Outcomes of the Surgical Treatment of Peripheral Neuromas of the Hand and Forearm

A 25-Year Comparative Outcome Study

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Purpose: Peripheral neuromas within the upper extremity result in significant disability. Treatment options vary, and established protocols have yet to be determined. We performed a long-term outcome comparison examining different treatment options for peripheral upper extremity neuromas to determine which method provided superior results using a validated upper extremity outcome measurement system.

Methods: A retrospective chart review was performed for all patients undergoing surgical intervention from 1980 to 2005 for a symptomatic neuroma of the hand or forearm. Patients' charts were reviewed for medical history, etiology of neuroma, and treatment outcomes. Patients were surveyed using the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire and pain evaluation questionnaires.

Results: We identified 127 eligible patients who had their index procedure performed at our institution. Fifty-six patients completed the questionnaires. In all cases, verification of a neuroma was made on pathologic and surgical examination. Follow-up averaged 240 months from the time of surgery. Mean age at the time of surgery was 40 years (range, 19–72 years). Of all the patients, 11 were treated with muscle or bone transposition, 17 with simple excision, and 28 with nerve repair and neurolysis. Mean DASH score at the final follow-up was 19.75 (range, 0–78.3). Patients who underwent neuroma excision with nerve repair had significantly lower postoperative DASH scores, averaging 11.42, compared with either muscle or bone transposition or simple excision (mean DASH score, 22.4 and 32.0, respectively, $P = 0.01$). The number of neuroma procedures ($P = 0.04$), preoperative pain severity ($P = 0.03$), and postoperative pain severity ($P = 0.04$) all affected the final DASH score. Fifteen patients (27%) required more than 1 surgery. Simple neuroma excision resulting in the highest incidence of reoperations (47%).

Conclusions: Treatment of upper extremity neuromas remains a complicated problem. Within this study, nerve repair yielded improved DASH scores compared with nerve transposition or the use of simple resection. Resection alone was associated with an unacceptable recurrence rate and should be discouraged as treatment for upper extremity neuromas. Prior surgical procedures, neuroma size, and the severity of preoperative pain may all adversely impact the success of surgical intervention.

Key Words: neuroma, hand, forearm, nerve, DASH

(*Ann Plas Surg* 2012;00: 00–00)

Peripheral neuromas in the hand and forearm are often disabling and adversely affect overall limb function. Neuromas are bulbous swellings that form as a result of abnormal and disorganized regeneration of unmyelinated nerve endings and can become painful on repetitive local trauma.[1–4] Painful neuromas develop frequently after peripheral nerve trauma, such as a laceration, compression, crush, or penetrating trauma.[5] Digital amputation within the upper extremity is a common cause of neuroma formation and can lead to chronic pain in 10% to 25% of patients.[6,7]

Despite their frequency, a definitive treatment modality for the successful management of painful neuromas within the forearm and hand has yet to be established.[3] More than 150 treatment methods have been described to control pain after neuroma formation; however, comparative outcome studies are scarce.[8–12]

The purpose of this study was to examine the effectiveness of different surgical procedures performed for the treatment of painful peripheral neuromas of the hand and forearm. In addition, we wished to examine if neuroma location and previous attempts at surgical treatment affected the overall outcome. Our null hypothesis was that no difference will exist in functional outcomes regardless of the surgical procedure performed to manage the neuroma, the area in which the neuroma occurred, or the number of attempts at previous surgical cure.

METHODS

This study was approved by our institutions investigational review board. Patients at our institution diagnosed with a peripheral neuroma between 1980 and 2005 were identified from a surgical database and their medical records were reviewed. Inclusion criterion included patients who had received surgical treatment for their painful neuroma with a pathologic and/or surgical diagnosis of a neuroma in the hand or forearm, as documented by surgical note and pathologic specimen, and had a minimum of 2 years of follow-up. Patients with neuromas occurring at or proximal to the elbow were excluded. Additional exclusion criteria included patients who had other concomitant nerve injuries in conjunction with their neuroma, patients who were deceased at the time of data collection (and thus could not perform the study questionnaire), patients younger than 18 years, and those who did not undergo a surgical procedure for the management of their neuroma. Patient demographics, injury mechanism, neuroma classification, hand dominance, associated symptoms, pathologic specimen size, and repair type data were collected.

