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Magnetic resonance neurography in the diagnosis of neuropathies of the lumbosacral plexus: a pictorial review☆,☆☆

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ABSTRACT

Magnetic resonance neurography (MRN) is an important tool to detect abnormalities of peripheral nerves. This pictorial review demonstrates the MRN features of a variety of neuropathies affecting the lumbosacral plexus (LSP) and lower extremity nerves, drawn from over 1200 MRNs from our institution and supplemented by the literature. Abnormalities can be due to spinal compression, extraspinal compression, malignancy, musculoskeletal disease, iatrogenesis, inflammation, infection, and idiopathic disorders. We discuss indications and limitations of MRN in diagnosing LSP neuropathies. As MRN becomes more widely used, physicians must become familiar with the differential diagnosis of abnormalities detectable with MRN of the LSP.

1. Introduction

High-resolution magnetic resonance imaging (MRI) of peripheral nerves, or magnetic resonance neurography (MRN), is a technique for identifying anatomy and pathologic lesions of peripheral nerves [1,2]. While the diagnosis of peripheral neuropathy remains electroclinical, MRN has emerged as a helpful technique for localizing lesions and elucidating the underlying etiology. Indeed, MRN can sometimes be more informative than electrodiagnostic investigations [3].

Technical aspects of MRN have been recently reviewed [4–7]. Modern MRN uses high magnetic field strength (1.5 or 3 T) with high-resolution multiplanar structural sequences optimized for peripheral nerve visualization. MRN can help localize lesions by directly observing nerve signal abnormalities or by identifying myopathic changes in a particular nerve distribution; detect incidental lesions mimicking neuropathic symptoms; or exclude neuropathy by revealing completely normal imaging characteristics of both muscle and nerve [8]. Among its other uses, MRN is indicated to identify sites of entrapment [9]; help identify patients who would benefit from surgery [10]; evaluate the extent of nerve repair after surgery [11]; identify peripheral nerve tumors [12]; differentiate radiation damage from recurrent tumor [13]; and identify the extent of diffuse neuropathies [6].

In this pictorial essay, we review the utility of MRN in diagnosing lesions of the lumbosacral plexus (LSP) and contiguous neural elements, supplementing the existing literature with our own audit of almost 1300 MRNs of the LSP. We illustrate the variety of diagnoses that can be identified by MRN of the LSP and highlight information that MRN may yield when ordered for appropriate indications.

Of note, many lesions that affect the LSP are best diagnosed clinically without imaging, such as postpartum obturator mononeuropathies. Others are diagnosed easily with conventional imaging, such as retroperitoneal hematoma or pelvic abscesses. Although MRN can help visualize these abnormalities, these conditions will not be reviewed here.

1.1. The LSP

The LSP encompasses the spinal roots and interconnections linking the lumbosacral spinal cord to the nerves of the lower extremities. The complex anatomy and relative inaccessibility to electrodiagnostic testing make the diagnosis of nerve disorders affecting the LSP challenging. Diagnosis normally relies on a combination of the clinical exam, electromyography/nerve conduction studies (EMG/NCS), and traditional MR or computed tomographic (CT) spinal imaging. However, electroclinical studies assess function, not structure, and they are often limited in interrogating the deeper nerves of the LSP. Traditional MRI and CT are limited by spatial resolution with regards to identifying individual nerve structure and pathology. Although MRN has already been

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Table 1
"Routine" protocol for LSP magnetic resonance neurogram

Coronal and axial T1	TR/TE 600/min; 3/0 thickness; matrix 384/192; 3.5×4 NEX; FOV 32 coronal, 24 axial
Coronal, axial, and sagittal T2 IDEAL sequences	TR/TE 3700/70; 3/0 thickness; matrix 256/160; 6×2 NEX; FOV 32 coronal, 24 axial)]
Axial DWI	*B* value 600; 4/0 thickness

TR, repetition time; TE, echo time; NEX, number of excitations; FOV, field-of-view; IDEAL, iterative decomposition of water and fat with echo asymmetry and the least-squares estimation.

shown to add clinically useful information beyond that provided by traditional MRI and EMG/NCS [3], MRN has not yet been widely adopted mostly due to insufficient awareness and technical expertise in the broader medical community.

1.2. MRN of the LSP

MRN adapts conventional imaging techniques for optimal peripheral nerve visualization. This usually includes multiplanar high-resolution T1 and heavily T2-weighted fat-suppressed sequences [1]. Compared with muscle, normal peripheral nerves have isointense T1 and isointense to slightly hyperintense T2 signal. T1-weighted sequences with 2–4-mm slice thickness and high resolution (<1 mm^2 pixel size) are excellent for demonstrating the fascicular pattern of the normal nerve, outlining the epineurial fat plane, and delineating the anatomic structures surrounding the nerve [14]. Fat-suppressed T2-weighted imaging enables sensitive detection of water content alterations in a variety of nerve pathologies. Because the intrinsic T2 hyperintense signal of fat surrounding a nerve may mask the T2 prolongation effect of nerve pathology, fat suppression techniques are routinely utilized with T2 imaging [14,15].

Recent technological advances, including 3-T scanners and robust accelerated acquisition schemes, enable routine incorporation of three-dimensional (3D) sequences allowing for thinner slices (less than 1 mm), approximating in-plane matrix dimensions. The resulting isotropic voxel size also allows for maximum intensity projection, multiplanar, and curved-planar reformations, thereby increasing signal-to-noise ratio and better delineating complex LSP anatomy [16,17].

