Anterior Interosseous Nerve Syndrome Reconsidered

A Critical Analysis Review

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Abstract

» Anterior interosseous nerve syndrome (AINS) represents a form of neuralgic amyotrophy (Parsonage-Turner syndrome).

» AINS does not originate from external compression of the AIN in the forearm.

» Fascicular constrictions (FCs) of the median nerve are identified within the anterior interosseous fascicular group at or above the medial epicondyle.

» Spontaneous recovery is not ensured, leaving up to 30% of patients with permanent weakness or palsy.

» Fascicular microneurolysis of the median nerve, performed at or above the elbow, is a treatment option for patients who do not recover spontaneously.

The etiology, natural history, and treatment of anterior interosseous nerve syndrome (AINS) has been a matter of debate for nearly a century. This syndrome typically presents with a prodrome of arm and/or forearm pain lasting hours or days, followed by a flexion palsy of the thumb (flexor pollicis longus [FPL]), with or without distal interphalangeal joint flexion of the index finger (flexor digitorum profundus index [FDP(I)]) and/or forearm pronation (pronator quadratus [PQ]). The 2 most common theories for this condition's origin are a compressive neuropathy within the forearm or an idiopathic immune-mediated peripheral neuritis[1]. Parsonage and Turner included 5 cases of AINS in their original description of neuralgic amyotrophy (NA) in 1948[2]. While AINS can present following an upper-extremity traumatic event, direct traumatic injury to the AIN is not considered "AINS" as it represents a different pathophysiology and is decidedly rare[1]. Weakness of the AIN-innervated muscles secondary to an extrinsic mass (i.e., a tumor or a hematoma) is infrequent and also represents a different pathophysiology[1]. The disagreement over etiology has resulted in variable treatment guidelines, ranging from an indefinite nonoperative approach to surgical decompression in the forearm[3-5].

Recent reports of abnormal fascicular morphology within the median nerve above the elbow of affected patients and the ability of high-resolution imaging to identify and localize these abnormalities have provided new insight. Based on a critical review of the anatomy, the etiology, the prognosis, and the treatment of AINS, the following points are described below:

1. AINS represents a form of neuralgic amyotrophy (Parsonage-Turner syndrome).
2. AINS does not originate from external compression of the AIN in the forearm.

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3. Fascicular constrictions (FCs) of the median nerve are identified within the anterior interosseous fascicular group at or above the medial epicondyle.
4. Spontaneous recovery is not ensured, leaving up to 30% of patients with permanent weakness or palsy.
5. Fascicular microneurolysis of the median nerve, performed at or above the elbow, is a treatment option for patients who do not recover spontaneously.

AINS Represents a Form of NA

NA (neuralgic amyotrophy, or Parsonage-Turner syndrome) is an idiopathic peripheral axonopathy manifesting with acute shoulder or upper-extremity pain, followed within days by severe motor palsy and subsequent complete denervation, as measured on electrodiagnostic studies, in the distribution of ≥1 motor peripheral upper-extremity nerve[1,4,6].

The presentation and history of AINS are consistent with NA across multiple reports. Both conditions are commonly preceded by an antecedent stressful event, or trigger, such as surgery, trauma, strenuous exercise, vaccination, pregnancy, or viral illness[7-9]. Ipsilateral periscapular, shoulder, arm, or elbow pain is the first symptom in 90% of patients with NA[9]. This same pain prodrome preceding paralysis has been reported consistently in a mean of 82% of patients with AINS (Table I). Patients may have multicentric or bilateral NA and many have AIN involvement[10]. Other nerves include the spinal accessory, phrenic, suprascapular, long thoracic, axillary, musculocutaneous, radial, and posterior interosseous nerves[11-13]. Electrodiagnostic studies validate the inclusion of AINS as a form of NA; both conditions are classified as axonopathies, with complete or near-complete muscle denervation and discrete or absent motor unit recruitment[6,14-16]. While sensory involvement has been reported in up to 28% of cases of AINS[4], it is typically identified in separate nerves, most commonly the lateral antebrachial cutaneous, the radial sensory, or the medial antebrachial cutaneous[6].

