Split Pectoralis Major Transfer for Chronic Medial Scapular Winging

W. Stephen Choate, M.D., Adam Kwapisz, M.D., and John M. Tokish, M.D.

Abstract: Scapular winging can be a significant source of chronic pain, weakness, and disability of the shoulder. Isolated serratus anterior palsy from long thoracic nerve injury, which is the most common cause of this condition, produces prominent winging and medial malpositioning of the inferior angle of the scapula. In the case of persistent symptoms despite conservative care, treatment options primarily include scapulothoracic fusion and pectoralis major transfer. Outcomes of scapulothoracic fusion are notable for a high complication rate and limited functional improvements. We describe our technique of indirect, split pectoralis major transfer to the inferolateral scapula with allograft tissue augmentation for the surgical treatment of chronic medial winging. This procedure provides dynamic stabilization of the scapula with secure and tension-free tendon transfer. Advantages over alternative treatments include a relatively low complication rate, acceptable cosmesis, and better range of motion. The rationale and technical aspects of this procedure are discussed. Additional clinical studies are warranted to compare outcomes for the direct and indirect split transfer methods.

Primary scapular winging is an under-recognized cause of shoulder dysfunction. It is characterized by abnormal scapulothoracic posturing and dynamic control. Muscle fatigue, rotator cuff weakness, subacromial impingement, bicep tendinitis, and glenohumeral instability symptoms are often associated. For this reason, many patients receive misdiagnoses initially and present with a history of chronic, persistent shoulder complaints.[1,2] The most common cause of scapular winging is isolated serratus anterior paralysis from long thoracic nerve injury. Causes can be variable and include penetrating, compressive, or stretch injury in the acute traumatic or chronic repetitive injury setting.[2,3] Collision or overhead athletes, manual laborers, and homemakers are particularly at risk of this condition.[4]

Long thoracic nerve palsy typically resolves within 8 to 12 months.[5] In such cases, physical therapy aimed at preventing glenohumeral stiffness and strengthening the scapular stabilizers is the definitive treatment. However, persistent winging and shoulder fatigue can occur in up to 25% of patients after a minimum 1-year course of conservative care.[2] In the absence of clinical or electrodiagnostic evidence of nerve recovery, surgical treatment may be indicated. Options are variable, with distinct advantages and disadvantages associated with each.

Scapulothoracic fusion (STF) has been proposed as a primary definitive surgical treatment, particularly in heavy laborers, patients with combined muscular lesions, and patients in whom prior soft-tissue surgery has failed.[6,7] Unfortunately, this procedure is characterized by a high complication rate (up to 50%) and modest range-of-motion improvements.[6-10] Additional options include neurolysis or nerve transfer but are less effective in the chronic setting with irreversible muscle motor endplate degeneration.[4,11]

Dynamic pectoralis major transfer to the scapula has been shown to be an effective treatment method for this condition. Multiple technical variations exist for this procedure, with little evidence to support one technique over another. The purpose of this article is to introduce and describe our technique for split pectoralis major

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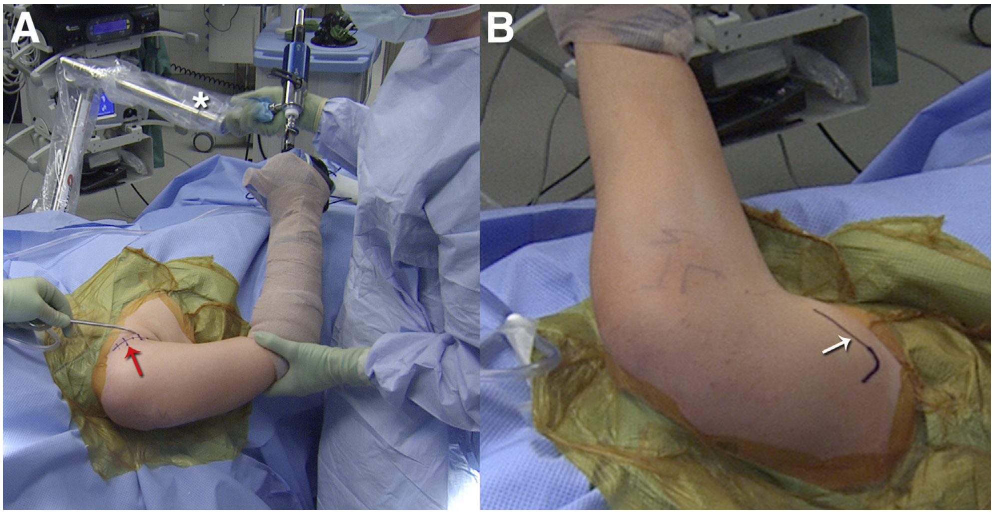

