Original Article

Role of High-resolution Ultrasonography in the Evaluation of Ulnar Nerve Involvement in Patients with Leprosy

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Abstract

Background: Leprosy remains an important cause of peripheral neuropathy in endemic regions, with nerve involvement being the major determinant of long-term disability. The ulnar nerve is commonly affected. Conventional clinical assessment has limited ability to objectively quantify nerve damage. High-resolution ultrasonography (HRUS) enables structural evaluation of peripheral nerves in a non-invasive manner. **Objective:** The objective of the study was to assess ulnar nerve involvement using HRUS in patients with leprosy and to compare ultrasonographic findings with clinical examination. **Materials and Methods:** This prospective observational study was conducted at a tertiary care center from March 2024 to August 2025 and included 49 clinically diagnosed leprosy patients. All patients underwent clinical examination and HRUS of the ulnar nerve using a 12–18 MHz linear transducer. Cross-sectional area (CSA), fascicular pattern, echogenicity, and intraneural vascularity on power Doppler were evaluated. **Results:** The mean age was 43.86 ± 15.20 years, with male predominance (65.3%). Borderline tuberculoid (30.6%) and borderline lepromatous (26.5%) types were most frequent. HRUS detected ulnar nerve thickening in 89.8% of patients compared with 77.6% by clinical examination. Mean CSA was 11.90 ± 4.58 mm^2. Loss of fascicular pattern was seen in 63.3%, altered echogenicity in 87.8%, and increased intraneural vascularity in 57.1%. HRUS showed sensitivity 93.6%, specificity 50.0%, positive predictive value 97.8%, negative predictive value 25.0%, and overall accuracy 91.8% for detecting ulnar nerve involvement. **Conclusion:** HRUS is a useful, noninvasive adjunct for objective detection and characterization of ulnar nerve involvement in leprosy and complements clinical assessment.

Keywords: Hansen's disease, high-resolution ultrasonography, leprosy, nerve thickening, peripheral neuropathy, ulnar nerve

Résumé

Contexte: La lèpre demeure une cause majeure de neuropathie périphérique dans les régions endémiques, l'atteinte nerveuse constituant le principal déterminant de l'invalidité à long terme. Le nerf ulnaire est fréquemment touché. L'évaluation clinique conventionnelle ne permet que de manière limitée de quantifier objectivement les lésions nerveuses. L'échographie à haute résolution (EHR) permet une évaluation structurelle des nerfs périphériques de manière non invasive. **Objectif:** L'objectif de cette étude était d'évaluer l'atteinte du nerf ulnaire par EHR chez des patients atteints de lèpre et de comparer les résultats échographiques aux données de l'examen clinique. **Matériel et méthodes:** Cette étude observationnelle prospective a été menée dans un centre de soins tertiaires de mars 2024 à août 2025 et a inclus 49 patients chez qui un diagnostic clinique de lèpre avait été posé. Tous les patients ont bénéficié d'un examen clinique et d'une EHR du nerf ulnaire à l'aide d'une sonde linéaire de 12 à 18 MHz. La surface en coupe transversale (SCT), l'aspect fasciculaire, l'échogénicité et la vascularisation intraneurale (évaluée par Doppler couleur) ont été analysés. **Résultats:** L'âge moyen des patients était de 43,86 ± 15,20 ans, avec une prédominance masculine (65,3 %). Les formes borderline tuberculoïde (30,6 %) et borderline lépromateuse (26,5 %) ont été les plus fréquemment observées. L'EHR a permis de détecter un épaississement du nerf ulnaire chez 89,8 % des patients, contre 77,6 % lors de l'examen clinique. La SCT moyenne s'élevait à 11,90 ± 4,58 mm². Une perte de l'aspect

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Access this article online

Quick Response Code:

Website: www.annalsafrmed.org

DOI: 10.4103/aam.aam_168_26

How to cite this article: Nikhil K, Patil S, Janagond AB. Role of high-resolution ultrasonography in the evaluation of ulnar nerve involvement in patients with leprosy. Ann Afr Med 0;0:0.

