7 Complications of Carpal Tunnel Release

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Introduction

Back in 1980, Giannikas and Touliatos [1], described in their book "The Surgery of the Wounded Hand", the value of the median nerve:

> In primitive mammals, the fifth brain conjugation (the trident) is the primary information gathering center. In human, the primary function of the fifth conjugal was supplanted by the median nerve. Mated with vision, the touch sensor, leads us to trace the truth about the objective world that surrounds us. [1] (originally written in Greek language)

Actually, the median nerve, which gives sensation to the main pinching fingers of our hands, clearly contributed the most in the evolution of the human species. On the contrary, dysfunction of the median nerve leads to a significant reduction in our ability to live in daily life.

The most common pathology of the median nerve is the pressure within the carpal tunnel, called carpal tunnel syndrome (CTS). A great variety of approaches for surgical decompression of the median nerve has been described. The classic open incision, the classic extended, and the mini open are the most often utilized procedures. A transverse incision has also been suggested by a few surgeons. On the other hand, many surgeons prefer to perform minimally invasive techniques, namely endoscopy or using special knifes designed for carpal tunnel release.

Although the procedure is simple, complications following carpal tunnel release, either open or endoscopic, are common. Das and Brown in 1976 [2] and MacDonald et al. [3] in 1978, were reported complications rate 12–15%. Lilly and Magnell, in 1985 found the percentage of complication up to 7% [4], and Mackinnon and Dellon, in 1988 up to 5% [5]. They reported 16 complications in total of 500 cases (3.2%). They had 5 painful scars, 3 CRPS, 2 recurrent CTS, 1 thenar motor branch injury, 1 superficial palmar arch injury and 4 infections [5].

Incomplete release, nerve laceration, painful scar and CRPS, are the most common complications. Nevertheless, a lot of other complications can occur. Knowledge of these complications is very important, since it can help the surgeon to reduce their rate. Correct choice of the surgical approach, adequate and atraumatic surgical technique, use of loupes for magnification, and careful postoperative follow-up are the key factors which will help the surgeon to reduce the rate of complications. Moreover, early recognition of

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these complications as well as the knowledge for immediate treatment leads to the best possible outcome.

Chronicity of median nerve compression with thenar atrophy is a poor prognostic factor for complete clinical recovery. Neglected atrophy may be irreversible; it is therefore necessary to explain this to the patient. On the other hand, sensory restoration is usually complete, although a small degree of numbness on the pulp of the fingers may persist for a few weeks.

Classification of Carpal Tunnel Surgery Complications

The major question is: what makes carpal tunnel surgery unsuccessful? First, one should exclude having a pathology other than carpal tunnel syndrome. The differential diagnosis of a carpal tunnel syndrome includes cervical spine disorders, brachial plexus abnormalities, thoracic outlet syndrome, pronator syndrome and anterior interosseous syndrome. Careful clinical examination with the aid of imaging and electrodiagnostic studies will help provide the correct diagnosis. A second reason may be incorrect surgical technique, which lead to significant morbidity of the hand. Last but not least, inadequate patient's cooperation, along with other unspecified and unpredictable factors can affect the final result.

For better recognition and easier classification, we can divide complications into three groups: intraoperative, early postoperative and late postoperative.

- *The intraoperative complications* are related to iatrogenic injuries. Complete or partial lacerations of the nerves and tendons are not rare. Minimally invasive techniques increase the intraoperative complication rate, especially during the surgeon's learning curve, but lately, specific endoscopic instruments have reduced the frequency of these injuries.
- *Early postoperative* complications (up to 1 month postoperatively) usually are more serious and increase the patient discomfort dramatically. Incomplete release of the transverse carpal ligament (TCL) will lead to significant deterioration of the symptoms. Wound care problems also need special management.
- Finally, *late postoperative* complications are usually more difficult to recognize and treat. They can last for many months and require special management of the patient. Enhancing patient-doctor confidence is very important. It is prerequisite to extensively explain the problem to the patient and to inform him in detail how you will deal with his problem and what may the expected outcome be.

Intraoperative Complications

> Your hands will only achieve what your eyes can see

Intraoperative Magnification Can Minimize Intraoperative Complications!

