Decompression and Neurolysis of the Long Thoracic Nerve is Effective in Reversing Scapular Winging

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Abstract

Background: Long thoracic nerve injury leading to scapular winging is a common entity. Inciting causes include closed trauma through compression, stretching, traction, and direct application of extrinsic force. Other causes include penetrating injury and neuritides such as Parsonage- Turner syndrome. The current paper describes our surgical experience in 18 consecutive patients presenting with long thoracic nerve palsy with closed mechanisms of injury. This is the largest reported series of long thoracic nerve decompression and neurolysis in the literature. *Methods*: Three of these eighteen patients exhibited bilateral scapular winging and underwent bilateral surgery. Follow-up was conducted through clinic visits, (where scapular winging was evaluated) as well as through phone conversations, where patients were (questioned/evaluated) utilizing eleven differing facets within four domains of the World Health Organization Quality of Life questionnaire. *Results*: Eighteen of twenty-two (82%) long thoracic nerve decompressions and neurolyses resulted in improvement of scapular winging. In patients less than 10 years out from onset of winging, 100% exhibited at least some degree of improvement. Pain was a common concurrent condition (35%), and this was improved, at least moderately in half (45%) of patients with pain. Shoulder instability persisted in 4 patients out of 19 following surgery, even in 2 patients who received some relief from the winging itself. **( )** *Conclusions*: Surgical decompression and neurolysis of the long thoracic nerve results in significant improvement in scapular winging in appropriate patients and should be considered a primary functional reconstructive modality in these patients.

Introduction

Winging of the scapula due to long thoracic nerve palsy is a common diagnosis [1,2,3,4,5,6,7,8,9,10] and should be treated as a significant functional problem. It must be recognized that scapular winging is not simply 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. Other described resultant anomalies include adhesive capsulitis, subacromial impingement and brachial plexus radiculitis [5]. Traditional management has relied on conservative therapy [2,3,11,12, 13,14] and in some refractory cases, pectoralis tendon transfers for stabilization of the scapula [4,5,12,13,15]. Scapulothoracic arthrodesis is considered in other instances [16]. Probably in most patients, surgery is not undertaken and relief of symptoms is inadequately obtained. Chronic shoulder instability and pain are the result.

Scapular winging often results from insults to the long thoracic nerve. Part of the susceptibility of the nerve to injury arises from unique anatomical features. The nerve itself is small in diameter and fragile- appearing, in contrast to the relatively robust adjacent nerves of the brachial plexus. The lengthy course of the nerve from its C5 through C7 root origins through to the inferior border of the serratus anterior muscle also presents multiple anatomic locations for potential injury. Surgical dissections in the axilla as during mastectomy can cause direct injury to the nerve in the infraclavicular region, with an incidence 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, 19, 20]. Several patients in the current study were thought to have sustained an insult to the nerve through direct compression by the middle scalene muscle during contraction while exercising. Another category of patients included those who sustained a direct extrinsic crush to the nerve in the region of the middle scalene muscle; in this group, the middle scalene was thought to be a possible secondary source of injury.

The anatomic basis for long thoracic nerve injury by the middle scalene was first described by Skillern in 1913 [20]: “the long thoracic nerve is exposed to trauma as it traverses the scalenius medius”. The proposed mechanism for injury has been succinctly described by Birch and colleagues: “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”[18]. Certainly in our experience, strenuous upper extremity activity or a history of lifting heavy weights is present in most patients. Two patients had a specific history of direct compression of the supraclavicular fossa during deep massage treatments with associated pain and paresthesia during treatment. Disa described four patients with stretch or traumatic causes of their winging; the middle scalene contributed to the injuries in all cases[19].

Management of this problem by resection of the scalene muscle and neurolysis of the long thoracic nerve appears to have been first described by Birch in 1998 [18], although a 1995 paper by

Chen reports scalene resection as a way to free compression of the dorsal scapular nerve [21]. Chen planned the operation for the dorsal scapular nerve, but does incidentally mention the long thoracic nerve as also passing through the middle scalene. The largest previous series to the current one is by Disa and colleagues in 2001 in which experience with 4 patients is described [19].

