Surgical and Clinical Decision Making in Isolated Long Thoracic Nerve Palsy

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Abstract

Background: Isolated long thoracic nerve palsy results in scapular winging and destabilization. In this study, we review the surgical management of isolated long thoracic nerve palsy and suggest a surgical technique and treatment algorithm to simplify management. **Methods:** In total, 19 patients who required surgery for an isolated long thoracic nerve palsy were reviewed retrospectively. Preoperative demographics, electromyography (EMG), and physical examinations were reviewed. Intraoperative nerve stimulation, surgical decision making, and postoperative outcomes were reviewed. **Results:** In total, 19 patients with an average age of 32 were included in the study. All patients had an isolated long thoracic nerve palsy caused by either an injury (58%), Parsonage-Turner syndrome (32%), or shoulder surgery (10%); 18 patients (95%) underwent preoperative EMG; 10 with evidence of denervation (56%); and 13 patients had motor unit potentials in the serratus anterior (72%). The preoperative EMG did not correlate with intraoperative nerve stimulation in 13 patients (72%) and did correlate in 5 patients (28%); 3 patients had a nerve transfer (3 thoracodorsal to long thoracic at lateral chest, 1 pec to long thoracic at supraclavicular incision). In the 3 patients who had a nerve transfer, there was return of full forward flexion of the shoulder at an average of 2.5 months. **Conclusions:** A treatment algorithm based on intraoperative nerve stimulation will help guide surgeons in their clinical decision making in patients with isolated long thoracic nerve palsy. Intraoperative nerve stimulation is the gold standard in the management of isolated long thoracic nerve palsy.

Keywords: long thoracic nerve, isolated long thoracic nerve palsy, electromyography, nerve transfer, long thoracic nerve transfer

Introduction

Isolated long thoracic nerve palsy results in scapular winging and destabilization, causing pain, weakness, and limited forward flexion of the shoulder.^{7,8,24,25} The etiology may be trauma, tumor, infection, idiopathic neuritis, or iatrogenic injury.^{6,9,21} The natural history of this condition suggests that the majority of cases seem to resolve spontaneously within 2 years.^{8,17} However, at least 25% of patients will have persistent symptoms prompting surgical intervention.¹⁷ It is difficult to predict which patients will resolve spontaneously and which will require surgical intervention, and thus, the management of this patient population is controversial.⁶ Electromyography (EMG) studies are a helpful tool but cannot reliably predict outcome.⁶

Surgical treatment options typically focus on the mechanical correction of scapular winging, including muscle, tendon, or fascial flap reconstruction.^{2,7,16} The optimal surgical treatment, however, would preserve the natural

serratus anterior motor function. This can be achieved with long thoracic nerve decompression (in the setting of conduction block)^{4,10-14,20,22} or by nerve transfers that reinnervate the serratus anterior muscle.^{15,19,23,24} Nerve transfers allow nearby healthy axons to reinnervate the injured serratus anterior muscle close to the motor endplates and prior to atrophy.¹⁵

In this study, we review the surgical management of isolated long thoracic nerve palsy and suggest a surgical technique and treatment algorithm to simplify management. We

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also examine the utility of EMG and intraoperative nerve stimulation in the management of this patient population.

The long thoracic nerve is derived from the cervical nerve roots C5, C6, and C7. It typically passes through the middle scalene muscle lateral to the trunks of the brachial plexus. It then travels along the anterior chest wall to innervate the serratus anterior muscle.^{1,8,25} The contribution of 3 nerve roots to the long thoracic nerve may make it susceptible to traction with the potential for differential excursion on each root as well as compression as the nerve passes through the scalene muscle.

There are 3 main approaches to the long thoracic nerve: the distal axillary/thoracic approach, proximal or supraclavicular approach, and the 2-level proximal and distal approach. The distal approach has been more commonly described in the literature.^{10-12,15,22,24} Authors describe decompression alone as treatment for isolated long thoracic nerve palsy refractory to conservative management.^{10-12,22} Le Nail et al reported a retrospective review of 52 distal long thoracic nerve decompressions in a young patient population.¹¹ The improvement was excellent or good in 87% of patients, and 62% completely corrected their winged scapula.¹¹ Others reported similar findings; reports emphasize performing the decompressions within 6 months of the initial paralysis.^{10,12,22} There are 2 reports of distal thoracodorsal to long thoracic nerve transfers in 6 patients.^{15,24} Five of these were performed in conjunction with other nerve transfers in patients with C5/C6 brachial plexus injuries.²⁴ One was a single case study for isolated long thoracic nerve palsy.¹⁵

