REVIEW

Scapulothoracic Arthrodesis: Indications and Surgical Technique

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ABSTRACT

Scapulothoracic motion accounts for approximately one-third of total shoulder elevation. Disorders affecting the muscles that attach to the scapula coordinating scapulothoracic motion or injury to the nerves that innervate these muscles can result in winging of the scapula and subsequent scapular dyskinesis. Examples include facioscapulohumeral dystrophy (FSHD), neuralgic amoyotrophy, poliomyelitis, long thoracic nerve palsy (affecting serratus anterior), spinal accessory nerve palsy (affecting trapezius), and dorsal scapular nerve palsy (affecting rhomboids and levator scapulae). Loss of scapular stabilization results in an unstable base for efficient glenohumeral motion, scapular winging, and subsequent loss of shoulder motion. Scapulothoracic arthrodesis provides rigid fixation of the scapula to the thorax, and long-term results of the procedure have generally been favorable. A surgical technique for scapulothoracic fusion and the results of the senior author's surgical experience are presented.

HISTORICAL PERSPECTIVE

In the past, patients with scapular winging were treated with orthotic devices that attempted to stabilize the scapula against the posterior chest wall. These devices were not well tolerated by patients, and efficacy was limited.[1–5] Surgical options for scapular stabilization other than various muscle transfers that provide dynamic scapular stability include scapulopexy and scapulothoracic arthrodesis. Scapulopexy procedures were thought to be advantageous when compared to scapulothoracic arthrodesis because the less rigid fixation provided by scapulopexy still allowed for some scapular motion and immediate postoperative mobilization was possible. In addition, the concerns of stress fractures, nonunion, and respiratory compromise secondary to reduced rib excursion from arthrodesis procedures could be avoided.

The first description of attempted surgical stabilization of the scapula by scapulopexy appeared in 1906 by Putti.[6] He presented a case report involving interscapular fixation that resulted in vascular compromise of the upper extremity. In 1927 Henry described the use of fascia lata strips placed through the medial border of the scapula and looped around the spinous processes of the thoracic vertebrae as a treatment of scapular winging due to chronic trapezius paralysis.[7] A similar technique was described in 1932 by Whitman for treatment of serratus paralysis.[8] A modification of this technique was reported by Rinaldi in 1964.[9] Dickson described a technique for scapular stabilization using fascia lata bands along with transposition of the pectoralis major.[10] Dewar and Harris used fascia lata strips and lateral transfer of the levator scapulae to provide scapular stability.[11] Lowman used one or several strips of fascia lata to connect the medial borders of both scapulae.[12] Ketenjian used strips of fascia lata, Mersilene tape, or Dacron strips to secure the medial border of the scapula to the underlying ribs.[13] Vukov and coworkers performed a scapulopexy by attaching the inferomedial angle of the scapula to the next lower rib using synthetic ribbon.[14]

Despite the theoretical advantages of scapulopexy to scapulothoracic arthrodesis, the results of the various scapulopexy procedures deteriorated with time due to stretching and loosening of the constructs. Nove-Josserand performed a scapulothoracic arthrodesis in 1921 using a portion of the fourth rib without internal fixation. This was not reported in the literature until 1967 by Stromboni.[15] In 1961 Howard[16] performed scapulothoracic arthrodeses using cortical tibial bone graft struts with screw fixation. Bunch described the use of iliac crest bone graft and stainless steel wire fixation of the scapula to the rib cage.[17,18] A similar technique was described by Jakab

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and coworkers,[19] Twyman and colleagues,[20] and Andrews and coworkers.[21] In 1990 Letournel and colleagues published their results of an arthrodesis technique securing a rib through a window in the medial border of the scapula with plate and screw fixation along with wire-plate fixation of the scapula inferiorly.[22] A technique using stainless steel wires and plate fixation of the scapula with bone graft augmentation was published by Hawkins and coworkers in 1990.[23] A case report by Kocialkowski and colleagues in 1991 described bilateral scapulothoracic arthrodeses in a patient with facioscapulohumeral dystrophy using screw fixation of the scapula to the underlying ribs augmented with humeral allograft struts and posterior iliac crest autograft.[24] In another case report, Szomor used allograft Achilles tendon strips along with allograft and posterior iliac crest autograft to secure the scapula to the underlying ribs.[25]

INDICATIONS/ CONTRAINDICATIONS

For the presence of scapular winging, patients are evaluated with both shoulders completely exposed. Examination begins by inspection of the shoulders posteriorly with the arms at rest. Injury to the long thoracic nerve or muscular disorders affecting the serratus anterior musculature will result in the scapula assuming a position of superior migration with medial rotation of the inferior border of the scapula. Injury to the spinal accessory nerve affecting the trapezius muscle will cause the scapula to assume a protracted position with inferior migration and lateral rotation of the inferior border of the scapula (Fig. 1). These positions will be accentuated as the patient is asked to forward elevate the arm. Injury to the dorsal scapular nerve affecting the rhomboids and levator scapulae will present in a similar fashion as patients with trapezius palsy, with the inferior border of the scapula being pulled inferiorly and laterally due to the unopposed action of the serratus anterior muscle.[26]

