Ultrasound-Guided Percutaneous Injection, Hydrodissection, and Fenestration for Carpal Tunnel Syndrome: Description of a New Technique

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ABSTRACT

Objective: Carpal tunnel syndrome, caused by compression of the median nerve deep to the flexor retinaculum, is the most common entrapment neuropathy. Most patients are initially treated with conservative measures such as splinting. When conservative measures fail, interventional techniques are considered the next step. Many studies have appeared comparing open surgical flexor retinaculum release to blind injections of corticosteroids into the carpal tunnel, but neither technique has proven superior to the other. Advantages of injection are: lower level of invasiveness, faster recovery, and ease of the technique. Occasional failures and complications occur with all techniques.
Method: We have been using an ultrasound-guided procedure of percutaneous hydrodissection of the median nerve away from the deep surface of the flexor retinaculum, followed by fenestration of the flexor retinaculum along a path parallel to the long axis of the arm, starting from the level of the distal part of the capitate bone and progressing proximally to the level of the radio-lunate joint, the intent being to lower the pressure exerted by the flexor retinaculum on the nerve. We have treated a series of 44 wrists in 34 patients who had electrically-proven carpal tunnel syndrome, using this technique of hydrodissection and fenestration, performed using standard injection equipment and an ultrasound system. All patients had typical carpal tunnel syndrome symptoms, and presented to us for interventional treatment after conservative measures had failed. No patient had had previous surgery, and two had had blind carpal tunnel steroid injections, without hydrodissection or fenestration. Outcomes were defined as:

- Excellent-all symptoms resolved,
- Fair-some residual symptoms, or return of symptoms, but improved compared to prior to procedure,
- Failure-required open surgical release.

First follow-up periods after procedure

ranged from 3-60 weeks, averaging 32 weeks. Second follow up periods varied from 25-96 weeks, averaging 63 weeks. Patients were contacted by telephone, or seen in follow-up in clinic, to determine outcomes.

Results:

- Excellent at first followup, lost to second followup--two wrists, too little time to judge second followup---0ne wrist
- Excellent at first followup and second followup—19 wrists
- Excellent at first followup, fair at second followup--9 wrists
- Fair at first followup and second followup—five wrists
- Fair at first followup, lost to second followup--one wrist
- Fair at first followup, to little time to judge second followup--2 wrists
- Failure—5 wrists

No complications were encountered.

Conclusion: Ultrasound-guided hydrodissection and fenestration is a viable, easy, relatively non-invasive therapy for carpal tunnel syndrome that can result in prolonged symptom relief, and may be a way to postpone, or even obviate the need for, open release.

INTRODUCTION

Carpal tunnel syndrome, involving compression of the median nerve deep to the flexor retinaculum, is one of the most common nerve compression syndromes encountered in musculoskeletal medical practice, and has a variety of causes and disease associations.[1-3] Most patients are initially treated with conservative measures using some combination of removing the offending or causative activity, treating the underlying disease, physical therapy, occupational therapy, and/or splinting. When conservative measures fail, interventional techniques are considered the next step.

Many studies have appeared comparing open surgical flexor retinaculum release to blind injections of corticosteroids into the carpal tunnel, but there is no agreement on which is preferable. This is in part because outcomes from both techniques vary depending on a variety of factors.[4] Advantages of injection are: lower level of invasiveness, faster recovery, and ease of the technique. The main disadvantage is that symptom relief is often short-lived, it may not provide a permanent solution, and some patients ultimately need surgical release.[4-9] Occasional failures and complications occur with all treatment methods, including surgery, and to a great degree, outcomes depend on the severity of the compression, the duration of symptoms, and the degree of irreversible nerve damage.[4,10-12]

We have been using an ultrasound-guided procedure of mobilizing the nerve away from the deep surface of the flexor retinaculum by percutaneous hydrodissection, followed by fenestration and splitting the laminar layers of the flexor retinaculum. The intent is to lower the pressure exerted by the flexor retinaculum on the median nerve, potentially offering a longer-lasting solution than simple blind injection. We have found our method to be safe, effective, minimally invasive, far cheaper than open surgical release, and relatively easy to learn and perform. Recovery time is measured in hours instead of days or weeks, and the technique can be repeated if necessary. Herein we report our series of 44 consecutive procedures, with outcomes at times ranging from 3 to 96 weeks.

