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Clinical Article

Endoscopic Release of Carpal Tunnel Syndrome ; Temporal Correlation between Symptomatic and Electrophysiological Improvements in Postoperative Carpal Tunnel Syndrome

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Objective : We evaluate temporal correlations between postoperative symptomatic and electrophysiological improvements, and assessed the recovery time required for patients with carpal tunnel syndrome(CTS) before returning to routine activities.
Methods : 30 CTS patients were treated via the endoscopic monoportal approach, from March 2001 to September 2003. We assessed the symptoms (hyperesthesia in the finger tips, or abnormal sensations and painful numbness or night pain) and electrophysiological changes in the preoperative state, 1 month and 6 months after surgery. We marked the times at which patients became able to return to activities of daily living and work, after undergoing endoscopic carpal tunnel release.
Results : At the end of the follow-up period, high levels of achievement and good outcomes were observed, with respect to both the symptoms and electrophysiological studies. We discovered significant differences between the preoperative and postoperative periods, especially in terms of motor nerve onset latency from 4.50 ± 1.43 to 3.97 ± 0.69 and sensory nerve conduction velocity, the wrist-to-finger from 19.81 ± 10.03 to 28.18 ± 11.01 and wrist-to-palm from 23.34 ± 13.40 to 31.79 ± 13.38($P< 0.05$ for each comparison). The average time interval required before return to activities of daily living was 26.4 days, and time interval required before return to work was 48.08 days.
Conclusion : Electrophysiological improvements are largely consistent with symptomatic relief, but there is some disparity between electrophysiological and symptomatic improvement.

KEY WORDS : Carpal tunnel syndrome · Symptom · Electrophysiological study · Return to activities of daily living · Return to work.

Introduction

Patients with carpal tunnel syndrome(CTS) exhibit a variety of symptoms. Typically, these include soreness or paresthesia of the entire hand with the exception of the little finger, with an intensification of pain with extended use of the affected hand and wrist. Most cases of CTS affect the patient bilaterally, but the symptoms are more severe on the dominant side. In some cases, atrophy is seen in the abductor muscle of the thumb, among the thenar muscles[9]. Other symptoms include tingling sensations in the finger tips but not the palm, decreased hand function caused by hand stiffness or pseudo-weakness coupled with mild tingling sensation, and mild night pain. CTS cases are treated either conservatively or surgically. There should be accurate diagnostic criteria for surgery, so in this study we assessed and considered such criteria as; postoperative symptomatic improvement and prognosis, correlations between electrophysiological changes and symptoms, loss of hand function, return to activities of daily living(RADL), return to work(RTW), and complications.

Materials and Methods

Patient population

We examined 44 hands of 30 patients who had undergone CTS surgery at our hospital from March 2001 to September 2003. Among the 30 subjects(44 hands), 14 patients(13 females and one male) exhibited bilateral CTS, whereas in 11 patients only the right hand was affected, and only the left hand in five. Patients' ages varied significantly, ranging from 30 to 74 years, with a m-ean age of 51.37 ± 11.19 years. The symptoms had persisted for between one and 120 months, with

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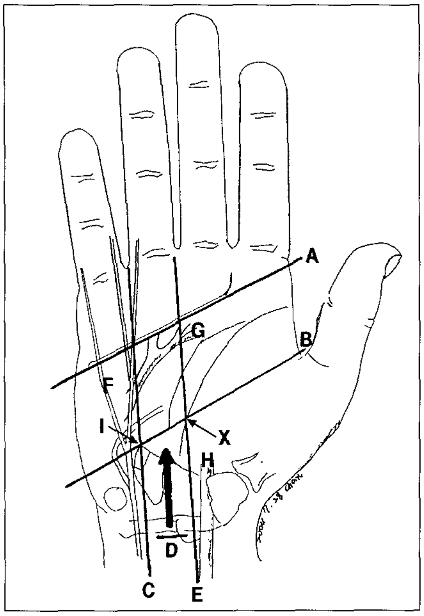

