RESEARCH PAPER

Role of Ultrasonography and Magnetic Resonance Imaging in the Evaluation of Neuromuscular Pathologies at a Tertiary Care Hospital in India

Dr. Needhi Bhaskarrai Kher[1], Dr. Nikunj Desai[2], Dr. Asutosh Dave[3], Dr. Drashti Patel[4]

[1]Second Year Resident, Department of Radiodiagnosis, GCS Medical College, Hospital & Research Centre, Ahmedabad, Gujarat, India

[2]Professor, Department of Radiodiagnosis, GCS Medical College, Hospital & Research Centre, Ahmedabad, Gujarat, India

[3]Professor and Head, Department of Radiodiagnosis, GCS Medical College, Hospital & Research Centre, Ahmedabad, Gujarat, India

[4]Assistant Professor, Department of Radiodiagnosis, GCS Medical College, Hospital & Research Centre, Ahmedabad, Gujarat, India

Corresponding author: Dr Drashti Patel, Department of Radiodiagnosis, GCS Medical College, Hospital & Research Centre, Ahmedabad, Gujarat, India

Email id: drashti1403@gmail.com

Conflict of interest: No! Conflict of interest is found elsewhere considering this work.

Source of Funding: There was no financial support concerning this work.

Role of Ultrasonography and Magnetic Resonance Imaging in the Evaluation of Neuromuscular Pathologies at a Tertiary Care Hospital in India

Abstract

Background: Neuromuscular disorders comprise a heterogeneous group of conditions affecting peripheral nerves and skeletal muscles. Imaging has an increasingly important role in lesion localization, characterization, assessment of disease extent, and treatment planning. High-resolution ultrasonography (USG) provides rapid, dynamic, and high-resolution evaluation of superficial nerves and muscles, whereas magnetic resonance imaging (MRI) provides excellent soft-tissue contrast, multiplanar assessment, and visualization of deep structures.

Aim: To evaluate the role of USG and MRI in the diagnosis and characterization of neuromuscular pathologies.

Materials and Methods: This prospective observational study included 50 patients presenting with clinical features suggestive of neuromuscular pathology who underwent both high-resolution USG and MRI. USG assessment included nerve caliber, cross-sectional area, echotexture, fascicular pattern, continuity, vascularity, muscle architecture, and dynamic abnormalities. MRI assessment included nerve morphology and signal intensity, muscle edema, fatty infiltration, atrophy, structural abnormalities, and associated soft-tissue or osseous findings. Imaging findings were correlated with the final diagnosis established clinically.

Results: USG and MRI demonstrated complementary diagnostic utility across the spectrum of neuromuscular disorders. USG was particularly useful for superficial peripheral nerve abnormalities, entrapment neuropathies, focal nerve enlargement, traumatic nerve lesions, and dynamic assessment. MRI was advantageous for deep-seated lesions, evaluation of disease extent, muscle edema, denervation changes, fatty infiltration, and associated structural abnormalities.

Conclusion: USG and MRI are complementary modalities in neuromuscular imaging. USG provides accessible, dynamic, high-resolution assessment of superficial nerves and muscles, while MRI provides comprehensive evaluation of deeper structures and secondary muscle changes. Their integrated use can improve lesion localization and characterization.

Keywords: Denervation, Magnetic resonance imaging, Muscle, Neuromuscular disorders, Neuropathy, Peripheral nerve, Ultrasonography

How to cite this article: Needhi Bhaskarrai Kher1 Dr. Nikunj Desai2 Dr. Asutosh Dave3 Dr. Drashti Patel4. Role of Ultrasonography and Magnetic Resonance Imaging in the Evaluation of Neuromuscular Pathologies at a Tertiary Care Hospital in India. Int J Drug Deliv Technol. 2026;16(89s):960-967. DOI: 10.25258/ijddt.16.89s.100.

Introduction

Neuromuscular disorders comprise a broad spectrum of diseases involving peripheral nerves and skeletal muscles. Accurate localization and characterization of these abnormalities are essential for diagnosis, prognostication, and appropriate treatment planning [1–5].

Traditionally, clinical examination and electrodiagnostic studies, including nerve conduction studies and electromyography, have been central to the evaluation of neuromuscular disorders. However, these techniques predominantly provide functional information and may have limitations in directly demonstrating the underlying structural abnormality. Advances in high-resolution ultrasonography and magnetic resonance imaging have considerably expanded the role of imaging in neuromuscular disease [6,7,8].

