Anterior and Posterior Interosseous Neurectomy for the Treatment of Chronic Dynamic Instability of the Wrist

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Abstract The purpose of this study was to determine the results of combined anterior and posterior interosseous neurectomy (AIN/PIN) in patients with chronic wrist pain secondary to dynamic instability, and to determine the predictability of selective AIN/PIN blocks with respect to pain relief, grip strength, and outcome of the neurectomy. A prospectively accrued chronic wrist pain registry was undertaken. Inclusion criteria were patients with arthroscopically confirmed dynamic wrist instability who had undergone a diagnostic AIN/PIN injection, followed by a single dorsal incision neurectomy. All patients completed Disabilities of the Arm, Shoulder and Hand outcome questionnaires preoperatively and at intervals postoperatively. Pre- and postoperative range of motion, grip strength, and percentage pain relief were recorded. Over a 3-year

period, 50 wrists (48 patients) were enrolled: average follow-up was 28 months (range: 24–42 months). The average improvement in grip strength after denervation was 16% ($p = 0.076$), the average improvement in subjective pain rating was 51% ($p < 0.0001$), and the average improvement in Disabilities of the Arm, Shoulder, and Hand scores was 15 points ($p = 0.0039$). Improvement of pain from diagnostic injections was not predictive of final improvement of pain; however, improvement in grip strength after diagnostic injections did correlate with improved grip strength after surgery. Lack of improvement in subjective pain rating or grip strength after diagnostic injection approached statistical significance. There was no decrease in range of motion postoperatively. Fourteen patients (16 wrists) failed as defined by need for subsequent surgery. The results of AIN/PIN neurectomy demonstrate that it may be an effective alternative to wrist salvage or reconstructive procedures within the first few years of follow-up.

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Introduction

Chronic wrist pain secondary to carpal instability or degenerative arthritis can be a debilitating condition [27, 50]. Once diagnosed, conservative treatment with immobilization, splinting, oral nonsteroidal anti-inflammatory medications, or intraarticular steroid injections often provides transient pain relief [27, 36, 50]. However, surgical intervention—including arthroscopic or open debridement of interosseous ligament tears, reconstruction or repair of the incompetent interosseous ligaments, proximal row

carpectomy, and total or partial wrist arthrodeses—is often required [1, 2, 4, 7, 19, 22–25, 27, 28, 31, 32, 35–37, 39–47, 49, 50, 53]. Partial and total wrist arthrodeses are performed as salvage procedures and can significantly decrease range of motion (ROM) and grip strength [2, 4, 19, 23, 24, 32, 36, 37, 41, 42, 44, 47, 49, 53]. Despite an improvement with pain, loss of motion and grip strength can be more disabling to active individuals than the wrist pain itself.

In 1966, Wilhelm [51] described the treatment of chronic wrist pain in patients with Kienböck's disease and degenerative arthritis secondary to scaphoid nonunions by total denervation of the wrist. Total wrist denervation diminished pain yet maintained wrist motion. Subsequent reports of total wrist denervation have greatly varied, demonstrating good results in 12–95% of patients with chronic wrist pain secondary to carpal instability, degenerative arthritis, and fracture nonunions [5, 9, 11, 21, 26, 33, 51].

To avoid multiple incisions and extensive dissection, partial denervation of the wrist has been used in several studies [3, 8, 12, 13, 16, 34]. A number of studies have shown that partial neurectomies are inconsistent in their effectiveness in relieving chronic wrist pain compared to total wrist denervation [8, 12, 13, 16, 18, 21].

In 1998, Berger [3] described a single dorsal incision to perform a denervation of the anterior and posterior interosseous nerves (AIN/PIN). Weinstein and Berger [48] recently reported that 76% of chronic wrist pain patients with degenerative arthritis or static dissociative carpal instability improved their pain rating; in their report, preoperative injection of anesthetic correlated with ultimate pain relief and DASH scores. Despite these findings, the effectiveness of a combined AIN/PIN neurectomy in patients with chronic dynamic wrist instability is unknown.