Intraoperative complications of open (OCTR) or endoscopic (ECTR) carpal tunnel release are usually iatrogenic nerve, tendon and vessels laceration. Although carpal tunnel release is one of the most often performed operations in the world, the occurrence of major neurovascular and tendon injuries associated with both OCTR and ECTR is not rare. The nerves that can be involved are both median and ulnar nerve. The median nerve has the higher incidence of damage as it is found anatomically just below the transverse carpal ligament. Complete or partial laceration of the median nerve, motor branch injury, single digital nerve damage or palmar cutaneous branch can occur (Figs. 7.1 and 7.2) [2, 6]. On the other hand, laceration of the communicating ramus between the median and ulnar nerve or laceration of the ulnar nerve itself may also happen. The high incidence of these injuries, especially of the motor branch, is directly related to the high percentage of anatomical variations that have been reported [7–9]. Lanz, classified the median nerve variations in carpal tunnel in four groups [10]. Group I includes variations in the course of the thenar branch. The second group includes the accessory branches at the distal carpal tunnel. In third group, one can

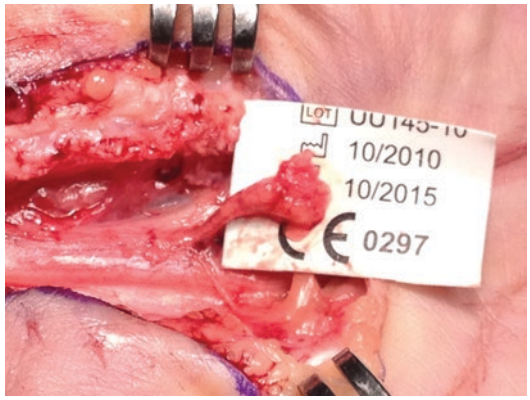

Fig. 7.1 Intra-operative photograph of injury of the motor branch of median nerve after laceration during previous open carpal tunnel release

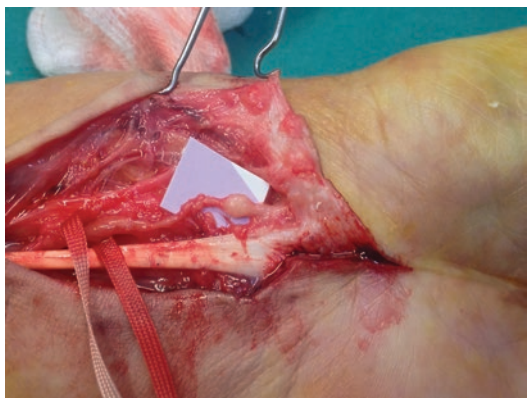

Fig. 7.2 Intra-operative photograph of painful neuroma of palmar cutaneous nerve after open carpal tunnel release

recognize a high division of the median nerve. Finally, the forth group includes the variations with accessory branches proximal to the carpal tunnel. Normally, the motor branch becomes recurrent at the distal margin of the TCL before entering to the thenar muscles. Poise in 1974, reported the relationship of the thenar branch to the transverse carpal ligament (group I). He found three types of variations: 46% extraligamentous, 31% subligamentous, and 23% transligamentous [11]. Other authors have also reported a large number of anatomic variations of the motor branch of the median nerve. Accessory branches (group II) of the motor nerve (double motor branch) at the distal carpal tunnel are not common. More common are the branches from the volar or even the ulnar aspect of the nerve. The high division of the median nerve (group III) is associated with the median artery. In the majority of the cases both parts of the nerve have the same diameter. An accessory lumbrical muscle between the two branches can also be found. Accessory branches proximal to the carpal tunnel (group IV) are rare. The branches run within the transverse carpal ligament distally. The branches can be motor or sensory. All these many variations of the median nerve can be the cause of intraoperative median nerve injury. Ulnar nerve injury is uncommon and usually is the result of improper surgical technique. Release of the TCL in the ulnar side decreases the probability of injury of the median nerve itself and the palmar cutaneous branch. On the other hand, extreme ulnar dissection can lead to ulnar nerve damage. For many years, a lot of surgeons preferred radical decompression of the median nerve with epineural neurolysis and complete tenosynovectomy of the flexor tendons. This technique can increase the possibility for median nerve intra-neural trauma and tendon laceration. Additionally, it can lead to neuroapraxia with median nerve paresthesia. In the long term, various complications as skin and tendon adhesions, neuro-dermodesis phenomenon and painful neuromas have also been reported.

Cases with nerve laceration should be promptly recognized and timely repaired. Direct repair with microsurgery techniques must be the treatment of choice. Any post-operative deficit, motor or sensory, must be evaluated very carefully. Early re-exploration of the median or ulnar nerve is necessary for the evaluation of the injury and its potential reconstruction. Delayed treatment with nerve grafts following internal neurolysis has worse outcome and must be our last solution. Regarding the palmar cutaneous branch injury, we must procced to direct repair in intraoperative cases, while in neuroma cases treatment is performed with excision of the neuroma and relocation of the distal edge into the pronator quadratus muscle. Overall, palmar cutaneous nerve injury must be avoided, as the resulting neuroma is very painful and the treatment is always problematic.