High-resolution USG allows direct visualization of superficial peripheral nerves and muscles. Normal peripheral nerves demonstrate a characteristic fascicular appearance, with hypoechoic fascicles surrounded by hyperechoic connective tissue. Pathological processes may result in nerve enlargement, altered echogenicity, loss of normal fascicular architecture, discontinuity, or abnormal vascularity. USG also permits real-time dynamic examination and comparison with the contralateral side [9,10,11].

MRI provides excellent soft-tissue contrast and a large field of view and can evaluate both superficial and deep neuromuscular structures. Abnormal peripheral nerves may demonstrate enlargement and increased signal intensity on fluid-sensitive sequences. MRI is particularly valuable for demonstrating muscle denervation, which may manifest as edema-like signal abnormalities in the acute or subacute phase and as muscle atrophy and fatty replacement in chronic disease [12,13,14,15].

Although both modalities are increasingly employed in clinical practice, their relative and complementary roles

require systematic evaluation. The present study was undertaken to assess the utility of USG and MRI in patients presenting with neuromuscular pathologies.

Aim and Objectives

Aim: To evaluate the role of ultrasonography and magnetic resonance imaging in the diagnosis and characterization of neuromuscular pathologies.

1. To characterize the ultrasonographic findings in various neuromuscular pathologies.
2. To characterize the MRI findings in neuromuscular pathologies.
3. To compare USG and MRI findings with the final diagnosis.
4. To evaluate the complementary role of USG and MRI in lesion localization and characterization.

Materials and Methods

Study design

This prospective observational study was conducted in the Department of Radiodiagnosis at Tertiary Care Institute of India over a period of one year, from July 2025 to June 2026.

Study population

The study included 50 patients presenting with suspected neuromuscular pathology and undergoing evaluation with both USG and MRI.

Inclusion criteria

Patients presenting with clinical features suggestive of neuromuscular pathology; patients undergoing both ultrasonography and MRI for evaluation of the suspected abnormality; and patients providing informed consent.

Exclusion criteria

Patients in whom either USG or MRI examination could not be completed; patients with contraindications to MRI; patients with severe motion artifacts or technically inadequate imaging precluding reliable interpretation; patients without adequate clinical or diagnostic information for establishing the final diagnosis.

Ultrasonography technique

High-resolution ultrasonography was performed using an appropriate high-frequency linear-array transducer. The affected nerve or muscle was evaluated in longitudinal and transverse planes, with comparison with the contralateral side wherever appropriate. Nerve caliber, cross-sectional area, fascicular architecture, echogenicity, focal or diffuse enlargement, continuity, perineural abnormalities, vascularity, muscle bulk, architecture, echogenicity, focal muscular lesions, and dynamic abnormalities were assessed [16,17]. (Figure 1 and 2)



Figure 1: Ultrasound image showing diffuse increased echogenicity in posterior compartment of right thigh (biceps femoris muscle) with relative loss of normal fibrillar echotexture suggesting muscle edema/Inflammatory changes

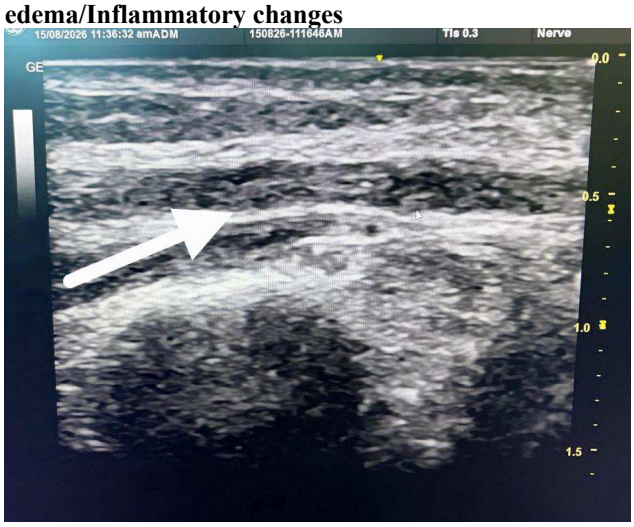


Figure 2: Ultrasonography image demonstrating diffuse thickening and hypoechogenicity of the ulnar nerve, with enlargement of the nerve fascicles, suggestive of ulnar neuropathy

