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Microneurolysis of Long Thoracic Nerve Injury Is Effective in Reversing Scapular Winging: Long-Term Results in 50 Cases

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Mini Abstract

Winging of the scapula due to long thoracic nerve palsy is common but frequently underapreciated. Our experience with 50 such palsies constitutes the largest series of nerve decompression and neurolysis reported in the literature. This procedure significantly improves scapular winging and should be considered a primary modality of functional restoration.

Abstract

STUDY DESIGN: Prospective case series.

OBJECTIVE: To evaluate thoracic nerve decompression and neurolysis in treating long thoracic nerve palsy following closed injury.

BACKGROUND: Long thoracic nerve injury leading to scapular winging is common, often caused by closed trauma through compression, stretching, traction, direct extrinsic force, penetrating injury, or neuritides such as Parsonage-Turner syndrome. This is the largest series of long thoracic nerve decompression and neurolysis in the literature.

METHODS: Winging was bilateral in 3 of the 47 patients, yielding a total of 50 procedures. Follow-up (average of 25.7 mo) consisted of physical examination and phone conversations. The degree of winging was measured by the operating surgeon (RKN). Patients also answered questions covering 11 quality-of-life facets spanning four domains of the World Health Organization Quality of Life questionnaire.

RESULTS: Thoracic nerve decompression and neurolysis improved scapular winging in 49 (98%) of the 50 cases, producing "good" or "excellent" results in 46 cases (92%). At least some improvement occurred in 98% of cases that were less than 10 years old. Pain reduction through surgery was good or excellent in 43 (86%) cases. Shoulder instability affected 21 patients preoperatively and persisted in 5 of these patients after surgery, even in the 5 patients with persistent instability who experienced some relief from the winging itself.

CONCLUSIONS: Surgical decompression and neurolysis of the long thoracic nerve significantly improve scapular winging in appropriate patients, for whom these techniques should be considered a primary modality of functional restoration.

KEY WORDS

long thoracic nerve decompression and neurolysis; scapular winging; peripheral nerve injury; scapular instability; compression injury; closed injury; functional restoration

KEY POINTS

- Scapular winging is a common condition whose significance is underappreciated.
- Thoracic nerve decompression and neurolysis improves scapular winging.
- Microneurolysis often treats the cause of the problem rather than the result of the injury.

Introduction

Winging of the scapula due to long thoracic nerve palsy is a common diagnosis[1–10] and should be treated as a significant functional problem, not simply as an aesthetic issue. The compensatory muscular activity required to improve shoulder stability is associated with secondary pain and spasm due to muscle imbalances and tendonitis around the shoulder joint. Winging also leads to adhesive capsulitis, subacromial impingement, and brachial plexus radiculitis.[5] Traditional management has relied on conservative therapy[2, 3, 11–14] and, in some refractory cases, scapular stabilization via transfer of the pectoralis tendon.[4, 5, 12, 13, 15] A less common approach has been scapulothoracic arthrodesis.[16] Most patients probably never undergo surgery and hence live with chronic shoulder instability and pain.

Scapular winging often results from insults to the long thoracic nerve, whose unique anatomical features increase its susceptibility to injury. Compared to the relatively robust adjacent nerves of the brachial plexus, the long thoracic nerve is small in diameter and appears fragile. Another point of comparison is the amount and appearance of connective tissue, which is less abundant and translucent instead of opaque in the long thoracic nerve. The lengthy course of the nerve (from C5–C7 down to the inferior border of the serratus anterior muscle) also presents multiple anatomic locations for potential injury. Surgical dissection in the axilla (e.g., during mastectomy) can directly injure the nerve in the infraclavicular region; the incidence of such injury is as high as 30%.[17]

Perhaps the most important anatomic feature associated with injury is the course of the long thoracic nerve through the fibers of the middle scalene muscle in the supraclavicular region.[18–20] Several of our patients had apparently sustained nerve injury during exercise when the contractions of the middle scalene muscle directly compressed the long thoracic nerve.

