Manske RC, Wolfe C, Page P, Voight M. Diagnostic Musculoskeletal Ultrasound in the Evaluation of the Median Nerve. *IJSPT*. 2025;20(5):756-761. doi:10.26603/001c.136985

MSK Ultrasound Bites: Tips and Tricks

Diagnostic Musculoskeletal Ultrasound in the Evaluation of the Median Nerve

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Keywords: musculoskeletal ultrasound, median nerve, overuse injury, rehabilitation, dynamic imaging

https://doi.org/10.26603/001c.136985

International Journal of Sports Physical Therapy

Vol. 20, Issue 5, 2025

The median nerve is a crucial structure in the forearm and wrist, responsible for motor and sensory functions. Accurate diagnosis of nerve injury is essential for appropriate treatment planning and optimizing patient outcomes. Although magnetic resonance imaging (MRI) and nerve conduction studies (NCS) are the gold standard for nerve assessment, diagnostic musculoskeletal (MSK) ultrasound offers a portable, real-time, and cost-effective alternative that is gaining traction in rehabilitation and sports medicine settings. MSK ultrasound has emerged as a valuable, non-invasive imaging modality for evaluating median nerve pathology, including carpal tunnel syndrome (CTS), nerve entrapment, and traumatic nerve injuries. This article reviews the utility of MSK ultrasound in evaluating the median nerve injury, including its anatomy, common injury patterns, sonographic techniques, and clinical implications for professional rehabilitation. By integrating MSK ultrasound into clinical practice, providers can improve the accuracy of diagnosis, monitor healing progression, and guide rehabilitation strategies for optimal patient outcomes.

INTRODUCTION

The most common median nerve injury in the wrist is carpal tunnel syndrome (CTS).[1,2] This entrapment neuropathy develops as the median nerve is contained within a relatively inflexible carpel tunnel. Increased compartmental pressures lead to local nerve ischemia, releasing inflammatory factors that cause edema, leading to further increased compression.[3] Symptoms of CTS include nocturnal paresthesia involving the thumb, index, middle and radial half of the ring finger with sparing of the thenar eminence, progressing to daytime symptoms and eventual atrophy of the thenar eminence.[4]

ANATOMY OF THE MEDIAN NERVE

The median nerve begins as the extension of the medial and lateral cords of the brachial plexus in the axillary region. It descends in the arm lateral to the brachial artery until the insertion of the coracobrachialis, where it crosses in front, and in rare cases, behind the artery to move to the medial side of the arm near the anterior cubital fossa. At that location, it runs behind the lacertus fibrosus and is separated from the joint by the brachialis muscle. The median nerve received its name from the middle position at the end of the brachial plexus and the forearm.[5] As it descends further in the forearm, it runs between the two heads of the pronator teres. From that point it runs beneath the flexor digitorum, laying on the flexor digitorum profundus more superficially as it passes underneath the transverse carpal ligament (flexor retinaculum) into the palm. At the hand, the median nerve gives motor branches to the thenar eminence, and second lumbrical muscles, as well as sensory branches to the radial half of the palm and the radial three and half digits.[6] Its motor function is to the flexor aspect of the forearm, hand, and thumb to innervate the pronator teres, palmaris longus, flexor digitorum superficialis, flexor carpi radialis, and via the anterior interosseus nerve (AIN), the flexor pollicis longus, the flexor digitorum profundus, and the pronator quadratus.

Understanding the structure and innervation of the median nerve is essential for accurate MSK ultrasound assessment and differentiation of injury type and severity.

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THE ROLE OF MSK ULTRASOUND IN NERVE EVALUATION

ADVANTAGES

- Real-Time Imaging: Allows dynamic evaluation of median nerve integrity while the wrist and forearm are moved through available range of motion.
- High-Resolution Visualization: Provides detailed images of soft tissue structures, including individual nerves in the forearm and wrist.
- Accessibility and Cost-Effectiveness: MSK ultrasound is portable, widely available, and less expensive than MRI.
- Dynamic Stress Testing: Enables direct visualization of nerve mobilization, thickening, or disruption during functional movements.

LIMITATIONS

- Operator Dependency: Requires skill and experience for accurate interpretation of findings. The ability to sonograph peripheral nerves is to a large extend influenced by the operator and the availability and technical considerations of state-of-the-art equipment.[7]
- Depth Limitations: Visualization of deeper structures may be less effective compared to MRI.
- Artifacts and Shadows: Bone and calcifications may create image artifacts, requiring adjustments in probe positioning and frequency.

