Carpal Tunnel Syndrome: Electrophysiological Grading and Surgical Results by Minimum Incision Open Carpal Tunnel Release

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Abstract

The safety and effectiveness of the minimum incision technique were assessed in 138 hands of 108 consecutive patients with carpal tunnel syndrome treated from April 1, 1997 to March 31, 2006. Clinical and electrophysiological examinations were conducted before and after surgical decompression. All hands were divided into early, mild, moderate, and severe groups based on preoperative electrophysiological severity. We examined the surgical outcomes of the affected hands in each group. Nocturnal or daytime dysesthesia, which had been present in 132 (96%) of the 138 hands preoperatively, was completely relieved in 124 (94%) of the 132 hands. Complete relief was achieved in 7 (100%) of the 7 hands in the early group, 68 (99%) of the 69 hands in the mild group, and 45 (94%) of the 48 hands in the moderate group. Complete relief was achieved only in 4 (50%) of the 8 hands in the severe group, and 3 (38%) of the 8 hands did not show any improvement. No painful or hypertrophic scar formation was observed in this series. Only 2 patients complained of postoperative scar discomfort after more than 12 months, which completely disappeared by 14 months after surgery. Minimum incision open carpal tunnel release is a safe and reliable procedure with a high rate of functional improvement and patient satisfaction. Postoperative results were satisfactory regardless of the degree of preoperative electrophysiological severity if preoperative sensory nerve action potentials were detected.

Key words: carpal tunnel syndrome, minimum incision, median nerve, transverse carpal ligament, electrophysiological study

Introduction

Carpal tunnel syndrome (CTS) is caused by compression of the median nerve at the wrist, resulting in symptoms of pain and dysesthesia in the hand. Approximately 1% of the general population is affected by CTS. The diagnosis of CTS can be established easily based on the patient’s history and physical examination, and confirmed by electrophysiological testing. Conservative therapy may be helpful in some patients with CTS, but most patients ultimately require surgery.

Many surgical methods have been described, including conventional open carpal tunnel release (OCTR) with a long palmar curvilinear incision, minimal incision OCTR, and endoscopic carpal tunnel release (ECTR). Conventional OCTR is considered to provide superior safety and cost effectiveness, and ECTR achieves more rapid recovery. However, which of these methods is the most effective and beneficial remains unclear. Evaluation of surgical results must consider the severity of CTS, but there is no widely accepted grading method.

Here we describe our experience with minimum incision OCTR, which combines the advantages of direct observation of the conventional OCTR technique with the advantages of the ECTR technique. We also conducted electrophysiological tests on all hands before and after surgery to assess the degree of median nerve impairment. The minimum incision OCTR technique is considered appropriate for neurosurgeons since it is a simple technique and does not require any training or the use of specialized equipments.
Materials and Methods

I. Patients
This study included 108 patients affected by idiopathic CTS, 26 males and 82 females aged from 29 to 85 years (mean 55 years), who underwent minimum incision OCTR performed by a single neurosurgeon (J.I.) from April 1, 1997 to March 31, 2006. Surgery was performed on the right hand in 41 patients, the left hand in 39 patients, and both hands (performed at separate sessions) in 29 patients (total 138 hands). The hand with predominant symptoms was treated first. The mean follow-up period was 22 months (range 12–24 months). CTS was diagnosed based on the patient’s history and physical examination, and measurements of nerve conduction velocity.

II. Signs and symptoms
The characteristic signs and symptoms of our patients did not differ from those described elsewhere.12,35) Nocturnal or daytime dysesthesia was present in 132 (96%) of the 138 hands. Additional symptoms and signs included positive Phalen’s test in 90 hands (65%), positive Flick test in 108 hands (78%), positive Tinel’s sign in 41 hands (30%), atrophy of the thenar eminence in 17 hands (12%), tenderness of the thenar eminence in 98 hands (71%), inability of opposition in 41 hands (30%), and arm pain in 80 hands (58%).