Another category of injury involved a direct extrinsic crush of the nerve in the region of the middle scalene muscle; in this group of patients, the middle scalene was thought to be a possible secondary source of injury.

In 1913, Skillern[20] first described the anatomic basis of long thoracic nerve injury by the middle scalene: “the long thoracic nerve is exposed to trauma as it traverses the scalenius medius.” Birch and colleagues[18] have succinctly described the proposed mechanism of injury: “stabilization of the forequarter on the chest wall [is] commonly associated with a strong sustained inspiration…[this action will] bring the scalenius medius into action to stabilize the first rib and the thoracic cage…[therefore] there is a liability to trapping of the nerve to the serratus at or near its point of emergence from the muscle.” Most of our patients relate a history of strenuous upper-extremity activity or of lifting heavy weights. Two of our patients had experienced direct compression of the supraclavicular fossa during deep massage treatments with associated pain and paresthesia during treatment. Disa and coworkers[19] described four patients with winging caused by stretching or trauma; the middle scalene contributed to the injuries in all four cases.

Birch and associates[18] first described the management of this problem by resection of the scalene muscle and neurolysis of the long thoracic nerve in 1998, although a 1995 paper by Chen[21] reports scalene resection as a way to free compression of the dorsal scapular nerve. Chen planned the operation for the dorsal scapular nerve but incidentally mentions that the long thoracic nerve also passes through the middle scalene. Prior to our series, the largest had been the four-patient experience of Disa and colleagues[19] in 2001.

Materials and Methods

Forty-seven consecutive patients underwent surgery after evaluation for a winging scapula. Winging was bilateral and symptomatic in three patients; three others had clear but asymptomatic winging of the contralateral side. The total number of operations was 50. The most common symptoms were initial discomfort and spasm of the affected shoulder girdle muscles, with shoulder instability and winging of the scapula. Twenty-one patients (42%) were unable to abduct and flex the shoulder beyond 90 degrees. Thirty-one (62%) had a history of weight-lifting (bodybuilding or lifting heavy objects such as furniture). In five patients (10%), winging followed rigorous throwing exercises such as playing softball or tennis for an extended period. In two patients (4%), winging immediately followed deep massage in the area of the supraclavicular fossa, and one patient (2%) was a postal worker with a several-year history of repetitive overhead movement performed in the course of daily work activities. One patient (2%) gave a detailed history of direct trauma to the supraclavicular area: a ladder had fallen on him at work. One patient (2%) experienced winging immediately following a motorbike accident wherein the affected arm and shoulder were jerked forward sharply while the patient held onto the handlebars during a fall. Nine (18%) patients had idiopathic onset of winging. Of the 50 cases, 32 were right-sided nerve injuries and 18 were left-sided nerve injuries. Most patients were right-hand dominant.

Patient Evaluation

Physical examination formed the basis for management and evaluation. In each case, the senior author (an experienced brachial plexus surgeon) performed both the examination and the surgery, with each procedure following the same protocol (defined below). The same author performed follow up evaluation at an average of 25.7 months.

In all patients, physical examination revealed medial deviation of the inferior angle of the scapula and prominent winging of the medial border of the scapula with backward pressure on the shoulder during forward protraction. The scapula also showed superior elevation. Overhead movements of the arm and shoulder caused significant discomfort and feelings of shoulder instability: 31 (62%) of 50 patients were unable to flex or abduct the shoulder beyond 90 degrees. In the absence of established grading systems for the serratus anterior muscle, the degree of winging was quantified by estimation of the angle between the plane of the scapula and the posterior chest wall. British Motor Grading (BMG) was applicable to examination of the upper trunk. Physical examination revealed weakness of the deltoid, spinati, and biceps muscles (BMG, 3–4) in 38 cases. As Disa and associates[19] had earlier observed, this finding is consistent with concurrent injury to the upper trunk of the brachial plexus.

