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Sonia Lucaciu,
Antonia Iliescu,
Cosmin-Nicodim Cindea,
Diana Elena Teacoe,
Alexandru Breazu,
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Titus Fagarasi,
Vicentiu Saceleanu

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Sonia Lucaciu[1], Antonia Iliescu[2], Cosmin-Nicodim Cindea[2], Diana Elena Teacoe[1], Alexandru Breazu[1], Claudia Elena Popa[2], Titus Fagarasi[1], Vicentiu Saceleanu[2]

[1] County Clinical Emergency Hospital of Sibiu, ROMANIA
[2] "Lucian Blaga" University of Sibiu, UK

ABSTRACT

Carpal Tunnel Syndrome (CTS) is the most common peripheral nerve entrapment neuropathy, caused by compression of the median nerve at the wrist. It leads to hand pain, numbness, tingling, and weakness, often affecting the thumb, index, middle, and ring fingers. CTS frequently requires surgical treatment (carpal tunnel release) when symptoms are moderate to severe or unresponsive to conservative measures.

We analysed a cohort of 442 CTS patients treated surgically over the last 10 years at the County Clinical Emergency Hospital of Sibiu (312 women, 130 men; 308 urban residents, 134 rural; average age 59 years) and compared the outcomes and characteristics with findings from the literature. This report examines risk factors and comorbidities associated with CTS, surgical outcome metrics (recurrence, failure, complications), bilateral involvement patterns, laterality, urban-rural differences, and occupational contributions, supported by recent studies.

Keywords
carpal tunnel,
electromyography,
surgical complications,
peripheral nerve surgery,
decompression,
risk factors

INTRODUCTION

Carpal Tunnel Syndrome (CTS) is the most common peripheral nerve entrapment neuropathy, caused by compression of the median nerve at the wrist. It leads to hand pain, numbness, tingling, and weakness, often affecting the thumb, index, middle, and ring fingers. CTS frequently requires surgical treatment (carpal tunnel release) when symptoms are moderate to severe or unresponsive to conservative measures.

We analyzed a cohort of 442 CTS patients treated surgically over the last 10 years at the *County Clinical Emergency Hospital of Sibiu* (312 women, 130 men; 308 urban residents, 134 rural; average age 59 years) and compared the outcomes and characteristics with findings from the literature. This report examines risk factors and comorbidities associated with CTS, surgical outcome metrics (recurrence, failure, complications), bilateral involvement patterns, laterality, urban–rural differences, and occupational contributions, supported by recent studies.

Corresponding author:
Cosmin-Nicodim Cindea

"Lucian Blaga" University of Sibiu, Romania

cindea.cos@gmail.com

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Patient Demographics and Risk Factors for CTS

Gender and Age

In our series, about 70% of patients were female (312 women vs. 130 men), reflecting the well-known female predominance in CTS. Population studies show women have significantly higher incidence rates of CTS than men (approximately 2–3 times higher) [1]. Hormonal and anatomical differences are thought to contribute, and CTS most often manifests in middle age (commonly in the 40–60 year range) [2,3]. Our patients' average age was 59, consistent with the typical age of CTS sufferers (CTS is uncommon in youth and increases in prevalence until late midlife) [4].

Common Risk Factors and Comorbidities

Multiple medical and lifestyle factors contribute to CTS risk, with most patients in our cohort having at least one known risk factor.

