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ARTICLE

Surgical intervention for carpal tunnel syndrome in individuals with spinal cord injuries—patient characteristics, diagnostic considerations, and treatment outcomes

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Abstract

Study design A retrospective chart audit.

Objectives To characterize SCI patients with carpal tunnel syndrome (CTS) and evaluate the diagnostic rationale for surgical decision-making.

Setting Swiss Paraplegic Centre, Nottwil, Switzerland.

Methods Retrospective investigation of medical history, diagnostics, surgeries, and outcomes of surgical treatments of CTS in patients with para- and tetraplegia.

Results We identified a total of 77 surgeries for CTS in 55 patients: 16 females (25 surgeries) and 39 males (52 surgeries) with spinal cord injury. The majority (47 persons, 68 surgeries) were paraplegic (level of lesion Th2 and below); 8 persons (9 surgeries) were tetraplegic (level of lesion Th1 and above). ASIA scores in the tetraplegic group were A: 0, B: 1, C: 4, D: 3 while complete lesions predominated in the paraplegic group (A: 32, B: 4, C: 5, D: 6). Sixty-six out of 77 patients reported total relief of symptoms. Neither nerve conduction velocity nor motor amplitude correlated well with the severity of CTS. Co-morbidity and specific risk factors were rare.

Conclusions SCI patients with CTS respond well to surgical decompression of median nerve regardless of level and type of spinal cord lesion and risk factors. Nerve conduction parameters and clinical findings can provide additional diagnostic support of CTS although nocturnal hand paresthesia, wrist pain at and after loading as well as failed conservative treatment are the main indications for surgical interventions. Based on symptomatology, clinical findings, and nerve conduction studies, we propose a decision-making tree for suggesting surgery or not.

Introduction

Carpal tunnel syndrome (CTS) is more common in people with spinal cord injuries (SCI) than in the general population [1–6]. In paraplegic and tetraplegic persons, the upper extremities fulfill a more demanding task than in able-body individuals, including locomotion and weight-bearing.

Diagnostics of CTS is primarily clinical. Medical history will often reveal classical symptoms as numbness in the region of median nerve distribution or nocturnal pain relieved by shaking the hands. Other symptoms as clumsiness or weakness in advanced stages are often reported [1, 7]. Clinical examination with provocative tests and sonography can confirm diagnosis [7, 8]. Nerve conduction studies (NCS) are often recommended in evaluating the location of nerve compression and the extent of nerve damage [9, 10]. Reference values in NCS have been set for CTS [10] but there is a lack of knowledge verifying if they are also valid in patients with spinal cord injury. As peripheral sensory nerve fibers originate in the extramedullar dorsal ganglion, sensory nerve action potentials are not affected by spinal cord injury—unless there is a peripheral nerve lesion, i.e., nerve entrapment or nerve damage at the level of the spinal cord injury. Compound motor action potentials are often pathologic at the level of injury due to intramedullar damage of ventral horn cells—and not only because of suspected peripheral nerve compression [11, 12]. Still, there are several publications describing pathologic NCS indicating a median nerve mononeuropathy in para- and tetraplegic persons without clinical symptoms for CTS and vice versa [1, 2, 4, 6]. Depending on the location of

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nerve entrapment, surgery can often relieve symptoms [7, 13]. Hand surgeons faced with the problem of false-positive and false-negative diagnostic results of CTS in persons with SCI have to decide whether to offer surgery or proceed with conservative measures.

Studies specifically addressing diagnostics and outcomes after surgery of peripheral nerve entrapment syndromes are rare in people with SCI [14]. We believe that the lacking information is, at least partly, due to the multifold of caregivers providing surgical nerve decompressions in different outpatient settings and not necessarily in communication with a spinal unit. In the current retrospective study, all patients were examined, diagnosed, operated, and controlled within the framework of a comprehensive spinal cord injuries hospital. This single-centre study highlights the demographics of CTS in persons with SCI and provides an algorithm for management.

