Med Pregl 2025; LXXVIII (5-8): 141-147. Novi Sad: maj-avgust.

# OUTCOME PREDICTORS OF CARPAL TUNNEL RELEASE SURGERY

## *PREDIKTORI ISHODA HIRURŠKOG LEČENJA SINDROMA KARPALNOG TUNELA*

**Marija MARINKOVIĆ[1,2], Vanja TATALOVIĆ[1,2], Anja RISTIĆ[2], Isidora ĐOZIĆ[1,2], Sveto BJELAN[1,2] and Jelena NIKOLIĆ[1,2]**

ORCID NUMBER
Marija Marinković – 0000-0002-5346-1922
Vanja Tatalović – 0009-0008-1942-706X
Anja Ristić – 0009-0004-5802-8046
Isidora Đozić – 0000-0003-1680-8488
Sveto Bjelan – 0009-0008-7418-0717
Jelena Nikolić – 0000-0003-3399-8543

University Clinical Center of Vojvodina, Novi Sad
Clinic for Plastic and Reconstructive Surgery[1]
University of Novi Sad, Faculty of Medicine Novi Sad[2]

Original study
*Originalni naučni rad*
UDK 617.576-036
https://doi.org/10.2298/MPNS2508141M

**Abstract**

**Introduction.** Open surgical decompression is considered the most efficient treatment for carpal tunnel syndrome and is associated with excellent outcomes in approximately 70-90% of cases. This study aimed to determine whether a correlation exists between potential predictors of postoperative outcomes and patient satisfaction following surgical procedure. **Material and Methods.** This retrospective study utilized data collected from the database of the University Clinical Center of Vojvodina and supplemented by telephone interview. Four categories of potential predictors were analyzed: patient-related factors, comorbidity-related factors, clinical findings, and other relevant factors. **Results.** A statistically significant positive correlation was identified between patient gender and postoperative satisfaction scores. Additionally, pain intensity, nocturnal pain, and postoperative complications demonstrated statistically significant negative correlations with satisfaction scores. **Conclusion.** Understanding predictors of surgical outcomes can assist patients in making informed decision regarding treatment and in setting realistic expectations about functional recovery following carpal tunnel decompression.
**Key words**: Carpal Tunnel Syndrome; Treatment Outcome; Decompression, Surgical; Patient Satisfaction; Recovery of Function

**Sažetak**

**Uvod.** Otvorena hirurška dekompresija kod sindroma karpalnog tunela predstavlja najefikasniji vid lečenja. To je najčešće izvođena terapijska metoda, sa oko 70–90% odličnih ishoda. Ova studija ima za cilj da utvrdi da li postoji korelacija između potencijalnih prediktora ishoda i zadovoljstva pacijenta rezultatom operativnog zahvata. **Materijal i metode.** U ovoj retrospektivnoj studiji podaci su prikupljeni iz informacionog sistema Univerzitetskog kliničkog centra Vojvodine i putem telefonskog intervjua. Analizirane su četiri kategorije potencijalnih prediktora: faktori u vezi sa ispitanikom, faktori u vezi sa komorbiditetima ispitanika, faktori u vezi sa kliničkim nalazom i ostali faktori. **Rezultati.** Utvrđena je statistički značajna pozitivna korelacija između pola i zadovoljstva ispitanika ishodom operacije, kao i negativna korelacija između bola, noćnog bola i nastanka postoperativnih komplikacija sa pacijentovom ocenom ishoda. **Zaključak.** Poznavanje prediktora ishoda može da olakša pacijentima donošenje informativne odluke o modalitetu lečenja i prilagođavanje očekivanja o funkcionalnom oporavku.
**Ključne reči**: sindrom karpalnog tunela; ishod lečenja; hirurška dekompresija; zadovoljstvo pacijenta; funkcionalni oporavak

