Digital Flexor Tendons of the Hand: Normal Ultrasonographic Anatomy*

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Superficially located tendons of the body can be easily assessed by ultrasonography with high frequency, short focused transducer. But, there has been no reports of detailed anatomic studies of digital flexor tendons of the hand by using ultrasonography. Thus, we performed the ultrasonography of the hands of normal volunteers, and report normal ultrasonographic findings.

Images were obtained in axial and longitudinal planes from the wrist to the insertion site of each tendon. In addition, the movement of the tendon was observed at rest, and during flexion and extension of each finger.

The ultrasonographic sectional anatomy of flexor tendons and their neighbouring structures were successfully demonstrated, and the understanding of it will provide a useful background knowledge for the diagnosis of pathologic conditions.

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Digital flexor tendons of the hand, which are so superficially located in palmar aspect of the hand and wrist, can be easily assessed by high-resolution ultrasonography with high frequency, short focused transducer. Ultrasonography of the tendons was reported in certain areas of the body, but there are few reports of detailed sonographic anatomic study of the digital flexor tendons of the hand in the literature.\(^1\)\(^-\)\(^4\) We performed ultrasonography of the digital flexor tendons of normal hands, and report the normal ultrasonographic sectional anatomic findings.

**ANATOMY**

There are nine digital flexor tendons in each hand: one thumb flexor, the flexor pollicis longus (FPL), and eight finger flexors, the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP). In palmar aspect of the wrist, they pass through the narrow osseofibrous tunnel, called the carpal canal, with the median nerve. The carpal canal is confined by flexor retinaculum ventrally and carpal bones dorsally. Over the metacarpals, the FDS and FDP tendons diverge and spread out from the carpal canal toward the fingers, and the FDP tendons give origin to four lumbrical muscles. The FPL tendon runs along the medial border of thenar muscles buried between the two heads of the flexor pollicis brevis muscles. At the level of metacarpophalangeal joint, they enter the narrow digital canals. Approximately over the middle of the proximal phalanx, the FDS tendons split into two halves, and are perforated by the FDP tendons. The half of the each half decussate around the FDP tendon, and non-decussating the other half of each half continue on the same side of the FDP tendon. Then they reunite behind the FDP tendon as they become inserted on the border of the middle phalanx. The FDP tendon has a broad insertion site on the base of the distal phalanx. On the other hand, the FPL tendon passes between the two sesamoids of the thumb, and is inserted into the distal phalanx of the thumb.\(^5\)

**SUBJECTS and METHODS**

Ten hands of 5 healthy volunteers were examined by ultrasonography. A linear mechanical sector scanner (Picker, Microview) with a 10 Mhz, 5.7cm focus transducer was used. The transducer is housed within a water path, and is capable of imaging a 3cm x 4cm field at 15 frames per second. The subjects were placed in sitting position with their hands supinated on the scanning table. Images were obtained in axial and longitudinal planes from the wrist to the insertion site of the tendon. In axial sections, next levels were specified and analyzed in detail: proximal and distal carpal canal, proximal and distal metacarpal, and the digital canal. The longitudinal sections were performed along the course of each tendon. The movement of the tendon was also observed at rest, and during flexion and extension of each finger. In addition, the specific tendon movement was attempted to assess during the test of strength of the specific muscle. For example, for the FDP3 tendon, which is the flexor of distal phalanx of the middle finger, the observation of it was done during flexion of distal phalanx of the middle finger against the resistance with the proximal and middle phalanx stabilized in extension.

**RESULTS**

(1) The Carpal Canal (Fig. 1)

In transverse section, the elliptically shaped carpal canal, confined by flexor retinaculum and the carpal bones, contains 9 digital flexor tendons and the median nerve. The median nerve is eccentrically located in radial, superficial portion of the canal, and has an echogenicity lower than the tendons with flattened ovoid shape. The flexor tendons are depicted
as ovoid or round hyperechoic densities, closely packed within the canal. The tendons so closely lie that it is somewhat difficult to delineate them clearly on ultrasonography. But they have relatively constant relationships between themselves within the canal: the ulnar half of the canal is occupied by the FDS 4 and 5 tendons in superficial portion, and the FDP 3,4 and 5 tendons in deep portion. The radial half is occupied by the FPL tendon in the most radial side, the median nerve most superficially, the FDS 3 tendon lying just infero-ulnar side of the median nerve, and the FDS 2 and FDP 2 tendon lying deep to the median nerve (Fig. 1a).

The median nerve is also delineated in longitudinal section as a hypoechoic tubular density which runs over the flexor tendon groups (Fig. 1b). The elevation and rotation of the tendon occurs during the contraction of it, and brings about subtle changes of its shape and location in transverse section of carpal canal. For example, during the isolated contraction of FDP 2, which is obtained by flexion of distal phalanx of the index finger against the resistance with the proximal and distal phalanx stabilized, clockwise rotation and slight elevation of the FDP 2 tendon could be observed on realtime image. At the same time, the FDS 2 is also elevated and rotated by the...
FDP 2, and the median nerve is rotated and displaced inferiorly, by which FDS 3 is displaced downward (Fig. 1 c,d).