All patients underwent electromyography of the brachial plexus and long thoracic nerve distribution prior to physical examination. Serratus anterior abnormalities were present in 44 (88%) patients; subtle, transient abnormalities of the serratus examination were detected in 3 (6%). Abnormal EMG results all described neuropraxic injury with no loss of axonal continuity. Presurgery MRI was performed in 12 patients and yielded normal results except in 9 cases of possible atrophy of the serratus anterior muscle.

All 47 patients had undergone regular physical therapy prior to surgery. Eight patients who had experienced symptoms for longer than 7 years did describe possible minor improvement with conservative management, but all felt that their winging constrained the scope and intensity of their physical activity at work, in daily living, and during recreational activity. The final determination of surgical suitability rested on several parameters. The injury generally had to have occurred at least 3 months before surgery. Four exceptions were made. Two were patients in whom a previous contralateral decompression and neurolysis had yielded excellent results. The other was a patient with severe winging and instability following major trauma in a motorcycle accident; this patient's EMG results were markedly abnormal and suggested possible loss of long thoracic nerve continuity, so the surgery was planned as an exploration with possible nerve grafting. One patient was an Olympic swimmer who wished decompression about 6 weeks after onset of winging so that he would be able to return to training for his national Olympic qualifying trials. From preoperative inability to abduct and flex the arm beyond 90 degrees, he improved to the extent that he qualified with ease.

Another parameter was the exclusion of patients who had experienced progressive improvement with physical therapy; patients were considered suitable if they had slowly progressive symptoms or if conservative management had led to no functional improvement. Another consideration was a history that strongly suggested injury to the long thoracic nerve in the region of the middle scalene muscle. Scapular winging and proximal extremity weakness after the lifting of heavy weights and aggressive throwing motions does support the theory of middle and anterior scalene compression of contained nerves. Another important cause was thought to be direct extrinsic pressure to the relatively superficial long thoracic nerve and the upper plexus in the supraclavicular area. Stretching and axial traction of these nerve elements by various mechanisms was considered significant. Abnormal EMG results were considered to confirm the presence of severe injury, but the lack of such abnormalities was not considered a contraindication to surgery when clinical evidence strongly supported severe injury.

Once patients were considered to be surgical candidates, they participated in a thorough discussion of the risks and potential benefits of surgery. Patients were informed of the options of continuing conservative management, pectoralis tendon transfer, or scapulothoracic fusion.

Patients understood that, according to our knowledge of the physiologic properties of denervated skeletal muscle, including the serratus anterior, an excellent surgical outcome was less likely if the onset of winging was more than 10 years prior to surgery.

In all patients, followup consisted of serial physical examination (by the same person who had conducted the preoperative examination) and long-term postoperative evaluation through phone conversations using the World Health Organization Division of Mental Health WHOQOL–100 field trial questionnaire to assess multidimensional changes in the quality of life following operative treatment. This assessment utilized 11 different facets spanning four quality-of-life domains. The field trial questionnaire used a scale of 1–5 to grade changes in quality of life, 1 being minimal change, 2 being moderate change, 3 being good improvement, 4 representing excellent improvement and 5 being extreme change. The Wilcoxon signed ranks test was used for statistical analysis.

Surgical Technique

Patients were placed in the lawn-chair position, with a shoulder roll. The head and neck were abducted away from the side of surgery. The entire supraclavicular area was prepared and draped with a thyroid sheet. The skin incision was created one fingerbreadth posterior and parallel to the clavicle. The incision was sinusoidal and extended 6 to 8 cm lateral to the palpated lateral clavicular border of the sternocleidomastoid muscle. Dissection proceeded through the platysma muscle, taking care to protect the underlying supraclavicular nerves. The omohyoid muscle was resected to allow access to the scalene fat pad and to remove a potential compressive structure of the brachial plexus. The scalene fat pad was elevated from inferior to superior, revealing the upper brachial plexus. Identification of the suprascapular branch of the upper trunk required great care: this branch tends to travel within the middle layers of the scalene fat pad and is theoretically prone to iatrogenic injury at this point.