MRI technique

MRI was performed using appropriate surface or dedicated coils according to the anatomical region. The protocol included multiplanar T1-weighted, T2-weighted, and STIR or other fluid-sensitive fat-suppressed sequences, with diffusion-weighted and postcontrast imaging whenever clinically indicated. Nerve caliber, signal intensity, fascicular morphology, continuity, site and extent of involvement, muscle edema, atrophy, fatty infiltration, fascial or soft-tissue abnormalities, space-occupying lesions, and associated osseous or joint abnormalities were assessed [18–22]. (Figure 3 and 4)

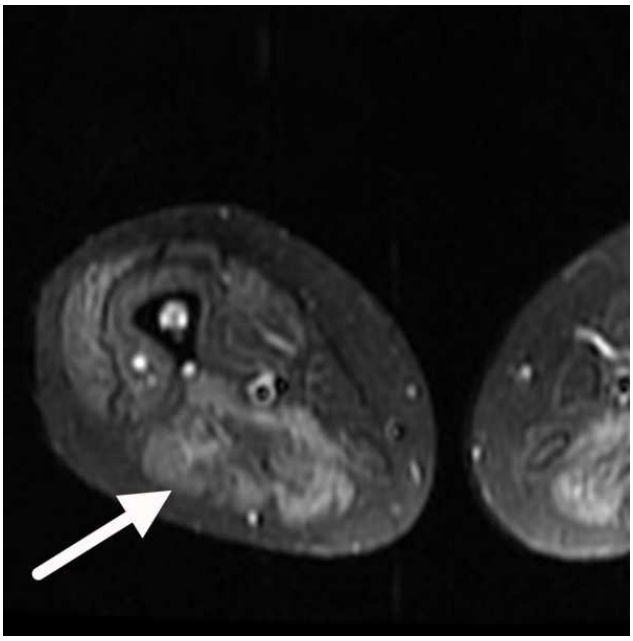


Figure 3: MRI STIR image demostrating hyperintense signal in right biceps femoris muscle associated with increased fluid-sensitive signal suggesting edema/inflammatory changes

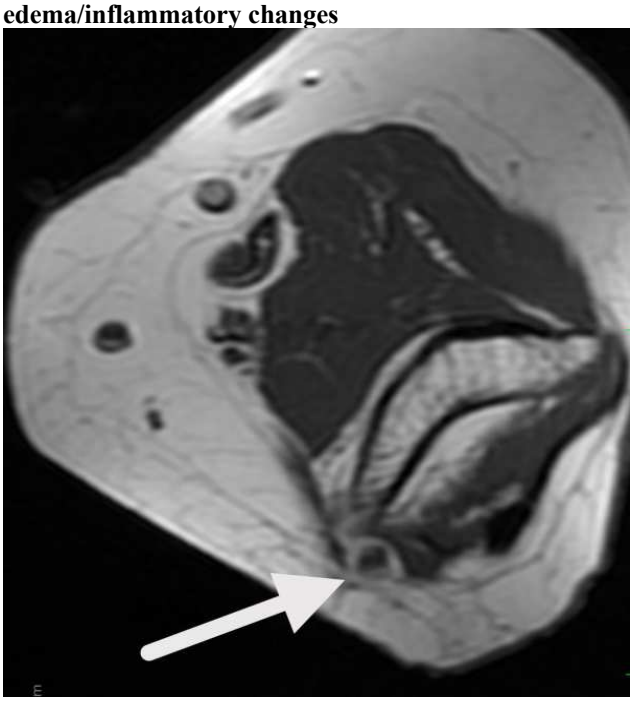


Figure 4: MRI image demonstrating diffuse thickening and increased T2 W signal intensity of the ulnar nerve, with enlargement of the nerve, suggestive of ulnar neuropat

Results

A total of 50 patients with clinically suspected neuromuscular pathology were evaluated using both high-resolution USG and MRI. The spectrum of abnormalities included entrapment neuropathies, traumatic peripheral nerve injuries, inflammatory neuropathies, peripheral nerve sheath tumors and other focal nerve lesions, muscle injuries, inflammatory muscle abnormalities, and acute or chronic denervation-related muscle changes.

On USG, peripheral nerve pathology was characterized by focal or diffuse nerve enlargement, increased cross-sectional area, altered echogenicity, distortion of normal fascicular architecture, discontinuity in traumatic lesions, and abnormal vascularity in selected cases. USG provided excellent delineation of superficial nerves and permitted dynamic assessment at potential sites of entrapment.