Concerning the vascular structures, the most common injuries are those of the superficial palmar artery arch and its branches and of the median nerve artery. Radial and ulnar artery injury is rare. When vascular injury is the case, recognition and repair of the lesion is necessary. When tourniquet is applied, release of the tourniquet before skin closure is recommended with proper hemostasis to avoid hematoma formation postoperatively. Hematoma, pseudoaneurysm, palmar pain or discoloration can occur if one neglects treatment. Microsurgery techniques are required for vessel reconstruction. For the median nerve artery injury more attention is needed, as the possibility of nerve injury is higher. Intraneural dissection is necessary before median nerve artery cauterization. Drains are not recommended by the majority of surgeons.

Tendon lacerations are also rare and it can be partial or complete. Superficial tendons are most common affected. Profundus tendons are only rarely injured. Direct repair remains the treatment of choice.

Nevertheless, how often is an intraoperative iatrogenic injury? The majority of Orthopaedic and Hand surgeons believe it is impossible to have intraoperative injuries in their practice.

Palmer and Toivonen in 1999 [12], published an article about complications of endoscopic and open carpal tunnel release. The authors sent a questionnaire to 1253 members of the American Society for Surgery of the Hand asking for information on complications resulting from both ECTR or OCTR. Respondents were instructed to report only on intraoperative complications. The question was how many nerve, tendons and vascular injuries they had in their practice and how these injuries were treated. In addition, the respondents were asked which of the intraoperative injuries (nerve, arterial or tendons) they had seen in the last 5 years were their own or referred by another physician. Of the 1253 Hand Surgeons questioned, there were 616 (49%) with open carpal tunnel release and 708 (57%) with use of endoscopic release.

Median nerve injuries were reported with both OCTR and ECTR techniques. There were 283 major complications from the 616 Hand Surgeons following OCTR, including 147 nerve lacerations, 29 ulnar lacerations, 54 digital, 34 vessel and 19 tendon lacerations. On the other hand, there were 455 major complications from surgeons who preferred ECTR, including 100 median nerve, 88 ulnar nerve and 77 digital nerve lacerations. Moreover, there were 121 vessel and 69 tendons lacerations. It should be noted that a large proportion of intraoperative injuries was not recognized during surgery, especially with the endoscopic techniques compared with the open techniques.

The incidence of intraoperative injuries is not low. The surgeon must be prepared to recognize and treat his complications. Based on our clinical experience we believe that some nerve injuries can occur during ECTR due to minimal surgical exploration and limited visualization. In the OCTR group however, there was also a large number of median and ulnar nerve injuries. In fact, there is no significant higher incidence of intraoperative soft tissue damage in ECTR versus OCTR, although open procedures offer better visibility and security. Selection of the surgical method for CTS release must comply with the surgeon's knowledge and surgical experience. Medicolegal implications associated with iatrogenic injuries following carpal tunnel syndrome surgery are common and surgeons should make great effort to avoid them [13, 14].

Early Complications

Early complications after carpal tunnel surgery occur up to 1 month postoperatively. Usually CTS symptoms improve on the first postoperative day. Persistence of symptoms is generally correlated to inadequate median nerve decompression. This is the most common major early complication and usually occurs with aggravation of symptoms.

Wound care problems as hematoma, superficial or deep infection are other early complications.

Inadequate Decompression of the Median Nerve

Incomplete release of the transverse carpal ligament is common in both OCTR and ECTR. It may include incomplete sectioning of the distal or proximal TCL, incomplete sectioning of the distal antebrachial fascia and complete lack of TCL sectioning.

Incomplete sectioning of the distal TCL is probably the most common complication in carpal tunnel surgery (Figs. 7.3 and 7.4), especially with the mini open techniques and in cases with transverse wrist incision [15]. Clinically, Phalen test is often negative, as there is release of the proximal part of TCL, which is responsible for median nerve compression during wrist flexion. On the other hand, Gilliatt and Wilson test is positive due to compression of the nerve in the distal carpal tunnel. Positive Tinel sign also can be seen in the palm, but negative in the wrist flexor region. Negative is also the Bedeschi sign, which evaluates the presence of tension in the anterior wrist region. Nevertheless, the most reliable sign remains the persistence or deterioration of the symptoms. Clinical diagnosis of incomplete distal TCL sectioning can be confirmed by imaging with CT-scan, MRI, or even with electrodiagnostic studies (EMG). Normally, EMG studies improve as early as 2 weeks postoperatively. In cases with incomplete TCL release, EMG values will deteriorate [16–18].