### Introduction

Carpal tunnel syndrome (CTS) is a compressive neuropathy resulting from mechanical-ischemic injury of the median nerve, caused by a disproportion between the size of the carpal canal and its contents. The canal is formed by the carpal groove – bounded laterally by the tubercle of the scaphoid and the tubercle of the trapezium, and medially by the pisiform and the hook of the hamate – while its roof consists of the flexor retinaculum and the distal portion of the antebrachial fascia [1]. CTS occurs more frequently in women (2.5:1), most commonly between the ages of 40 and 60. Numerous systemic and local factors contribute to its development, including repetitive wrist movements and occupational strain, acromegaly, renal insufficiency and dialysis, amyloidosis, myxedema, diabetes mellitus, pregnancy, menopause, rheumatoid arthritis, as well as wrist fractures, tenosynovitis, palmar infections, and burns [2]. Obesity has also been identified as a significant risk factor. Each one-unit increase in body mass index (BMI) – equivalent to a weight gain of 2.7 kg in an average individual – increases the risk of CTS by approximately 8%. Several mechanisms have been proposed to explain this association: work environments often designed for individuals of average body dimensions may inadequately accommodate people with higher BMI; obesity predisposes of arthritis; and increased adipose tissue may further reduce carpal tunnel capacity. Another major occupational factor is daily exposure to vibrating tools, which may cause both direct nerve injury through vibration and ischemic nerve damage via secondary vasoconstriction [3].

✉ Corresponding author: Vanja Tatalović, E-mail: vanja.tatalovic@mf.uns.ac.rs

***Abbreviations***

| | |
|---|---|
| CTS | – carpal tunnel syndrome |
| EMNG | – electromyoneurography |
| ICD-10 | – 10th revision of the International Classification of Diseases |
| BMI | – body mass index |
| RA | – rheumatoid arthritis |

Clinically, CTS is characterized by pain and dysesthesia, typically affecting the first three and a half digits, with possible radiation into the forearm. Symptoms are most intense at night, frequently waking patients. In advanced cases, examination may reveal thenar muscle atrophy. Diagnostic challenges arise because subjective complaints often do not correspond with objective findings. Provocative tests, such as Tinel's and Phalen's, show greater sensitivity and specificity in advanced disease, but their diagnostic accuracy decreases considerably in early stages when dysesthesia is the predominant symptom. Electromyoneurography (EMNG) remains the most reliable diagnostic method. Differential diagnosis must exclude C6–C7 radiculopathy, which may mimic sensory deficits, and T1 radiculopathy, which can lead to thenar atrophy [4].

Treatment begins with conservative measures: management of underlying systemic conditions, reduction of occupational strain, nighttime splinting in a neutral position, and local corticosteroid injections. Long-term use of diuretics, nonsteroidal anti-inflammatory drugs, or oral corticosteroids is not supported by the literature [5]. Surgical treatment – open decompressive retinaculotomy – is indicated when conservative therapy fails or when sensory and motor deficits (with or without thenar atrophy) are present [5]. Decompression is achieved by transection of the flexor retinaculum. Open surgical decompression remains the gold standard because it allows complete visualization of the region, adaptation to anatomical variations, and protection of neurovascular structures. It is considered safe and reliable, with high rates of functional recovery and patient satisfaction; up to 85% of patients return to their previous occupation following the procedure and rehabilitation [6]. Approximately 10% of patients, however, experience poor outcomes including persistent or recurrent symptoms, or the appearance of new symptoms. Endoscopic resection of the retinaculum is also used, and although postoperative pain may be less pronounced with this technique, overall outcomes are comparable [7]. Some studies favor the endoscopic approach because due to return to work, an important consideration in predominantly working-age population, but the final decision depends on the surgeon recommendation and patient preference [8].

The severity of clinical symptoms plays a central role in the decision to operate. Symptoms tend to be more severe in obese patients and those with vitamin B12 deficiency. Among patients with more pronounced symptoms, diabetes mellitus is more common, although this correlation is not statistically significant. While occupation is a known risk factor for the development of CTS, it has not been shown to influence symptom severity [9]. A review of prognostic studies on surgical outcomes in median nerve compressive neuropathy classified potential predictors into four groups: patient-related factors, comorbidities, clinical or physical findings, and other factors such as duration of paid sick leave [10].