Elevation of the scalene fat pad was followed by exploration of the upper trunk and its trifurcation into the anterior and posterior divisions and the suprascapular nerve. Epineurial scarring was typically evident at this point, and microsurgical instruments and technique were used for external neurolysis. Anterior scalene resection was also performed at this time, although this was generally partial and sufficient only to release the most superficial fibers compressing the upper trunk. Thus, resection typically involved 15% or 20% of the thickness of the anterior scalene muscle.

The long thoracic nerve was then exposed laterally and posteriorly to the upper trunk. Disa and colleagues[19] discussed the inadequacy of standard gross anatomic descriptions of the long thoracic nerve in the supraclavicular area, which depict the nerve as being more medial. The long thoracic nerve and its tributary branches are delicate in this location, no more than 2 to 3 mm in diameter. The nerve's lack of substance in relation to the bulk of the serratus anterior muscle predisposes the neuromuscular unit to dysfunction. The passage of the nerve through the thick middle scalene muscle further complicates the situation.

Once isolated, the nerve was neurolysed internally and externally using microsurgical instruments and the operating microscope, a technique that respects the delicate nature of the nerve and decreases surgical scar formation within the operative field. As with the anterior scalenectomy, the middle scalene was resected enough to decompress the long thoracic nerve and its tributary branches as they traverse and exit the muscle. A demarcated area of compression within the nerve was apparent in 47 (94%) of the 50 procedures, more so toward the exit point of the nerve from the muscle. This area exhibited narrowing and surface neovascularization of the epineurium at the site of compression. One case required complete resection of the middle scalene; the other 49 cases required partial release. This amount was enough to expose the long thoracic nerve and remove the circumferential muscle fibers of the middle scalene.

In all cases, the long thoracic nerve and upper trunk underwent direct electrical stimulation with a Radionics (Burlington, MA) intraoperative nerve stimulator. The contractions of the serratus anterior appeared to improve subjectively to the operating surgeon (RKN) uniformly following decompression and neurolysis. Furthermore, recovery occurred within 24 hours in 50% of cases, perhaps indicative of a degree of nerve injury less than Sunderland Grade 1 (focal demyelination), and yet functionally significant. This may be classified as a Sunderland Grade 0.5 injury, where the myelin of the injured nerves is apparently intact and a different mechanism is responsible for loss of function. One possibility is that of “silent synapses”, wherein release of acetylcholine at the motor end plate is inhibited by a mechanical trauma to the nerve.

Prior to closure, the superior-most and inferior margins of the surgical wound were examined to identify and release compressive fascial bands potentially capable of compressing the upper trunk and the long thoracic nerve. This examination was accomplished sharply under direct vision and with sharp dissection into the recesses of the wound.

Wounds were closed in three layers, with reconstruction of the platysma and two skin layers. No drains were used. Postoperative management consisted of immediate institution of active range of motion at the shoulder and neck. By the third postoperative day, patients were to have a full range of motion at or beyond preoperative levels, when possible.

Results

As noted earlier, our series of 47 consecutive patients, accounting for 50 long thoracic nerve decompression and neurolysis procedures, constitutes the largest such series in the literature. Forty-four (88%) of 50 decompressions and neurolyses resulted in significant improvement of scapular winging. The range of time to improvement was 1 day to 3 mo. Winging was improved in 98% of patients who had experienced winging for less than 10 years. Pain was a common concurrent condition (25 cases, or 50%), and this was improved in 73% of those with pain. Shoulder instability with difficulty abducting and flexing the shoulder beyond 90 degrees affected 31 patients preoperatively and was relieved in all patients following surgery.

