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ORIGINAL PAPER

Pre-operative grip force as clinical predictor for weakness after transversal carpal ligament release

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Abstract

Background Temporary or long-lasting loss of grip force after open carpal tunnel release (CTR) in carpal tunnel syndrome (CTS) patients is well known and caused by changes in biomechanical conditions through sectioning of the transverse carpal ligament. We hypothesize to find predicting factors for loss of grip strength.

Methods We performed dynamometer testing of overall hand grip, tip pinch, and key pinch grip prior, 3 and 6 months after open CTR in 42 CTS subjects. Changes in these three main variables related to pre-operative grip, tip pinch and key pinch forces as well as gender and age were analyzed for significant results (*t* test, Pearson and Spearman correlations, descriptive statistics; 2-tailed $p = .05$).

Results At 3-month post-CTR, overall hand grip force decreased significantly by 11.7% ($p = .006$), whereas key pinch and tip pinch only decreased by 5.6 and 3.5% ($p < .0004$). At 6-month post-CTR our subjects showed, compared to pre-operative level, an increase of overall grip force to 94.6% ($p = .242$) and an improvement of tip pinch to even 107% ($p = .169$) and key pinch to 102% ($p = .675$). Further investigation showed that subjects with a strong grip prior to the operation seem to lose more strength 3 and 6 months after operation than subjects with average or low strength results (3 months: Spearman −.522.; 6 months: Spearman −.569, $p = .000$).

Conclusions Pre-operative dynamometer assessment can predict loss of grip force and therefore create realistic post-operative expectations. Patients at risk for prolonged weakness after surgery (especially male subjects with high pre-operative grip force), could, instead of early surgical transversal carpal ligament release, profit from enrolling into an extended conservative therapy (immobilization and anti-inflammatory medication). Additionally, these patients undergoing CTR could enroll into an intensive post-operative occupational therapy with focus on grip force training to improve their recovery.

Level of Evidence: Level III, risk / prognostic study

Keywords CTS · TCL · Transverse carpal ligament · Grip force · Hand · Hand surgery

Introduction

Carpal tunnel syndrome (CTS) is the most frequent peripheral nerve compression syndrome of the human body [1]. The causes for CTS can be diverse but share an increase of pressure in the carpal tunnel which causes pain and sensomotoric symptoms as well as nerve injury with or without muscle atrophy [2–7]. After unsuccessful conservative therapy with immobilization with or without anti-inflammatory medication for at least 2 weeks, decompression of the median nerve through transverse carpal ligament (TCL) release also called open carpal tunnel release (CTR) represented

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the gold standard therapy. Though major downsides are relatively uncommon and outweighed by the upsides the vast majority of the time, post-operative loss of grip strength, possible iatrogenic nerve injury, or recurrence of symptoms are possible [8–10].

Depending on the cause, loss of grip force after TCL release can be temporary or long-lasting. Consequences of the surgical procedure like swelling, pain, or inflammation can cause a decrease in overall strength, which should recover after completion of the healing process [11]. On the other hand, the biomechanical consequences of TCL sectioning are permanent [12–14]. The role of TCL as a stabilizer for the carpal arch, as pulley for flexor tendons and origin for thenar and hypothenar muscles has been extensively studied [15, 16]. Because of TCL release, pressure in the carpal tunnel decreases through widening of the carpal arch, resulting in a decline of symptoms. This widening process increases during grip force load [11]. Although TCL sectioning relieves compression of the median nerve, it seems to be the cause for biomechanical changes resulting in decreased grip force post-operatively [8]. Compared with a fast recovery in sensibility deficit and pain, motor dysfunction like loss of grip force gets weakened even more through TCL sectioning and recovers much slower [8, 17, 18]. The adaption to new biomechanical conditions seems to be a slow process and explains the delayed recovery in hand grip, tip pinch (index finger and thumb pinch), and key pinch (pinch between thumb and radial side of index finger) forces.

Gellman et al. reported recovery of normal grip strength by 3 months and beyond (116%) at 6 months, Olsen et al. reported recovery by 25 weeks, Netscher et al. reported patients exceeding pre-operative grip strength at 3 months, and Bednarski et al. also reported exceeding pre-operative grip measurements at 3 months (109%), 6 months (123%), and 12 months (138%) [8, 9, 18, 19].

Netscher et al. also reported a faster grip strength recovery in patients which underwent partial TCL reconstruction after initial release and strengthens the role of the TCL as a key structure for normal function of biomechanics in the carpal tunnel [19]. However, pre-operative grip force should not be mistaken with normal healthy grip strength levels, because at the time a patient enrolls into pre-operative procedures and testing, symptoms like pain already impair grip strength.