Methods

We searched the clinic-intern database for all patients who had undergone surgery for median nerve compression in the carpal tunnel from 2012 till the beginning of 2020 (8 years). Persons in whom American Spinal Injury Association (ASIA) impairment score was not applicable were excluded. Variables included demographics, level and date of spinal cord lesion, ASIA impairment score, date of surgery, comorbidities, patient history, and clinical tests of CTS, NCS, and outcome of surgery. We recorded NCS with date of examination, motor latency, motor amplitude, and sensory nerve conduction velocity for the median nerve. We documented obesity and other comorbidities that are known as risk factors for CTS as outlined by Cagle et al. [15]—these are thyroid disease, diabetes, inflammatory disease, and other neuropathy of the upper extremity. We assessed the medical records of all our patients for medical history, physical examination, and prior treatment (cortison infiltration, splinting, surgery) or concomitant surgery with the carpal tunnel release.

Surgery indication score

We developed a scoring system to introduce an algorithm for diagnosing CTS in patients with spinal cord injury with clinical and electrodiagnostic measures. Diagnosis and decision for surgery is based on three criteria groups: (1) clinical history, (2) physical examination, and (3) NCS.

Clinical history

In reviewing clinical history of our patients, we classified symptoms as light (intermittent tingling, discomfort; 1 point), moderate (predominantly nocturnal pain with disturbed night sleep; 2 points), and severe (unbearable pain, loss of sensation, muscle weakness; 3 points).

Physical examination

Physical examination included wrist flexion/Phalen test or carpal compression/Durkan test [16], Tinel test, and sensory disturbances, each scoring 1 point with a total of 3 points if all were positive.

Nerve conduction studies

Due to our institutional guidelines and according to international standards [10], values >4 ms for distal median motor latency, <5 mV for median motor amplitude at the wrist, and <45 m/s for median sensory nerve conduction velocity are validated as pathologic for carpal tunnel syndrome. Each one was given 1 point if rated pathologic.

This makes a maximum score of 9 points when all criteria in these 3 criteria groups are positive. By requiring no less than 1 point from "Clinical history", symptom-free patients would not be operated initially regardless of supplemental points from both "Physical examination" and "Nerve conduction studies". With 2 or 3 points obtained in category "Clinical history" and strong "Physical examination" findings (3 points), surgery could be recommended with/without supportive "Nerve conduction studies". Likewise, if patient reports substantial symptoms (2 or 3 points under "Clinical history"), robust "Nerve conduction studies" results (3 points) would justify carpal tunnel release with or without positive "Physical examination".

The scoring system has yet to be validated. However, since all patients were assessed and operated within a comprehensive spinal cord injury hospital and annually followed up according to the in-house guidelines, we would have detected missed CTS diagnosis if present.

Preparation for surgery

Each patient was instructed by a therapist how to transfer to and from wheelchair, typically over the fist, and conduct essential daily activities post-surgery. The therapist supervised practical training when needed.

Surgery

Decompression of the median nerve at the carpal tunnel was conducted as a minimal-incision open procedure described by Bromley [17] with exception of the closure of the palmar aponeurosis, which was always left open in our series. In recurrent carpal tunnel syndrome, typically diagnosed within 6 months post primary surgery, we used an extended approach. All procedures were performed by a surgeon

Table 1 Patient characteristics.

	Tetraplegia	Paraplegia Th7 & above	Paraplegia Th8 to L1
Gender			
Female	2	12	2
Male	6	11	22
Mean age at the time of surgery (years)	65.5 (±11.3)	59.8 (±11)	61.7 (±8.8)
Female	60.6 (±11)	59.9 (±12.5)	63.6 (±1.8)
Male	75.1 (±1.4)	59.7 (±9.2)	61.6 (±9.1)
Mean interval SCI to surgery (years)	14.2 (±15.7)	24.2 (±14.5)	29.1 (±14.2)
Number (percentage) of patients with risk factors for CTS	3 (37.5%)	5 (21.7%)	2 (8.3%)
Number of recurrent CTS surgeries (total number of CTS surgeries)	3 (9)	0 (35)	4 (33)
Symptoms			
Light	2	7	7
Moderate	5	18	22
Severe	2	10	4
NCS (median nerve)			
Mean (SD) mot. lat. (ms)	4.5 (±1.2)	6.3 (±1.6)	5.7 (±1.8)
Mean (SD) mot. amp. (mV)	4.8 (±4.2)	4.5 (±3.1)	4.6 (±2.8)
Mean (SD) sens. vel. (m/s)	47.2 (±23)	32.4 (±17.4)	38 (±17.5)
Outcome (symptom relief)			
Good	6	29	31
Partial	3	2	2
None	0	4	0