Patients and Methods

Nineteen consecutive patients were operated upon after evaluation for a winging scapula. Three patients had symptomatic bilateral winging, and 3 more had clear winging of the contralateral side, although not symptomatic. A total of 22 operative procedures were performed. The most common symptoms were initial discomfort and spasm of the affected shoulder girdle muscles, with eventual shoulder instability and winging of the scapula. Twelve patients (63%) had a history of weight-lifting preceding their winging, either during bodybuilding or by lifting heavy objects such as furniture. Three patients (16%) had onset of winging following rigorous throwing exercises playing softball or tennis over an extended period of time. Two patients (11%) noted winging immediately after deep massage in the area of the supraclavicular fossa, and one patient (5%) was a postal worker with a several year history of repetitive overhead movement performed in the course of daily work activities. One patient (5%) gave a detailed history of direct trauma to the supraclavicular area by a ladder falling on him at work. One patient (5%) had immediate onset of winging following a motorbike accident where the affected arm and shoulder were jerked forward sharply while holding the handlebars during a fall. Ten of nineteen patients had isolated right-sided nerve injuries; six of nineteen patients had isolated left-sided nerve injuries. The remaining three patients had bilateral injuries. All patients were right hand dominant.

Patient Evaluation

The physical examination of each patient formed the basis for management and evaluation. Examination was performed by the senior author in each case, an experienced brachial plexus surgeon. All surgical procedures followed the same protocol (defined below) and were performed by the senior author. Followup evaluation was also performed by the senior author at an average of 19.9 months.

The physical examination of all patients 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 as in pushing off a wall. Superior elevation of the scapula was also noted. Overhead movements of the arm and shoulder caused significant discomfort and feelings of shoulder instability, and fully ten of twenty (50%) of 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 centimeters of posterior projection of the inferior scapular border at the point of maximal winging. British Motor Grading (BMG) was applicable to upper trunk examination. Twenty-two of twenty-two (100%) examined upper extremities had a physical examination consistent with weakness of the deltoid, spinati and biceps muscles, having BMG ranging between 3 and 4. This finding is consistent with concurrent injury to the upper trunk of the brachial plexus, an observation also made by Disa et al.

All patients underwent electromyography of the brachial plexus and long thoracic nerve prior to physical examination. In 12 of 22 extremities (55%), no serratus anterior abnormalities were found, in 7 examinations (32%) subtle, transient abnormalities in the serratus examination were described, and in one patient (5%), evidence of supraclavicular long thoracic nerve injury was clearly documented prior to surgery, with possible loss of continuity. Six extremities did exhibit electrical abnormalities consistent with upper trunk injury. In most abnormal EMGs, neuropraxic injury was described, with no loss of axonal continuity. Ten patients had undergone MRI testing prior to surgery and all were read as normal, except for a single report describing possible atrophy of shoulder girdle muscles.

All 19 patients had undergone regular physical therapy prior to surgery. Five patients, all with symptoms greater than 7 years did describe possible minor improvement with conservative management, but all felt constrained in terms of the scope and intensity of their physical activity at work, in daily living and during recreational activity.

The final determination of surgical suitability was made by considering several parameters. Patients generally had to have been out at least 6 months from their injury. Two exceptions were made, one in a patient who had an outstanding result from a previous contralateral decompression and neurolysis, and the other in a patient with severe winging and instability following major trauma in a motorcycle accident. In the latter case, the patient had a markedly abnormal EMG with possible loss of long thoracic nerve continuity, and the surgery was planned as an exploration with possible nerve grafting. Patients should not have had progressive improvement with physical therapy, but rather exhibited slowly progressive symptoms or lack of functional improvement with conservative management as a prerequisite to surgery.

Another preoperative consideration was the presence of a strong history suggestive of injury to the long thoracic nerve in the region of the middle scalene muscle. Scapular winging and proximal extremity weakness after lifting of heavy weights and aggressive throwing motions does support the theory of middle and anterior scalene compression of contained nerves. Direct extrinsic pressure to the relatively superficial long thoracic nerve and the upper plexus in the supraclavicular area was also thought to be an important causative factor. Stretching and axial traction of these nerve elements by various mechanisms was considered significant. The presence of electrophysiologic abnormalities was considered confirmatory of severe injury but the absence of electrical testing abnormalities was not a contraindication to surgery in the presence of a strong clinical picture.