In 8 (9%) of 50 extremities, patients reported the development of a 2 cm^2 swelling at the area of incision between 3 and 6 weeks after surgery. In every case, the swelling resolved spontaneously within 1 week and may have represented a seroma, although it would be unusual for a seroma to appear so late.

All 47 patients completed the WHOQOL-100 field trial questionnaire. The average rating of the 11 facets of quality of life was 3.4, or “excellent” improvement. All responses were positive, affirming improvement, except for three patients who noted that their appearance, pain, or sleeping had worsened slightly since surgery. The Wilcoxon signed ranks test indicated that the 11 QOL categories were significant, with all p values $< .001$ (Table 1). The average response to surgical treatment was 3.6 for patients treated within 2 years of the onset of winging and 1.84 for patients treated after 8 years of onset.

Importantly, a correlation was noted between length of time from onset of winging to surgery and the final result of surgery. A longer delay was associated with a poorer outcome (Figure 1).

No infections or other complications were noted. One patient who had been injured while playing softball initially showed improved function followed by a partial recurrence 6 months after surgery. The recurrence was related to premature resumption of pitching softball in competitive games and had not resolved 6 months after the recurrence. This patient is being considered for a pectoralis tendon transfer.

Discussion

Scapular winging is a significant public health problem and an important cause of functional disability. The health care community underappreciates the morbidity associated with long thoracic nerve dysfunction; awareness of this morbidity and of management options is needed. We agree with Fery,[22] who argues that the traditional approach to scapular winging—conservative treatment—is based on inadequate data; Fery favors a more aggressive approach involving surgery. In our series, 10 of 50 (20%) affected nerves had been injured more than 6 years prior to evaluation, and all of these patients were left with significant functional deficits. Ten (100%) of these patients responded to surgery, and 7 of the 10 (70%) did so within 1 week of surgery. The average time to improvement was 5 days, with a range of 1 day to 3 months. In addition, many patients whose winging had begun more than 2 years prior to surgery experienced improvement following surgery. These findings support the efficacy of nerve surgery as treatment and diminish the possibility that improvement was spontaneous.

Surgical decompression and neurolysis appears to be an effective and rational treatment modality in specific cases of supraclavicular injury to the long thoracic nerve. Risk factors for supraclavicular nerve injury include a history of vigorous athletic maneuvers with the affected extremity, lifting of heavy weights, and direct external pressure on the area (as in deep massage). Injury to the upper trunk of the brachial plexus is also associated with the proposed stretch or compression mechanisms that cause the injury. The shoulder examination is somewhat unreliable with upper-trunk disease because the long-standing scapular instability secondarily affects deltoid and spinati strength. However, all of our patients showed biceps weakness to BMG 3 or 4, which constitutes direct evidence of upper-trunk injury.

Anatomically, the long thoracic nerve and the upper trunk are intimately related; the long thoracic nerve occurs immediately posterior and lateral to the upper trunk. It is easy to understand that an axial load along the course of the brachial plexus affects these structures, both by direct stretch forces and by compression of the intramuscular scalene portions of the upper trunk and long thoracic nerve. The relatively delicate structure of the long thoracic nerve is contrasted with the densely composed upper trunk and predicts the consequences of trauma to each element: given similarly applied forces, the upper trunk shows less dysfunction than the long thoracic nerve.

It is therefore understandable that electrophysiologic examination of the upper trunk–supplied muscles of the affected extremity often reveal no clear abnormalities, the upper trunk injury being relatively minor.[19, 23] EMG testing of the serratus anterior, however, reveals greater dysfunction in many cases. The lack of supportive electrical data is probably related to the difficulty of placing a recording needle within the substance of the serratus anterior muscle, given its relatively deep location on the chest wall. In our experience, electromyographers are sometimes reluctant to approach the serratus anterior with a recording needle for fear of traversing the chest wall and causing a pneumothorax. The tendency toward normal results with serratus anterior testing in our population may then be ascribed to inadvertent testing of the latissimus dorsi, teres major, or other unaffected chest wall muscles. The long thoracic nerve was in continuity in all cases, which also might decrease the ability of EMG studies to uncover subtle denervation abnormalities that are nonetheless functionally significant.

