Manual Therapy Versus Surgery for Carpal Tunnel Syndrome: 4-Year Follow-Up From a Randomized Controlled Trial

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Objective. No study to our knowledge has investigated the effects longer than 1 year of manual therapy in carpal tunnel syndrome (CTS). The purpose of this study was to investigate the effects of manual therapy versus surgery at 4-year follow-up and to compare the post-study surgery rate in CTS.

Methods. This randomized controlled trial was conducted in a tertiary public hospital and included 120 women with CTS who were randomly allocated to manual therapy or surgery. The participants received 3 sessions of physical therapy, including desensitization maneuvers of the central nervous system or carpal tunnel release combined with a tendon/nerve gliding exercise program at home. Primary outcome was pain intensity (mean and the worst pain). Secondary outcomes included functional status, symptom severity, and self-perceived improvement measured using a global rating of change scale. Outcomes for this analysis were assessed at baseline, 1 year, and 4 years. The rate of surgical intervention received by each group was assessed throughout the study.

Results. At 4 years, 97 (81%) women completed the study. Between-group changes for all outcomes were not significantly different at 1 year (mean pain: mean difference [MD] = −0.3, 95% CI = −0.9 to 0.3; worst pain: MD = −1.2, 95% CI = −3.6 to 1.2; function: MD = −0.1, 95% CI = −0.4 to 0.2; symptom severity: MD = −0.1, 95% CI = −0.3 to 0.1) and 4 years (mean pain: MD = 0.1, 95% CI = −0.2 to 0.4; worst pain: MD = 0.2, 95% CI = −0.8 to 1.2; function: MD = 0.1, 95% CI = −0.1 to 0.3; symptom severity: MD = 0.2, 95% CI = −0.2 to 0.6). Self-perceived improvement was also similar in both groups. No between-group differences (15% physical therapy vs 13% surgery) in surgery rate were observed during the 4 years.

Conclusions. In the long term, manual therapy, including desensitization maneuvers of the central nervous system, resulted in similar outcomes and similar surgery rates compared with surgery in women with CTS. Both interventions were combined with a tendon/nerve gliding exercise program at home.

Impact. This is the first study to our knowledge to report clinical outcomes and surgical rates during a 4-year follow-up and will inform decisions regarding surgical versus conservative management of CTS.

Lay summary. Women with CTS may receive similar benefit from a more conservative treatment—manual therapy—as they would from surgery.

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Carpal tunnel syndrome (CTS) is considered the most common entrapment neuropathy of the upper extremity. The estimated incidence of CTS in the United States has been reported to be 542 per 100,000 in women.[1] Its prevalence rate ranges from 6.3% to 11.7%, depending on the definition of cases.[2] Since CTS affects middle-age active workers, it is associated with substantial health care costs and economic burden. For instance, the overall annual cost associated with CTS in the United States exceeds $2 billion.[3]

Conservative and surgical approaches are the therapeutic strategies most commonly applied for the management of CTS. Current guidelines recommend different interventions, such as orthoses, exercise, and manual therapy[4,5]; however, no consensus exists as to which option is more effective. In fact, surgery continues to be the treatment approach most commonly used for CTS,[6] although differences with conservative management are relatively smaller than expected.[7,8] Similarly, several trials investigating cost-effectiveness of conservative versus surgical approaches have found similar health care costs for both treatments, although the incremental cost-utility ratio is slightly favorable for surgery due to better outcomes in the surgery groups.[9,10]

It is important to note that most conservative treatments used for CTS, such as splinting, laser, and steroid injections, are mainly based on local approaches over the wrist. Fernández-de-las-Peñas et al have conducted a randomized controlled trial investigating the effects of an approach consisting of manual therapies including desensitization maneuvers of the central nervous system versus surgery in women with CTS and observed that this manual therapy approach obtained better short-term and similar long-term effects on pain intensity and related-function than surgery.[11] Similarly, a posterior economic analysis of the same trial showed that manual therapy was equally effective, but less costly, compared with surgery for CTS.[12] This randomized controlled trial provides promising results for the management of CTS, but long-term follow-up is clearly needed.