After establishing indications for surgery, all patients participated in a thorough discussion of the risks and potential benefits of surgery. Patients were informed of the options of continuing conservative management or of pectoralis tendon transfer or scapulothoracic fusion. Patients understood that those out 18 months or more from onset of winging were less likely to have an excellent outcome based on known physiologic properties of denervated skeletal muscle, including the serratus anterior.

Following surgery, all patients were followed with serial physical examination by the preoperative examiner. Additionally, patients received long-term postoperative evaluation through phone conversations using the World Health Organization Division of Mental Health WHOQOL – 100 field trial questionnaire to assess multidimensional change in quality of life following operative treatment **(http://www.who.int/msa/qol/ql5.htm).** This assessment was performed utilizing eleven different facets within four domains of quality of life, including: physical health, psychological, level of independence, and social relations. The facets included assessment of energy and fatigue, pain, sleep, body image and appearance, feelings toward self, range of motion, ability to perform activities of daily living, dependence on medications, ability to do work, personal relationships and social support, and overall quality of life. Any change in quality of life was assessed according to the 1 to 5 scale incorporated in the field trial questionnaire; 1 being no change, 3 being moderate change, and 5 being extreme amount of change.

Surgical Technique

At surgery, patients were placed in the lawn- chair position, with a transverse 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. Great care must be taken to identify the suprascapular branch of the upper trunk, as it tends to travel within the middle layers of the scalene fat pad, and is theoretically prone to iatrogenic injury at this point.

Once the scalene fat pad was elevated, the upper trunk and its trifurcation into the anterior and posterior divisions and the suprascapular nerve was explored. Typically, epineurial scarring was evident at this point, and external neurolysis with microsurgical instruments and technique was performed. Anterior scalene resection was also performed at this time, although this was generally partial, and only sufficient to release the most superficial fibers compressing the upper trunk. This typically amounted to 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 point out the underappreciated anatomy of the long thoracic nerve in the supraclavicular area, and discuss the inadequacy of standard gross anatomic descriptions showing the nerve to be more medial. It is worth noting that the long thoracic nerve is delicate and no more than 2 to 3 millimeters in diameter in this location. Its lack of substance in relation to the bulk of the serratus anterior muscle teleologically predisposes the neuromuscular unit to dysfunction. The situation is made worse by the passage of the nerve through the thick middle scalene muscle.

Once the nerve was isolated, it was then neurolysed using microsurgical instruments and the operating microscope. This was necessary because of the delicate nature of the nerve and to decrease surgical scar formation within the operative field. As with the anterior scalenectomy, the middle scalene was resected sufficiently to decompress the long thoracic nerve as it traversed and exited the muscle. In 6 of 22 surgical procedures (27%), a demarcated area of compression within the nerve was clearly noted, more so toward the exit point of the nerve from the muscle. This took the form of a narrowing and rubor of the epineurium, perhaps representing neovascularization at the site of compression. In one case, a complete resection of the middle scalene was required, and in the other 21 cases, a partial release of 15% or slightly more was accomplished. This was suitable to expose the long thoracic nerve and at least remove the circumferential muscle fibers of the middle scalene.

Direct electrical stimulation of the long thoracic nerve and upper trunk was performed in all cases, with a Radionics ™ intraoperative nerve stimulator. Current of up to 10 milliamps was used to stimulate contraction of the serratus anterior and the muscles supplied by the upper trunk. It was interesting that the contractions of the serratus anterior appeared uniformly to improve following decompression and neurolysis. It is a point of speculation as to the importance of this electrical "overstimulation" of the nerves in assisting recovery of the paralyzed muscles. It is compelling to note that even in cases where no clear anatomic point of epineurial compression could be noted, recovery of serratus function was excellent. Further, in fully 50% of cases, recovery was noted within 24 hours, an unusual circumstance in most situations of nerve decompression.

Prior to closure, an examination of the superior- most and inferior margins of the surgical wound was performed to identify and release compressive fascial bands potentially capable of causing compression of the upper trunk and the long thoracic nerve. This was accomplished sharply under direct vision and with blunt digital 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 active range of motion at the shoulder and neck. By the third postoperative day, patients were to have a full range of motion at preoperative levels or beyond, where capable.