Fig 1. With the patient in the lazy lateral decubitus position for surgery on the right side, a SPIDER2 pneumatic arm positioner (asterisk), attached at the head of the bed on the nonoperative side, allows simultaneous access to the pectoralis major tendon (A) and the inferolateral scapula (B). The planned anterior deltopectoral (red arrow) and posterior inferolateral scapular border (white arrow) incisions are marked. The arm is positioned in forward elevation with in-line traction to provide access to the scapula.

transfer in the treatment of chronic isolated medial scapular winging due to long thoracic nerve palsy.

Surgical Technique

Step 1: Preoperative Workup

Patients with scapular winging frequently complain of generalized shoulder, neck, and periscapular pain. Additional symptoms include nonspecific fatigue and weakness. The initial workup should include plain radiographs of the chest, cervical spine, shoulder, and scapula. Routine physical examination of the shoulder requires assessment of static and dynamic scapula posturing and movement. Particular attention should be paid to the movement of the inferior angle with humeral forward elevation. Manual stabilization of the scapula during overhead motion may diminish symptoms and improve function, which would support the diagnosis of primary scapular dysfunction. One should also assess for shoulder instability or symptomatic labral tearing, which can produce secondary scapular dysfunction. In many cases, magnetic resonance imaging of the shoulder is warranted to investigate for primary intra-articular pathology. Diagnostic injections are also helpful in localizing potential sources of pain. Neurodiagnostic studies including electromyography and nerve conduction velocity testing are useful adjuncts to confirm the diagnosis and are most helpful no earlier than 6 weeks after a discrete traumatic injury. In cases of more global upper extremity weakness, genetic testing is indicated to rule out facioscapulohumeral dystrophy.

Step 2: Patient Positioning

After induction of general anesthesia and administration of a muscle relaxant, the patient is repositioned into the lazy lateral (45° posterior tilt) decubitus position with the assistance of a beanbag. Wide draping to the midline is performed, both anteriorly and posteriorly, to ensure adequate exposure. The ability to manipulate the medial aspect of the scapular body is critical for achieving static reduction of the winged deformity. A SPIDER2 pneumatic arm positioner (Smith & Nephew, Andover, MA) is attached to the proximal third of the operating room table with the central post pointing upward. This positioner allows simultaneous access to the pectoralis major tendon and the inferolateral scapula (Fig 1). Although a long axillary incision may be used, we prefer a 2-incision approach for this procedure. Anteriorly, a 3- to 4-cm vertical skin incision is marked from the coracoid tip to the proximal axillary fold. Posteriorly, a 3- to 4-cm skin incision is drawn in line with the lateral border of the scapula's inferior angle.

Step 3: Pectoralis Major Harvest

The skin is incised, and electrocautery is used to dissect through the subcutaneous tissue layer. The deltopectoral interval is developed, and the cephalic vein is mobilized laterally with the deltoid. Wide subcutaneous tissue flaps are created to optimize visualization. The proximal and distal extent of the pectoralis major musculotendinous junction is identified. The undersurface of the pectoralis is mobilized bluntly with a finger starting at the inferior border and then carried laterally toward the humeral insertion. With assistance from the limb positioner, the arm is brought into slight abduction and external rotation to further expose the muscle belly. Approximately 6 to 8 cm medial to the tendinous insertion, a fibrous raphe, which delineates the sternal head from the more proximal and superficial clavicular head, can be identified (Fig 2). A pair of hemostats is used to separate the muscle bellies. A Penrose drain is then passed around the sternal head