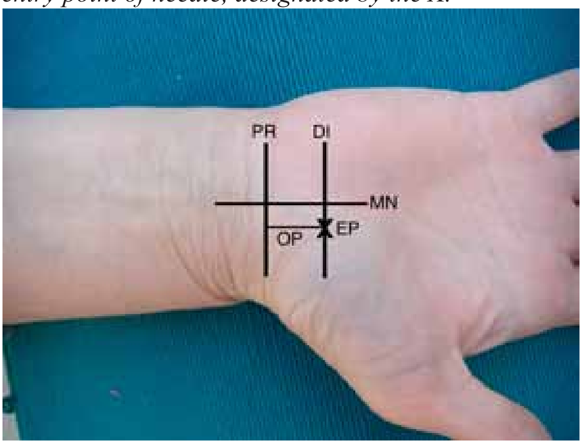
PATIENTS AND METHODS

Patients were included in this series in the order they presented to the rheumatology practices of two of the authors (NW and DGM), rheumatologists experienced in ultrasound-guided interventional musculoskeletal procedures. The Internal Review Board of the University of Wisconsin designated this retrospective review to be a quality assurance project and found it in compliance with the IRB's standard, and to present no ethical concerns. Patients were included provided that they had symptoms typical for carpal tunnel for at least 4 months, eg, pain and numbness in the median nerve sensory distribution, nocturnal worsening of symptoms, worsening of symptoms while driving, holding a telephone hand set, or gripping.

All patients had EMG/NCV confirmation of that condition. None of the patients had previously had open carpal tunnel release, and two patients had had previous blind carpal tunnel injection without fenestration or hydrodissection. Patients were instructed that carpal tunnel steroid injections are standard therapy when conservative measures fail. In addition, the entire procedure was described and patients were shown how our technique differs from blind carpal tunnel steroid injection, ie, that hydrodissection (using the jet of injected isotonic fluid from the needle tip) is used to separate the median nerve from the deep surface of the flexor retinaculum along nearly its entire course within the carpal tunnel, that a series of perforations of the flexor retinaculum is done along the long axis of the forearm from the distal to the proximal borders of the carpal tunnel, and that all of the above is done under direct visualization in real time using ultrasonographic guidance, to avoid damaging the nerves and blood vessels. All of the above is done under direct visualization in real time using ultrasonographic guidance, to avoid damaging the nerves and blood vessels. The palmar sensory branch of the median nerve, which can be damaged in open procedures as well as in blind injections of the carpal tunnel, can be avoided, since it is visible under ultrasound along its course on the ulnar aspect of the flexor carpi radialis tendon and distally in a more ulnar position.[13]

Both wrists were done in 10 patients and one wrist was done in each of the remaining 24 patients. The technique used was as follows: Using a General Electric LogiQ e ultrasound system with a 10-12 mHz linear array probe, the proximal border of the procedure area was defined by visualizing the radiolunate joint with the probe in the anatomical sagittal plane, and drawing a line on the volar forearm skin along the intersection of the anatomic axial plane at the radiolunate joint, with the skin (line PR, Figure 1). Then the distal end of the procedure area was defined in the same manner, at about 1 cm distal to the distal wrist crease, at the distal end of the capitate bone, where a second line, parallel to the first, was drawn (line DI).