A review of the literature concluded that most studies on CTS only include a 1-year follow-up period.[13] Additionally, the same review also observed that, although surgery reported positive long-term results, the recurrence rate ranges from 5% to 57%.[13] Tang et al reported that individuals with bilateral severe CTS who received bilateral surgery exhibited positive results 9 years after the surgical procedure.[14] However, this was a prospective case series including individuals with severe bilateral CTS, which does not represent the general population of CTS cases. The recent systematic review conducted by Burton et al observed that most CTS patients (23%–89%) receiving conservative local treatments experienced negative outcomes at 3 years and that surgery rates after initial conservative management were as high as 60%.[15]

Therefore, the objectives of the current analysis were to investigate the 4-year effects of a manual therapy approach for CTS compared with carpal tunnel release surgery and to determine the recurrence rate of post-treatment carpal tunnel release surgery in the same cohort of women with CTS.[11]

Methods

Study Design

This study was a continuation of a randomized controlled trial with a 4-year evaluation end point,[11] performed in a general hospital in Spain, to evaluate the long-term effects of manual therapy including desensitization maneuvers targeting the central nervous system and compared with surgery in women with CTS. Full details of the trial, participants, interventions, and results of the outcomes at short- and mid-term follow-up periods are reported elsewhere.[11] The study was approved by the Hospital Universitario Fundación Alcorcón (HUFA) Institutional Review Board (PI01223-HUFA12/14), and the trial was prospectively registered (ClinicalTrials.gov: NCT01789645).

Participants

As previously described, women with clinical and electrophysiological findings of CTS were recruited from a local regional hospital in Spain.[11] Participants had to exhibit symptoms (eg, pain or paresthesia in the median nerve distribution), clinical signs (eg, Tinel/Phalen sign), and electrodiagnostic deficits of median nerve conduction according to the guidelines of the American Association of Electrodiagnosis, the American Academy of Neurology, and the American Physical Medicine and Rehabilitation Academy.[16] The 9 exclusion criteria were as follows: sensory/motor deficit in the ulnar or radial nerve; older than 65 years; previous hand surgery or steroid injection treatment; multiple diagnoses in the upper extremity; cervical and/or upper extremity trauma; any systemic disease causing CTS (eg, diabetes mellitus, thyroid disease); comorbid musculoskeletal pain conditions (eg, rheumatoid arthritis and/or fibromyalgia); pregnancy; and presence of depressive symptoms (Beck Depression Inventory-II score of >8 points). Participants signed an informed consent form prior to their inclusion.

Randomization and Masking

Patients were randomly assigned to receive manual therapy or surgery as previously described.[11] Briefly, concealed allocation was performed by using a computer-generated randomized table of numbers created by an external statistician not involved in other parts of the study. Individual and sequentially numbered index cards with the random assignment were prepared, folded, and placed in sealed opaque envelopes. A different researcher opened the envelope and proceeded with treatment allocation.

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Due to the nature of the interventions (surgery vs manual therapy), it was not possible to mask therapists or patients. However, the clinician who collected follow-up data was masked with regard to group allocation.

Interventions

Participants allocated to the manual therapy group received 3 treatment sessions, once per week, of manual therapy consisting of desensitization maneuvers of the central nervous system for a duration of 30 minutes.[11] Briefly, the desensitization maneuvers included soft tissue mobilization techniques targeting anatomical-related sites of potential entrapment of the median nerve (eg, scalene, pectoralis minor, biceps brachii, pronator teres muscle), lateral glide mobilization of the cervical spine, and tendon/nerve gliding exercises.[11] As previously described, interfaces were examined by the clinician and then treated according to the following clinical findings: pain on palpation and reproduction of any of the patient's symptoms.[11] Manual therapy approaches included in the trial are described in Appendix 1. Patients also received an educational session on how to perform tendon and nerve gliding exercises as homework if necessary.

Patients randomly allocated to the surgery group underwent open or endoscopic release of the carpal tunnel. Since no evidence supports 1 particular surgical procedure, surgery was based on the preferences of surgeons and patients.[17]Additionally, patients allocated to this group received the same educational session for performing tendon/nerve gliding exercises as the manual therapy group.[11] The educational session and homework included a tendon/nerve gliding exercise, which was the same in both groups and is described in Appendix 2.

Outcomes

The primary outcome was the intensity of hand pain.[11] An 11-point numerical pain rating scale (0 = no pain and 10 = maximum pain) was used to determine the patients' current level of hand pain and the worst level of pain experienced in the preceding week. Since no minimal clinically important difference exists for hand pain, a change of 2 points or a 30% decrease in baseline score was considered as clinically relevant.[18]