Results

Our surgical experience includes 19 consecutive patients presenting with long thoracic nerve palsy, 16 unilateral and 3 bilateral. This is the largest reported series of long thoracic nerve decompression and neurolysis in the literature. Eighteen of twenty-two (82%) decompressions and neurolyses resulted in significant improvement of scapular winging. The average time to improvement was 5 days, the range being 1 day to 3 months. In patients less than 10 years out from onset of winging, 100% exhibited measurable improvement in winging. Pain was a common concurrent condition (35%), and this was improved in 43% of those with pain. Shoulder instability persisted in 4 patients out of 19 following surgery, even in 2 patients who received some relief from the winging itself.

In 3 0f 22 extremities (14%), patients reported the development of a 4 cm.^{2} swelling at the area of incision between 3 and 6 weeks after surgery. This in every case resolved spontaneously within one week and may have represented a seroma, although the late appearance of the swelling makes this an unusual presentation.

Sixteen of 19 patients completed the World Health Organization WHOQOL-100 field trial questionnaire; three patients were lost to follow-up. The average response for the 16 patients on the 11 facets of quality of life assessment was 2.92, or "moderate amount" of improvement. All responses were positive, affirming improvement, except for two patients who indicated that either their pain or sleeping had become slightly worse since surgery. The average response for patients who received surgical treatment within 2 years of winging was 3.28; and for patients who received surgical treatment after 8 years of scapular winging was 1.75.

No infections or other complications were noted. One patient who sustained the injury while playing softball had an initial improvement in function followed by a partial recurrence 6 months after surgery. The recurrence was unrelated to physical activity and occurred apparently spontaneously. 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 morbidity associated with long thoracic nerve dysfunction is underappreciated by the health care community, and much more awareness of management options is needed. We are in agreement with Fery, who argues that the traditional approach to scapular winging by conservative treatment is based on inadequate data, and favors a more aggressive approach with surgery [22]. In our series, 9 of 20 (45%) nerves evaluated were more than 6 years out from onset of injury and all of these patients were left with significant functional deficits. Seven of nine of these patients (78%) responded to surgery, and five of seven (71%) 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 greater than 2 years out from the onset of winging experienced improvement following surgery. These findings support the efficacy of nerve surgery as a modality of treatment, and diminish the likelihood that spontaneous improvement was the cause of improvement.

Surgical decompression and neurolysis appears to be an effective and rational treatment modality in specific instances where supraclavicular injury to the long thoracic nerve is identified. 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 causative of the injury. In terms of upper trunk pathology, the shoulder examination is somewhat unreliable, as the long- standing scapular instability will secondarily affect deltoid and spinati strength. However, biceps weakness to BMG 3 or 4 was invariably found in the current patient group, and this is 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 will affect 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: the upper trunk will exhibit lesser degrees of dysfunction than the long thoracic nerve given similarly applied forces.

It is therefore understandable that electrophysiologic examination of the upper trunk- supplied muscles of the extremity often will not reveal clear abnormalities, the upper trunk injury being relatively minor, although present [19,23]. EMG testing of the serratus anterior, however, might be expected to find a greater degree of 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. It has been our experience that 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 readings after serratus anterior testing in our population may then be inferred as arising from inadvertent testing of the latissimus dorsi, teres major or other unaffected chest wall muscles. The long thoracic nerve was in continuity in all cases and this also might decrease the ability of EMG studies to uncover subtle denervation abnormalities that yet have significant functional consequences.

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.

The suggested paradigm for scapular winging of long thoracic nerve origin, then is:
(1) Evaluation of the clinical picture with attention to 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 attention to scapular movements and strength; Kuhn's thorough discussion of the differentiating evaluative factors between long thoracic injury and 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 centimeters, with extreme loss of function recognized as greater than 5 cm. (3) electrical studies should be ordered, in order possibly to recognize loss of continuity in the long thoracic nerve, indicating possible need for nerve grafting or nerve transfer; the lack of abnormal findings electrically should not negate the indication for surgery should clinical findings suggest surgical intervention (4) patients less than 7 years out from injury are candidates for nerve surgery in the absence of other contraindications such as established loss of continuity of the nerve greater than 18 months; patients between 7 and 10 years out from injury are relative candidates for nerve surgery and good outcomes are less predictable. Patients greater than 10 years out from injury should primarily be approached with tendon transfers, with nerve surgery a secondary option.