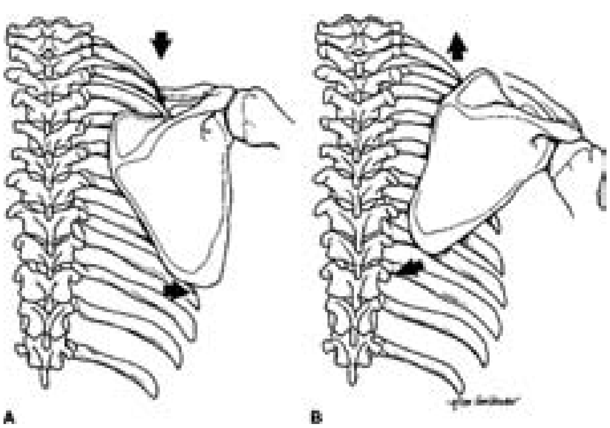

FIGURE 1. Position of the scapula with primary scapular winging due to trapezius palsy (A) and serratus anterior palsy (B). (© 1995 American Academy of Orthopaedic Surgeons. Reprinted from the *Journal of the American Academy of Orthopaedic Surgeons*, Volume 3(6), pp 319–325 with permission.)

Atrophy of the muscles about the shoulder girdle should be noted. Patients with an injury to the spinal accessory nerve will demonstrate atrophy of the trapezius musculature and weakness with attempted shrugging of the shoulder. Patients with an injury to the dorsal scapular nerve may show atrophy of the rhomboids and levator scapulae along the medial border of the scapula. Examination of individuals with facioscapulohumeral dystrophy will reveal atrophy of the trapezius, rhomboids, serratus anterior, and latissimus dorsi. Patients with scapular winging will generally be unable to obtain complete forward elevation or arm abduction, and winging of the scapula will be seen with active shoulder motion. Winging of the scapula can also be elicited by asking the patient to perform a push-up against the wall (Fig. 2).

In patients with a suspected nerve injury, electromyography is used to confirm the diagnosis. Patients with facioscapulohumeral dystrophy may present with isolated unilateral scapular winging but will generally have bilateral scapular winging, facial muscular weakness, and a family history of the disorder.[27] Patients typically present with symptoms between the second and fourth decades of life. Genetic testing is recommended for patients suspected of having facioscapulohumeral dystrophy, as the disease has been shown to be associated with deletion of a region of the long arm of chromosome 4 (4q35).[28]

Most patients with neuropraxic nerve injuries will spontaneously recover within 1 year.[1,4,5,29–31] Conservative treatment, including rehabilitation and strengthening of the remaining shoulder girdle musculature, is the initial recommended treatment to maintain muscle strength and motion about the glenohumeral joint. Patients with a history of penetrating trauma resulting in nerve injury can be considered for early nerve exploration and repair with or without nerve grafting.[32]

Patients with symptomatic scapular winging due to neurologic injury for greater than 1 year with EMG evidence of complete denervation and patients with documented neuromuscular disease with progressive loss of shoulder function despite conservative treatment efforts are candidates for surgical intervention. Surgical procedures include muscle transfers, scapulopexy, and scapulothoracic arthrodesis. Multiple procedures describing muscle transfers for the treatment of scapular winging have been described and are beyond the scope of this text.[8,10,26,33–42] Muscle transfers are not indicated in patients with progressive neuromuscular diseases such as facioscapulohumeral dystrophy. As stated earlier,

FIGURE 2. Scapular winging of the left shoulder. The patient is asked to perform a push-up against the wall.

scapulopexy procedures have fallen out of favor because the initial functional improvements seen with these procedures deteriorate with time due to stretching and loosening of the stabilizing constructs.

Indications for scapulothoracic arthrodesis include patients with severe scapular winging secondary to long thoracic nerve palsy, spinal accessory nerve palsy, or dorsal scapular nerve palsy who have failed conservative rehabilitative measures and dynamic muscle transfers. In these patients, scapulothoracic arthrodesis should be considered a salvage procedure. Patients with facioscapulohumeral dystrophy and patients with paralysis of multiple muscles about the shoulder are also candidates for arthrodesis. Copeland and Howard[43] described a test in which the examiner manually stabilizes the scapula against the posterior chest wall to prevent scapular winging. The patient is then asked to forward elevate the arm. If the amount of forward elevation and the ability to maintain shoulder elevation is significantly improved from performing the test without the scapula stabilized, then patients can be expected to benefit from scapulothoracic arthrodesis (Fig. 3).