The purpose of our study is threefold: (1) to evaluate the effectiveness of the combined AIN/PIN neurectomy in patients with arthroscopically confirmed chronic dynamic wrist instability with respect to pain relief, functional parameters, and DASH scores; (2) to determine whether pain relief with selective AIN/PIN blocks are predictive of the outcome of the combined neurectomy; and (3) to determine whether improvement in grip strength following selective blocks is predictive of final grip strength and outcome following neurectomy.

Materials and Methods

Between October 1997 and October 2000, all patients at a single medical institution with chronic wrist pain were enrolled into a prospectively accrued database. The inclusion criteria of this study included skeletally mature individuals with wrist pain of more than 3 months duration,

which had arthroscopically confirmed dynamic carpal instability, had failed conservative treatment, and had undergone the AIN/PIN neurectomy. Exclusion criteria included any patient with previous wrist surgery, less than 3 months of wrist pain, static carpal instability, degenerative arthritis on plain radiographs, no desire for neurectomy, had undergone alternative procedures, or was lost to follow-up.

All patients with chronic wrist pain underwent a detailed history, a systematic physical examination of bilateral wrists, radiographs, and three-phase wrist arthrography. Conservative treatment was initially provided and included a combination of immobilization, oral anti-inflammatory medications, and intraarticular steroid injections. Patients who failed conservative treatment (continued pain or failure to relieve symptoms) underwent a midcarpal and radiocarpal wrist arthroscopy and a single dorsal incision AIN/PIN neurectomy. Preoperatively, all patients completed the Disabilities of the Arm, Shoulder and Hand outcomes questionnaire (DASH) and underwent a diagnostic AIN/PIN selective block. Selective blockade of the anterior and posterior interosseous nerves was performed by injecting 1% lidocaine without epinephrine into the fourth compartment floor approximately 1 cm proximal to the proximal edge of the distal radioulnar joint [3]. After 1–2 cc was injected around the posterior interosseous nerve, the needle was directed across the interosseous membrane, and 1–2 cc was injected around the anterior interosseous nerve. Grip strengths were obtained both pre- and postselective block by using a JAMAR Dynamometer (JAMAR Hand Dynamometer Model 1, Clifton, NJ, USA), set to the third ring for males and second ring for females. All patients were asked to rate their pain relief provided by the selective block on a 100-point scale, where 0 represented no pain relief and 100 indicated complete pain relief.

All wrist arthroscopies were performed in a similar manner. A systematic radiocarpal and midcarpal arthroscopy was performed under regional or general anesthetic. The radiocarpal joint was evaluated by using a 2.7-mm 30° arthroscope (Linovatec, Largo, FL, USA) through the 3–4, 4–5, and 6U portals. The midcarpal joint was evaluated through the midcarpal ulnar and midcarpal radial portals. Instability was graded by the Geissler classification [17], and chondromalacia was graded by using a modified Outerbridge classification [29, 30]. The status and stability of the intrinsic and extrinsic ligaments as well as the chondral surfaces were evaluated. Once the diagnosis of dynamic chronic wrist instability was made (normal static radiographs, but abnormal live fluoroscopy or arthroscopic findings), the AIN/PIN neurectomy was performed as described by Berger [3]. A longitudinal 3- to 4-cm dorsal incision centered between the radius and the ulna was made just proximal to the proximal edge of the distal radioulnar joint (Fig. 1). The floor of the fourth compartment and

Figure 1 (a) The anterior and posterior interosseous neurectomy is performed through a dorsal longitudinal incision proximal to the distal radioulnar joint and extends proximally for 3–4 cm. (Printed with permission of the Mayo Foundation.) (b) Clinical photograph demonstrating the incision (longitudinal) after arthroscopy (transverse portal incisions).

posterior interosseous nerve was exposed. A 1-cm portion of the PIN was removed (Fig. 2). The interosseous membrane was incised, the distal sensory portion of the AIN was identified, and a 1-cm section was removed (Fig. 3). The skin was closed with sutures, and a bulky hand dressing with volar plaster splint was applied. Postoperatively, a short arm cast was applied for 3 weeks, and sutures were removed between 10 and 14 days. At the end of 3 weeks of immobilization, a ROM protocol and strengthening program was initiated.