Secondary outcomes included functional status and symptom severity subscales of the Boston Carpal Tunnel Questionnaire[19] and self-perceived improvement with the Global Rating of Change. Higher scores on the Boston Carpal Tunnel Questionnaire indicate worse function and greater symptom severity. The minimal clinically important differences have been determined to be 0.74 points for the function subscale and 1.14 points for the symptom severity subscale.[20] Within the Global Rating of Change, scores of +4 and +5 are indicative of moderate changes in patient's status, whereas scores of +6 and +7 indicate large changes. In the original trial, outcomes were assessed at baseline and 1, 3, and 6 months and 1 year after treatment.[11] The current analysis reports outcomes at baseline and 1 and 4 years after treatment. We also defined a successful outcome when at least 1 of the following items, based on their respective minimal clinically important differences, was present: a reduction of $\geq$0.74 point or 1.14 points, respectively, on the Boston Carpal Tunnel Questionnaire function or symptom severity subscale[20] or a decrease of $\geq$2 points or a 30% reduction from baseline scores in the intensity of hand pain.[18]

In the current follow-up analysis, we also assessed the rate of surgical interventions (first in the manual therapy group or repeat surgery in the surgical group) during all follow-up periods. Finally, participants were also asked if they received other conservative treatments during the 4-year follow-up period.

Data Analysis

Sample size was initially calculated for detecting clinical changes in the intensity of hand pain at 1-year follow-up.[11] Statistical analysis was performed using SPSS software (Version 22.0, SPSS, Chicago, IL, USA) conducted according to the intention-to-treat principle for patients in the group to which they were originally allocated. Missing data were estimated using multiple imputations. Since this long-term follow-up analysis is non-inferiority testing, a per-protocol analysis was also conducted (data not shown) to determine convergent findings with both approaches (intention-to-treat vs per-protocol). Descriptive statistics were used to describe participants' features at baseline in both groups and can be found in the original report of the trial.[11] Our evaluation included mixed-model repeated-measured analyses of covariance with time as the within-subject factor and group as the between-subject factor and adjusted for baseline scores for detecting between-group differences in all outcomes at 1- and 4-year follow-up periods. To enable comparison of effect sizes, standardized mean differences (MDs) were calculated by dividing the between-group difference mean score by the pooled SD, if significant differences are observed. We also used chi-square tests to compare self-perceived improvement, as assessed with the Global Rating of Change, and success rates at 1- and 4-year follow-up periods in both groups. Finally, chi-square tests were also used for detecting between-group differences within surgical intervention rate and the use of other conservative treatments during the 4-year follow-up period.

Role of the Funding Source

The sponsor had no role in the design, collection, management, analysis, or interpretation of the data, draft, review, or approval of the manuscript or its content. The authors were responsible for the decision to submit the manuscript for publication, and the sponsor did not participate in this decision.

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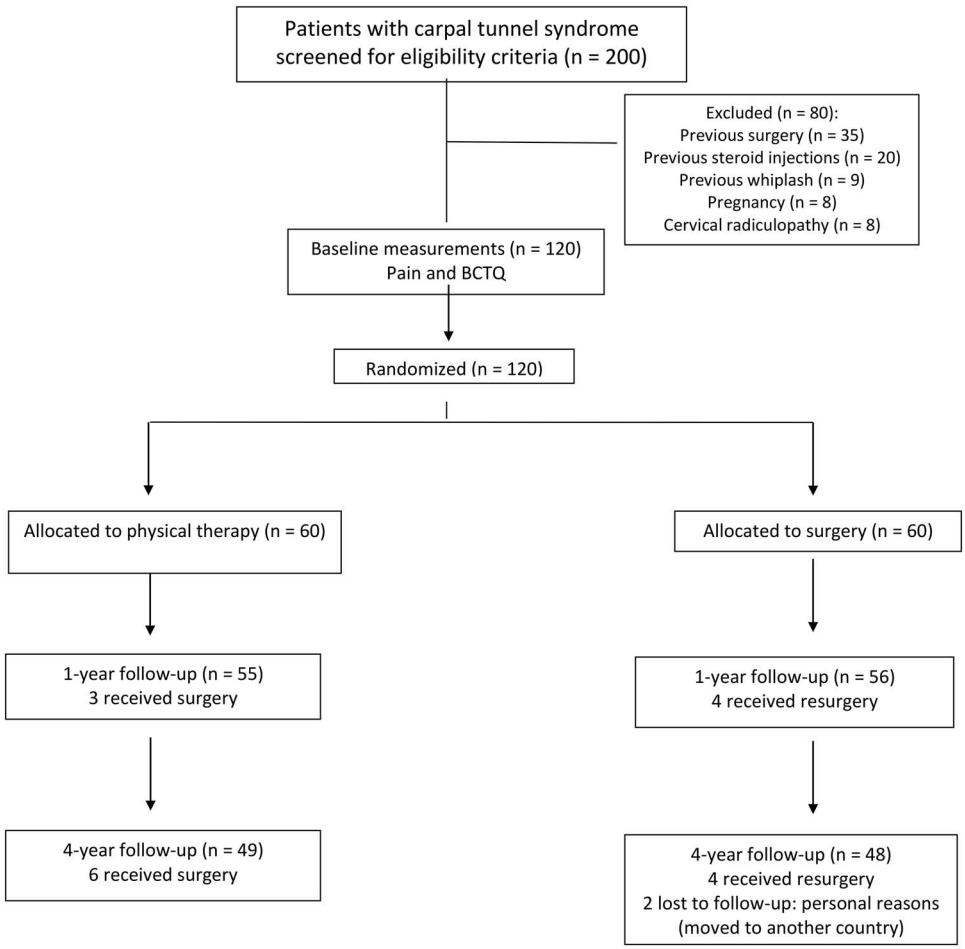

