Normal Ultrasound Anatomy of the Triangular Fibrocartilage of the Wrist: A Study on Cadavers and on Healthy Subjects

Lionel Pesquer, MD,1,2 Michel Scepi, MD, PhD,3,4 Morgan Bihan, MD,1 Romain Vialle, MD,1 Jean Pierre Richer, MD,3,4 Jérôme Roumy, MD,5 Jean-Pierre Tasu, MD, PhD1,4

1 Department of Radiology, CHU Jean Bernard, BP 57 86021 Poitiers, France
2 Sport Clinic of Bordeaux – Mérignac, 9 rue Jean Moulin 33700 Mérignac, France
3 Department of Surgery, CHU Jean Bernard, BP 57 86021 Poitiers, France
4 Laboratory of Anatomy, University of Poitiers, rue de la Ricetica, 86000 Poitiers, France
5 Department of Nuclear Medicine, CHU Jean Bernard, BP 57 86021 Poitiers, France

Received 17 July 2008; accepted 1 August 2008

ABSTRACT: Purpose. To report the normal sono-
graphic anatomy of the triangular fibrocartilage (TFC) of the wrist in cadavers and volunteers.

Method. Five hands from cadavers were examined sonographically before and after wrist dissection, during which the TFC was marked with surgical wires. Twenty volunteers without wrist limitation or pain, and without any history of wrist disease or inflammatory arthritis (mean age, 26 years (range, 19–45 years) were also examined.

Results. Sonograms showed that the meniscus and the TFC were clearly separated. The meniscus appeared as a triangular structure that was homogeneous and slightly hyperechoic. Compared with the meniscus, the TFC appeared hypoechoic. The same patterns were observed for cadavers and volunteers. In 3 volunteers (15%), the TFC was not visualized.

Conclusions. Using high-resolution ultrasound systems, the TFC can be separated from meniscus. However, visualization of the TFC remains limited due to its deep location and the presence of acoustic shadowing from bony structures.

Keywords: wrist; ultrasound; anatomy; triangular fibrocartilage; meniscus; ligaments

The triangular fibrocartilage (TFC) complex is a small piece of cartilage and ligaments located distal to the ulna on the ulnar side of the wrist. It serves as a spacer between the ulna and the carpal bones. It consists of 5 components: the TFC, the dorsal and volar radioulnar ligaments, the ulnolunate and ulnotriquetral ligaments, the extensor carpi ulnaris (ECU) sheath, and the meniscus.1–3 Lesions of the TFCC relate mainly to TFC tears and are usually investigated using arthrography, arthro-CT, MRI, or arthro-MRI. However, these imaging modalities are expensive and/or invasive, and their sensitivity and specificity for diagnosing abnormalities are still being debated.4–6 Recently, sonography has been proposed for evaluating TFC lesions.7–10 While the normal TFC appears as a homogeneous, hyperechoic triangular structure, tears were found to be hypoechoic.7,8 These findings are in agreement with the previously reported appearances of other fibrocartilages, such as the knee meniscus and the labrum of the shoulder.11,12 Although cadaver studies have been performed for the knee13 and the shoulder,12 there has been no such study for the TFC. The aim of this study was to study the sonographic appearance of the TFC in such cadavers and in normal volunteers.

SUBJECTS AND METHODS
The cadaver study included 5 human hands (mean age at death of the bodies, 55 years [range, 45–63 years]). The medical histories of the patients were unavailable. Our institutional ethics committee approved the use of the cadavers,
and specific agreement from next of kin was not required. The cadavers were preserved at \(-40^\circ\text{C}\) and were thawed for 24 hours at room temperature prior to dissection. Postero-anterior and lateral radiographs of the wrist were obtained prior to sonographic examination to confirm the absence of osseous abnormalities. Dissections were performed by an experienced hand surgeon (M.S.). The first step was an incision of the dorsal aspect of the wrist. After reclining the extensor structures, the capsule was resected. The medial and the lateral insertions of the TFC were marked with surgical wire to serve as landmarks during the sonographic examination. Figure 1 shows a coronal section of the wrist of one of the cadavers.