level 3 or higher according to Tang [18]. After completion of the surgery and the wound dressing, the wrist was supported with an elastic bandage for 10–14 days.

Postoperative assessments

In general, patient-perceived outcomes were evaluated 4–6 weeks post-surgery by the surgeon as total, partial or no relief of symptoms. At follow-ups, we encourage our patients to refer again to our unit or alert the responsible rehabilitation physician if experiencing reappearance of symptoms of peripheral nerve compression.

Results

We identified a total of 77 surgeries for CTS in 55 patients with spinal cord injury, seven of which were revision surgeries. Gender distribution was as follows: 16 female (25 surgeries), 39 male (52 surgeries) (Table 1). The majority (47 persons, 68 surgeries) were paraplegic (level of lesion Th2 and below), 8 persons (9 surgeries) were tetraplegic (level of lesion Th1 and above) (Fig. 1). The predominance of ASIA A lesions in the paraplegic group remained true when dividing the paraplegic group according to the International Wheelchair Basketball Federation (IWBF) classification for rating trunk stability [19] (Fig. 2). There were no patients with a spinal cord lesion below L1.

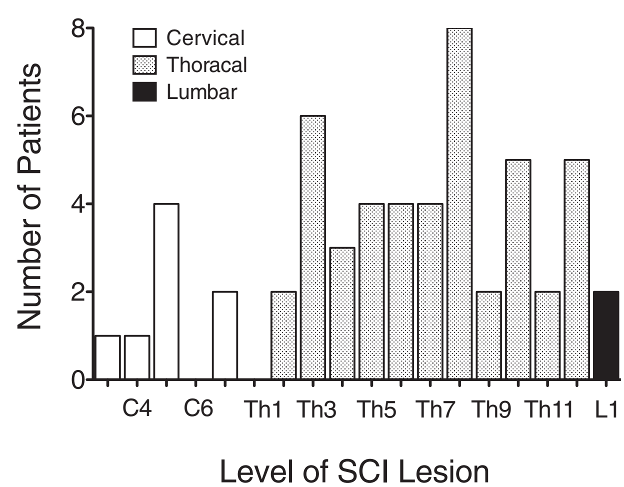

Fig. 1 Number and distribution of CTS surgeries among patients with different SCI lesion levels. Note that the majority of the patients operated had paraplegia (Th2-Th12).

Overall, mean age at the time of surgery was slightly higher for persons with tetraplegia than for paraplegic

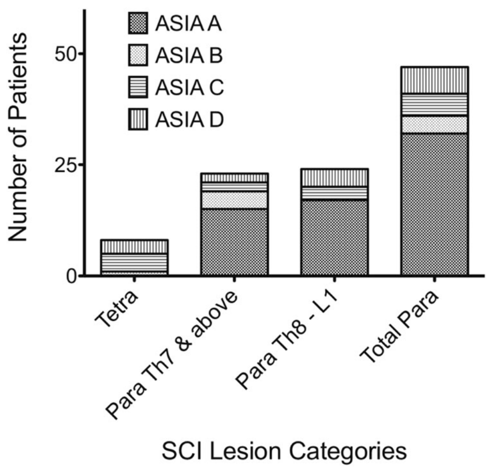

Fig. 2 Number and distribution of CTS surgeries among different ASIA score categories. Para = Paraplegia, Tetra = Tetraplegia.

persons (Table 1). Time from onset of spinal cord lesion to surgery was shorter in the tetraplegic than in the paraplegic group.