Patients were followed up at periodic interval; at each visit, their wrists were examined for ROM, grip strength, and provocative maneuvers. Each patient subjectively rated his or her pain relief on a 100-point scale and completed a DASH outcomes questionnaire; satisfaction with the procedure was rated by the patient. All patients with chronic wrist pain underwent a detailed history, a systematic physical examination of bilateral wrists, radiographs, and three-phase wrist arthrography at each follow-up visit as excellent, good, fair, or poor. Failure

of the AIN/PIN neurectomy was defined as the need for a subsequent surgical procedure, as requested by the patient.

Statistical analysis was performed by using STATA 5.0 (Stata Corporation, College Station, TX, USA) with a significance set at $\alpha \leq 0.05$. Preoperative and postoperative motions, grip strengths, and DASH scores were compared by using signed-rank test. Outcome measures of most recent follow-up grip strength and pain score were tested against the results of the diagnostic blocks by using signed-rank tests. Multiple logistic regression and χ^2 tests were used in evaluating the prognostic factors of treatment failure. Changes in DASH scores, grip strength, and pain relief were tested against the results of the diagnostic blocks by using signed-rank tests and Spearman correlation coefficients. Kaplan–Meier survivorship analysis was performed to determine the survivorship of the AIN/PIN neurectomy using subsequent surgery as an endpoint.

Figure 2 (a) The extensor tendons of the fourth extensor compartment are retracted ulnarward, exposing the floor of the fourth compartment. On the radial aspect of the fourth compartment, the posterior interosseous nerve is easily identified, and a 1-cm portion is removed. (DRUJ = distal radioulnar joint; R = radius; U = ulna; IOM = interosseous membrane; AIAp = posterior division of the anterior interosseous nerve). (Printed with permission of the Mayo Foundation.) (b) The fourth extensor compartment tendons are retracted ulnarward, and the posterior interosseous nerve is easily exposed.

Figure 3 (a) The interosseous membrane is divided, exposing the anterior interosseous nerve as well as the anterior interosseous artery. The anterior interosseous nerve is isolated and a one-centimeter portion is excised. (Printed with permission of the Mayo Foundation.) (b) Clinical example of the location of the anterior interosseous nerve.

Results

Of the 232 patients enrolled into the chronic wrist pain registry during the 3-year inclusion period, 50 patients with 54 involved wrists underwent an AIN/PIN neurectomy for relief of pain. Of the 50 patients, 48 individuals with 50 wrists met the inclusion criteria and formed the study cohort with an average follow-up after AIN/PIN neurectomy at 28 months (range: 24–42 months). The average age of the patient was 30 years (range: 16–57 years); the gender breakdown was 32 males and 16 females. The dominant wrist was involved in 31 patients, nondominant in 15, and bilateral in two. Forty-four patients were active-duty military members. Twenty-seven patients had occupations requiring heavy use of their hands, while the remaining had nonmanual labor or minimal labor activities.

The average duration of wrist pain prior to our evaluation was 3.5 years (range: 3 months–12 years). The location of the pain was central in 41 wrists, ulnar in five wrists, and radial in four wrists. Among the patients who recalled their mechanism of injury, 17 had wrist injuries

resulting from a fall (on the outstretched hand), three sustained injuries after a motor vehicle accident, and 27 suffered injuries from other traumatic mechanisms (twisting, lifting, crushing, etc.). One patient did not recall a mechanism. All patients underwent trials of nonsteroidal anti-inflammatory medications and/or splints to alleviate their pain.

On physical examination, all patients had focal tenderness of the scapholunate interval, lunotriquetral interval, or both. Forty-two wrists had central tenderness (both scapholunate and lunotriquetral tenderness), six had radial tenderness only, and two had ulnar tenderness only. Carpal instability examination included palpation of the intercarpal ligaments, scapholunate and lunotriquetral provocative examination, and tests for nondissociative carpal instability. Eight wrists had a preoperative exam consistent with dynamic scapholunate instability, four had exams consistent with dynamic lunotriquetral instability, and 38 had a combination of both scapholunate and lunotriquetral dynamic instability.

Radiographs of the affected wrists were interpreted as normal, without evidence of static carpal instability, degenerative arthrosis, avascular necrosis, carpal nonunions, or malunions. Three-phase arthrograms demonstrated communications between the radiocarpal and midcarpal joints through the lunotriquetral or scapholunate ligament in 19 wrists. Triangular fibrocartilage complex (TFCC) perforations, as evidenced by dye flow between the distal radioulnar joint and the radiocarpal joint, were observed in four wrists. Dye pooling was seen in the lunotriquetral or scapholunate interval after midcarpal arthrography in 33 wrists.