A contraindication to scapulothoracic arthrodesis is the patient with an injury to the axillary nerve or significant strength deficit of the deltoid muscle secondary to neuromuscular disease, as the deltoid becomes the primary muscle involved in shoulder motion after scapulothoracic arthrodesis. Relative contraindications include severe osteoporosis (preventing adequate fixation), a history of smoking (increasing the risk of nonunion), and severe respiratory compromise. With respect to respiratory compromise, although fusion of the scapula to the posterior rib cage does restrict thoracic motion with respiration and causes a decrease in vital capacity, only 1 study has reported a clinically significant decline in respiratory function in a single patient as a result of arthrodesis.[22]

■ PREOPERATIVE PLANNING

Preoperative imaging studies for all patients should include standard anteroposterior (AP), scapular-Y, and axillary lateral views of the affected shoulder to rule out bony pathology. If the patient has scapular winging as a result of nerve palsy, EMG studies obtained at least 1 year after injury should document complete denervation of the affected muscle. If the patient has had prior surgery to the affected shoulder, such as attempted nerve repair or muscle transfers, operative notes describing what was performed should be obtained to prepare the surgeon for the abnormal anatomy that may be encountered upon performing the arthrodesis. Patients with medical comorbidities and those patients with facioscapulohumeral dystrophy require preoperative medical clearance prior to surgery. All patients are fitted preoperatively with a gunslinger brace for postoperative immobilization.

■ SURGICAL TECHNIQUE

After induction of general anesthesia and administration of preoperative intravenous antibiotics, the patient is placed prone on a Wilson spine table, allowing the abdomen to hang free to facilitate ventilation and decrease intraabdominal venous pressure. Pads are placed under all bony prominences, including the chest wall, pelvis, knees, and contralateral arm. The arm on the operative side is placed in approximately 90 degrees of abduction and external rotation and 20–30 degrees of adduction in the horizontal plane a well-padded arm board with support under the entire length of the extremity with rolled blankets and/or foam padding. The operative field should include the spine, ipsilateral neck, arm, trunk, and posterior superior iliac spine for procurement of bone graft (Fig. 4). The operative field should be draped such that the arm is allowed to move freely during the procedure.

FIGURE 3. Scapula stabilizing test. (A), First the patient is asked to raise both arms forward and maintain this position with the arm horizontal until fatigue causes it to drop to the side (patient had previous fusion on the right side). (B), The test is then repeated with the scapula manually held downward to the chest wall by the examiner to prevent winging. If maintenance of flexion or abduction is found to be easier and the fatigue test is prolonged, a scapulothoracic fusion may be indicated. (Reprinted with permission from Copeland, Levy, Warner, et al)[44].

Bony landmarks, such as the superior, medial and inferior borders of the scapula, the scapular spine, and the spinous processes of the seventh cervical and first four thoracic vertebrae along with their associated ribs should be identified (Fig. 5). The spine of the scapula should overlie the fourth rib, and the scapula should be rotated such that the angle formed by the spinous processes and the medial border of the scapula measures 20–30 degrees. This position is generally obtained when the arm is placed in the previously mentioned position.

FIGURE 4. Area of surgical preparation for scapulothoracic fusion.

FIGURE 5. Anatomic landmarks and surgical incision for scapulothoracic fusion. Note how the spine of the scapula aligns with the spinous process of the fourth thoracic vertebrae.

An incision is made along the medial border of the scapula through the skin and subcutaneous tissues. Hemostasis is obtained with electrocautery. Once the trapezial fascia is identified, a large lateral flap is raised to completely expose the dorsal surface of the trapezius muscle as it overlies the scapula. A small fenestration is made in the trapezius just inferior to the lateral aspect of the scapular spine. Electrocautery is then used along the scapular spine to elevate the supraspinatus and infraspinatus from the underlying scapula. A Cobb elevator is also used to facilitate exposure. The supraspinatus and infraspinatus muscles are elevated in a subperiosteal fashion to expose the medial 3 cm of the scapular body. A portion of the lateral trapezius may need to be incised to allow for proper exposure of the supraspinatus fossa. A towel clip is then placed through the scapular spine, and the scapula is elevated to place tension on the rhomboid insertions into the medial scapular border. These muscles are typically atrophic and may even be replaced by fibrofatty tissue. The rhomboids are then detached from the medial scapula, and the subscapularis is elevated from the ventral scapular body, exposing the medial 6 cm of scapular body. An incision is then made through the raphé between the rhomboids and serratus posterior to expose the subscapularis bursa. This intermuscular interval is relatively avascular, and bleeding in this area should be minimal. Using the seventh cervical spinous process as a landmark, the third, fourth, fifth and sixth ribs are then exposed circumferentially by elevating the serratus posterior with electrocautery and a small elevator. Careful subperiosteal dissection of the ribs should be performed to separate the inferior border of the ribs from their associated neurovascular bundles and the ventral aspect of the ribs from the parietal pleura. This exposure facilitates wire passage around the ribs and ensures that adequate bony apposition can be obtained between the ribs and the underlying 3 cm of medial scapula (Fig. 6). Any serratus posterior, subscapularis, or intervening intercostal musculature that may interfere with bony apposition should be carefully excised, and this typically involves resecting the medial 6 cm of intervening muscle (Fig. 7).