Comorbidities as risk factors for CTS were found in 3 persons in the tetraplegic group: 1 female with other neuropathic pain, 2 males; one with thyroid disease and the other with inflammatory disease plus diabetes. In the paraplegic group, 7 persons with comorbidities were found: 2 female (1 diabetes, 1 thyroid disease), 5 male (2 with obesity, 1 with obesity and diabetes, 1 with inflammatory disease, and 1 other neuropathy).

Mean (SD) age at time of surgery for CTS in tetraplegic and paraplegic persons without risk factors was 61 (13.3) and 60.3 (9.9) years. All patients undergoing carpal tunnel release had NCS prior to surgery, NCS data were accessible in 61 of 77 cases (79.2%). Analysis of nerve conductions studies in patients with carpal tunnel syndrome showed a mean (SD) sensory nerve conduction velocity for the median nerve of 47.2 (23.1) m/s in the tetraplegic group vs 35.5 (17.8) m/s in the paraplegic group, mean (SD) distal median motor latency/motor amplitude was 4.5 (1.2) ms/4.8 (4.2) mV vs 6.0 (1.7) ms/ 4.6 (3.0) mV respectively. Outcome assessments revealed a total relief of symptoms in 66 surgeries (85.7% responders to carpal tunnel surgery). Those with no (4 cases) or partial (7 cases) relief of symptoms (non-responders) had advanced stage CTS as indicated by their medical history or NCS values except one patient. She preoperatively suffered from serious neuropathic pain, which was only partially relieved by surgery.

We found information of all 3 criteria groups (medical history, physical examination, NCS) in 54 surgeries: 48 stated total relief of symptoms after surgery (47 with a score ≥5), while the remaining 6 stated partial or no relief of symptoms (all of them with a score ≥5) (Fig. 3).

Discussion

This study reports a structured diagnostic approach for carpal tunnel syndrome in patients with SCI. We believe that the proposed scoring system combining symptoms and clinical and neurophysiological examination increases the accuracy of diagnosing CTS, and facilitates the choice of treatment (Fig. 4). Secondly, we are confident that a comprehensive SCI hospital with short internal referral routines secures timely diagnosis and treatment of PNES. In addition, it is likely that any recurrence of CTS would be more expediently discovered in a comprehensive unit with regular check-up of SCI patients.

Our study demonstrated that paraplegic persons more frequently undergo surgery for carpal tunnel syndrome than individuals with tetraplegia. Studies of CTS in able-body cohorts indicate that heavy and long-lasting loading plays an etiological role in males [7]. In SCI persons, manual wheelchair driving may represent such an overload circumstance especially in those who have manual work, much time of outdoor driving on uneven surface, and persons involved in demanding sports, e.g., wheelchair basketball or rugby. Another cause of discrepancy can be that hand sensation disturbances is frequently present due to the SCI per se and may therefore be neglected or underdiagnosed in patients with tetraplegia. However, the number of tetraplegic persons undergoing surgery for CTS was relatively small in our series. Most of them were operated in the past 3 years, when our consciousness about the high incidence of PNES in tetraplegic persons was increased with growing experience. This may be the reason why the time since SCI and CTS surgery was shorter.

Demographics in our study population for carpal tunnel surgery are different than in persons without spinal cord injury. While in normal population, carpal tunnel syndrome with subsequent surgery affects predominantly women with an age of around 50 years [7, 20, 21], our patient group consisted of 69% of men with a mean age of 60 years. The overrepresentation of males with SCI cannot fully explain the observed difference. The cause of idiopathic CTS in women is often referred to hormonal factors [7]. The fact that endocrine changes may occur after SCI [22], may account to protect women with SCI for developing CTS.