Wrist arthroscopy demonstrated that all patients had at minimum a single intercarpal ligament dynamic instability with at least a Geissler grade III instability. However, 39 wrists had a combination of scapholunate and lunotriquetral dynamic instability of a minimum Geissler grade III. Severe grades of chondromalacia (Outerbridge grade 3 and 4) or eburnated bone were not observed in this patient cohort. In four patients with TFCC perforation on arthrogram, a central TFCC perforation was found, and they underwent arthroscopic debridement to a stable base. All neurectomies were performed concurrently with the wrist arthroscopy. There were no perioperative complications related to wrist arthroscopy or neurectomies.

Range of Motion

Average ROM and grip strength at an average of 28 months (range: 24–42 months) follow-up are shown on Table 1. Differences in ROM from preoperative measures were not statistically significant ($p = 0.432$).

Table 1 Pre- and post-operative wrist range of motion and grip strength.

	Preoperative	Contralateral wrist	Final postoperative
Flexion (°)	52	58	69
Extension (°)	63	67	58
Radial deviation (°)	19	20	20
Ulnar deviation (°)	36	40	32
Grip strength (kg)	34	50	40

Grip Strength

The average preoperative grip strength of the affected side was 34 kg (range: 6–60 kg) compared to the unaffected side, which was 50 kg (range: 20–100 kg) (bilaterally affected patients were not included in this calculation). After the diagnostic block of the AIN/PIN, the average grip strength increased to 41 kg (range: 21–65 kg), which represented an average percent improvement of grip strength of 24.2% (range: –25% to 173%). In some patients, grip strength decreased, and percent change was recorded as a negative value. Increase in grip strength after diagnostic block was statistically significant ($p < 0.0001$). At follow-up, the average improvement of grip strength was 16% (range: –33% to 150%). Improvement in grip strength at follow-up represented a statistically significant change from preoperative grip strength ($p = 0.076$). Improvement in grip with block correlated with post-AIN/PIN improvement of pain ($r = 0.386$, $p = 0.0128$).

Pain Relief

Pain relief was measured on a 100-point scale, with 100 representing complete relief and 0 representing no relief of pain. The average pain relief after diagnostic block averaged 79.2 (range: 20–100); this represented a statistically significant difference from preinjection pain relief ($p < 0.0001$). At follow-up, pain relief on the 100-point scale was 50 (range: 0–90). Improvement in follow-up pain relief was a statistically significant improvement from preoperative pain relief ($p < 0.0001$).

Outcome Measures

The average preoperative DASH score was 42 (range: 7–100), compared to the average follow-up DASH score of 27 (range: 0–90). The differences in pre- and postoperative DASH scores were statistically significant ($p = 0.0003$). There was an overall 85% satisfaction with the

results of neurectomy with patients reporting a perceived improvement in grip strength and pain relief. Twenty-five patients reported excellent results, 15 good, four fair, and four poor.

A statistically significant correlation between pain relief and DASH scores was observed ($r = -0.4263$, $p < 0.0039$); however, there was no correlation between improvement of change in grip strength and DASH scores ($r = -0.0127$, $p = 0.4411$). Improvements in grip strength at follow-up correlated with the improvement in pain ($r = 0.386$, $p = 0.0128$).

Diagnostic AIN/PIN injection as a predictor of final outcome

There was no correlation between pain relief after block and follow-up postoperative pain relief ($r = -0.900$, $p = 0.5734$). The improvement in grip strength after block correlated to postoperative follow-up grip strength ($r = 0.5797$, $p < 0.0001$); additionally, improvements in post-block grip strengths were statistically similar to the improvement in follow-up grip strengths ($p = 0.3746$). Thus, improvement in grip strength after diagnostic block was predictive of improvement in grip strength at follow-up. When there was a failure of improvement in grip strength and pain relief with the diagnostic injection, failure of AIN/PIN neurectomy approached statistical significance ($p = 0.0586$).