III. Electrophysiological study
Electrophysiological tests were performed on all hands before surgery and at 1, 3, 6, 12, and 24 months postoperatively. Nerve conduction velocity was measured using an electromyograph (Viking IV System; Nicolet Biomedical Japan, Tokyo). The temperature of the extremity was not monitored. Motor nerve conduction velocity was measured using a recording electrode placed at the center of the abductor pollicis brevis muscle. Stimuli were applied to the wrist joint 70 mm proximal to the recording electrodes. Distal motor latency and compound muscle action potential (CMAP) were measured. Retrograde sensory nerve conduction velocity (SCV) was measured by placing a recording ring electrode at the base of the ring finger. The median nerve was then stimulated at the wrist, and the antidromic sensory nerve action potentials were recorded and measured.

Evaluation of the severity of CTS is important from the therapeutic and prognostic points of view. Segmental demyelination is frequently observed in early CTS, and progresses to axonal degeneration with increase in the clinical severity.27) Conduction velocity decreases significantly in segmental demyelination. However, axonal degeneration is not directly correlated with further conduction disorders.18,19) The CMAP amplitude decreases with axonal degeneration, and reflects clinical severity better than conduction velocity, although no dramatic change is recognized at the early stage. Therefore, SCV measured across the transverse carpal ligament in CTS is useful in the initial diagnosis but does not adequately reflect the clinical severity.26,31,32) The CMAP amplitude reflects the functional state of the axons and is a useful parameter for assessing the clinical grade. The mean SCV and CMAP values obtained from 30 healthy volunteers (mean age 59 years) at our institute were 56.4 ± 5.7 m/sec (mean ± standard deviation) and 11.8 ± 3.3 mV, respectively.

The hands were divided into 4 classes on the basis of the following electrophysiological classification: Early group included hands with normal values of SCV and CMAP (SCV ≥45 m/sec and CMAP ≥6 mV); mild group included hands with only lower SCV (SCV <45 m/sec and CMAP ≥6 mV); moderate group included hands with lower SCV and CMAP (SCV <45 m/sec and CMAP <6 mV); and severe group included hands with no sensory response. In the present study, SCV of 45 m/sec (2 standard deviations below the mean of normal volunteers) was considered abnormal. To distinguish between the mild and moderate groups, a CMAP value of 6 mV was arbitrarily selected based on the impression that patients with values exceeding 6 mV demonstrated excellent and quick symptomatic relief. Neuropathological pattern analysis between the parameters allowed the recognition of atypical pictures (i.e., abnormal CMAP with normal SCV). The identification of such cases may suggest more extensive diagnostic investigations to exclude underlying systemic disease and any other pathogenesis. In this series, hands with atypical electrophysiological findings were excluded from surgical intervention.

IV. Surgical indications
The indications for minimum incision OCTR in this series were as follows: Clinical diagnosis of CTS was established; electrophysiological testing revealed decreased SCV below the normal values; and patients continued to be symptomatic for more than 1 month after conservative treatment, which included modification of work activities and administration of anti-inflammatory agents. Minimum incision OCTR was considered regardless of the electrophysiological severity in any patient with severe clinical symptoms, even if the patient had normal SCV. Only a very few patients had a combination of
findings such as CMAP <6 mV and normal SCV, and these patients were excluded from surgical intervention.

V. Surgical technique

The patient was positioned supine, with the arm abducted and forearm supinated on an arm board. The procedures were performed under intravenous regional anesthesia using a tourniquet in the operating room. A 25 mm-long longitudinal incision was made in the axis of the radial border of the ring finger, immediately radial to the hook of the hamate, which is a landmark of the ulnar border of the carpal tunnel, originating at a point 40 mm distal from the distal wrist crease (Fig. 1A). After the incision was made, a sharp dissection was performed through the subcutaneous fatty tissue to the underlying palmar aponeurosis in the hand. The palmar aponeurosis was dissected sharply, until the distal edge of the transverse carpal ligament was visible. Fat is always visible at the distal end of the ligament. The dissector was then inserted from the distal edge of the transverse carpal ligament to protect the median nerve (Fig. 1B). The distal portion of the ligament was dissected sharply with a 15-blade knife. Once the distal portion of the ligament was exposed, the underlying median nerve was clearly visible. Moreover, the ligament was transected completely with scissors in a plane under direct visualization (Fig. 1C).