Fig. 1. Safe zone for transverse carpal ligament incision and related structure. The safe zone is within a area defined by the ulnar proximal margin of the superficial palmar arch(G), radial border extension line of the little finger(C), radial border extension line of the ring finger(E). A : distal palmar crease transverse extension line. B : Kaplan's line. C : radial border extension line of the little finger. D : skin incision site. E : radial border extension line of the ring finger. F : ulnar nerve. G : superficial palmar arch. H : flexor carpi radialis. I : hook of hamate. X : emergence site of the median nerve motor branch. Large arrow : direction of transverse carpal ligament incision.

a mean of 51 months. Five patients complained of symptoms persisting for more than 10 years and could not remember exactly how long they had been afflicted. The remaining 25 patients had been exhibiting symptoms for an average of 34.17months. In terms of patients' medical histories, five patients were diagnosed with hypertension, two had hypertension with cerebral infarction, two had diabetes mellitus although no diabetic neuropathic findings were reported in the eletrophysiological studies, two had liver disease and two suffered from pulmonary tuberculosis. However, the remaining 17 patients exhibited no associated medical diseases. Among the 30 patients who had undergone surgery, 15 worked mainly with their hands, and 15 were housewives. Out of the 15 job-related hands or wrist overuse patients, four patients were farmers, four were manual laborers, one was typist, and six were restaurant workers. Out of the 15 housewives, all but two were currently either menopausal or post-menopausal with an average age of 54.93 years old.

Patients presenting the characteristic symptoms and signs of CTS, with positive nerve conduction studies, and who are found to have normal bony structures of the carpal tunnel in the carpal tunnel view can become candidates for endoscopic carpal tunnel release via monoportal approach(ENDOCARP®, Linvatec, Largo, Florida in U.S.A).

The Gachon medical school, Gil hospital's criteria for a positive median nerve conduction study result are more than 3.9m/s motor nerve onset latency, less than 50.6m/s motor nerve conduction velocity(NCV), less than 34.5m/s sensory NCV between the finger and wrist, less than 40.6m/s sensory NCV between the palm and wrist, and less than 48.1m/s sensory NCV between the wrist and elbow.

Surgical technique

The patient is placed in the supine position on the operating table with the involved arm abducted 90 degrees and the hand placed on a hand table. The hand is prepared and draped in the usual fashion. The tourniquet is inflated to 250mmHg. The volar aspect of the wrist is painted with betadine solution, and then 3cc of 1% lidocaine is infiltrated into the skin over the proposed incision site, using a 25-gauge needle. The needle is then introduced into the carpal tunnel at about a 45 degree angle along the long axis of the forearm and another 4cc of lidocaine is injected. The external landmarks on the volar aspect of the wrist are used to locate the distal margin of the transverse carpal ligament. The pisiform bone is palpated and marked on the ulnar aspect of the wrist. The cardinal line of Kaplan is drawn from the apex of the interdigital fold between the thumb and the index finger toward the ulnar side of the hand, parallel to the distal palmar crease. This line passes approximately 4~5mm in front of the pisiform bone. A second line is drawn parallel to the ulnar border of the ring finger, proximally toward the wrist. This line intersects the cardinal line at a point which is radial and distal to the pisiform bone. The point at which these lines intersect corresponds to the hook of hamate(the distal ulnar attachment of the transverse carpal ligament). Next, the intersection of the thenar crease is marked at the cardinal line. The motor branch of the median nerve emerges from beneath the transverse carpal ligament and makes a recurrent course at this point. The distal border of the transverse carpal ligament lies between these two reference points(Fig. 1).