Figure 1.
Flow diagram of participants from randomization to 4-year follow-up by intention-to-treat (ITT).

Patient and Public Involvement

Patients were not involved in the study design, but they actively participated in the trial during the intervention period because they were asked for a home exercise program, if needed.

Results

Participants

From a total of 120 patients initially included in the original trial and randomly allocated into manual therapy (n = 60) or surgery (n = 60), 111 (92.5%) completed the 1-year[11] and 97 (81%) completed the 4-year follow-up main analysis. The flow diagram of participants during the trial leading to the 4-year follow-up period is shown in Figure 1. As previously described, original baseline variables did not differ between the groups.[11] Similarly, baseline scores of the final sample (n = 97) included in the 4-year analysis did not significantly differ (Tab. 1). No significant differences (all *P*s > .439) were found on demographic or clinical baseline data between patients who completed the study (n = 97) and those who did not (n = 23).

Changes in Pain and Function

As previously reported,[11] patients receiving manual therapy exhibited higher decreases at 1 and 3 months in mean pain intensity and higher decreases at 1, 3, and 6 months in the worst pain intensity than those receiving surgery (Fig. 2). The main results of the current analysis revealed no significant (all *P*s > .2) between-group differences at 1 year (mean pain: MD = −0.3, 95% CI = −0.9 to 0.3; worst pain: MD = −1.2, 95% CI = −3.6 to 1.2; function: MD = −0.1, 95% CI = −0.4 to 0.2; symptom severity: MD = −0.1, 95% CI = −0.3 to 0.1) and 4 years (mean pain: MD = 0.1, 95% CI = −0.2 to 0.4; worst pain: MD = 0.2, 95% CI = −0.8 to 1.2; function: MD = 0.1, 95% CI = −0.1 to 0.3; symptom severity: MD = 0.2, 95% CI = −0.2 to 0.6). Table 2 shows baseline, 1-year, and 4-year data for pain and function outcomes.

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Table 1.
Baseline Characteristics by Treatment Assignment of the Sample Included at the 4-Year Follow-up[a]

Characteristic	Physical Therapy Group (n = 49)	Surgery Group (n = 48)
Age, y	47 (10)	48 (8)
Years with pain	3.6 (2.8)	3.9 (2.0)
Occupation[b]		
Work at home	25 (51)	24 (50)
Secretary/office	24 (49)	24 (50)
Unilateral/bilateral arm distribution[b]		
Unilateral symptoms, right side	6 (12)	8 (17)
Unilateral symptoms, left side	3 (6)	2 (4)
Bilateral symptoms	40 (82)	38 (79)
Severity[b]		
Minimal CTS	13 (26)	10 (21)
Moderate CTS	19 (39)	24 (50)
Severe CTS	17 (35)	14 (29)
Mean intensity of pain (NPRS score = 0–10)	4.8 (1.5)	4.9 (2.1)
Worst pain experienced last week (NPRS score = 0–10)	6.7 (1.7)	6.9 (2.0)
Functional status for CTS (BCTQ score = 1–5)	2.3 (0.5)	2.4 (0.6)
Severity status for CTS (BCTQ score = 1–5)	2.5 (0.7)	2.7 (0.7)
BDI-II (score = 0–21)	3.7 (2.6)	4.0 (2.3)

[a] Data are reported as mean (SD) unless otherwise indicated. BCTQ = Boston Carpal Tunnel Questionnaire; BDI-II = Beck Depression Inventory-II; CTS = carpal tunnel syndrome; NPRS = numerical pain rating scale.
[b] Data are reported as number (percentage) of participants.