Fig. 7.3 Intra-operative photograph showing incomplete TCL sectioning during revision CTR

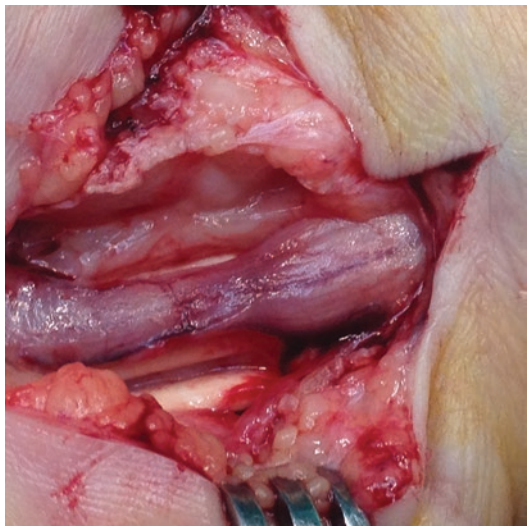

Fig. 7.4 Intra-operative photograph of the median nerve during revision surgery after incomplete TCL sectioning. Note hourglass appearance of the median nerve due to excessive compression

Many authors have reported on their experience following a repeat carpal tunnel release. The majority of them found that incomplete release of the distal TCL was the most common cause for the unsuccessful outcome [15, 19, 20].

Incomplete release of the distal part of the antebrachial fascia is not common. Normally, distal part of the antebrachial fascia does not compress the median nerve. Makinnon suggested that the etiology can be a thickening of the antebrachial fascia as a result from previous trauma of the wrist and forearm [21]. There is usually a persistence of symptoms, but their deterioration is rare. A previous incision not extending proximal to the wrist flexor crease is an indicative element. Phalen and Gilliatt and Wilson tests are positive. Tinel and Bedeschi signs are also positive. CT-scan and/or MRI can be used to confirm the diagnosis. Surgical release of the distal part of the antebrachial fascia is the treatment of choice. Close attention must be paid to perform atraumatic dissection of the subcutaneous tissues from the fascia, otherwise the subcutaneous vessels can be injured and an hematoma may occur. Fascial release must extend approximately 2–3 cm proximal to the wrist flexor crease [19–21].

Complete lack of TCL sectioning is extremely rare, yet not impossible. A few authors have

reported such cases. We should however keep in mind the possibility of healing of an incomplete sectioned TCL, in such a way the surgeon who performs the reoperation erroneously considers the TCL as unsectioned [18, 22].

Hematoma

Hematomas after CTS release surgery can arise from severe vascular injuries and from small cutaneous vessels [23]. Atraumatic surgical technique, adequate surgical field, proper hemostasis prior to closure, potential use of drain and the coagulation status of the patient are essential factors to be taken into account, in order to avoid hematoma formation.

Aggressive tenosynovectomy without meticulous hemostasis may also be a reason for postoperative hematoma.

Considering discontinuation of aspirin preoperatively, Brunnetti et al., demonstrated that the continuation of aspirin did not increase the risk of complications [24].

Similarly, AAOS guidelines underline that "Limited evidence supports that the patient might continue the use of aspirin preoperatively" [25]. Based on the same guidelines, no reliable evidence exists for the use of other anticoagulants.

In case of a confirmed hematoma either with clinical evaluation, MRI or ultrasound, the surgeon should consider re-operatation for drainage and irrigation, in order to avoid nerve and tendons adhesions. Once again we recommend dropping the tourniquet prior to closure.

Infection

Post-operative infection following carpal tunnel surgery, whether it's superficial or deep, is quite uncommon in our practice and in the medical literature as well. Several risk factors have been recognized. The necessity of prophylactic antibiotics is being discussed.

Hanssen et al. [26] in their retrospective study of 3620 Carpal Tunnel Syndrome surgeries, reported deep post-operative infection in 17 cases (0.47%). They identified as statistically significant risk factors the intraoperative steroid solution injection into the carpal tunnel, flexor tendon synovectomy, prolonged operative time and the use of surgical drain. Infection rate in males was higher (0.87%) than in females (0.25%). Staphylococcus aureus was the most common pathogen (15 out of 17 cases).

Werner et al. [27] in their analysis of over 450,000 Medicare patients that underwent open carpal tunnel release only 1466 developed postoperative infection (0.32%). They also noted that independent positive risk factors for infection were younger age, male sex, obesity, alcohol, tobacco and comorbidities including diabetes, chronic liver disease, chronic kidney disease, chronic lung disease, peripheral vascular disease, inflammatory arthritis and depression [27].