The exposed ribs and ventral surface of the scapula are then lightly decorticated with a high speed burr. A malleable retractor should be used to protect the underlying parietal pleura when decorticating the superior and inferior aspects of the ribs. Care should be taken to not remove excessive bone from the thin scapular body. A looped 18-gauge Luque wire is passed under each exposed rib in a subperiosteal fashion to minimize the risk of injuring the parietal pleura. The wire is then cut at the loop, creating 2 individual wires under each rib (Fig. 8). A 4- or 5-hole 4.5 mm reconstruction plate is then contoured to match the infraspinatus fossa along the medial scapular border. The bur is then used to place a single hole in the medial aspect of the supraspinatus fossa directly over the third rib. The contoured plate is placed in the infraspinatus fossa, and 3 drill holes are made through the exposed scapular body over the fourth, fifth and sixth ribs. To protect the underlying pleura and ribs with their associated neurovascular structures, a malleable retractor should be used during creation of the drill holes. The 2 wires around the fourth rib are passed first through the most proximal drill hole in the infraspinatus fossa and the most proximal hole in the plate and loosely twisted back onto themselves. If the scapula is positioned appropriately, the spine of the scapula should overlie the fourth rib. The procedure is repeated for the fifth and sixth ribs. The wires around the third rib are then passed through the drill hole in the supraspinatus fossa and loosely approximated (Fig. 9).

FIGURE 6. Surgical dissection demonstrating subperiosteal dissection of the third, fourth, fifth and sixth ribs as well as the medial portion of the scapula.

To assess for any compromise of the underlying pleura, the wound is filled with sterile saline solution, and a large breath is provided to the patient by the anesthesiologist. Any bubbles observed at this time are indicative of a tear in the underlying pleura and should be addressed accordingly. In addition, 2–3 mL of 0.25% Marcaine are injected at the inferomedial border of each exposed rib

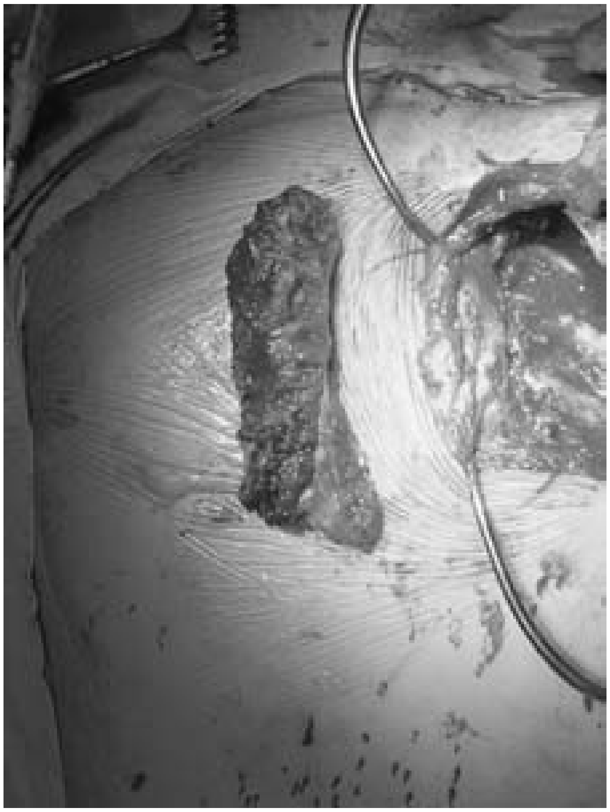

FIGURE 7. Resected portion of medial scapular musculature.

to provide postoperative analgesia and to minimize atelectasis from poor inspiratory efforts secondary to pain.

Bone graft is then obtained from the posterior superior iliac spine. The graft is placed between the third, fourth, fifth and sixth ribs under the exposed medial scapula. If necessary, synthetic bone graft material may be used to augment the bone graft obtained from the pelvis. The scapula is then positioned such that the angle formed by the spinous processes and the medial border of the scapula measures 20–30 degrees and the inferomedial pole of the scapula is approximately 5–7 cm lateral to the spinous processes. The wires are then sequentially tightened to afford compression between the exposed scapula, bone graft, and posterior ribs. The plate is used to distribute the tension throughout the construct and to prevent the wires from cutting out of the thin bone in the infraspinatus fossa.

After adequate tensioning of the wires, any remaining bone graft is placed along the medial border of the scapula in close contact with the ribs (Fig. 10). The elevated supraspinatus and infraspinatus origins are then allowed to fall back to their original positions, providing soft tissue coverage over the hardware. The rotator cuff musculature and scapular stabilizers are then reapproximated to the medial border of the scapula. The wound is then closed in layers, and a subcuticular stitch is used for the skin. A sterile dressing is applied, and the patient is then carefully rolled supine while minimizing excessive motion of the extremity. The arm is placed in a gunslinger brace in 10 degrees of external rotation, 15 degrees of abduction, and neutral shoulder flexion/extension for immobilization postoperatively.

A portable AP view of the chest is obtained in the recovery room and repeated on postoperative day 1 to check for the presence of a pneumothorax or pleural effusion (Fig. 11). A neurovascular examination is also performed in the recovery room once the patient can cooperate with the examination to rule out an injury to the brachial plexus or arterial blood supply to the upper extremity. The patient is hospitalized for 72–96 hours for pain management and initiation of physical therapy.

RESULTS

Between 1994 and 2004 the senior author (AAR) has performed 32 scapulothoracic fusions on 25 patients. Eighteen patients (25 shoulders) underwent fusion for facioscapulohumeral dystrophy, and 7 patients (7 shoulders) underwent fusion secondary to trauma to the affected shoulder. Three of the 7 patients who sustained trauma to the shoulder had spinal accessory nerve palsy

FIGURE 8. Passage of looped 18 gauge Luque wires around third, fourth, fifth and sixth ribs.