All factors associated with the onset of CTS, the severity of symptoms, and the choice of treatment ultimately influence surgical outcomes, quality of life, and patient satisfaction. Identifying predictive factors enables clinicians to establish realistic expectations for patients regarding functional recovery and supports informed decision-making. Furthermore, understanding these predictors allows for individualized treatment planning, potentially improving surgical effectiveness and patient satisfaction through improved quality of life. Awareness of these predictors may also guide refinements in operative and postoperative management.

The aim of this study was to determine whether selected potential predictors are associated with patient-reported satisfaction following surgical decompression for CTS. The analyzed predictors included age, sex, occupation, hobbies, lifestyle habits, comorbidities and precipitating conditions, severity of clinical symptoms and EMNG findings, type of treatment, postoperative management and patient compliance, postoperative complications, and preoperative expectations.

## Material and Methods

This retrospective study was conducted over a four–year period, from January 2020 to January 2024, and included patients diagnosed with carpal tunnel syndrome who underwent surgical treatment at the Clinic for Plastic and Reconstructive Surgery, University Clinical Center of Vojvodina, Novi Sad. Clinical information was extracted from the hospital information system and supplemented through telephone interviews. The study was approved by the Ethics Committee of the University Clinical Center of Vojvodina (No. 00-258, November 16, 2023). Patients were identified using a diagnosis-based search in the hospital database, selecting those coded as G56.0 – Carpal Tunnel Syndrome according to the 10th revision of the International Classification of Diseases (ICD-10).

Potential predictors of outcome following open surgical decompressive retinaculotomy were selected based on previously published literature and classified into four categories: patient-related factors, comorbidity-related factors, clinical findings, and other contributing factors.

1. *Patient-related factors*

The analyzed patient-related variables included age, sex, and body mass index (BMI), calculated as body weight divided by body height squared (kg/m²).

2. *Comorbidity-related factors*

Comorbid conditions potentially influencing the outcome of surgical decompression were evaluated. These included: diabetes mellitus, thyroid disorders, rheumatoid arthritis, menopause, pregnancy, use of oral contraceptives or hormone replacement therapy, thoracic outlet syndrome, cervical spine disorders, gout, poor general health status, presence of an arteriovenous fistula for hemodialysis, and lifestyle habits such as smoking and excessive alcohol consumption.

3. *Clinical findings*

Clinical parameters assessed were: the presence and duration of symptoms, electromyoneurography (EMNG) findings, thenar eminence muscle atrophy, identification of hourglass deformity, neurolysis, and postoperative physiotherapy.

4. *Other factors*

Additional predictors included occupation, the possibility of taking medical leave, the surgical technique performed, and the occurrence of postoperative complications. Patient expectations and satisfaction with the surgical outcome were also analyzed.

Satisfaction was assessed via telephone interview, during which 101 respondents rated their outcome on a 1-5 scale, with 5 indicating the highest level of satisfaction.

Data were recorded in Microsoft Excel and analyzed using SPSS statistical software. After assessing the distribution of variables with Kolmogorov–Smirnov test, statistical analysis was performed using Spearman's rank correlation coefficient for continuous variables and biserial correlation for dichotomous variables. A p-value < 0.05 was considered statistically significant.

## Results

From January 2020 to December 2023, a total of 202 decompressive median nerve retinaculotomies were performed at the Day Hospital of the Clinic for Plastic and Reconstructive Surgery, University Clinical Center of Vojvodina. Of the operated patients, 72.8% (n = 147) were women and 27.2% (n = 55) men. The mean age was 64 ± 12 years (range: 30–93). The mean satisfaction score with the final surgical outcome was 4.06.