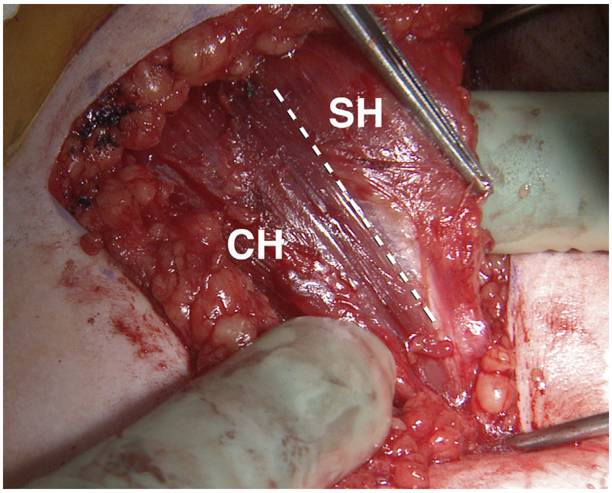

Fig 2. With the patient in the lazy lateral decubitus position for surgery on the right side, the pectoralis major is identified through the anterior incision. Approximately 6 to 8 cm medial to its tendinous insertion, a fibrous raphe (dashed line) delineates the sternal head (SH) from the more proximal and superficial clavicular head (CH).

and pulled distally to expose the fibrous bands that connect to the clavicular head (Fig 3). These are taken down with Metzenbaum scissors, and the dissection is carried laterally for full exposure of the tendinous portion of the sternal head. With an Army-Navy retractor in place to protect the clavicular head tendon, electrocautery can be used to release the most lateral aspect of the sternal head attachment to the humerus. During tendon release, a finger is placed over the underlying biceps long head tendon to prevent iatrogenic injury. Blunt and sharp release of surrounding fascia and connective tissue is necessary to ensure optimal excursion of the harvested musculotendinous unit (Fig 4). Care is taken to avoid overly aggressive dissection and mobilization, particularly over the muscle undersurface. After harvest, meticulous hemostasis within the anterior wound is performed.

Step 4: Scapula Exposure

The arm is repositioned with in-line traction away from the body in approximately 140° of forward elevation to expose the scapula. A skin incision is made, and electrocautery is used to dissect through the subcutaneous tissue. The latissimus dorsi musculature is split in line with its fibers and retracted to exposure the deeper teres major muscle layer, which is also split to expose the underlying lateral cortical shelf of the scapula. Electrocautery and a Cobb elevator are used to subperiosteally dissect the subscapularis from the anterior surface and the teres minor from the posterior surface of the scapula for exposure of the inferior angle. By use of digital dissection from the anterior and posterior wounds, a submuscular tissue tunnel is created within the axilla to connect the 2 incisions. Care is taken to bluntly dissect along the chest wall, within the distal aspect of the axilla and below the latissimus muscle, to avoid neurovascular injury. A Penrose drain may be passed back and forth through the tunnel to widen its borders and ensure smooth graft passage (Fig 5).

Step 5: Preparation for Tendon Transfer and Allograft Augmentation

Attention is turned toward assessment of the pectoralis major length-to-transfer distance. With the assistance of a Kelly clamp or tonsil hemostat, the pectoralis major sternal head is then passed from anterior to posterior to approximate a direct transfer to the scapula. If the length is inadequate, a semitendinosus allograft augmentation is selected for indirect transfer. Although use of an ipsilateral or contralateral semitendinosus autograft is also an option, we prefer to avoid the additional morbidity and operative time required for autograft tissue harvest. The semitendinosus graft is incorporated into the sternal head by a Pulvertaft tendon weave technique and heavy nonabsorbable suture. The free end of the graft is then whipstitched to assist in tunnel passage (Fig 6). For additional tissue bulk and transfer strength, the semitendinosus may be doubled over onto itself and sutured, after the Pulvertaft weave, for a double-limb indirect transfer. In this case the 6-mm-diameter semitendinosus allograft was believed to be of adequate size and strength for single-limb transfer.

Step 6: Scapula Tunnel Preparation and Tendon Transfer

A point-to-point clamp is used to laterally deliver the inferior angle of the scapula into the operative field (Fig 7).

