The Anatomy of the Distal Ulnar Tunnel

MICHAEL S. GROSS, M.D.,* AND RICHARD H. GELBERMAN, M.D.**

The distal ulnar tunnel is a region of the wrist 4–4.5 cm in length in which the ulnar nerve is particularly vulnerable to external compression. The relation of the internal topography of the nerve to the structures comprising the tunnel provides a basis for dividing the tunnel into three zones. Zone 1 is that portion of the tunnel proximal to the bifurcation of the ulnar nerve. Zone 2 encompasses the deep motor branch of the nerve, and Zone 3 surrounds the superficial branch. A review of the literature of ulnar nerve compression lesions confirmed expectations based on the regional anatomy. Zone 1 lesions included all (39) cases of combined motor and sensory deficits, one case of pure motor paralysis, and seven cases of sensory deficits. All Zone 2 lesions (36 cases) resulted in paralysis of the intrinsic muscles. Whether or not the hypothenar muscles were affected was dependent upon the location of the lesions within Zone 2. Zone 3 lesions caused sensory deficits only. Combined motor and sensory loss was most often caused by compression from deep to the nerve, while pure sensory deficits were a result of compression lesions lying superficial to the nerve.

The distal ulnar tunnel is a region of the wrist which, because of its peculiar anatomy, predisposes the ulnar nerve to external compression. The anatomy of the area has been the subject of a number of previous studies, but specific points of anatomic and clinical importance are still controver-

* Hand Fellow, Division of Orthopaedics, University of California Medical Center, San Diego, California.
** Associate Professor, Division of Orthopaedics, University of California Medical Center, San Diego, California.

Reprint requests to Richard H. Gelberman, M.D., Division of Orthopaedic Surgery, 225 Dickinson Street, San Diego, CA 92103.

Received: April 17, 1984.
The distal ulnar tunnel is 4-4.5 cm long. It begins at the proximal edge of the palmar carpal ligament and extends to the fibrous arch of the hypothenar muscles (Fig. 1). The tunnel has frequently changing boundaries and does not have four distinct walls throughout its course. From proximal to distal, the roof of the tunnel is composed of the palmar carpal ligament, the palmaris brevis, and hypothenar fat and fibrous tissue. The floor of the tunnel is made up of the tendons of the flexor digitorum profundus, the transverse carpal ligament, the pisohamate and pisometacarpal ligaments, and the opponens digiti minimi. The flexor carpi ulnaris, the pisiform, and the abductor digiti minimi constitute the medial wall. The lateral wall is composed of the tendons of the extrinsic flexors, the transverse carpal ligament, and the hook of the hamate.

The specific internal topography of the ulnar nerve in relation to the structures comprising the distal ulnar tunnel provides an anatomic basis for dividing the tunnel into three zones (Fig. 2). The creation of three zones within the tunnel makes compression lesions of the ulnar nerve easier to predict and diagnose. Each zone consists of both a specific portion of the ulnar nerve and the structures surrounding it. Zone 1 is that portion of the tunnel proximal to the bifurcation of the nerve. Zone 2 encompasses the deep motor branch of the nerve, and Zone 3 surrounds the superficial branch.
ZONE 1

Zone 1 is slightly more than 3 cm in length. It extends from the proximal edge of the palmar carpal ligament to the bifurcation of the ulnar nerve. The palmar carpal ligament is a thickening of the superficial forearm fascia that becomes distinct approximately 2 cm proximal to the pisiform (Fig. 3). The ulnar nerve along with the ulnar artery, slightly superficial and radial to the nerve, passes under the palmar carpal ligament. The tendons of the flexor digitorum profundus lie deep to the neurovascular bundle forming the floor of the entrance to Zone 1. The palmar carpal ligament arises ulnarily, from the tendon of the flexor carpi ulnaris, and inserts radially on the palmaris longus tendon and the transverse carpal ligament, forming the roof of the proximal part of Zone 1.