A 1cm transverse incision is made at the second distal wrist crease, following the line drawn along the radial border of the ring finger. In patients in whom the palmaris longus tendon is intact, this point usually lies ulnar to the insertion of this tendon. The skin edge is retracted with skin hooks. The transverse fibers of the antebrachial fascia of the forearm are exposed by both sharp and blunt dissection. A curved hemostate is used in order to split the transverse fibers of the antebrachial fascia in the direction in which they run. These fibers blend distally with the transverse carpal ligament. A curved hemostate is introduced into the carpal tunnel through the opening in the antebrachial fascia, and the underspace of the transverse carpal ligament is scraped in order to remove the synovium. The wrist is slightly extended. The proximal end of the transverse

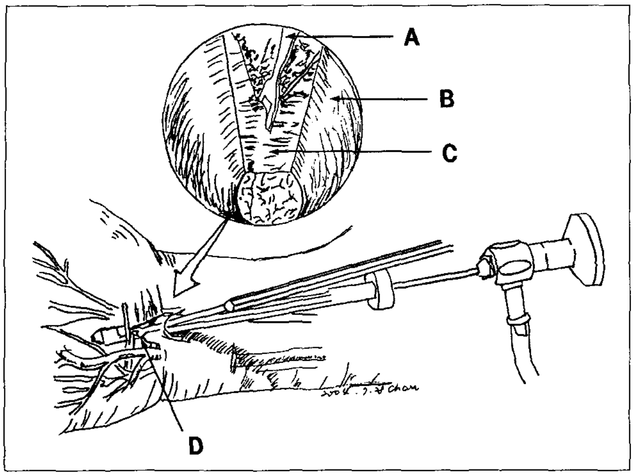

Fig. 2. Schematic diagram showing the cannula, the knife, and the partially cut transverse carpal ligament as seen through the arthroscope. A : knife. B : cannula. C : transverse carpal ligament as seen through the scope. D : transverse carpal ligament(being cut).

carpal ligament is picked up and the obturator is introduced into the carpal tunnel. The length to which the obturator is to be introduced into the carpal tunnel is externally measured, beginning at the hook of the hamate up to the incision site. The obturator is inserted into the cannula, and the cannula is then introduced into the carpal tunnel along the line of the ring finger. The cannula should lie against the hook of hamate with the slot of the cannula facing the palm. Also, the degree to which the cannula is to be introduced is externally measured in order to ensure that the cannula is not pushed all the way into the palm. Care must be taken to avoid forcing the cannula too far into the palm, so as to prevent injury to the superficial palmar arch and the communicating branch of the ulnar nerve. Due to the configuration of the carpal tunnel, the tip of the cannula tends to point radially. The wrist is extended using three or four folded towels, which are placed underneath the patient's wrist. It may be helpful to use an anti-fogging agent on the arthroscopic lens prior to its insertion into the cannula in order to obviate lens condensation. The obturator is removed and a 3mm, 30-degree arthroscope without a sleeve is introduced through the proximal end of the cannula, thereby enabling the surgeon to visualize the transverse carpal ligament. The scope is pulled back just far enough so that the proximal border of this ligament is in its sights. The knife is then placed into the cannula slot and the concavity of the knife blade is engaged against the proximal end of the ligament. Under direct arthroscopic visualization, the transverse carpal ligament is divided by pushing the knife in a proximal to distal direction. The knife is then removed, a probe is introduced into the cannula, and the cut margins of the ligament are palpated. The cannula is then removed, and the wound is closed with 5.0 nylon interrupted suture. A soft dressing is applied, and the patient is then encouraged to immediately begin to move the wrist and fingers[20](Fig. 2).

Classification according to symptoms and electrophysiological abnormalities

Symptomatic changes after surgery, including tingling sensations in the hand, hyperesthesia, abnormal sensations in the finger tips, and painful numbness or night pain were evaluated as follows; 1. No symptoms after surgery; 2. Mild remaining symptoms despite postsurgical improvement; 3. Symptoms equal to those experienced preoperatively; and 4. Symptoms worse than those experienced preoperatively.