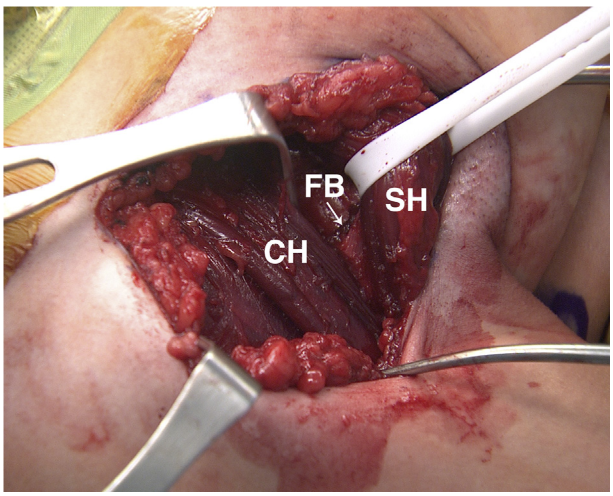

Fig 3. With the patient in the lazy lateral decubitus position for surgery on the right side, the pectoralis major is identified through the anterior incision. Retraction of the sternal head (SH) and clavicular head (CH) muscle bellies exposes the fibrous bands (FB) connecting the 2 structures. These bands are released to gain access to the lateral tendinous insertion of the sternal head.

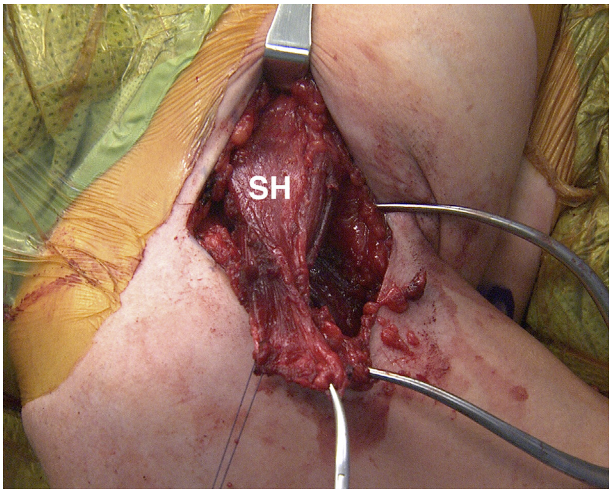

Fig 4. With the patient in the lazy lateral decubitus position for surgery on the right side, the pectoralis major is identified through the anterior incision. After harvest and mobilization of the sternal head (SH) musculotendinous unit, total length and tendon size are assessed.

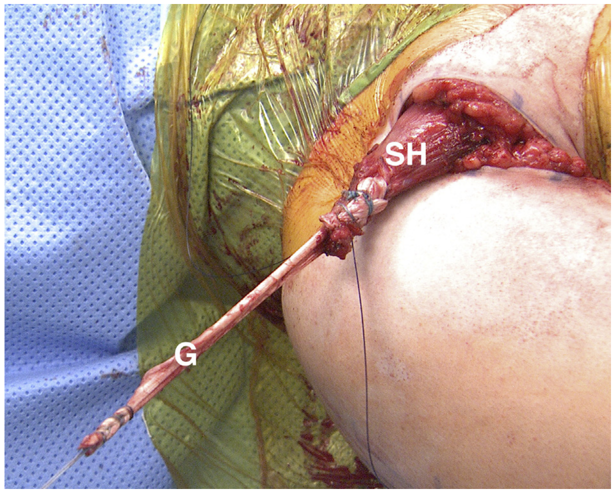

Fig 6. The semitendinosus allograft (G) is incorporated into the pectoralis major sternal head (SH) using a Pulvertaft tendon weave technique and heavy nonabsorbable suture to add length for indirect transfer to the scapula. With the patient in the lazy left lateral decubitus position, the right arm is repositioned to the patient's side out of traction for this portion of the procedure.