Histological data support an immune etiology for NA and AINS; Pan et al. consistently found perivascular CD8-positive T-lymphocyte infiltration, edema, and fibrosis on microscopic examination of biopsies from 15 affected nerves, including 2 AIN specimens[17]. Based on the presence of CD8-positive T lymphocytes in combination with demyelination and axonal loss, they suggested that an immune reaction against certain nerve fiber components was the pathophysiologic cause of NA. Ultrasound findings are similar to those of other immune-mediated conditions, as noted by Arányi et al., who found segmental diffuse nerve or fascicular enlargement to be a common finding in a cohort of 14 patients with NA, including 3 with AIN involvement[18]. This swelling is typical of other immune-mediated nerve pathologies, including chronic inflammatory demyelinating polyneuropathy[19]. Sneag et al. demonstrated hourglass constrictions in nerves affected by NA, including 2 patients with AIN involvement, using high-resolution magnetic resonance imaging (MRI), and they postulated that these focal abnormalities are unique and specific to NA[20]. The extensive overlap in clinical course, histopathology, imaging, and surgical findings, as well as the contemporaneous appearance of NA and AINS in the same patient, support Parsonage and Turner's theory that AINS is a form of NA.

AINS Is Not a Forearm Condition

External compression or entrapment of the AIN as the etiology of AINS was proposed over 5 decades ago[21,22]. However, analysis of the anatomy of the AIN within the forearm suggests that external compression of the nerve within the forearm could not explain all of the clinical features of AINS. Fibers that eventually form the AIN maintain their distinct topography within the median nerve shortly after the median nerve's takeoff from the brachial plexus[23]. The AIN fascicular bundle resides in the posterior or posteromedial position within the main trunk of the median nerve in the arm[24]. The AIN proper emerges from the median nerve at 8 to 10 cm distal to the medial epicondyle after it passes deep to the pronator teres (PT) and the arch of the flexor digitorum superficialis. In order to compress the AIN in isolation and spare the median nerve sensory fascicles, isolated involvement of the AIN fascicular group would have to occur distal to the AIN takeoff from the median nerve. Compression proximal to this point should result in additional motor or sensory loss in the hand, which has yet to be reported[1,25]. While anecdotal reference has been made to fibrous bands that have been identified during decompression, there is no consistent finding in the surgical literature of a particular compressive band or site of compression of the AIN in the forearm[1,3,21,25].

Moreover, a compressive etiology originating in the forearm does not adequately explain the frequent occurrence of selective denervation of only 1 or 2 of the 3 AIN-innervated muscles. Independent paralysis of the FDP(I) and the FPL is common; in 69 patients who were examined by Werner, only 34 (49%) demonstrated involvement of both muscles[10]. An additional 25 (36%) and 10 (15%) showed isolated FPL and FDP(I) involvement, respectively. Both cases described by Kiloh and Nevin were incomplete, and the authors agreed with Parsonage and Turner that such "a paralysis cannot anatomically be a peripheral or nerve-root distribution."[26] Nagano[1] and Sood and Burke[7] found similar variance (Table II). No explanation has been proposed for how external compression of the AIN fascicular group would selectively and entirely denervate 1 or 2 muscles of the AIN fascicular group and completely spare others.

TABLE I Incidence of Pain Prodrome at Time of Symptom Onset Among Patients with AINS*

Authors	% (No.) of Patients Experiencing Prodromal Pain
Miller-Breslow et al. (1990)[14]	100 (10/10)
Nagano et al. (1996)[25]	89 (8/9)
Yasunaga et al. (2003)[34]	100 (3/3)
Seki et al. (2006)[40]	81 (17/21)
Park et al. (2013)[3]	73 (8/11)
Pan et al. (2014)[17]	67 (2/3)
Maldonado et al. (2016)[11]	75 (12/16)
Sneag et al. (2020)[12]	71 (32/45)

*AINS = anterior interosseous nerve syndrome.