Mean values and standard deviation for motor latency and sensory velocity of median nerve indicated that they are close to the pathologic-defined margins, especially in tetraplegic persons. That means that we not only did surgery in patients where CTS was clearly defined by NCS, but also in a mentionable number of patients below the pathologic limits. This is not surprising when considering the number of false-positive and false-negative results for NCS in patients without symptoms [1, 2, 4, 6]. We found that in our patient group, the reported symptoms were either confirmed by one or more positive criteria in the physical examination prior to

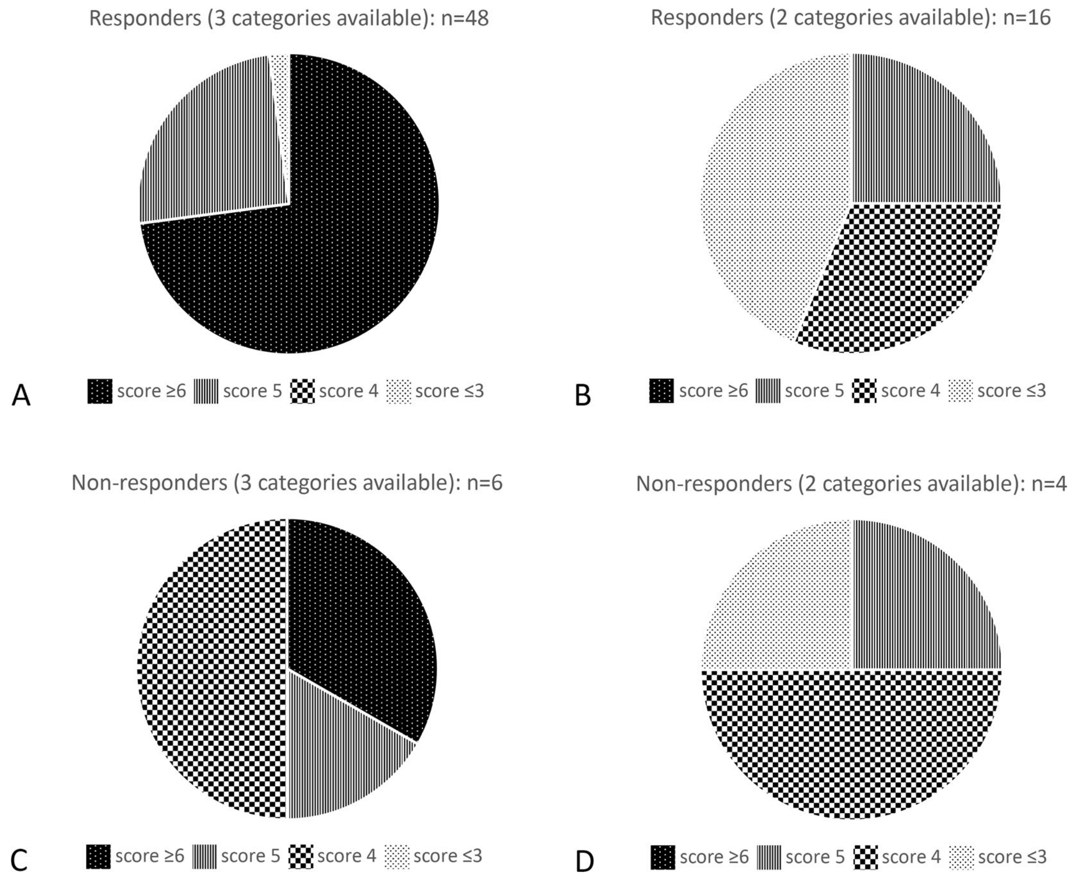

Fig. 3 Number of CTS surgeries based on scoring system for symptoms, clinical examination, and nerve conduction studies. Responders (**A** and **B**): number of surgeries with total relief of symptoms after median nerve decompression at the carpal tunnel. Non-responders (**C** and **D**): number of surgeries with no or partial relief of symptoms after median nerve decompression at the carpal tunnel. *Scoring* (3 criteria groups with 3 criteria each). Clinical history (mandatory)—light: 1 point, moderate: 2 points, severe: 3 points. Physical examination—Tinel sign: 1 point, Durkan or Phalen: 1 point, sensory disturbances: 1 point. NCS—median distal motor latency >4 ms: 1 point, sensory nerve conduction velocity <45 m/s: 1 point, median motor amplitude at the wrist <5 mV: 1 point.