Neuromas were classified according to where they occurred within the hand and forearm as has been previously described in the literature.[10] Zone I neuromas include those involving the digital nerves and the terminal branches of nerves innervating the dorsum of the hand. Zone II neuromas include those neuromas occurring in the palm of the hand and in the distribution of the dorsal branch of the ulnar nerve. Zone III neuromas include those neuromas occurring in the forearm, including the radial border of the wrist.[10]

Clinical assessment included the identification of a preoperative and postoperative Tinel sign. Subjective functional and sensory data were obtained from the medical records. Neuroma size was based on the calculated volume from dimensions reported in pathologic specimen reports. Preoperative and postoperative pain was evaluated for severity and character through a postoperative questionnaire in a fashion similar to that previously described in the literature. Pain

Received July 11, 2011, and accepted for publication, after revision, March 28, 2012.
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Presented at the American Association of Plastic Surgeons Meeting, March 2010, San Antonio, TX.
Conflicts of interest and sources of funding: none declared.
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ISSN: 0148-7043/12/0000-0000
DOI: 10.1097/SAP.0b013e3182583cf9

was assessed using a 4-point grading scale: none, mild, moderate, and severe.[9,10] All patients within the study also completed the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and the DASH work module; these questionnaires are validated testing instruments to assess hand and arm function.[13] Both the DASH and the DASH work module scores can range from 0 to 100, with a score of 100 indicating the most severe disability.

The Wilcoxon signed-rank test was used for all matched comparisons. Kruskal-Wallis analysis of variance was used for analyzing medians in nonparametric groups and χ^2 was used to analyze categorized qualitative data. Significance was set at 0.05. The statistical analysis was performed using SAS Statistical Discovery JMP version 8.0 (SAS, Inc, Cary, NC).

RESULTS

One hundred twenty-seven patients who met the inclusion criteria were identified. Seventy-one patients were lost to follow-up, leaving 56 patients who were treated for 56 individual neuromas. The study population consisted of 20 women (36%) and 36 men (64%), with a mean age of 40 years (range, 19–72 years). Mean follow-up was 240 months (range, 38–342 months). Mechanisms of injury included 43 cases of trauma and 13 iatrogenic complications after other surgeries. Of the trauma cases, 21 were due to lacerations, 14 to crush or blunt injuries, 6 to amputation, and 2 to other causes. Thus, other concomitant injuries may have been present on initial injury but did not influence the neuroma procedure later used.

Twenty-nine neuromas (52%) occurred in the dominant limb. Twenty-six patients were involved in workman's compensation coverage. Mean time from initial presentation to the patient's first surgery was 2 months (range, 0–24 months). A preoperative Tinel sign was performed in 42 patients and was positive in 35. Preoperative pain evaluations were available for 55 patients (98%), with average rating of moderate pain; 7 patients (13%) reported mild pain, 16 (29%) reported moderate pain, and 20 (36%) had reported severe pain. Of the 43 patients with mild or greater pain, 27 (63%) experienced constant aching pain.

Associated symptoms in addition to pain were noted in 48 patients, with 11 (23%) noting hypoesthesia in the affected area, whereas 5 (10%) reported parasthesias and 17 (35%) reported both. The remaining 15 patients reported weakness (n = 4), stiffness (n = 4), "burning" (n = 4), edema (n = 1), infection (n = 1), and hypothermia (n = 1) with or without numbness and tingling. Before undergoing surgery, 32 patients (57%) tried other treatment modalities including, but not limited to, medication, splinting, transcutaneous electrical nerve stimulation (TENS), injection, and therapeutic nerve blocks. Of the 32 patients, 18 (56%) gained no benefit, 13 (41%) gained partial benefit, and 1 (3%) found complete pain relief after a nerve block.

The findings at surgery included 42 (75%) true neuromas and 14 (25%) neuromas in continuity. Twenty-eight neuromas occurred in zone I, 19 in zone II, and 9 in zone III. All 28 neuromas in zone I occurred within the digital nerves. Operative procedures were performed by 1 of 10 surgeons over the 25–year period. Surgical procedures included the resection of the neuromas and transposition of the remaining nerve stump into muscle or bone in 11 patients, simple excision of the neuromas in 17 patients, and nerve repair in 28 patients. Of the 17 neuromas excised, 1 also received cryotherapy and 2 had silicone caps placed. Of the 28 nerves repaired, 8 were grafted and 20 underwent neurolysis with neurorrhaphy.

Postoperative pain evaluations were available for all 56 patients with an average rating of mild pain. Twelve (21%) reported mild pain, 18 (32%) reported moderate pain, and 8 (14%) reported severe pain. The improvement in postoperative pain ratings was statistically significant (P = 0.02). Postoperatively, of the 38 patients who still experienced pain, 19 (50%) experienced constant aching pain.