MRI demonstrated nerve enlargement and increased signal intensity on fluid-sensitive sequences in affected nerves. Muscle involvement was particularly well demonstrated on MRI. Acute and subacute denervation changes appeared as edema-like increased signal intensity on fluid-sensitive sequences, whereas chronic abnormalities demonstrated muscle volume loss and fatty replacement on T1-weighted images.

USG was advantageous for superficial nerve assessment, dynamic evaluation, rapid contralateral comparison, and identification of focal abnormalities. MRI was advantageous for deep-seated nerves, evaluation of the full anatomical extent of disease, demonstration of muscle denervation patterns, and detection of associated soft-tissue and osseous abnormalities.

The two modalities demonstrated complementary value: targeted USG provided detailed morphological and dynamic assessment of superficial lesions, whereas MRI provided broader anatomical coverage and evaluation of secondary muscular changes.

Table 1: Pathology Distribution

Pathology	**No. of Patients**
Entrapment neuropathy	20
Traumatic peripheral nerve injury	1
Peripheral nerve sheath tumor / focal nerve lesion	9
Inflammatory neuropathy-leprosy	4
Muscle injury	1
Inflammatory myopathy	12
Denervation-related muscle changes	3
Total	50

Table 2: Comparative Radiological Utility of USG and MRI in the Study

Pathology / Imaging Target	USG – Principal Contribution	MRI – Principal Contribution	Overall Radiological Role

Entrapment neuropathy	Nerve enlargement, increased CSA, fascicular distortion, dynamic assessment and contralateral comparison	Nerve signal/caliber and structural cause of compression; useful for deep/proximal lesions	USG particularly useful as initial imaging for superficial entrapment; MRI complementary in atypical/deep disease
Traumatic peripheral nerve injury	Continuity, focal swelling, fascicular disruption, neuroma and dynamic relation to adjacent structures	Deep injury, associated soft tissue and secondary denervation changes	USG provides high-resolution focal assessment; MRI defines extent and secondary muscle involvement
Peripheral nerve sheath tumor / focal nerve lesion	Superficial hypoechoic lesion, nerve continuity and Doppler vascularity	Superior lesion characterization, extent and neurovascular relationships	MRI preferred for deep lesions and preoperative mapping; USG useful for superficial lesions
Inflammatory neuropathy-leprosy	CSA/fascicular enlargement and intraneural vascularity	Proximal nerves, plexuses and nerve roots; nerve signal abnormality	Complementary; MRI extends assessment beyond sonographically accessible nerves
Muscle injury	Superficial fibrillar disruption, hematoma and dynamic assessment	Muscle edema and extent, especially deep/multicompartmental injury	USG useful for superficial/dynamic assessment; MRI for deeper or extensive injury
Inflammatory myopathy	Altered muscle echogenicity/architecture	STIR hyperintensity, distribution, symmetry and biopsy-site assessment	MRI provides broader assessment of muscle disease

			burden
Denervation-related muscle changes	Altered echogenicity, thickness and architecture	Acute/subacute edema-like signal; chronic atrophy and fatty replacement	MRI provides more comprehensive assessment and may help localize nerve involvement

The distribution of cases and the observed imaging patterns support a complementary, modality-based approach. USG is most advantageous where high spatial resolution, dynamic assessment, superficial nerve visualization, and contralateral comparison are required. MRI contributes greater anatomical coverage and superior assessment of deep nerves, muscle edema, denervation, atrophy, fatty replacement, and associated structural abnormalities (Table 2).

Discussion

Neuromuscular disorders encompass a heterogeneous group of conditions involving peripheral nerves and skeletal muscles. Although clinical examination and electrophysiological studies remain important for functional assessment, imaging provides direct morphological information regarding the site, extent, and underlying cause of disease. In the present study, high-resolution USG and MRI demonstrated complementary roles across different neuromuscular pathologies [3,7,10,14–18].

Taken together, these comparisons strengthen the main result of the present study rather than suggesting that one modality is universally superior. The 40% prevalence of entrapment neuropathy in the current study emphasizes the practical value of high-resolution USG for superficial nerve disease, while the 24% frequency of inflammatory myopathy and the presence of denervation-related changes highlight situations in which MRI provides additional information about muscle involvement. This study therefore supports a targeted workflow in which USG is particularly useful as an accessible first-line examination for superficial peripheral nerve and muscle abnormalities, while MRI is used when lesions are deep, extensive, proximal, anatomically complex, or associated with denervation, edema, atrophy, or fatty replacement [31–35].