Severe weakness or palsy of median nerve-innervated muscles proximal to the AIN distribution also has been reported in AINS, supporting the concept of a more extensive and proximal median motor neuropathy. Nagano followed a cohort of 43 patients with AINS; paralysis of the PT was demonstrated in 12 patients, paralysis of the flexor carpi radialis (FCR) was demonstrated in 11 patients, and paralysis of the palmaris longus (PL) was demonstrated in 12 patients[1]. Sneag et al. found that 9 of 18 patients with AINS had PT and/or FCR denervation on electrodiagnostic examination[12]. In a study of 16 patients with anterior interosseous neuropathy, Maldonado et al. also demonstrated involvement of muscles independent of an AIN distribution in 60% of the cohort, with no median sensory involvement except in 4 cases of documented carpal tunnel syndrome[11]. Electrodiagnostic studies showed that 9 of 15 patients who were studied with electromyography (EMG) had additional electrodiagnostic abnormalities of the median nerve (to the PT and the FCR), the radial nerve (to the triceps, the extensor indicis, and the extensor carpi ulnaris), or the axillary nerve (to the deltoid). A retrospective MRI review in the same study demonstrated atrophy of additional muscles (the PT/FCR, the FPL, the extensor carpi radialis brevis, the extensor carpi ulnaris, and the trapezius) in all 16 patients, and revealed no evidence of extrinsic AIN compression in the proximal aspect of the forearm. The authors hypothesized that this diffuse pattern of nerve involvement was more consistent with an inflammatory or immune etiology as opposed to extrinsic compression.

The results of surgical exploration for AINS support the imaging findings that have been described. Based on early surgical findings, AINS was initially believed to be caused by compression in the forearm, either due to anatomical variants or secondary to fibrous bands that formed following trauma or surgery[21]. Trauma and surgery are known triggers for AINS, even in the absence of direct injury to the forearm[1]. Spinner reported the results of 10 cases of AIN palsy, including 4 with a history of forearm trauma. On exploration of the forearm, only 1 of these patients had evidence of direct traumatic injury to the AIN[22]. Eight of 33 cases that were examined by Hill et al. presented with a history of forearm trauma, and no evidence of direct AIN injury was found in the 5 patients who underwent surgery[21]. This suggests that AIN palsies caused by direct nerve trauma are rare and should be considered a distinct etiology from AINS[26]. Nagano explored the forearms of 10 patients with nontraumatic AIN palsy and found only 1 case that had potential compression by a fibrous band[27]. Park et al. performed surgery on 11 patients; 7 showed possible areas of compression, but only 4 showed any morphologic changes of the AIN[3]. As noted by Nagano in a cohort of 23 patients, 4 nerves showed evidence of swelling or adhesion to adjacent tissue, while 19 were normal in appearance and without evidence of entrapment[1]. Ochi et al. found no evidence of compression among 18 patients who were evaluated for spontaneous AIN palsy[28]. These

TABLE II Frequency of Incomplete AINS in Multiple Cohorts*

Authors	No. of Patients	No. (%) of FPL + FDP(I)	No. (%) of FPL Only	No. (%) of FDP(I) Only
Parsonage and Turner (1957)[46]	8	6 (75)	2 (25)	0
Werner (1989)[10]	69	34 (49)	25 (36)	10 (15)
Sood and Burke (1997)[7]	16	9 (56)	5 (31)	2 (13)
Nagano (2003)[1]	39	19 (49)	11 (28)	9 (23)
Sneag et al. (2020)[12]	45	22 (49)	18 (40)	5 (11)

*AINS = anterior interosseous nerve syndrome, FPL = flexor pollicis longus, and FDP(I) = flexor digitorum profundus of the index finger.

results suggest that compression of the AIN within the forearm could account for only a minority of AINS cases.