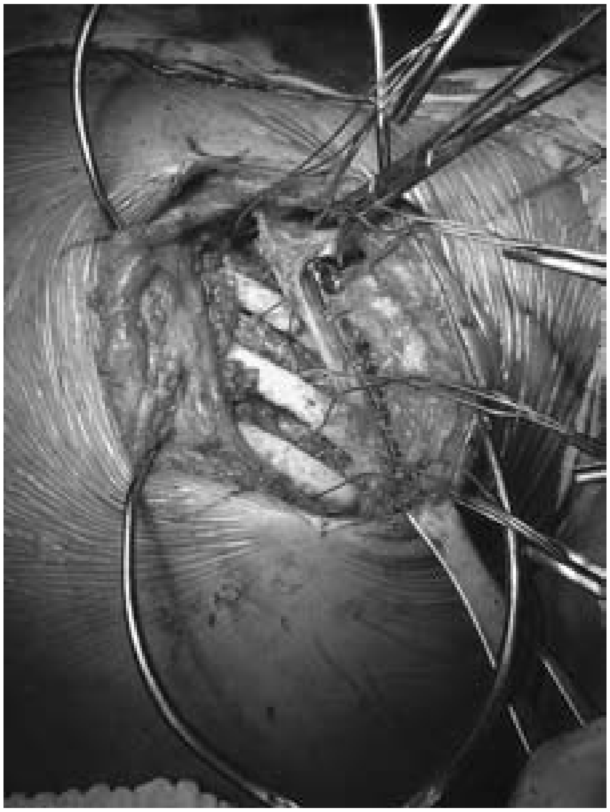

FIGURE 9. Passage of wires through scapula and plate.

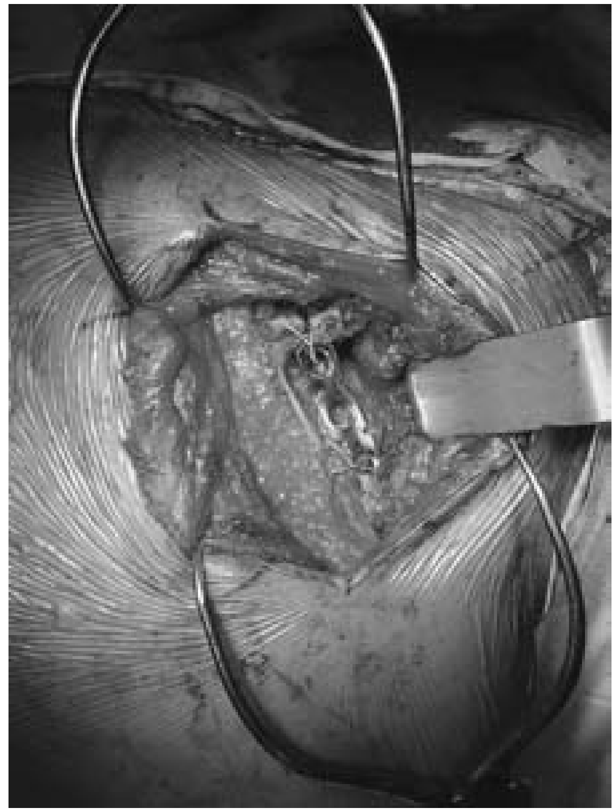

FIGURE 10. Completed construct with excess posterior iliac crest bone graft placed along the medial border of the scapula.

(2 occurred as a result of a posterior cervical lymph node biopsy, and 1 occurred after resection of a Pancoast tumor). One patient had a long thoracic nerve palsy, 1 patient had an avulsion-type injury of the rhomboids and trapezius muscles, and the remaining 2 patients had scapular winging due to trauma from an unknown mechanism of action.

Pre- and postoperative range of motion data were available on 23 of the 32 fusions (72%), with an average follow-up of 34 months (SD ± 30 months; range = 6 weeks–95 months). Forward flexion improved 38 degrees from an average of 74 degrees preoperatively (SD ± 14 degrees; range = 50–100 degrees) to an average of 112 degrees postoperatively (SD ± 29 degrees; range = 40–150 degrees) ($P < 0.0001$). External rotation at the side decreased 6 degrees from an average of 53 degrees preoperatively (SD ± 18 degrees; range = 20–90 degrees) to an average of 48 degrees postoperatively (SD ± 22 degrees; range = 20–90 degrees)($P = 0.34$).

Pre- and postoperative Simple Shoulder Test data were available on 23 of the 32 fusions (72%), with an average follow-up of 38 months (SD ± 28 months; range = 12 weeks–95 months). The average number of positive responses increased 45% from 5.5/12 preoperatively (SD ± 3.5; range = 0–12) to 8/12 postoperatively (SD ± 3; range = 2–12) ($P = 0.01$). With respect to specific questions in the

FIGURE 11. AP radiograph of chest demonstrating left shoulder scapulothoracic fusion.