A further point of comparison is provided by Guimaraes et al. [35], who evaluated 12 patients with inclusion body myositis using US and MRI on the same day. They reported 84% sensitivity and 100% specificity for ultrasound compared with MRI for detection of muscle abnormalities, with an overall accuracy of 86.8%. Their results demonstrate that USG can perform well even in chronic neuromuscular muscle disease when the abnormality is accessible and when an appropriate sonographic grading approach is used. This study did not restrict its population to inclusion body myositis and did not calculate modality-specific diagnostic accuracy; nevertheless, the finding that USG can demonstrate abnormal muscle architecture and echogenicity while MRI defines fat replacement and atrophy is concordant with their observations [35].

Paramalingam et al. [34] also reported that ultrasound could detect muscle pathology in idiopathic inflammatory myopathy, although its specificity for distinguishing individual pathological processes was limited. In their prospective study, ultrasound showed sensitivity ranging from 67% to 100% for detecting muscle pathology demonstrated on MRI, while specificity varied widely. Increased echogenicity was sensitive but not specific for the underlying muscle abnormality. This is compatible with the present study's complementary-modality model. The current data suggest that USG is well suited to identify and characterize accessible muscle abnormalities, whereas MRI is better positioned to determine the distribution, depth, edema pattern, atrophy, and fatty replacement when the sonographic finding requires further characterization [34].

The findings of Yoshida et al. [33] further support the interpretation of increased muscle echogenicity in this study. Their study included 42 patients with idiopathic inflammatory myopathies and 25 controls, and muscle echo intensity was higher in affected patients and correlated with creatine kinase and muscle strength in non-inclusion-body-myopathy cases. This distinction is important because echogenicity may reflect more than active inflammation, including chronic structural change and fatty replacement. Therefore, the current findings support the use of USG as a screening and characterization tool, while avoiding the assumption that an echogenic muscle pattern alone establishes the exact pathological subtype [33].

The muscle component of this study also showed agreement with comparative inflammatory myopathy literature. In the current cohort, inflammatory myopathy accounted for 12 of 50 patients (24%). USG demonstrated altered muscle echogenicity and architecture, while MRI better demonstrated STIR hyperintensity and the distribution of muscular involvement. Walter et al. [32] prospectively compared muscle ultrasound with whole-body MRI in patients with newly diagnosed idiopathic inflammatory myopathy and found MRI abnormalities in all patients, with edema demonstrated in 76% of evaluated muscles. Semi-quantitative and qualitative ultrasound nevertheless identified abnormalities in most patients despite examining fewer muscles. These findings support our observation that ultrasound can detect clinically useful muscle abnormalities efficiently, whereas MRI provides a wider anatomical survey and is more

sensitive to inflammatory edema [32].

For peripheral nerve disease, this study found that USG was particularly useful in entrapment neuropathies, focal nerve enlargement, fascicular distortion, dynamic assessment, and traumatic nerve abnormalities. This observation is closely aligned with the comparative study by Zaidman et al. [31] with suspected focal peripheral nerve pathology. Among the patients with confirmed pathology, ultrasound detected 43 of 46 lesions compared with 31 of 46 lesions on MRI, with reported sensitivity of 93% for ultrasound and 67% for MRI and similar specificity.

Overall, the pattern observed in this study is consistent with the published literature: ultrasonography contributed most strongly to assessment of superficial and sonographically accessible nerve or muscle abnormalities, whereas MRI added value for deep structures, broader disease distribution, muscle edema, denervation, and chronic tissue change [31–35].

Entrapment neuropathies

Entrapment neuropathies represent an important application of high-resolution peripheral nerve ultrasonography. Carpal tunnel syndrome involving the median nerve and ulnar nerve entrapment, particularly around the elbow, can be evaluated using USG. The affected nerve may demonstrate focal or diffuse enlargement, increased cross-sectional area proximal to the site of compression, reduced echogenicity, and distortion of normal fascicular architecture. USG also permits contralateral comparison and dynamic evaluation. MRI can demonstrate increased caliber and increased signal intensity of the affected nerve and can identify surrounding structural causes of compression. Thus, USG may serve as a valuable first-line imaging investigation for superficial entrapment neuropathies, while MRI is useful in atypical, proximal, deep, or structurally complex cases [1,2,4,10,11,15,19].