A broad retractor is positioned between the scapula and the chest wall anteriorly. A deeper retractor is necessary to expose the posterior aspect of the scapula as well. With reference to the thickened cortical border and the thinner body, a point approximately 1 cm proximal to the inferior angle and 1 cm medial to the lateral edge is identified for the transosseous tendon transfer site. A 6-mm-diameter drill or reamer is used to create a tunnel, from posterior to anterior. Care is taken to ensure preservation of a 6- to 8-mm bony bridge to the cortical edges to avoid fracture. Once loose osseous debris is removed from the wound, the graft is then passed through the hole, from anterior to posterior, and doubled back over itself for fixation (Fig 8). An operative assistant is required to manually reduce the

Fig 5. With the patient in the lazy left lateral decubitus position, the right arm is positioned in forward elevation with in-line traction to provide access to the axilla and posterior scapula. By use of blunt digital dissection against the chest wall, a submuscular tissue tunnel is created within the axilla (A) to connect the anterior and posterior incisions. A Penrose drain (arrows) may be passed back and forth through the tunnel to widen its borders and ensure smooth graft passage. The patient's head is oriented to the left in the photograph.

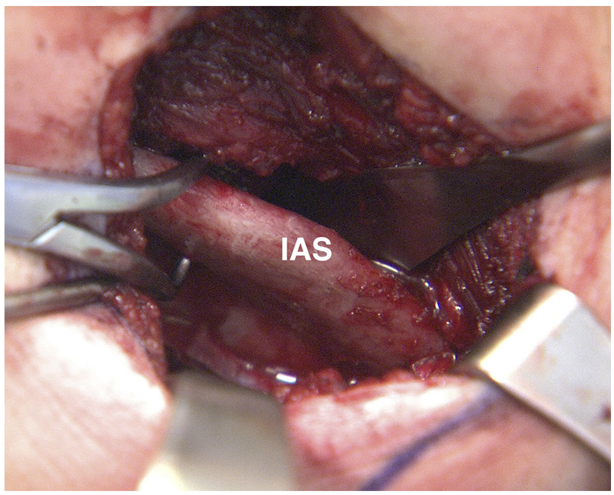

Fig 7. With the patient in the lazy left lateral decubitus position, the right arm is positioned in forward elevation with in-line traction to provide access to the scapula. Following the approach to the inferolateral scapular border, a point-to-point clamp can be used to laterally deliver the inferior angle of the scapula (IAS) into the operative field for improved access. A Cobb elevator is placed anteriorly to retract the subscapularis musculature. A 6-mm drill is used to create the intraosseous tunnel. Care is taken to preserve a 6- to 8-mm bone bridge to the cortical edges to prevent iatrogenic fracture.

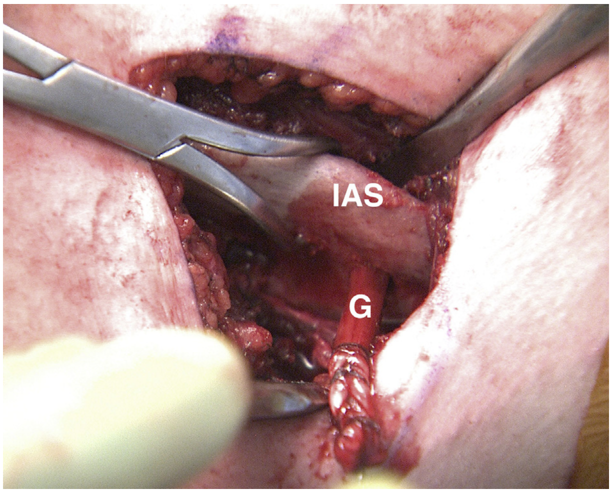

Fig 8. With the patient in the lazy left lateral decubitus position, the right arm is positioned in forward elevation with in-line traction to provide access to the scapula. After preparation of the scapula bone tunnel, the pectoralis major sternal head with semitendinosus graft (G) is passed from anterior to posterior through the inferior angle of the scapula (IAS). Plenty of residual length is available to adjust transfer tension and suture the graft back over itself for fixation.

scapula against the chest wall and push the inferior angle as laterally as possible while the graft is tensioned to hold reduction and tied to itself with heavy nonabsorbable suture (Fig 9). Excess graft is cut and removed. After tendon transfer, gentle dynamic examination at the shoulder is performed to confirm a stable construct with corrected scapular motion. The wound is thoroughly irrigated, and electrocautery is used to ensure meticulous hemostasis. The teres major and latissimus dorsi muscular layers are reapproximated for wound closure. Anteriorly, the deltopectoral interval is closed in similar fashion. The subcutaneous tissue and skin are closed for both incisions. No drain is usually required. After placement of sterile dressings, the arm is secured in a sling and abduction pillow for postoperative immobilization.