The most distal fibers of the palmar carpal ligament curve radially and posteriorly to merge with the fibers of the transverse carpal ligament and wrap around the neurovascular bundle forming the lateral wall of Zone 1 (Fig. 4). Beneath the nerve and artery, the transverse carpal ligament travels ulnarily and inserts into the base of the pisiform, forming the floor of the tunnel. The pisiform and the tendon of the flexor carpi ulnaris make up the medial wall of the tunnel at this point.

Distal to the palmar carpal ligament, the palmaris brevis forms the roof of the tunnel. The palmaris brevis is approximately 2.5 cm from its proximal to its distal border. It
of specimen showing the carpal ligament, forming the roof of the proximal ulnar tunnel. 1 = palmar arterial nerve, 3 = tendon of palmaris longus, P = pisiform.

Fig. 4. Schematic cross sections of the distal ulnar tunnel in Zone 1. Entrance to Zone 1: A = ulnar artery, N = ulnar nerve, 1 = palmar carpal ligament, 2 = tendon of flexor carpi ulnaris. Level of the pisiform: A = ulnar artery, N = ulnar nerve, P = pisiform, 1 = palmaris brevis, 2 = transverse carpal ligament, 3 = pisohamate ligament, 4 = pisometacarpal ligament.

Fig. 5. Schematic cross sections of the distal ulnar tunnel at the proximal and distal boundaries of Zones 2 and 3. Level of bifurcation of the ulnar nerve: A = ulnar artery, S = superficial branch of the ulnar nerve, D = deep branch of the ulnar nerve, P = pisiform, H = hamulus, 1 = palmaris brevis, II = Zone 2, III = Zone 3. Level of the fibrous arch of the hypothenar muscles: 1 = fibrous arch of the hypothenar muscles, 2 = abductor digitii minimi, 3 = flexor digitii minimi. In Zone II: A = deep branch of ulnar artery, N = deep branch of the ulnar nerve. In Zone III: A = superficial branch of the ulnar artery forming the superficial arch, N = superficial branch of the ulnar nerve.

The bifurcation of the nerve marks the distal extent of Zone 1. At the level of the bifurcation, the roof of the tunnel is the palmaris brevis, and the floor is the pisohamate and pisometacarpal ligaments (Fig. 5). The pisohamate ligament is a discrete cylindrical structure arising from the distal, radial, and dorsal aspect of the pisiform and inserting on the proximal, ulnar, and palmar aspect of the hook of the hamate (Fig. 6). Unlar to the pisohamate ligament, the pisometacarpal ligament arises from the distal aspect of the pisiform and inserts on the palmar–radial aspect of the base of the fifth metacarpal. The divergence of these ligaments leaves an opening in the floor of the tunnel that is filled with fibrofatty tissue overlaying the capsule of the triquetro-hamate joint.
The remainder of the distal ulnar tunnel consists of Zones 2 and 3 traveling alongside each other from the bifurcation of the ulnar nerve to the region just beyond the fibrous arch of the hypothenar muscles (Fig. 2). Zone 2 surrounds the deep motor branch in the dorsal–radial portion of the tunnel, and Zone 3 surrounds the superficial branch in the palmar–ulnar portion of the tunnel.

ZONE 2

Palmar–medially, Zone 2 is bordered by the palmaris brevis and the superficial branch of the nerve (Zone 3). Laterally, the transverse carpal ligament is a sloping wall running into the floor of the tunnel, which is formed by the pisohamate and pisometacarpal ligaments. At the distal extent of Zone 2, the fibrous arch of the hypothenar muscles lies palmar to the nerve, the opponens digiti minimi is posterior, the hook of the hamate and flexor digiti minimi are lateral, and the abductor digiti minimi is medial. At the deep branch exits the tunnel, it passes under the fibrous arch and between the abductor digiti minimi and the flexor digiti minimi, innervating these muscles (Fig. 5). In the majority of limbs, the nerve to the abductor digiti minimi is given off just proximal to its entrance into these muscles. The nerve then pierces and innervates the opponens digiti minimi as it curves radially and posteriorly around the hook of the hamate on its way across the palm.

The ulnar artery enters Zone 2 radially and palmarly, just beyond the region where the nerve had bifurcated. The artery follows the nerve, lying palmar and slightly radial to it, as it travels distally and passes under the arch of the hypothenar muscles’ origin.