SONOGRAPHIC TECHNIQUE FOR EVALUATING THE MEDIAN NERVE

EQUIPMENT SETUP

- Probe Type: Because of the superficial nature of the median nerve at the wrist, a high-frequency, linear array transducer is normally used.[8]
- Patient Position: The patient is seated on the opposite side of the table near the edge to be closer to the examiner. The hand is supinated and neutral with the wrist and fingers in minimal flexion. The probe is placed in either the transverse short axis (SAX) or longitudinal axis (LAX) near the crease of the palmar wrist.
- Dynamic Assessment: Stress maneuvers, such as elbow and wrist flexion and extension, as well as forearm supination and pronation, can be applied during MSK ultrasound to reveal nerve instability, as well as hyper- or hypo-mobility.

NORMAL SONOGRAPHIC APPEARANCE

The median nerve is clearly identifiable in SAX by a well circumscribed ovoid structure with hypoechoic fascicles in a honeycomb-like pattern deep to the roof of the carpal tunnel, the flexor retinaculum, and more superficial to the flexor digitorum superficialis and flexor digitorum profundus tendons. The median nerve is also very compressible and will alter its shape depending on the volume of the anatomical spaces with which it courses. The median nerve cross-sectional area (CSA) can be measured in four sites: 1) the proximal border of the pronator quadratus muscle, 2) proximal to the carpal tunnel inlet, 3) at the tunnel inlet, and 4) at the tunnel outlet.[9]

PATHOLOGICAL FINDINGS IN MEDIAN NERVE PATHOLOGY AT WRIST

A maximal CSA of 12 mm^2 or greater at any location is typically diagnostic for CTS.[6] More recent evidence shows that CSA may vary based on subgroupings including age, sex, ethnicity, geographical location, and method of CSA assessment.[10] An increase in size greater than 2 mm comparing proximal (at pronator quadratus) to distal (at wrist crease) can diagnose carpal tunnel syndrome with 99% accuracy.[11]

Carpal Tunnel Syndrome can be identified by the following images:

- Hypoechoic thickening due to swelling and edema
- Disruption of fibrillar pattern
- Associated joint effusion

CLINICAL IMPLICATIONS FOR REHABILITATION PROVIDERS

MSK ultrasound provides real-time feedback for rehabilitation professionals, facilitating early diagnosis and intervention. Key applications include:

- Early Detection of Injury / Accurate Injury Grading: MSK ultrasound can quickly differentiate between a sprain and a more severe ligament tear to help guide treatment planning.
- Dynamic Functional Testing: Rehabilitation professionals can use MSK ultrasound during physical therapy sessions to monitor recovery and assess ligament function dynamically. Serial MSK ultrasound imaging aids in assessing ligament remodeling and readiness for rehabilitation progression.
- Guided Interventions: Ultrasound imaging assists in precision-guided dry needling or injections, such as corticosteroids for inflammation.
- Patient Education: Real-time imaging serves as a visual aid to explain the nature of the injury and set realistic expectations for recovery.