TABLE 1. Effects of Variables on Functional and Sensory Outcomes

Outcome Variable	DASH	DASH Work Module	Postoperative Pain
Sex	0.63*	0.48*	0.25*
Age	0.42*	0.58*	0.21*
Dominant hand involved	0.44*	0.50*	0.30*
Mechanism of injury	0.82*	0.18*	0.62*
Workman's compensation	0.05†	0.14*	0.80*
Preoperative pain	0.03†	0.14*	0.16*
Postoperative pain	0.04†	0.60*	
Zone	0.63*	0.87*	0.55*
Digit involvement	0.81*	0.62*	0.53*
Preoperative Tinel sign	0.72*	0.85	0.61*
Postoperative Tinel sign	0.06*	0.78*	0.53*
Time of presentation to procedure	0.65*	0.77*	0.15*
Follow-up time	0.49*	0.84*	0.37*
Procedure	0.01†	0.02†	0.64*
Neuroma type	0.44*	0.89*	0.46*
Neuroma size	0.24*	0.04†	0.43*
Use of prior alternative treatments	0.09*	0.04†	0.44*
No. neuroma surgeries	0.002†	0.03†	0.05†
Multiple previous procedures	0.11*	0.14*	0.20*

Data are P values.
*Not significant.
†Significant

The time from neuroma diagnosis to surgery and the time from surgery to final clinical evaluation were not found statistically significant to influence the pain grade. As shown in Table 1, the only factor that was found to influence postoperative pain was the number of previous neuroma surgeries, with more surgeries being associated with a higher postoperative pain grade (P = 0.05).

Postoperatively, 36 patients had associated symptoms including numbness and/or tingling in 28 patients (78%). The remaining 8 patients had weakness (n = 4), stiffness (n = 2), burning (n = 1), cold sensitivity (n = 1), and phantom pain (n = 1) with or without numbness and tingling.

Postoperative DASH scores were available for 54 patients (96%). The mean DASH score was 19.75 (SD, 20.5; median, 11.67; range, 0–78.3). The mean DASH score for patients with no pain after surgery was 13.8, with mild pain 13.7, with moderate pain 19.5, and with severe pain 41.2. Scores from the DASH work module were available for 40 patients (71%) because 13 patients (23%) did not currently work. The mean DASH work module score was 13.6 (median, 0; range, 0–69).

As seen in Table 1, higher DASH scores, indicating greater disability, were significantly associated with multiple neuroma surgeries (P = 0.002), greater preoperative pain severity scores (P = 0.03), greater postoperative pain severity (P = 0.04), patients' involvement in workman's compensation lawsuit (P = 0.05), and an operation of either transposition to bone/muscle or simple excision when compared with nerve repair (P = 0.01).

Higher DASH work module scores were associated with larger neuroma size at the time of surgery (P = 0.04) and greater number of surgical procedures (P = 0.03). Although the use of alternative treatments made no difference in postoperative pain

TABLE 2. Subcategorical Comparison of Procedure Types

Outcome Procedure	n	Mean DASH	Mean DASH Work Module	Mean Pain Rating	>1 Procedure, n (%)
Transposition into muscle or bone	11	22.42	13.29	Mild	4 (36)
Simple excision	17	31.98	25.00	Moderate	8 (47)
Nerve repair	28	11.42	4.86	Mild	3 (11)

assessment, it was found to influence DASH work module scores and neared significance for DASH scores.

Testing for a Tinel sign was performed in 30 patients after surgery and was positive in 25 patients. The presence or absence of a Tinel sign was not predictive of functional outcomes. Neither the duration of time from clinical presentation to surgical intervention nor the length of follow-up was associated with changes in DASH scores outcomes. Neither the zone nor the presence of digital involvement had any impact on functional or sensory outcomes.

As seen in Table 2, the type of procedure performed was found to affect functional outcome as measured by the DASH ($P = 0.01$) and DASH work module ($P = 0.02$), with nerve repair being superior. Worth noting, no trends were identified to indicate the development of new therapies over time or variations in the procedures used over time.

Forty-one patients required only 1 surgical procedure for adequate treatment of their neuroma. These surgeries included muscle/bone transposition in 7, simple excision in 9, and nerve repair in 28. As detailed in Table 3, 20 procedures failed, which was defined as a patient experiencing severe postoperative pain, having a DASH score greater than 40.25—1 SD above the mean—or requiring additional procedures. In those that failed, 15 patients (27%) required an additional 39 surgeries with those patients on average receiving 3.6 surgeries (range, 3–7 surgeries). Nerve repair had the highest rate of success ($P = 0.02$).