Outcomes from the surgical literature suggest that neurolysis or decompression of the AIN within the forearm is no more effective than observation. Hill et al. found similar degrees of recovery with forearm AIN neurolysis at an average of 25 months from onset (92%; 22 of 24) and observation alone (100%; 5 of 5)[21]. In a study by Miller-Breslow et al., the 2 patients with AINS who underwent surgery at an average of 6 months after onset and the 8 patients who were only observed all recovered, but the degree of functional recovery was not documented[14]. Sood and Burke also found that time to recovery and extent of recovery did not differ between patients undergoing nonoperative treatment versus decompression within the forearm[7]. Wong and Dellon compared outcomes of AINS in the neurological and surgical literature and found that >90% of patients in both groups (50 operative, 82 nonoperative) attained some degree of recovery (although no consistent definition of recovery was described)[8]. Only 1 study demonstrated a difference between forearm exploration and observation, with 11 (73%) of 15 in the operative group recovering "satisfactory" function compared with 2 (40%) of 5 in the nonoperative group at the 4-year follow-up. No objective measure of strength was recorded[29]. Overall, these outcomes suggest that surgical intervention targeting the forearm does not yield substantially different results from nonoperative management.

The inability to identify a consistent compressive etiology explains why AINS differs from other forearm neuropathies such as carpal tunnel, cubital tunnel, ulnar tunnel, pronator teres, and radial tunnel (posterior interosseous nerve) syndromes. Forearm compressive syndromes typically manifest with demyelination and neurapraxia of both motor and sensory fibers in the nerve. Only in untreated or chronic cases does axonopathy occur in compressive syndromes. By electrodiagnostic and clinical criteria, AINS is an acute axonopathy that is associated with immediate and complete muscular paralysis without a neurapraxic component[1,16]. No other nerve entrapment syndrome in the arm or forearm involves a prodrome of intense pain, acute onset of complete paralysis or near-complete paralysis of selected muscles innervated by a mixed motor-sensory nerve, and sensory sparing. Only posterior interosseous nerve syndrome spares sensory fibers because compression occurs distal to the takeoff of the sensory fibers of the radial nerve at an identified anatomical site of compression. Extrinsic masses (hematoma or tumor) are another rare cause of isolated AIN dysfunction, having only been confirmed through imaging or surgery in scattered case reports[30,31]. In 1 case of compression by a tumor, the onset of weakness was relatively slow, occurring over 6 months, and complete palsy did not occur[30]. Of the 59 cases of AIN palsy that were reported by Sood and Burke, Miller-Breslow et al., Hill et al., and Spinner, none involved compression secondary to an extrinsic mass, suggesting that this is a rare cause of AIN dysfunction[7,14,21,22].

Overall, the constellation of anatomical, electrodiagnostic, imaging, and surgical evidence suggests that AINS does not originate within the forearm. Given the lack of evidence to support neurolysis of the AIN in the forearm, an alternate etiology of its pathogenesis and treatment should be considered.

FCs of the Median Nerve Are Identified within the Anterior Interosseous Fascicular Group at or Above the Medial Epicondyle

Hourglass constrictions (HGCs) and FCs[12] are marked by focal narrowing of a nerve or a nerve fascicle and have been described in the literature in association with AIN palsy for decades[3,25,32-34]. They appear to be a common feature of AINS: Nagano found these constrictions in 22 (96%) of 23 patients who underwent surgical neurolysis for spontaneous AINS[1]. Recently, HGCs also have been identified in the suprascapular, axillary, musculocutaneous, spinal accessory, long thoracic, radial, posterior interosseous, and PT/FCR fascicles of the median nerves[17-19]. HGCs are similar in appearance across different nerves, both morphologically and histologically. FCs are unique in that they may selectively affect individual fascicular groups within a mixed motor-sensory nerve. Imaging studies have revealed additional similarities. Sneag et al. found that constrictions in multiple nerves, including the AIN, could be consistently localized on MRI through the presence of a "bullseye sign" immediately preceding the lesion on axial images[20]. Arányi et al. found a spectrum of fascicular findings with ultrasonography in 16 patients with AIN palsy and in 54 other nerves that were affected by NA, including swelling, incomplete constriction, complete constriction, and nerve "torsion."[35]