surgery. Although the physical examination in our CTS patients is standardized, documentation was missing in some cases. Thus, data are partially incomplete regarding this section. Other patients did undergo carpal tunnel release in context with other surgery when their medical history was suspicious for median nerve mononeuropathy or when previous conservative treatment failed. In our series, 61 surgeries had documented preoperative NCS. All of them had pathologic values in one or more of the above-mentioned criteria. The majority of them responded to our surgical treatment suggesting that NCS can be a useful adjunct tool for diagnosing CTS in patients with SCI. Indeed, NCS did guide us for treatment decisions in both directions, i.e., surgery or no surgery in accordance with current research [23]. For example, for a patient with mild symptoms and lacking clear NCS support of CTS, continued conservative treatment may be advocated without risk of deteriorating the median nerve functionality. This approach is supported by our scoring system. The majority of patients with complete criteria data (medical history, physical examination, NCS) available reported a good outcome with a calculated score ≥5 (Fig. 3A). In those scoring ≥5 but stating partial or no relief, we must keep in mind that they had advanced stages of CTS as indicated by NCS and outcome assessment was too short (<6 weeks) for detecting nerve regeneration.

Both clinical examination and NCS are merely snapshots of the potential median nerve compression. The only long-term observation is made by the patient herself/himself. Hence, the scoring system for surgical intervention requires at least one point extracted from symptoms. In other words, no symptom-free patient was operated.

Considering the potential biomechanical effects after division of the flexor retinaculum [24, 25] and facing the fact that our group of patients greatly relies on their hand function in terms of weight-bearing and extreme wrist positions, we would expect less favorable outcomes after carpal tunnel release than in able-body individuals. Nonetheless, revision surgery for carpal tunnel syndrome occurred only rarely in our series, suggesting that the majority of patients had a successful outcome after surgery,