Harness et al. [28] in a multicenter retrospective review of 3003 patients who underwent uncomplicated carpal tunnel release, identified 11 cases of surgical site infection. From those 11 patients 5 had prophylactic antibiotics and 6 did not, 4 had deep infections and 7 superficial. Infection rate in patients with diabetes was not statistically different from nondiabetic population. They concluded that antibiotic use did not decrease the risk of infection therefore surgeons should carefully consider the risks and benefits of routinely using prophylactic antibiotics in carpal tunnel surgery.

Bykowski et al. [29] in their retrospective review of 8850 cases of clean, elective hand surgery found an infection rate of 0.35%. Surgical site infection did not significantly differ between patients receiving antibiotics (0.54%) and those who did not (0.26%). They also found that, even though diabetes, procedure length and smoking were factors associated with the development of infection, prophylactic antibiotics did not reduce the risk of infection among these patients. Overall, they concluded that antibiotics should not be routinely administered to patients who undergo clean, elective hand surgery.

American Academy of Orthopaedic Surgeons on 2016 published evidence-based clinical practice guidelines concerning the management of carpal tunnel syndrome [25] mentioning that

"Limited evidence supports that there is no benefit for routine use of prophylactic antibiotic prior to carpal tunnel release because there is no demonstrated reduction in postoperative surgical site infection."

In conclusion, infection after carpal tunnel release although uncommon, is a reality which may endanger patient's health. Close postoperative follow up is mandatory, so as to allow for an early diagnosis and treatment of infection.

Rare Major Early Complications

Skin and palmar fascial necrosis following carpal tunnel surgery is extremely rare.

Greco and Curtsinger in 1993, reported necrotizing fasciitis infection as a complication of a carpal tunnel release [30]. A 31 years old diabetic woman presented with the condition following CTS release. Total excision of the palmar skin and fascia was required for the control of the woman's specific condition.

Postsurgical pyoderma gangrenosum following carpal tunnel release has also been reported by Ruebhausen et al., in 2017 [31]. A 33-year-old woman presented on the 2nd postoperative day with wound drainage and pain. Three days later, her symptoms were worse. After a lot of debridements, surgical forearm amputation was selected for the safest and best outcome for the patient.

Another pyoderma gangrenosum after carpal tunnel release was reported by Giugale and Balk, in 2018 [32]. It was treated with multiple debridements and administration of systemic corticosteroids, eventually with hand survival.

Another rear early complication was described by Tiengo et al. [33]. This was a case of critical upper limb ischemia after CTR in patient diagnosed for CTS confirmed by EMG study. This serious complication occurred in the presence of undiagnosed thoracic outlet syndrome obliterating subclavian artery and additionally occlusion of the humeral artery and the final result was necrosis of the distal third of the thumb and index finger. Authors believe that acute occlusion of collaterals due to brachial tourniquet was the reason of limb ischemia. This case underlines the importance of careful clinical examinations knowing that double crush syndromes do exist and that the diagnosis if finally clinical.

The recognition of these rare serious complications is very important, as early diagnosis and adequate treatment can result in hand salvage.

Late Postoperative Complications

We can classify late postoperative complications following carpal tunnel release in two groups. The first one is associated with recurrent symptoms, while the second one with the onset of new symptoms. Recurrence of symptoms is often caused by the fibrotic scar tissue formation around the nerve and by the hypertrophic tenosynovitis of the flexor tendons. The onset of new symptoms may be associated with the surgical procedure and skin incision, or can occur as a result of iatrogenic nerve injury. The complications which are not affected from the incision include pillar pain, piso-triquetral pain syndrome and of course CRPS.

Recurrence of Carpal Tunnel Syndrome

Carpal tunnel surgical release has consistently an excellent outcome. The majority of patients are absolutely free of symptoms after a period of a few months. However, recurrent carpal tunnel syndrome occurs in up to 19% of patients following CTR. There are two major categories where we can classify recurrence. The first one is attributed to pathology unassociated with the primary carpal tunnel syndrome and surgical release, such a distal radius fracture, tumors, pregnancy, diabetes or a systemic disease as rheumatoid arthritis, which lead to a hypertrophic tenosynovitis of the flexor tendons. The second group includes pathologies associated with an extensive scar formation and traction neuropathy following the first operation.

Evaluation and understanding of the causes for recurrence is very critical for the subsequent treatment. Clinical examination is also very

important and further studies (computed tomography [CT] scan or magnetic resonance imaging [MRI] and electrodiagnostic studies) may be necessary for correct diagnosis.