Administration of intravenous MRI contrast agents may be helpful to supplement conventional structural imaging techniques, particularly when there is suspicion for pathology which may violate the integrity of the blood–nerve barrier, such as inflammatory or neoplastic neuropathies [18,19]. As with T2 sequences, fat suppression is usually applied with postcontrast imaging so that enhancement is not masked by the intrinsic T1 shortening effect of adjacent fat.

Diffusion-weighted imaging (DWI) with high diffusion sensitizing gradient moments (i.e., *b*-value ≥500 s/mm^2) takes advantage of the anisotropic diffusion of water within nerve fibers, preferentially paralleling the course of axonal bundles. DWI enhances nerve contrast, increasing sensitivity to pathologic alterations in nerve internal architecture [20,21]. DWI with acquisition of at least six noncollinear diffusion gradient directions allows tensor modeling and diffusion tensor tractography [22,23]. A hybrid 3D imaging technique combining a weaker diffusion sensitizing gradient moment that maintains T2

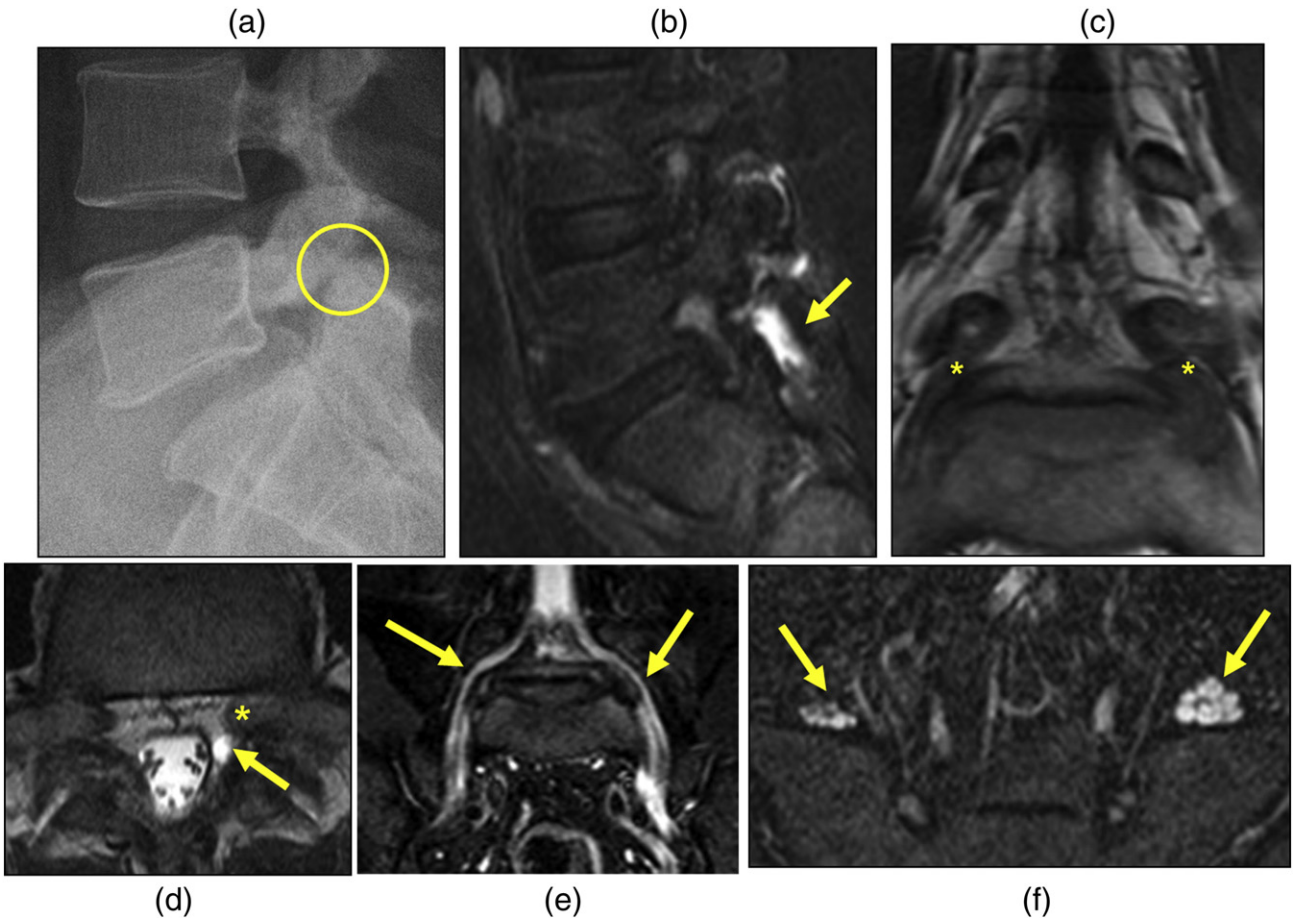

Fig. 1. A 38-year-old man with bilateral L5 radiculopathy due to isthmic spondylolisthesis. (a) Lateral radiograph demonstrates L5 pars defects (circle). (b) Sagittal T2 fat-suppressed image shows L5-S1 facet effusion with joint diastasis. (c) Coronal T1 image shows bilateral foraminal narrowing with L5 root compression, left>right (asterisks). (d) Axial T2 image demonstrates a left L5-S1 facet synovial cyst (arrow) that contacts the left L5 dorsal root ganglion (asterisk). (e, f) Coronal and axial IDEAL T2 images from subsequent lumbar neurogram show enlarged and edematous bilateral L5 roots, left > right (arrows) due to resultant mechanical compression.