Safety parameters during endoscopic carpal tunnel release: An anatomic study

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ARTICLE INFO

Keywords:

Endoscopic
Carpal tunnel
Nerve
Anatomy
Safety

1. Introduction

Endoscopic carpal tunnel release was first introduced in 1989.^{1,2} Further understanding of the risks of this technique were published as it gained popularity.³ Additional reports shed light on important anatomic structures at risk during endoscopic carpal tunnel release.^{4,5} Several cadaveric studies followed to better understand the risks and adequacy of this technique.^{6–9} With increasing popularity, safety parameters and risks of endoscopic release were compared to the open approach where it was demonstrated that both techniques are comparable in outcomes and adverse events.⁶

In most cases, complications of endoscopic carpal tunnel release are a result of damage to structures near the cutting edge of the instrument. Although there is literature to demonstrate the anatomical relationship between the cutting edge of the instrument and the superficial palmar arch,⁸ there are few publications that evaluate distance between the knife edge and the common digital nerves, the ulnar artery, or the ulnar nerve.^{7,10}

The purpose of this study is to assess the distance from the knife edge to the ulnar artery, ulnar nerve, digital nerve for the third and fourth web space during endoscopic carpal tunnel release.

2. Materials and methods

Fresh frozen cadaver arm specimens transected at the mid-humerus level were obtained [n = 18]. There were an equal number of left and right hands. Two thirds of the specimens were obtained from female

cadavers [66%].

Full exposure of the TCL was obtained. This was performed by excising the following structures: skin and subcutaneous tissue from mid-forearm to the palmar digital crease, palmaris longus from its distal insertion in the flexor retinaculum and palmar aponeurosis to its proximal musculotendinous junction. Distal to the transverse carpal ligament, the palmar fat pad and the palmar fascia were excised to expose the common digital nerves for the third and fourth web-space, ulnar artery, and superficial palmar arch. All dissections were performed by the same hand surgeon.

The cutting instrument was then inserted into the carpal tunnel under direct visualization until the tip of the blade was seen appearing distal to the TCL. The cutting instrument was positioned to transect the TCL perpendicular to its fibers. Measurements in neutral position and 30° of wrist extension were obtained from the tip of the cutting instrument to the nearest aspect of following anatomic structures: third and fourth common digital nerves, ulnar nerve, ulnar artery and fourth web space. Measurements were performed using a 4"/100 mm Brass Pocket Caliper, Empire®, Mukwonago, WI. Measurements from the distal wrist crease to the antebrachial fascia were recorded. The number of knife passes to fully transect the carpal ligament were also recorded. Statistical analysis was performed using www.socscistatistics.com for a two-tailed unpaired T-Test.

3. Results

The distance from the distal wrist crease to the antebrachial fascia

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<https://doi.org/10.1016/j.jor.2019.08.012>

Received 5 June 2019; Accepted 11 August 2019

Available online 12 August 2019

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Fig. 1. The distal wrist crease and antebrachial fascia are demarcated by the red and blue lines, respectively..

Fig. 2. The red line depicts the measurement from the distal tip of the knife blade to the ulnar artery.

was 0.55 ± 3.5 mm. No significant differences between males and females were observed, $p = 0.51$. [Fig. 1]. The ulnar nerve was seen to be within 10 mm in 100% [18/18] of specimens. The ulnar artery was within 5 mm of the release site in 16/18 samples or 88% of specimens. [Fig. 2].

A significant increase in distance from the tip of the instrument to the common digital nerve of the fourth web space was identified when measurements were taken in a wrist neutral position vs 30° of extension, 5.1 ± 1.88 mm vs. 6.5 ± 1.89 mm, $p = 0.019$. [Fig. 3. Table 1].

A significant increase in distance from the tip of the instrument to the common digital nerve of the third web space was identified when measurements were taken in a wrist neutral position vs 30° of extension, 2.88 ± 2.18 mm vs. 4.22 ± 3.19 mm, $p = 0.003$. [Fig. 4. Table 1].

Fig. 3. Distance from tip of the cutting instrument to the common digital nerve [yellow line] of the fourth web-space..

Table 1
Average distance from knife tip to anatomic structures at risk.

Structure	Average distance from Knife tip (mm)	P-Value (paired T Test)
Common Digital Nerve of 3rd Web Space	2.9 (SD 2.2) (neutral) 4.2 (SD 3.2) (extension)	0.003
Common Digital Nerve of 4th Web Space	5.1 (SD 1.9) (neutral) 6.5 (SD 1.9) (extension)	0.019

SD: Standard Deviation.

Fig. 4. Demonstrates the proximity of the tip of the cutting instrument to the common digital nerve of the third web-space.

The average measurement of the transverse ligament in the axis of the fourth Metacarpal bone was 30.9 mm [Range 23–40 mm]. An average of 2.6 [2–4] knife passes were needed to transect the transverse carpal ligament. The flexors tendons of the Long, Ring or Small fingers were not injured in any of the specimens. The recurrent branch of the median nerve was located along the radial aspect of the transverse carpal ligament and was extra-ligamentous in all specimens. Of note, a palmaris profundus muscle was identified in one of the specimens.

4. Discussion

As first described, Okutsu showed excellent results with only three

of the forty-five patients developing a subcutaneous hematoma and a single patient developing recurrence after an average follow-up of 14 months⁽¹⁾. Chow, with a two-incision technique, reported 142 endoscopic carpal tunnel releases with an average follow up of 15.5 months. The only complication identified was neurapraxia of the ulnar nerve which completely resolved after 4 weeks.¹¹ No injuries were observed after TCL transection in our specimens.