- **Diabetes Mellitus:** Diabetics have a 90% higher risk of developing CTS due to chronic hyperglycemia-induced neuropathy. In our series, 126 patients (28.5%) had diabetes, aligning with its known high co-incidence with CTS [5].
- **Obesity:** Excess weight increases intracarpal pressure, raising CTS risk. Studies confirm a strong correlation between high BMI and CTS, which was evident in our patient group, where 172 patients (39%) were obese [6].
- **Thyroid Disorders:** Hypothyroidism can cause median nerve compression through myxedematous changes, a pattern observed in 41 patients (9.3%) in our cohort [7].
- **Rheumatoid and Inflammatory Arthritis:** Chronic synovitis from RA compresses the median nerve, commonly leading to CTS. Other inflammatory conditions like gout and psoriatic arthritis may have similar effects. In our cohort, 38 patients (8.6%) had RA or another inflammatory arthritis.
- **Pregnancy and Hormonal Factors:** Hormonal fluctuations, fluid retention, and anatomical changes in pregnancy and menopause increase CTS risk, as noted in 67 female patients (15.2%), who reported onset or worsening of symptoms during pregnancy or menopause.
- **Repetitive Hand Use and Occupational Factors:** Jobs involving repetitive wrist motions (e.g., factory work, typing, vibrating tools) are significant CTS risk factors. Many patients had prolonged exposure to such tasks. In our study, 185 patients (41.9%) had occupations associated with CTS risk. Prior wrist injuries (fractures, sprains) were also observed as contributors in 34 cases (7.7%) [8].

Other comorbidities in our series included hypertension (198 patients, 44.8%) and osteoarthritis (89 patients, 20.1%), both common in older populations. Chronic kidney disease, hormonal contraceptive use, and connective tissue disorders are additional potential risk factors reported in literature (1). Our patient cohort—older, predominantly female, and with high diabetes and obesity prevalence—mirrors established epidemiological data on CTS risk factors.

Bilateral Involvement and Hand Laterality

Prevalence of Bilateral CTS

CTS frequently affects both hands, either simultaneously or sequentially. Studies report that 50–80% of CTS patients develop bilateral involvement. In our cohort, 225 patients (54.7%) eventually had symptoms in both hands, and 94 patients (22%) required surgery on both hands. Many underwent surgery on one hand and later developed significant symptoms in the opposite hand, aligning with clinical observations that CTS often progresses over time [9].

Impact on Treatment

The high bilateral prevalence influenced surgical strategies. Staged surgery was the preferred approach, addressing the more symptomatic or non-dominant hand first, followed by the second hand after sufficient recovery. This method optimized postoperative function and minimized disability during healing. Simultaneous bilateral CTR was rare due to potential recovery challenges. Staged surgery outcomes were generally successful, but careful monitoring for contralateral symptom progression was essential [10].

Dominant vs. Non-dominant Hand (Right vs. Left)

The right hand was affected in 266 cases (60.2%) compared to 176 cases (39.8%) on the left, reflecting the predominance of right-hand dominance and greater cumulative hand use. This distribution aligns with literature reporting a slightly higher right-hand involvement in CTS [11]. However, bilateral CTS and variable presentation highlight the importance of

evaluating both hands in all patients, even if initial symptoms are unilateral.

Surgical Outcomes: Recurrence and Failure Rates

Carpal tunnel release (CTR) is highly effective, with most patients achieving significant symptom relief. However, a small subset experiences recurrence or requires additional interventions.

- **Success Rate:** The vast majority of our 442 patients had significant improvement. Only 32 patients (7.2%) reported persistent symptoms, and 9 patients (2%) required revision surgery. These results align with literature indicating that 69% of patients become symptom-free long-term, with nearly all showing partial improvement [12].
- **Recurrence Rates:** True recurrence (symptom return after a pain-free interval) is uncommon when the ligament is fully released. In our cohort, 9 patients (2%) required reoperation, matching reported revision rates of 1–5% . Including minor symptom persistence, recurrence rates can reach 10–25% in broader studies [13].
- **Risk Factors for Recurrence/Revision:**
  - **Incomplete Decompression:** The leading technical cause of recurrence, found in all revision cases in our study.
  - **Male Sex:** Males had a slightly higher revision rate, reflecting trends seen in larger studies [14].
  - **Rheumatoid Arthritis:** Present in 38 patients (8.6%), RA was linked to a higher likelihood of persistent CTS and revision surgery [15].
  - **Smoking:** Identified in 14 revision cases, smoking is associated with poorer surgical outcomes.
  - **Bilateral Surgery:** Simultaneous bilateral CTR is linked to higher revision risk; our staged approach mitigated this.
  - **Endoscopic Technique:** Though not used in our cohort, endoscopic CTR has a higher reported recurrence rate than open CTR [16].