Table 2.
Primary and Secondary Outcomes at Baseline, 1 Year, and 4 Years by Randomized Treatment Assignment[a]

Parameter	Outcome Group	Baseline	1 y	4 y
Mean level of hand pain (NPRS score = 0–10)	Physical therapy	4.8 (4.3–5.3)	1.4 (1.0–1.8)	2.3 (1.7–2.9)
	Surgery	4.9 (4.4–5.4)	1.7 (1.2–2.2)	2.2 (1.5–2.9)
Worst level of hand pain experienced in preceding week (NPRS score = 0–10)	Physical therapy	6.7 (6.1–7.3)	2.0 (1.2–2.8)	4.0 (3.3–4.7)
	Surgery	6.9 (6.3–7.5)	3.2 (2.5–3.9)	3.8 (3.0–4.6)
Function subscale of BCTQ (score = 1–5)	Physical therapy	2.3 (2.1–2.5)	1.5 (1.3–1.6)	1.5 (1.3–1.7)
	Surgery	2.4 (2.2–2.6)	1.6 (1.4–1.8)	1.4 (1.2–1.6)
Severity subscale of BCTQ (score = 1–5)	Physical therapy	2.5 (2.3–2.7)	1.5 (1.4–1.6)	1.7 (1.5–1.9)
	Surgery	2.7 (2.5–2.9)	1.6 (1.4–1.8)	1.5 (1.3–1.7)

[a] Data are expressed as mean (95% CI). BCTQ = Boston Carpal Tunnel Questionnaire; NPRS = numerical pain rating scale.

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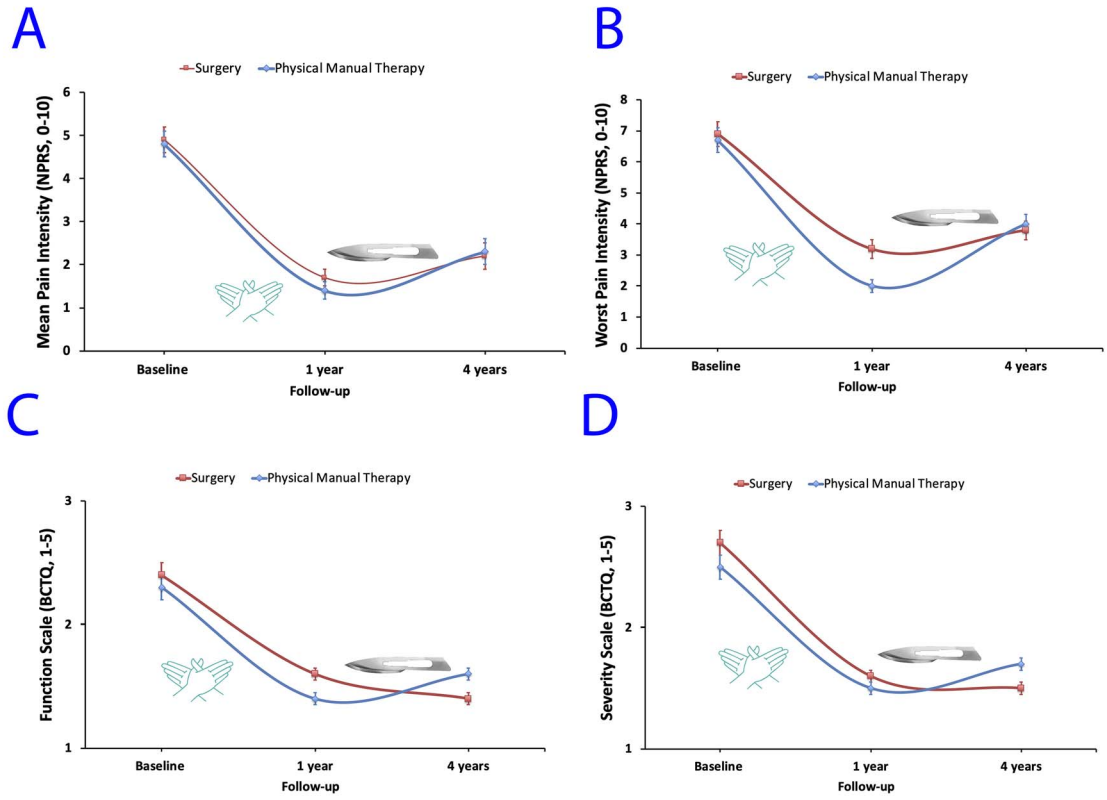

Figure 2.
Evolution of all outcomes (pain on the numerical pain rating scale [NPRS] [A and B] and Boston Carpal Tunnel Questionnaire [BCTQ] [C and D]) throughout the course of the study stratified by randomized treatment assignment. Data are means (SEs).