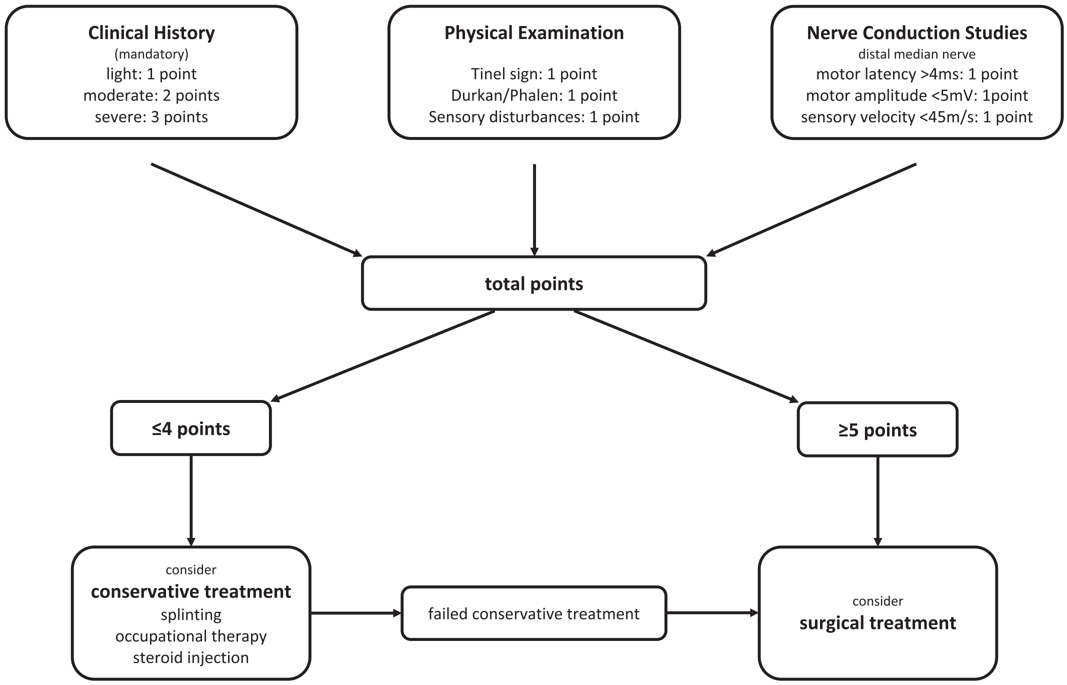

Fig. 4 Proposed algorithm for decision-making in CTS treatment. Diagnosis and decision for surgery is based on 3 criteria groups: Clinical History, Physical Examination and Nerve Conduction Studies. Clinical History includes symptoms with 3 different levels of severity: light (intermittent tingling, discomfort), moderate (nocturnal pain with disturbed night sleep), and severe (unbearable pain, loss of sensation, muscle weakness).

assuming that they otherwise would have been referred to our center again. We assume that we optimized the outcomes by instructing the patients regarding nerve- and scar-protecting wheelchair transfer- (over the closed fist) and propelling-techniques [26]. This often precludes outpatient surgery. In the current retrospective study, all patients were examined, diagnosed, operated, and controlled within the framework of a comprehensive spinal cord injuries hospital which allowed for a more reliable description of the patient demographics as well as diagnostical considerations and clinical results. That is where we see the strength of a comprehensive unit for spinal cord injured patients: it leaves few patients undetected regardless of the type of problem, it provides reproducible results by standardized protocols (surgical techniques and postoperative procedures including patient instructions) and it recognizes complications early by wide acceptance and publicity in the population with prompt access to follow-up.

Limitations

The retrospective nature of the study as well as the lack of documented long-term outcomes must be considered. Indeed, in the majority of our CTS cases, patients reported a total relief of symptoms several weeks after surgery, but we did not follow them over years. Some patients ($n = 11$) had incomplete clinical examination records (<3 criteria documented).

Conclusions

In patients with SCI and CTS, surgical decompression of median nerve is normally successful regardless of level and type of spinal cord lesion and risk factors. The relative over-representation of CTS in paraplegia vs. tetraplegia calls for attention on shoulder muscle strength training as well as wheelchair propelling and transfer techniques. Nerve conduction parameters and clinical findings can provide additional diagnostic support of CTS although nocturnal hand paresthesia, wrist pain at and after loading as well as failed conservative treatment are the main indications for surgical interventions. Based on symptomatology, clinical findings, and NCS, we propose a refined decision-making tree for treatment.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the Ethics Committee of Northwestern and Central Switzerland, project number 2020-2020-01837.

