EDITOR'S CHOICE

Multiple Compression Syndromes of the Same Upper Extremity: Prevalence, Risk Factors, and Treatment Outcomes of Concomitant Treatment

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Purpose Multiple nerve compression syndromes can co-occur. Little is known about this coexistence, especially about risk factors and surgical outcomes. Therefore, this study aimed to describe the prevalence of multiple nerve compression syndromes in the same arm in a surgical cohort and determine risk factors. Additionally, the surgical outcomes of concomitant treatment were studied.

Methods The prevalence of surgically treated multiple nerve compression syndromes within one year was assessed using a review of patients' electronic records. Patient characteristics, comorbidities, and baseline scores of the Boston Carpal Tunnel Questionnaire were considered as risk factors. To determine the treatment outcomes of simultaneous treatment, patients who underwent concomitant carpal tunnel release (CTR) and cubital tunnel release (CubTR) were selected. The treatment outcomes were Boston Carpal Tunnel Questionnaire scores at intake and at 3 and 6 months after the surgery, satisfaction 6 months after the surgery, and return to work within the first year.

Results A total of 7,867 patients underwent at least one nerve decompression between 2011 and 2021. Of these patients, 2.9% underwent multiple decompressions for the same upper extremity within one year. The risk factors for this were severe symptoms, younger age, and smoking. Furthermore, the treatment outcomes of concomitant CTR and CubTR did not differ from those of CubTR alone. The median time to return to work after concomitant treatment was 6 weeks. Patients who underwent CTR or CubTR alone returned to work after 4 weeks.

Conclusions Approximately 3% of the patients who underwent surgical treatment for nerve compression syndrome underwent decompression for another nerve within 1 year. Patients who report severe symptoms at intake, are younger, or smoke are at a greater risk. Patients with carpal and cubital tunnel syndrome may benefit from simultaneous decompression. The

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Received for publication June 20, 2022; accepted in revised form January 25, 2023.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/23/4805-0008
https://doi.org/10.1016/j.jhsa.2023.01.024

time to return to work may be less than if they underwent decompressions in separate procedures, whereas their surgical outcomes are comparable with those of CubTR alone. *(J Hand Surg Am. 2023;48(5):479−488.*

Type of study/level of evidence Therapeutic IV.

Key words Carpal tunnel syndrome, cubital tunnel syndrome, patient-reported outcome measurements, peripheral nerve decompressions, risk factors.

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THE MOST COMMON UPPER-EXTREMITY nerve compression is carpal tunnel syndrome (CTS), followed by cubital tunnel syndrome (CubTs).[1−5] Other less common nerve compressions occur at the Guyon canal and radial tunnel and include pronator teres syndrome and lacertus syndrome.[6]

If the same nerve is compressed at two different levels, the term "double crush syndrome" is used.[7−9] Most of these cases involve proximal compression at the root or brachial plexus and distal compression along one of the primary peripheral nerves.[8,10,11]

In addition to double crush syndrome, patients can experience compression syndromes of different nerves of the same arm.[12] This is manifested when decompression of a single nerve is performed, the patient is not relieved of their symptoms, and treatment results are unsatisfactory because of the coexistence of another nerve compression.[13−17] The literature on the etiology of multiple compression syndromes is scarce.[18−21]

Some risk factors associated with multiple compression syndromes have been described. For example, Zhang et al[19] reported that patients who underwent concomitant carpal tunnel release (CTR) and cubital tunnel release (CubTR) were 2.5 times more likely to have diabetes than those who underwent CTR or CubTR alone.

Moreover, little is known about whether patients treated surgically for multiple compression syndromes during the same session achieve comparable treatment results as those who undergo single nerve decompression.[12]

Therefore, the aim of our study was to assess the prevalence of multiple nerve compression syndromes in a surgical cohort, determine potential risk factors for belonging to this cohort, and analyze the surgical outcomes of concomitant decompression for multiple compression syndromes.

METHODS

Study design

A cohort study was performed using data from a consortium of 18 hand surgery practice sites in the Netherlands. All patients who underwent at least one nerve decompression between 2011 and 2021 were included. The records of these patients were examined to determine which procedure the patients underwent and whether they were treated for another nerve compression syndrome in the same arm concomitantly or subsequently within 1 year. Additional inclusion criteria were patients aged 18 years or older, signed informed consent for the use of their data for research purposes, and available patient characteristics at intake. Patients were excluded if their second surgery within 1 year was a revision surgery or decompression of a nerve of the contralateral arm.