Self-Perception of Improvement

Manual therapy and surgical groups did not significantly differ on success criteria in the intention-to-treat analyses at 1 ($P > .264$) and 4 ($P > .288$) years (Tab. 3). Self-perceived improvement assessed with the Global Rating of Change was also similar at 1 ($P = .169$) and 4 ($P = .242$) years after treatment in both groups (Tab. 3).

Surgery Rate and Other Conservative Treatments

No significant between-group differences in surgery rate were found ($P = .448$) during the 4-year follow-up period. In patients originally allocated to the manual therapy group, 9 (15%) received surgery, 3 before the 1-year follow-up period, and the remaining 6 during the 4-year period. Similarly, in patients allocated to the surgery group, 4 received surgery or repeat surgery during the 1-year follow-up and another 4 during the 4-year follow-up (Fig. 1). No significant differences within the time frame from which patients received their first-time surgery (manual therapy group: 1.6 [SD = 1] years) or their repeat surgery (surgery group: 1.8 [SD = 0.7] years) intervention were observed.

No significant differences ($P = .270$) existed in the number of patients allocated to the manual therapy who seek and received other conservative intervention during the 4-year follow-up (n = 12, 24.5%) versus those allocated to the surgery group (n = 16, 33%). These participants reported that they have sporadically attended physical therapy for their pain.

Discussion

The current randomized controlled trial found that manual therapy consisting of manual therapies including desensitization maneuvers of the central nervous system and surgery combined with a tendon and nerve gliding exercise program at home resulted in similar outcomes on pain and function in women with CTS at 1- and 4-year follow-up periods. Similarly, self-perceived improvement, post-intervention surgical rate, and other conservative interventions received were also similar in both groups.

To our knowledge, this is the first randomized controlled trial investigating the effects of manual therapy in CTS at a follow-up of 4 years.[4,7,8,13] Our data indicate that both interventions seem to be equally effective long term since all outcomes demonstrated similar changes at 1 year and

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Table 3.
Follow-Up Self-Perceived Recovery and Successful Outcomes in Surgical and Manual Therapy Groups[a]

Parameter	1-y Follow-Up [11]		4-y Follow-Up	
	Physical Therapy Group (n = 55)	Surgery Group (n = 56)	Physical Therapy Group (n = 49)	Surgery Group (n = 48)
Self-perceived improvement on the Global Rating of Change (−7 to +7)				
Moderate changes				
+4	7 (13)	10 (18)	4 (8)	4 (8)
+5	15 (27)	12 (21)	5 (10)	5 (10.5)
Large changes				
+6	5 (9)	17 (30)	9 (18)	8 (16.5)
+7	12 (22)	13 (23)	19 (39)	16 (33)
Successful outcomes (≥0.6 point or ≥1.14 points on the BCTQ for function or severity, respectively, or ≥2 points on the NPRS or 30% improvement in pain intensity)[b]				
One criterion	44 (76)	50 (83)	31 (63)	32 (67)
All criteria	31 (53)	27 (45)	22 (45)	21 (44)

[a] Data are reported as number (percentage) of participants. BCTQ = Boston Carpal Tunnel Questionnaire; NPRS = numerical pain rating scale.
[b] For physical therapy at 1-year follow-up, n = 58; for surgery at 1-year follow-up, n = 60.

4 years. Nevertheless, changes in the manual therapy group on the worst pain experienced the previous week exhibited a potential trend for worsening (from 2.0 to 4.0 points) to a greater extent compared with the surgery group (from 3.2 to 3.8), although it was not significantly different and only occurred in this outcome. The clinical relevance of this trend should be investigated in the context of a 4-year follow-up period. An important finding was that only 15% of those women who received manual therapy required surgery 4 years after the intervention. This is contrary to previous findings suggesting a surgery rate of 60% after localized conservative treatment.[15] Current data may be related to a clinical reasoning underlying manual therapy used in this study. Previous studies examining the effectiveness of physical therapy versus surgery for CTS mainly used localized therapeutic approaches that solely target the wrist and/or hand, resulting in limited evidence.[4–10] These approaches are based on the traditional premise that CTS is considered as localized pathology just associated with a peripheral lesion at the carpal tunnel, but current evidence suggests that CTS is a complex disorder exhibiting sensitization mechanisms.[21,22] Therefore, the proposed manual therapy approach included soft tissue mobilizations and nerve/tendon gliding techniques directed at the entire upper extremity accordingly to current nociceptive theories on CTS.[23] Therefore, it seems that manual therapies including desensitization maneuvers of the central nervous system may be more effective than localized interventions targeting only the hand and/or the wrist in this population. Obviously, it is important to consider that both groups also received a tendon/nerve gliding exercise program as homework, which could also influence 1- and 4-year follow-up outcomes. Similarly, it is also difficult to determine the effects of the other conservative intervention used by patients during the 1- and 4-year follow-up periods; nevertheless, the use of other interventions was similar between groups and was sporadic.