Traumatic peripheral nerve injury

High-resolution USG enables direct assessment of nerve continuity and may demonstrate focal swelling, altered fascicular architecture, partial or complete discontinuity, neuroma formation, and surrounding scar tissue. Dynamic examination can depict the relationship of the nerve to adjacent structures. MRI provides a larger field of view and is particularly useful for deep injuries, associated soft-tissue abnormalities, and secondary denervation changes in muscles supplied by the affected nerve [1,4,7,10,12,13].

Peripheral nerve sheath tumors and focal nerve lesions

Peripheral nerve sheath tumors, particularly schwannomas and neurofibromas, can be evaluated using both modalities. On USG, these lesions commonly appear as well-defined hypoechoic masses in continuity with a peripheral nerve, and Doppler imaging can assess internal vascularity. MRI provides superior characterization, determination of lesion extent, and assessment of the relationship with surrounding neurovascular structures, making it particularly important for preoperative mapping and deep lesions [1,4,6,7,10,14,23].

Inflammatory neuropathies- Leprosy

Inflammatory neuropathies may produce diffuse or segmental nerve enlargement and abnormalities of the fascicular pattern. USG may demonstrate increased cross-sectional area, reduced echogenicity, fascicular enlargement, and increased intraneural vascularity. MRI and MR neurography can demonstrate enlargement and increased signal intensity of affected nerves and are advantageous for proximal nerves, plexuses, and nerve roots that are less accessible to ultrasonography [6,8–10,13,24].

Muscle injury

USG is useful for superficial muscle injuries because it permits dynamic examination and assessment during contraction. Muscle tears may demonstrate disruption of normal fibrillar architecture, focal heterogeneous areas, hematoma, or retraction. MRI provides excellent visualization of muscle edema and the anatomical extent of injury and is particularly useful when deeper muscles or multiple compartments are involved [3,5,25,26].

Inflammatory myopathies

Inflammatory muscle disorders may produce altered muscle architecture and echogenicity on ultrasonography. MRI has a particularly important role because inflammatory edema is readily demonstrated on STIR or other fluid-sensitive fat-suppressed sequences. MRI can assess multiple muscle groups simultaneously, demonstrate the distribution and symmetry of involvement, and assist in selection of a suitable biopsy site [5,7,14,27,28].

Denervation changes

MRI is particularly valuable for demonstrating secondary muscle changes resulting from nerve injury. Acute and subacute denervation may manifest as increased signal intensity within affected muscles on fluid-sensitive sequences, while chronic denervation produces muscle volume loss and fatty replacement on T1-weighted images. The distribution of affected muscles may help localize the level of nerve involvement. USG can demonstrate altered muscle echogenicity, thickness, architecture, and bulk, but MRI generally provides a more comprehensive assessment of the distribution and extent of denervation [7,12,13,20–22].

Comparative role of USG and MRI

USG and MRI should be regarded as complementary rather than competing modalities. USG is particularly advantageous for superficial peripheral nerves, entrapment neuropathies, dynamic assessment, traumatic nerve lesions, superficial nerve sheath tumors, superficial muscle injuries, contralateral comparison, and image-guided procedures. MRI is particularly advantageous for deep or proximal nerves, plexuses, extensive lesions, muscle edema, inflammatory changes, acute and chronic denervation, muscle atrophy and fatty replacement, deep muscle pathology, associated structural abnormalities, and preoperative assessment [1,3,6,7,10,12–14,20–22,27,28].

Clinical implications

A practical approach is to use high-resolution USG as an initial imaging modality for suspected superficial entrapment neuropathy or focal peripheral nerve abnormality. MRI can subsequently be performed when the lesion is deep, sonographic findings are inconclusive, proximal extension is suspected, or secondary muscle denervation needs assessment. In patients presenting predominantly with muscular symptoms or suspected inflammatory myopathy, MRI may be preferred because it evaluates multiple muscle compartments and

demonstrates edema, fatty infiltration, and atrophy [1,4,6,7,10,14,27,28].