These findings emphasize that proper surgical technique and patient risk management are crucial to minimizing recurrence and optimizing long-term outcomes.

Surgical 'Failures' or Persistent Symptoms

A small subset of patients did not experience full symptom relief post-surgery. In our cohort, 14 patients (3.2%) had persistent significant symptoms in the early postoperative period. Contributing factors included:

- **Misdiagnosis or Concurrent Neurologic Conditions:** Conditions such as cervical radiculopathy, diabetic peripheral neuropathy, or ulnar nerve compression can mimic CTS. Proper preoperative diagnosis using clinical exams and EMG helped prevent unnecessary surgeries in many cases [17].
- **Anatomical Variants:** Rare nerve anomalies like bifid median nerves or median-ulnar anastomoses can complicate diagnosis and surgery, leading to persistent symptoms. These variants must be considered in refractory cases [18].
- **Scar Tissue and Fibrosis:** Postoperative fibrosis can re-compress the nerve, occasionally requiring revision surgery. One patient (0.2%) in our study needed a secondary procedure to release excessive scar tissue.
- **Intraoperative Nerve Injury:** Nerve damage is exceedingly rare (<1%) in CTR. We recorded no cases of iatrogenic nerve laceration, likely due to careful intraoperative visualization and the open surgical technique used in all cases.

Postoperative Complications

Carpal tunnel release is a low-risk surgery with minimal complications. Among 442 patients, we observed:

- **Infection Rates:** Only 2 patients (0.5%) developed superficial wound infections, both resolving with antibiotics. No deep infections or abscesses were recorded. This aligns with literature indicating infection rates of <1% in CTR cases. A multicenter study of 3,003 CTR surgeries found infection rates of 0.37%, with deep infections occurring in <0.5% of cases [19].
- **Risk Factors for Infection:** Infection was rare regardless of comorbidities. One infected patient had diabetes, but studies suggest no significant difference in infection rates between diabetic and non-diabetic CTS patients. Routine prophylactic antibiotics were not used, consistent with best practices given the low infection risk. Some literature suggests younger males have a slightly higher risk of complications post-CTR, but severe

cases (e.g., requiring reoperation) remain under 0.1% [20].

- **Other Complications:** No cases of permanent nerve or tendon injury were recorded. Minor issues, such as transient pillar pain or scar tenderness, occurred in 38 cases (8.6%), resolving within weeks to months. Our complication rates were at or below published benchmarks, which estimate major complications (nerve, vessel, or tendon injury) in 0.9% of CTR cases and minor complications (e.g., wound issues, transient pain) in ~10% [21]. The use of open mini-incision techniques in all patients likely contributed to the low complication rate.

Urban vs. Rural Disparities in Surgery Rates

Our dataset showed a notable urban-rural disparity: 308 patients (69.7%) were from urban areas, while 134 (30.3%) were from rural regions. This suggests higher surgery rates or better healthcare access in urban populations. Several factors likely explain this trend:

- **Healthcare Access:** Urban residents have closer access to hospitals, hand surgeons, and nerve conduction studies, facilitating earlier diagnosis and treatment. In contrast, rural patients may delay care due to long travel distances or limited specialist availability. A U.S. study found only ~5% of CTR surgeries were performed on rural patients at tertiary centers, highlighting access disparities [22].
- **Awareness and Referrals:** Urban patients may be more aware of CTS and its treatment options, with higher referral rates from primary care providers. Rural patients may attribute symptoms to physical labor and seek care later, often with more severe symptoms.
- Occupational Factors: Urban jobs (e.g., assembly line, office work) involve repetitive hand movements, increasing CTS risk. Rural occupations, while physically demanding, may not always involve repetitive hand motions to the same extent. However, some rural industrial areas report high CTS incidence [23].
- **Healthcare Infrastructure and Socioeconomics:** Urban areas generally have more surgeons and shorter wait times for elective procedures. Rural patients may face delays due to fewer specialists. Socioeconomic factors also play a role—urban patients may have better insurance coverage and financial means for surgery [24].