The second approach to the long thoracic nerve, the proximal or supraclavicular approach, has been published by several authors.^{4,13,14,20} Disa et al first published their results after supraclavicular decompression of the long thoracic nerve in 4 patients.⁴ Scapular winging was resolved in all patients. Subsequently, Nath and Schippert published similar findings after supraclavicular decompression.^{13,14,20}

The third approach to the long thoracic nerve is a 2-level approach. Tomaino reported a medial pectoral to long thoracic nerve transfer in 1 patient with an isolated long thoracic nerve palsy.²³ In this case, 2 incisions were made, both proximal and distal, and an interposed sural nerve graft was placed from the medial pectoral nerve proximally to the long thoracic nerve distally.²³ Ray et al reported the first 2-level nerve transfer for the long thoracic nerve palsy in a patient with isolated long thoracic nerve palsy.¹⁹ In this case, the patient had a proximal medial pectoral nerve to long thoracic nerve transfer and a distal thoracodorsal to long thoracic nerve transfer.¹⁹

There is no consensus in the literature regarding the best management of isolated long thoracic nerve palsy. Using our clinical experience, we have devised a clinical and surgical algorithm to simplify the management of these complicated patients.

Materials and Methods

Institutional review board approval was obtained prior to commencing this study. A retrospective review of patients treated surgically for isolated long thoracic palsy between 2009 and 2015 was performed. Nineteen patients who had a long thoracic decompression and/or a nerve transfer for serratus anterior reinnervation were identified. Preoperative demographics, history, EMG, and physical examinations were reviewed. Intraoperative nerve stimulation, surgical decision making, operative intervention, and postoperative outcomes were reviewed. Patients with no clinical recovery of serratus anterior motor function 6 months from the date of injury/insult to the nerve were offered surgery. Intraoperative nerve stimulation using a handheld nerve stimulator was performed on all patients, and intervention was guided by these results combined with preoperative EMG studies (Table 1).

Surgical Technique

All procedures were performed by the senior author using loupe magnification. Patients were placed in a supine position with the affected arm partially abducted. A 6-cm transverse supraclavicular incision was made. The anterior and middle scalene muscles, the phrenic nerve, and components of the brachial plexus were identified. The long thoracic nerve was identified, usually within and/or behind the middle scalene muscle, and stimulated. Contraction of the serratus anterior muscle was noted if present. The long thoracic nerve was explored, and any areas of compression were released. Common areas of compression included fibrous bands within the middle scalene muscle, the middle scalene muscle itself, or large transverse blood vessels (typically a tortuous vein). Fibrous bands within the middle scalene were divided, and a complete middle scalenectomy was performed detaching the muscle from its attachment to the first rib. Transverse compressive vascular structures were divided. Neurolysis of the long thoracic nerve was performed, and any fibrous epineurium surrounding the nerve was removed.

The long thoracic nerve was again stimulated. If there was contraction of the serratus anterior muscle after decompression, then the surgery was deemed complete. If there was no contraction of the serratus anterior muscle after decompression, the long thoracic nerve was explored at a second site, the lateral chest wall.

On one occasion, an end-to-end medial pectoral to long thoracic nerve transfer was performed through the supraclavicular incision. In this scenario, the medial pectoral nerve was identified as the most superior fascicle in the middle trunk of the brachial plexus, neurolysed to a single fascicle as the donor nerve, and divided distally behind the clavicle. The long thoracic nerve was divided proximally. The 2 nerve ends were approximated and sutured in a tension-free manner.

Table 1. Patient Demographics, EMG Results, and Procedure(s) Performed.