Based on our results, the proposed conservative approach may be considered as a first-line treatment option for CTS before subsequently considering surgery. This proposal is in line with the fact that most patients typically prefer conservative management as the first therapeutic option because of the higher rate of complications associated with surgery. Nevertheless, there is evidence suggesting that outcomes are inferior if patients first receive conservative treatment instead of surgery.[24] Again, this assumption is based on an application of localized conservative treatments and not the current proposal based on nociceptive pain mechanisms. Current clinical guidelines propose the use of conservative treatments in mild to moderate, and sometimes severe, cases of CTS[4,5]; however, no consensus exists on which patients would better benefit from either conservative or surgical treatment. Therefore, identification of patients who will benefit from each intervention is needed.

The results of this randomized controlled trial should be considered according to the potential strengths and limitations. Strengths included the application of a manual therapy approach applying clinical reasoning based on current nociceptive theories of CTS and inclusion of different therapies (manual therapy vs surgery) in either treatment group, although both groups received the same

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tendon/nerve gliding exercise program as homework. Further, we included a 4-year follow-up. Nevertheless, it should be recognized that we had a 20% loss to follow-up, but this was similar in both groups. In fact, loss to follow-up for most participants was due to surgery within the manual therapy group or repeat surgery within the surgery group, which was one of the objectives of this 4-year follow-up analysis. In fact, the per-protocol analysis revealed the same findings where there was no difference between groups for any of the outcomes.

Among the limitations, multicenter studies controlling for site and therapist effects in subsequent trials might enhance the generalizability of our results. Similarly, the strict inclusion and exclusion criteria used in this study could limit the generalizability of these results. Second, patients and clinicians were not blinded with regard to the treatment intervention due to the nature of the treatments. Third, we did not consider the role of psychological variables, such as mood disorders or sleep disturbances. Additionally, we did not reassess provocative tests used in the physical examination, such as the Phalen or Tinel test, or electromyographic data at any follow-up period, which could also elucidate potential between-group differences. Fourth, patients allocated to the manual therapy group received 3 sessions based on the author clinical experience since no available data exist on the frequency and dose of therapy. We do not know if a greater number of sessions would reveal differences between interventions, as it has been observed with the application of corticosteroid injections.[25] Fifth, only women with CTS were included. In addition, compliance with home exercises was not monitored and, hence, the influence of this co-intervention on long-term outcomes is unknown at this stage.

This randomized controlled trial found that manual therapy consisting of desensitization maneuvers of the central nervous system and surgery combined with a tendon and nerve gliding exercise program as homework resulted in similar outcomes in women with CTS at 4 years. Similarly, self-perceived improvement, post-intervention surgical rate, and other conservative interventions received were also similar between groups. Manual therapy can be considered a first-line treatment option for CTS as it is equally effective of surgery.

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Ethics Approval

This study was approved by the Hospital Universitario Fundación Alcorcón Institutional Review Board (PI01223-HUFA12/14).

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Clinical Trial Review Registration

This trial was prospectively registered at ClinicalTrials.gov (NCT 01789645).

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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Appendix 1. Description of Manual Therapy Interventions

Technique: Manual compression of the scalene muscles.

Description of Technique: The patient lies supine with the cervical spine in a neutral position. The therapist applied a manual pain-free compression over the anterior/middle scalene muscle for 1 minute (Suppl. Fig. 1).

Technique: Manual mobilization of the costoclavicular space.

Description of Technique: The patient was side-lying with the affected extremity up. The second and third fingers of the caudal hand of the therapist contacted the anterior part of the axilla, behind the pectoralis minor tendon. The thumb of the cranial hand contacted the superior part of the clavicle bone. The therapist applied a transverse mobilization for 1 minute (Suppl. Fig. 2).

Technique: Manual compression of the pectoralis minor muscle.