These findings are consistent with the results of high-resolution magnetic resonance neurography (MRN) of 20 patients with AINS in a study by Pham et al.[6]. In all of the patients, MRN of the median nerve fascicles revealed segments of T2-weighted hyperintensity, with focal lesions limited to the anterior interosseous fascicular bundle within the arm. No similar lesions were discovered in the forearm. Ultrasound studies yielded similar findings. Nakashima et al. used ultrasonography to identify FCs of the AIN in 2 of 4 patients, both at or above the elbow; both FCs were subsequently confirmed at surgery[36]. Sunagawa et al. found FCs within the AIN fascicle immediately proximal to the elbow in 7 of 7 patients using ultrasonography, which also were confirmed at surgery[37]. A 2020 study by Sneag et al. followed 2 AINS cohorts (collectively 45 patients)[12]. MRI revealed FCs (63 total) in all 22 median nerves at an average of 2.4 cm proximal to the

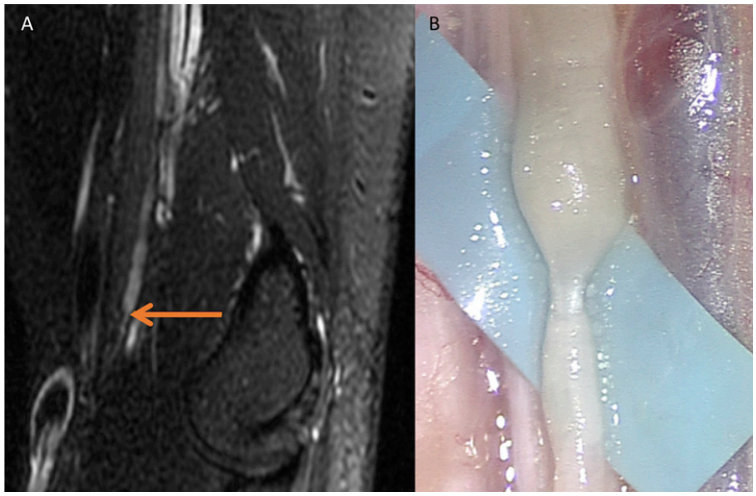

Fig. 1

Figs. 1-A and 1-B A 30-year-old woman presented with 16 months of paralysis of the left thumb and the index finger. **Fig. 1-A** Oblique sagittal T2-weighted Dixon fat-suppressed MRI reveals focal intrinsic constriction of the AIN above the elbow (arrow) with a severe reduction in fascicle caliber. **Fig. 1-B** Operative findings, which demonstrate an FC following internal neurolysis, correspond to imaging findings.

medial epicondyle. In 20 of 22 cases, FCs were discovered at an average of 4.7 cm proximal to the medial epicondyle within the posteromedial bundle, which is the expected location of the AIN fascicular group within the median nerve proper[12,38,39] (Fig. 1).

These constrictions appear to be a common feature of AINS (Table III) and may have prognostic value in predicting recovery[35]. The consistent localization of this pathoanatomy at a location above the medial epicondyle further supports the hypothesis that AINS originates proximal to the forearm.

Spontaneous Recovery Is Not Ensured, Leaving Up to 30% of Patients with Permanent Weakness or Palsy

In the 1990s, operative management of AINS was discouraged because it was believed that surgery did not change the natural history of the condition[7,21,40,41]. These principles were based on observations that approximately two-thirds of patients affected by AINS spontaneously recovered function within 3 months of onset[1,14] and were bolstered by inconsistent results from surgical exploration of the forearm.

