The Open Orthopaedics Journal
DOI: 10.2174/0118743250367501250506062636, 2025, 19, e18743250367501
ISSN: 1874-3250
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RESEARCH ARTICLE **OPEN ACCESS**

The Effect of the Lumbrical Muscle Position on Carpal Tunnel Syndrome

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Abstract:

Introduction: Carpal tunnel syndrome (CTS) is a compressive neuropathy of the median nerve at the wrist, yet the role of lumbrical muscles in CTS remains unclear. This study investigates the impact of lumbrical muscle position on the outcomes of open carpal tunnel release in CTS patients.

Methods: Patients with CTS indicated for surgical release underwent pre-operative ultrasound to dynamically assess lumbrical positioning, followed by open carpal tunnel release with flexor tenosynovectomy. Intra-operative assessment of lumbrical position was recorded relative to the transverse carpal ligament (TCL), and patients completed the Boston Carpal Tunnel Questionnaire pre-and post-operatively.

Results: A total of 147 wrists in 114 patients were included in the study. On pre-operative ultrasound assessment, the most proximal lumbrical position in maximal passive finger flexion was distal to the TCL in 13 cases, at the level of the TCL in 19 cases, and proximal in 115 cases. Intra-operatively, the most proximal lumbrical muscle position was distal in 19 cases, at the level of the TCL in 69 cases, and proximal in 59 cases. Patients with more proximal lumbrical positioning had poorer clinical outcomes, with less improvement in manual workers compared to non-manual workers. Intra-operatively, greater excursion was observed in manual workers compared with non-manual workers. Manual workers were seen to have less clinical improvement post-operatively.

Conclusion: This study suggests that greater lumbrical excursion into the carpal tunnel is associated with worse outcomes following release, especially in manual workers. These findings may assist in patient discussions on surgical expectations and outcomes.

Keywords: Carpal tunnel syndrome, lumbricals, flexor tenosynovectomy, carpal tunnel release, Boston Carpal Tunnel Questionnaire, ultrasound.

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Cite as: Clarnette J, Shunmugam M, Rezaian P, McLean J. The Effect of the Lumbrical Muscle Position on Carpal Tunnel Syndrome. Open Orthop J, 2025; 19: e18743250367501. http://dx.doi.org/10.2174/0118743250367501250506062636

Received: November 17, 2024
Revised: February 17, 2025
Accepted: March 18, 2025
Published: May 13, 2025

1. INTRODUCTION

Carpal tunnel syndrome (CTS) is a compressive neuropathy of the median nerve at the level of the wrist. CTS is characterised by a variety of symptoms, including pain, numbness, paraesthesia, and loss of grip strength in the hand and wrist [1, 2]. Many conditions have been reported to be associated with the development of CTS,

such as inflammatory arthropathies, trauma, diabetes, acromegaly, hypothyroidism, and pregnancy [3]. The mechanisms of CTS development are varied and may involve a combination of carpal tunnel narrowing or internal carpal tunnel pathology.

Internal carpal tunnel pathologies, such as ganglions, severe flexor tenosynovitis, or soft tissue masses adjacent to the flexor sheaths, may contribute to internal compression of the median nerve and the development of carpal tunnel syndrome [4]. Other physiological structures, such as the lumbrical muscles, may also contribute to dynamic internal compression of the median nerve within the carpal tunnel. The potential contribution of the lumbrical muscle position relative to carpal tunnel syndrome is poorly understood.

The hand has four lumbrical muscles that originate from the tendons of the Flexor Digitorum Profundus (FDP) and insert onto the radial side of the fingers [5]. Some reports have raised the possibility of hypertrophied lumbricals or those with more proximal insertions contributing to the development and/or severity of carpal tunnel syndrome [6-8]. Other studies have investigated the dynamic position of the lumbrical muscles on ultrasound and confirmed that the lumbricals frequently migrate proximally into the carpal tunnel [9-12]. Siegel *et al*. reported that the lumbrical muscles were more proximal in patients undergoing carpal tunnel release (CTR) for CTS when compared with normal cadaveric wrists [13]. However, to our knowledge the potential contribution of the dynamic lumbrical muscle position has not been investigated on a large scale, nor correlated with pre-operative imaging findings or clinical outcome following CTR surgery.

