Scapular winging is abnormal scapulothoracic posture and motion resulting from numerous underlying etiologies. It is a rare disorder, reported in only 14 patients in a 3-year period at the Harvard Shoulder Service, although the true incidence is largely unknown because of underdiagnosis. Most commonly it is categorized anatomically as medial or lateral, although categorization based on primary and secondary etiologies is also useful. Primary winging occurs when muscular weakness disrupts the normal balance of the scapulothoracic complex. Secondary winging occurs when pathology of the glenohumeral joint interrupts the coordinated motion of the scapula. Abnormal scapulothoracic kinematics overload the compensatory musculature, limit shoulder strength and range of motion, and cause pain. Patients may experience pain at rest or with activity, causing them to lose the ability to abduct the shoulder and perform overhead tasks. Delay in diagnosis may lead to traction brachial plexopathy, periscapular muscle spasm, frozen shoulder, subacromial impingement, and thoracic outlet syndrome. In cases of nerve transection, outcomes are improved with early detection and surgical repair. Although the sources of scapular winging are many, understanding the anatomy of the scapulothoracic articulation is essential to prescribing treatment.

Anatomy and Biomechanics

The scapula is a triangular bone overlying the second to seventh ribs on the posterior thorax. Medial, lateral, and superior borders of the scapula converge to form superior, lateral, and inferior angles. The scapula is thin centrally, with focal thickening posteriorly in the scapular spine and peripherally in the coracoid, glenoid, and acromion processes. At rest, the scapula is rotated 30° anterior on the chest wall and 20° forward in the sagittal plane, while the inferior angle is tilted 3° upward.

As the largest bone in the shoulder complex, the scapula serves as the attachment site for 17 muscles. Scapulothoracic, scapulohumeral, and ro-
tator cuff muscles stabilize the scapula to the thorax, provide power to the upper limb, and synchronize glenohumeral motion. Other than muscles, only the acromioclavicular and coracoclavicular ligaments provide skeletal stabilization to the scapula, thus affording the scapulothoracic interval considerable movement. Elevation of the scapula in the craniocaudal axis and upward rotation are accomplished by the trapezius muscle. Anterior and lateral motion, described as scapular protraction, is produced by the serratus anterior and pectoralis major and minor muscles. Conversely, scapular retraction relies on the rhomboid major and minor muscles.

Active arm elevation to 90° depends on a ratio of glenohumeral to scapulothoracic motion of approximately 2:1. As the limb is elevated, the scapular center of rotation migrates proximally and laterally from the midportion in the first 30° of elevation toward the glenoid base in the next 60°. The net effect is an upward and lateral rotation of the inferior pole. Simultaneously, the coracoid and acromion processes move superior and posterior, thereby increasing the distance to humeral impingement.

In the overhead athlete, upward rotation, retraction, and internal rotation of the scapula are even greater with arm elevation. Periscapular weakness resulting from overuse may manifest as scapular dysfunction (ie, winging). Furthermore, power generation during windup, and force dissipation on follow-through, rely on increased scapular retraction and protraction, respectively. Loss of motion in this plane can affect the thrower’s power and place unnecessary strain on the posterior shoulder capsule. Precise coordination and synchrony of the periscapular muscles are required to avoid injury under these high-intensity loads.

Serratus Anterior Muscle

The serratus anterior is a flat muscle that originates from the first nine ribs and follows a posterosuperior direction around the thoracic wall, where it inserts onto the medial border of the scapula. Bertelli and Ghizoni described three functional components of the serratus anterior. The upper portion originates from the first and second ribs and inserts onto the superomedial aspect of the scapula. This portion facilitates lateral rotation of the inferior scapular angle during overhead activities. The middle portion originates from the third, fourth, and fifth ribs and inserts onto the vertebral border of the scapula, acting to protract the scapula. The lower portion originates from ribs six through nine and inserts onto the inferobasal scapula angle (Figure 1). In addition to scapular protraction, the lower portion rotates the inferior angle of the scapula upward and laterally. As a unit, the serratus anterior muscle acts to protract and stabilize the scapula, orienting the glenoid for effective use of the upper extremity.