However, evidence suggests that functional recovery often is incomplete. More than 60% of a 246-patient cohort with NA experienced residual weakness or sensory symptoms after ≥3 years following onset[9]. Among these, 30% experienced <50%

TABLE III Spectrum of Imaging Findings in Patients with AINS*

Authors	Modality	No. of Patients	Findings
Nakashima et al. (2014)[36]	US	4	2 of 4 demonstrated HGCs
Pham et al. (2014)[6]	MRI	20	20 of 20 showed hyperintense T2-weighted fascicular lesions
Arányi et al. (2015)[18]	US	3	3 of 3 showed fascicular enlargement, torsion, or an HGC
Sneag et al. (2017)[20]	MRI	3	3 of 3 showed peripheral signal hyperintensity with central hypointensity proximal to the HGCs, also known as the "bullseye sign"
Sunagawa et al. (2017)[37]	US	7	7 of 7 found to have HGCs
Sneag et al. (2020)[12]	MRI/US	22/23	22 of 22 in the MRI cohort showed HGCs 20 of 23 in the US cohort showed fascicular swelling; 9 of 23 showed HGCs

*AINS = anterior interosseous nerve syndrome, US = ultrasound, HGCs = hourglass constrictions, and MRI = magnetic resonance imaging.

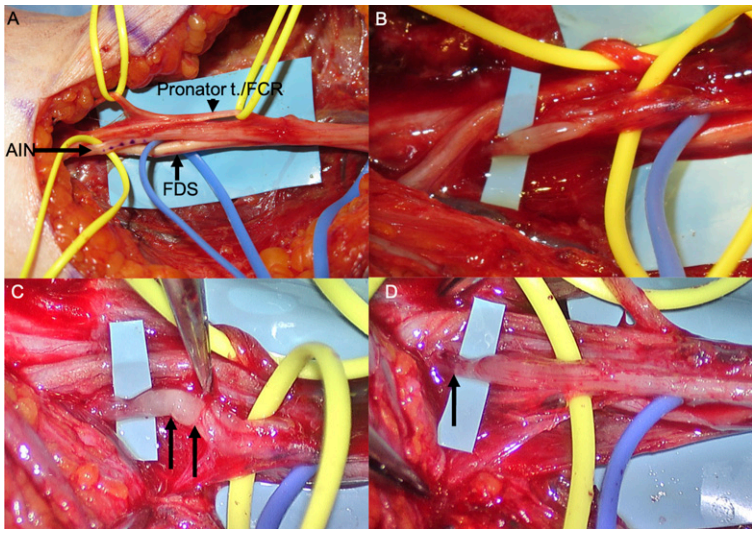

Fig. 2

Figs. 2-A through 2-D Intraoperative photographs. (Reproduced, with permission, from: Sneag DB, Saltzman EB, Meister DW, Feinberg JH, Lee SK, Wolfe SW. MRI bullseye sign: an indicator of peripheral nerve constriction in Parsonage-Turner syndrome. Muscle Nerve. 2017;56[1]:99-106. © 2016 Wiley Periodicals, Inc.) **Fig. 2-A** Dissection of the median nerve demonstrating the anterior interosseous nerve (AIN), the pronator teres/flexor carpi radialis (pronator t/FCR), and the flexor digitorum superficialis (FDS) fascicles. **Fig. 2-B** Examination under 25× magnification reveals an hourglass constriction that is limited to the AIN fascicle. **Fig. 2-C** Neurolysis demonstrates swelling of the nerve fascicle proximal to the constriction (arrows). **Fig. 2-D** Distal to the constriction (black arrow), the nerve fascicle appears translucent.

subjective motor recovery, while 20% had <M4 strength. In a study of spontaneous AINS by Schantz and Riegels-Nielsen, 3 of 5 patients who were treated expectantly had persistent paralysis 4 years after symptom onset[29]. Feinberg et al. studied the natural history and electrodiagnostic recovery of 29 patients with Parsonage-Turner syndrome, including 6 with isolated AIN palsies[16]. Only 3 of these 6 patients recovered full electrodiagnostic function after 1 year. In another study, among 12 patients who were diagnosed with AINS by clinical examination, electrodiagnostic studies, and MRI and were followed for an average of 21 months, 6 experienced partial recovery and 3 experienced no improvement[12]. In a separate ultrasound-documented cohort within the same study, among 25 limbs examined, 9 demonstrated partial recovery while 16 showed no recovery[12]. Some investigators have proposed that the severity of the HGCs is an important contributing factor to the variability in recovery[1,42]. The consensus in the literature is that nonoperative management of AINS is not always effective or appropriate[35,42].

