# High Frequency Ultrasound Imaging for Diagnosing Carpal Tunnel Syndrome

**Corinne E. Wessner BS, RDMS, RVT,**
**Priscilla Machado MD, Shawn Peterson DO,**
**Flemming Forsberg PhD, Kibo Nam PhD**

## Introduction

Carpal tunnel syndrome (CTS) can be challenging to diagnose with no reference standard for diagnosis. Some approaches to diagnosing CTS are physical examination, clinical provocative tests, and electrodiagnostic studies. For classic CTS cases, diagnosis is based on clinical findings and physical examination. For complicated cases, electrodiagnostic studies and high frequency ultrasound imaging can help determine the severity for CTS diagnosis and clinical management. Electrodiagnostic studies can be uncomfortable for some patients, due to the invasiveness and small electric shocks. Noninvasively, imaging modalities such as magnetic resonance imaging (MRI) and high-frequency ultrasound can be used for characterization of the median nerve. However, MRI can be expensive, time consuming and inaccessible. High-frequency ultrasound imaging is a useful alternative for median nerve characterization (including size quantification) in CTS patients considering recent technological advancements, noninvasiveness, comfortability, and cost-effectiveness.

Recent studies have examined the diagnostic criteria for CTS utilizing high-frequency ultrasound imaging.[1,2,3] A common finding of CTS on high-frequency ultrasound was median nerve vascularity. Some well-established and regularly used imaging modes to evaluate median nerve vascularity are color and power Doppler Imaging (CDI and PDI, respectively). CDI and PDI are used extensively to evaluate tissue vascularity and characterize normal and/or abnormal vascularity in tissues and organs. However, these two imaging modes lack the sensitivity to depict the slow blood flow found in the vessels associated with CTS.

Throughout the years, ultrasound manufacturers have continuously highlighted new imaging technologies to advance the field. In an effort to improve the sensitivity for visualizing microvasculature structures, Canon Medical Systems (Otawara, Japan) has developed a novel technique called Superb Micro-vascular Imaging (SMI). SMI uses an algorithm to minimize motion artifact and optimize the microvasculature components that otherwise are removed with traditional high-pass filters used in conventional Doppler modes. SMI suppresses clutter while maintaining high frame rates for improved microvasculature imaging. Over the last couple of years, this technology has advanced the field in a variety of ultrasound applications such as high frequency, abdominal, and OB/Gyn ultrasound imaging.[4,5]

Canon Medical Systems has introduced cutting-edge high-frequency transducers to the diagnostic ultrasound market. In particular, the PLI-2004BX transducer has a center frequency of 20 MHz and a frequency range of 8.8-24 MHz. This transducer has excellent image quality and anatomical sensitivity for high-frequency ultrasound imaging with a capability of scanning at depths of 3-4 cm. The combination of improved high-frequency transducers and SMI technology leads to an excellent development for CTS imaging.

## Methods

Our team at Thomas Jefferson University has an ongoing, pilot study to assess the microvasculature characteristics within the median nerve in healthy volunteers and patients diagnosed with CTS using high-frequency ultrasound. This prospective clinical trial was approved by our university's Institutional Review Board and recruitment started in June 2018. Currently, ten volunteers and thirteen positive CTS patients have been enrolled in the study. The purpose is to compare the utility of CDI, PDI, and SMI to the current clinical practices for CTS and determine if SMI can visualize blood vessels and microvascular flow associated with CTS better than conventional CDI and PDI modes.

Participants are scanned while seated on a stretcher with their arm extended, palm facing upward supported by a table. In a transverse plane, the sonographer starts at the wrist region and acquires a cross-sectional measurement of the median nerve using an Aplio i800 system (Canon Medical Systems, Otawara, Japan) with a high frequency PLI-2004BX transducer. After the measurement, the sonographer turns longitudinally at the wrist region to evaluate the median nerve vascularity with CDI, PDI, Color SMI (cSMI), and Monochrome SMI (mSMI).

## Results

Figure 1 demonstrates the median nerve at the right wrist region with yellow calipers. Figure 1a shows the median nerve in a longitudinal plane using the PLI-2004BX transducer. This transducer has superior speckle patterns with enhanced details at less than 1 cm. Figure 1b demonstrates the median nerve in a longitudinal plane using the PLI-1205BX. The PLI-1205BX has greater penetration in the far-field with the capability of imaging at depths beyond 2.5 cm.

