Ultrasound-Guided Hydroneurolysis of the Median Nerve for Recurrent Carpal Tunnel Syndrome

HAND
2019, Vol. 14(3) 413–421
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DOI: 10.1177/1558944717731855
hand.sagepub.com

Scott M. Fried¹ and Levon N. Nazarian²

Abstract

Background: Recurrent carpal tunnel syndrome is often associated with perineural scarring around the median nerve. Surgical options include relatively invasive procedures, such as fat pad grafting, ligament reconstruction, muscle transfer, and nerve wraps. All have limited success because of the possibility of repeated recurrent scarring postoperatively. **Methods:** We discuss a technique involving injection with external hydroneurolysis of the median nerve under ultrasound guidance for recurrent carpal tunnel. Injection enables a gentler dissection of the surrounding tissues compared with open external neurolysis, with less chance of recurrent scarring. This technique is a unique alternative to repeat operative intervention in recurrent carpal tunnel, as well as a prelude to repeat open decompression and salvage procedures. **Results:** Ultrasound-guided injection with external hydroneurolysis of the median nerve is a safer, more limited procedure compared with repeat open surgery, usually performed in an office setting. This procedure limits risk, anesthesia, and operating/recovery room expenses, offering relief in 70% to 80% of cases. Furthermore, in the 20% to 30% of patients with inadequate relief, surgery remains a viable option. US provides important information on the anatomy of the median nerve and carpal canal and can rule out covert pathology. **Conclusions:** We offer an alternative treatment for recurrent carpal tunnel syndrome, a difficult problem for which many surgeons recommend nonoperative treatment. US provides objective data concerning residual nerve compression and allows for dynamic assessment. Theoretically, this also offers a viable solution for surgeons and their patients with recurrent carpal tunnel syndrome before being pressed to consider repeat open surgery.

Keywords: carpal tunnel, ultrasound, muscle ultrasound, subsynovial connective tissue (SSCT), injection, recurrent carpal tunnel

Introduction

Carpal tunnel syndrome is the most commonly diagnosed neuropathy of the upper extremity.^{3,34} Carpal tunnel syndrome was originally described in 1854 by Sir James Paget. The diagnosis and treatment of this disease as a compression neuropathy was popularized by Dr George Phalen in the 1950s. Approximately 5 million adults in the United States have carpal tunnel syndrome, and there is a 10% risk of developing carpal tunnel syndrome in a person's lifetime.^{3,13} Approximately 500 000 carpal tunnel releases are performed annually.³¹

There are a variety of treatment methods for carpal tunnel syndrome with varied degrees of success.^{12,20,32,37} The methods with proven effectiveness, such as wrist neutral splinting, therapy, and injection, offer relief in up to 70% of cases. Some studies have shown that injection yields an even higher success rate, approaching 90% or higher, when performed under ultrasound (US) guidance.^{2,7,10,15,19,23,26,27} The choice of optimal

treatment for carpal tunnel syndrome depends on the severity, the duration of symptoms, and patients' preferences.⁴⁴ Surgery for carpal tunnel is considered the gold standard in treatment. Improvement of this condition has been reported as almost 100% in some studies. However, studies have shown varied degrees of long-term improvement, with some reporting as low as 70% long-term improvement.^{4,6,17,18,22,30}

Surgical techniques vary, but all of them aim to divide the transverse carpal ligament. Surgery generally requires a formal operating room setting in a hospital or surgical

¹The Upper Extremity Institute, Blue Bell, PA, USA

²Thomas Jefferson University, Philadelphia, PA, USA

Supplemental material is available in the online version of the article.

Corresponding Author:

Scott M. Fried, The Upper Extremity Institute, 1515 Dekalb Pike, Suite 204, Blue Bell, PA 19422, USA.

