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The ulnar nerve in the cubital tunnel: a fetal study

Running headline: Ulnar nerve in the cubital tunnel

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ABSTRACT

The ulnar nerve (UN), a terminal branch of the medial cord of the brachial plexus, is located posteromedial to brachial artery coursing along medially in the arm from the anterior to the posterior compartment through the arcade of Struthers. It passes posterior to medial epicondyle of humerus and enters the cubital tunnel. Thereafter, exiting through the distal part of the cubital fossa to enter the medial side of the forearm between the two heads of the flexor carpi ulnaris muscle underneath Osborne’s ligament to enter the anterior compartment of the forearm. Entrapment of the UN at the cubital tunnel results in a pain and a tingling sensation on the medial side of the forearm and fourth and fifth digits. This fetal study documented the course of the UN within the cubital tunnel and its anatomical relations utilizing bilateral microscopic dissection of twenty-five fetuses (gestational age between 19 – 36 weeks).

The UN followed the standard anatomical course in 96% (48/50) of the specimens, however it was found to lie deep to the muscles of the cubital tunnel in 6% (3/50). The radial artery joined the UN distal to the cubital tunnel in 8% (4/50), while the superior ulnar collateral artery (SUCA) was posteriorly related to the UN in 32% (16/50) of specimens. The Osborne ligament (crossed between the two heads of the flexor carpi ulnaris muscle, posterior to the medial epicondyle of the humerus) was present in all specimens 100% (50/50). It had a mean length of 6.32 ± 0.97 mm and 6.30 ± 1.10 mm on the left and right sides, respectively. The
The current study observed that the flexor pronator aponeurosis (FPA) was present in 2% (1/50) of specimens. Knowledge of the normal and variable anatomical course of the UN in the cubital tunnel in this study may assist in the diagnosis and treatment of compressive neuropathy of the UN in the cubital tunnel.

Key words: ulnar nerve, cubital fossa, fetal study and anatomical course

INTRODUCTION

The ulnar nerve (UN) is the larger terminal branch of the medial cord of the brachial plexus formed by the ventral rami of C8 and T1, with occasional branches from C7 (Yamada et al., 2013 and Becker and Manna, 2018). In its course, it runs on the medial side of the brachial artery in the middle-third of the arm, pierces the medial intermuscular septum with the superior ulnar collateral artery (SUCA), runs in the arcade of Struthers between the septum and the medial head of the triceps (Moore et al., 2014 and Caetano et al., 2017). The arcade of Struthers is described as a musculotendinous band, located at variable distances superior to the medial epicondyle of the humerus between the medial intermuscular septa and the medial head of the triceps brachii muscle (Depukat et al., 2014, Caetano et al., 2017 and Mizia et al., 2020). The ulnar nerve then passes posterior to the medial epicondyle of humerus, to enter the forearm medial to the olecranon of the ulna (Macchi et al., 2014 and Moore et al., 2014). At this juncture, a tendinous ligamentous arch is stated to span between the humeral and ulnar heads of flexor carpi ulnaris muscle (FCU) which is referred to as the Osborne ligament (Sawardeker et al., 2015 and Granger et al., 2017). The cubital tunnel is a fibromuscular canal beneath the Osborne ligament (Siemionow et al., 2007). The Osborne ligament forms the roof of the canal laterally, and the floor is formed by the medial collateral ligament, the joint capsule of elbow and olecranon process (Sawardeker et al., 2015). This tunnel can be divided into three parts: viz. (i) the entrance posterior to the medial epicondyle; (ii) the fascial aponeurosis joining two heads of the FCU and (iii) at the muscular bellies (Xarchas et al., 2007).

The UN slopes postero-medially together with the ulnar vessels in the forearm deep to anterior margin of flexor carpi ulnaris (FCU) and flexor digitorum profundus (FDP), giving motor branches to both muscles (Standring et al., 2015).