Submitted: 17-Feb-2026 **Revised:** 20-Mar-2026
Accepted: 23-Apr-2026 **Published:** 20-May-2026

fasciculaire a été constatée chez 63,3 % des patients, une altération de l'échogénicité chez 87,8 % et une augmentation de la vascularisation intraneurale chez 57,1 %. Pour la détection de l'atteinte du nerf ulnaire, l'EHR a présenté une sensibilité de 93,6 %, une spécificité de 50,0 %, une valeur prédictive positive de 97,8 %, une valeur prédictive négative de 25,0 % et une précision globale de 91,8 %. **Conclusion:** L'EHR constitue un outil complémentaire utile et non invasif pour la détection objective et la caractérisation de l'atteinte du nerf ulnaire dans le cadre de la lèpre ; elle vient ainsi compléter l'évaluation clinique.

Mots-clés: Maladie de Hansen, échographie à haute résolution, lèpre, épaississement nerveux, neuropathie périphérique, nerf ulnaire

Introduction

Leprosy, caused by *Mycobacterium leprae*, remains an important cause of preventable peripheral neuropathy in endemic regions and continues to contribute substantially to disability.[1] Every year, nearly 200,000 new cases are reported globally, with India contributing more than half of the total burden.[1] The disease presents a complex clinical spectrum ranging from tuberculoid to lepromatous forms, with borderline manifestations between these polar extremes.[2] Nerve involvement may occur early and sometimes precedes visible skin lesions, highlighting the need for timely detection to prevent irreversible damage.[1] Peripheral nerve damage represents the most dreaded aspect of leprosy as it is the primary cause of disability and deformity, leading to social stigma.[3] Neural damage results from direct bacillary invasion of Schwann cells combined with host immune-mediated inflammation, producing edema, fibrosis, and ultimately irreversible damage if untreated.[4]

The ulnar nerve is among the most frequently involved nerves due to its superficial anatomical course and relative susceptibility to temperature variation, making it particularly suitable for imaging assessment.[5] Clinical assessment traditionally relies on nerve palpation for thickening and tenderness, sensory testing, and voluntary muscle testing.[6] However, these methods have significant limitations in detecting early or subclinical involvement, are subjective in nature, and cannot quantify nerve enlargement or differentiate between edematous and fibrotic changes.

High-resolution ultrasonography (HRUS) has emerged as a valuable, noninvasive, and cost-effective modality for peripheral nerve evaluation.[7] Unlike conventional ultrasonography, HRUS employs transducers with frequencies of 10–18 MHz or higher, providing exceptional spatial resolution for visualizing internal nerve architecture, including individual fascicles and surrounding epineurium.[8] Ultrasonographic evaluation can detect changes such as nerve thickening, altered echogenicity, loss of fascicular pattern, inflammatory changes, and increased vascularity on Doppler imaging.[9] These findings often precede clinical symptoms, enabling earlier diagnosis and treatment initiation.[9] Quantitative measurement of nerve cross-sectional area (CSA) provides objective and reproducible parameters for baseline assessment and follow-up.[10] The technique is well suited for serial examinations during multidrug therapy and for detecting changes associated with lepra reactions. Characteristic imaging patterns have been described, with hypoechoic appearance suggesting active inflammation and hyperechoic changes indicating chronic fibrosis.[11,12]

However, further clinical correlation of ultrasonographic findings with disease severity and disability status is needed to better define its practical role in routine assessment. This study aims to evaluate the role of HRUS in detecting and characterizing ulnar nerve abnormalities in leprosy patients and to correlate imaging findings with clinical parameters and disability status.

Materials and Methods

This prospective observational cross-sectional study was conducted in the Department of Radiodiagnosis at a tertiary care center, over 18 months from March 2024 to August 2025. Sample size calculation was based on a previous study by Dugad *et al*.,[13] using the formula $n = (Z \times \sigma/d)^2$ where $Z = 1.96$ (95% confidence interval), $\sigma = 5.35$ (standard deviation [SD]), and $d = 1.5$ (margin of error), yielding a minimum required sample size of 49 patients.

Inclusion criteria comprised adults aged >18 years with clinically diagnosed and biopsy-proven leprosy patients referred from the Department of Dermatology, Venereology, and Leprosy. Exclusion criteria included patients with post-ulnar nerve surgery history, systemic lupus erythematosus, other peripheral neuropathy causes, diabetes mellitus, hypothyroidism, HIV infection, and trauma-related peripheral nerve diseases.