Email: askdoctorscott@gmail.com

center, the use of a tourniquet, and either sedation or general anesthesia. Postoperative monitoring in the recovery room is generally required, as well as a formal outpatient stay. Surgical variations include “open” incision release, mini-open incision, and a number of endoscopic release techniques.¹ Reported surgical success rates vary between 70% and 98%.^{4,6,17,18,22,29,30,33} These reports have shown that up to 25% or 30% of patients remain symptomatic or manifest early recurrence of symptoms.^{4,6,17,18,22,30} The most commonly reported finding when reoperating on these recurrent cases is incomplete release of the transverse carpal ligament. However, in many cases, the ligament is adequately released, but symptoms return. Abzug, Jacoby, and Osterman¹ have proposed the following: “If the transverse carpal ligament was adequately released during the index procedure, the second most commonly cited reason for recurrence is due to perineural fibrosis tethering the median nerve within the carpal tunnel.”^{8,16,24,30,40,43} Furthermore, they state that because of the limited ability of controlling scar formation, revision decompression and neurolysis of the median nerve for treating perineural fibrosis often provides disappointing results.^{22,38,46}

Proposed repeat procedures, such as fat pad grafts, ligament reconstruction, muscle transfer, and nerve wraps, often yield even more disappointing results. Scarring around the nerve, especially the epineurium and perineural tissues, is thought to cause progressive changes in the nerve and restriction of the nerve’s motion. This situation results in carpal tunnel symptomatology.^{14,24} According to Strickland et al, this is the reason why conservative care is often met with disappointing results in attempting to treat these recurrent cases.³⁹ Unfortunately, the results of repeat surgery are often equally disappointing. Although a number of procedures are advocated surgically to treat this recurrent perineural fibrosis, the issue of repeat recurrent scarring is not easily addressed when dealing with new surgical trauma.

Using static, as well as dynamic, US evaluation, this recurrent scarring of the median nerve at the carpal tunnel after ligament release, reconstruction, muscle transfer, and fat pad grafts can be documented and observed. Part of the problem in some median nerve issues is constriction of the nerve, as well as restriction of movement secondary to post-procedure recurrent scarring. Similar patterns of this scarring are also observed in nonoperated carpal tunnel. The most common areas of scar fixation of the nerve are the undersurface of the transverse carpal ligament and the flexor tendon sheath within the carpal canal.^{41,42} Furthermore, consistent with the work of Abzug, Jacoby, and Osterman,¹ information supplied by dynamic carpal tunnel US studies has clearly demonstrated that in some cases of carpal tunnel syndrome, especially recurrent carpal tunnel, the pathological cause may not be simple compression or recurrent compression of the median nerve within the carpal canal. The

pathological cause may be the nerve’s inability to escape the direct and indirectly imparted pressure within the canal from making a fist, pinching, and wrist posture, as well as synovitis, instead. These actions result in compression of the nerve and subsequent constriction of movement from the perineural scar.

Dynamic US

New forms of diagnostic technology have resulted in new methods of evaluating and observing the structures in the carpal tunnel. Dynamic US allows viewing of the median nerve in the carpal canal, as can be achieved with a magnetic resonance imaging scan. Dynamic US also enables determination of how the nerve interacts with the surrounding structures in the canal. With this ability, we are able to observe what occurs during various phases of making a fist, wrist flexion, and extension, as well as fingering and pinching activities. US data have clearly demonstrated the ability to visualize compression of peripheral nerves from the brachial plexus to the carpal tunnel.^{2,7,10-12,14,15,19,23,26-28,41,42} Any individual who is skilled in US evaluation is aware that the median nerve is not a static structure within the carpal canal.²¹

The flexor tendons are dynamic and move through the canal. In addition, the tenosynovium changes in character with activity and various stages of inflammation. The median nerve is in fact dynamically mobile within the carpal tunnel, interacting with the other contents of the carpal canal. The median nerve changes its position in response to motion of the flexor tendons and with wrist motion. In some cases, especially in recurrent carpal tunnel, the nerve is entrapped in a postoperative scar. In this situation, the median nerve is unable to move “out of harm’s way” when other structures are in dynamic motion, and results in compression and subsequent clinical symptoms. This “sliding over” appears to be essential for protecting the nerve from direct compression by the flexor tendons and isolated pinching from the flexor pollicis longus. When the median nerve is bound by scarring and cannot shift in position, the compressive forces then cause the classic carpal tunnel symptoms.