Good positioning of the surgeon, good lighting, and firm retraction were required to divide the ligament as far proximally as possible and always proximal to the distal wrist crease. The incision was made on the ulnar side of the median nerve where the palmar cutaneous and the recurrent motor branches are less likely to be encountered. The wound was then closed with subcutaneous 4-0 absorbable suture, and 4-0 interrupted nylon mattress sutures were used to reapproximate the palmar skin. The mean time required for this surgery was 26 minutes (range 18–40 minutes). Blood loss was always <5 ml. The sutures were removed 8–12 days after surgery. No splinting or immobilization was employed.

Results

I. Electrophysiological study

There were 7 hands in the early group, 71 in the mild group, 50 in the moderate group, and 10 in the severe group, and the mean age was 43, 53, 56, and 74 years, respectively. The mean SCV was 49 m/sec and mean CMAP was 10.7 mV in the early group; 31 m/sec and 9.9 mV, respectively, in the mild group; and 24 m/sec and 3.9 mV, respectively, in the moderate group. Almost all hands in the mild and moderate groups showed electrophysiological improvement in an early postoperative follow-up study. However, only 3 of the 8 hands in the severe group exhibited improvement in a late follow-up study. None of the hands showed electrophysiological worsening.

II. Clinical outcome

Table 1 shows the overall results with regard to dysesthesia. Nocturnal or daytime dysesthesia, preoperatively present in 132 hands, was completely relieved in 124 hands (94%) and improved in 5 (4%). Complete relief was achieved in only 4 (50%) of the 8 hands in the severe group, which was significantly worse than other groups ($\chi^2$ test, $p < 0.05$).

Table 2 shows the time required for complete
Table 1 Overall results with regard to dysesthesia

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>No. of hands</th>
<th>Complete relief</th>
<th>Improvement</th>
<th>No improvement</th>
<th>Worse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>7</td>
<td>7 (100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mild</td>
<td>69</td>
<td>68 (99%)</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moderate</td>
<td>48</td>
<td>45 (94%)</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe</td>
<td>8</td>
<td>4 (50%)*</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>124 (94%)</td>
<td>5 (4%)</td>
<td>3 (2%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

*Significantly smaller than other groups ($\chi^2$ test, $p<0.05$).

Table 2 Duration after surgery for complete relief from dysesthesia

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>No. of hands</th>
<th>Duration for complete relief</th>
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</thead>
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<tr>
<td></td>
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<td>Early</td>
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<td>7</td>
</tr>
<tr>
<td>Mild</td>
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<td>65</td>
</tr>
<tr>
<td>Moderate</td>
<td>45</td>
<td>30</td>
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<tr>
<td>Severe</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>124</td>
<td>102</td>
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</table>

Discussion

I. Surgical methods and results

Until recently, conventional OCTR with a long palmar curvilinear incision was the standard procedure. This procedure is very safe and effective, with most series reporting well over 90% success rates, but has a relatively high incidence of scar problems such as painful and hypertrophic scar formation and scar discomfort. Painful and hypertrophic scar formation is thought to usually be caused by the incision crossing the wrist perpendicular to the flexion crease. Moreover, scar discomfort has been attributed to injury of the palmar cutaneous branch of the median nerve, with subsequent neuroma formation. New surgical techniques were introduced to reduce postoperative morbidity and scar problems after conventional OCTR.