*1. Patient-related factors*

A weak negative correlation was observed between age and satisfaction with surgical outcome ($\rho = -0.174$), though it did not reach statistical significance ($p > 0.05$, $p = 0.086$). The mean height of participants was 170.5 ± 8 cm, mean body weight 78.6 ± 11.5 kg, and mean BMI 26.9 ± 3 kg/m². BMI showed a weak negative, non-significant correlation with surgical outcome ($\rho = -0.141$, $p = 0.166$). A statistically significant positive correlation was found between sex and surgical outcome ($\rho = 0.241$, $p < 0.05$, $p = 0.017$). Female patients reported a higher mean satisfaction score (4.2/5), approximately 15% greater than that of male patients (3.65/5).

*2. Comorbidity-related factors*

Among the 101 surveyed patients, 20 had diabetes mellitus, 19 had thyroid disorders, 4 had rheumatoid arthritis, 17 had cervical spine disease, 8 had gout, 1 had thoracic outlet syndrome, and 1 was undergoing dialysis via an arteriovenous fistula.

Of the 66 female respondents, 37 were postmenopausal, 50 had experienced at least one pregnancy, 8 used oral contraceptives, and 3 were receiving hormone replacement therapy. Additionally, 42 respondents were smokers and 8 reported regular alcohol

**Table 1.** Comorbidity-related potential predictors

| Potential predictor | Spearman correlation coefficient (ρ) | p |
|---|---|---|
| Diabetes | -0.001 | 0.995 |
| Thyroid dysfunction | -0.066 | 0.519 |
| Rheumatoid arthritis | -0.118 | 0.248 |
| Cervical spine disease | 0.013 | 0.903 |
| Gout | -0.069 | 0.497 |
| Menopause | -0.171 | 0.257 |
| Pregnancy | -0.03 | 0.822 |
| Oral contraceptives | 0.251 | 0.1 |
| Excessive alcohol consumption | -0.119 | 0.254 |
| Smoking | -0.189 | 0.066 |

consumption. Overall, comorbidities showed no significant correlated with surgical outcome ($\rho \approx 0$, $p > 0.05$). Among women, menopause demonstrated a weak negative correlation with surgical outcome ($\rho = -0.171$), but this was not statistically significant ($p > 0.05$). Lifestyle factors such as smoking and alcohol use also showed weak, non-significant negative correlations with surgical outcome ($p > 0.05$) **(Table 1).**

*3. Clinical findings*

The average duration of symptoms prior surgery was 3.5 years. Symptom duration did not correlate significantly with postoperative outcome ($p = 0.691$). Pain ($\rho = -0.3$, $p < 0.01$, $p = 0.002$) and nocturnal pain ($\rho = -0.267$, $p < 0.01$, $p = 0.008$) were both significantly and negatively correlated with surgical outcome. Other clinical parameters demonstrated only weak, non-significant correlations.

*4. Other factors*

Additional variables included postoperative complications, bilateral hand involvement, and preoperative expectations. Postoperative complications occurred in 9 patients (8%) and were significantly associated with poorer outcomes ($\rho = -0.395$, $p < 0.01$). Bilateral symptoms showed no correlation with final outcome ($\rho \approx 0$). Expected outcome demonstrated a weak positive, non-significant correlation with postoperative satisfaction ($\rho = 0.148$).

## Discussion

In this study, we examined a range of factors previously identified in the literature as potential predictors of patient satisfaction following open decompressive carpal tunnel release. The aim was to identify patients at greater risk of suboptimal surgical outcomes based on negative predictors, thereby enabling more detailed preoperative counseling and more accurate adjustment of expectations regarding treatment results.

Carpal tunnel syndrome (CTS) is the most common compressive neuropathy [11]. Previous population studies show a bimodal age distribution, with incidence peaks at 50–54 and 75–84 years [12]. Older patients demonstrate more pronounced thenar muscle atrophy, a higher frequency of nocturnal paresthesias and pain, and more marked sensory and motor neuron loss [13].