The epineurium and subsynovial connective tissue (SSCT) can be readily seen on US evaluation and appear as hyperechoic (white) compared with the nerve.^{9,45} Adhesiveness of the surrounding tissues can be evaluated in dynamic testing and with needle manipulation of the nerve during procedures. In normal cases, there is a thin layer of hyperechoic tissue around the nerve. When this tissue becomes thickened, this is easily identified on a US examination. With dynamic US testing and with wrist flexion/extension and dynamic compression testing, the median nerve with perineural adhesions cannot move dynamically about the canal during various phases of wrist and digital motion. The

median nerve may become fixed or bound in one position in the canal. When this situation occurs, the resulting pressure surrounding the nerve is much more compressive. This could result in the mechanism described by Sanders and Haug³⁶ of repeated microtrauma to the nerve on an intermittent basis. The nerve loses its ability to float or move out of the way of the flexor tendon forces and becomes intermittently compressed beneath the transverse carpal ligament. This is clearly demonstrated by dynamic evaluation wherein patients are asked to make a fist during US examinations (see Dynamic Video online).

Historical Background of the Injection Procedure for Carpal Tunnel

Injections produce inconsistent results in the treatment of carpal tunnel syndrome.²⁵ Specifically, blind injections in the carpal tunnel have had some success and, in certain cases, offer benefit to patients. US-guided injection studies show consistent improvement between 70% and 90%, even 100% relief from carpal tunnel problems without open surgery compared with blind injections. Through the use of real-time US, we currently have the opportunity to perform guided injections and procedures.^{5,28,35} This technique allows observation of exactly where the needle and injected medium are placed and enables absolute visualization of spread of the injected material.²⁵

US-guided injections also offer the benefit of safely looking at the nerve throughout the injection, avoiding the possible complications of blind injections and allowing placement of the injected medium directly in the perineural sheath.

Manipulation of the nerve and surrounding tissues using US can also be achieved, similar to using a probe in arthroscopic procedures. US also offers the ability to evaluate the median nerve, space in the carpal canal, tenosynovitis, adhesion of the nerve to the volar surface of the transverse carpal ligament, and perineural scarring. With US-guided injections, an injected medium can be placed in the carpal tunnel, around the flexor tendons themselves or, in our procedure, in the perineural sheath. By placing saline solution or lidocaine in the perineural sheath, we are able to expand the sheath or the surrounding tissues around the nerve. This leads to increased mobility of the nerve and decreased compression or tethering from the sheath or adhesion around the nerve itself, with the same effectiveness as open external neurolysis.

This procedure has been performed on 35 patients with no complications. Furthermore, 75% of patients showed improvement, as documented by serial physical examinations and modified Disabilities of the Arm, Shoulder and Hand (DASH) scores recorded at each follow-up office visit.

Although some of the early improvement post procedure may be related to the combination of neurolysis and the effect of the corticosteroid, the longer term relief appears to be on

the basis of the added external neurolysis. The objective data on repeat US examinations up to 3 years post procedure show less SSCT binding and decreased swelling of the median nerve. Furthermore, patients allergic to steroid who had only lidocaine injection with the hydroneurolysis attained equally effective results.

In this technique article, we discuss specific injection with external hydroneurolysis of the median nerve under US guidance for the treatment of carpal tunnel syndrome, especially recurrent carpal tunnel. This injection enables gentler dissection of the surrounding tissues with less chance of recurrent scarring. Hydroneurolysis offers a unique alternative option to repeat operative intervention in recurrent carpal tunnel, as well as a prelude to simple decompression.

The indications for this procedure are patients with carpal tunnel and especially recurrent carpal tunnel who have US evidence of nerve compression with thickened SSCT and evidence of constriction or compression on US preoperative testing. Electromyogram and nerve conduction velocity (EMG/NCV) positivity is also a relative indication, although not mandatory, if the US and clinical findings dictate an appropriate diagnosis of EMG-negative carpal tunnel syndrome. All patients in this study were EMG/NCV-positive.

Contraindications to the procedure are similar to those for any injection, including proven allergy to lidocaine. A relative contraindication is steroid allergy, but the procedure has been done in these patients using lidocaine alone with equally good results.