Figure 1. *Photograph of lines drawn on the volar forearm skin to guide needle placement and procedures. Line DI: distal edge of operative area. Line PR: proximal edge of operative area. Line MN: line tracing course of the median nerve. Line OP: path under which operative procedures were done. EP: entry point of needle, designated by the X.*



The probe was then oriented to visualize the middle of the median nerve in its longitudinal axis (ie, in the anatomic sagittal plane). A line was drawn on the skin of the volar forearm along the intersection of the skin and the anatomic sagittal plane containing the middle of the median nerve, (line MN), and another line, parallel to line MN, was drawn along the intersection of the anatomic sagittal plane 2-3 mm radial to the median nerve, and the skin (line OP). The operator can choose to place line OP 2-3 mm ulnar to the median nerve, instead of radial to it, to further minimize the chance of damaging the palmar cutaneous branch of the median nerve. The intersection of line OP and line DI was the entry point of the needle. The skin in

Figure 2. *Ultrasound image of carpal tunnel in the transverse (anatomical axial) plane. MN: median nerve (bifid in this case). Down-pointing thin arrows: flexor retinaculum. X: target of operative needle tip underlying line Op. FL: flexor tendons of the fingers. SC: scaphoid bone. LUN: lunate bone.*

Figure 3*. Ultrasound image of carpal tunnel in the transverse (anatomical axial) plane during hydrodissection showing injected fluid, and needle tip placement. MN: median nerve. Down-pointing thin arrows: flexor retinaculum. Needle tip is viewed in short axis.*

the entire area was then sterilized with 2% chlorhexidine solution in 70% isopropyl alcohol (Chloraprep®).

An alternative very useful technique for marking the course or position of underlying structures (such as nerves, tendons, and vessels) with accurate skin lines was suggested by one of the authors (TBC), and was also employed in our procedures. To insure that the line drawn on the skin is exactly overlying any structure, that structure is visualized in short axis (ie, perpendicular to its course), and then a non-abrasive piece of straight thin wire, or a length of uncoiled smooth paper clip, is introduced with its long axis exactly perpendicular to the long axis footprint of the probe. This paper clip segment is interposed between the skin and the probe, in the gel layer, and casts an easily visible acoustic shadow onto the screen image. The paperclip is moved until the narrow acoustic shadow it casts encompasses the structure to be marked, all the while keeping the paper clip segment perpendicular to the probe long axis. Pressure is then exerted on the paper clip so as to indent the skin. The resulting small skin indentation is marked with a pen or permanent marker, and this mark therefore runs directly over the structure.

Under ultrasonographic guidance with the probe oriented in the transverse (anatomic axial) plane of the carpal tunnel, a 30g needle was introduced nearly perpendicular to the skin surface at the entry point defined previously, pointing slightly proximal along line OP, and 1% lidocaine was injected from the skin along a track ending at the deep surface of the flexor retinaculum. That needle was then withdrawn, and the procedural (20g) needle was then introduced along the anesthetized track, and was advanced to a position almost directly deep to the entry point, so as not to damage the nerve, viewed by ultrasound in short axis (Figure 2). Starting at this position, the injection of about 11 cc of hydrodissection fluid was begun, directly deep to line OP, using the jet of fluid near the needle tip to carefully separate the median nerve from the deep surface of the retinaculum (figure 3), and was continued proximally along line OP until line PR was reached. The fluid consisted of 9 cc of normal saline, 1 cc of 1% lidocaine, and 1 cc of 40 mg/ml triamcinolone acetonide.

Next, using a superficial to deep pecking motion, starting with the needle almost com-

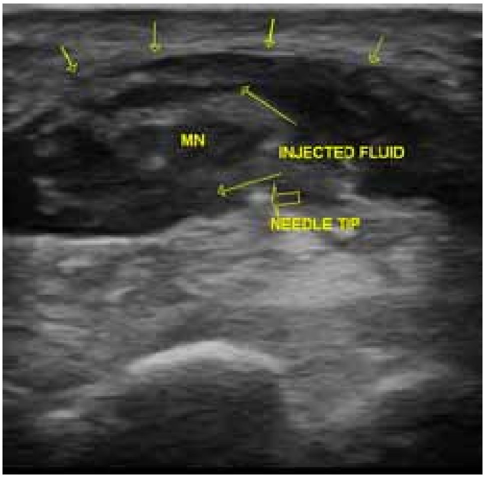
Table 1.