It should be noted that associated pain and inflammation related to 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 established pain as the presenting primary symptom with varying degrees of associated winging does not always respond favorably to surgery, and unhappy patients can be the result, even if the goal of surgery, i.e. reversal of winging is met.

Postoperative management is generally restricted to gentle range of motion therapy and electrical stimulation. Patients with longstanding winging are placed on daily stretching protocols for up to one year following surgery, and strengthening to begin after that time. Patients with winging less than 2 years begin strengthening after 3 months of ROM therapy. As mentioned by Kuhn and Hawkins [5], 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 increasingly have a role in managing long thoracic nerve- related scapular winging. Long thoracic nerve decompression and neurolysis treats the cause of the problem in many cases, 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 will be needed to improve the management of scapular winging.

Name	Energy	Pain	Sleep	Appearance	Feelings towards self	Mobility/ROM	ADLs
M	5	2	4	5	5	5	5
Mc	5	2	4	5	5	5	5
B	3.5	3	4	4	4	3	3.5
W	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Wf	1.5	1.5	1.5	1.5	1.5	1.5	1.5
P	1	1	1	1	1	1	1
O	3	3	3	3	1.5	1	2.5
J	2	1	1	1	1	1	1
Me	5	4	5	5	5	5	5
Ma	5	4	5	5	5	5	5
Ph	5	4	4.5	4	4	4	4
Pa	4.5	4	4	4	4.5	5	2
S	3	2	3	4	3	4	3
Oh	3	3	3	2	3	2	3
C	1	2	1	1	1.5	2	1
R	1	**0**	2	1	2	1	1
G	1	4	1	3	1		1
Gr	3	1	**0**	3	5	3	4.5
Ro	5	5	5	4.5	4	5	5
	3.11	2.53	2.82	3.08	3.08	3.06	2.92

						Average	Average
Name	Medications	Work	Relationships	Overall QOL	Average	Left	Right
M	3	5	5	5	4.50		4.45
Mc	3	5	5	5	4.50	4.45	
B	2	3	5	4	3.50	3.55	
W	1.5	1.5	1.5	1.5	1.50		1.50
Wf	1.5	1.5	1.5	1.5	1.50	1.50	
P	1	1	1	1	1.00	1.00	
O	3		3	3	3.00		2.60
J	3	1	1	2	1.75		1.36
Me	5	5	5	5	5.00		4.91
Ma	5	5	5	5	5.00	4.91	
Ph	2.5	4	2	4	3.13		3.82
Pa	4	3	3.5	4	3.63	3.86	
S	3	0	3	3	2.25		2.82
Oh	3	3	3	3	3.00		2.82
C	4	2	1	1	2.00	1.59	
R	1.5	2	1	1	1.38		1.23
G	2.5	2			2.25	1.94	
Gr	1.5	3	2	3.5	2.50		2.68
Ro	4	5	1	3	3.25		4.23
	2.84	2.89	2.75	3.08		2.85	2.95
				2.89			

	Duration of	Duration of	2 years or	1 year or
Name	Winging (mo)	Winging (yrs)	less	less
M	15	1.25	4.45	
Mc	24	2	4.45	
B	15	1.25	3.55	
W	120	10		
Wf	144	12		
P	132	11		
O	84	7		
J	12	1	1.36	1.36
Me	72	6		
Ma	84	7		
Ph	3	0.25	3.82	3.82
Pa	24	2	3.86	
S	24	2	2.82	
Oh	108	9		
C	24	2	1.59	
R				
G	108	9		
Gr	3	0.25	2.68	2.68
Ro	12	1	4.23	4.23
			3.28	3.02

	1 to 2 years	greater than	greater than	from 2 to 8
Name		2 years	8 years	years
M	4.45			
Mc	4.45			
B	3.55			
W		1.5	1.5	
Wf		1.5	1.5	
P		1	1	
O		2.6		
J				
Me		4.91		
Ma		4.91		
Ph				
Pa	3.86			
S	2.82			
Oh		2.82	2.82	
C	1.59			
R				
G		1.94	1.94	
Gr				
Ro				
	3.45	2.65	1.75	