Typically, compression of the UN occurs at the cubital tunnel, however the nerve is also vulnerable at other sites around the elbow (Siemionow et al., 2007; Macchi et al., 2014).
These sites are classified as either pre-cubital, cubital tunnel or post-cubital tunnel compression sites (Cutts, 2007; Siemionow et al., 2007). Since, the compression sites are variable, anatomical knowledge of the relations of the UN is important (Siemionow et al., 2007; Macchi et al., 2014; Becker and Manna, 2018).

Therefore, this study aimed at documenting the course of the UN with a focus on the anatomical relations within the cubital tunnel.

**MATERIALS AND METHODS**

A bilateral dissection of 25 fetal cadavers (n=50), 11 females and 14 males between 19 – 36 gestational weeks, was performed to expose muscles of the forearm and reveal the UN in the cubital tunnel, in order to document its course and relations. The presence of the arcade of Struthers, anconeus epitrochlearis muscle, flexor-pronator aponeurosis (FPA), Osborne’s ligament, the superior ulnar collateral artery, radial artery and ulnar artery was also documented together with anatomical variations (if present). A morphometric analysis of the Osborne’s ligament was performed by measuring the distance between the medial epicondyle and the lateral border of the olecranon process using a digital sliding caliper in order to determine the size of the cubital tunnel. The fetal cadavers were sourced from the Department of Clinical Anatomy at the University of KwaZulu-Natal (Westville Campus). Ethical clearance was obtained (BE397/17). Fetuses whose forearms were deformed by traumas, malformations, scars or any other macroscopic evidence of pathology were excluded from this study. The data was captured and analysed using the Statistical Package for Social Sciences (SPSS version 23.0) software. A p-value of less than 0.05 was deemed statistically significant.

**Reliability and Validity**

Morphometric analysis of the Osborne’s ligaments was performed by an inter-observer on 5 random cadavers using the sliding digital calliper. The Intra-Class Correlation Coefficient test was then employed to assess the inter-observer reliability. A 0.989 significance for the mean Osborne’s ligament length between both observers was found which denotes excellent agreement.

**RESULTS**

The course and relations of the ulnar nerve
The UN passed through the cubital tunnel in 96% (48/50) of the specimens, while it was absent in 4% (2/50) (Fig. 1). In its course through the cubital tunnel, the UN was located deep to the FCU and supero-lateral to the FDP in 6% (3/50) (Fig. 2). The superior ulnar collateral artery (SUCA) accompanied the UN into the cubital tunnel in 32% (16/50) in at least one side of the present study prior to its anastomoses with the ulnar recurrent arteries (Table I; Fig. 3 and 4). A statistically significant correlation between the course of the UN and SUCA was documented in this study with a $p$-value of 0.042.

The ulnar artery accompanied the UN as it passes through the cubital fossa in 34% (17/50) (Fig 5 and 6). In 2% (1/50) of the specimens, the UN was covered medially by a common flexor pronator aponeurosis (Fig. 7). The radial artery followed the standard anatomical course in 92% (46/50) of the specimens, however it accompanied the UN distal to the cubital tunnel in 8% (4/50) (Fig. 8).

**Arcade of Struthers**

All specimens sampled in this study showed that the arcade of Struthers was absent. This may be due to the developmental stages of fetuses used.

**Osborne’s ligament**

The Osborne’s ligament was found in 100% of specimens (50/50) (Fig. 9), but varied from a thin aponeurotic structure to a thickened fascial band. The anconeus epitrochlearis muscle, an analogue to the Osborne’s ligament was found in 2% (1/50) of the specimens (Fig. 10). The Osborne ligament had a mean length of $6.32 \pm 0.97$ and $6.30 \pm 1.10$ mm on the left and right sides, respectively (Table II). This study found no statistically significant relationship between the length of Osborne ligament and laterality (right: $p = 0.55$ and left $p = 0.65$).