The severity of neurophysiological CTS impairments was assessed by an Italian CTS study group, resulting in the following neurophysiological classification[15,17]. CTS hands are divided into six groups according to neurophysiological findings : extreme, absence of motor and sensory responses (EXT); severe, absence of sensory response and abnormal distal motor latency(SEV); moderate, abnormal digit/wrist sensory nerve conduction velocity and abnormal distal motor latency(MOD); mild, abnormal distal motor latency(MILD); minimal, abnormal segmental and comparative test only(MIN); and negative, normal findings on all tests(NEG). According to electrophysiological studies, changes in motor nerve onset latency, motor NCV, sensory NCV between the finger and wrist, sensory NCV between the palm and wrist, and sensory NCV between the wrist and elbow were classified as either normal or abnormal before surgery, and then re-classified postoperatively, at one month and six months. Table 1 displays the results obtained from changes in CTS symptoms and electrophysiological studies. Any decreases in hand function were evaluated before surgery, and six months after surgery, by asking the patient whether they could hold on to a light object for more than five minutes. The other items, including the possible time before return to activities of daily living (RADL), and return to work(RTW), operation site tenderness, and complications were also evaluated.

Statistical significance was determined via analysis of variance (one way ANOVA) and modified t-tests in order to delineate the specific differences between groups and times. A p-value of less than 0.05 was considered to be statistically significant.

Results

Clinical improvements and changes in electrophysiological studies findings

We detected no significant differences in data on times for symptom improvement, and in terms of electrophysiological changes between acute onset patients and chronic onset patients during the evaluation period.

Tingling sensations usually changed postoperatively. At one month, tingling sensation had improved in 43 hands, and pain had improved in all. Tingling sensation had disappeared in 20 hands, and pain had disappeared in 22. At six months, tingling sensations was reported to have improved in 43 hands, and pain in 44 hands, similar improvements to what was seen after one month; pain had disappeared in 28 hands, and tingling sensation had also disappeared in 28 hands. Both symptoms had disappeared in 26 hands at six months after surgery(Fig. 3). Motor nerve onset latency was normal in only six hands before surgery, but improved to normal in 12 hands at the one month follow-up, and at six months had improved to normal in 19 hands. Motor NCV was normal in 37 hands before surgery, and had improved to normal in 4 hands at one month, and 6 hands at six months. Sensory NCV between the finger and wrist was abnormal in 44 hands before surgery, and had improved in 34 hands at one month, and in 35 hands at six months. However, at six months, it improved to normal in 10 hands. Sensory NCV between the palm and wrist was abnormal in 42 hands before surgery, but had improved in 32 hands at one month, and had improved in 35 hands at six months. Sensory NCV values between the palm and wrist were normal in only 2 hands before surgery, and had improved to normal in 8 hands at six months. Sensory NCV between the wrist and elbow was normal in 40 hands before surgery, and improved to normal in 2 hands at six months. Thus, motor nerve onset latency improved quickly, but sensory NCV improved slowly in the six months after surgery(Fig. 4).

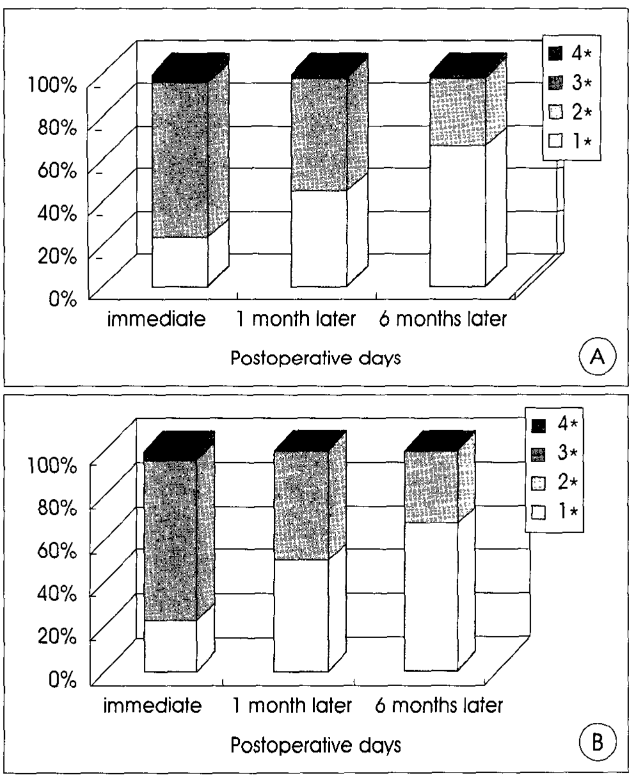

Fig. 3. Distribution of postoperative symptomatic changes. A : dysesthesia of the finger tip, abnormal sensation. B : painful numbness or night pain 1* : symptom free 2* : remaining symptom but improved state 3* : static state 4* : aggravation state.