Sonographic examination was performed with a Sequoia scanner and an 8–15-MHz linear-array probe operating at 15 MHz (Siemens, Mountain View, CA); the figure shows the probe’s position for the examination (Figure 2). Focal zone, imaging depth, and postprocessing parameters were optimized for musculoskeletal imaging. Real-time compound spatial imaging was used. Two radiologists performed the examinations. Transverse and sagittal scans from both dorsal and palmar approaches and coronal scans were obtained. The TFC was studied before and after placement of the wires. Visibility, echo pattern, and thickness of the TFC were evaluated, as well as the visibility and echo pattern of the meniscus homologue and the ECU. The echogenicity of each structure was described as hypoechoic, isoechoic, or hyperechoic relative to the meniscus. The thickness of the TFC was measured at its midpoint on the coronal scan.

The wrists of 20 asymptomatic volunteers (mean age, 26 years [range, 19–45 years]) with negative clinical examination of the wrist and no history of wrist disease or inflammatory arthritis were examined with sonography. Information about the ongoing study was communicated to the subjects, and oral informed consent was obtained from all participants. This part of the study did not require specific approval by the...
local ethics committee. The subjects were seated upright in front of the operator. The nondominant wrist was selected to avoid the possibility of degenerative lesions on the TFC. The same ultrasound equipment as that used in the cadaver study was employed. The 8–15-MHz linear-array probe was placed over the wrist. The wrist was scanned in the coronal, sagittal, and transverse planes positioning of the probe for coronal scans. The wrist was also examined in flexion and hyperextension and in radial and ulnar deviations. Visibility, thickness, and echopattern of the TFC were evaluated and documented. The thickness of the TFC at its midpoint was measured on coronal view.

RESULTS

Cadaveric Study

No osteoarthritic changes or TFC calcifications were observed on the radiographs of the 5 cadaveric wrists. On the sonograms, the meniscus appeared as a relatively well-defined homogeneous and slightly hyperechoic triangular structure located between the distal aspect of the TFC and the cortex of the triquetrum (Figure 3). The echogenicity of the meniscus was not modified by anisotropic effects. The TFC appeared as a homogeneous triangular structure with well-delineated margins (Figure 3) compared with the meniscus, which was hypoechoic. On coronal scans (scanning through the ECU), the radial insertion of the TFC was masked by the shadow from the ulnar styloid process. The part of the TFC closest to the ulnar process remained difficult to visualize on transverse and sagittal images for the same reason. Therefore, it was not possible to image the entire TFC. Due to its depth, the TFC was not visible using the palmar approach. Only the dorsal and coronal approaches proved to be informative. The mean thickness of the TFC was 2.2 mm (range, 1.8–3.1 mm). The ECU tendon had a fibrillar echogenic appearance compared with the meniscus (Figure 3). The echogenicity of the ECU tendon was altered with changes in the beam incidence due to anisotropy artifact, whereas that of the TFC was not.

Healthy Subjects

The meniscus appeared as a hyperechoic triangular structure located at the distal part of the TFC above the cortex of the triquetrum. Its echogenicity was not affected by the incidence angle of the beam. The TFC appeared as a triangular, relatively well-defined structure in 17/20 (85%) subjects (Figure 4). The mean thickness of the disc was 2.6 mm (range, 1.9–4.0 mm). Compared with the meniscus homologue, the TFC was hypoechoic. In 3/20 (15%) subjects, the TFC could not be visualized. The ECU tendon appeared as a fibrillar echogenic structure on the coronal scans. Its echogenicity was modified with changes in the beam incidence due to anisotropy. In the neutral and prone position of the wrist, the tendon appeared in its gutter on the medial aspect of the ulna. With the wrist in the supine position, the tendon appeared thinner and partially displaced. In one subject, subluxation of the tendon was observed in dynamic tests.

DISCUSSION

This study shows that the TFC and the meniscus can be distinguished by sonographic examination, and that the TFC is hypoechoic compared with the meniscus, both in cadavers and in vivo.