Final considerations in peripheral neuromas include the mechanism of injury, age, hand dominance, and existence of a preoperative Tinel sign. None of these factors had any influence on postoperative function or pain.

DISCUSSION

Peripheral neuromas in the hand and forearm can be debilitating and difficult to treat. Reports show that patients with painful neuromas can be notably impaired functionally but may also be unable to maintain gainful employment.[14,15] Prevention of neuroma formation would clearly be the best alternative. Specific surgical techniques have been described to prevent neuroma formation after amputation,[16–19] and techniques specifically focused on addressing the nerve during surgery have also been described.[20] However, these preventative measures are not always successful and often surgical treatments must be sought. The superiority of any 1 surgical treatment over any other is largely debated.

Surgical treatment options include simple excision; translocation to muscle, bone, vein, or subcutaneous tissue[11,21–25]; neurorrhaphy[20,26]; silicone capping[27]; ligation; coagulation[28]; toe transplants for amputated digits[29,30]; epineural and nerve stripping[31,32]; vascular flap and muscle graft transfers[33–37]; nerve stimulation[38,39]; and placement of artery, vein, or silicone conduits for nerves with still-present distal segments.[40]

Several considerations for optimal treatment selection have been suggested, such as the location of the neuroma, classification of pain, and type of neuroma.[41] The contribution of location is arguable, as some state pain in zone III is most difficult to treat,[11] whereas others note worse results in zone I.[22] Moreover, some literature suggests different treatments should be used in different zones. For example, zone I neuromas can be buried in the lateral aspect of the proximal phalanx or in the dorsolateral surface of the nearest metacarpal bone,[9] zone II neuromas in the pronator quadratus muscle,[10,12,42] and zone III neuromas in the brachialis or brachioradialis muscle.[11,43] Analysis in this study revealed that neither the zone nor the involvement of digits had any impact in pain assessment or functionality.

Two main types of neuromas exist—traumatic neuromas and neuromas-in-continuity—which, together, made up the majority seen in these patients. Traumatic neuromas develop on injured, partially transected, or severed (amputation neuromas) nerves after some sort of trauma. Neuromas-in-continuity form because of axonal disruption with epineurial continuity after nerve injury.[8] The type of neuroma was not found to impact pain of functionality.

In addition to the location and type of neuroma, the effects of the size of the neuroma are debatable. In the feet, smaller, more organized, and less irritated neuromas are less symptomatic, whereas larger neuromas impact postoperative pain.[44] Patient satisfaction is directly related to the size of the neuroma.[45] This may, in part, be because smaller neuromas tend to have more regularly-directed axonal orientation[8] and have less connective tissue involvement.[46] The size of the neuroma in the hand has been suggested to not correlate with the amount of pain,[8] although this may relate to the location and frequency of use in the involved area. Although the size of the neuroma made no difference in patients' pain or overall function in this study, it did have an impact on specialized function, as assessed

TABLE 3. Success and Failure by Procedure Type

Outcome Procedure	n	Severe Pain, $P = 0.42$	>1 Procedure, $P = 0.02$	DASH > 40.25,* $P = 0.07$	Failure†	Success, $P = 0.02$
Transposition into muscle or bone	11	1 (9)	4 (36)	3 (27)	5 (45)	6 (55)
Simple excision	17	4 (24)	8 (47)	4/16 (25)	10 (59)	7 (41)
Nerve repair	28	3 (11)	3 (11)	1/27 (4)	5 (18)	23 (82)

Values are n (%).
*DASH greater than 40.25 was defined by 1 SD beyond patient population mean. DASH, n = 54 patients; percentages based on available DASH n.
†Failure was defined as any 1 of the 3 other criteria listed.

by the DASH work module. This has never been reported in the literature, and it warrants consideration.

Previous studies have determined the magnitude of the injury bears no relationship to the development of pain.[12] This is consistent with our study, although we also found that the mechanism of injury failed to influence postoperative function. Age, hand dominance, and a Tinel sign did not have an influence on pain or function. It is worth noting that a postoperative Tinel sign did near significance, although the strength and significance of its effect would likely be better revealed in a larger multicenter study.