The diagnoses of nerve compression syndromes were based on clinical presentation, with EMG performed as indicated by the Dutch Society for Neurology guidelines.[22,23] Subsequently, a standardized protocol was used for follow-up.

From the initial cohort, patients who underwent concomitant CTR and CubTR were included for the evaluation of treatment outcomes because they were expected to be the largest samples. Treatment outcomes were compared among patients who underwent concomitant CTR and CubTR, those who underwent CTR alone, and those who underwent CubTR alone. Patients were excluded if there were no patient-reported outcome measurements (PROMs) at intake or 6 months after surgery. In addition, patients who underwent decompressions in multiple procedures within 1 year were excluded. The local institutional review board approved the study, and all patients provided written informed consent allowing their data to be used for research purposes.

Measurements

The prevalence of multiple nerve compression syndromes treated surgically within 1 year was measured in percentages. In this subgroup, the type and combination of decompressions were examined.

The potential risk factors for having multiple sites of nerve compression surgically treated within 1 year were analyzed. These included age, sex, diabetes, body mass index, current smoking status, duration of symptoms in weeks, severity of symptoms based on the Boston Carpal Tunnel Questionnaire (BCTQ) at intake, intensity of occupation, disorders of the nervous system, medical history of cardiovascular disease, and rheumatic diseases. This information was derived from questionnaires that were filled at intake. A hand therapist determined the intensity of occupation based on the following three categories: light (eg, office job), medium (eg, cleaning), and heavy (eg, construction work).

The treatment outcomes in patients who underwent concomitant decompressions compared with those in patients who underwent a single decompression were determined. These outcomes were measured using PROMs at intake and 6 months after surgery. These PROMs comprise BCTQ scores,[24] satisfaction with treatment results,[25] and return-to-work (RTW) data. The BCTQ is a validated questionnaire divided into two domains: Symptom Severity Scale (SSS) and Functional Status Scale (FSS).[26] The International Consortium for Health Outcomes Measurement Hand and Wrist Working Group has suggested the BCTQ as an appropriate PROM for follow-up of patients with nerve compression syndromes.[27]

To determine satisfaction with treatment results, a validated questionnaire was used to score the patients' satisfaction after surgery based on five choices: excellent, good, fair, moderate, and poor.[25]

Moreover, patient-reported RTW data were analyzed. The patients were asked to complete an online questionnaire on RTW at 6 weeks and 3, 6, and 12 months after nerve decompression. Return to work was defined as the first time a patient reported returning to performing original work for a minimum of 50% of the original hours per week. The time of RTW was measured in weeks using a previously reported method.[28]

Sample size

To determine whether this study was sufficiently powered for analysis, *post hoc* power calculations were performed. The number of available patients was used to calculate the effect size that could be detected using a conventional power of 80% and a significance level of 0.05 (Appendix A, available online on the *Journal*'s website at www.jhandsurg.org).[29]

Statistical analysis

Bootstrap analysis was used to determine the 95% confidence interval (CI) for the prevalence of patients with multiple nerve compression syndromes in a surgical cohort. Bootstrap analysis is an appropriate way to calculate the CI of which the estimate is based on data without making unreasonable assumptions.[30]

A multivariable logistic regression model was used to investigate the independent contribution of potential risk factors for having multiple nerve compressions surgically treated within 1 year, including all nerve compression syndromes. The outcome of this model is a dichotomous variable, wherein 1 represents having multiple nerve compressions and undergoing surgical treatment within one year. In addition, intraclass correlation coefficient (ICC) calculations were used to examine whether there was clustering of patients with specific risk factors at certain practice sites.

To compare treatment outcomes between patients who underwent concomitant CTR and CubTR and those who underwent CTR or CubTR alone, *t* tests were used. In addition, ICC calculations were performed to determine whether there was clustering of surgical decision-making, based on the SSS at intake, by surgeons. Moreover, subgroup analyses were performed using matched groups based on propensity score matching.[31,32] Propensity score matching permits comparison of patients by balancing covariates and accounting for confounding effects from selected variables. The patients were matched by age, sex, occupational status, duration of symptoms, severity of symptoms, and functional status of the BCTQ at intake. Patients who underwent concomitant CubTR and CTR were matched on a 1:2 basis with those who underwent CTR alone and on a 1:1 basis with those who underwent CubTR alone. The treatment outcomes in these matched groups were analyzed using *t* tests. Additional surgical information was reported.