The serratus anterior muscle is innervated by the long thoracic nerve, originating from the 5th, 6th, and 7th cervical nerve roots. Branches of C5 and C6 combine to form the proximal nerve behind the middle scalene muscle, which innervates the upper portion of the serratus muscle. After passing behind the brachial plexus, a branch from C7 contributes to the nerve, thereby providing branches to the middle and lower portions of the serratus muscle. The long thoracic nerve travels beneath the clavicle and first rib, coursing on the lateral chest wall in the midaxillary line. The nerve averages 21.9 cm in length, and its superficial course makes it susceptible to injury.

Trapezius Muscle

The trapezius is a large muscle that has a broad origin from the external occipital protuberance, the medial
one third of the nuchal line (ie, the ligamentum nuchae), and the spines of the 7 cervical and 12 thoracic vertebrae. The muscle converges into three separate points of insertion, reflecting their complementary roles. The superior fibers insert onto the posterior clavicle. The medial fibers insert onto the medial aspect of the acromion. The inferior component ends in an aponeurosis, inserting onto the spine of the scapula. The superior and inferior fibers elevate and rotate the scapula laterally, moving the glenoid upward to accommodate shoulder abduction. The middle fibers stabilize the scapula during movement.

The trapezius is innervated by cranial nerve XI, the spinal accessory nerve. Neurons in the upper spinal cord coalesce to form the nerve before it enters the skull at the foramen magnum. The nerve traverses the base of the skull before exiting through the jugular foramen, along with the glossopharyngeal (IX) and hypoglossal (XII) nerves. The spinal accessory nerve is notable for being the only cranial nerve to enter and exit the skull. The nerve penetrates the deep surface of the sternocleidomastoid muscle and enters the posterior triangle of the neck at the level of the upper and middle thirds of the sternocleidomastoid muscle. The nerve is superficial throughout its course and associated with a chain of 5 to 10 lymph nodes. Its sinuous course and superficial nature place the nerve at risk during surgical dissection of the posterior triangle of the neck.

### Rhomboid Muscles

Deep to the trapezius, the rhomboid minor muscle originates from the ligamentum nuchae and the spinous processes of C7 and T1. Inferior to this muscle lies the rhomboid major, which originates from the spinous processes of T2 through T5. The rhomboid minor muscle inserts at the level of the scapular spine, whereas the rhomboid major inserts distally on the medial scapula to the inferior angle. Both muscles serve to retract and elevate the scapula while rotating the inferior angle medially. The dorsal scapular nerve innervates the rhomboid muscles, which derive mainly from the C5 nerve root.

### Levator Scapulae

The levator scapulae are also innervated by the C5 nerve root via the dorsal scapular nerve. These muscles originate from the first four cervical vertebrae and insert onto the medial borders of the scapulae. The levator scapulae elevate the scapula and assist in rotating the glenoid inferiorly.

### Etiology of Winging

Primary scapular winging describes dysfunction in one or more of the scapulothoracic stabilizers (ie, serratus anterior, trapezius, rhomboids) that causes a muscular imbalance in scapular alignment. Secondary winging occurs in association with other pathologies (eg, subacromial bursitis, disorders of the glenohumeral joint).

### Serratus Anterior Muscle Palsy

The most common cause of primary scapular winging is paralysis of the serratus anterior muscle after insult or injury to the long thoracic nerve. Injury to this nerve includes compression, traction, and laceration; the most common injury is neurapraxia after blunt or stretch injury. The superficial course along the lateral chest wall places the long thoracic nerve at risk of compression or contusion. Automobile accidents, falls from a height, and sporting accidents are reported causes. Sudden depression of the shoulder and twisting of the neck are causes of stretch injury that have been cited in serratus anterior palsy.