Simple Shoulder Test, the number of patients who could place their hand behind their head, place a coin on a shelf, lift 1 pound and 8 pounds to shoulder level, and carry 20 pounds at the side more than doubled. In contrast, the number of patients who could wash their opposite shoulder declined by 50% (12 preoperatively vs. 6 postoperatively). The number of patients able to reach the small of the back also diminished slightly (18 preoperatively vs. 15 postoperatively). The average visual analog pain scale value decreased from a preoperative mean of 4 (SD ± 3; range = 0–9) to a postoperative mean of 2 (SD ± 2; range = 0–7) ($P = 0.0003$).

Pre- and postoperative American Shoulder and Elbow Surgeons (ASES) scores were available on 15 of the 32 fusions (48%), with an average follow-up of 28.5 months (SD ± 18 months; range = 5 months–62 months). The average preoperative ASES score was 57 (SD ± 7; range = 7–87), which improved to 68 postoperatively (SD ± 23; range = 22–93) ($P = 0.06$). Of note, when comparing ASES scores of patients undergoing scapulothoracic fusion for facioscapulohumeral dystrophy to patients undergoing scapulothoracic fusion for other reasons, the facioscapulohumeral dystrophy patients had higher pre and postoperative ASES scores; however, substantially greater improvements were seen in the non-facioscapulohumeral dystrophy patients. In the facioscapulohumeral dystrophy group (n = 10; avg. f/u = 29.5 months (SD ± 20 months; range = 5 months–62 months)), the pre- and postoperative ASES scores were 73 and 78, respectively ($P = 0.37$). In contrast, in the non-facioscapulohumeral dystrophy group (n = 5; avg. f/u = 26.5 months (SD ± 14.5 months; range = 12 months–44.5 months)), the pre- and postoperative ASES scores were 25 and 48, respectively ($P = 0.11$). Postoperative ASES scores were available on 22 of the 32 fusions (69%). With an average follow-up of 39.5 months (SD ± 27 months; range = 5 months–95 months), the mean score was 68 (SD ± 23; range = 22–97).

COMPLICATIONS

Twenty-four complications occurred in 18 patients, thus making the complication rate 75%. Only 7 complications (22%) required additional surgery. The most common complications encountered were wire failure despite evidence of a solid fusion mass (5 patients), adhesive capsulitis (3 patients), inferior scapular prominence requiring a second surgery (3 patients), brachial plexus palsy requiring rib resection (2 patients) and nonunion/pseudarthrosis (2 patients). Other complications included pneumothorax (2 patients), pleural effusion (2 patients), thoracic outlet syndrome (1 patient), pneumonia (1 patient), scapula fracture (1 patient), deep venous thrombosis (1 patient) and *C. difficile* infection (1 patient).

Only 1 patient with wire failure required a second surgery, not for the wire, but for a prominent inferior scapular border. No patient developed symptoms secondary to the broken wires. Two of the 3 cases of adhesive capsulitis occurred in the same individual who underwent staged bilateral scapulothoracic fusions. Both resolved with physical therapy. The third case of adhesive capsulitis resolved with an intraarticular injection of corticosteroid and physical therapy. Two patients underwent resection of the inferior 2 cm of the scapula because of a symptomatic scapular prominence. These patients both underwent bilateral scapulothoracic fusions and had a component of thoracic scoliosis that contributed to the unilateral scapular prominence. Both patients did well after the partial scapular resection. Two individuals experienced a brachial plexus palsy postoperatively that necessitated an exploration and first rib resection in one patient and a first and second rib resection in the second patient (this patient had also developed thoracic outlet syndrome). Despite some improvements in symptoms after rib resection, both patients continued to show some residual neurologic deficit. Two patients developed a nonunion/pseudarthrosis. One patient elected not to have additional surgery, and 1 patient underwent subsequent revision bone grafting that eventually led to a solid fusion and a satisfactory result. A pneumothorax was discovered in 2 patients intra-operatively, and this was managed with forced expiration under anesthesia with simultaneous suction via a drainage tube that was removed at the time of wound closure. The patients were observed with subsequent resolution of symptoms. A small pleural effusion developed in 1 patient who was observed. The patient who developed a pneumonia after surgery resolved the infection with a course of oral antibiotics. The patient who suffered the scapula fracture healed uneventfully. The deep venous thrombosis and *C. difficile* infection occurred in the same patient. The deep venous thrombosis was treated with a short course of subcutaneous enoxaparin followed by oral warfarin.

A review of the literature reveals the most common complications seen after scapulothoracic fusion are hardware failure, pneumothorax, nonunion, pleural effusion, and transient pleuritic chest pain.[16–25,43–47] Despite these complications, most of the patients did not require additional surgery.