Evaluation of force (grip force, tip pinch force, and key pinch force) can be achieved with dynamometer testing (kg), using either digital, pneumatic, mechanic, or hydraulic devices [20]. In a study from Dodds et al. peak median grip force is described as 51 kg for males and 31 kg for females [21]. Not only overall grip strength but also tip pinch and key pinch forces are highly dependent on age and gender [20–22]. These hand functions are impaired in CTS patients and get deteriorated even more through CTR [23].

This study surveys possible clinical predictors of post-operative loss of overall hand grip, tip pinch, and key pinch force in 42 CTS subjects which underwent open carpal tunnel release. We believe greater grip, tip pinch, and key pinch strength in patients prior to carpal tunnel release will result in greater loss of grip strength 3 and 6 months postoperatively. Finding predicting factors for loss of grip strength can provide realistic post-operative expectations for patients and surgeons as well as adapting patient management with therapeutic consequences.

Methods and material

We examined 42 subjects which underwent open carpal tunnel release at the Department of Plastic and Reconstructive Surgery, Rudolf Foundation Hospital, Vienna. All subjects were diagnosed CTS through electrophysiological nerve conduction velocity, clinical diagnostics tools like Hoffmann-Tinel and Phalen sign as well as evaluation of symptoms like pain and dysesthesia. In our study, subjects with recurrent CTS were not considered. In case of a bilateral CTS, only the first hand treated was analyzed. No further inclusion or exclusion criteria were applied. We performed dynamometer testing of hand grip, tip pinch, and key pinch strength prior, 3 and 6 months after open CTR (Preston pinch gauge and Jamar hand dynamometer). Subjects were seated in an upright position and samples were taken three times for each test, with 30 s recovery time in between (mean value counted).

Changes in these three main variables related to pre-operative grip, tip pinch, and key pinch forces as well as pain score (VAS-score adapted from 0 to 100) were analyzed for significant results (t test, Pearson and Spearman correlations, descriptive statistics; two-tailed $p = .05$).

This study was approved by the local ethics committee (Ethics Committee of Vienna [Ethikkommission der Stadt Wien] (EK-17-139-VK)).

Results

Our population consisted of 42 subjects with CTS syndrome verified by clinical symptoms and nerve conduction velocity (mean distal motor latency was 6.9 ± 2.9 ms). Sixty-four percent were females and 36 % males with a mean age of 61.6 ± 14.2 years (mean age of male subjects was 63.0 and mean age of female subjects was 60.9 years). Thirty-eight percent of all subjects showed pre-operative signs of thenar atrophy.

Symptoms of pain (VAS Score 0–100) showed clear improvement with a significant reduction of 50.2% less pain 3 months after operation ($p = .0002$). Eighty-eight percent showed a positive Hoffmann-Tinel sign and 93 % positive Phalen sign pre-operative.

At 3-month post-CTR, overall hand grip force decreased significantly by 11.7 % ($p = .006$), whereas key pinch and tip pinch only decreased by 5.6 and 3.5 % ($p < .0004$). At 6-month post-CTR our subjects showed, compared to pre-operative level, there is an increase of overall grip force to 94.6 % ($p = .242$) and an improvement of tip pinch to even 107 % ($p = .169$), and key pinch to 102 % ($p = .675$) (Fig. 1).

Further investigation showed that subjects with a strong grip prior to the operation seem to lose more strength 3 and 6 months after operation than subjects with average strength results (3 months: Spearman correlation −.522; $p = .000$; Pearson correlation −.552; $p = .000$; 6 months: Spearman correlation: −.569; $p = .000$, Pearson correlation −.575; $p = .000$; all results significant at $p = .01$) (Fig. 2).

Key pinch and tip pinch showed similar results with high force subjects losing more strength at 3 and 6 months post-CTR. Men had more loss of grip force at 3 ($p = .02$) and 6 ($p = .07$) months because they also showed 99% higher grip forces than females pre-operatively (mean grip force of 38.1 ± 12.6 kg and 19.0 ± 7.6 kg, $p = .0003$), therefore losing more grip force through CTR. In contrast to gender, age did not show any correlation with loss or gain of grip force 3 and 6 months post-OP.

Interestingly, no significant correlation could be shown between pre-operative VAS score and loss or gain of key pinch, tip pinch, or overall hand grip force.

Discussion

This study showed that subjects with strong grip forces are at risk for a prolonged period of weakness after TCL release. At 3 and 6 months post-operative, they had significant more loss of grip force than patients with smaller pre-operative grip strength. In most patients, compared to normative data, pre-operative grip force is already impaired by pain or even nerve injury. Considering gender and age, our subjects showed pre-operative reduced hand grip forces compared with normative data from healthy subjects at their peak median grip force (men −25.4%; females −38.6%) [21].