Failures of AIN/PIN Denervation

Failure of AIN/PIN neurectomy, as defined by the need for a subsequent surgical procedure for pain relief, occurred in 16 wrists (14 patients). Of the 16 wrists that underwent a subsequent procedure, four wrists underwent ligament reconstruction, and 12 wrists underwent a limited arthrodeses. Eight of the 16 wrists reported that

Figure 4 Kaplan–Meier analysis using subsequent surgical intervention as the endpoint demonstrated a 68% survival rate at 28 months.

although the AIN/PIN neurectomy provided some pain relief, patients requested a more definitive procedure prior to being separated from military service. Multiple logistic regression analysis demonstrated no statistically significant relationships between failure and age ($p = 0.501$), gender ($p = 0.448$), occupation ($p = 0.864$), military status ($p = 0.654$), dominant hand involvement ($p = 0.582$), and diagnosis ($p = 0.443$). Kaplan–Meier survivorship curve demonstrated a 68% survivorship at 28 months, when failure was defined as need for additional surgery (Fig. 4).

Discussion

Denervation for the treatment of wrist pain has evolved from total denervation of the wrist [5, 6, 11–13, 15, 16, 18, 26, 51, 52] to posterior interosseous nerve denervation [8, 34], to combined anterior and posterior interosseous nerve denervations [3, 48]. Denervation of the wrist offers the advantage of pain relief, while minimizing the prolonged immobilization, loss of motion, and muscle atrophy often associated with surgical reconstructions or limited carpal arthrodeses. Total denervation of the wrist was described by Wilhelm [51] for the palliation of chronic wrist pain associated with degenerative arthrosis, Kienböck's disease, and carpal nonunions. Subsequent to Wilhelm's report, total denervation of the wrist has been advocated for primary osteoarthritis, posttraumatic arthrosis, intraarticular distal radius fractures, Kienböck's disease, carpal fractures, and/or dislocations [5, 6, 11, 14–16, 18, 21, 26, 51, 52]. The results of total denervation have been reported to be good in 12–95% of patients [5, 6, 11, 18, 21, 26, 51, 52]. In 1972, Geldmacher et al. [18] reported excellent results in 72% (and satisfactory results in 13%) of his patients who had undergone total denervation for degenerative arthrosis. Buck-Gramcko [5] reported that 95% of patients had improvement of pain; however, 26% still had pain, but reported it decreased in severity. In 1983, Eckerot et al. [11] reported 56% pain relief with total denervation for scaphoid nonunion, Kienböck's disease, osteoarthritis, and posttraumatic arthritis. In a report on long-term results of total denervation of the wrist in 29 patients, Ishida et al. [21] demonstrated only 12% to be pain-free, with 24% satisfied with their surgery.

Although concerns on creating a neuropathic joint are present, there has not been a reported case after total denervation since the technique was introduced in 1957 by Wilhelm [51]. Despite numerous accounts of good results from total denervation of the wrist, the procedure requires multiple incisions and extensive dissection to identify the approximately 15 articular nerves of the wrist. In avoidance of multiple incisions and extensive dissection, partial denervations have gained popularity in the treatment

of chronic wrist pain [8, 9]. Denervation of the posterior interosseous nerve, however, has not been as successful as total denervation. In a comparison of total denervations to posterior interosseous nerve denervations, Ferres et al. [12] demonstrated good or better results occurred in only 26% of patients treated with posterior interosseous nerve denervation, compared to 86% of patients with total denervation. Dellon [8] reported that 90% of patients who underwent an isolated PIN neurectomy had subjective pain relief; however, the etiology of wrist pain was wide-ranging and included 17 of 40 wrists with “wrist sprains.”

In 1993, Fukumoto et al. [16] demonstrated that the primary innervation of the wrist consisted of the posterior interosseous nerve, and the lateral antebrachial cutaneous and articular branches from the main trunk of the ulnar nerve. Accessory innervation consisted of the anterior interosseous nerve, palmar cutaneous branch of the median nerve, deep and dorsal branches of the ulnar nerve, and a branch from the superficial branch of the radial nerve to the first intercarpal space. Of all the nerves innervating the wrist, the deep ulnar branch is the only one that cannot be divided, as it provides motor nerves to the intrinsic muscles of the hand. In an anatomical study of the pronator quadratus muscle, it was noted that the articular branch of the anterior interosseous nerve was distal to the motor branches to the pronator quadratus [9, 38]. It was also noted that the anterior and posterior interosseous nerves came within 2 mm of each other, distal to the motor branch of the anterior interosseous nerve. From this observation, Berger [3] described the technique of a combined anterior and posterior interosseous nerve denervation via a single dorsal incision. Of the 23 patients who underwent the combined anterior and posterior interosseous nerve denervation for chronic wrist pain secondary to posttraumatic arthrosis or static carpal instability, 79% reported a decrease in pain with a 76% satisfaction rate [48].