The log-rank test was used to evaluate whether the duration of RTW differed among patients who underwent concomitant treatment, those who underwent CTR alone, and those who underwent CubTR alone.

RESULTS

Prevalence

Figure 1 shows the process of cohort creation. In total, 7,867 patients underwent nerve decompression

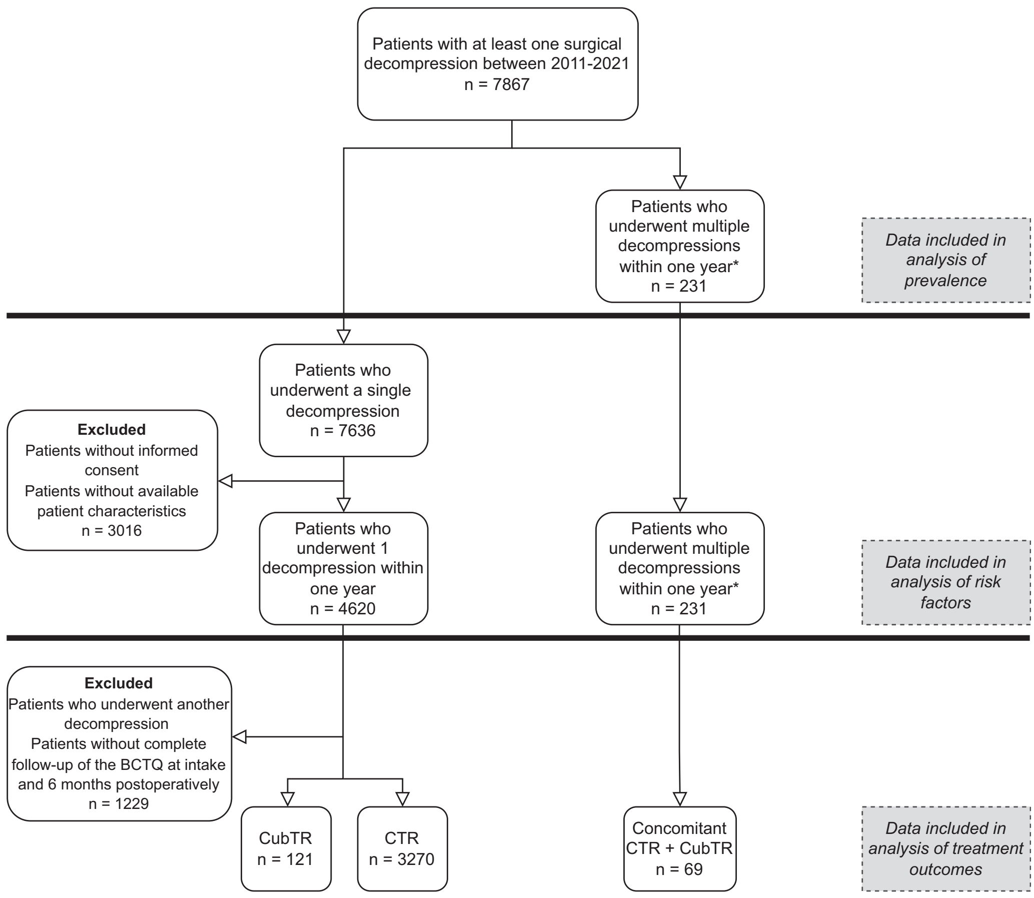

FIGURE 1: Establishment of the study cohort. *All combinations of multiple decompressions were included in the analysis of risk factors. All other combinations are depicted in Figure 2.

of the upper extremity (2011−2021). Of them, 231 underwent surgery for multiple nerve compression syndromes within 1 year, leading to a prevalence of 2.9% (95% CI, 2.6−3.3). The combination of CTR and CubTR was the most common (67%), followed by CTR and radial tunnel release (12%). All combinations are depicted in Figure 2.