The first group requires typical management with revision of carpal tunnel release and synovectomy when needed, as the treatment of choice. Additional procedures may be necessary, such as a correction osteotomy for distal radius malunion or a tumor excision. The second group needs special management. External or internal neurolysis must be followed by vascularized soft tissue coverage or by the vein wrapping technique [34, 35]. The technique of hypothenar fat flap is described in Chap. 9 and the vein wrapping technique is described in Chap. 25.

New Symptoms Appearance

Loss of Hand Grip Strength

Releasing the transverse carpal ligament can results in a decrease of the hand grip and pinch strength. Quite enough studies have estimated the time required for grip and pinch strength to return to the preoperative level. Gellman et al. [36] found that 3 weeks after surgery the strength was at the 28% of the preoperative level, at 6 weeks post-op it was at 73% and it returned to the preoperative level after 3 months. At 6 months after the release, the grip was increased to 116%. The pinch grip had a faster recovery, which was 74%, 96% and 108% of the preoperative level at 3, 6 weeks and 3 months accordingly. Six months post-op, the pinch was 126% of preoperative level [36]. There were a lot of other studies that reporting similar results, although a few authors reported complete recovery after a longer period [37, 38]. There has also been a question whether TCL reconstruction offers faster recovery, and some studies have suggested TCL lengthening-reconstruction. Many techniques have been described for the ligament reconstruction in the first plane, but the results are similar [39, 40]. Overall, TCL lengthening-reconstruction may provide a quicker recovery, but in the long term, restoration of handgrip strength does not seem to have any significant difference compared with patients who didn't undergo this procedure. In everyday practice, the routine need for TCL reconstruction is low and the majority of surgeons does not perform it, as they don't believe it is necessary. In fact, the reduction of the grip strength after carpal tunnel surgery is temporary and rarely leads to significant functional disability. Additionally, the decreased grip power is quite often due to painful scar and pillar pain and this can confuse the diagnosis. The use of a postoperative splint is also controversial. TCL reconstruction for unacceptable reduction of grip power of the hand may be needed in extremely rare cases and only a few methods have been described with the use of local flaps or tendon grafts.

In our practice, we think that a bulky soft dressing for a period of 2–3 weeks, to allow for TCL healing, is enough.

Over the last years, the Hand Surgeons' interest has been to determine whether grip strength recovery differed when open and endoscopic surgical techniques were compared. There is an ongoing debate whether endoscopic methods present advantages. Bande et al. [41] and Brown et al. [42] did not find significant difference between the two methods. On the other hand, MacDermid et al. [43] suggested that endoscopic decompression of the median nerve offers a rapid grip strength recovery compared to the open release.

Tendon Complications

Trigger Finger

Implication of carpal tunnel surgery in the appearance of trigger finger (TF) has been described in the literature. It is believed that the anterior displacement of flexor tendons as a consequence of TCL division during release of median nerve, alters the biomechanics of the tendon-pulley system of the hand and may predispose to trigger finger [44].

Hombal et al. [45] reported trigger finger incidence of 21.9% after CTS surgery. Mackinnon also observed trigger finger after CTR [21].

Fu-Yu et al. [46] in their retrospective, nationwide cohort study of 2605 CTR reported the overall incidence of trigger digits was 3.63-fold greater in the CTR cohort than in non CTR. They also found that the incidence of trigger finger was highest in the first 6 months and then significantly decreased.

In order to avoid this complication immobilization of the wrist in slight extension for 2 weeks, allowing the fingers free to move, may be considered.

Adhesions Between Flexor Tendons

Tenosynovitis and adhesions between flexor tendons into carpal tunnel are common in patients with systemic disease, as rheumatoid arthritis. Carpal tunnel syndrome in these patients can have as a result, apart from the symptoms of the median nerve neuropathy, limited finger and wrist motion due to reduction of flexor tendon gliding. In these cases, carpal tunnel surgical decompression requires synovectomy of flexor tendons in addition to the TCL sectioning. On the other hand, a few surgeons prefer to perform this procedure routinely, when serious tenosynovitis is found. Synovectomy can be followed by adhesions of the flexor tendons due to surgical trauma and the inevitable hematoma [47]. The clinical result is limited hand function with or without recurrence of the median nerve compression symptoms. Diagnosis may be confirmed by MRI or ultrasound.

This complication can be avoided with intraoperative appropriate hemostasis when synovectomy is performed. In most of the cases, intensive rehabilitation program can improve the finger and wrist motion, otherwise a reoperation in needed. Careful tenolysis with diligent hemostasis and drain insertion are necessary. Tenolysis must be performed by local anesthesia for intraoperative control of finger movement. Early intensive finger and wrist rehabilitation is imperative.