Description of Technique: The patient is side-lying with the affected extremity up with the shoulder abducted 90°. The therapist places the caudal hand over the rib cage behind the pectoralis minor muscle, and the cranial hand grasps the elbow of the patient. The therapist maintains a pain-free compression over the pectoralis minor muscle for 3 minutes (Suppl. Fig. 3).

Technique: Longitudinal stroke of the biceps muscle.

Description of Technique: The patient lies supine with the upper extremity relaxed, the elbow is extended, and the forearm supinated. The therapist applies 5 longitudinal strokes over the biceps brachii muscle from a cranial to caudal direction (Suppl. Fig. 4).

Technique: Manual mobilization of the bicipital aponeurosis.

Description of Technique: The patient lies supine with the shoulder abducted and the elbow flexed to 90°. The therapist grasps the bicipital aponeurosis (lacertus fibrosus) of the biceps brachii muscle with one hand. The other hand grasps the wrist of the patient and then rhythmically extends the elbow of the patient 10 times (Suppl. Fig. 5).

Technique: Manual mobilization of the pronator teres muscle.

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Description of Technique: The patient lies supine with an extended elbow and the forearm in neutral. The cranial hand of the therapist palpates the pronator teres muscle. The caudal hand grasps the wrist. The therapist rhythmically pronates the forearm of the patient 10 times during this technique (Suppl. Fig. 6).

Technique: Manual mobilization of the transverse carpal ligament.

Description of Technique: The patient lies supine with the upper extremity relaxed. The therapist grasps the wrist of the patient with the thumbs on the region of the carpal tunnel. The remaining flexed index fingers are placed over the back of the wrist. The therapist rhythmically provides an extension movement of the wrist 10 times (Suppl. Fig. 7).

Technique: Manual stretching of the palmar aponeurosis.

Description of Technique: The patient lies supine with the elbow flexed to 90°. The therapist grasps all the fingers by opening the hand of the patient. The therapist induces an opening motion of the fingers with slight wrist extension for 10 repetitions (Suppl. Fig. 8).

Technique: Manual mobilization of lateral glide of the cervical spine.

Description of Technique: The patient lies supine with the cervical spine in neutral. The caudal hand of the therapist supports the patient's mid-cervical spine at the C5/C6 level. The cranial hand of the therapist is placed on the contra-lateral side of the neck of the patient. A lateral glide of the cervical spine was applied as a translational movement of the neck away from the symptomatic side. The intervention was completed over 5 minutes in 2 sets of 2 minutes each with 1 minute rest between sets (Suppl. Fig. 9).

Technique: Tendon/nerve gliding exercise targeting the median nerve.

Description of Technique: The patient was supine with the cervical spine in neutral. This tendon/nerve gliding exercise was performed by alternating the following positions of the upper extremity: 1, shoulder girdle depression, glenohumeral abduction and lateral rotation, forearm supinated, elbow flexed, and wrist/thumb/and fingers extension (Suppl. Fig. 10); 2, shoulder girdle depression, glenohumeral abduction/lateral rotation, forearm supinated, elbow extended, and wrist/thumb/fingers flexion (Suppl. Fig. 11). The exercise was completed in 2 sets of 10 repetitions min each with 1 minute rest between sets.

Appendix 2. Guideline for Tendon/Nerve Gliding Exercises for Home

All participants received an educational session where the therapist explained the effects and potential benefits of tendon/nerve gliding exercises for their pain condition on how performing the exercises as homework, if needed. The therapist explained the following tendon/nerve gliding exercises:

Exercise 1: The patient places the affected upper extremity in elbow flexion and wrist extension for 30 seconds (Suppl. Fig. 12).

Exercise 2: The patient places the affected upper extremity in elbow extension and wrist in neutral or in flexion for 30 seconds (Suppl. Fig. 13).

Exercise 3: If possible, the patient places the affected upper extremity with both elbow and wrist extension for 30 seconds (Suppl. Fig. 14).

Exercise 4: The patient was prescribed a "slider" technique targeted the median nerve. The patient alternates the following sequence: 1, glenohumeral abduction and external rotation, forearm supinated, elbow flexed, and wrist/thumb/and fingers extension with the cervical spine in neutral position (Suppl. Fig. 15); 2, from the same position the patient increases elbow flexion and at the same time the cervical spine goes into contra-lateral side-bending (Suppl. Fig. 16); 3, from the same position the patient puts elbow extension and at the same time the cervical spine goes into homo-lateral side-bending towards the symptomatic side (Suppl. Fig. 17). The sequence was repeated 5 times, if conducted.

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