References

1. Asheghan M, Hollisaz MT, Taheri T, Kazemi H, Aghda AK. The prevalence of carpal tunnel syndrome among long-term manual wheelchair users with spinal cord injury: a cross-sectional study. J Spinal Cord Med. 2016;39:265–71.
2. Davidoff G, Werner R, Waring W. Compressive mononeuropathies of the upper extremity in chronic paraplegia. Paraplegia. 1991;29:17–24.
3. Sie IH, Waters RL, Adkins RH, Gellman H. Upper extremity pain in the postrehabilitation spinal cord injured patient. Arch Phys Med Rehabil. 1992;73:44–48.
4. Yang J, Boninger ML, Leath JD, Fitzgerald SG, Dyson-Hudson TA, Chang MW. Carpal tunnel syndrome in manual wheelchair users with spinal cord injury: a cross-sectional multicenter study. Am J Phys Med Rehabil. 2009;88:1007–16.
5. Zukowski LA, Roper JA, Shechtman O, Otzel DM, Hovis PW, Tillman MD. Wheelchair ergonomic hand drive mechanism use improves wrist mechanics associated with carpal tunnel syndrome. J Rehabil Res Dev. 2014;51:1515–24.
6. Tun CG, Upton J. The paraplegic hand: electrodiagnostic studies and clinical findings. J Hand Surg Am. 1988;13:716–9.
7. Genova A, Dix O, Saefan A, Thakur M, Hassan A. Carpal tunnel syndrome: a review of literature. Cureus. 2020;12:e7333.
8. Choi SJ, Ahn JH, Ryu DS, Kan CH, Jung SM, Park MS, et al. Ultrasonography for nerve compression syndromes of the upper extremity. Ultrasonography. 2015;34:275–91.
9. Kane NM, Oware A. Nerve conduction and electromyography studies. J Neurol. 2012;259:1502–8.
10. Jablecki CK, Andary MT, Floeter MK, Miller RG, Quartly CA, Vennix MJ, et al. Practice parameter: electrodiagnostic studies in carpal tunnel syndrome. Report of the American Association of Electrodiagnostic Medicine, American Academy of Neurology, and the American Academy of Physical Medicine and Rehabilitation. Neurology. 2002;58:1589–92.
11. Curt A, Dietz V. Nerve conduction study in cervical spinal cord injury: significance for hand function. NeuroRehabilitation. 1996;7:165–73.
12. Krasilovsky G. Nerve conduction studies in patients with cervical spinal cord injuries. Arch Phys Med Rehabil. 1980;61:204–9.
13. Toussaint CP, Perry EC III, Pisansky MT, Anderson DE. What's new in the diagnosis and treatment of peripheral nerve entrapment neuropathies. Neurol Clin. 2010;28:979–1004.
14. Barr C, Suarez P, Ota D, Curtin CM. Is carpal tunnel release under-utilized in veterans with spinal cord injury? J Spinal Cord Med. 2011;34:563–8.
15. Cagle PJ Jr, Reams M, Agel J, Bohn D. An outcomes protocol for carpal tunnel release: a comparison of outcomes in patients with and without medical comorbidities. J Hand Surg Am 2014;39:2175–80.
16. Durkan JA. A new diagnostic test for carpal tunnel syndrome [published correction appears in J Bone Joint Surg Am 1992 Feb;74(2):311]. J Bone Jt Surg Am. 1991;73:535–8.
17. Bromley GS. Minimal-incision open carpal tunnel decompression. J Hand Surg Am. 1994;19:119–20.
18. Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur Vol. 2016;41:365–6.
19. Curtis KA, Kindlin CM, Reich KM, White DE. Functional reach in wheelchair users: the effects of trunk and lower extremity stabilization. Arch Phys Med Rehabil. 1995;76:360–7.
20. Day CS, Makhni EC, Mejia E, Lage DE, Rozental TD. Carpal and cubital tunnel syndrome: who gets surgery? Clin Orthop Relat Res. 2010;468:1796–803.
21. Mondelli M, Giannini F, Giacchi M. Carpal tunnel syndrome incidence in a general population. Neurology. 2002;58:289–94.
22. Huang TS, Wang YH, Lai JS, Chang CC, Lien IN. The hypothalamus-pituitary-ovary and hypothalamus-pituitary-thyroid axes in spinal cord-injured women. Metabolism. 1996;45:718–22.
23. Mackenzie SP, Stone OD, Jenkins PJ, Clement ND, Murray IR, Duckworth AD. et al. Carpal tunnel decompression in patients with normal nerve conduction studies. J Hand Surg Eur Vol. 2020;45:260–4.
24. Morrell NT, Harris A, Skjong C, Akelman E. Carpal tunnel release: do we understand the biomechanical consequences? [published correction appears in J Wrist Surg. 2016;5:167]. J Wrist Surg. 2014;3:235–8.
25. Brooks JJ, Schiller JR, Allen SD, Akelman E. Biomechanical and anatomical consequences of carpal tunnel release. Clin Biomech. 2003;18:685–93.
26. Boninger ML, Impink BG, Cooper RA, Koontz AM. Relation between median and ulnar nerve function and wrist kinematics during wheelchair propulsion. Arch Phys Med Rehabil. 2004;85:1141–5.