**DISCUSSION**

**The course and relations of the ulnar nerve**

This study found that in 96% (48/50) of the specimens, the standard course of the UN was documented, viz. the nerve crosses the medial collateral ligament of the elbow and enters the flexor compartment of the forearm between the two heads of the flexor carpi ulnaris (FCU), then traveled distally between the FCU and flexor digitorum profundus muscles (Heithoff, 2010; Moore 2010; Macchi et al., 2014).
However, the course of the UN can vary. Assmus et al. (2015) documented the UN in the cubital tunnel whereby the nerve had a superficial course, anterior to the medial epicondyle but did not penetrate the fascia between the FCU muscles. In this study, the radial artery accompanied the UN, distal to the cubital tunnel, from the middle third of the forearm was documented as a unique finding.

An elliptically shaped fibrous tunnel formed by the flexor pronator aponeurosis was observed (2%), however previous literature indicated the incidence of the flexor pronator aponeurosis (FPA) to range between 43.5% - 100% (Green et al., 1999; Gonzalez et al., 2001) (Table III). Siemionow et al. (2007) documented that the elliptically shaped tunnel may be a cause of UN compression.

**Arcade of Struthers**

The arcade of Struthers was observed in previous literature (Siemionow et al., 2007; Macchi, et al., 2014), however it was not present in the specimens used in this study. This could be due to the sample size or the use of fetuses instead of adult cadavers. Furthermore, Bartels (2003) and Caetano et al. (2017) stated that the occurrence of the arcade of Struthers is rare and observed in 0.7% to 2.5% of the population. Furthermore, Mizia et al. (2020) found that the arcade of Struthers is a valid anatomical structure that is present in most individuals; however, its presence is highly variable.

**Osborne’s ligament**

An Osborne's ligament was documented in 100% of specimens, however the ligament varied from a very thin aponeurotic structure to a thickened muscle. An anconeus epitrochlearis muscle found in one of the specimens, has been described as the cause of UN neuritis (Joshi and Joshi 2002). The mean length of the Osborne ligament in this study was 6.32 ± 0.97 mm on the left side and 6.30 ± 1.10 mm on the right side (Table II). The length of the Osborne ligament differed with previous reports such as Gonzalez et al. (2001) who found its average length as 4.6mm. Variations in the length of the Osborne ligament to a previous study can be attributed to the fact that previous studies were conducted on adult cadavers, while the current study was conducted on fetuses.

The superior ulnar collateral artery (SUCA) accompanied the UN into the cubital tunnel in 32% and a significant correlation was observed between presence of the superior ulnar collateral artery and the course of UN.
Limitations of the study
The present study only included fetal specimens, as there is a shortage of adult cadavers. A further study is required to document the histology of the Osborne ligament as this was not done in this study.

CONCLUSIONS
The understanding of the anatomy of the UN is important for the diagnosis and treatment of conservative and surgical lesions of the UN in the cubital region. In this study, the potential sites of UN compression may be at the cubital tunnel; beneath the FCU; Flexor pronator aponeurosis (elliptically shaped tunnel) and the Osborne ligament. Knowledge of the anatomy of the UN in the cubital tunnel may be essential to mitigate the risk of injury during the now increasingly performed endoscopically assisted decompression surgery (Assmus et al., 2015).

Acknowledgement
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The authors of this study sincerely wish to thank and acknowledge the human fetal cadaveric donors and their families for the donation of their remains to science. This selfless donation enabled us to conduct this anatomical study and contribute to the existing knowledge of the UN in the cubital tunnel, which may assist in fetal surgical procedures. We truly appreciate theses donations to anatomical science.

REFERENCES

**Table I.** Presence/absence of the superior ulnar collateral artery in relation to laterality (n=50)

<table>
<thead>
<tr>
<th>Presence/absence</th>
<th>Incidence</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present on left side only</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>Present on right side only</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>Bilaterally present</td>
<td>8</td>
<td>16%</td>
</tr>
<tr>
<td>Bilaterally absent</td>
<td>26</td>
<td>52%</td>
</tr>
<tr>
<td>Absent on left side only</td>
<td>5</td>
<td>10%</td>
</tr>
<tr>
<td>Absent on right side only</td>
<td>3</td>
<td>6%</td>
</tr>
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</table>