Collision athletes, including football and ice hockey players as well as wrestlers, are at risk of injury to the long thoracic nerve. Repetitive activities with the head tilted away from the nerve and the arm overhead—as occurs in baseball pitchers, javelin throwers, and tennis servers—may place the long thoracic nerve on stretch. Similarly, upper extremity overuse in industrial laborers and homemakers may also contribute to serratus anterior muscle palsy. Iatrogenic causes of long thoracic nerve injury range from compression injury associated with positioning under anesthesia to surgical disruption occurring in association with anterior cervical decompression, mastectomy, first-rib resection, axillary dissection, and thoracosotomy tube placement.

Sites of compression along the course of the long thoracic nerve include the middle scalene muscle, proximal to the first rib, between the clavicle and second rib, and the inferior angle of the scapula. Hester et al described a fascial sling at the level of the first intercostal space enveloping the long thoracic nerve. They suggested that dynamic “bowstringing” of the nerve could occur with abduction and external rotation of the upper extremity and cited this bowstringing as a possible source of compression neuropathy.

Atraumatic lesions of the long thoracic nerve have also been reported. Paralysis of the serratus anterior muscle has been associated with C7 radiculopathy, emphasizing the substantial contribution of this nerve root to its innervation. Transient brachial neuritis, Guillain-Barré syndrome, Arnold-Chiari malformation, systemic lupus erythematosus, viral
illness, and Lyme disease have been implicated in serratus anterior palsy.19,21

Trapezius Muscle Palsy

Paralysis of the trapezius muscle, similar to that of the serratus anterior muscle, is largely neurogenic because of spinal accessory nerve injury. Anatomically, its superficial course in the posterior triangle of the neck places the nerve at risk. Falls from a height and motor vehicle accidents have been associated with spinal accessory nerve traction injury. Blunt trauma, such as assault or a direct blow from a football tackle or a lacrosse or hockey stick, may be associated with spinal accessory nerve palsy.22 Similarly, penetrating gunshot wounds, stabbings, and bite injuries have been implicated.15,23,24

The most common cause of trapezius palsy is iatrogenic injury to the spinal accessory nerve during cervical lymph node biopsy or mass excision.25,26 In one study of 83 patients with trapezius palsy, 71% of injuries were iatrogenic in nature.25 Iatrogenic injury to the spinal accessory nerve during neck surgery is the second most common nerve injury, after that of the median nerve during carpal tunnel surgery.27

Rhomboid Muscle Palsy

Rhomboid muscle paralysis, although less common than trapezius muscle paralysis, may cause scapular winging because of dorsal scapular nerve injury. Patients may report vague shoulder and upper arm pain that mimics thoracic outlet syndrome. Entrapment of the dorsal scapular nerve beneath a hypertrophic middle scalene muscle is the most common cause.28 However, traction or avulsion of the C5 nerve root may occur with heavy lifting and motor vehicle accidents.28 Cervical radiculopathy involving the C5 nerve root may also manifest as medial scapular winging.4

Fascioscapulohumeral Dystrophy

Fascioscapulohumeral dystrophy (FSHD) is an autosomal dominant genetic neuromuscular dystrophy linked to chromosome 4q35 that predominantly affects the face, shoulder girdle, and upper limb muscles.4 Weakness in the trapezius, levator scapulae, and rhomboids relative to preserved strength in the deltoid and rotator cuff muscles leads to severe scapular winging.29 Patients typically demonstrate shoulder girdle pain, scapular instability, and weakness to arm abduction and flexion. Diagnosis is made with genetic testing.