Risk factors

Boston Carpal Tunnel Questionnaire outcomes in 4,620 patients who underwent a single nerve decompression were available. All patient characteristics are shown in Table 1. Higher severity of symptoms at intake was associated with greater odds of having multiple nerve compression syndromes, with an odds ratio (OR) of 1.46 (95% CI, 1.18−1.80). This OR indicates that patients with one point more on the SSS have a 46% increase in the odds of being treated for multiple nerve compression syndromes within 1 year. Other risk factors were younger age (OR, 0.97; 95% CI, 0.96−0.98)—meaning that with each decreasing year of age, the odds of being treated for multiple nerve compressions within 1 year increased by 3%—and current smoking (OR, 1.14; 95% CI, 1.06−1.94). In contrast,

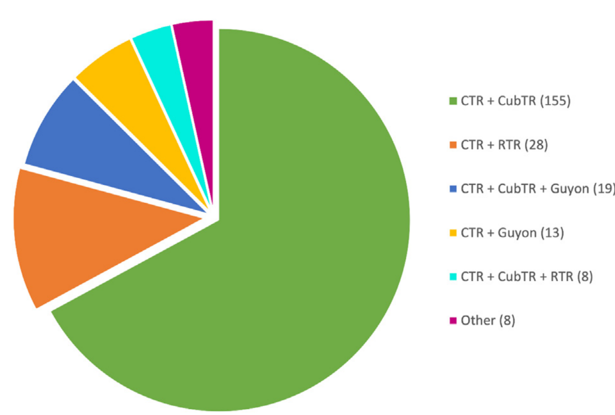

FIGURE 2: Diagram of the distribution of the different combinations of surgical decompressions in patients with multiple nerve syndromes (N = 231). These surgical decompressions were performed concomitantly or subsequently within 1 year. RTR, radial tunnel release.

TABLE 1. Baseline Characteristics of All Patients With a Single Surgical Nerve Decompression and Those With Multiple Nerve Compression Syndromes Requiring Surgical Treatment Within 1 Year

Patient Characteristics	Single Surgical Nerve Decompression N = 4,620	Multiple Nerve Compression Syndromes Requiring Surgical Treatment N = 231	*P**
Age (y), mean (SD)	54 (13)	48 (13)	<.05
Sex (male), %	1,335 (29)	60 (26)	.377
Diabetes mellitus (yes), %	296 (6)	13 (6)	.737
Smoking (yes), %	960 (21)	73 (32)	<.05
BMI (kg/m^2), mean (SD)	27 (5)	27 (4)	.304
SSS, mean (SD)	2.9 (0.7)	3.1 (0.6)	<.05
Intensity of occupation, %			
No paid employment	1,517 (33)	74 (32)	.763
Light (eg, office job)	1,116 (24)	63 (27)	.299
Medium (eg, cleaning)	1,301 (28)	66 (29)	.741
Heavy (eg, construction work)	686 (15)	28 (12)	.211
Medical history of cardiovascular disease (yes), %	464 (10)	10 (4)	.006
Medical hx of thrombosis or vasculitis (yes), %	50 (1)	3 (2)	.421
Medical hx brain or other nerve diseases (yes), %	136 (3)	5 (4)	.822
Medical hx of bone or muscle diseases (yes), %	1,003 (22)	52 (23)	.837
Medical hx of rheumatoid arthritis (yes), %	641 (14)	29 (13)	.638
Anticoagulation use (yes), %	451 (10)	8 (6)	.166

BMI, body mass index; hx, history.
**P* values represent differences between patients who underwent a single surgical nerve decompression and those who underwent multiple surgical decompressions within 1 year.

heavy occupational intensity (OR, 0.51; 95% CI, 0.31−0.82) and medical history of cardiovascular disease (OR, 0.48; 95% CI, 0.23−0.88) were associated with decreased odds (Table 2).

The ICC calculations showed no indication of clustering of patients with specific risk factors at certain practice sites (all ICCs < 0.01).

Surgical outcomes

Sixty-nine patients underwent CTR and CubTR concomitantly. At intake, these patients showed no significant difference in the SSS scores compared with those who underwent CTR alone (3.0 vs 2.9, respectively; $P = .06$). However, they reported significantly worse scores on the FSS compared with those who underwent CTR alone (2.7 vs 2.5, respectively; $P < .05$). In addition, patients who underwent CubTR alone did not differ from those who underwent concomitant treatment in terms of both SSS and FSS scores at intake (SSS: 2.8 vs 3.0, respectively; $P = .061$; FSS: 2.5 vs 2.7, respectively; $P = .14$) (Table 3).

