accuracy increased to 88% in patients ($n = 34$) with neoplastic or traumatic disorders.

Mass Involving the Plexus

MR imaging often determines whether a mass is intrinsic or extrinsic to the plexus and, for extrinsic masses, determines the site of the displaced and compressed nerve fibers before surgical intervention.[5] Such information is valuable for neoplastic processes (such as nerve sheath tumors, metastases, direct extension of non-neurogenic primary tumor, and lymphoma) and for benign processes (such as fibromatosis [most common], lipoma, myositis ossificans, ganglioneuroma, hemangioma, and lymphangioma).[6] The information from MR imaging aids in preoperative planning.[6-8]

Brachial plexopathy caused by metastatic disease is most often seen in patients with breast or lung carcinoma. Metastases from breast are most common and involve the plexus mainly by lymphatic spread. Other primary malignancies (eg, melanoma, gastrointestinal or genitourinary carcinomas), that metastasize to lymph nodes, soft tissue, or bone and result in plexopathy, have been reported.[4,9-11] Soft tissue tumors, such as sarcomas and aggressive fibromatosis also infiltrate the plexus.[9,12]

The most common neurogenic tumors of the plexus are the benign nerve sheath tumors: neurofibroma (50%–65%), and Schwannoma (18%–20%).[13,14] The roots are the most frequent site of involvement.[11] Malignant peripheral nerve sheath tumors (MPNSTs) account for 14% of the neurogenic tumors and are found mainly in patients with neurofibromatosis or a history of previous radiation therapy to the plexus region.[13,15-17]

Traumatic Injury

Traumatic injury to a peripheral nerve can range from disruption of axonal conduction with preservation of anatomical continuity to severed nerve with complete loss of continuity.[18,19] Trauma can result in compression, stretching, or laceration of plexal components, perineural fibrosis, or avulsion of nerve roots from the spinal cord.

It is important to distinguish intraspinal nerve root avul-

Table 1: Clinical Condition—Brachial Plexopathy

	MRI, neck, and/or chest, and/or upper extremity		CT, neck, and/or chest, and/or upper extremity		X-ray, chest	X-ray, cervical spine	FDG-PET, whole body
	Without and with contrast	Without contrast	Without and with contrast	Without contrast			
Sudden onset	8[a]	7[a]	5[a]	4[a]	3	3	1
Chronic	8[a]	7[a]	5[a]	4[a]	3	4	2[b]
Post-traumatic, nonacute*	8[a]	7[a]	4[a]	5[a]	3	3	1
Cancer patient; no history of local radiation therapy	8[a]	7[a]	5[a]	4[a]	4	3	7[c]
Cancer patient; post-radiation therapy	8[a]	7[a]	5[a]	4[a]	4	3	7[d]

Note:—Appropriateness criteria scale from 1 to 9; 1, least appropriate; 9, most appropriate.
* CT myelography, cervical and/or thoracic spine = rating of 6, X-ray, myelography, cervical and/or thoracic spine = rating of 5 and usually performed with CT.
[a] One or more anatomically contiguous studies may be appropriate depending on clinical circumstances.
[b] May be appropriate if malignancy suspected.
[c] May be useful for staging and characterizing local lesion.
[d] Best imaging tool to distinguish between tumor recurrence and radiation plexopathy.

Table 2: Clinical Condition—Lumbar Plexopathy

	MRI, abdomen and/or pelvis		CT, abdomen and/or pelvis		X-ray, lumbosacral spine	FDG-PET, whole body
	Without and with contrast	Without contrast	Without and with contrast	Without contrast		
Sudden onset	8[a]	7[a]	5[a]	4[a]	3	1
Chronic	8[a]	7[a]	5[a]	4[a]	4	2[b]
Post-traumatic, nonacute	8[a]	7[a]	4[a]	5[a]	3	1
Cancer patient; no history of local radiation therapy	8[a]	7[a]	5[a]	4[a]	3	7[c]
Cancer patient; post-radiation therapy	8[a]	7[a]	5[a]	4[a]	3	7[d]

Note:—Appropriateness criteria scale from 1 to 9; 1, least appropriate; 9, most appropriate.
[a] One or more anatomically contiguous studies may be appropriate depending on clinical circumstances.
[b] May be appropriate if malignancy suspected.
[c] May be useful for staging and characterizing local lesion.
[d] Best imaging tool to distinguish between tumor recurrence and radiation plexopathy.