Secondary Causes

Secondary winging describes abnormal scapulothoracic motion as a result of glenohumeral joint pathology. Patients often have normal electromyography (EMG) findings of the long thoracic, accessory, and dorsal scapular nerves. Painful intra-articular conditions of the glenohumeral joint cause patients to compensate for lost motion with the scapulothoracic articulation. Scapular stabilizers, such as the serratus anterior and trapezius muscles, quickly fatigue under the increased demands, producing winging.4 Common causes include subacromial bursitis, adhesive capsulitis, rotator cuff tears, and shoulder instability.35,30

Posterior glenohumeral instability, in particular, causes winging for two reasons. First, painful subluxation evokes reflexive deactivation of the serratus anterior muscle and loss of scapular control. Kinematic studies have shown that patients with posterior instability have de-centering of the humeral head on the glenoid, suggesting scapulothoracic dysfunc-

Patient Evaluation

Patients with scapular winging frequently report shoulder or upper back pain, fatigue, or muscle weakness, especially with elevation of the arm above the shoulder level. Difficulty with activities of daily living (eg, combing one’s hair, brushing teeth) or overhead tasks in the workplace may be noted. Athletes participating in tennis, volleyball, or golf may also report limitations. Patients with a prominent scapula may report that they feel discomfort while sitting against hard surfaces or while driving for long periods. Periscapular pain may be the result of muscle cramping compensating for isolated weakness in serratus anterior or trapezius muscle palsy. Age, occupa-
tion, sporting demands, and prior level of functioning are additional elements that may guide treatment once a diagnosis is established.9

Physical examination for scapular winging begins by undressing the patient’s shoulders and back to the waistline. Failure to adequately visualize the patient’s entire back may cause the physician to overlook an otherwise obvious deformity. Assessing the alignment of the scapula can most easily be performed while viewing the patient from behind, with his or her arms hanging at the sides. Although atrophy of the periscapular muscles may be discreet, the examiner should carefully inspect for shoulder asymmetry.

Weakness in the scapular stabilizer muscles often presents in predictable patterns. Injury to the long thoracic nerve and paralysis of the serratus anterior muscle causes medial winging (Figure 2). The scapula assumes a superior translation, with the inferior pole rotated medially.

Conversely, paralysis of the trapezius muscle causes the affected shoulder to droop with lateral winging. The scapula is translated inferiorly, and the inferior angle is rotated laterally (Figure 3). Palpation of the scapula may elicit tenderness, crepitus, or snapping coincident with scapulothoracic bursitis. A palpable clunk with shoulder abduction may be a sign of an underlying osteochondroma.34

Static and dynamic deformities can be differentiated by the position of the scapula with range of motion of the shoulder. The examiner begins by assessing forward elevation and abduction while holding the scapula reduced to the chest wall to evaluate the glenohumeral joint. Patients with serratus anterior muscle palsy have difficulty with active forward elevation beyond 120°. Patients with trapezius muscle palsy have difficulty with shrugging the affected shoulder and with abduction; they frequently have asymmetry of the trapezius visible with anterior or posterior viewing of the shoulder.35

The elevation and external rotation test can differentiate serratus anterior muscle palsy from posterior instability that causes serratus muscle dysfunction. If winging produced with forward elevation is eliminated with glenohumeral external rotation, then posterior instability is confirmed. Contraction of the external rotators and tightening of the posterior capsuloligamentous complex prevent posterior subluxation and serratus anterior “shut down.” Persistent winging with this maneuver suggests a complete serratus anterior muscle paralysis.

Isolated strength testing should also be performed. Trapezius muscle function can be assessed with a resisted shoulder shrug. Rhomboid and levator scapulae strength can be evaluated by having the patient place his or her hands on the hips and pushing the elbows posterior against resistance. Weakness in the serratus anterior muscle can be easily appreciated with the shoulder flexed to 90° while the patient performs push-ups. Medial winging may be immedi-
ate obvious, or it may manifest with muscle fatigue after 5 to 10 repetitions.

**Diagnostic Testing**

The initial workup of the patient with scapular winging should include plain radiographs of the chest, cervical spine, shoulder, and scapula. Images may help identify cervical spine disease, shoulder disorders, fracture malunions, osteochondromas, or accessory ribs. Use of advanced imaging is recommended for patients with comorbid conditions. CT may help to better characterize osteochondromas. MRI is reserved for patients with cervical disk disease, shoulder instability, or rotator cuff tears.10,15

Nerve conduction velocity and EMG are valuable adjuncts to confirm physical examination findings and to distinguish neuromuscular causes of scapular winging.22 Specific orders to evaluate the spinal accessory and long thoracic nerves are recommended to avoid an incomplete examination.22 Repeat EMG studies may be useful in 3- to 6-month intervals to evaluate the patient for improvement.