The primary aim of this study is to investigate whether the dynamic lumbrical position reported on pre-operative ultrasound is associated with clinical outcomes following open CTR surgery. The study also aims to investigate if lumbrical position intra-operatively is associated with clinical outcomes or if there is a correlation between manual workers and non-manual workers. We hypothesise that dynamic lumbrical position on pre-operative ultrasound is not associated with a difference in clinical outcome.

2. MATERIALS AND METHODS

The patients included in the study were collected from an ongoing database of patients undergoing open carpal tunnel release surgery. The study protocol was approved by the Central Adelaide Health Network Ethics Committee.

One hundred and fourteen patients over 18 years of age were recruited from a single senior hand surgeon’s practice. A preliminary diagnosis of CTS was confirmed with a combination of patient history and clinical examination, with or without the addition of electrodiagnostic tests. Patients with recalcitrant CTS symptoms who had exhausted conservative management and who were indicated for surgical carpal tunnel release (CTR) were considered for the study. Eligible participants underwent an informed consent process. Demographic data were collected for all patients pre-operatively. There were no study advertisements or incentives, and participants were not paid for their involvement. Written informed consent was obtained from all patients prior to inclusion.

Exclusion criteria included a history of previous CTR surgery, median nerve damage, or a peri-operative consideration that indicated an endoscopic CTR in preference to an open procedure. Although pregnancy was not considered an exclusion, no pregnant patients were recruited. Cervical disease affecting the peripheral nerves, along with coincident ulnar or radial compressive neuropathy, was recorded and not considered an exclusion criterion.

2.1. Ultrasound Imaging

All patients underwent pre-operative ultrasound imaging. The patient's position was according to EULAR guidelines. The scans were performed by a senior musculoskeletal sonographer and reported by a senior musculoskeletal radiologist. The sonographer and radiologist were not blinded to the preliminary diagnosis of CTS but were blinded to other non-radiological data being collected.

An Esaote MyLab5 with an LA435 probe (18–6 MHz) was used. Greyscale ultrasound (GSUS) settings were adjusted for each patient to obtain the optimal image. For Power Doppler ultrasound (PDUS), the frequency was set to the maximum of 8 MHz, with a pulse repetition frequency of 500 Hz. Low wall filters were used. The upper border of the box size was flush with the skin.

The position of the lumbricals was dynamically assessed in real-time relative to the proximal and distal extents of the transverse carpal ligament (TCL).

2.2. Intra-operative Assessment

Of the 114 patients recruited for the study, 81 patients underwent a unilateral surgical procedure, and 33 underwent bilateral procedures, resulting in 147 wrists included in the study. All patients underwent an open release of the TCL by a single-hand senior surgeon, who was blinded to the radiological outcomes. An open release of the TCL and carpal tunnel decompression with flexor tenosynovectomy was performed in all patients. Adequate CTR was confirmed for all patients by visual inspection of the proximal and distal extents of the TCL. It was assessed objectively whether the surgeon could fit an index finger easily into the carpal tunnel with the fingers in full extension following debridement of the flexor tenosynovium and surrounding stromal tissue.

Dynamic lumbrical muscle position was recorded specifically with reference to the hook of the hamate and pisiform bones, which reflect the distal and proximal extents of the transverse carpal ligament, respectively. For each case, it was noted whether the lumbrical muscles reached these points with the patient's fingers in maximal passive flexion. Therefore, for each case, the position of the lumbricals in maximal finger flexion could be

described as distal to the TCL (*i.e.*, distal to the hook of hamate), at the level of the TCL (*i.e.*, between the hook of hamate and pisiform bones), proximal to the TCL (*i.e.*, extending proximal to the pisiform bone).