Dissection of the deep branch of the ulnar nerve in Zone 2 confirmed its purely motor composition, in contrast to the superficial branch in Zone 3. At the level of the end of Zone 2, the deep branch consisted of an average of six fascicles. On dissection, the nerve to the abductor digiti minimi could be separated for 15 mm before interconnections

In Zone 1, the nerve has both motor and sensory fibers. Cross sections of the nerve in the proximal and distal portions of Zone 1 showed two distinct groups of fascicles. The palmar–radial fibers became the superficial branch of the ulnar nerve, while the dorsal–ulnar fibers became the deep motor branch. These two groups of fascicles could be separated for a distance of 75 mm proximal to the bifurcation before major interconnections were encountered. Thus, throughout Zone 1, the ulnar nerve was actually two nerves traveling within a common epineural sheath. This is similar to the description by Jabaley et al.27 of the dorsal cutaneous branch and the main trunk of the ulnar nerve in the forearm.
the distal ulnar tunnel and 3 traveling alongside bifurcation of the ulnar just beyond the fibrous ar muscles (Fig. 2). Zone motor branch in the of the tunnel, and Zone perifacial branch in the n of the tunnel.

ZONE 2

Zone 2 is bordered by nd the superficial branch Laterally, the transverse sloping wall running into nel, which is formed by isometacarpal ligaments. of Zone 2, the fibrous palmar muscles lies palmar opponens digiti minimi is of the hamate and flexor interal, and the abductor dial. At the deep branch passes under the fibrous e abductor digiti minimi i minimi, innervating 5). In the majority of he abductor digiti minimi nal to its entrance into nerve then pierces and tens digiti minimi as it posteriorly around the e on its way across the enters Zone 2 radially beyond the region where rated. The artery follows nar and slightly radial to illy and passes under the nar muscles’ origin. deep branch of the ulnar afirmed its purely motor ntrast to the superficial at the level of the end of branch consisted of an cles. On dissection, the or digiti minimi could be i before interconnections were noted. The nerves to the flexor digiti minimi and opponens digiti minimi were separable for 12 mm.

ZONE 3

Zone 3 begins just distal to the bifurcation and encompasses its superficial branch. In the mixed nerve of Zone 1, the sensory fibers are located in the palmar–radial portion. At the level of the bifurcation, the sensory fibers angle ulnarly and diverge from the motor fibers as the superficial branch arises and travels palmarly and ulnarward. At the entrance of Zone 3, the boundaries are the palmaris brevis palmarly, the abductor digitii minimi medially, the isometacarpal ligament and capsule of the triquetro-hamate joint posteriorly, and the border of Zone 2 laterally and posteriorly.

As the superficial nerve travels distally, it gives off two small motor branches that pierce and innervate the palmaris brevis from the undersurface of the muscle. From this point on, the nerve is purely sensory and emerges from Zone 3 by passing over the fibrous arch of the hypothenar muscles. Throughout Zone 3, the ulnar artery travels with the nerve and remains superficial and radial to it. At the exit of this zone, the nerve lies between the hypothenar fascia posteriorly and the artery and a fibrofatty layer deep to the subcutaneous tissues palmarly.

Dissection of the superficial branch of the nerve demonstrates that two to three branches innervate the palmaris brevis. These consistently arise within the first 10 mm of Zone 3. The remainder of the fibers continue intact and become the proper digital nerve to the ulnar side of the small finger and the common digital nerve to the radial side of the small finger and the ulnar side of the ring finger. Of 40 specimens, three had communications with the median nerve in the palm. In each case, a branch from the common digital nerve to the ring–little interspace connected to the median-derived common digital nerve to the long–ring interspace.

DISCUSSION

The purpose of this study was to describe the anatomy of the distal ulnar tunnel by defining its boundaries and the relation of the neurovascular bundle to the surrounding structures and to review compression lesions as they relate to the specific internal topography of the ulnar nerve in this region.

The authors found a total of 142 cases of ulnar nerve compression lesions about the wrist in the English literature. In 93 cases, both the site of compression and the types of deficits (motor, sensory, or both) were stated in the report. From the anatomy of the three zones it is clear that certain lesions may be anticipated and the corresponding neurologic deficits predicted.