All eligible patients who satisfied the inclusion criteria were approached for participation and written informed consent was obtained. A structured pro forma was used to record demographic details, clinical complaints, disease duration, treatment history, and examination findings. Detailed clinical history evaluation included assessment of skin lesions, sensory symptoms, motor weakness, and peripheral nerve examination for thickening and tenderness. Clinical classification was recorded according to the Ridley–Jopling classification system, and disability status was graded using the World Health Organization (WHO) disability grading system.[14,15]

HRUS examination of the ulnar nerve was performed bilaterally using GE Voluson S8 BT18 and GE Versana Premier ultrasound systems equipped with high-frequency linear array transducers (10–18 MHz). Patients were positioned with the elbow flexed at approximately 90° and resting on the examination table for cubital tunnel examination, while the arm was positioned in slight supination for forearm and wrist examination. The ulnar nerve was traced from the axilla to Guyon canal using transverse and longitudinal scans based on standard anatomical landmarks.[16]

HRUS examinations were performed by experienced radiologists and were blinded to clinical disability grading. Parameters evaluated included nerve CSA measured at the medial epicondyle level by tracing inside the hyperechoic epineurial rim, echogenicity (subjectively compared with adjacent muscle), fascicular pattern, presence of focal lesions or abscess, and intraneural vascularity on Doppler imaging. Doppler settings were standardized with low pulse-repetition frequency (approximately 500–800 Hz), low wall filter, and optimized gain adjusted just below background noise to improve slow-flow detection. Each measurement was obtained three times and averaged to reduce intraobserver variability.

HRUS nerve involvement was defined as the presence of increased CSA beyond reference range, altered echogenicity, fascicular disruption, increased Doppler vascularity, focal or diffuse thickening, constriction, or abscess.[16,17] For patients with bilateral abnormalities, the more severe side was used for per-patient analysis. Clinical nerve examination was used as the reference standard for determining ulnar nerve involvement in diagnostic performance analysis.

Data were entered into Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA) and analyzed using SPSS version 26.0 (IBM Corporation, Armonk, New York, USA). Continous variables were expressed as mean and SD and analyzed using one-way analysis of variance. Categorical variables were expressed as frequency and percentage and analyzed using the Chi-square test. All statistical tests were two-tailed, with $P < 0.05$ considered statistically significant.

Table 1: Baseline demographic and clinical characteristics (*n*=49)

Parameter	*n* (%) or mean±SD
Age (years)	
18–20	4 (8.2)
21–40	18 (36.7)
41–60	18 (36.7)
>60	9 (18.4)
Mean±SD	43.86±15.21
Gender	
Male	32 (65.3)
Female	17 (34.7)
Disease duration (months)	
Mean±SD	26.63±19.55
Ridley–Jopling type	
Borderline tuberculoid	15 (30.6)
Borderline lepromatous	13 (26.5)
Lepromatous	8 (16.3)
Tuberculoid	7 (14.3)
Mid-borderline	5 (10.2)
Indeterminate	1 (2.0)
Clinical findings	
Skin lesions	40 (81.6)
Sensory loss	39 (79.6)
Palpable nerve thickening	38 (77.6)
Motor weakness	24 (49.0)
Previous lepra reaction	12 (24.5)
WHO disability grade	
Grade 0	12 (24.5)
Grade 1	24 (49.0)
Grade 2	13 (26.5)

SD=Standard deviation, WHO=World Health Organization

Results

The study included 49 adult patients with leprosy, predominantly middle-aged (mean age 43.86 ± 15.21 years), with nearly three-quarters between 21 and 60 years. There was a male predominance (65.3%). Borderline forms constituted the majority of cases, with borderline tuberculoid (30.6%) and borderline lepromatous (26.5%) being the most common. Clinically, skin lesions (81.6%), sensory loss (79.6%), and palpable nerve thickening (77.6%) were frequent, while motor weakness was present in about half (49.0%). Most patients had established disability at presentation, with 75.5% falling into WHO disability grades 1 or 2 [Table 1].