Conclusion

High-resolution ultrasonography and MRI are valuable and complementary modalities for the evaluation of neuromuscular pathologies. USG is particularly useful for superficial peripheral nerves because of its high spatial resolution, dynamic capability, accessibility, and ability to rapidly compare the affected and contralateral sides. MRI provides superior soft-tissue contrast, a larger field of view, and better evaluation of deep neuromuscular structures. It is particularly valuable for demonstrating muscle denervation, edema, atrophy, fatty replacement, disease extent, and associated structural abnormalities. Integration of clinical examination, electrophysiological studies, USG, and MRI provides a comprehensive diagnostic approach and can improve lesion localization and characterization [1,3,6,7,10,12–14,20–22,27,28].

References

1. Martinoli C, Bianchi S, Derchi LE. Ultrasonography of peripheral nerves. Semin Ultrasound CT MR. 2000;21(3):205-213. doi:10.1016/S0887-2171(00)90043-X.
2. Beekman R, Visser LH. High-resolution sonography of the peripheral nervous system—a review of the literature. Eur J Neurol. 2004;11(5):305-314. doi:10.1111/j.1468-1331.2004.00773.x.
3. Walker FO, Cartwright MS, Wiesler ER, Caress J. Ultrasound of nerve and muscle. Clin Neurophysiol. 2004;115(3):495-507. doi:10.1016/j.clinph.2003.10.022.
4. Lawande AD, Warrier SS, Joshi MS. Role of ultrasound in evaluation of peripheral nerves. Indian J Radiol Imaging. 2014;24(3):254-258. doi:10.4103/0971-3026.137037.
5. Pillen S, van Alfen N. Skeletal muscle ultrasound. Neurol Res. 2011;33(10):1016-1024. doi:10.1179/1743132811Y.0000000010.
6. Chhabra A, Andreisek G, Soldatos T, Wang KC, Flammang AJ, Belzberg AJ, et al. MR neurography: past, present, and future. AJR Am J Roentgenol. 2011;197(3):583-591. doi:10.2214/AJR.10.6012.
7. Filler AG, Maravilla KR, Tsuruda JS. MR neurography and muscle MR imaging for image diagnosis of disorders affecting the peripheral nerves and musculature. Neurol Clin. 2004;22(3):643-682. doi:10.1016/j.ncl.2004.03.005.
8. Kerasnoudis A, Pitarokoili K, Behrendt V, Gold R, Yoon MS. Nerve ultrasound score in distinguishing chronic from acute inflammatory demyelinating polyneuropathy. Clin Neurophysiol. 2014;125(3):635-641. doi:10.1016/j.clinph.2013.08.014.
9. Van den Bergh PYK, van Doorn PA, Hadden RDM, et al. European Academy of Neurology/Peripheral Nerve Society guideline on diagnosis and treatment of chronic inflammatory demyelinating polyradiculoneuropathy. J Peripher Nerv Syst. 2021;26(3):242-268.
10. Hobson-Webb LD, Padua L, Martinoli C. Ultrasonography in the diagnosis of peripheral nerve disease. Expert Opin Med Diagn. 2012;6(5):457-471. doi:10.1517/17530059.2012.692904.
11. Cartwright MS, Hobson-Webb LD, Boon AJ, Alter KE, Hunt CH, Flores VH, et al. Evidence-based guideline: neuromuscular ultrasound for the diagnosis of carpal tunnel syndrome. Muscle Nerve. 2012;46(2):287-293. doi:10.1002/mus.23389.
12. Weber MA, Jestaedt L. Secondary MR imaging features of nerve damage: muscle denervation. Magn Reson Imaging Clin N Am. 2025;33(3):437-454. doi:10.1016/j.mric.2025.03.004.
13. Wolf M, Wolf C, Weber MA. Neurogenic myopathies and imaging of muscle denervation. Radiologe. 2017;57(12):1038-1051. doi:10.1007/s00117-017-0316-x.
14. Paik JJ, Christopher-Stine L, Boesen M, Carrino JA, Eggleton SP, Denis D, et al. The utility of muscle magnetic resonance imaging in idiopathic inflammatory myopathies: a scoping review. Front Immunol. 2025;16:1455867. doi:10.3389/fimmu.2025.1455867.
15. Padua L, Martinoli C, Liotta G, Di Pasquale A, Gregori B, Tonali P. Heterogeneity of nerve ultrasound in carpal tunnel syndrome. Muscle Nerve. 2010;42(3):384-389.
16. Visser LH. High-resolution sonography of the peripheral nervous system. J Clin Neurophysiol. 2006;23(4):287-299.
17. Padua L, Coraci D, Erra C, Pazzaglia C, Paolasso I, Loreti C, et al. Carpal tunnel syndrome: ultrasound, neurophysiology, and clinical findings. J Neurol. 2016;263(11):2268-2273.
18. Simon NG, Narasimhan G, Muppidi S, Dimachkie MM. Peripheral nerve ultrasound in the diagnosis of neuropathy. Curr Opin Neurol. 2016;29(5):584-590.
19. Chang KV, Wu WT, Özçakar L. Ultrasound imaging for the diagnosis of peripheral nerve entrapment and neuropathy. Phys Med Rehabil Clin N Am. 2018;29(1):99-116.
20. West GA, Haynor DR, Muñoz del Rio A, et al. MR imaging of denervated skeletal muscle. Radiographics. 2000;20:S67-S81.
21. Polak JF, Jolesz FA, Adams DF. Magnetic resonance imaging of skeletal muscle. N Engl J Med. 1985;312(13):803-808.
22. Fleckenstein JL, Watumull D, Conner KE, et al. Muscle proton spin-spin relaxation times and work-related muscle fatigue: MR imaging findings. Radiology. 1993;188(3):803-807.
23. Soldatos T, Chhabra A, et al. High-resolution 3-T MR neurography of peripheral nerves and plexuses. Radiographics. 2013;33(3):E1-E17.
24. Zaidman CM, Harms MB, Pestronk A. Ultrasound of denervated muscles: findings and clinical correlation. Muscle Nerve. 2011;43(5):667-675.
25. Bianchi S, Martinoli C. Ultrasound of musculoskeletal system: muscle and tendon injuries. Radiol Clin North Am. 1999;37(4):713-733.
26. Lee JC, Healy J. Sonography of lower limb muscle injury. AJR Am J Roentgenol. 2004;182(2):341-351.
27. Mercuri E, Pichiecchio A, Allsop J, et al. Muscle MRI in inflammatory myopathies and muscular dystrophies. Eur Radiol. 2007;17(1):1-10.
28. Pinal-Fernandez I, Casal-Dominguez M, Mammen AL. Immune-mediated necrotizing myopathy. Curr Rheumatol Rep. 2018;20(4):21.