Interestingly, rural patients in our cohort were generally older and had lower BMIs than urban patients. This mirrors studies indicating rural CTS patients often present later and may have atypical symptoms [25]. To improve equity in CTS care, initiatives such as telemedicine consultations and surgical outreach programs could help bridge this gap.

These findings highlight the need for improved CTS awareness, early diagnosis, and accessible treatment options in rural populations to prevent long-term disability.

Occupational and Professional Factors

Repetitive strain and occupational hand use are well-known contributors to CTS. In our study, 185 patients (41.9%) had jobs involving repetitive wrist motions, such as factory work, office typing, or manual labor. Based on literature, nearly 47% of CTS cases are considered work-related [26], suggesting that ~200 patients in our series may have developed CTS due to occupational strain.

- **High-Risk Professions**: Common CTS-related jobs include assembly line workers, cashiers, office workers, and manufacturing laborers. Certain industries report 13–15 CTS cases per 1,000 workers annually.
- **Physical Demands:** Jobs involving vibrating tools, repetitive grasping, and fine motor tasks (e.g., sewing, cleaning) also contribute to CTS risk. Our urban hospital likely treated many such workers.
- **Interaction with Medical Risk Factors:** Work-related CTS was often seen in patients with additional risk factors like diabetes, obesity, or rheumatoid arthritis. A diabetic factory worker or an obese office clerk may experience more severe CTS due to the combination of systemic and occupational strain.

To reduce work-related CTS, ergonomic interventions, wrist splints, and employer-supported modifications should be promoted. Patients returning to high-risk jobs post-surgery benefited from workplace adjustments to prevent recurrence. 40–50% of our CTS cases were likely occupational in origin, underscoring CTS as both a medical and workplace health issue. Improved workplace

ergonomics and early intervention can help reduce the burden of CTS and the need for surgery.

Cross-Reference with Broader Studies and Our Dataset Comparison

Our 442-patient dataset over 10 years aligns with broader CTS studies in several key aspects:

- Gender Ratio: Our female-to-male ratio was 2.4:1 (312 women, 130 men), consistent with epidemiologic reports showing 2:1 to 4:1 ratios. Studies indicate 60–75% of CTS patients are female, supporting our findings [27].
- Age Profile: The average age was 59 years (range 20–87), comparable to large studies where most CTS surgeries occur between 50–70 years [28]. Elderly patients (>75 years) had longer hospital stays (2.6 vs. 1.7 days), likely due to monitoring for comorbidities.
- Urban vs. Rural Distribution: Our 69.7% urban, 30.3% rural patient split highlights an access gap. While less extreme than the 95:5 ratio seen in some U.S. tertiary centers, it suggests rural patients may delay surgery or face referral barriers [29].
- Bilateral Cases: 225 patients (50.9%) had bilateral CTS, with 94 (22%) undergoing staged bilateral surgeries. This matches studies showing 50–80% bilateral involvement on nerve studies, though not all require immediate surgery [30].
- Recurrence and Revision Rates: Our 1–2% revision rate aligns with published 1.5% rates for reoperation. Most cases of recurrence in our series were due to incomplete decompression or underlying conditions, similar to reported findings.
- Comorbidities: Our high prevalence of diabetes (28.5%), obesity (39%), and RA (8.6%) mirrors literature indicating metabolic and inflammatory disorders increase CTS risk.

Case Reports

To illustrate real-world clinical scenarios, we present two representative cases highlighting key aspects of bilateral CTS presentation, surgical management, and postoperative outcomes.

Case 1

Bilateral CTS in a 69-Year-Old Male with Diabetes A 69-year-old right-handed male with type 2 diabetes and hypertension presented with progressive numbness, tingling, and grip weakness in both hands, more severe on the left. Symptoms interfered with daily activities, including buttoning his shirt and gripping objects. Nerve conduction studies confirmed severe CTS bilaterally, with prolonged median nerve latencies. Conservative treatments, including wrist splints and NSAIDs, provided little relief.