In our study, all cadaver specimens had a recurrent motor branch of the median nerve in the extraligamentous position. According to Lanz, 46% are extraligamentous, 31% were subligamentous and 23% were transligamentous.¹² Similar findings were observed by McKinnon with 66% extraligamentous, 22% subligamentous and 11% transligamentous.¹³ One palmaris profundus belly muscle and tendon was identified as the only aberrant anatomic finding in our specimens.

The weaknesses of this study fall on the reproducibility of the anatomical dissection in its exactitude. The only structures excised were the skin, subcutaneous tissue and fat pad. Although, the carpal tunnel is a fixed structure the excision of these structures may slightly displace some of the measured structures. An additional area of potential error is the accuracy of the measurements made with a caliper when the distances measured are of only a few millimeters. Also, the measurements do not include the change in distance from the tip of the knife to the structure of interest with extension from neutral position. The authors strongly believe this distance increases for all structures with wrist extension. Finally, the measurements were made by a single observer and are therefore subject to observer bias.

In 1991, Agee et al. reported a two-point four percent (2/82) rate of ulnar nerve neurapraxia in patients undergoing endoscopic release. A single patient had recurrence of symptoms due to incomplete endoscopic release at the proximal transverse carpal ligament [TCL]. Agee et al. also introduced the concept of The Safe Zone which was described as an area within a triangle defined by the ulnar half of the distal edge of the TCL, the common digital branch of the median nerve, and the ulnar proximal margin of the superficial palmar arch [SPA].³ In our study, the ulnar nerve was found to be within 10 mm of the tip of the blade in all specimens.

In a series of 24 cadavers, the average distance between the distal edge of the TCL and the superficial palmar arch was reported as 12 mm [range 0–27 mm]. The width of the transverse carpal ligament averaged 13 mm [range 10–19 mm], incomplete releases were found in 50% of the specimens and these were thought to be due to errors in technique. No digital nerve or vascular injuries were observed.⁶ However, the distance to the digital nerves from the distal edge of the TCL was not recorded. Seiler et al. described the average distance from the distal edge of the TCL to the ulnar artery and ulnar nerve to be 4 ± 2.2 mm and 6 ± 2.0 mm, respectively. Two specimens had incomplete releases and one specimen had a partial transection of the SPA.⁷ Rotman reported the importance of positioning the cutting device in the long axis of the ring finger to avoid placing the blade directly beneath the median nerve.⁸ Levy et al. evaluated the distance from the distal TCL to the common digital nerve of the third web-space in neutral position [5.3 mm, range 2–9 mm] and in wrist hyperextension [6.6 mm, range 4.5–8 mm].¹⁰ A statistically significant increase in distance from the tip of the blade to the third and fourth common digital nerves with wrist hyperextension was identified in our specimens, establishing the importance of adequate positioning during endoscopic release.

Agee performed a 63-center prospective study with over one-thousand patients using the Agee carpal tunnel release system. An average of 2.2 passes of the blade were required to divide the transverse carpal ligament completely and in 72.1% of cases [738/1022], release was completed in 1 or 2 passes.¹⁴ There was a significant increase in number of passes in patients of larger frame. One of the main limitations of our study was the use of a total of 5 endoscopic release devices for all 18 specimens. However, when a new device was utilized, a single pass of the knife did not fully transect the TCL in any of those five specimens. This device is labelled and approved for single use only, therefore,

comparing our results to in vivo studies is not possible.

Sacks reported that the average length of the transverse carpal ligament from proximal to distal using the longitudinal line of the 3rd web space was 28.5 ± 0.8 mm,¹⁵ Stecco reported the TCL at 22–26 mm. In our study the average measurement of the TCL in the axis of the 4th Metacarpal bone was 30.9 mm [Range 23–40 mm].¹⁶

We observed the TCL carries a downward slope of approximately 25–30° when travelling from its thenar to hypothenar attachments. Prior to transection of the TCL we rotated our cutting device 30° counterclockwise along its axis. This maneuver places the TCL and the cutting blade at 90° allowing for a better cutting edge and may decrease the number of blade passes for total TCL transection. Minimizing blade passes could lead to a decreased risk of injury to the nearby structures described.

5. Conclusions

Understanding the anatomic relationships from the distal tip of the knife edge to the nearby structures at risk, which are within millimeters, provides the foundation for minimizing complications during endoscopic carpal tunnel release. The flexor tendons are not at risk of injury during TCL release due to the protective dorsal covering of the cutting instrument. Extension of the wrist by 30° can significantly protect the common digital nerves of the third and fourth web spaces from injury. Rotation of the cutting device in a 30° counterclockwise fashion prior to transection allows for better opposition of the cutting edge to the TCL. Further studies are needed to determine the impact of this maneuver in the number of passes and its correlation to the number of complications.

Author Contribution

Jorge I. Quintero: Conceptualization, methodology, validation, formal analysis, investigation, resources, writing – original draft, writing – review and editing, visualization, supervision.

Cesar S. Molina: Methodology, formal analysis, investigation, resources, writing – original draft, writing – review and editing, visualization, project administration.

Christina Kauffman: Conceptualization, methodology, validation, formal analysis, investigation, resources, writing – original draft, writing – review and editing, visualization, supervision.

Elkin Galvis: Conceptualization, methodology, validation, formal analysis, investigation, resources, writing – original draft, writing – review and editing, visualization, supervision.

Conflicts of interest

There are no conflicts of interest for any of the authors involved in this study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors wish to thank the individuals of the University of Louisville Willard Body Program who donated their bodies and tissues for the advancement of education and research.

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