Blumenthal et al. reported a higher prevalence of muscle weakness, atrophy, and electrophysiological abnormalities in older adults, although subjective symptoms and hand function impairment did not differ significantly, suggesting that diagnosis in the older patients should rely more heavily on objective findings rather than patient-reported symptoms [14].

Although these data indicate age as a possible predictor of outcome, we did not establish a statistically significant correlation between age and postoperative satisfaction. Townshend et al. and Hobby et al. reported poorer outcomes in patients older than 60 years with more severe the symptoms [15,16].

CTS predominantly affects women, who often report more severe symptoms [17]. Mondelli et al. found more intense symptoms in women without corresponding clinical or electrophysiological severity [18]. Some authors attribute the higher incidence among women to a presumed tendency toward symptom exaggeration [19], while studies from India emphasize occupational factors and intensified manual labor as contributors to the higher prevalence and severity in women [20–22].

In our study, female participants reported significantly higher satisfaction with the final surgical outcome than male patients (average score 4.2/5 vs. 3.65/5), despite having a longer duration of symptoms prior to surgery (average symptom duration 3.7 years). This correlation reached statistical significance, indicating that female sex may be associated with more favorable subjective outcomes.

Conversely, Hobby et al. reported no sex-based differences in postoperative results despite more severe symptoms and functional limitations in women [16].

Body mass index (BMI) is well established as a risk factor for CTS development, likely because increased adipose tissue elevates the volume of structures within the carpal tunnel [23–25].

Obese individuals (BMI > 29) have a 2.5-fold higher risk of developing CTS compared to those with a BMI < 20 [26].

While high BMI is consistently linked to CTS onset, our findings showed only a weak, non-significant negative correlation between BMI and postoperative outcome, indicating that BMI is not a predictor of surgical success.

The literature similarly lacks strong evidence that age, BMI, or sex independently influence postoperative outcome following open carpal tunnel decompression, although results may be less predictable in patients > 70 years; nevertheless, high satisfaction in this group confirms the benefit of surgery when appropriate counseling is provided [10].

CTS occurs in up to one-third of diabetic patients (33%), ten times more often than in the general population [27–29]. Despite the higher incidence in this population, predicting surgical outcome remains challenging. Phalen [30] and Choi & Ahn [31] found no direct association between diabetes and postoperative function, with most patients achieving satisfactory improvement. Al-Qattan et al. reported that

approximately one-quarter of diabetic patients experience persistent postoperative numbness, often despite minimal or mild abnormalities on preoperative nerve conduction studies [32].

Thyroid dysfunction – particularly hypothyroidism – is also cited as a risk factor for CTS, potentially due to mucinous or mucopolysaccharide deposition around the median nerve or synovial edema in uncontrolled hypothyroidism [33]. Obese hypothyroid patients are considered especially susceptible [34].

Rheumatoid arthritis (RA) contributes to CTS pathogenesis but is not consistently associated with poorer postoperative outcome [35,36], although RA patients may show increased median nerve cross-sectional area, which tends to decrease with disease duration [37].

Studies indicate that up to 81% of patients with unsatisfactory outcomes following median nerve decompression also exhibit symptoms and/or signs of cervical radiculopathy, a condition referred to as double crush syndrome [38]. This syndrome represents the coexistence of cervical spine lesion and carpal tunnel syndrome, and although its clinical relevance is debated, the proposed mechanism involves proximal disruption of axonal transport that predisposes the distal nerve segment to dysfunction [39].

Despite their coexistence, the severity of the two conditions is generally not correlated; however, evaluation of both is recommended due to their frequent concurrence [40]. Importantly, even patients with EMG-confirmed double crush syndrome may achieve good or even excellent postoperative outcomes [31].

Gout is an extremely rare cause of carpal tunnel syndrome. Tophi may accumulate within flexor tendons, tendon sheaths, the floor of the carpal tunnel, or even the median nerve itself, producing pain, numbness, and weakness [41].