POSTOPERATIVE MANAGEMENT

Post-operatively the arm is maintained in the gunslinger brace for 6 weeks. Immediately after surgery patients are instructed on active elbow, wrist, and hand range of motion exercises. Grip strengthening is also initiated immediately post-operatively. Patients return to the office 10 to 14 days after surgery for a wound check and suture

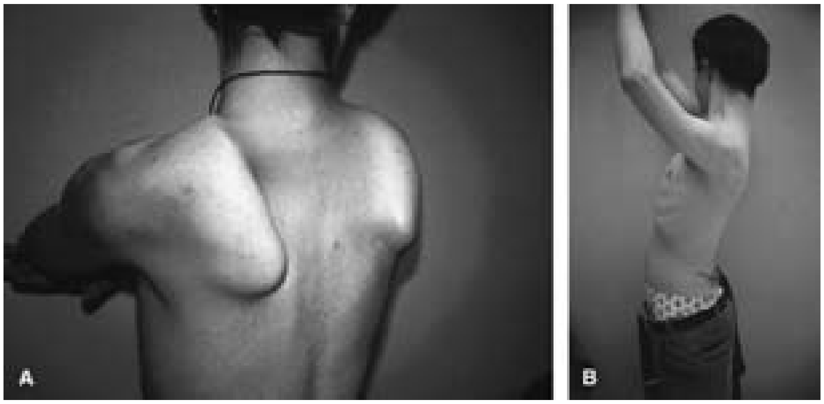

FIGURE 12. Pre- (A) and postoperative (B) photographs of a patient with facioscapulohumeral dystrophy who underwent staged bilateral scapulothoracic fusions.

removal. They are then seen again in 1 month, when radiographs of the shoulder are repeated. At this visit patients are instructed to wean themselves out of the gunslinger brace. Patients are seen in subsequent visits at 4 to 6 week intervals until radiographs and physical examination demonstrate fusion of the scapula to the thoracic wall.

Supervised physical therapy is initiated at 2 to 3 weeks after surgery at a frequency of 2 to 3 times per week. Patients are also given a home exercise program to perform on the days when they do not attend formal sessions. For the first 6 weeks therapy consists of shoulder pendulum exercises with active elbow and wrist motion and grip strengthening. At 6 weeks the patient comes out of the brace and begins passive and active-assisted shoulder motion and progresses to full active range of motion in all planes over the next 6 weeks. The goal is to obtain 120 degrees of shoulder elevation. Shoulder strengthening exercises begin at 3 months with isometric exercises focusing mainly on the deltoid and progressing to rubber band and dumbbell resistance exercises. Activity can be increased as tolerated (Fig. 12).

REFERENCES

1. Foucar HO. The ''clover leaf'' sling in paralysis of the serratus magnus. *BMJ*. 1933;2:865–866.
2. Horowitz MT, Tocantins LM. Isolated paralysis of serratus anterior (magnus) muscle. *J Bone Joint Surg*. 1938;20:720–725.
3. Wolfe J. The conservative treatment of serratus palsy. *J Bone Joint Surg*. 1941;23:959–961.
4. Johnson JTH, Kendall HO. Isolated paralysis of the serratus anterior muscle. *J Bone Joint Surg Am*. 1955;37A:567–574.
5. Wiater JM, Flatow EL. Long thoracic nerve injury. *Clin Orthop*. 1999;368:17–27.
6. Putti V. L'osteodesi interscapolare in un caso di miopatia atrofica progressiva. *Arch Ortop*. 1906;23:319–331.
7. Henry AK. An operation for slinging a dropped shoulder. *Br J Surg*. 1927;15:95.
8. Whitman A. Congenital elevation of the scapula and paralysis of serratus magnus muscle. *JAMA*. 1932;99:1332–1334.
9. Rinaldi F. Terapia chirurgica nella forma ''facioscapulo-omerale'' Della distrofia muscolare primitive. *Clin Ortop*. 1964;16:233–243.
10. Dickson FD. Fascial transplants in paralytic and other conditions. *J Bone Joint Surg*. 1937;19:405–412.
11. Dewar FP, Harris RI. Restoration of function of the shoulder following paralysis of the trapezius by fascial sling fixation and transplantation of the levator scapulae. *Ann Surg*. 1950;132:1111–1115.
12. Lowman CL. *Abdominal Fascial Transplants*. Ann Arbor, MI: JW Edwards; 1954.
13. Ketenjian AY. Scapulocostal stabilization for scapular winging in facioscapulohumeral muscular dystrophy. *J Bone Joint Surg Am*. 1978;60A:476–480.
14. Vukov V, Ukropina D, Bumbasirevic M, et al. Isolated serratus anterior paralysis: a simple surgical procedure to reestablish scapulo-humeral dynamics. *J Orthop Trauma*. 1996;10:341–347.
15. Stromboni A. La scapulo-costopexie dans les paralysies du grand dentelé et du trapeze. Thesis 326. Paris, 1967.
16. Howard RC. Thoraco-scapular arthrodesis. *J Bone Joint Surg*. 1961;43B:175. Abstract.
17. Bunch WH. Scapulo-thoracic fusion for shoulder stabilization in muscular dystrophy. *Minn Med*. 1973;56:391–394.
18. Bunch WH, Siegal IM. Scapulothoracic arthrodesis in fascioscapulohumeral muscular dystrophy. *J Bone Joint Surg Am*. 1993;75A:372–376.
19. Jakab E, Gledhill RB. Simplified technique for scapulocostal fusion in facioscapulohumeral dystrophy. *J Pediatr Orthop*. 1993;13:749–751.
20. Twyman RS, Harper GD, Edgar MA. Thoracoscapular fusion in facioscapulohumeral dystrophy: clinical review of

a new surgical method. *J Shoulder Elbow Surg*. 1996;5: 201–205.