Minimum incision OCTR was designed to provide a high degree of safety and flexibility while minimizing postoperative disability. The procedure allows direct, complete, and verifiable release of the transverse carpal ligament. The median nerve is easily visualized and protected during the surgery. The courses of the palmar cutaneous branch and recurrent motor branch of the median nerve show many anatomic variations. The success of the procedure depends on careful avoidance of injury to these nerves. Therefore, surgeons must recognize such anatomic variations and perform surgery under direct visualization of the median nerve.

Surgery in our series achieved complete relief from sensory dysesthesia in 94% of hands, and improvement in an additional 4% of hands, but some dysesthesia persisted. Minimum incision OCTR provided complete relief in 88%, improvement in 8%, and no improvement or worse in 4% of 378 hands. Conventional OCTR achieved 79% good, 15% fair, and 6% poor results in 535 hands. Our good results can be attributed to high diagnostic accuracy and careful patient selection based on the
electrophysiological testing, and less invasiveness of the technique.

II. Electrophysiological classification and surgical results

Our nerve conduction study was intended to confirm the diagnosis, assess clinical severity, predict the outcome, and evaluate postoperative improvement objectively. The hands were divided into 4 groups based on the delay of the SCV and decrease in CMAP observed for the abductor pollicis brevis muscle.

Complete relief was achieved in 100% in the early group, 99% in the mild group, 94% in the moderate group, and 50% in the severe group. The severe group had significantly worse outcome (p < 0.05). Reports of the relationship between the degree of preoperative electrophysiological severity and results of surgery are contradictory.5,8,11,15) In our study, the postoperative results were satisfactory regardless of the degree of preoperative electrophysiological severity, if preoperative sensory nerve action potentials were detectable. Three of the 4 hands in the severe group that achieved complete relief were classified into the moderate group at the initial diagnosis, but their condition deteriorated during nonsurgical treatment. In contrast, the 3 hands that did not achieve improvement were classified into the severe group at the initial diagnosis. The duration of no electrophysiological sensory response may be associated with poor prognosis.

Previous studies have reported rapid improvement after surgery.4) However, few published studies have examined the relationship between the degree of preoperative electrophysiological severity and postoperative rapidity of improvement. In our study, many patients received excellent symptomatic relief within 1 week in the early and mild groups. However, complete relief was achieved within 1 week in only 67% (30/45) of the patients in the moderate group. Complete relief from dysesthesia occurred after 1 month in the severe group. Complete clinical recovery and significant electrophysiological improvement immediately after decompression are only possible if the surgery is performed at a very early stage.23) Our findings confirm that marked and rapid improvement can be observed in the early and mild groups, whereas complete improvement is delayed in the moderate group. We recommend early surgical decompression for complete and rapid clinical improvement.

Marked clinical improvement can be observed in severe cases.4,13) Surgery provides 75% or more symptom relief in 78% of patients with severe CTS.10) Moreover, nerve conduction velocity definitely improved in the severe CTS group but did not return to normal. Spontaneous resolution of the symptoms is rare in cases of severe CTS, and motor function deteriorations are often observed without surgery. We think that surgical decompression is beneficial for patients with severe CTS, because this is the only means of definitive cure. However, the patients should be aware that the surgical results in this group are worse than those in other groups.

III. Complications

Common complications include injury to the recurrent motor branch, incomplete transection of the flexor retinaculum, painful neuroma formation in the palmar cutaneous branch, prolonged scar tenderness, wound infection, and reflex sympathetic dystrophy.20,22,28) None of these complications were observed in our series. The low risk of complications in our study can be attributed to the following: limited number and length of short incisions in the ulnar border of the carpal tunnel, one surgeon with good knowledge of the technique performing all procedures, and surgery performed under direct visualization.

V. Conclusion

Minimum incision OCTR is a safe and reliable procedure with a high rate of functional improvement and patient satisfaction. Postoperative results are satisfactory regardless of the degree of preoperative electrophysiological severity, if preoperative sensory nerve action potentials were detectable.

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