Step 7: Postoperative Rehabilitation

A conservative rehabilitation program is followed to prevent stretching and attenuation of the graft in the early postoperative period. The patient is immobilized in a sling for 6 weeks. During this time, only elbow, wrist, and hand exercises are performed. Between weeks 6 and 8, the patient participates in a passive motion phase. During this period, supine forward elevation and external rotation are progressed to full from 0° to 90° and from 0° to 30°, respectively. Motion is initially in the supine position only, which is important for scapular stabilization. The patient is converted to motion in the upright position slowly, as tolerated. Once upright, the scapula is manually stabilized during passive overhead stretching. Starting in week 9, active range of motion is initiated in the supine position and progressed in all planes. A goal of full overhead motion is set for 12 weeks. Starting in week 13, the resistive and strengthening phase of recovery begins with a focus on periscapular and rotator cuff strengthening. The patient is counseled against strenuous overhead activity, downward or overhead lifting of more than 25 lb, and participation in contact sports for a minimum of 6 months after surgery. Biofeedback training is an important aspect of the rehabilitation program. Attention is paid to reactivation of the pectoralis major musculature through resisted shoulder adduction exercises with the arm in the forward flexed position. Video 1 shows the surgical technique in step-wise fashion.

Discussion

Scapular winging can be a primary or secondary disorder of the shoulder. First described by Velpeau[12] in 1837, isolated serratus anterior palsy producing medial malpositioning of the inferior angle of the scapula is recognized as the most common cause of primary scapular winging. In the setting of long thoracic nerve palsy, initial management is conservative and often successful.[9,13] In those patients who have persistent symptoms after 12 to 24 months of nonoperative care, surgical treatment may be indicated.

STF offers the theoretical advantage of a durable, static solution to this problem. STF was initially described for the treatment of scapular winging due to facioscapulohumeral muscular dystrophy,[14,15] but results of STF in the treatment of nondystrophic conditions, such as

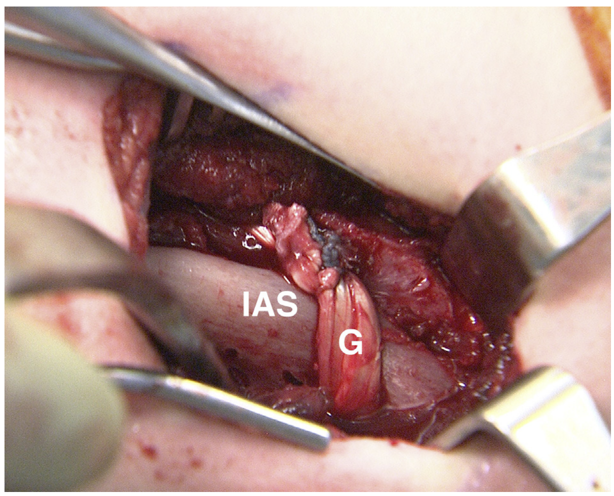

Fig 9. With the patient in the lazy left lateral decubitus position, the right arm is positioned in forward elevation with in-line traction to provide access to the scapula. The final construct is shown after split pectoralis major tendon–graft (G) transfer and suture fixation. The scapula is stabilized with its inferior angle (IAS) translated laterally. Excess graft is removed.