**Management**

Most cases of scapular winging are the result of neurapraxic injury. Neurapraxic injury commonly resolves within 6 to 9 months.18 Once diagnosis is made, nonsurgical therapies should be initiated to maintain shoulder motion and prevent stiffness. In the absence of penetrating trauma or previous surgery, many authors recommend a course of nonsurgical treatment of 12 to 24 months to observe for nerve recovery1,10,16 (Figure 4).

Initial treatment consists of activity modification, analgesics, and nonsteroidal anti-inflammatory drugs. Elevation of the arm above shoulder level should be limited and aggravating activities avoided.1 Physical therapy should include range of motion exercises and stretching and strengthening of the scapular stabilizers, cervical muscles, and rotator cuff. Patients may progress to a home exercise program once exercises can be performed appropriately under supervision.

Sling immobilization may be helpful for pain control in the acute period, although prolonged immobili-
Scapular winging resulting from spontaneous neuromuscular palsy, traction injury, or contusion that does not resolve within 12 to 24 months is an indication for dynamic muscle transfer. Chronic serratus anterior muscle palsy is effectively addressed with transfer of the sternal head of the pectoralis major muscle to the inferior angle of the scapula. Post reported on eight patients treated with sternal head transfer of the pectoralis extended with fascia lata autograft. All eight patients had an excellent result at 2 years. Warner and Navarro reviewed the results of eight patients treated with pectoralis transfer augmented with hamstring autograft for serratus anterior palsy. At 32 months, seven patients had resolution of winging and normal scapulothoracic kinematics. One patient was lost to follow-up after deep infection resulted in graft removal.

Perlmutter and Leffert reported their experience with pectoralis major muscle transfer in 16 patients at 4-year follow-up. The authors transferred the sternal and clavicular heads of the pectoralis with fascia lata autograft augmentation. Fourteen patients (88%) regained full, active shoulder elevation, and winging resolved in 12. Constant scores increased from 36 preoperatively to 92 points postoperatively. All 14 patients returned to their prior work requirements. Two reconstructions failed because of graft stretching; these patients progressed to scapulothoracic arthrodesis. Both noted improvement, although not resolution, of pain.

More recently, Povacz and Resch demonstrated successful transfer of the pectoralis without augmentation. After conducting an anatomic study in 40 cadavers, they suggested that the sternal head alone is of suitable length for transfer. Three patients were treated with their technique, and all reported subjective satisfaction, although no further objective assessments were reported. Obviating the need for tissue augmentation spares the patient the risk of graft failure and the morbidity of a secondary surgical site for autograft harvest. Additional study is necessary to determine the role of tissue augmentation in the management of serratus anterior palsy.

Trapezius muscle palsy resistant to nonsurgical treatment or nerve exploration is managed with the Eden-Lange dynamic muscle transfer. Originally described in 1924, the procedure involves lateralization of the rhomboid major, rhomboid minor, and levator scapulae insertions on the scapula, thereby allowing them to act synergistically for the three components of the trapezius. Bigliani et al reported results in 22 patients treated with Eden-Lange transfers. At 7 years, 13 patients had regained normal shoulder function, and 6 were satisfactory. Three patients reported difficulty with work or sport requiring overhead activity. Unsatisfactory outcomes were associated with concomitant serratus anterior muscle weakness.

Romero and Gerber reported on 16 patients (including 2 children) with follow-up of 29 years. Nine patients reported an excellent result and had returned to work and sport without limitations. All patients regained abduction above the horizontal, and 11 were pain free. Constant scores were not statistically significantly different from those of the unaffected arm at final follow-up. The two children were completely satisfied with the procedure at 32 and 34 years, respectively. According to the authors, the outcomes of Eden-Lange transfers are durable in both children and adults at long-term follow-up.