On HRUS, ulnar nerve thickening was detected in 89.8% of patients, with a mean CSA of 11.90 ± 4.59 mm^2 (range 6–22 mm^2). Echotexture abnormalities were common, with altered echogenicity seen in 87.8% and loss of fascicular pattern in 63.3%. Increased intraneural vascularity on Doppler was observed in 57.1%, suggesting active neuritis in a substantial subset. Thickening was most often diffuse (38.8%) or focal (36.7%). Complications such as nerve constriction (22.4%) and abscess (8.2%) were also identified on HRUS [Table 2].

HRUS detected ulnar nerve involvement in 45 of 49 patients (91.8%). Findings were concordant with clinical

Table 2: High-resolution ultrasonographic findings of the ulnar nerve (*n*=49)

HRUS Parameter	*n* (%) or mean±SD
Nerve thickness	
Increased	44 (89.8)
Normal	5 (10.2)
CSA (mm^2), mean±SD (range)	11.90±4.59 (6–22)
Echogenicity	
Hypoechoic	18 (36.7)
Mixed	18 (36.7)
Hypoechoic with fascicular loss	7 (14.3)
Normal	6 (12.2)
Any altered echogenicity	43 (87.8)
Loss of fascicular pattern	31 (63.3)
Increased Doppler vascularity	28 (57.1)
Pattern of thickening	
Diffuse	19 (38.8)
Focal	18 (36.7)
Segmental	6 (12.2)
Complications	
Nerve constriction	11 (22.4)
Nerve abscess	4 (8.2)

HRUS=High-resolution ultrasonographic, SD=Standard deviation, CSA=Cross-sectional area

assessment in 44 cases, whereas HRUS identified involvement not evident clinically in 1 case and missed involvement suspected clinically in 3 cases. Overall, HRUS showed a sensitivity of 93.6%, specificity of 50.0%, positive predictive value of 97.8%, negative predictive value of 25.0%, and an overall accuracy of 91.8% for detecting ulnar nerve involvement [Table 3].

Ultrasonographic abnormalities were observed across all Ridley–Jopling types without statistically significant differences. Increased nerve thickness was common in every subtype (76.9%–100%). Loss of fascicular pattern and increased Doppler vascularity were also distributed across the spectrum, and nerve abscesses were seen only in borderline lepromatous and lepromatous cases. None of these differences reached statistical significance (all $P > 0.05$), and the indeterminate group was excluded from statistical testing due to small sample size [Table 4].

Mean ulnar nerve CSA varied numerically among leprosy types, being highest in the mid-borderline group and lowest in the lepromatous group, but the overall difference was not statistically significant ($P = 0.176$). This indicates that although CSA values differed between subtypes, the variation was not significant in this cohort [Table 5].

Discussion

HRUS is an increasingly used adjunctive tool in the evaluation of leprous neuropathy, providing an objective and reproducible assessment of peripheral nerves. In the present study of 49 leprosy patients, HRUS detected ulnar nerve thickening in 89.8% of cases compared with 77.6% by clinical palpation, indicating higher detection by imaging. The high sensitivity observed in our cohort supports its added value alongside clinical examination. Bathala *et al*. described a characteristic pattern of ulnar nerve enlargement with maximum thickening approximately 4 cm above the medial epicondyle (mean CSA 12.3 ± 4.2 mm^2), which is comparable to our mean CSA of 11.90 ± 4.58 mm^2 and higher than established normal reference values.[18] Sreejith *et al*. also demonstrated significantly higher detection of nerve thickening with HRUS compared with clinical examination (47% vs. 20%, $P < 0.001$), while Jain *et al*. reported poor agreement between palpation and ultrasonography ($\kappa = 0.30$).[16,19] Zaidman *et al*. further showed that ultrasound has higher sensitivity than magnetic resonance imaging (MRI) for peripheral nerve pathology detection with comparable specificity, supporting its role as a useful first-line imaging modality.[20] Subclinical nerve involvement was detected in a small proportion of our patients, consistent with the concept reported by Luppi *et al*. in high-risk contacts, although their study population differed.[10]

Table 3: Diagnostic performance of high-resolution ultrasonographic for detecting ulnar nerve involvement compared with clinical examination ($n = 49$)