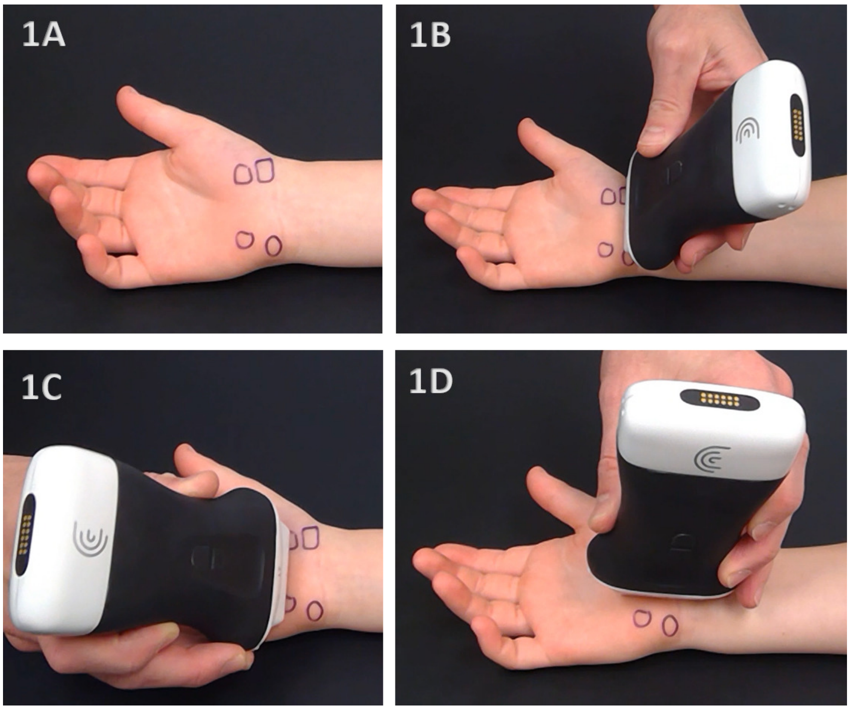
LIMITATIONS AND CHALLENGES

Despite its advantages, MSK ultrasound cannot entirely replace MRI and NCS for complex cases. Additionally, the expertise required for optimal imaging technique limits its immediate adoption across all rehabilitation settings.

CONCLUSION

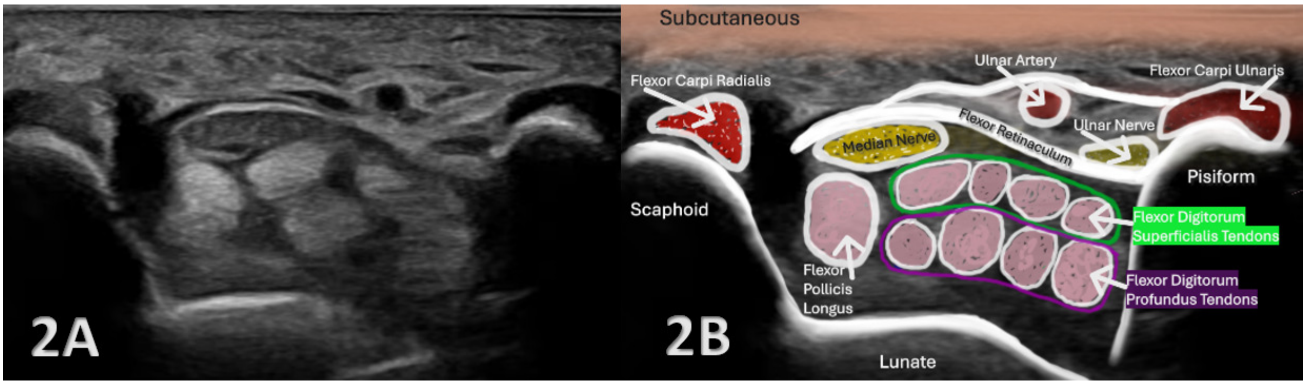
Diagnostic MSK ultrasound is a valuable tool for the evaluation of the median nerve at the wrist, offering fast, accurate, and cost-efficient imaging for rehabilitation professionals. Its ability to provide real-time, dynamic assessments makes it particularly suited for rehabilitation providers who can integrate the MSK ultrasound findings into clinical decision-making, optimizing treatment strategies and improving patient outcomes. However, practitioners must be adequately trained to maximize its diagnostic potential. By integrating MSK ultrasound into practice, rehabilitation providers can enhance patient care, improve outcomes, and reduce the burden of false diagnoses or delayed treatment.

Published: May 01, 2025 CDT.