Table 1. Operative Steps, Pearls, Pitfalls, and Solutions

Operative Step	Pearl	Pitfall	Solution
Step 1: Preoperative workup	The surgeon should manually stabilize the scapula during active forward elevation and determine whether typical pain complaints are relieved and function is improved, which would confirm winging as the primary pathology.	Failure to diagnose primary shoulder or neck pathology as a cause of scapular winging can occur.	The initial workup should include plain radiographs of the chest, cervical spine, shoulder, and scapula. Physical examination should assess for shoulder instability or symptomatic labral tearing.
Step 2: Patient positioning	A pneumatic limb positioner centered over the proximal third of the operating room table allows dual access to the anterior and posterior aspects of the shoulder for the 2-incision technique.	Inadequate intraoperative access to the medial border of scapula can occur.	Wide draping should be performed with nonsterile adhesive barriers, and sterile drapes should be taken to the midline spine posteriorly.
Step 3: Pectoralis major harvest	Correct identification of the raphe between the sternal and clavicular heads is important to prevent muscular injury, which can cause poor excursion and denervation.	A truncated pectoralis major musculotendinous harvest can occur.	The surgeon should create wide subcutaneous flaps to optimize visualization in the operative field and should retract the more superficial clavicular head proximally to identify the most lateral insertion point of the sternal head tendon.
Step 4: Scapula exposure	The surgeon should digitally dissect the axillary channel simultaneously from anterior and posterior for proprioceptive guidance and avoidance of divergent paths.	Neurovascular injury can occur within the axillary tunnel.	Dissection should be performed carefully along the chest wall within the distal extent of the axillary wound to ensure the transferred pectoralis major structure does not compress or impinge on the brachial plexus.
Step 5: Preparation for tendon transfer and allograft augmentation	The surgeon should measure the length-to-transfer distance before deciding to augment with a graft. In many cases a direct transfer is achievable after adequate pectoralis mobilization.	A poorly secured graft to a shortened pectoralis major tendon is possible.	Use of the Pulvertaft weave technique through a portion of the pectoralis muscle extends the working length of the tendon and secures graft incorporation.
Step 6: Scapula tunnel preparation and tendon transfer	A point-to-point clamp should be used through the scapula body with a strong pull laterally to assist in delivering the scapula into the operative wound for tunnel drilling.	Fracture of the inferior pole of the scapula can occur.	The surgeon should mark the site for the tenodesis hole at least 1 cm proximal to the inferior edge and 1 cm medial to the lateral cortical edge to avoid blowout.
Step 7: Postoperative rehabilitation	Rehabilitation should progress slowly. Particularly with the indirect transfer method, there is a risk of graft elongation and failure.	Prolonged immobilization, leading to stiffness and secondary scapular dyskinesis or recurrent winging, is possible.	Proper balance between protection and immobilization is important. A team approach to rehabilitation is critical. Good communication with the therapist is needed. Manual scapular stabilization should be performed during overhead stretching.

isolated serratus anterior or trapezius weakness, have also been reported.[6,8,9,16] Bizot et al.[6] were the first authors to publish outcomes of STF in the treatment of serratus anterior paralysis. After a retrospective review of 10 patients with a mean follow-up period of 6.2 years, a 30% nonunion rate was reported. Although 6 patients were able to return to manual labor, mean active abduction and forward flexion were limited to 93° and 101°, respectively. In comparing outcomes of STF for both dystrophic and nondystrophic conditions (42 STFs in 34 patients; mean follow-up period, 5 years), Sewell et al.[9] reported a 26% clinical failure rate. Overall functional outcome scores were lower for the nondystrophic group. Other authors have noted a similarly high complication rate.[7,8] Krishnan et al.[8] published outcomes of STF using a plate and wire construct in 24

Table 2. Advantages and Disadvantages

Advantages	
	Dynamic solution for dynamic problem
	Optimizes range of motion
	Added length from graft allows tension-free muscle transfer
	Relatively low perioperative morbidity and complication rate compared with scapulothoracic fusion
Disadvantages	
	Inadequate treatment for dystrophic causes of scapular winging
	Risk of recurrence particularly in young laborers and overhead athletes
	Attenuation of graft over time can lead to recurrence
	May cause unacceptable cosmetic deformity of chest

shoulders with a variety of clinical disorders. More than 50% of patients had complications, which ranged from pneumothorax to pleural effusion, hardware failure, pseudarthrosis, and persistent pain. In addition to these short-term risks, Atmaca et al.[17] used a computer model to demonstrate increased acromioclavicular and glenohumeral joint loads after STF, which may increase the risk of osteoarthritis in the long-term. Finally, in the setting of failed STF, revision surgical options can be limited.