In our study, we examined the correlation between these comorbidities and patient-reported surgical outcome, and no association was found ($\rho \approx 0$). Thus, comorbidities did not appear to limit surgical success or influence the choice of treatment modality.

Some studies have shown that patients with concomitant thoracic outlet syndrome have markedly poor outcomes after carpal tunnel decompression, with up to 80% experiencing unfavorable results [35]. In our cohort, only one patient had this diagnosis, preventing a meaningful analysis.

Similarly, although an arteriovenous fistula is the preferred vascular access for hemodialysis, a recognized but underreported complication is hand numbness and paresthesia consistent with carpal tunnel syndrome, possibly due to venous hypertension and the steal phenomenon causing microischemia [42].

Only one patient in our study was undergoing dialysis, precluding analysis; however, the literature suggests that full functional recovery may still be expected [43].

Although our findings did not demonstrate correlations between patient comorbidities and surgical outcome, other studies have reported such associations. Because surgical treatment is typically reserved for more advanced cases requiring thorough preoperative evaluation, comorbidities may be detected during the diagnostic process [44]. A more robust assessment of their impact would require a larger sample size. Poor general health is also cited as a potential predictor of suboptimal outcome and higher postoperative complication rates [45,46].

A limitation of our study is its retrospective design, which did not allow standardized preoperative assessment using validated scoring systems. Additionally, although menopause, pregnancy, oral contraceptive use, and hormone replacement therapy are recognized risk factors for developing carpal tunnel syndrome [35], none of these factors were identified as predictors of poor postoperative outcome in our study.

We also assessed lifestyle-related predictors such as cigarette smoking and frequent alcohol consumption (more than two drinks per day). Nancollas [47] reported poorer functional recovery and persistent symptoms in smokers and heavy alcohol users; however, we found only weak, non-significant negative correlations.

According to some authors, early decompression of the affected nerve is essential for complete recovery [31,48], while others argue that symptom duration does not significantly affect postoperative outcome [49]. Consistent with the latter, our study showed no correlation between symptom duration and outcome. In contrast, symptom severity – especially pain and nocturnal pain – may be considered predictors of poorer perceived results.

Electromyoneurography (EMNG) abnormalities have not been consistently associated with surgical outcome [50], even though EMNG is widely regarded as the diagnostic gold standard [51]. Our results similarly showed a weak but non-significant negative correlation.

Arons et al. [52] conclude that the presence of "hourglass" deformity of the median nerve is not considered a negative prognostic factor. Atrophy of the abductor pollicis brevis is linked in some studies to poorer outcomes and persistent postoperative numbness [49,53], although Mondelli et al. reported that satisfactory clinical and electrophysiological improvement is still achievable [54].

We found no association between surgical outcome and the presence of hourglass deformity, abductor pollicis brevis atrophy, or postoperative physiotherapy, aligning with the findings of Pomerance and Fine [55], who reported no differences in return-to-work time or functional improvement with physiotherapy

Finally, many cited studies are based on low-level evidence. The lack of robust, consistent predictors highlights the need for well-designed prospective studies to better identify parameters that influence outcomes following open carpal tunnel decompression. Such evidence would enable more accurate prognostication and support informed decision-making for both patients and surgeons.

## Conclusion

Among the analyzed parameters, a significant correlation was found with patient sex, with female sex emerging as a positive predictor of surgical outcome. In contrast, the presence of pain and nocturnal pain in the clinical presentation, as well as the occurrence of postoperative complications, were identified as negative predictors of patient satisfaction following surgical treatment of carpal tunnel syndrome. Recognizing these factors enables more accurate patient counseling regarding treatment expectations and helps clinicians individualize both therapy and postoperative care, ultimately improving the quality and efficiency of management. Furthermore, it facilitates the identification of patients at increased risk of complications and supports more effective clinical decision-making in their follow-up.

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Rad je primljen 5. XI 2025.
Recenziran 4. XII 2025.
Prihvaćen za štampu 4. XII 2025.
BIBLID.0025-8105:(2025):LXXVIII:5-8:141-147.