21. Andrews CT, Taylor TC, Patterson VH. Scapulothoracic arthrodesis for patients with facioscapulohumeral muscular dystrophy. *Neuromuscul Disord*. 1998;8:580–584.
22. Letournel E, Fardeau M, Lytle JO, et al. Scapulothoracic arthrodesis for patients who have fascioscapulohumeral dystrophy. *J Bone Joint Surg Am*. 1990;72A:78–84.
23. Hawkins RJ, Willis B, Litchfield RB. Scapulothoracic arthrodesis for scapular winging. In: Post M, Morrey BF, Hawkins RJ, eds. *Surgery of the Shoulder*. St. Louis, MO: Mosby Year Book; 1990:356–359.
24. Kocialkowski A, Frostick SP, Wallace WA. One-stage bilateral thoracoscapular fusion using allografts. A case report. *Clin Orthop*. 1991;273:264–267.
25. Szomor Z, Fermanis G, Murrell G. Scapulothoracic fusion for a stroke patient with Achilles tendon allograft. *J Shoulder Elbow Surg*. 2000;9:342–343.
26. Chavez JP. Pectoralis minor transplant for paralysis of the serratus anterior. *J Bone Joint Surg Br*. 1951;33B:228–230.
27. Kissel JT. Facioscapulohumeral dystrophy. *Semin Neurol*. 1999;19:35–43.
28. Wijmenga C, Frants RR, Brouwer OF, et al. Location of facioscapulohumeral muscular dystrophy gene on chromosome 4. *Lancet*. 1990;336:651–653.
29. Horowitz MT, Tocantins LM. An anatomic study of the role of the long thoracic nerve and the related scapular bursae in the pathogenesis of local paralysis of the serratus anterior muscle. *Anat Rec*. 1938;71:375–385.
30. Kuhn JE, Hawkins RJ. Evaluation and treatment of scapular disorders. In: Warner JJP, Iannotti JP, Gerber C, eds. *Complex and Revision Problems in Shoulder Surgery*. Philadelphia, PA: Lippincott–Raven Publishers; 1997: 357–375.
31. Barron OA, Levine WN, Bigliani LU. Surgical Management of Chronic Trapezius Dysfunction. In: Warner JJP, Iannotti JP, Gerber C, eds. *Complex and Revision Problems in Shoulder Surgery*. Philadelphia, PA: Lippincott–Raven Publishers; 1997:377–384.
32. Kuhn JE, Plancher KD, Hawkins RJ. Scapular winging. *J Am Acad Orthop Surg*. 1995;3:319–325.
33. Eden R. Zur Behandlung der Trapeziuslähmung mittelst Muskelplastik. *Dtsch Z Chir*. 1924;184:387–397.
34. Hass J. Muskelplastik bei serratuslahmung (ersatz des gelahmten musculus serratus anterior durch den muculus teres major). *Zetschr Orthop Chir*. 1931;55:617–622.
35. Durman DC. An operation for paralysis of the serratus anterior. *J Bone Joint Surg*. 1945;27A:380–382.
36. Herzmark MH. Traumatic paralysis of the serratus anterior relieved by transplantation of the rhomboidei. *J Bone Joint Surg Am*. 1951;33A:235–238.
37. Steindler A. Reconstruction of the poliomyelitic upper extremity. *Bull Hosp Joint Dis*. 1954;15:21–34.
38. Lange M. The operative treatment of irreparable trapezius paralysis [in German]. *Istanbul Tip Fak Mecmuasi*. 1959; 22:137–141.
39. Langenskiöld A, Ryöppy S. Treatment of paralysis of the trapezius muscle by the Eden-Lange operation. *Acta Orthop Scand*. 1973;44:383–388.
40. Zeier FG. Treatment of winged scapula. *Clin Orthop*. 1973; 91:128–133.
41. Marmor L, Bechtol CO. Paralysis of the serratus anterior due to electrical shock relieved by transplantation of the pectoralis major muscle: a case report. *J Bone Joint Surg*. 1963;45A:156–160.
42. Bigliani LU, Perez-Sanz JR, Wolfe IN. Treatment of trapezius paralysis. *J Bone Joint Surg Am*. 1985;67:871–877.
43. Copeland SA, Howard RC. Thoracoscapular fusion for facioscapulohumeral dystrophy. *J Bone Joint Surg Br*. 1978; 60B:547–551.
44. Copeland SA, Levy O, Warner GC, et al. The shoulder in patients with muscular dystrophy. *Clin Orthop*. 1999;368: 80–91.
45. Berne D, Laude F, Laporte C, et al. Scapulothoracic arthodesis in facioscapulohumeral muscular dystrophy. *Clin Orthop*. 2003;409:106–113.
46. Bizot P, Teboul F, Nizard R, et al. Scapulothoracic fusion for serratus anterior paralysis. *J Shoulder Elbow Surg*. 2003;12:561–565.
47. Mackenzie WG, Riddle EC, Earley JL, et al. A neurovascular complication after scapulothoracic arthrodesis. *Clin Orthop*. 2003;408:157–161.