Sensory NCV was measured prior to surgery between the finger and wrist, and between the palm and wrist. Both of these measurements were below normal ranges, at 19.81±10.03 and 24.34±13.40m/s, respectively. On the other hand, measurements of sensory NCV between the wrist and elbow were normal at 56.86±5.57m/s. At one and six months after surgery, sensory NCV values between the finger and wrist were 25.59±10.59m/s and 28.18±11.01m/s, respectively, while sensory NCV values between the palm and wrist were 30.09±14.01m/s and 31.79±13.38m/s, respectively. Thus, symptomatic improvements compared with patients' condition before surgery had occurred, but sensory NCV measurements still fell below normal ranges. Sensory NCV between the wrist and elbow was normal at one and six months, at 57.23±4.12m/s and 57.63±3.96m/s, respectively.

Motor nerve onset latency was 4.50±1.43m/s before surgery, 3.82±1.02m/s at one month, and 3.97±0.69m/s at six months. Motor NCVs were measured to be 53.54±12.88m/s, 55.00±13.07m/s, and 56.43±3.43m/s at these times respectively, evidencing improvement in motor nerve onset latencies. Sensory NCV between the finger and wrist, NCV between the palm and wrist, and motor nerve onset latency were all significantly improved (P< 0.05). Neither motor NCV nor sensory NCV between the wrist and elbow changed significantly after surgery(Table 1).

Table 1. The findings of electrophysiological studies before and after operation (ANOVA test, P<0.05)

Electrophysiological Studies			Postoperation	Postoperation 1month	Preoperation 6months	P-value
Sensory	NCV* (m/s)	F-W*	19.81±10.03	25.59±10.59	28.18±11.01	<0.05
		P-W*	23.34±13.40	30.09±14.01	31.79±13.38	<0.05
		W-E*	56.86± 5.57	57.23± 4.12	57.64± 3.96	>0.05
Motor		Onset latency (m/s)	4.50± 1.43	3.82± 1.02	3.97± 0.69	<0.05
		NCV*(m/s)	53.54±12.88	55.00±13.07	56.43±3.43	>0.05

NCV* : Nerve conduction velocity F-W* : Finger to wrist P-W* : Palm to wrist W-E* : Wrist to elbow

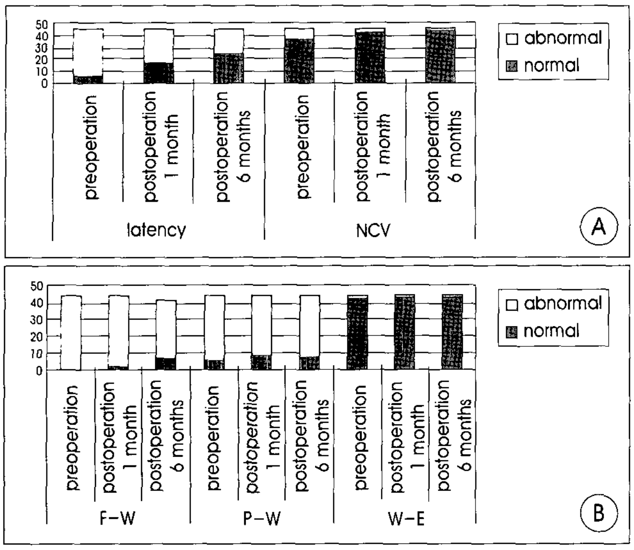

Fig. 4. Distribution of postoperative electrophysiological changes. A : latency and NCV of motor fiber. B : NCV of sensory fiber.