2.3. Clinical Outcomes

Patients completed a Boston Carpal Tunnel Questionnaire (BCTQ) pre-operatively and at a minimum of three months post-operatively. This is a validated patient-reported outcome measure consisting of two parts [14]. The Symptom Severity Scale (SSS) has 11 questions, and the Functional Status Scale (FSS) has eight questions. All questions are scored from 1-5 (one indicating no symptoms and five indicating very severe symptoms). The final SSS and FSS scores were calculated as an average of the scores for each question, resulting in an overall score of 1-5 (1 indicating no symptoms and 5 indicating severe symptoms)

2.4. Statistical Analysis

Statistical analysis was performed using the SPSS V28.0 statistical package. Fisher's exact tests were used for 2x2 tables, with Phi as a measure of correlation. Kendall's Tau C was used for estimating associations between dichotomous and ordinal variables. Dichotomous by continuous variables were tested using a Mann-Whitney U test, and continuous by ordinal variables were estimated using Kendall's Tau B. P-values of <0.05 were considered significant.

3. RESULTS

Patient cohort and demographic data are presented in Table **1**.

Table 1. Demographic data.

Age	58 ± 14 (range 20-86)
Male	90 (61%)
Manual worker	83 (56%)
Comorbidities	
- Diabetes	17 (12%)
- Hypothyroidism	9 (6%)
- Heart disease	15 (10%)
- Rheumatoid arthritis	8 (5%)
- Kidney disease	1 (1%)
- Alcoholism	38 (26%)
- On anticoagulation	29 (20%)

3.1. Ultrasound

Pre-operative dynamic ultrasound recorded that with maximal passive finger flexion, the most proximal lumbrical muscle position was:

1. Distal to the TCL in 13 (9%) cases.
2. At the level of the TCL in 19 (13%) cases.
3. Proximal to the TCL in 115 (78%) cases.

3.2. Intra-operative

Intra-operative dynamic lumbrical assessment recorded that with maximal passive finger flexion, the most proximal lumbrical position was:

1. Distal to the TCL in 19 (13%) cases.
2. At the level of the TCL in 69 (47%) cases.
3. Proximal to the TCL in 59 (40%) cases.

The average reported duration of CTS symptoms pre-operatively was 2.5 ± 2.4 years. The average pre-operative symptom severity scale (SSS) was 3.1 ± 0.7, and the average pre-operative functional status score (FSS) was 2.4 ± 0.9. The post-operative BCTQ scores were collected an average of 14 months (Range: 3 to 36 months) after surgery and improved to 1.4 ± 0.6 and 1.3 ± 0.7, respectively.

Table **2** shows the clinical scores according to the position of the lumbricals on pre-operative dynamic ultrasound. Table **3** shows the clinical scores with reference to the position of the lumbricals on intra-operative assessment. Table **4** shows the lumbrical position of manual workers compared with non-manual workers. Table **5** shows the clinical scores of manual workers compared with non-manual workers.

Table 2. Lumbrical position on ultrasound comparison with clinical scores.

-	**Distal to TCL (n=13)**	**Level of TCL (n=19)**	**Proximal to TCL (n=115)**	**p-value**
Pre-op SSS	3.12 ± 0.76	3.10 ± 0.67	3.04 ± 0.69	p=0.599
Pre-op FSS	2.02 ± 0.89	2.53 ± 0.92	2.36 ± 0.87	p=0.652
Post-op SSS	1.03 ± 0.10	1.48 ± 0.69	1.43 ± 0.65	**p=0.011**
Post-op FSS	1.00 ± 0.00	1.48 ± 0.95	1.33 ± 0.62	**p=0.022**
Improvement in SSS	2.08 ± 0.74	1.61 ± 0.82	1.61 ± 0.88	p=0.169
Improvement in FSS	1.02 ± 0.89	1.05 ± 0.86	1.03 ± 0.88	p=0.912

Table 3. Lumbrical position intra-operatively comparison with clinical scores.

-	**Distal to TCL (n=19)**	**Level of TCL (n=69)**	**Proximal to TCL (n=59)**	**p-value**
Pre-op SSS	3.13 ± 0.72	3.14 ± 0.66	2.93 ± 0.70	p=0.275
Pre-op FSS	2.68 ± 0.66	2.31 ± 0.97	2.29 ± 0.82	p=0.190
Post-op SSS	1.20 ± 1.31	1.41 ± 0.64	1.46 ± 0.70	p=0.140
Post-op FSS	1.22 ± 0.34	1.33 ± 0.70	1.34 ± 0.66	p=0.561
Improvement in SSS	1.93 ± 0.70	1.73 ± 0.84	1.46 ± 0.91	**p=0.021**
Improvement in FSS	1.47 ± 0.69	0.98 ± 0.89	0.95 ± 0.87	p=0.097

Table 4. Lumbrical position comparison with manual workers.