Six months after surgery, patients who underwent CTR alone reported better outcomes on the SSS and FSS than those who underwent concomitant treatment (SSS: 1.6 vs 2.0, respectively; $P < .05$; FSS: 1.6 vs 2.0, respectively; $P < .05$). In contrast, the treatment outcomes of CubTR alone at 6 months were comparable with those of concomitant treatment in terms of both SSS and FSS scores (SSS: 2.0 vs 2.0, respectively; $P = .9$; FSS: 1.8 vs 2.0, respectively; $P = .2$) (Table 3; Figs. 3 and 4). The average improvement exceeded the minimal clinically important difference of 0.7 and 0.3 for the SSS and FSS, respectively.[33]

The ICC calculations showed no indication of clustering by the surgeon (n = 23) for surgical decision-making, and as for all the treatments, the ICC was lower than 0.01.

Patients who underwent CTR alone reported significantly higher satisfaction with the treatment results than those who underwent concomitant CTR and CubTR. In contrast, patients who underwent CubTR alone reported being equally satisfied

TABLE 2. Risk Factors for Development of Multiple Nerve Compression Syndromes Requiring Surgical Treatment Within 1 Year

Risk Factor	OR*	95% CI	*P*†
Age	0.97	0.96–0.98	<.001
Sex (male)	1.14	0.82–1.56	.43
Diabetes mellitus	1.17	0.62–2.03	.61
Smoking	1.44	1.06–1.93	.02
BMI	0.99	0.96–1.02	.43
Duration of symptoms	1.00	1.00–1.00	.34
Intensity of occupation			
Light (eg, office job)	0.88	0.61–1.27	.50
Medium (eg, cleaning)	0.70	0.49–1.01	.06
Heavy (eg, construction work)	0.51	0.31–0.82	.01
Medical history of cardiovascular disease	0.48	0.23–0.88	.03
Medical history of bone or muscle diseases	1.14	0.80–1.60	.45
Medical history of rheumatic diseases	0.91	0.58–1.37	.65
Severity of symptoms at intake	1.45	1.18–1.79	<.001

BMI, body mass index.
*A multivariable logistic regression model was performed to determine the ORs.
†*P* values represent the significance of the correlation between the potential risk factor and having multiple nerve compression syndromes requiring surgical treatment within 1 year.

TABLE 3. BCTQ Scores in Mean (SD) at Intake and 6 months After Surgery. Overall Satisfaction With Treatment in Number (%) at 6 Months After Surgery

Patient Reported Outcome Measurements	Concomitant Treatment (CTR + CubTR) N = 69	CTR N = 3,270	*P* Concomitant Treatment Versus CTR*	CubTR N = 121	*P*† Concomitant Treatment Versus CubTR*
SSS at intake	3.0 (0.61)	2.9 (0.66)	.062	2.8 (0.73)	.061
SSS at 6 mo after surgery	2.0 (0.81)	1.6 (0.65)	<.05	2.0 (0.73)	.888
FSS at intake	2.7 (0.75)	2.5 (0.78)	.009	2.5 (0.83)	.144
FSS at 6 mo after surgery	2.0 (0.90)	1.6 (0.68)	<.05	1.8 (0.80)	.215
Satisfaction with treatment results 6 mo after surgery (%)					
Excellent	16	33		18	
Good	33	40		31	
Fair	25	16		26	
Moderate	16	8		21	
Poor	10	3		4	

**t* tests were performed to compare treatment outcomes.
†*P* represents the differences in the outcomes in terms of the BCTQ between concomitant treatment and CTR and CubTR separately.

as those who underwent concomitant treatment (Table 3).

The median time of RTW did not differ among the treatments ($P = .09$) (Fig. 5) patients who underwent CTR or CubTR alone returned to work at a mean time of 4 weeks after surgery, whereas concomitantly treated patients returned after a mean time of 6 weeks (Fig. 5).