Previous case reports have proposed the concept of surgical long thoracic nerve decompression and described positive effects of nerve surgery.[18, 19] The current study expands the data base of nerve-based management of scapular winging caused by supraclavicular long thoracic nerve injury. Muscle- and tendon-based surgical procedures should remain an important tool in management of refractory, symptomatic scapular winging. However, the growing understanding that long thoracic nerve decompression is effective and associated with minimal morbidity suggests that it is the initial treatment of choice in appropriate cases of scapular winging.

With these thoughts in mind, we suggest the following paradigm for scapular winging of long thoracic nerve origin:

1. Clinical evaluation with particular attention to the cause of injury or associated events, if known. Patients with symptomatic scapular winging related to injury localized at the long thoracic nerve near the middle scalene are candidates for nerve surgery.
2. Direct physical examination, with particular attention to scapular movements and strength. Kuhn's thorough discussion of the evaluative factors that differentiate long thoracic nerve injury from other causes is worth following.[5] Strength of the serratus anterior muscle can be quantified by measuring the maximal protrusion at the inferior scapular angle in centimeters. Normal is 0 cm; any value exceeding 5 cm signifies extreme loss of function.
3. Electrical studies should be ordered to recognize any loss of continuity in the long thoracic nerve, which could indicate the need for nerve grafting or nerve transfer. The

lack of abnormal findings with electrical testing should not obviate surgery when clinical findings suggest surgical intervention.

4. The following guidelines are useful in terms of surgical candidacy and time since onset of injury: patients whose injury is less than 7 years old are candidates for nerve surgery in the absence of other contraindications, such as established loss of continuity of the nerve for more than 18 months; patients whose injury is between 7 and 10 years old are relative candidates for nerve surgery, although good outcomes are less predictable; patients whose injury is greater than 10 years old should primarily undergo tendon transfer, with nerve surgery as a secondary option.

Pain and inflammation associated with established scapular instability do not automatically improve even with successful flattening of the scapula. In our experience, these symptoms usually do improve, but unpredictably so. We have noted that when the primary presenting symptom is established pain with varying degrees of associated winging, patients are not always happy with the results of surgery, even if the goal of surgery (i.e., reversal of winging) is met.

Postoperative management is generally restricted to gentle range-of-motion (ROM) therapy and electrical stimulation. Patients with longstanding winging are placed on daily stretching protocols for up to 1 y following surgery; strengthening can begin after that time. Patients with winging of less than 2 y duration begin strengthening after 3 mo of ROM therapy. As Kuhn and Hawkins[5] mention, ROM therapy is important in preventing and treating adhesive capsulitis at various shoulder girdle joints.

Conclusions

Winging of the scapula is an important public health problem. The scope of the problem is not well-appreciated by treating physicians, and many if not most sufferers are left with pain and ongoing functional deficits. Peripheral nerve surgical techniques have a growing role in managing scapular winging related to the long thoracic nerve. In many cases, long thoracic nerve decompression and neurolysis treats the cause of the problem rather than the result of the injury. The effectiveness and low morbidity of nerve surgery in these situations suggests that it is the treatment of choice in many cases. Ongoing research efforts in surgical techniques and conservative management are needed to improve the management of scapular winging.

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Tables

Table 1. Test Statistics

Facet	Energy	Pain	Sleep	Appearance	Feelings	ROM	ADLs	Meds	Work	Relationships	Overall
Z-Score	–3.845	–3.741	–3.736	–3.837	–3.838	–3.745	–3.839	–3.843	–3.640	–3.744	–3.736
p Value	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001

ROM, range of motion; ADLs, activities of daily living; Meds, mediciations.

Figures (TIF or EPS only)
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