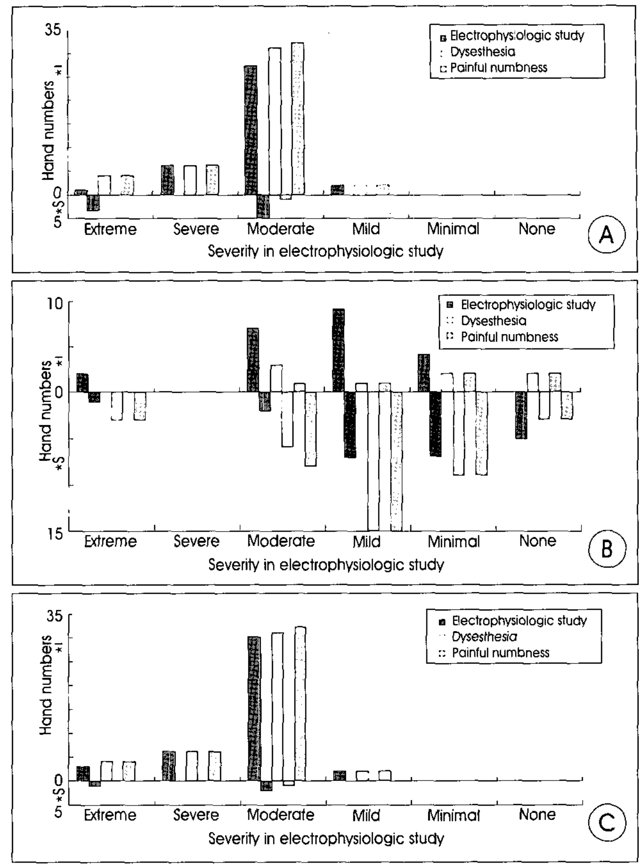

Fig. 5. Comparison of electrophysiological studies with symptoms. A : 1month after operation. B : between 1 and 6 months after operation. C : 6 months after operation. I* : improved state S* : static state.

In 4 hands manifesting 'EXT' electrophysiological abnormalities, one hand had improved at postoperative one month, 3 hands had improved at postoperative six months, but symptoms were improved in 4 hands, only one day after surgery. In 32 hands exhibiting 'MOD' electrophysiological abnormalities, 27 hands had improved at one month, 30 hands had improved at six months, and with respect to hyperesthesia and pain, all 32 hands had improved, except one hand which exhibited persisting hyperesthesia. Among the 12 hands exhibiting normal electrophysiological results at six months in all 44 hands, 9 hands were symptom-free, indicating that electrophysiological improvements accompanied symptomatic improvements in most cases, but not in all(Fig. 5). As to whether the patient could hold on to an object for more than 5 minutes, the answer was "no" for 8 hands before surgery, and for six at six months after surgery. Among these, electromyography was designated as 'MILD' in three, 'MIN' in two, and 'NEG' in three, indicating discrepancy with regard to hand function and electromyographical findings.

Time interval of a RADL and RTW

The time interval for return to RADL ranged from 7 to 90 days, with an average of 26.4 days. The time taken to RTW ranged from 7 to 180 days, with an average of 48.08 days. In one patient exhibiting 'NEG' electrophysiological findings at six months after surgery, symptoms were mild, but the patient was unable to go back to RADL and RTW. In the two patients exhibiting 'MILD' electrophysiological findings at six months after surgery; one patient exhibited no symptoms, but was unable to go back to RTW; the other patient was in mild pain with remaining symptoms despite improvement after surgery, but was unable to go back to RADL and RTW. In two patients exhibiting 'MIN' electrophysiological findings at six months after surgery; one patient had no symptoms, but was unable to go back to RADL and RTW; the other patient was in mild remaining symptoms, despite improvement after surgery, but was unable to go back to RTW. We detected no correlation with symptoms and RTW with electrophysiological changes.