Bowstringing of the Flexor Tendons

A rare complication of CTS release surgery is the anterior subluxation of the flexor tendons. TCL proper healing that follows its sectioning during surgery is necessary for the unobstructed functioning of the pulley system at the carpal tunnel and thus the correct positioning of flexor tendons and median nerve in their canal [23].

An increase in the anteroposterior diameter and subsequently of the volume of carpal canal is happening due to TCL sectioning which leads to anterior displacement of its contents [48].

In rare cases, inappropriate TCL healing will lead to bowstringing of the flexor tendons, which will be demonstrated clinically with a cord like appearance when fingers and wrist are actively flexed. Implicated factors are the excision of a part of TCL, the maintenance of the hand in a flexed position postoperatively and the TCL sectioning on its radial side.

A short period of wrist immobilization in slight extension is recommended in order to avoid this rare complication allowing normal healing of TCL.

In a few cases that bowstringing should be addressed surgically, surgeon has to decide among methods of TCL reconstruction [49].

Painful Scar

All surgical scars are painful for the first postoperative period, but after a few weeks they become painless. Some scars have the tendency to become hypertrophic or keloid. Usually, keloid scars are more painful that hypertrophic ones. However, the most important contributor to scar pain intensity variability remains unidentified [47, 50].

Bedeshi [23], suggested three causes for the origin of a painful cutaneous scar. The first one is a neuroma of the palmar cutaneous nerve (usually) or of a branch of the radial nerve. The second reason may be the formation of minineuromas of the cutaneous terminal endings of both median and/or ulnar nerves cutaneous scar formation and adhesions to the median nerve.

Neuroma of palmar cutaneous nerve is the main cause of a painful scar. The most dangerous incisions are the transverse and those, which are located radially, around the thenar eminence [8]. The pain is localized radially over the distal wrist flexor crease. Pressure on the scar causes pain with reflection to the thenar region. Palmer and Toivonen in theirs article [12] which included a

questionnaire to the members of the ASSH, reported 117 injuries of the palmar cutaneous branch with OCTR and only 17 with ECTR.

Minineuromas of the cutaneous terminal endings of both median and/or ulnar nerve after open CTS release are common as these branches offer sensation to the palm. Taleisnik [8] has described the safe zone for avoidance the median nerve micro-branches and Engber et al. [51] the corresponding ones for ulnar nerve. Recent studies by Matloub et al. [52], suggested an incision on the central axis of the fourth ray, as it is more secure to avoid injuries of the palmar cutaneous terminal endings. Biyani and Downes [53] suggested two separate small incisions proximal and distal of the TCL to protect the highly innervated skin.

Generally, the postoperative scar can be painful and sensitive, especially during the first weeks. However, the majority of these scars become painless after a period of a few months. For this period, conservative treatment must be followed with scar massage, steroid cream or injections and a program of desensitization. Only in very few cases, revision of the scar is necessary and this may be done after a period of at least 6 months postoperatively.

The scar tissue formation between the median nerve and the scar itself is a more complex, especially in cases where we have subluxation of the median nerve anteriorly. The etiology is a lack of proper healing of the TCL. Predisposition factors are: radial incision and TCL sectioning, removal of a part of TCL and post-operative wrist flexion posture [54]. The symptoms are very intense with pain over the scar even with light touch, Tinel sign and a sensation of electric current. The superficial location of the median nerve can be confirmed by MRI.

For avoidance of this complication, an ulnar palmar incision must be selected. In cases that will be shown, a second surgery was required. Median nerve neurolysis, soft tissue coverage and/or TCL reconstruction may be necessary.

Pillar Pain

Postoperative pain after carpal tunnel release can be located both in the thenar and hypothenar region. The pain becomes worse with pressure over the scar. In addition, grip strength can be limited. The etiology is not clearly defined. Mini neuromas from palmar cutaneous nerve have been implicated. The postsurgical soft tissue edema can also be another cause. Other authors believe that pillar pain has a muscle origin, and it is the result of a transient instability of the aponeurotic insertion of the thenar and hypothenar muscles. There is no relationship with the type of the incision and there is no significant difference between patients operated either with open or endoscopic techniques [55–57].

Pillar pain usually resolves after a period of a few months (normally, this period is between 2 and 12 months). This is the reason why several authors agree with the hypothesis of thenar and hypothenar muscles instability. After healing of the aponeurotic scar, the stability is restored and the symptoms subside. According to this hypothesis, few surgeons have suggested the use of a postoperative splint for a period of 2 months with the wrist in slight extension, in order to favor healing of the transverse carpal ligament, yet there is insufficient documentation.