Figure 2a shows the median nerve in a transverse plane at the level of the wrist. The cross-sectional measurement of the left median nerve is 7.78 $mm^2$ in a normal volunteer. Figures 2b and 2c demonstrate CDI and PDI, respectively, both showing a lack of Doppler signal in the median nerve.

Figures 2d and 2e shows cSMI and mSMI of the median nerve. In the SMI modes, we can appreciate the lack of signal within the median nerve with greater depiction of vessels surrounding the nerve.

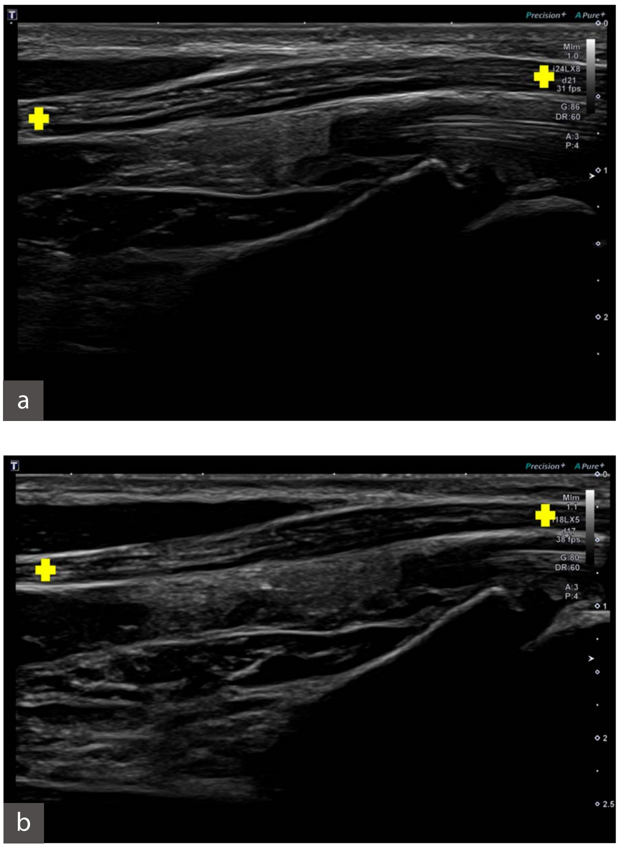


**Figure 1** High Frequency Transducer. (a) PLI-2004BX (b) PLI-1205BX

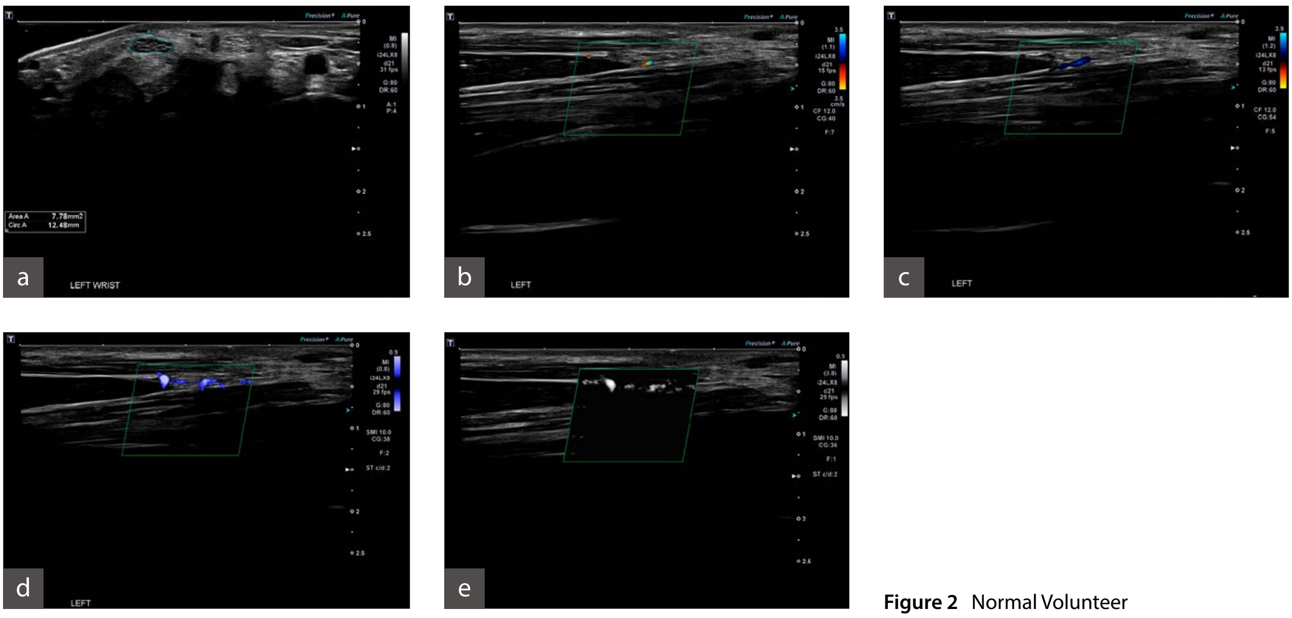


**Figure 2** Normal Volunteer

Figure 3a shows an enlarged median nerve in the transverse plane at the level of the right wrist in this CTS participant. The cross-sectional measurement of the right median nerve is 13.31 $mm^2$.