The use of a local injection of anesthetic to block the nerves to be denervated has been reported to simulate the efficacy of a denervation [3, 5, 8, 10, 18]. Weinstein and Berger [48] reported that, although the initial pain relief from the block may result in excellent relief of pain, the ultimate relief of pain did not correlate with the initial injection results. In our study, the degree of pain relief obtained with selective blocks did not correlate with the ultimate pain relief of the AIN/PIN denervation. However, the pain relief after injection—and the ultimate pain relief—were statistically significant compared to preoperative and preinjection levels of pain. Improvements in grip strength following selective blocks statistically correlated with final grip strengths at an average of 28 months follow-up. Failure of improvement in grip strength and pain relief after block approached statistical significance in predicting failure of the AIN/PIN denervation.

It was interesting to note that an improvement in DASH scores did not occur with improvement of grip strength and diminishment of pain, as one might expect. The reason for this is unclear; however, as the DASH is a 30-question subjective measure of upper extremity function, it may not be sensitive enough to the changes in grip strength and diminishment of pain in this setting.

Although wrist denervation (total or partial) has been performed in a variety of maladies of the wrist, its use in chronic dynamic carpal instability has not been reported. The initial treatment of chronic dynamic carpal instability is conservative with emphasis on oral nonsteroidal anti-inflammatory medications, intraarticular corticosteroid injections, splinting, temporary immobilization, and modification of activities. After failure of conservative measures, many patients, especially those whose livelihoods depend on continual use of their wrists, demand or seek surgical intervention. Surgical intervention includes limited carpal arthrodesis, interosseous ligament repair or reconstruction, capsulodesis, ligament debridement, or synovectomy [1, 7, 20, 22, 27, 31, 32, 35, 36, 42, 43, 45–47, 50]. A majority of surgical reconstructive options (ligament repair, reconstruction, or capsulodesis) require extensive dissection, prolonged immobilization, and loss of motion. Similarly, salvage procedures, including intercarpal arthrodeses, result in significant losses of motion. A surgical procedure that would palliate or diminish pain, maintain carpal motion, and improve grip strength without prolonged immobilization or “down time” would be ideal. AIN/PIN neurectomy in patients with arthroscopically confirmed chronic dynamic carpal instability resulted in 51% improvement in pain and 16% improvement in grip strength, while maintaining ROM at 1–3 years follow-up. Additionally, when the denervation failed, subsequent surgical procedures could be performed without “burning any bridges.”

Limitations of this study include the lack of a control group, the relatively short period of follow-up, and the potential of secondary gain. The average follow-up in this cohort is 28 months. Ferreres et al. [12], when comparing their PIN denervations to Dellon’s series [8], elucidates that although improvement is observed in the short term, less of an improvement is observed at 24 months. Despite this report, our survivorship data, using need for additional surgery as failure, demonstrate a 68% survivorship at 28 months.

Limitations notwithstanding, this research is unique in that it identifies a large cohort of patients with arthroscopically documented dynamic wrist instability with chronic pain treated by AIN/PIN denervation. Our results demonstrate that AIN/PIN denervation improves grip strength, provides pain relief, maintains motion, and improves outcome measures (DASH) at a mean follow-up of 28 months. In the short-term follow-up, the AIN/PIN denervation

has a low morbidity with a high patient satisfaction and may delay or obviate the need for a motion limiting procedure. The favorable outcome of the neurectomy can be predicted by the increase in grip strength after the selective injection and prediction of failures based on lack of improvement of grip strength, and pain approached statistical significance. AIN/PIN denervation is an effective and simple treatment alternative for patients with chronic wrist pain secondary to dynamic carpal instability that maintained ROM, and it did not complicate future surgical procedures.

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