	Clinical positive	Clinical negative	Total
HRUS positive	44 (89.8)	1 (2.0)	45 (91.8)
HRUS negative	3 (6.1)	1 (2.0)	4 (8.2)
Total	47 (95.9)	2 (4.1)	49 (100)

HRUS=High-resolution ultrasonographic

Beyond nerve size, HRUS provided structural information that is not reliably obtainable on routine clinical examination. Loss of fascicular pattern was observed in 63.3% of patients, comparable to Gupta *et al*., who reported similar rates, and likely reflects inflammatory infiltration and architectural distortion.[21] Echogenicity alterations were present in the majority of cases in our study, including hypoechoic and mixed patterns, indicating varying stages of inflammatory and reparative changes. Dugad *et al*. reported high sensitivity and positive predictive value for echogenicity changes, supporting their diagnostic relevance as reported previously.[13] Power Doppler evaluation demonstrated increased intraneural vascularity in over half of our cases, suggesting possible active neuritis. Prior studies have shown an association between Doppler vascularity and reactional states. Chaduvula *et al*. documented a marked reduction in endoneural blood flow following treatment, and Gupta *et al*. also found vascularity to correlate with clinical reactions.[21,22] We did not observe statistically significant differences in ultrasonographic parameters across Ridley–Jopling types, suggesting that sonographic nerve involvement may be demonstrable across the disease spectrum, although subgroup sizes were limited.

HRUS also enabled the identification of additional morphological abnormalities, such as nerve abscesses and focal constrictions in a subset of patients, which are clinically relevant and may influence management decisions. Compared with advanced imaging modalities, HRUS is generally more accessible and practical for routine use in many settings. Oberoi *et al*. reported that although MRI may detect more instances of nerve thickening, ultrasonography demonstrates good specificity and positive predictive value with the advantages of lower cost, portability, and fewer contraindications.[23] These features make HRUS suitable for routine evaluation

Table 4: Ultrasonographic findings across Ridley–Jopling types

Parameter	BT ($n = 15$)	BL ($n = 13$)	LL ($n = 8$)	TT ($n = 7$)	BB ($n = 5$)	*P*
Increased thickness	15 (100)	10 (76.9)	7 (87.5)	6 (85.7)	5 (100)	0.351
Fascicular loss	12 (80.0)	8 (61.5)	4 (50.0)	3 (42.9)	3 (60.0)	0.501
Increased vascularity	9 (60.0)	7 (53.8)	5 (62.5)	4 (57.1)	2 (40.0)	0.984
Nerve abscess	0	2 (15.4)	2 (25.0)	0	0	0.242

BT=Borderline tuberculoid, BL=Borderline lepromatous, LL=Lepromatous leprosy, TT=Tuberculoid leprosy, BB=Mid-borderline

Table 5: Ulnar nerve cross-sectional area by leprosy type

Leprosy type	CSA (mm^2), mean±SD
BT	12.07±3.77
BL	12.15±5.43
Lepromatous	9.25±1.17
Tuberculoid	11.43±5.26
BB	16.20±5.54
Indeterminate	9.00
P	0.176

SD=Standard deviation, CSA=Cross-sectional area, BT=Borderline tuberculoid, BL=Borderline lepromatous, BB=Mid-borderline

and follow-up of patients with leprosy-related neuropathy.

The present study has certain limitations. The sample size was relatively small and derived from a single center. Subgroup analysis across Ridley–Jopling types was constrained by unequal and small category numbers, reducing statistical power for between-group comparisons. Clinical and ultrasonographic assessments were not blinded to each other, introducing the possibility of observer bias. In addition, correlation with electrophysiological studies and longitudinal follow-up after treatment were not included, so the temporal relationship between sonographic changes and functional outcomes could not be assessed.

Conclusion

HRUS is a useful, noninvasive adjunct for the evaluation of peripheral nerve involvement in leprosy, providing an objective and reproducible assessment that complements clinical examination. It allows better detection and morphological characterization of nerve pathology and supports assessment of inflammatory activity at presentation. HRUS is applicable across different clinical types of leprosy and is practical for routine use due to its accessibility and real-time imaging capability. Its incorporation into evaluation can strengthen diagnostic assessment and aid clinical decision-making in leprous neuropathy.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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