(2) Over the Metacarpal

In contrast to the narrow carpal canal, each tendon spreads out, and is well separated by the adjacent lumbrical muscles, and echogenicity of which is much hypoecic than that of the tendon. The FPL tendon become buried in the thenar muscles (Fig. 2a, 3a). In transverse sections, the FDS and FDP tendons form an vertical 2-layer arrangement with the FDS occupying the superficial position, and the FDP running deeper to the FDS except the flexor tendons to the index finger. The FDS 2 and FDP 2 tendons have an horizontal 2-layer arrangement: the FDP 2 lies in radial side of the FDS 2 (Fig. 2).

In longitudinal sections, they show typical ultrasonographic features of the tendon: a hypoecic tubular density composed of multiple fine parallel echogenic lines, which represents collagen fibrils of the tendon (Fig. 3).

(3) the Digital Canal

The FDS tendon lies superficial to the FDP tendon in transverse section over the proximal phalanx until the FDS splits into two halves, and is penetrated by the FDP, where the each half embraces the FDP on its both sides. On the further distal section of the proximal phalanx, the each half is found deep to the FDP: the position of each half of the FDS changes from a superficial to a lateral, and then a deep side of the FDP (Fig. 4).

On the paramidline longitudinal section over the middle phalanx, the insertion site of the FDS on the palmar aspect of the middle phalanx can be clearly depicted. The insertion of the FDP at the base of the distal phalanx is also delineated (Fig. 5).

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Fig. 2. Transverse section over the metacarpal
A. Over the proximal second metacarpal.
B. Over the proximal third and fourth metacarpal.
C. Over the distal third and fourth metacarpal.
FPB= flexor pollicis brevis; IO= interossei; L 2,3,4 = lumbricalis 2,3,4 ; s 2,3,4, = FDS 2,3,4; P 2,3,4 = FDP 2,3,4; R = radial side.
DISCUSSION

The echogenecity of the tissue is related primarily to the stiffness of it, and collagen is considered a major source of the echogenecity.\(^6\) Rich collagen fibrils of the tendon seem to make them highly echogenic, and provide a good contrast to the adjacent tissues such as muscle or nerve, which contains less collagen. But the tendon may vary in the echogenecity from the intense hyperechoic one to the falsely hypoechoic one due to various relationships between the angle of the acoustic beam and the orientation of the tendon fibrils (Fig. 3). For that reason, subtle control of transducer angle should be done during the scanning.

The digital flexor tendons were most easily demonstrated over the metacarpals, because they are well separated by lumbral muscles. On the other hand, in the carpal canal, where the tendons are crowded within the narrow space, the clear delineation of each tendon was somewhat troublesome, but they could be identified and defined by observing the movement of each tendon during flexion and extension of each finger. The median nerve within the carpal canal, which is compressed in carpal tunnel syndrome, was easily distinguished due to its lower echogenecity than that of the tendons surrounding it.

Other imaging modalities, computed tomography (CT) and magnetic resonance imaging (MRI), also enabled to depict the soft tissue structures of the hand and wrist.\(^7\)\(^-\)\(^9\) Especially MR, with its multiplanar capabilities and high contrast resolution, visualized the intricate anatomy of the hand and wrist excellently.\(^9\) In comparison with MR, ultrasonography is capable of multiplanar imaging with comparable quality of the image. In addition to low cost and short imaging time, ultrasonography has an advantage of realtime imaging which enable...

Fig. 3. Longitudinal section over the metacarpal
A. along the FPL tendon. The tendon displays intense hyperechogenicity in good contrast with hypoechoic muscle.
B. Along the FDP2 tendon.
C. Along the FDP & FDP3 tendon. They appear hypoechoic than a. and b. FPB = flexor pollicis brevis; L1 = first lumbral; AP = adductor pollicis; D = distal side.
Fig. 4. The digital canal over the proximal phalanx of middle finger.
A. The midline longitudinal section. The FDS is found over the FDP in proximal level, and behind the FDP in distal level.
B.C.D. Transverse section of the proximal phalanx.
   b. at the base. c. at the midportion. d. at the distal portion s = FDS; P = FDP; mp = metacarpophalangeal joint; D = distal side.

Fig. 5. The digital canal: the insertion of FDS ans FDP. (×2 magnification)
A. The paramidline longitudinal section of the middle phalanx. The insertion site of the FDS tendon at the midportion of middle phalanx (arrow).
B. Longitudinal section of the distal phalanx. The insertion site of the FDP (arrow)
   PIP = proximal interphalangeal joint; DIP = distal interphalangeal joint; D = distal side.
us to evaluate the movement of tendons and the relationships between them. Thus, ultrasonography is expected to be a useful examination for the assessment of the various conditions of digital flexor tendons and their adjacent soft tissues including trauma, tumor and carpal tunnel syndrome.

CONCLUSION

The ultrasonographic sectional anatomy of digital flexor tendons of the hand and their neighbouring tissues were successfully demonstrated by high-resolution ultrasonography. The understanding of the normal ultrasonographic findings of them will provide a useful background for the ultrasonographic diagnosis of their pathologic conditions.

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