When considering treatments, it is worth noting that previous studies assert that 20% to 30% of neuromas remain problematic regardless of the therapeutic treatment initially applied.[47] Although initially found to have 68% excellent or satisfactory results,[48] treatment with simple excision has been found to have a reoperative rate of 65% and considered unsatisfactory because excision is often performed in the primary procedure and ultimately contributes to neuroma formation in the first place.[9,49] Secondary neurorrhaphy has been found to result in only modest relief,[5,49] and results of neurolysis with or without nerve wrapping have been poor.[11] Burial in bone can result in recurrent pain due to the tight tethering or irritation of the nerve as it crosses the edge of the bone tunnel.[9]

Nerve transposition is a popular treatment method and has excellent reported results with lower reoperative rates and is applicable to multiple types of neuromas[49–51]; however, it has been found to be less effective when transposition is performed in the thenar, hypothenar, and intrinsic hand muscles.[23,49] In addition, burial in the pronator quadratus muscle has been found to limit movement because of pain during wrist extension, supination, and pronation.[12] Silicone capping has been shown equally effective as burying the nerve within a muscle flap.[51] Silicone tubes applied to nerves can fail if not cut long enough because regenerated axons pass through and form a neuroma just distal to the tube.[21] Vein conduits can also fail should the lumen collapse.[21] Treatment failures for any of the above techniques may also be due to cut branches of overlapping nerves and incomplete removal of the involved nerves, especially in cases of sensory cutaneous nerves.[52–54]

Unfortunately, many of the above treatment options fail, and reoperations are frequent. However, some reports have shown that excellent results can still be achieved in patients with 3 or more previous neuroma operations,[53] although positive results do tend to diminish with more than 3 surgical attempts[22]; this is likely due to altered anatomy.[55] Our study revealed a reoperation rate of 27%, which is similar to that reported in the literature.[9] We also found that both function and pain deteriorated with a greater number of operations.

Although the above discussion denotes deficiencies with many procedures, this study supports the superiority of nerve repair for the treatment of painful neuromas. Functional assessment based on both the DASH score and the DASH work module score revealed that nerve repair resulted in higher levels of function. Nerve repair also proved to be the most successful procedure examined; patients who underwent nerve repair did not experience severe pain after surgery, only required a single surgical procedure for neuroma management, and reported DASH scores that were less than 1 SD above the mean.

Apart from surgical procedures, alternative treatments also exist, such as lidocaine patches, percussion, nerve blocks, injections, and transcutaneous vibratory stimulation.[39,55–60] Although these treatments do not actually help heal the neuroma, they can mask pain.[55] The patients in this study did not experience sufficient symptom relief with alternative treatments and thus required surgery. Although sufficient symptom relief had not been obtained, it is possible that partial relief may have allowed the patients to continue working with the hand, which previous studies have shown to be beneficial[53] and thus resulted in better postoperative function. Intuitively, one would assume that pain may influence ultimate function, as has been previously documented for general peripheral nerve injuries.[61] This study supported that assumption based on DASH scores. We noted that postoperative and preoperative pain affects postoperative DASH scores. Unfortunately, in this retrospective study, we were unable to acquire a preoperative DASH score, thus the change in DASH scores could not be evaluated for each patient. Future prospective studies will hopefully be able to incorporate a preoperative and postoperative DASH into the patient evaluation.

The primary strength of this article is the long-term follow-up and correlation of the DASH score with neuroma treatment. Although the DASH score has been used for previous studies of general peripheral nerve injury,[61] it has never been incorporated into a study assessing peripheral neuromas. Also of importance, the length of follow-up inherent to this study is extensive compared that of other studies. Pain assessment is known to be dependent on time from injury.[9,44] Although previous hand studies suggest that painful symptoms tend to develop within 12 weeks of nerve injury or neuroma treatment,[24] a study of neuromas of the feet revealed pain assessment changed at 12 months and even more at 36 months. Such studies suggest that a true assessment of surgical benefit may require over 3 years of follow-up.[44]

Weaknesses of the study include the large number of surgeons performing these procedures and any biases in surgical decision making by these surgeons with regard to neuroma treatment. Obviously, such biases could be removed with a randomized trial. In addition, although preoperative pain assessment was obtainable after surgery, 1 weakness with this study is the absence of a preoperative functional assessment. This is unavoidable given the nature of a retrospective study. An additional weakness of the study is the small sample size; although patient numbers in this study are large in comparison to those of other studies, larger patient numbers will allow for a multivariate analysis. Large patient numbers will be possible with a prospective multicenter trial.

In conclusion, the treatment for symptomatic upper extremity neuromas remains a difficult problem.[62,63] Within this study, we found nerve repair to produce the best outcomes, including an improved DASH scores and fewer reoperative procedures when compared with nerve transposition or the use of simple neuroma resection. Resection alone was associated with an unacceptable recurrence rate and should be discouraged as treatment for upper extremity neuromas. Prior surgical procedures, neuroma size, and the severity of preoperative pain may all adversely impact the success of any type of surgical intervention. Further prospective studies are warranted.

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