Patients with FSHD or those who do not obtain relief with dynamic muscle transfer are candidates for scapulothoracic stabilization. Gianinni et al reviewed the results in nine patients with FSHD treated with wire fixation to the thoracic ribs without fusion. Winging resolved in all patients, and statistically significant gains in abduction strength were found at 1 year. One
patient developed pneumothorax that resolved spontaneously within 48 hours.

Krishnan et al. recently reported their results of scapulothoracic arthrodesis for FSHD and refractory winging using plates and wires in 22 patients (24 shoulders). Pulmonary complications developed in 11 shoulders (46%), and 7 shoulders (29%) developed pseudarthrosis. These authors have since advocated for routine thoracostomy tube placement and iliac crest autograft to minimize complications.

**Authors’ Preferred Treatment**

For neurapraxia, observation of 6 to 12 months is undertaken because the condition can resolve without surgery. Acute transections are best managed with repair and nerve grafting, when necessary. For recalcitrant neurapraxia, surgical muscle transfer is recommended.

Patients with serratus anterior muscle palsy are treated with pectoralis major muscle transfer augmented with autogenous hamstring graft. Patients are placed in the lateral decubitus position with the arm and ipsilateral leg draped free. An anterior deltopectoral incision in the axillary fold is used to detach the pectoralis major tendon. We prefer to transfer the entire pectoralis tendon because both heads of the muscle offer improved strength. Semitendinosis tendon is harvested with open-ended tendon strippers, although hamstring allograft may be substituted. The hamstring autograft is woven into the pectoralis with No. 2 nonabsorbable suture in a Pulvertaft weave (Figure 5). The pectoralis is brought medial to the conjoined tendon, and blunt dissection with a long curved clamp is used to create a tunnel in the scapulothoracic interval. The inferomedial corner of the scapula is exposed through a posterior incision, and the tendon is retrieved. The hamstring graft is then passed through drill holes in the scapula and appropriately tensioned. A technical pearl is to pass the graft around the medial border initially, then through a drill hole in the scapula from posterior to anterior. The graft is wrapped around the medial border once more, tensioned, and sewn to itself (Figure 6). Appropriate tensioning may be confirmed when the muscle of the pectoralis reaches the scapular body. This technique is less demanding because the sewing is done on the posterior surface of the scapula rather than anteriorly, beneath the scapula. In patients with recalcitrant trapezius palsy who require a muscle transfer, a modified Eden-Lange procedure is used. With a high-speed end-cutting burr, the muscles are detached from the medial scapula with 5 mm of bone. This allows secure fixation of the muscle reattachments (Figure 7, A). In our experience, the short tendons of these muscles do not hold suture well, thus making muscle transfers difficult under tension. The infraspinatus muscle is elevated subperiosteally, the levator scapulae and rhomboid minor muscles are lateralized 5 cm onto the scapular spine, and the rhomboid major muscle is transferred 5 cm into the infraspinatus fossa. Osteotomies are secured with nonabsorbable suture through drill holes (Figure 7, B).

Postoperatively, muscle transfer patients are immobilized for 6 to 8 weeks. After the first week, passive shoulder pendulum exercises are begun under the guidance of a physical therapist. Passive abduction exercises are performed, with the patient supine to minimize graft stress. Active strengthening is withheld until 8 weeks, and patients are cautioned to avoid manual labor and sports for up to 6 months.

**Summary**

Scapular winging is a rare, potentially debilitating disorder with many causative factors. Diagnosis is largely clinical and relies on a high index of suspicion. A common pitfall is the failure to undress the patient’s shoulders and back to the waistline, which permits adequate visualization of any obvious deformity. Early diagnosis and surgical intervention improve the outcomes of patients with nerve transection. Although most cases resolve with nonsurgical management, good outcomes are possible with both acute neurolysis and dynamic muscle transfers in chronic cases.
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