-	-	**Manual worker**	**Non-manual worker**	**p-value**
Ultrasound	Distal to TCL	9	4	p=0.624
	Level of TCL	10	9	
	Proximal to TCL	64	51	
Intra-operative	Distal to TCL	5	14	**p=0.016**
	Level of TCL	40	29	
	Proximal to TCL	38	21	

Table 5. Clinical scores comparison with manual workers.

-	Manual worker	Non-manual worker	p-value
Pre-op SSS	2.99 ± 0.67	3.14 ± 0.70	p=0.178
Pre-op FSS	2.23 ± 0.87	2.51 ± 0.88	p=0.051
Post-op SSS	1.48 ± 0.70	1.31 ± 0.52	p=0.318
Post-op FSS	1.33 ± 0.66	1.31 ± 0.64	p=0.752
Improvement in SSS	1.51 ± 0.88	1.83 ± 0.82	**p=0.009**
Improvement in FSS	0.90 ± 0.83	1.20 ± 0.91	**p=0.043**

4. DISCUSSION

This study has investigated the association of lumbrical muscle position in patients with carpal tunnel syndrome and the reported clinical outcome following open carpal tunnel release with flexor tenosynovectomy. The lumbrical position was measured with the fingers in a position of maximal flexion on both active dynamic ultrasound and passive intra-operative observation at the time of surgery.

There was a significant improvement in the postoperative clinical scores, with the average SSS score improving from 3.1 to 1.4 and the average FSS score improving from 2.4 to 1.3. These improvements are consistent with the high rate of success in treating CTS with open carpal tunnel release reported in the literature [15].

The active lumbrical position measured on dynamic ultrasound correlated with both the post-operative SSS and FSS scores. Patients whose maximal lumbrical excursion distal to the TCL had an average post-operative SSS score of 1.03 and an FSS score of 1.00. These scores increased to 1.48 (SSS) and 1.48 (FSS) when the maximal excursion was at the level of the TCL and to 1.43 (SSS) and 1.33 (FSS) when the maximal excursion was proximal to the TCL. These results suggest that those with lumbrical muscles that do not extend as far proximally as the TCL on ultrasound report a better postoperative clinical outcome.

Similarly, the lumbrical position measured intra-operatively correlated with improvement in the SSS score post-operatively. Patients with maximal lumbrical excursion distal to the TCL reported an average improvement of 1.93, compared with 1.73 for those with excursion at the level of the TCL and 1.46 for those with excursion proximal to the TCL. This suggests that less lumbrical excursion into the carpal tunnel is associated with greater improvement in symptoms.

These results suggest that patients with less excursion of the lumbrical muscles into the carpal tunnel have less improvement in clinical outcomes following CTR surgery. It is possible that lumbrical muscles with greater excursion contribute to the intrinsic compression of the median nerve even after decompression of the TCL and, therefore, cause some symptoms to persist. Interestingly, the extent of excursion of the lumbricals seen on both ultrasound and intra-operatively did not influence the pre-operative clinical scores. This suggests that the lumbricals may not significantly contribute to symptoms in patients with carpal tunnel syndrome prior to surgical decompression.

This study also examined manual workers, with reference to dynamic lumbrical position and clinical scores. There was no difference observed in the active excursion of the lumbricals between manual workers and non-manual workers when measured on dynamic ultrasound. There was, however, a difference noted when measured intra-operatively, with greater excursion observed in manual workers compared with non-manual workers. This potentially relates to larger lumbricals developing in manual workers as a result of more frequent use of their hands and, therefore, being more likely to migrate further proximally with maximal finger flexion. Cross-sectional lumbrical size is difficult to assess accurately and/or routinely and was not assessed as part of this study.