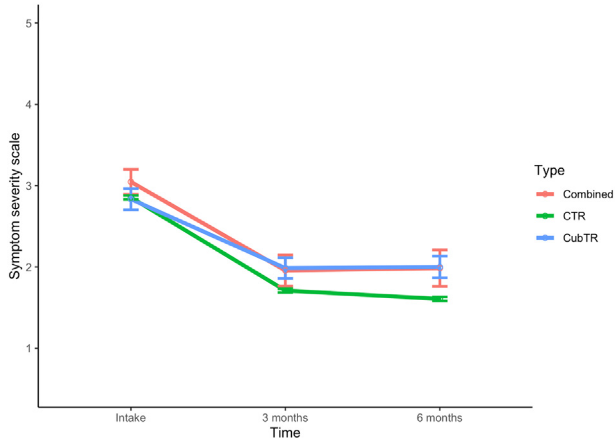

FIGURE 3: BCTQ SSS over time for concomitant treatment (CTR and CubTR), CTR alone, and CubTR alone. Preoperative and postoperative measurements of BCTQ SSS for concomitant treatment (CTR and CubTR), CTR alone, and CubTR alone. The graph indicates mean values at intake and at 3 and 6 months of follow-up, with error bars representing the 95% CI of the mean.

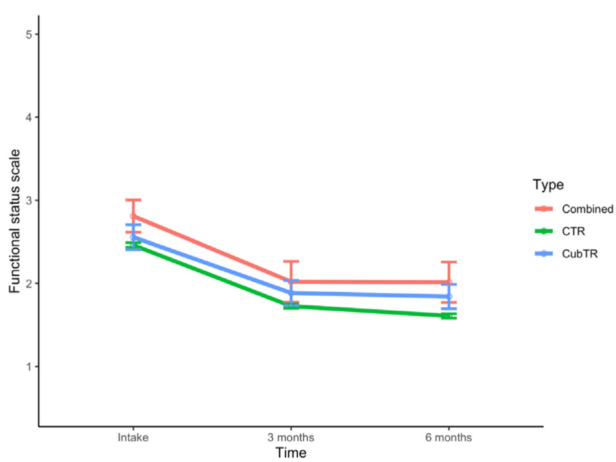

FIGURE 4: BCTQ FSS over time for concomitant treatment (CTR and CubTR), CTR alone, and CubTR alone. Preoperative and postoperative measurements of BCTQ FSS for concomitant treatment (CTR and CubTR), CTR alone, and CubTR alone. The graph indicates mean values at intake and at 3 and 6 months of follow-up, with error bars representing the 95% CI of the mean.

Matched subgroup analyses

In total, 69 patients underwent concomitant CTR and CubTR. Therefore, 138 patients who underwent CTR alone (1:2) and 69 patients who underwent CubTR alone (1:1) were matched. After matching, patients who underwent CTR alone reported significantly better outcomes on both the SSS and FSS than those who underwent concomitant treatment (SSS: 2.0 vs 1.7, respectively; $P < .05$; FSS: 2.0 vs 1.7, respectively; $P < .05$).

In contrast, there was no significant difference in treatment outcomes 6 months after surgery between patients who underwent concomitant treatment and those who underwent CubTR alone (SSS: 2.0 vs 2.0, respectively; $P = .99$; FSS: 2.0 vs 1.8, respectively; $P = .15$). All subgroup analyses are shown in Appendix A (available online on the *Journal*'s website at www.jhandsurg.org).

Sample size

For all analyses, a small or small-to-medium effect size could be detected (Appendix B, available online on the *Journal*'s website at www.jhandsurg.org).

DISCUSSION

This study aimed to assess the prevalence of multiple nerves affected by compression in a sample of patients who underwent surgery and determine the potential risk factors for belonging to this sample. Moreover, the treatment outcomes of concomitant CTR and CubTR were determined.

The prevalence of multiple nerve compression syndromes in a surgical cohort was 2.9%. We found that severe symptoms at intake, younger age, and smoking are associated with a higher risk of multiple compression syndromes, requiring surgical treatment. Furthermore, the patients who underwent CTR alone reported superior outcomes than those who underwent simultaneous CTR and CubTR. In contrast, the patients who underwent CubTR alone had postoperative outcomes similar to those who underwent concomitant treatment. Moreover, the total time of RTW after surgery is generally shorter when patients undergo CTR and CubTR concomitantly than when they first undergo CTR alone and CubTR later or vice versa; however, this was not statistically significant.