Descriptions of the anatomy of the TFC complex are often conflicting, and some imagers have difficulty obtaining clear anatomic descriptions. The ulnar disc has been recently separated in 2 parts, the upper and lower laminae (also called the ligamentum subcruentum or meniscus).
Some authors considered the meniscus homologue as the result of a synovial fold modified by the local stress induced by the wrist movements.\textsuperscript{2} Histologically, the meniscus homologue is formed by an ill-defined region of dense fibrous connective tissue.\textsuperscript{15} The echogenicity of the meniscus can be explained easily: it consists of fibrous tissue, and sometime includes fat (Figure 5); it is therefore hyperechoic. By comparison, the TFC appears hypoechoic, in contrast to the normal pattern of other articular fibrocartilage such as knee meniscus.\textsuperscript{13} The TFC is fibrocartilage as well, but whereas the knee meniscus is a pure fibrocartilage, the TFC is a complex structure, formed by fibers extending from both the meniscus homologue and the radio-ulnar ligaments. These fibers are intermingled at their attachments. Moreover, the hyaline cartilage of styloid process merges with the fibrocartilaginous attachments of the TFC.\textsuperscript{15} This complex histologic structure could explain the sonographic findings of the TFC. The same pattern has been already described for the shoulder where, as with hyaline cartilage, the fibrocartilage in the attachment zone of the supraspinatus tendon appears hypoechoic.\textsuperscript{16}

Our results contrast with previous reports. Chiou et al\textsuperscript{7} described the normal TFC as a hyperechoic structure, but his findings were not correlated with anatomic data and they did not specifically address the meniscus. Also, they used a 7–10-MHz probe, which may be insufficient to resolve this region of complex anatomy. This may also explain the discrepancy with the more recent results obtained by Keogh et al\textsuperscript{8} using a 5–12-MHz probe. We believe that the structure identified as a normal TFC in those 2 reports is, in fact, the meniscus and not the TFC.

Sonography has been proposed as a rapid, readily available, noninvasive, and inexpensive modality for examining the wrist and the TFC.\textsuperscript{9,17} In fact, our results highlight the difficulties of imaging the TFC with sonography. The TFC lies deep within the wrist, and is thin and overshadowed by the ulnar styloid, which can make it impossible to image the TFC (15% of the time in our study).

In the TFCC, the structures that are the easiest to visualize are the ECU tendon and the meniscus homologue. Chiou et al\textsuperscript{7} scanned over the volar aspect of the wrist, but in our experience this method is difficult, an observation also made by Keogh et al.\textsuperscript{8} Like other investigators, we found scanning through the ECU tendon to be more effective and easier, although this method makes it more difficult to image the ulnar attachment and the deeper portions of the TFC. Transverse or sagittal scans using a dorsal approach are needed for imaging.

However, in 3 cases, the TFC was completely invisible, probably due to a lack of an ultrasound window. A positive ulnar variance could modify...
the disc visualization, reducing the size of the ulnocarpal space.\textsuperscript{18} This variance is very frequent and is estimated to be 41.9\% for the ulna plus, 25.7\% for neutral, and 32.4\% for ulna minus in a Caucasian population.\textsuperscript{19–21} Sonography of the TFC could perhaps be affected by these anatomic variations. A correlation with wrist radiographs could help resolve this issue.

The current study has some limitations, including the relatively small number of healthy subjects and the lack of symptomatic patients. As described previously,\textsuperscript{22,23} degenerative modifications of the TFC are very common and increase dramatically with age. In addition, this work focused on the TFC, meniscus, and the dorsal and volar radioulnar ligaments, but the ulnolunate and ulnotriquetral ligaments were not studied. Lesions on these elements are infrequent, but further studies are required to evaluate these components of the TFC.

ACKNOWLEDGMENTS

The authors thank Olivier Chariac and Bruno Lebiez (Siemens-Accuson, France) for their help in sonographic examination.

REFERENCES