Median Nerve

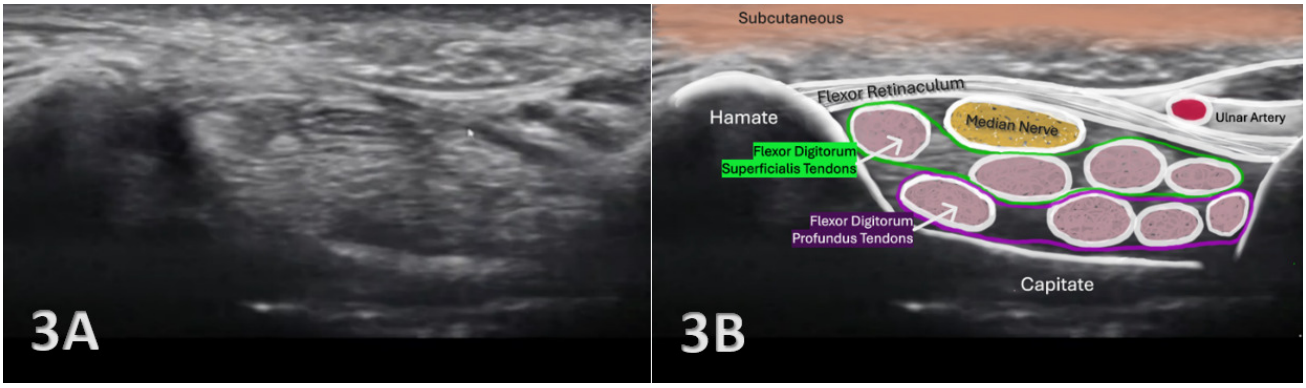
Figure 1A: Patient Positioning for Viewing Median Nerve in the Carpal Tunnel
For imaging the carpal tunnel, the patient should be seated comfortably in a chair facing the examiner. The forearm is positioned in supination with the palm facing upward and the dorsum of the hand resting on the examination table.
Figure 1B and 1C: Transducer Placement over the Carpal Tunnel in Short Axis View (SAX)
To obtain a short axis (SAX) view, place the transducer transversely across the proximal carpal tunnel, aligning it between the pisiform and scaphoid bones, Figure 1B. Gentle toggling of the transducer during scanning improves image quality by minimizing anisotropy and enhances differentiation of the median nerve from the surrounding flexor tendons. Moving the transducer slightly distally will allow viewing of the carpal tunnel outlet, Figure 1C. For the outlet view, the transducer is placed over the hook of the hamate and the trapezium tubercle.
Figure 1D: Transducer Placement over the Carpal Tunnel in Long Axis View (LAX)
To obtain a long axis (LAX) view, place the transducer in a longitudinal plane over the proximal and distal carpal tunnel in line with the median nerve. Gentle toggling of the transducer during scanning improves image quality by minimizing anisotropy and enhances differentiation of the median nerve from the surrounding flexor tendons.



NORMAL MEDIAN NERVE IN SHORT AXIS AT THE CARPAL TUNNEL INLET

Figures 2A and 2B: SAX of Median Nerve

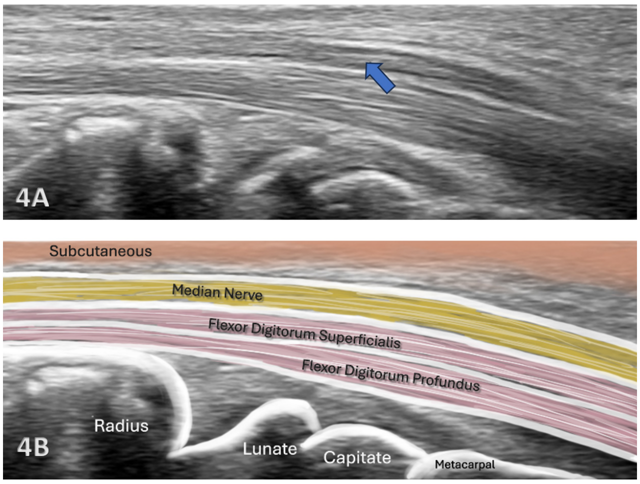
When performing a SAX view in ultrasound, (as positioned above in Figure 1B) it is often helpful to begin by identifying key bony acoustic landmarks. In this case, start by locating the carpal tunnel inlet after visualizing the median nerve. The median nerve is distinguished by its characteristic honeycomb appearance, displaying darker fascicles interspersed with connective tissue. This architecture contrasts with the surrounding flexor tendons, which exhibit a finer, more fibrillar texture. To further differentiate the median nerve from nearby structures, utilize a technique called toggling the transducer—a subtle rocking motion. Tendons are anisotropic, meaning their echogenicity changes with the angle of insonation; they may appear brighter or darker as the transducer angle shifts. In contrast, the median nerve maintains a more consistent appearance regardless of angle, aiding in its identification. At the carpal tunnel inlet, observe the rounded dome of the pisiform on the ulnar side and the curved surface of the scaphoid on the radial side. This is commonly the region where the median nerve shows its greatest cross-sectional area. The transverse carpal ligament (flexor retinaculum) forms the roof of the tunnel at this level. Adjacent to the pisiform, view the ulnar nerve and ulnar artery, which course through the ulnar tunnel (Guyon's canal). This canal is formed by the floor of the transverse carpal ligament and contains these neurovascular structures.