WRIST #	1ST EVAL- WEEKS POST-PROC/ GRADE	2ND EVAL- WEEKS POST-PROC/ GRADE
1	03 Ex	25 Ex
2	06 Ex	too little time
3	06 Ex	29 Ex
4	09 Ex	lost to follow-up
5	12 Ex	52 Ex
6	13 Ex	lost to follow-up
7	23 Ex	45 Ex
8	27 Ex	48 Ex
9	39 Ex	84 Ex
10	42 Ex	82 Ex
11	42 Ex	82 Ex
12	44 Ex	42 Ex
13	44 Ex	66 Ex
14	45 Ex	63 Ex
15	47 Ex	70 Ex
16	48 Ex	71 Ex
17	54 Ex	76 Ex
18	54 Ex	76 Ex
19	54 Ex	92 Ex
20	56 Ex	96 Ex
21	60 Ex	81 Ex
22	60 Ex	81 Ex
23	01 Ex	27 Fair
24	08 Ex	52 Fair
25	08 Ex	52 Fair
26	16 Ex	38 Fair
27	17 Ex	39 Fair
28	38 Ex	64 Fair
29	58 Ex	79 Fair
30	58 Ex	79 Fair
31	60 Ex	77 Fair
32	12 Fair	52 Fair
33	14 Fair	too little time
34	14 Fair	too little time
35	30 Fair	70 Fair
36	30 Fair	70 Fair
37	30 Fair	70 Fair
38	38 Fair	lost to follow-up
39	43 Fair	65 Fair
40	06 Failure	
41	09 Failure	
42	21 Failure	
43	54 Failure	
44	58 Failure	

pletely perpendicular to the skin at the entry point, and with the needle bevel turned to be in the sagittal plane, taking care to keep the needle inserted at the entry point, a series of about 150 perforations of the flexor retinaculum was made using ultrasound to visualize the needle tip to insure that the tip perforated the retinaculum on each pass, and did not contact the median nerve. By gradually flattening the angle between the needle shaft and the skin, while keeping the needle inserted at the entry point, the perforations were done along the course of line OP, from the entry point proximally to line PR. Small volume additional fluid injections to keep the nerve away from the path of the fenestrating needle were also employed if needed. Some of the fluid was also used to separate the laminated layers of the flexor retinaculum along this same course. The needle was then withdrawn. Finally, the patient was asked to flex the wrist forcibly against resistance to further weaken pressure of the fenestrated retinaculum on the nerve.

During the procedure, after hydrodissecting the nerve from the retinaculum, we found it possible to position the needle tip virtually anywhere in the carpal tunnel; superficial to the nerve, to either the radial or medial side of the nerve, and, importantly, deep to the nerve , which allowed injection of fluid into the tenosynovium of the flexor tendon groups.The flexor tendon tenosynovium is commonly thickened, increasing the magnitude of nerve compression in carpal tunnel syndrome.[14] This resulted in the injected fluid completely surrounding the median nerve, and contacting the underlying flexor tendon tenosynovium (Figure 4)

***Figure 4**. Ultrasound image of carpal tunnel in the transverse (anatomical axial) plane showing the needle tip viewed in short axis, placed deep to the median nerve (MN), and injected fluid surrounding the nerve superficially and deep (left-pointing thin arrows). Down-pointing thin arrows: flexor retinaculum.*



Patients were contacted by telephone within 4 days following the procedure, and were asked about any complications such as bleeding, pain, return of symptoms, or infection.

Patients were again contacted twice in the next 24 months either by telephone, or in a subsequent clinic visit, (see Table 1) for followup, to determine one of the following three outcomes:

- Excellent-all symptoms resolved,
- Fair-some residual symptoms, or return of symptoms, but improved compared to prior to procedure,
- Failure-required open surgical release.