In terms of postoperative complications, tenderness was present at the operation site in 11 hands after one month, but improved in six hands at six months. Phlebitis developed in one hand at the surgical site.

Discussion

Among peripheral nerve entrapment syndromes, carpal tunnel syndrome(CTS) is the most typical, affecting about 1% of the population, and its incidence is on the rise[5,6]. The etiology of CTS and related diseases are legion. They include trauma-related structural changes, such as distal radius fracture, lunate dislocation, post-traumatic arthritis, osteophytes, hemorrhages, and edema; systemic diseases, such as rheumatoid arthritis, diabetes mellitus, hypothyroidism, amyloidosis, gout, alcoholism, Raynaud's phenomenon, Paget's disease, and chronic renal failure or hemodialysis; hormonal changes, such as pregnancy, acromegaly and menopause; tumors or neoplasms, such as lipoma, ganglioma, and multiple myeloma; anomalous anatomy, such as aberrant muscles or median artery thrombosis and an enlarged persistent median artery; mechanical overuse of the hand caused by work requiring repeated hand motion and the handling of vibrating machinery[21]. CTS was associated with diabetes in two of our patients : all showed symptomatic improvement after surgery and were able to go back to work.

CTS is especially prevalent in women aged 30 to 70. Pathophysiologically, CTS is brought about by the development of venule congestion within the synovial membrane of the flexor tendon, resultant from chronic entrapment of the median nerve. Such congestion elicits edema and inflammation, and increases pressure in the carpal tunnel, leading to pain. Repeated shaking of the affected hand in order to ameliorate these symptoms leads to contracture and degeneration of the nerve epineurium and endoneurium, thereby bringing about poor axonal transmission and impaired joint function[10,18,21].

CTS is diagnosed by the presence of a tingling sensation in the hand, which tends to intensify at night, and also by atrophy of the thenar muscles. These symptoms are consistent with the distribution of the median nerve and with electrophysiological studies, and carpal tunnel X-ray views. Carpal tunnel syndrome is essentially a sensory phenomenon; the loss or impairment of superficial sensation affects the thumb, index, and middle fingers(especially the index finger), and may or may not split the ring finger(splitting does not occur in cases of plexus or root lesions). Weakness and atrophy of the abductor pollicis brevis and other median-innervated muscles occur in only the most advanced cases of compression. The pain associated with carpal tunnel syndrome often extends into the forearm and sometimes higher, and may be mistaken for disease of the cervical disc herniation. Similarly, involvement of the ulnar, radial, or median nerves may also be mistaken for brachial plexus or root lesions. A common cause of neck, shoulder, and arm pain is disc herniation in the lower cervical region. These syndromes are usually incomplete, in that only one or several of the typical findings are present. Cervical disc herniation is characterized by limitation with respect to the range of motion of the neck and aggravation of pain with movement (particularly upon hyperextension). Coughing, sneezing, and downward pressure on the head in the hyperextended position usually exacerbate the pain, and traction(even manual traction) tends to ameliorate it. The distinguishing feature of the mononeuropathy is that each individual peripheral nerve is involved in the symptoms and signs by the disease process. Electrophysiological studies can be helpful under these circumstances. In less severe cases, CTS can be more appropriately treated by physical therapy, medication, movement immobilization, fixation of the wrist, and by temporary fixation. Surgery is used to dissect the transverse carpal ligament, and thus decompress the median nerve. Phalen introduced a method for the dissection of the transverse carpal ligament for the first time in 1950, and this method has been widely accepted as the usual method for the surgical management of CTS[19]. However, certain drawbacks to this approach have been identified, such as pillar pain around the wide incision site of the transverse ligament, atrophy, scar tissue tenderness, and delays in returning to activities of daily living and to work. After Okutsu introduced endoscopic surgery in 1987, the minimally invasive carpal tunnel release method became popular[14].