By TCL sectioning, with a decrease in pressure in the carpal tunnel, symptoms of pain and hypesthesia resolve, but grip force gets deteriorated even more.

Interestingly, no significant correlation could be found between pre-operative VAS score and loss or gain in grip force post-TCL release. Subjects with high VAS pain score pre-operative, although claiming excellent pain relief results, showed only minor increases in hand grip, tip pinch, and key pinch force, though the authors thought, pain relief (50.2 % pain reduction, $p = .0002$) should have increased their hand functions by greater proportion. At 6 months post-TCL sectioning, overall hand grip force was still decreased by 5.4 %. While Netscher et al., Gellman et al., and Bednarski et al. reported recovery to pre-operative grip strength at 3 months post-operative, our subjects showed less quick recovery from initial post-operative loss of grip force [8, 9, 19]. In our cohort, the point of breakthrough for exceeding pre-operative grip force strength might occur later than usually 3-month post-operative. Only Olsen et al. showed similar results with a break through point of 25 weeks post-CTR [18]. Possible explanation is the slightly higher age of diagnosis than the normative peak incidence around 55 years [24]. At mean age of 61.4 years, age-related diseases like diabetes, high blood pressure, or rheumatism might slow down the recovery process. Of our subjects, 40.3 % showed signs of high blood pressure, 11.9 % had diagnosis of rheumatism, and 14.3 % had a diabetes type II (insulin dependent and non-insulin dependent). Subjects with high blood pressure, diabetes, or rheumatism showed a tendency towards higher loss of grip force (non-significant) after 3 and 6 month post-CTR than healthier subjects. Furthermore, duration of symptoms until surgery (mean of 34.5 months) may also be longer lasting than in other cohorts. Knowledge about these influencing factors through survey of medical history can be incorporated into the prognosis of recovery of each patient.

While hand grip force was still decreased after 6 months, tip pinch, and key pinch forces could improve. The authors believe that sectioning of the TCL

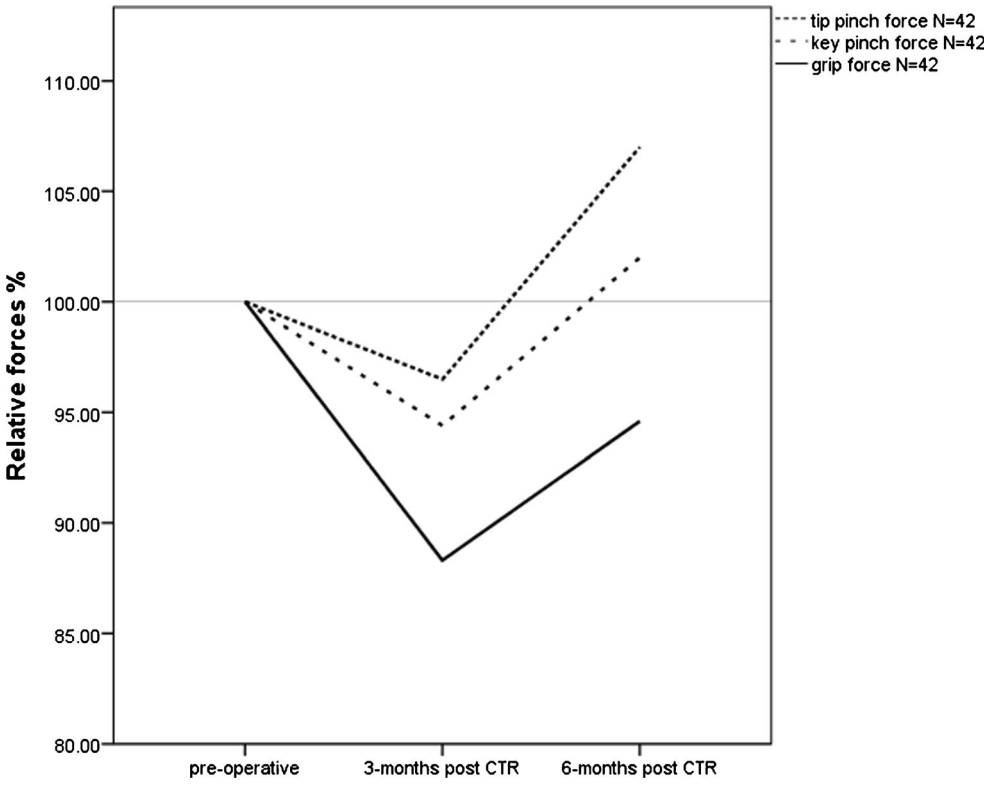

Fig. 1 Loss and regain of overall grip, tip-pinch, and key-pinch force after CTR at 3 and 6 months post-operative