With these issues in mind, the alternative procedure of dynamic muscle transfer to the scapula has gained popularity. A variety of techniques have been described, with results previously published for pectoralis major, pectoralis minor, levator scapulae, and rhomboid transfer.[1,3,18-23] The theoretical advantages of this technique over STF include perhaps less technical demand in performing the procedure, less perioperative morbidity, fewer complications, and better shoulder range of motion and function. First described and performed by Tubby[24] in 1904, pectoralis major transfer for the treatment of serratus anterior palsy has become the most common surgical treatment method for this condition. Results of both split sternal head transfer[1,25] and dual clavicular and sternal head transfer[26] have been reported. Other variations include a single- versus 2-incision approach, medial versus lateral scapular tenodesis, direct versus indirect transfer, and augmentation with allograft versus autograft tissue. In an anatomic study, Povacz and Resch[27] showed the sternal head direct transfer technique to have the necessary length and excursion for transosseous fixation to the inferior angle of the scapula. The theoretical advantage of this approach is the avoidance of an interposed graft, which may lengthen or attenuate with time. Our preference is to perform a direct tenodesis when possible; however, in our experience, an interposed graft is often required to augment native tendon bulk and to allow for an appropriately tensioned dynamic transfer.[23] One should also consider the potential adverse effects of overly aggressive pectoralis mobilization, which may result in traction injury to the medial and lateral pectoral nerves, muscular degeneration, and poorer function.[28] To our knowledge, no study has examined the comparative outcomes of autograft versus allograft augmentation with this procedure.

Streit et al.[26] reported outcomes of both direct (n = 4) and indirect (n = 22) transfer methods at a mean follow-up of 21.8 months. Contrary to our technique, they used hamstring autograft for augmentation and indirect transfer. Recurrent scapular winging was noted in 19% of shoulders. Final postoperative mean forward flexion and external rotation were 149° and 62.8°, respectively. The mean American Shoulder and Elbow Surgeons score improved from 28 to 67 ($P < .001$). The mean pain score on a visual analog scale improved from 7.7 to 3.0 ($P < .001$). No significant clinical difference was noted between the direct and indirect methods, although all 5 failures occurred in the indirect group. With the longest mean follow-up period available in the published literature (92.5 months), Tauber et al.[25] showed durable clinical results for direct pectoralis major transfer in the treatment of medial scapular winging. At final follow-up, the mean Constant score increased from 41 to 85.4 points. Mean active forward flexion, abduction, and external rotation were 171°, 161°, and 63°, respectively. The final outcomes were rated as excellent in 10 of 12 patients and good in the remaining 2. Multiple authors, with mean follow-up times ranging from 27 to 70 months, have reported good to excellent outcomes in 67% to 100% of patients by use of the indirect transfer method.[3,20,21,23] Chalmers et al.[29] retrospectively compared outcomes between patients treated with the indirect (n = 14) and direct (n = 10) transfer techniques. At a mean follow-up of 4.3 years, there were no significant differences in risk of recurrence, range of motion, or American Shoulder and Elbow Surgeons scores.

For cosmetic reasons, split pectoralis major transfer with preservation of the clavicular head anatomy appears to be favored over dual head harvest.[26] As an alternative to soft-tissue transfer, sternal head insertional osteotomy with bony reattachment to the scapula can also yield excellent and durable clinical outcomes.[25,30] The most frequently reported complications of pectoralis major transfer include transfer failure, infection, unsatisfactory cosmesis, and glenohumeral stiffness, with an incidence ranging from 8% to 22%.[3,20-23,25]

We present our technique for split pectoralis major transfer to the inferolateral scapula for treatment of chronic medial scapular winging (Table 1). Clinical outcomes are generally better than those of STF, with fewer short-term complications and less surgical morbidity (Table 2). Indirect muscle transfer with allograft tissue augmentation may be required in some instances and can yield reliable results.

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