Compared with open surgery, surgeons found that endoscopic release of the carpal tunnel resulted in better outcomes, with less pain occurring around the site of the transverse carpal ligament incision, less operation site tenderness, and improved grip strength. Moreover, patients were able to return to activities of daily living and to work sooner after endoscopic release[3,4]. Even after transverse carpal ligament incision, tendon prolapse ('bowstring' phenomenon) and decreased grasping power were found to improve after endoscopic release, as the technique causes no damage to the palmaris brevis, and less damage to the thenar muscle fibers, palmar fascia, subcutaneous tissue and skin than the open surgical method[8,21]. In our five ECTR cases, return to work proved to be a difficult proposition. It is probable that the patients were unable to go back to RTW due to increased tendon prolapse(bowstringing) at the wrist, and also to decreased grip strength. However, endoscopic surgery is not appropriate for all forms of CTS, such as patients with progressive palmaris brevis muscular atrophy requiring neurolysis or release of the thenar motor branch of the median nerve; those with obvious tenosynovitis or obvious mechanical problems, such as a bone fragment in the canal, or patients who had undergone prior surgery leaving scar tissue in the wrist[13].

Electrophysiological outcomes are compared both pre- and post-operatively in order to obtain data on the effects and prognoses of surgical treatment. However, these outcomes are not consistent with subjectively-reported symptomatic improvements in every patients[11,16,18]. Motor and sensory nerve abnormality may be undetectable or detectable only at a low level, in those patients who complain of severe symptoms.

Some patients complain of mild symptoms, despite definite electrophysiological changes in nerve abnormality. Our study showed symptomatic improvement in almost all cases, except for two patients who complained of serious numbness immediately after surgery, to the point that it woke them up at night. Electrophysiological improvements were also observed in most patients. Unlike those cases that showed no electrophysiological improvements despite complete symptomatic recovery, some patients complained of persistent pain, despite normal electrophysiological findings.

Most of our patients showed symptomatic improvements the first day after surgery. Electrophysiological improvements were more gradual. Symptomatic improvements after surgery involve a series of steps. Recovery from ischemia is achieved by pressure release through surgery, followed by sensory and motor NCV changes, nerve sheath remyelinization in the early stage, and nerve sheath regeneration later. Motor nerve onset latency in our patients had improved on postoperative day one, and then improved more gradually over the next six months, whereas sensory NCV improved more gradually. However, electrophysiological and symptomatic improvements were unlikely to be complete in chronic cases, or in patients with poor initial electrophysiological findings. Electrophysiological and symptomatic improvements probably cannot be correlated consistently, as the subjective sensation of pain intensity tends to be different in each individual[1,7]. Poor symptomatic improvement after surgery is associated with old age, a long medical history, thenar atrophy, long motor nerve onset latency, and a positive Phalen test[17].

The second most important outcome after surgery is the period before RADL, and return to work. Patients with CTS took a mean of 54 days to go back to work after open surgery. Chow et al. reported that 59% of patients were able to return to normal daily activities and work by 14 days after endoscopic surgery, and 89% within four weeks[5,12]. Our patients took a mean of 26 days to go back to normal daily activities, and 48 days to return to work. Our endoscopic release procedure thus proved to be better than open surgery, as 11 of the 30 patients (37%) were able to return to their daily activities within 10 days after surgery, and 18 out of 30(60%) went back to their prior occupations within 30 days. However, our outcomes were still poor compared with those reported by Chow et al.

Reported complications related to endoscopic release of carpal tunnel include; injury to motor and sensory branches of the median nerve, insufficient decompression, operation site pain or tenderness, reflex sympathetic dystrophy, adhesion of muscles and adjacent tissues to nerves, hematoma, infection, ganglioma, and sensory abnormality of ulnar nerve distribution[2,3,18]. We encountered operation site tenderness in five hands, and infection in one hand.

Conclusion

Electrophysiological and symptomatic improvements are observed in all patients by six months after endoscopic surgery. However, some patients show a little electrophysiological recovery, but significant symptomatic improvement, whereas some show significant electrophysiological improvements, but still complain of symptoms. According to the electrophysiological studies, motor onset latency improves relatively early, but sensory NCV values return very gradually to normal.

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