Figures 3b and 3c, show CDI and PDI with minimal internal vascularity. In Figures 3d and 3e, we can visualize the improved sensitivity and microvascularity with cSMI and mSMI within the median nerve.

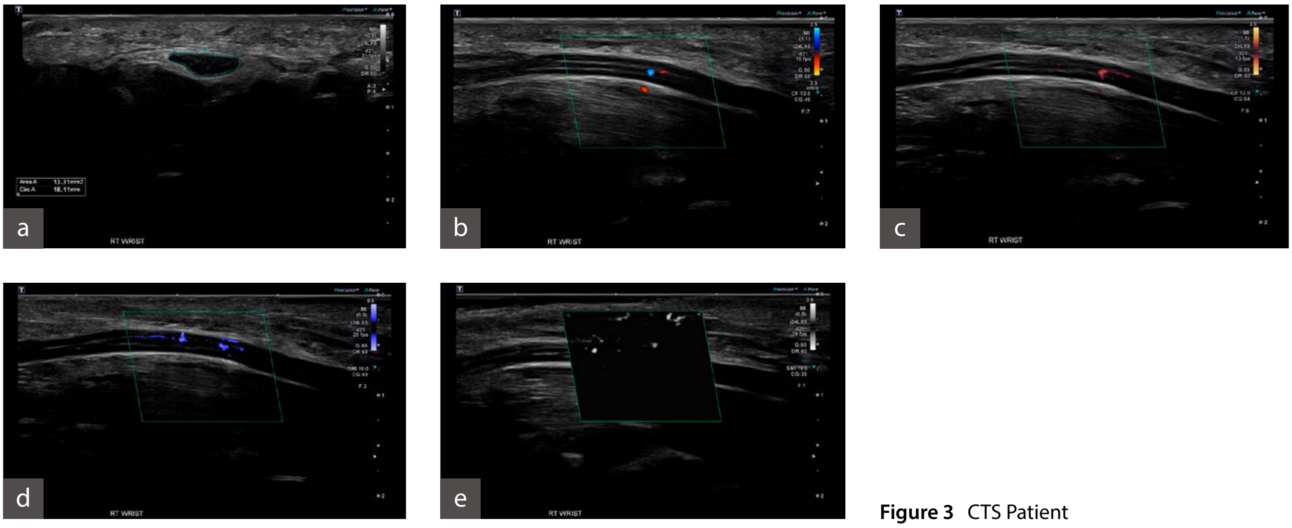


**Figure 3** CTS Patient

Figure 4a shows an enlarged median nerve in the transverse plane at the level of the right wrist. This patient's cross-sectional measurement of the right median nerve is 16.85 $mm^2$ and was the symptomatic wrist. We can appreciate the size difference between the last case study and this patient.

Figure 4b and 4c demonstrating CDI and PDI, with both imaging detecting blood flow within the median nerve. Figure 4d and 4e, shows cSMI and mSMI respectively, demonstrating improved microvascularity signal within the median nerve compared to traditional Doppler imaging modes.