The clinical scores were compared between manual workers and non-manual workers. Manual workers reported lower pre-operative SSS and FSS scores and higher post-operative SSS and FSS scores without reaching statistical significance. However, the resultant improvement in their SSS and FSS was significantly different. Manual workers reported an average improvement of 1.51 (SSS) and 0.90 (FSS), compared with 1.83 and 1.20, respectively, in non-manual workers. There are a few factors that potentially contribute to this. Firstly, manual workers were observed intra-operatively to have a greater lumbrical excursion. This may contribute to persistent symptoms post-operatively due to sustained intrinsic compression of the median nerve. Secondly, this result may reflect a higher level of baseline function and activity in this patient sub-group. Patients currently working as manual workers may have better pre-operative clinical scores as their overall function is greater. Even with significant symptoms from their CTS, it may not translate to a poor pre-operative clinical score. For a similar reason, their higher functional demands may make them more likely to notice residual symptoms post-operatively. A patient with a more sedentary lifestyle may notice very little residual symptoms simply because they do not put their hand and wrist under the same strains as a manual worker. Therefore, a manual worker may report a higher post-operative clinical score than a non-manual worker, despite similar clinical improvement, because their symptoms are more noticeable to them. The combination of these two factors may explain why there was less clinical improvement reported among manual workers in this study.

5. STUDY LIMITATIONS

This study should be considered with reference to its limitations. Differentiating patients into those who are manual workers and those who are not is a subjective self-reported measure. It may be that some patients were included in the incorrect group consequent to this assignment. Secondly, the lumbrical position measured passively intra-operatively and dynamically on ultrasound depends on the degree of flexion that can be achieved in

the fingers. Measurements were made at the point of maximal finger flexion. Patients with arthritis, prior trauma, or other factors limiting their finger flexion may alter the perceived maximal excursion of the lumbricals. Thirdly, this was a prospective study of patients undergoing an open carpal tunnel release with flexor tenosynovectomy. The results cannot necessarily be extrapolated to patients undergoing carpal tunnel release *via* endoscopic carpal tunnel release or open carpal tunnel release without flexor tenosynovectomy. Additionally, as the data was collected from an ongoing database of patients undergoing carpal tunnel release surgery, a formal power calculation prior to data collection was not undertaken. As the group under investigation was indicated for carpal tunnel release surgery, no control group of patients without carpal tunnel syndrome was included in the study.

CONCLUSION

In summary, this study has demonstrated that patients with a more lumbrical excursion into the carpal tunnel experience less symptomatic improvement following open carpal tunnel release with flexor tenosynovectomy compared to those with less excursion. This highlights the potential role of intrinsic muscle dynamics in the persistence of median nerve compressive symptoms despite adequate surgical decompression.

Additionally, this study suggests that manual workers report less improvement in symptoms compared to non-manual workers. This may be influenced by both anatomical factors, such as greater lumbrical excursion observed intra-operatively, and functional demands, where higher pre-operative activity levels may result in an increased awareness of residual symptoms post-operatively. These findings are particularly relevant when counselling patients about expected outcomes following carpal tunnel release.

While these results contribute to a deeper understanding of factors influencing post-operative recovery, further research is warranted to explore the exact mechanisms by which lumbrical excursion contributes to persistent symptoms. Future studies may benefit from incorporating advanced imaging techniques to assess lumbrical muscle morphology or assessment of intra-carpal pressures. Moreover, these findings raise important considerations for surgical decision-making. The extent of lumbrical muscle involvement in carpal tunnel syndrome could influence the selection of surgical techniques, such as modifications to tenosynovectomy or the potential role of adjunctive procedures targeting lumbrical excursion. This finding also highlights the importance of considering lumbrical excursion when consenting patients about the expected post-operative clinical outcome.

Ultimately, this study highlights the complexity of carpal tunnel syndrome, extending beyond simple median nerve compression, and emphasizes the role of dynamic muscle interactions within the carpal tunnel.

AUTHORS' CONTRIBUTIONS

M.S.: Study conception and design; P.R.: Data Data Analysis or Interpretation; J.C. and J.M.: Draft manuscript.

LIST OF ABBREVIATIONS

CTS	=	Carpal tunnel syndrome
TCL	=	Transverse carpal ligament
FDP	=	Flexor Digitorum Profundus

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research was approved by the CALHN Human Research Ethics Committee (R20180603).

HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committees and with the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

Informed consent was obtained from the participants.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIAL

The dataset has been uploaded and made available at: https://zenodo.org/records/15400204. The DOI is 10.5281/zenodo.15400203.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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