Fascicular Microneurolysis of AINS Above the Elbow Demonstrates Improved Outcomes Over Nonoperative Treatment or Decompression Below the Elbow

Given that recovery often is incomplete and that a subset of patients do not recover, other treatment options have been explored. Decompression within the forearm has not been shown to improve outcomes relative to nonoperative treatment[7,14]. Given the imaging and surgical findings demonstrating AIN fascicular swelling and constrictions proximal to the elbow in AINS, it is reasonable that surgical intervention be focused on this region. Sunagawa et al. performed fascicular neurolysis on FCs that were detected preoperatively with ultrasonography in 6 patients with AINS; 5 of these patients recovered to M4 strength[37]. Nagano found that 21 of 22 patients with AINS who were treated with internal neurolysis regained M3 or higher strength[1]. Nagano and colleagues conducted a separate study comparing 15 patients undergoing internal neurolysis at ≥3 months after onset, with 11 treated nonoperatively. After 24 months, all 15 (100%) of the patients in the surgical cohort had regained at least M3 strength compared with 9 (82%) of 11 in the nonsurgical group[43]. Pan et al. performed either internal neurolysis, neurorrhaphy, or nerve-grafting in 42 patients with 47 spontaneous nerve palsies at the sites of confirmed HGCs[17]. Among the 16 nerves (2 AINs) undergoing neurolysis, 15, including both cases of AIN palsy, experienced ≥M4 recovery at an average of 4 years of follow-up.

The presence of pathology at the level of the individual nerve fascicular groups requires both external and internal neurolysis. The technique begins with focal epineurotomy of the nerve trunk at the site of the suspected pathology under a microscope. Individual fascicular groups are then separated under higher magnification to identify the FCs. These lesions are treated with perineurolysis under 25× magnification to separate and divide oblique perineural bands that surround and constrict individual nerve fascicles (Figs. 2-A, 2-B, and 2-C). Interestingly, of the 3 fascicles within the AIN fascicular group, HGCs can exist in 1, 2, or all 3 of the fascicles, which may explain the variation in the involvement of muscles supplied by the AIN. The

TABLE IV Recommendations for Care*

Recommendation	Grade†
Forearm neurolysis should not be performed in nontraumatic cases of AINS	B
High-resolution MRI and/or ultrasound are recommended at or above the elbow to confirm the diagnosis and localize fascicular constrictions	B
Neurolysis of hourglass/fascicular constrictions at or above the elbow is recommended in patients with AINS who have not responded to nonoperative treatment	B

*AINS = anterior interosseous nerve syndrome, and MRI = magnetic resonance imaging. †According to Wright[47], Grade A = Good evidence (Level-I studies with consistent findings) for or against recommending intervention. Grade B = Fair evidence (Level-II or III studies with consistent findings) for or against recommending intervention. Grade C = Poor-quality evidence (Level-IV or V studies with consistent findings) for or against recommending intervention. Grade I = Insufficient or conflicting evidence not allowing a recommendation for or against intervention.

rationale behind internal microneurolysis is that excision of the perineural bands improves recovery by relieving the mechanical blockage that is caused by perineural fibrosis. This is supported by the histological findings of Pan et al., who consistently found replacement of nerve fibers by connective tissue at constriction sites, with near-complete absence of axonal fibers distally[17]. The translucent appearance of nerve fascicles within the HGCs on examination under the operating microscope further suggests that the fascicle is devoid of axons, supporting the electrodiagnostic findings of an axonopathy (Fig. 2-D).