The etiology of multiple nerve compression syndromes concomitantly or sequentially is not clear. This study showed that 231 out of 7,867 patients underwent multiple nerve decompressions within 1 year; 67% of these 231 patients underwent concomitant CTR and CubTR. Carpal tunnel release combined with radial tunnel release was the second most common, with 12%, whereas the combination of CubTR and radial tunnel release was only present in 0.4% of all the cases. To our knowledge, there is no literature about the prevalence of these multiple combinations of nerve compressions, except for the most common combination of CTR and CubTR.[18–21,34] The report by Zhang et al,[19] a retrospective cohort study, with a sample size of 1,454 patients who underwent CTR or CubTR,

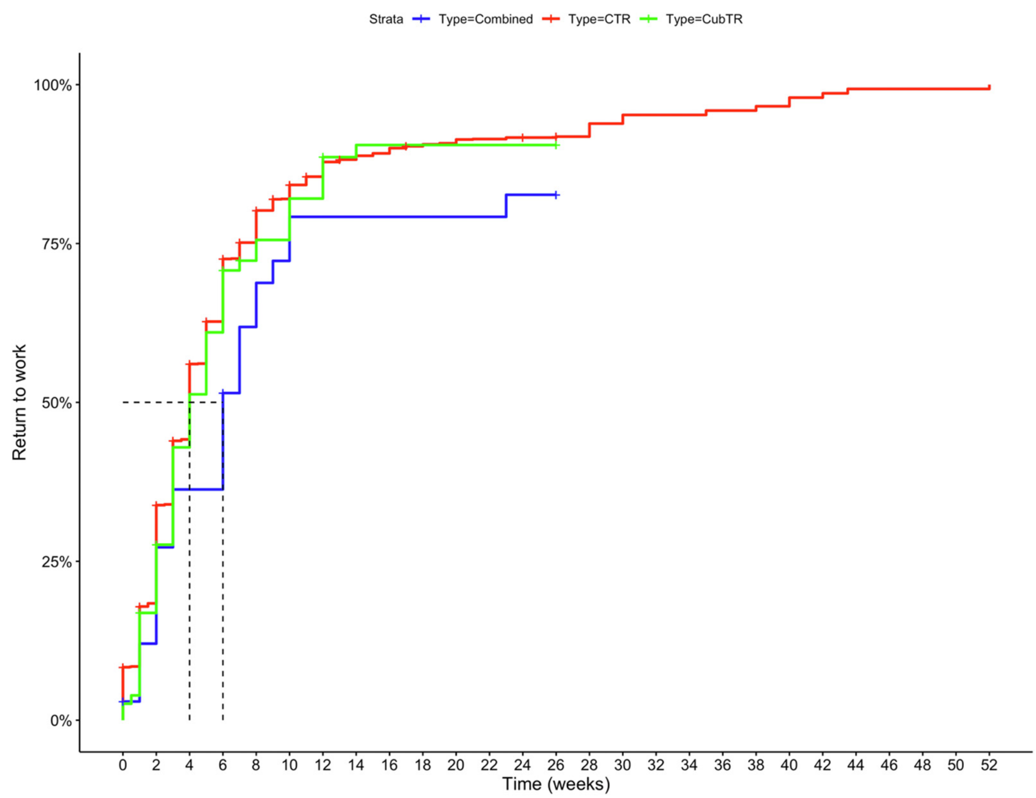

FIGURE 5: RTW of patients who underwent concomitant treatment (CTR and CubTR), CTR alone, and CubTR alone. The x axis represents the time in weeks, and the y axis represents the percentage of the original working hours per week. RTW was defined as the first time a patient reported returning to performing original work for a minimum of 50% of the original hours per week.

showed that 5.5% of the patients underwent both decompressions, which is higher than our overall prevalence of 2.9%. However, they included only patients who underwent CTR or CubTR.

Although previous studies have examined risk factors only for the combination of CTS and CubTS, we included all types of nerve compression syndromes in this study. For example, Zhang et al[19] stated that patients who underwent CTR and CubTR concomitantly were roughly 2.5 times more likely to have diabetes than those who underwent a single decompression. Our study found that diabetes was not associated with multiple nerve compression syndromes among patients who underwent surgical treatment. The different samples may have resulted in this discrepancy; our study included patients who underwent multiple decompressions within 1 year for the analysis of risk factors, whereas Zhang et al[19] only included patients who underwent concomitant CTR and CubTR.