Piso-Triquetral Pain Syndrome

Although, hypothenar pain after carpal tunnel surgery is not rare, symptoms usually subside within 2–12 months. However, a few patients continue to have tenderness over the piso-triquetral joint. Seradge and Seradge [58] in 1989, suggested as a potential cause for this continuing pain, the subluxation or articular arthrosis of the piso-triquetral joint. The stability of the pisiform is secured by the forces of the flexor carpi ulnaris and abductor digiti minimi ulnarly and the TCL radially. The inadequate healing of the TCL can lead to instability of the pisiform and articular incongruence. Secondly, an asymptomatic chondromalacia can be symptomatic. Lateral radiographs can reveal the subluxation and the arthritic changes and thus yield the diagnosis. Intra-articular local anesthesia positive test will confirm the pathology. For persistent chronic cases, pisiform excision has been suggested.

To avoid the poor or incorrect healing of the transverse carpal ligament, wrist immobilization in extension for 2 weeks is recommended by some authors [59].

Complex Regional Pain Syndrome

Reflex Sympathetic Dystrophy (RSD) or algodystrophy is the old definition for the condition that presents with edema, stiffness, loss of function and vasomotor instability, which today should better be called Complex Regional Pain Syndrome – CRPS. There are two types of CRPS: CRPS-I and CRPS-II. The CRPS-I (previously known as reflex sympathetic dystrophy) is when there no confirmed nerve injury, whereas in CRPS-II (previously known as causalgia) there is an associated confirmed nerve injury. However, although it is unclear if these disorders will always be divided into two types, their treatment is similar.

CRPS-I is well documented as a CTS postoperative complication with a varying rate of 1–5%. Prolonged acute pain postoperatively is considered to be one of the major factors which contribute to this disorder. Moreover, a relationship between psychological and behavioral factors and CRPS-I has been shown and in fact, it is believed that the exacerbation of pain and dysfunction in these patients could help maintain the condition.

The formation of hematoma and/or tight bandages also play an important role for the disorder; some authors have therefore proposed the regular use of drains in order to avoid the hematoma, while others regularly use compressive bandages, despite their potential harmful effect.

CRPS-II causes causalgia, which is a burning sensation of pain, constant and of great severity, which influences patient's life (Fig. 7.5). It is most often encountered after internal neurolysis, where the median nerve forms adhesions with the surrounding tissues. Various authors have therefore advised against internal neurolysis. Reoperations are also considered to increase the likelihood for CRPS-II. If treated late, CRPS-II may sometimes be impossible to treat despite advanced microsurgical techniques. This is especially the case when an iatrogenic injury to the nerve and a painful neuroma is the cause of CRPS-II.

Fig. 7.5 Image of a hand with CRPS II 1 month after open carpal tunnel release

CRPS treatment may require multidisciplinary approach. Different types of medications have been used such as steroids, bisphosphonates, anticonvulsants as well as physiotherapy and behavioral therapy [60]. When conservative treatment fails invasive treatments should be considered [61]. Sympathetic nerve blocks as well as sympathectomy have been described in the literature [62, 63].

It is the principal author's opinion that every factor which continues to cause pain and/or discomfort in the hand should be immediately addressed, so as to stop the vicious cycle which causes CRPS. If there isn't any triggering factor, other than nerve injury, as incomplete release or trigger finger, e.t.c., which should be addressed also surgically, aggressive pain management and/or sympathetic blockade with stellate ganglion injection may be the best treatment.

If encountered late, aggressive pain management and/or sympathetic blockade with stellate ganglion injection may be the best treatment with or without a repeat operation. Overall, prompt identification of the lesion and adequate surgical management is the only way to reduce the possibilities of a permanent debilitating painful condition in these patients.

Conclusions

Carpal tunnel syndrome was first described by Paget in 1854, but it was Phalen in 1966, who reported on his experience regarding diagnosis

and treatment of median nerve compressive neuropathy. Ever since, there has been great progress in Hand Surgery. Minimal invasive and endoscopic techniques are now used in everyday practice. However, despite these remarkable achievements in Hand Surgery, the rate of complications remains high; minimally invasive techniques may increase the complication rate due to narrow surgical field and worse visualization. The median nerve laceration is the most common complication in both techniques OCTR and ECTR and tendon laceration is more common after ECTR. The selection of the incision type is of critical importance in order to avoid painful scar formation. Improper TCL healing plays a critical role in the appearance of some types of complications. In conclusion, carpal tunnel surgery is certainly a simple procedure, but the surgeon must be ready to recognize and treat any potential complication.

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