**Table II.** Mean length and standard deviations of Osborne ligament (in mm)

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum length</th>
<th>Maximum length</th>
<th>Mean length</th>
<th>Std. Deviation</th>
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<tbody>
<tr>
<td>Age (weeks)</td>
<td>19.49</td>
<td>36.93</td>
<td>26.55</td>
<td>3.73</td>
</tr>
<tr>
<td>Right Osborne</td>
<td>4.64</td>
<td>8.82</td>
<td>6.30</td>
<td>1.09</td>
</tr>
<tr>
<td>Left Osborne</td>
<td>4.48</td>
<td>8.69</td>
<td>6.32</td>
<td>0.97</td>
</tr>
</tbody>
</table>

**Table III.** Descriptions of the flexor-pronator aponeurosis (FPA) in the cadaver studies
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Sample size</th>
<th>FPA (present/absent)</th>
<th>Length [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injera and Spinner</td>
<td>1986</td>
<td>10</td>
<td>Absent</td>
<td>1.5–2.0</td>
</tr>
<tr>
<td>Amadion et al.</td>
<td>1986</td>
<td>20</td>
<td>100%</td>
<td>5</td>
</tr>
<tr>
<td>Green et al.</td>
<td>1999</td>
<td>19</td>
<td>100%</td>
<td>2.9</td>
</tr>
<tr>
<td>Gonzalez et al.</td>
<td>2001</td>
<td>38</td>
<td>43.5%</td>
<td>4.2</td>
</tr>
<tr>
<td>Degeorges et al.</td>
<td>2002</td>
<td>24</td>
<td>45.8%</td>
<td>6</td>
</tr>
<tr>
<td>Siemionow et al.</td>
<td>2007</td>
<td>28</td>
<td>100%</td>
<td>5.6</td>
</tr>
<tr>
<td>Present study</td>
<td>2017</td>
<td><strong>50</strong></td>
<td><strong>2%</strong></td>
<td>Not measured</td>
</tr>
</tbody>
</table>
FIGURES

**Figure 1.** The standard description of ulnar nerve in the cubital tunnel; FCR – Flexor carpi radialis; FCU – Flexor carpi ulnaris; UN – Ulnar nerve.

**Figure 2.** The ulnar nerve lies deep to the cubital tunnel muscles; FCR – Flexor carpi radialis; FCU – Flexor carpi ulnaris; UN – Ulnar nerve; FDP – Flexor digitorum profundus.
Figure 3. The ulnar nerve in the arm accompanied by the SUCA; UN – Ulnar nerve; BB – Biceps brachii; T – Triceps; SUCA – Superior ulnar collateral artery.

Figure 4. The ulnar nerve in arm without the SUCA; UN – Ulnar nerve; BB – Biceps brachii; T – Triceps muscle.
Figure 5. The ulnar nerve in the cubital tunnel and forearm accompanied by the ulnar artery; FCR – Flexor carpi radialis; FCU – Flexor carpi ulnaris; UN – Ulnar nerve; UA – Ulnar artery.

Figure 6. The ulnar nerve in the cubital tunnel without the ulnar artery; FCR – Flexor carpi radialis; PL – Palmaris longus; FCU – Flexor carpi ulnaris; UN – Ulnar nerve.
**Figure 7.** The flexor pronator aponeurosis underneath heads of FCU; FCR – Flexor carpi radialis; FCU – Flexor carpi ulnaris; UN – Ulnar nerve; FPA – Flexor pronator aponeurosis.

**Figure 8.** The ulnar nerve accompanied by the radial artery; FCR – Flexor carpi radialis; FCU – Flexor carpi ulnaris; PL – Palmaris longus; FDP – Flexor digitorum profundus; UN – Ulnar nerve; RA – Radial artery; UA – Ulnar artery.
Figure 9. The Osborne ligament between the two heads of FCU; UN – Ulnar nerve; M – Medial epicondyle; OB – Osborne band; O – Olecranon process; FCR – Flexor carpi radialis; FCU – Flexor carpi ulnaris.

Figure 10. The anconeus epitrochlearis muscle between the two heads of the FCU; M – Medial epicondyle; AN - Anconeus epitrochlearis; O – Olecranon process; FCU – Flexor carpi ulnaris.