He initially underwent open carpal tunnel release (CTR) on the left hand, experiencing significant improvement in sensation and function. Postoperatively, he had delayed wound healing, likely due to his diabetic status, but no infection. He engaged in hand therapy to restore full dexterity. One year later, he developed worsening symptoms in his dominant right hand, necessitating a second CTR. The staged approach allowed uninterrupted hand function during recovery, and the second surgery also resulted in symptom relief. Follow-up at six months postoperatively showed full functional recovery, though mild residual numbness persisted in the fingertips. This case highlights diabetes as a risk factor for delayed recovery and reinforces the common bilateral nature of CTS, necessitating careful monitoring for progression in the contralateral hand.

Case 2

Bilateral CTS in a 72-Year-Old Female with Obesity A 72-year-old woman with obesity and hypertension developed progressive left-hand CTS symptoms, characterized by nocturnal pain and clumsiness while performing fine motor tasks. She had a gradual decline in hand strength and occasional hand swelling. Electrophysiologic studies confirmed moderate-to-severe median nerve compression bilaterally, though symptoms were more pronounced on the left.

She underwent staged CTR, starting with the more affected left hand. Postoperative recovery was uneventful, with full symptom resolution within six weeks. Physical therapy was initiated to improve grip strength. Within a year, she developed similar symptoms in the right hand, which was subsequently treated with CTR. Healing was smooth, and she regained full function without complications. Despite obesity being a recognized risk factor for CTS, it did not delay her postoperative recovery. At one-year follow-up, she reported complete resolution of symptoms in both hands, with no recurrence. This

case further demonstrates the high bilateral occurrence of CTS and the effectiveness of staged surgery in elderly patients, allowing gradual functional restoration without significant disability during recovery.

Both cases emphasize the importance of staged bilateral surgical planning, risk factor consideration (diabetes, obesity), and tailored patient management to optimize recovery and function. These cases also illustrate that while comorbidities may prolong healing, staged CTR remains a highly effective approach for managing bilateral CTS in medically complex patients.

Figure 1. Surgical skin antisepsis, local lidocaine anesthesia, and skin incision performed.

Figure 2. Surgical retractor, layer dissection, and exposure of the flexor retinaculum.

Conclusion

Key Findings

Our 442-patient analysis confirms that carpal tunnel release is highly effective, with outcomes aligning with international literature. The patient profile was predominantly female (70.6%), older adults (mean age 59 years), with common comorbidities like diabetes (28.5%), obesity (39%), and RA (8.6%). Bilateral CTS was frequent (50.9%), with 22% requiring staged surgery. The right hand was affected in 60.2% of cases. Surgery led to symptom relief in nearly all patients, with low recurrence (1–2%) linked to incomplete decompression, RA, or smoking. Complications were rare (infection 0.5%, no major nerve injuries). Urban patients comprised 69.7%, reflecting better access to care, while rural patients were underrepresented. Occupational factors played a role in 41.9% of cases.

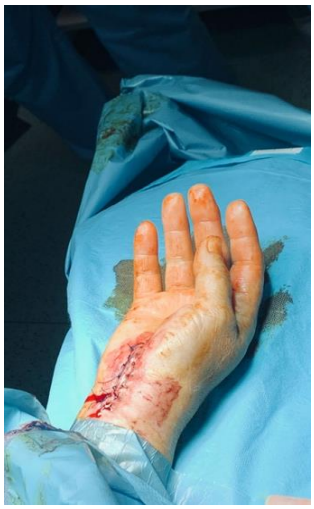

Figure 3. Skin closure with sutures.

Clinical Implications

Managing modifiable risk factors such as diabetes, obesity, and RA may improve outcomes. Open CTR remains the gold standard, offering low complication rates and high success. Patients should be aware of recurrence risks in RA and smokers. The urban-rural gap underscores the need for better rural access to care, and workplace interventions could prevent work-related CTS.

Final Thoughts

CTS is influenced by medical, occupational, and lifestyle factors. Our findings confirm high surgical success, the importance of early diagnosis, and the need for equitable access. CTR provides lasting relief with minimal risk, emphasizing the value of prevention, conservative management, and improved rural healthcare access.

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