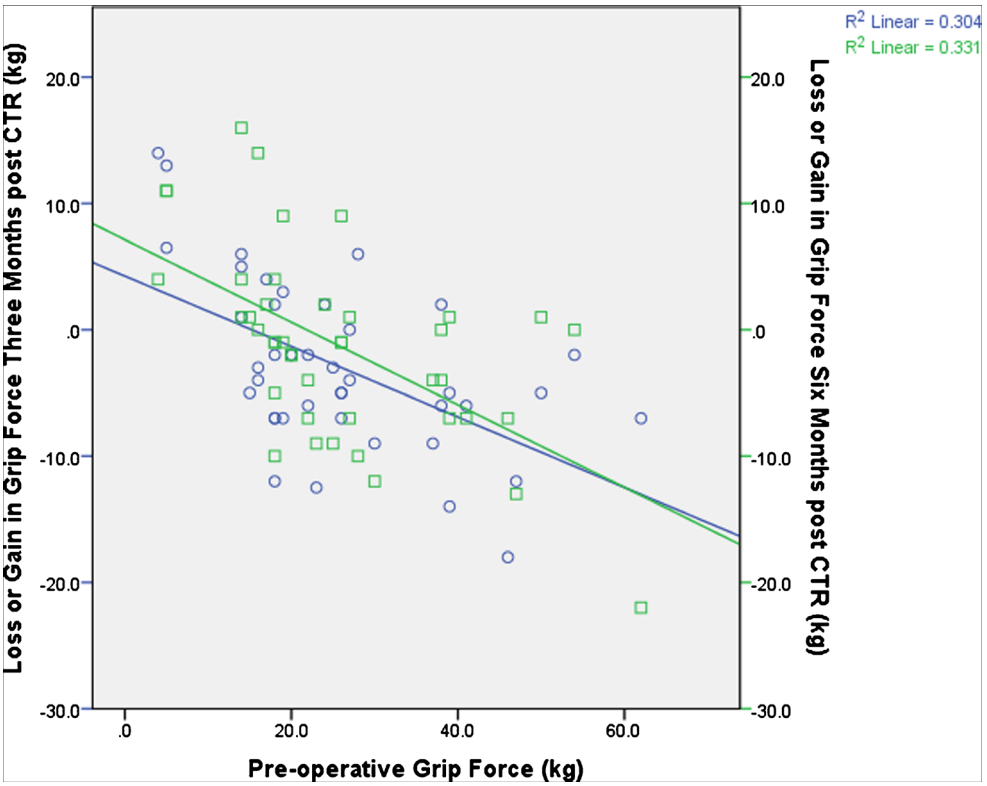

Fig. 2 Correlation between pre-operative grip force and loss of grip force at 3 (blue circles) and 6 (green squares) months post-CTR

causes higher function impairment of the long flexor tendons than of the intrinsic thenar and hypothenar muscles, therefore, recovering much quicker [7, 15].

Though dynamometer testing is an easy method requiring no experience and little time for evaluation, it is not part of standard pre-operative testing. Nevertheless, rough classification of grip strength can be done at the point of first handshake and examination.

Because CTR is an excellent method for symptom relief, conservative treatment for CTS patients without signs of nerve injury like thenar muscle atrophy is losing its domain as first line therapy. Especially patients with strong grip forces, who are at risk to suffer from a prolonged recovery, could, instead of early surgical transversal carpal ligament release, profit from enrolling into an extended conservative therapy (immobilization and anti-inflammatory medication). Additionally, patients undergoing CTR at risk for prolonged weakness after surgery (male subjects with high pre-operative grip forces) could enroll into an intensive post-operative occupational therapy with focus on grip force training to improve their recovery.

Further knowledge about predictors of open carpal tunnel release outcome can provide realistic post-operative expectations to assure a satisfied patient and surgeon.

Compliance with ethical standards

Funding This study did not receive any funding.

Conflict of interest Albert L. Niepel, Dirk Hellekes, Fuat Sokullu, Lara Steinkellner, and Fercan Kömürcü declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. /EK-17-148-0817, Ethics Committee of Vienna (Ethikkommission der Stadt Wien; Thomas-Klestil-Platz 8/2, TownTown, 1030 Vienna, Austria).

Informed consent was obtained from all individual participants included in the study.

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