According to our results, the risk factors associated with multiple nerve compression syndromes that are surgically treated are higher severity of symptoms at intake, younger age, and current smoking. We hypothesize that this higher severity of symptoms might be partly explained by these patients having another compression syndrome at intake, which may cause the symptoms to be considered more severe. Further research is required to verify this hypothesis.

Previous literature is in line with our results that current smoking is associated with nerve compression syndromes such as CTS, CubTS, and radial tunnel syndrome.[35–39] The most likely explanation for the association between smoking and peripheral nerve compressions is that smoking reduces blood supply to peripheral nerves, making them more sensitive to compression or traction. Additionally, nicotine can exacerbate the effects of ischemia in various tissues.[39]

Heavy occupational intensity seems to have a negative association with having multiple nerve compression syndromes, requiring surgical treatment. This is in contrast to previous literature that showed that physically demanding occupations are associated with, or stated to contribute to, CTS or CubTS.[40,41] However, in the literature, this has been described as a risk factor for single nerve compression syndromes, whereas the outcomes of this study defined the risk factors associated with multiple nerve compression syndromes in a surgical cohort. In addition, a medical history of cardiovascular disease was associated with lower odds of multiple nerve compression syndromes. There is a possibility that these negative associations may be explained by the surgeon's reluctance to operate on patients with comorbidities or higher-intensity occupations. Nevertheless, the etiology of these findings remains unknown and could be investigated in further research.

Previous research suggested that patients who underwent CTR alone achieved better treatment results than those who underwent CubTR.[42–45] Therefore, when these two treatments are performed concomitantly, CubTR could be the limiting factor for achieving satisfactory treatment outcomes. The current study confirms this hypothesis: the results of the patients who underwent concomitant CTR and CubTR were comparable with those of patients who underwent CubTR alone, with significant improvement in the SSS and FSS scores 6 months after surgery. Moreover, 6 months after surgery, these patients reported satisfaction scores equal to those who underwent CubTR alone. This is in line with studies by Phan et al[34] and Zhang et al,[19] who reported that patients who underwent simultaneous CTR and CubTR followed similar trajectories in the postoperative period as those who underwent CubTR alone.

The average time of RTW for patients who undergo concomitant CTR and CubTR is 6 weeks. In comparison, the patients who underwent CTR or CubTR alone reported returning to work after a mean time of 4 weeks. Stirling et al[46] also reported a median time of RTW of 4 weeks after CTR. The median time of RTW after CubTR is 20–48 days, depending on the invasiveness of the surgery.[47] However, when patients have both compression syndromes, their time of RTW is 2 weeks less after concomitant treatment than when they undergo these decompressions in separate procedures. At the same time, their postoperative outcomes are similar to those of patients who undergo CubTR alone.

The study has several limitations, including the retrospective review of the data. In addition, there were missing data in the single nerve decompression group for the analysis of potential risk factors. However, the power of our analysis was sufficient to test all variables.

Another shortcoming was the characteristics of our sample, which consisted only of surgically treated patients from one institution. Patients who received nonsurgical treatment or additional therapy at different hospitals were not included in our database. Therefore, our results may have been affected by a selection bias.

In conclusion, younger patients, patients who smoke, or patients who report severe symptoms at intake have higher odds of having multiple compression syndromes surgically treated within 1 year. Therefore, when patients with these characteristics present with a single nerve compression syndrome, they should be counseled about the risk of additional nerve compression.

For patients who experience symptoms of CTS and CubTs, our advice is to inform them about the possible option of concomitant treatment because the results of this treatment are as beneficial as those of CubTR alone, complication rates are similar with a single decompression, and the shorter total RTW time may be advantageous to the patient.

ACKNOWLEDGMENTS

We would like to thank all the patients for their participation. In addition, we would like to acknowledge the members of the Hand-Wrist Study Group; the caregivers and personnel at the Xpert Clinic, Handtherapie Nederland; and Equipe Zorgbedrijven for assisting in the routine outcome measurements that are the basis of this manuscript.

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