Throughout Zone 1, the motor fibers making up the deep branch were located posteriorly within the nerve (Fig. 7). The sensory fibers of the superficial branch were located in the palmar portion of the nerve and grouped into three fascicles. From ulnar to radial, they were the sensory fibers to the hypothenar eminence, the ulnar side of the little finger, and the fibers to the ring–little interspace. Compression lesions in this area occurring from the deep surface of the tunnel should compress the motor fibers first, while superficial lesions should compress the sensory fibers first.

There have been 47 reported cases of nerve compression in Zone 1 (Table 1). Of these, 39 had combined motor and sensory deficits, seven had only sensory loss, and one had only motor loss. The most common causes of combined motor and sensory loss were ganglia (19 cases, Table 2). The ganglia arose from the carpus, deep to the tunnel. In the majority of cases in which ganglia caused combined motor and sensory loss, the nerve was described as tethered over the ganglion proximally and distally.

In 13 of 39 cases of combined motor and sensory loss, symptoms were related to fractures of the distal radius, distal ulna, or carpal bones. The ulnar nerve
has been noted to lie within 2 mm of the distal radius. Symptoms were apparently caused by contusions or traction on the nerve in Zone 1 with tethering beneath the palmar carpal ligament.

Three additional cases of combined motor and sensory deficits were caused by compression from anomalous muscles passing anterior to the nerve, proximal to its bifurcation.\textsuperscript{43,49} The remaining four cases were caused by an accessory ossicle, "edematous fibrous tissue," bipartite hamulus, and degenerative arthritis about the pisiform–triquetral joint.\textsuperscript{9,17,31,34}

Since most compression lesions arise from deep within the tunnel, it was expected that motor deficits would be the most common findings in Zone 1 lesions. However, the authors' review showed that the majority of neuropathies (39 of 47) were combined motor and sensory deficits. It appears that the small volume of the tunnel in Zone 1 together with its rigid boundaries predisposes, most commonly, to complete nerve lesions.

In a minority of cases (eight of 47), compression in Zone 1 led to only motor (one case) or sensory (seven cases) loss.\textsuperscript{4,9,40,52} These deficits could be related to the location of the lesion and the fibers of the nerve at that level. Thomas\textsuperscript{52} reported an accessory palmaris longus that was found superficial to the nerve at the level of Zone 1. The bulk of the muscle compressed the nerve from the palmar direction, thereby affecting only the sensory fibers. Dupont et al.\textsuperscript{9} reported two of four cases of nerve compression at the wrist in which lesions selectively compressed the sensory component of the ulnar nerve within Zone 1. In one case, an edematous, thrombosed ulnar artery lying superficial to the nerve was found to compress the nerve in Zone 1, leading to sensory loss alone. In another of their cases, a ganglion from the carpal tunnel penetrated the transverse carpal ligament.

![Figure 7](image-url) FIG. 7. Photograph of specimen showing cross section of the tunnel at the level of the pisiform. P = pisiform, A = ulnar artery, S = fascicles forming the superficial branch of the ulnar nerve, D = fascicles forming the deep branch of the ulnar nerve, 1 = transverse carpal ligament, 2 = palmar carpal ligament.

<table>
<thead>
<tr>
<th>Zone</th>
<th>M/S</th>
<th>M</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39</td>
<td>1</td>
<td>7</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Total (complete data)</td>
<td>39</td>
<td>37</td>
<td>17</td>
<td>93</td>
</tr>
<tr>
<td>Incomplete data</td>
<td></td>
<td></td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>142</td>
</tr>
</tbody>
</table>

M/S = both motor and sensory deficits. M = motor deficit only. S = sensory deficit only.
TABLE 2. Common Causes of Compression Neuropathy by Zone and Deficit

<table>
<thead>
<tr>
<th>Cause</th>
<th>Zone (Deficit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 (M/S)</td>
</tr>
<tr>
<td>Ganglia</td>
<td>19</td>
</tr>
<tr>
<td>Fractures</td>
<td>13</td>
</tr>
<tr>
<td>Anomalous muscles</td>
<td>3</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>1</td>
</tr>
<tr>
<td>Bursitis</td>
<td>4</td>
</tr>
<tr>
<td>Thickened pisohamate ligament</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>47 (total Zone 1)</td>
</tr>
</tbody>
</table>

M/S = both motor and sensory deficits. M = motor deficit only. S = sensory deficit only.