This procedure is intended to duplicate the surgical freeing of the median nerve from the SSCT seen on the US examination through an atraumatic fluid hydrodissection. This tissue is consistent with perineural scar tissue, and the procedure is only an external neurolysis. This should be clearly differentiated from internal neurolysis, which is not performed and in fact specifically avoided, because this has been associated with resultant internal fibrosis.

This is a technique article, and follow-up studies will formally address procedure outcomes which will be studied prospectively.

This technique is an alternative, not a replacement for open repeat revision carpal tunnel surgery. Although it offers the benefit of safety as compared with repeat open techniques, its effectiveness versus repeat open surgery will need to be evaluated in head-to-head clinical studies in the future. We offer an alternative treatment for recurrent carpal tunnel syndrome, a difficult problem for which many surgeons recommend nonoperative treatment. The US provides objective data to determine whether residual compression of the nerve is present and allows for dynamic assessment. We also discuss the fact that US-guided injections, especially those with external hydroneurolysis, have a significantly higher success rate of treatment of carpal

Figure 1. General overview of the setup for the procedure of hydroneurolysis of the median nerve.

tunnel syndrome than blind injections. This is especially the case in recurrent carpal tunnel pathology. US-guided injection with external hydroneurolysis of the median nerve is a safe, more limited procedure, which can be performed in the office. This limits the risks, the need for anesthesia, and operating/recovery room expenses, offering relief for recurrent carpal tunnel in 70% to 80% of cases. Furthermore, in the 20% to 30% of patients who do not achieve adequate relief, surgery remains a viable option. US provides important information on the anatomy of the median nerve and canal and can rule out other covert pathology.

Materials and Methods

Technique and Equipment

A SonoSite M-MSK system and HFL5015-6 MHz transducer (SonoSite, Bothell, Washington) were used for all examinations. Comparison studies were performed on all patients to evaluate the opposite side to ensure that the pathology was consistent with the clinical disease. The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained for clinical participants.

Hydroneurolysis under US guidance is similar to open surgery, but with no incision and much less risk and cost. Specifically, when US is used to address nerve pathology and scarring, which occurs in carpal tunnel and other nerve

compression or fixation problems, we are able to free the nerve from its surrounding adhesions and scarring. We are also able to decompress the area using fluid pressure to achieve what is normally performed with scissor dissection.

This technique is performed using an US probe, and it depicts anatomy and the carpal tunnel structures, which can be assessed in a real-time fashion. Anesthesia is instituted in our institution on a 3-level basis. A Lidoderm patch is applied to the volar wrist and hand 30 minutes before procedure. Xanax 0.25 mg is provided to the patients with a sip of water. They are then provided with a relaxation/visualization tape to listen to throughout the procedure. This is the patient's choice, but 90% of patients choose to listen and rest throughout the procedure. Median nerve block is the final step and is applied at the time of initial injection under US guidance (Figure 1).

Nerve block anesthesia is applied as part of the actual procedure because lidocaine 1% plain is used for the hydrolysis procedure. The initial US-guided injection usually frees the portion of the nerve adjacent to the flexor tendons. This provides more than adequate supplemental nerve block and comfort to allow better control of pain and for proceeding to the more complete external hydroneurolysis of the nerve and surrounding structures (Figure 2).

Procedure (Technique)

After preparing and draping in the usual orthopedic sterile manner, initial injection with block augmentation is performed after visualizing the nerve in transverse and

Figure 2. (a) Initial injection is performed with a 25-gauge needle to add initial lidocaine. (b) A switch to a 22-gauge spinal needle was made according to the surgeon's preference.

Figure 3. A spinal needle is used to manipulate the soft tissues and for more optimal placement of the hydrodissection fluid to free the nerve from the subsynovial connective tissue.

longitudinal views. Once the nerve is completely visualized, as well as the epineurium and surrounding structures, hydroneurolysis is then performed with direct needle localization under US visualization (Figure 3).