First follow-up periods after the procedure ranged from 3-60 weeks, averaging 32 weeks. Second follow up periods varied from 25-96 weeks post-procedure, averaging 63 weeks, not counting the patients who were failures.

RESULTS

- Excellent at first followup, lost to second followup--2 wrists. Too little time to judge second followup--1 wrist
- Excellent at first followup and second followup—19 wrists
- Excellent at first followup, fair at second followup--9 wrists
- Fair at first followup and second followup—five wrists
- Fair at first followup, lost to second followup—one wrist
- Fair at first followup, too little time to judge second followup--two wrists
- Failure—5 wrists

Outcome data are shown in Table 1. Data for the second followup were not available on threee patients because too little time had elapsed since the first post-procedure evaluation to make a second evaluation meaningful, and three patients were lost to followup after the first evaluation. Patients who were evaluated as failures at the first evaluation were not recontacted for a second evaluation.

Patients reported that they did not experience discomfort during the procedure except for the initial anesthesia, which was considered very minor and brief. A few patients reported soreness around the entry point for two days after the procedure, but in none did this require analgesics or other treatment. Two patients reported a small painless ecchymosis near the entry point that did not require treatment. No patient reported worsening of carpal tunnel symptoms. There were no infections.

DISCUSSION

We have described our technique, and report our experience using a carpal tunnel injection hydrodissection and fenestration procedure to relieve symptoms of carpal tunnel syndrome. Our technique, in essence, is an extension of the commonly performed blind carpal tunnel steroid injection, and has the advantages of safety, accuracy of medication placement, effectiveness, noninvasiveness, ease of performance, and lower cost than open surgical release. To current blind injection, our technique adds direct visual guidance under ultrasound, actual separation of the median nerve from the compressing flexor retinaculum throughout the carpal tunnel by hydrodissection, and mechanical partial disruption of the retinaculum to decrease wall tension-generated compression on the nerve. This method does not result in complete section of the retinaculum such as is accomplished in open procedures, but complete sectioning may not be necessary, especially in less severe cases.[4, 10-12] Our procedure can be considered a viable intermediate treatment modality between conservative measures and open release. The magnitude of its advantage over other surgical and non-surgical treatment modalities can only be determined by a controlled comparative study, which was not the purpose of this mostly descriptive report.

We include hydrodissection to separate the median nerve from the retinaculum, separation of the several laminar layers of the retinaculum, and fenestration of the retinaculum, because pressure on the median nerve exerted by this structure within the carpal tunnel is what causes nerve malfunction and symptoms. Thus, any technique resulting in reduction of that pressure could be expected to be effective in treating this common entrapment syndrome. From a mechanical standpoint, decreasing the tension in a constricting cover such as the flexor retinaculum theoretically lowers the pressure exerted on structures deep to it. The degree and duration of this tension decrease was not determined in this study and awaits more detailed investigation. In a separate smaller study, we performed with a different set of patients, we did see functional improvement in patients undergoing this identical procedure.[15]

It has been observed that the tenosynovium of the flexor tendons underlying the median nerve is often edematous and inflamed in patients with carpal tunnel syndrome, and contributes to the increased pressure within the carpal tunnel.[14] Injection of this tissue, when swelling and inflammation are present, is recommended by some to help in reducing symptoms.[16] In performing our procedure, we did not use the separate ulnar toward radial approach described by Smith et al[16] to treat the flexor tendon tenosynovium, because we were able to create fluid spaces that completely surround the median nerve, within which the needle tip can be moved to virtually any position relative to the median nerve, including deep to it, so that flexor tendon tenosynovium can be accessed for injection of the glucocorticoid-containing hydrodissection fluid (Figure 4).

It is important to emphasize that this technique and others like it[16] must be performed with ultrasound guidance in real time, and should not be attempted unless experience and competence in ultrasound-guided procedures has been accomplished. It is now relatively convenient to obtain such training,[17] which provides expertise that is likely to become standard and state-of-the-art in many types of musculoskeletal practice in the near future.

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