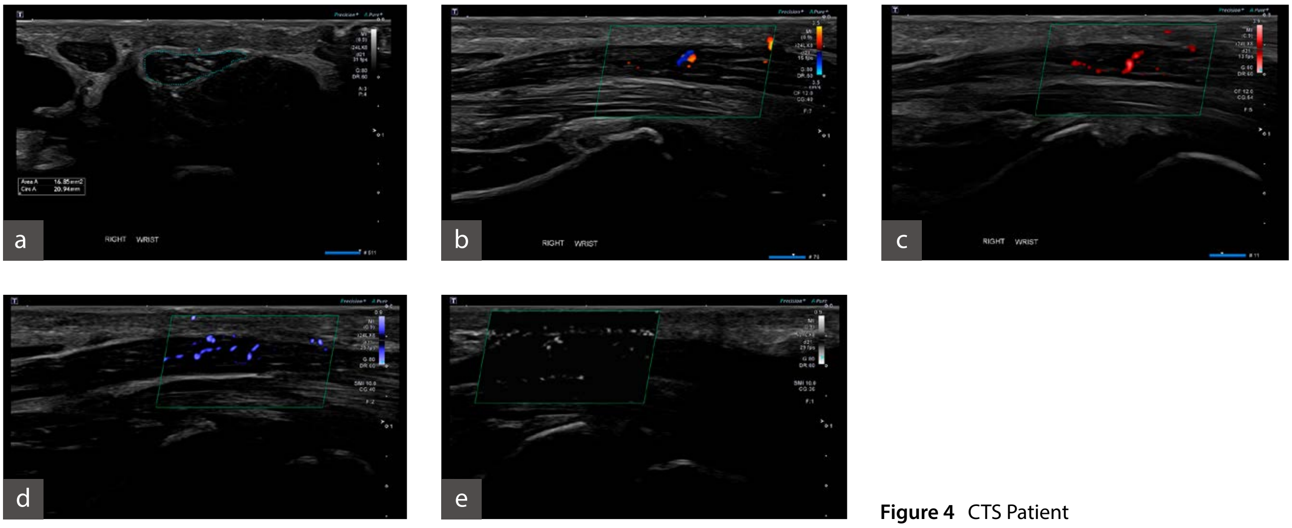


**Figure 4** CTS Patient

## Conclusion

In the three median nerve case studies presented here, we were imaging with a PLI-2004BX transducer at a depth of less than 1 cm. We could observe the improved microvascular branching and tortuous characteristics shown in the SMI modes that were not visualized on CDI or PDI. In our on-going clinical trial, we consistently experience greater sensitivity with SMI in depicting smaller vessels and branches compared to traditional Doppler modes. We expect the novel SMI technology will be appropriately integrated into many clinical ultrasound applications such as abdominal, OB/Gyn, lymphatic, and pediatric imaging.

## References:


1. Miyamoto H, Halpern EJ, Kastlunger M, et al. Carpal Tunnel Syndrome: Diagnosis by Means of Median Nerve Elasticity- Improved Diagnostic Accuracy of US with Sonoelastography. Radiology. 2014; 270:481-486.
2. Wipperman J, Goerl K. Carpal Tunnel Syndrome: Diagnosis and Management. American Family Physician. 2016; 94 (12): 993-999.
3. Ooi CC, Wong SK, BH Tan, A et al. Diagnostic Criteria of Carpel Tunnel Syndrome Using High-Resolution Ultrasonography: Correlation with Nerve Conduction Studies. Skeletal Radiology. 2014; 43: 1387-1394.
4. Forsberg F, Machado P, Stanczak M, et al. Assessing Carotid Plaque Neovascularity and Calcifications in Patients Prior to Endarterectomy. J Vasc Surg. 2019; 70(4):1137-1144.
5. Lim AKP, Satchithananda K, Dick EA, Abraham S, Cosgrove DO. Microflow imaging: new Doppler technology to detect low-grade inflammation in patients with arthritis. Eur Radiol. 2018;28:1046-1053.



CANON MEDICAL SYSTEMS CORPORATION
https://global.medical.canon




Model number: TUS-AI800 MWPUS0007EA 2021-03 CMSC/Produced in Japan