NORMAL MEDIAN NERVE IN SHORT AXIS AT THE CARPAL TUNNEL OUTLET

Figures 3A and 3B: LAX View of Median Nerve

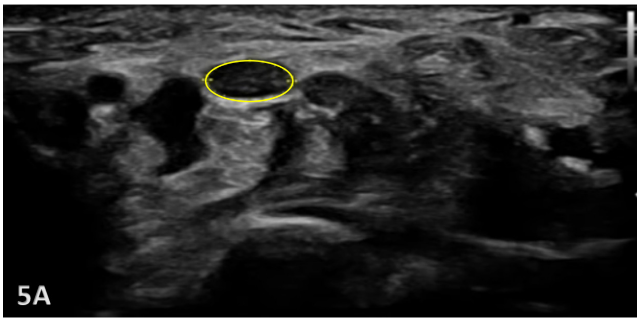
To view the median nerve in SAX, (as positioned above in Figure 1C) as it exits the carpal tunnel, continue scanning distally from the carpal tunnel inlet and the pisiform gradually disappears from view and is replaced by the hook of the hamate, marking the carpal tunnel outlet. This distal region is the most common site of median nerve entrapment. At this level, the transverse carpal ligament (Flexor Retinaculum) is often thicker, contributing to potential compression of the median nerve.



NORMAL MEDIAN NERVE IN LONG AXIS VIEW AT THE CARPAL TUNNEL

Figures 4A and 4B: LAX View of Median Nerve

For a LAX view of the median nerve, (as positioned above in Figure 1D) the transducer is placed into a longitudinal over the carpal tunnel. In this view, the median nerve appears superficial, lying above the flexor digitorum superficialis and flexor digitorum profundus tendons. The median nerve is easily recognized by its fascicular architecture, which remains distinct in this orientation. This scanning plane provides a clear view of the carpal tunnel space; gently mobilize the flexor tendons to observe their movement. While both the tendons and the median nerve exhibit excursion during finger motion, the median nerve displays less excursion compared to the tendons beneath it. This dynamic observation is a helpful method for evaluating median nerve mobility and for identifying structures within the carpal tunnel.



Pathology: Carpal Tunnel Syndrome

Figure 5A: SAX View of Median Nerve in the Carpal Tunnel

Ultrasound features of CTS include a hypoechoic, thickened median nerve with loss of the normal "honeycomb" fascicular pattern. Cross-sectional area (CSA) thresholds aid diagnosis: <8 mm² is normal, 8–12 mm² is borderline, and >12 mm² is abnormal. A CSA increase of >2 mm² from the forearm (pronator quadratus level) to the wrist (carpal tunnel) is 100% specific for carpal tunnel syndrome. In Figure 5A, the circumference measures 10 mm²

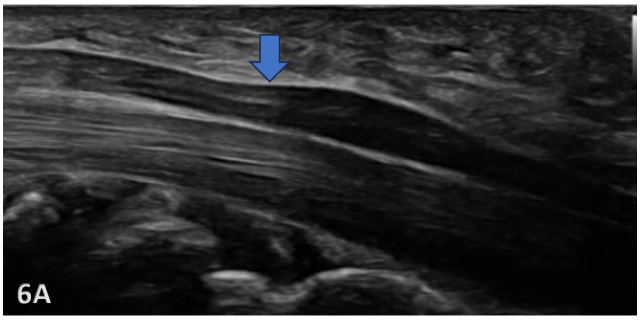


Figure 6A: LAX View of Median Nerve in the Carpal Tunnel

In diagnostic ultrasound of the median nerve at the wrist, the "notch sign" highlighted in Figure 6A with the blue arrow refers to a key finding observed in the LAX (sagittal) view in cases of CTS. As the median nerve approaches the proximal carpal tunnel, it typically appears thickened and hypoechoic, reflecting early swelling due to compression. At the level of the flexor retinaculum, the nerve then abruptly flattens, creating a distinct "notch" or step-off in its contour. This change in shape—thickened proximally and flattened distally—is known as the notch sign and is a hallmark of median nerve entrapment at the carpal tunnel inlet. This finding is often seen in conjunction with other sonographic features such as volar bowing of the flexor retinaculum and an increased cross-sectional area of the median nerve in the transverse view. The notch sign provides visual confirmation of mechanical compression and supports the clinical diagnosis of CTS.

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