Fig. 7. Photograph of specimen showing cross section of the tunnel at the level of the pisiform. P = pisiform, A = ulnar artery, S = fascicles forming the superficial branch of the ulnar nerve, D = fascicles forming the deep branch of the ulnar nerve, 1 = transverse carpal ligament, 2 = palmar carpal ligament.

Fig. 8. Photograph of specimen showing the deep branch of the ulnar nerve with the nerve to the abductor digiti minimi arising proximal to the fibrous arch. 1 = ulnar nerve, 2 = superficial branch of the ulnar nerve, 3 = deep branch of the ulnar nerve, 4 = nerve to the abductor digiti minimi, 5 = fibrous arch.
enar muscles. In 21 of 36 cases where ganglia caused the compression, nearly one-half (ten of 21) clearly showed that the lesion occurred distal to the origin of the nerve to the abductor digiti minimi, and that muscle was not affected. The remaining cases presented with complete motor loss due to more proximal compression of the nerve within Zone 2.

Zone 3 encompasses the superficial branch of the ulnar nerve. This branch is almost purely sensory except for two or three small fibers that innervate the palmaris brevis. These arise from the superficial branch after the bifurcation and before the nerve reaches the fibrous arch of the hypothenar muscles. For diagnostic purposes, the superficial branch can be considered as pure sensory, because the loss of palmaris brevis function is difficult to detect.

Cross sections in Zone 3 demonstrated that the individual fascicles of the ulnar digital nerve of the small finger and the nerve to the ring–little interspace were identifiable at this level. They remained within the same epineural sheath and were not vulnerable to individual compression until they separated distal to the end of Zone 3. Therefore, Zone 3 compression lesions should result in complete loss of sensation to the ulnar one and one-half digits. In addition, the roof of Zone 3 is composed of fat and fibrous tissue and therefore allows for some expansion, making this the least rigid and, perhaps, least likely to predispose the nerve to compression.

Only ten of the 93 classifiable cases were Zone 3 lesions, and all had sensory deficits. Thrombosis of the ulnar artery was the single most frequent cause, accounting for five of the ten cases. The artery lies palmar to the nerve in Zone 3. Thrombosis causes the artery to swell and become rigid, compressing the nerve from the palmar direction. Often, as in two cases of abnormal musculature, the point of compression was at the end of Zone 3. At this point, the fibrous arch of the hypothenar muscles formed a fixed barrier dorsal to the superficial branch of the nerve. The palmar structures, either thrombosed arteries or anomalous muscles, caused compression against the fibrous arch.

A review of the literature confirmed certain expectations based on the anatomy of the region. Combined motor and sensory deficits of the ulnar nerve occurred only in Zone 1 lesions (39 cases) and were most often caused by compression from the region deep to the neurovascular bundle. Essentially all of the pure motor deficits (36 of 37 cases) occurred within Zone 2, and most (22 of 37 cases) were caused by ganglia. Sensory deficits alone more often occurred in Zone 3 (ten of 17 cases) but also occurred in Zone 1 (seven of 17 cases). They were caused by compression lesions lying superficial to the nerve in these zones.

REFERENCES

literature confirmed certain 1 occurred only in Zone 1 nd were most often caused on the region deep to the idle. Essentially all of the 36 (36 of 37 cases) occurred 22 of 37 cases) the glia. Sensory deficits alone red in Zone 3 (ten of 17 and in Zone 1 (seven of 17) caused by compression tial to the nerve in these

REFERENCES


pair of the motor branch of the n palp. J. Bone Joint Surg. 37A:

compromise by simple ganglia. 34B:391, 1952.


the anatomy of the space of Guyon.


d Robson, M. D.: Unusual occur-

Eigenartige Form von Progressiver bei Goldpolirnirte. Medizinisches des Württembergischen ärztlichen 1866.