29. Wattjes MP, Kley RA, et al. Neuromuscular imaging: MRI and ultrasound in clinical practice. Eur Radiol. 2020;30:1-15.
30. Grimm A, Décard BF, Axer H. Ultrasound of the peripheral nerves: correlation with clinical and electrophysiological findings. Clin Neurophysiol. 2014;125(3):505-511.
31. Zaidman CM, Seelig MJ, Baker JC, Mackinnon SE, Pestronk A. Detection of peripheral nerve pathology: comparison of ultrasound and MRI. Neurology. 2013;80(18):1634-1640. doi:10.1212/WNL.0b013e3182904f3f.
32. Walter AW, Lim J, Raaphorst J, Smithuis FF, den Harder JM, Eftimov F, et al. Ultrasound and MR muscle imaging in new onset idiopathic inflammatory myopathies at diagnosis and after treatment: a comparative pilot study. Rheumatology (Oxford). 2022;62(1):300-309. doi:10.1093/rheumatology/keac263.
33. Yoshida T, Yamazaki H, Nishimori Y, Takamatsu N, Fukushima K, Osaki Y, et al. Correlation of muscle ultrasound with clinical and pathological findings in idiopathic inflammatory myopathies. Muscle Nerve. 2023;68(1):39-47. doi:10.1002/mus.27833.
34. Paramalingam S, Needham M, Harris S, O'Hanlon S, Mastaglia F, Keen H. Muscle B mode ultrasound and shear-wave elastography in idiopathic inflammatory myopathies (SWIM): criterion validation against MRI and muscle biopsy findings in an incident patient cohort. BMC Rheumatol. 2022;6:47. doi:10.1186/s41927-022-00276-w.
35. Guimaraes JB, Cavalcante WCP, Cruz IAN, Nico MA, Ormond Filho AG, Silva AMS, et al. Musculoskeletal ultrasound in inclusion body myositis: a comparative study with magnetic resonance imaging. Ultrasound Med Biol. 2021;47(8):2186-2192. doi:10.1016/j.ultrasmedbio.2021.04.019.