Patient	Age	Etiology	EMG fibs/PSV	EMG MUPs	Proximal decompression	Distal decompression	Nerve transfer
K.G.	43	Shoulder surgery	N	Y	Y		
L.P.	32	Injury	N	Y—Normal	Y		
D.T.	14	Parsonage-Turner	Y	Y	Y		
T.H.	46	Parsonage-Turner	N	Y	Y		
P.B.	46	Injury	Y	Y	Y		
S.R.	36	Injury	N	Y	Y		
M.M.	23	Shoulder surgery	N	Y—Normal	Y		
N.M.	21	Injury	NA	NA	Y		
M.W.	51	Injury	Y	None	Y		
J.N.	39	Parsonage-Turner	Y	Y	Y		
S.F.	17	Injury	N	Y—Normal	Y		
A.H.	28	Parsonage-Turner	Y	Y	Y		
M.H.	32	Injury	N	Y	Y		
J.F.	19	Injury	N	Y—Normal	Y		
D.B.	18	Injury	N	Y	Y		
S.K.	27	Injury	N	None	Y	Y	
G.B.	46	Injury	Y	None	Y	Y	1. Medial pectoral nerve ETE to long thoracic nerve proximally 2. Thoracodorsal nerve ETE to long thoracic nerve distally
W.F.	45	Parsonage-Turner	Y	None	Y	Y	Thoracodorsal nerve ETS to long thoracic nerve
T.L.	21	Parsonage-Turner	Y	None	Y	Y	Thoracodorsal nerve ETE to long thoracic nerve

Note. EMG = electromyography; fibs = fibrillations; PSV = positive sharp waves; MUPs = motor unit potentials; N = No; Y = Yes; NA = not performed; ETE = end to end; ETS = end to side.

For the lateral chest wall approach, a 15-cm longitudinal incision was made in the mid-axillary line. The long thoracic nerve was identified on the lateral chest wall and stimulated. If there was contraction of the serratus anterior muscle (after proximal decompression), then the surgery was deemed complete. If there was no contraction of the serratus anterior muscle (after proximal decompression), an end-to-end thoracodorsal nerve posterior branch to long thoracic nerve was performed. Through the same incision, the thoracodorsal nerve was identified on the anterior surface of the latissimus muscle. The long thoracic nerve was divided proximally and the posterior branch of the thoracodorsal nerve was divided distally to facilitate a tension-free repair.

On one occasion, when there was only a weak response to electrical stimulation, an end-to-side thoracodorsal to long thoracic nerve transfer was performed. In this scenario, the thoracodorsal posterior branch nerve was transferred to the side of the long thoracic nerve.

Results

In total, 19 patients with an average age of 32 were included in the study. All patients had an isolated long thoracic nerve palsy caused by either an injury (58%), Parsonage-Turner

syndrome (32%), or shoulder surgery (10%). All patients presented with severe scapular winging. Sixteen patients (84%) had limited active forward flexion of the shoulder (90° or less), and 3 patients had preservation of full active forward flexion.

Eighteen patients (95%) underwent preoperative EMG. Eight had evidence of denervation determined by the presence of fibrillations or positive sharp waves (42%). Evidence of active motor unit potentials (MUPs) were detected in the serratus anterior muscle in 13 patients (72%); 5 had no evidence of MUPs (28%). Of those with MUPs detected in the serratus anterior muscle, 4 were considered “normal” (31%) and 9 were “abnormal” (69%), suggesting chronic change in the muscle fibers. The preoperative EMG (as indicated by the presence of MUPs) did not correlate with intraoperative nerve stimulation in 13 patients (72%).

Surgical management of these 19 patients is detailed in Table 1. Three of the patients had nerve transfers and 16 had decompression.

Discussion

The majority of our patients with isolated long thoracic nerve palsy were young (average age 32), consistent with

prior reports of this palsy presenting in young people, commonly athletes.^{6,12,17,20} The etiology of isolated long thoracic palsy in our patients was primarily from trauma (58%) or Parsonage-Turner syndrome (32%), also consistent with published literature.^{5,6}

In the majority of peripheral nerve surgery cases, EMG is a critical component of the management plan for patients undergoing surgery. However, in our study, preoperative EMG correlated with intraoperative findings/nerve stimulation in only 28% of patients. Friedenberget al studied the natural history of 50 patients with isolated long thoracic palsy and failed to find a variable on EMG that significantly predicted clinical outcome.⁶ They also urged caution when using EMG findings to predict prognosis and guide the timing of surgical management.⁶ Similarly, Le Nail et al noted that they primarily use EMG to determine the isolated nature of the long thoracic nerve palsy and that it is not predictive of clinical outcome.¹¹

Some authors have performed postoperative EMGs with varied results, including persistent abnormalities despite normal clinical function and decreased distal motor latencies.^{10,11} None of the findings were significantly different from preoperative findings; however, the authors mentioned the use of nerve conduction studies in isolated long thoracic nerve palsy and suggested that monitoring the distal motor latency of the long thoracic nerve is important.^{10,11} Despite shortcomings, we continue to obtain preoperative EMGs to rule out other muscle involvement and also to document serratus anterior dysfunction.