Given that some patients with AINS show early signs of recovery, the criteria for internal microneurolysis should reflect the natural history of the disease. Akane et al. compared the results of neurolysis above the elbow to nonoperative management in 51 patients with AIN and posterior interosseous nerve palsy who had failed to recover for an average of 5.5 months. Among the patients with follow-up of at least 1 year after onset (approximately 6 months postoperatively), they discovered that 62.5% (10 of 16) of the operative cohort reached M4 strength compared with 35% (7 of 20) of the nonoperative group. They concluded that neurolysis was superior in cases without spontaneous recovery and with focal constrictions[4]. They made no specific recommendation regarding how long to wait before operating but suggested choosing a time based on the distance between the constrictions and the affected muscles.

In a study by Yamamoto et al., internal neurolysis was found to be superior to nonoperative treatment in patients with spontaneous AIN palsy who showed no recovery after 3 months[5]. All of the patients in their operative group were identified to have FCs at surgery. They found that 83% of the operative group reached M4 strength (not full strength but able to contract against resistance) and that this group had substantially greater muscle strength at 39 months after onset. They also recommended that internal neurolysis be offered if recovery is not observed within 6 months; this concurs with a study by Feinberg et al. that demonstrated that axonal regeneration should consistently begin by at least 6 months after the onset of symptoms[16]. Ochi et al. compared the outcomes of combined internal and external neurolysis through wide-incision surgery (forearm decompression and microneurolysis above the elbow) and minimal-incision surgery (only above the elbow) in 25 patients with AINS at an average of 5.3 months after onset[28]. They found that 82% of patients recovered ≥M4 strength, with no statistically significant difference in outcomes between the wide and minimal incision groups[28]. In the wide incision group, the authors found no evidence of external compression of the median nerve or the AIN in the forearm. At our own center, we performed fascicular perineurolysis targeting FCs in 6 patients with chronic recalcitrant AINS who had experienced no recovery at an average of 14 months of nonoperative treatment. At a mean of 13.6 months postoperatively, all 6 of the patients had recovered, and 5 had reached at least M4 strength, while only 1 of 6 patients with AIN palsy who were managed nonoperatively had recovered to this level[44].

Surgical intervention in cases of delayed recovery also has received endorsement in the neurology literature; van Alfen recently recommended high-resolution imaging evaluation and consideration of microneurolysis if patients show no signs of recovery within 6 months[45]. She based her recommendation on the demonstrated potential of neurolysis to release constrictions that may distort the fascicular architecture and impede axonal regeneration[1,28]. This suggests that internal neurolysis of constrictions is superior to observation in chronic cases when spontaneous recovery has not occurred. The optimal timing of surgery in the course of the disease has not been established; additionally, there has been no consensus as to whether time or the degree of FC should be used as the deciding variable. In order to better understand the role and timing of surgery, a multicenter prospective randomized study comparing

neurolysis to nonoperative treatment at different time points is necessary.

Overview

The evidence in the surgical and imaging literature indicates that current diagnostic and treatment recommendations for AINS should be reconsidered. The clinical prodrome, imaging, histology, electrodiagnostic findings, multicentricity, and surgical findings of AINS are consistent with a diagnosis of NA, an immune-mediated process. Based on our critical analysis of the literature, we propose that AINS be narrowly defined as an acute fascicular axonopathy that most frequently presents with a prodrome of severe shoulder, arm, or elbow pain, followed rapidly by clinical and electrodiagnostic palsy of ≥1 AIN-innervated muscle. Trauma represents a rare and distinctly separate etiology of AIN neuropathy. While observation is appropriate for initial management, the functional recovery rate is lower than previously suggested. High-resolution nerve-specific imaging using MRI and/or ultrasonography should be performed above the elbow to define FCs. Serial electrodiagnostic findings may help prognosticate neurological recovery and help guide surgical decision-making. In chronic cases without spontaneous recovery, epineurolysis and perineurolysis targeting FCs above the elbow are effective treatments, although additional studies are necessary to determine the optimal timing of such surgical intervention (Table IV).

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