Care is taken to completely free the nerve of all surrounding adhesion and any scarring. Dissection is carried out distally and proximally. The surrounding scar tissue is carefully isolated from the nerve, initially using a 25-gauge needle and then progressing to a 22-gauge spinal needle. This allows not only chemical hydromanipulation of the nerve and surrounding scar tissue but also mechanical teasing off of the nerve tissue with the side portions of the needle.

Injection is carried out with views in both planes. Care is taken not to inject the nerve itself and to free the surrounding tissues as completely as possible from any attachment to the flexor tendon sheath, as well as the undersurface of the

Figure 4. Lidocaine for hydroneurolysis and Depo-Medrol are injected on command by the assistant, keeping a steady, even pressure as instructed.

transverse carpal ligament. Injection is performed using 1% lidocaine plain. A second injection to the surrounding tissues is added at the end of the procedure with 1 mL (40 mg) of Depo-Medrol (methylprednisolone acetate injectable suspension; USP, Pfizer, New York; Figure 4).

Case Example I

This case demonstrates US images of preoperative recurrent scarring and SSCT surrounding the median nerve, and postoperative US images show the completely freed posthydroneurolysis median nerve (Figures 5 and 6).

Figure 5. Preoperative ultrasound images demonstrate scarring with the hyperechoic (white) subsynovial connective tissue (green arrow) surrounding this median nerve (a) beneath the transverse carpal ligament (b). This is seen on transverse cut images and longitudinal images as well.

Figure 6. Postoperatively excellent freedom of the nerve (a) from the subsynovial connective tissue adhesions is noted on transverse and longitudinal ultrasound images of the median nerve at the close of the procedure. The green arrows point to the dark black hypoechoic halo between the flexor tendons and the median nerve (a), created by the fluid dissection.

Case Example 2

This case demonstrates more detailed anatomic clarity of the hyperechoic SSCT and constriction of the median nerve on preoperative US images as well as postoperative US images demonstrating a clear halo surrounding the median nerve and immediate decrease in compression deformity after hydroneurolysis (Figures 7 and 8).

Key Features of the Procedure

- The nerve is completely freed proximally, distally, and volarly, as well as dorsally.
- Evaluation is performed before and after the procedure to assure that there is no evidence of other covert pathology in this region.

Figure 7. Preoperatively, note the significant scarring and indentation beneath the transverse carpal ligament (b) of this nonoperated median nerve (a), demonstrated for clarity, which sits over the arrow on the transverse ultrasound image. On the longitudinal view, note the significant and classic hourglass deformity of the median nerve (a). The hyperechoic (white) subsynovial connective tissue (arrow) is noted to surround and constrict the nerve, which is compressed beneath the ligament.

Figure 8. Postoperative ultrasound images demonstrate a clear halo surrounding the median nerve (a), and it is free beneath the transverse carpal ligament (b) and also from the flexor tendons (d). Note on longitudinal image continued improvement with decrease in swelling from the compression of the median nerve and further early resolution of hourglass deformity.

- The nerve is dynamically evaluated post procedure, assuring that it can freely move while making a fist, or performing wrist flexion/extension, and FPL pinching, and is unencumbered by the ligament or tendons.
- The nerve is evaluated to ensure that it is completely intact post procedure. All examinations and procedures described in this article were performed by the first author (S.M.F.) using the described technique.

Conclusion

We present here a viable option for surgeons operating on patients with recurrent carpal tunnel syndrome. This technique affords relief, approximating open procedures with minimal risk, while preserving the option of salvage procedures should the results be less than optimal. The procedure has minimal risk, is much less costly than open surgery, has no hospitalization costs, and can be performed in the office, with an essentially 0% complication rate in our experience.

We consider US-guided injection with external hydroneurolysis of the median nerve to be a safe and reasonable option for patients before considering revision carpal tunnel surgery.

Authors' Note

Online video images and case illustrations show our procedure in 2 cases of recurrent carpal tunnel and 1 case of severe nerve scarring, which would generally have the indication for an open neurolysis procedure. All cases had positive EMG/NCV studies and showed a positive clinical examination for carpal tunnel. The actual injection and live video of the full procedures can be viewed online.

Ethical Approval

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

Statement of Human and Animal Rights

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

Statement of Informed Consent

Informed consent was obtained for cited clinical participants.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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