There are many reasons why the serratus anterior muscle is difficult to evaluate electromyographically. The “muscle” consists of multiple small and thin muscles that are difficult to needle accurately, particularly in the setting of atrophy from denervation or disuse. The common sites of compression or entrapment are very proximal, making it impossible to use the “inching” technique to identify a conduction block. In addition, serratus anterior muscle weakness puts the scapula in an abducted/winged position, and thus, the serratus anterior muscle is not in the “normal” location in this patient population. It is imperative that the EMG is performed by an experienced neurologist with an understanding of muscle imbalance and scapular dyskinesis.

In part because of the unreliability of preoperative EMG, clinical judgment plays an important role in the management of these patients. Unimpressed by our 38% failure rate from simple proximal decompression, our clinical practice has shifted to place a higher emphasis on nerve transfer surgery in isolated long thoracic nerve palsy. Our success with end-to-side nerve transfers for recovery of ulnar intrinsic function has encouraged our more recent use of thoracodorsal to long thoracic end-to-side nerve transfers in patients with fibrillations in the serratus muscle. When considering the necessity of nerve transfers, one must consider the donor nerve morbidity, the morbidity of the procedure itself, and

the difficulty of reentering a scarred wound bed later if necessary. The availability and success of end-to-side nerve transfers play favorably into this clinical decision making. The development of an algorithmic approach to the intraoperative clinical decision making has taken us a number of years and is informed by this series of patients in whom we performed decompression at the chest, medial pectoral to long thoracic, and thoracodorsal to long thoracic nerve transfers in varying combinations.

Our current recommended clinical decision-making algorithm (Figure 1) is relatively independent of preoperative EMG findings. A recent article by Pinder and Ng¹⁸ illustrated the use of the Scratch Collapse Test to isolate a compression point in long thoracic nerve palsy in the chest. The “hierarchical” Scratch Collapse Test has been used in our practice to isolate primary and secondary compression points in other compression neuropathies,³ and we apply it to isolated long thoracic nerve palsy.

Using clinical examination and time since injury as our guideline, we recommend surgical decompression of the long thoracic nerve from a supraclavicular approach with middle scalenectomy and intraoperative nerve stimulation as our first step. Intraoperative stimulation is the gold standard in this decision tree. If there is a response in serratus muscle activation with intraoperative nerve stimulation, we recommend serial examination for at least 3 months for recovery of serratus anterior function. If no recovery, subsequent decompression of the long thoracic nerve from an anterior axillary line incision with intraoperative stimulation and thoracodorsal end-to-side to long thoracic nerve transfer is performed.

In the clinical scenario where no improvement in serratus anterior function is observed with supraclavicular decompression and intraoperative nerve stimulation, we recommend immediate decompression through an anterior axillary line incision with intraoperative stimulation. If adequate activation of the serratus anterior is achieved, an end-to-side thoracodorsal to long thoracic nerve transfer is performed to supercharge the reinnervation of the serratus anterior. If no serratus anterior function is observed, we recommend 2 nerve transfers to be performed simultaneously: the medial pectoral to long thoracic nerve transfer to reinnervate the superior muscle slips, and a second thoracodorsal to long thoracic end-to-end transfer to reinnervate the inferior muscle slips.

Conclusion

Isolated long thoracic nerve palsy, an entity with poorly understood etiology and variable clinical course, appears to have a component of multilevel compression neuropathy and unreliable EMG findings. The proposed clinical decision-making algorithm presented in this article takes into consideration the work of other surgeons by including both

Figure 1. Clinical and surgical decision-making algorithm for isolated long thoracic nerve palsy.

Note. EMG = electromyography; ETS = end to side.

proximal and chest-level decompression, as well as advances in nerve transfers to improve function in this patient population.^{4,5,10,19,20,23,24} Further evaluation and refinement of the algorithm is ongoing as we treat more patients with a multilevel surgical approach.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained from all individual participants in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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