Table 3: Clinical Condition—Sacral Plexopathy

	MRI, abdomen and/or pelvis		CT, abdomen and/or pelvis		X-ray, lumbosacral spine	X-ray, pelvis	FDG-PET, whole body
	Without and with contrast	Without contrast	Without and with contrast	Without contrast			
Sudden onset	8[a]	7[a]	5[a]	4[a]	3	3	1
Chronic	8[a]	7[a]	5[a]	4[a]	4	3	2[b]
Post-traumatic, nonacute	8[a]	7[a]	4[a]	5[a]	3	3	1
Cancer patient; no history of local radiation therapy	8[a]	7[a]	5[a]	4[a]	3	3	7[c]
Cancer patient; post-radiation therapy	8[a]	7[a]	5[a]	4[a]	3	3	7[d]

Note:—Appropriateness criteria scale from 1 to 9; 1, least appropriate; 9, most appropriate.
[a] One or more anatomically contiguous studies may be appropriate depending on clinical circumstances.
[b] May be appropriate if malignancy suspected.
[c] May be useful for staging and characterizing local lesion.
[d] Best imaging tool to distinguish between tumor recurrence and radiation plexopathy.

sion (preganglionic lesion) from brachial plexus interruption (postganglionic lesion) since the surgical treatment differs.[20] Somatosensory evoked potentials do not enable one to discriminate between incomplete avulsion and intact roots, or between intraforminal root avulsion and rootlet avulsion from the spinal cord. Hence imaging studies are recommended in the evaluation of post traumatic plexopathies.[21-25]

Overall, MR imaging has an advantage over CT and myelography, because it is better able to show both pseudomeningocele and peripheral postganglionic lesions. MR imaging demonstrates post-traumatic neuromas (tangles of regenerating nerve fibers), focal or diffuse fibrosis, and masses that compress or stretch the plexus, such as hematoma, clavicular fracture, and humeral dislocation.[2,4,11,26]

Entrapment Syndromes

Guided to the location of entrapment/compression by the clinical, neurologic and electrodiagnostic examination, MR imaging directly depicts nerve compression.[27] The brachial plexus and/or the subclavian/axillary artery or vein encounter three possible sites of compression along their course: the interscalene triangle, the costoclavicular space between the first thoracic rib and the clavicle, and the retropectoralis minor space. The value of MR imaging in diagnosing thoracic outlet syndrome is debated.[28,29]

Post-Treatment Evaluation

In patients with cancer and plexopathy following radiation therapy, imaging features that favor recurrent tumor are nonuniform, asymmetric, diffuse or focal enlargement, especially

the presence of an eccentric mass with postcontrast enhancement.[30,31] Imaging features that favor postradiation plexopathy are diffuse, uniform, symmetric swelling and T2 hyperintensity of the plexus within the radiation field. Diffuse, uniform postcontrast enhancement for months to years after treatment may also result from radiation injury.[31,32] Radiation fibrosis often has low signal intensity on T1-weighted and T2-weighted images,[33] and this may represent the more common appearance for chronic radiation injury.

Differentiation between radiation injury and recurrent cancer with axillary/supraclavicular metastases may not be possible for patients with diffusely abnormal signal intensity and enhancement of the plexus and surrounding tissues. FDG PET helps confirm metastases in patients with indeterminate MR imaging findings and is useful for depicting metastases elsewhere.[34]

Miscellaneous

When the clinical examination does not reveal an etiology for the patient's neuropathy, MR imaging may identify a focal or diffuse peripheral nerve or plexus structural abnormality, as in acquired and hereditary neuropathies.[35-40] Idiopathic brachial plexus neuritis, or plexitis, presents with sudden onset of severe, constant pain in the lateral neck, shoulder, scapula, or upper arm.[41] Involvement is bilateral in 10%–30% of cases.[42,43] Reported MR imaging findings range from normal[4] to diffusely enlarged and hyper intense nerves of the plexus on T2-weighted images, hypothesized to represent intraneural inflammation and edema.[11]

Conclusion

High-resolution MR imaging of brachial and lumbosacral plexuses aids careful treatment planning by peripheral nerve specialists.[44]

Appendix

Expert Panel on Neurologic Imaging: Brian C. Bowen, MD, PhD, Co-Author, University of Miami, Miami, Fla; David J. Seidenwurm, MD, Co-Author and Panel Chair, Radiologic Associates of Sacramento, Sacramento, Calif; Patricia C. Davis, MD, Panel Vice-chair; James A. Brunberg, MD; Robert L. De La Paz, MD; Pr. Didier Dormont; David B. Hackney, MD; John E. Jordan, MD; John P. Karis, MD; Suresh Kumar Mukherji, MD; Patrick A. Turski, MD; Franz J. Wippold II, MD; Robert D. Zimmerman, MD; Michael W. McDermott, MD, American Association of Neurologic Surgeons; Michael A. Sloan, MD, MS, American Academy of Neurology.

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