Scapulothoracic Fusion Using Multiple Suture Tape Cerclage

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Abstract: Scapulothoracic arthrodesis has been proposed for the treatment of painful scapular winging in patients with facioscapulohumeral muscular dystrophy. It was introduced to improve shoulder function. Several methods of fixation have been proposed to obtain the union of the scapula to the ribs. These include plates, screws, cables, or wires with or without bone grafting. The purpose of this manuscript is to describe the surgical technique of scapulothoracic arthrodesis using plate and cerclage suture tapes.

Level of Evidence: Level IV, treatment study (case series).

Key Words: arthrodesis, facio-scapulo humeral dystrophy, failed tendon transfer, scapular winging, scapula alata, trapezius, serratus anterior

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Abnormal scapulothoracic (ST) motion can be a debilitating condition, which can lead to poor shoulder range of motion, weakness, pain, and deformity. Most commonly, scapular dyskinesia and winging occur secondary to serratus anterior and/or trapezius dysfunction.[1] Different surgical interventions have been described to achieve both dynamic and static stabilization of the ST joint. Dynamic stabilization can be obtained by compensating for the function of the deficient muscle with different tendon transfers. Transfer of the sternal head of the pectoralis major has been proven to give satisfactory functional results in case of paralysis of the serratus anterior.[2] Similarly, transfer of the levator scapulae, the rhomboid major and rhomboid minor, has been proven to restore satisfactory function after paralysis of the trapezius.[3] However, if these fail or are in the setting of facioscapulohumeral dystrophy where functional donor tendons do not exist, classic dynamic stabilization procedures are no longer options.[4] Two types of static ST fixation have been described: (1) scapulopexy, in which bony fusion is not expected[5] and (2) arthrodesis, in which the scapula and rib cage are fused.[6] Several methods of fixation have been proposed to obtain the union of the scapula to the ribs. These include plates, screws, cables, or wires with or without bone grafting. Complication rates have been reported as high as 41%, with the majority related to hardware when passing sharp wires around the ribs. Indeed, the most feared complication of a scapula-thoracic fusion is an iatrogenic breach of the pleura leading to a pneumo and/or a hemothorax. This can happen when passing the metallic wires around the ribs as these are rigid and can be difficult to manipulate.

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To reduce these potentially severe problems and to avoid more benign problems related to metallic cerclages such as irritation or damage to the surrounding tissues,[7] we propose a novel method of fixation using flexible cerclage suture tapes.

ANATOMY

The shoulder joint complex is comprised of 5 separate joints. Three of these are classically described as true articulations: the glenohumeral (GH), the acromioclavicular, and the sternoclavicular. The other 2 correspond to sliding spaces, namely the subacromioclavicular (or subdeltoid) space and the ST joint.

The ST articulation is not a synovial joint[8] and is known as a syssarcosis. It is the serratus anterior that defines 2 sliding spaces[9]: (1) omo-serratus and (2) omo-thoracic.

The serratus anterior is a flat muscle, inserting itself on the lateral border of the first 8 to 9 ribs. It then follows the chest wall to insert on the medial and anterior border of the infero-medial scapular angle. It is innervated by the long thoracic nerve, originating from the C5 to C7 cervical roots. Its action is to maintain and stabilize the scapula against the thorax. It functions to assist in shoulder elevation by inducing posterior scapular tilt and allowing the humeral head to clear the acromion.

The trapezius muscle is a posterior muscle of the shoulder, neck, and trunk. It is very large and occupies the entire upper region of the back like a diamond. It is divided into 3 distinct bundles: (1) upper, (2) middle, and (3) lower. The upper trapezius elevates and upwardly rotates the scapula. The middle fibers retract the scapula and the shoulder. The lower trapezius depresses the medial scapula thereby assisting in the upward rotation of the scapula. It is innervated by the spinal root of the accessory nerve, which is responsible for motor function, and by the cervical nerves from the C3 to C4 cervical roots, which are responsible for pain perception and proprioception.

Normal shoulder motion is produced by both the GH joint (2/3) and the ST articulation (1/3). Specifically, the scapula assists by producing upward rotation, which maintains the acromiohumeral distance and the deltoid resting length as the arm is elevated.[10,11]

INDICATIONS

ST arthrodesis (STA) is indicated in cases of failed tendon transfer or for facioscapulohumeral muscular dystrophy (FSHD). FSHD is an autosomal dominant genetic disorder involving the facial and shoulder musculature. It is an uncommon condition, with a prevalence of ~1:21,000.[12] Scapular girdle involvement usually begins in the adolescent age or young adult, resulting in functional impairment of the upper limbs secondary to scapular instability. Weakness and fatigability of the scapular stabilizing muscles, particularly the serratus anterior, rhomboids, and trapezius, lead to an inability to maintain the scapula against the rib cage. This leads to instability of the deltoid and rotator cuff muscles origin, which remain functional until late in the natural course of the disease.

Contraction of these muscles leads to a painful scapular winging leading to a deficit in the abduction and anterior elevation of the shoulder, which makes overhead activities impossible for these young and active patients whose life expectancy is not reduced.[4]

CONTRAINDICATIONS

This technique is contraindicated:

- In an FSHD patient with normal periscapular and deltoid muscle function. In these patients, shoulder posture is normal and no functional limitations are expected. Surgery has no additional benefits and shoulder elevation decreases with STA due to loss of ST motion.[13]
- In patients with a nonfunctional rotator cuff and deltoid muscle. STA has very limited or no functional benefit and usually cannot improve shoulder elevation over 30 degrees.[13]

TECHNIQUE

Setup

The procedure is performed under general anesthesia with dual lumen intubation to deflate the lung on the operative side. The patient is positioned in a prone position (Fig. 1). The operating field includes the entire upper limb, from the scapula to the spine and the homolateral posterior iliac crest. The ipsilateral arm must be positioned at 90 degrees of abduction and 90 degrees of external rotation in the "Superman position" allowing contact between the scapula and ribs for fusion. The ipsilateral arm is draped, and care should be taken to ensure that internal rotation of the shoulder is possible to lift the scapula off of the chest wall to facilitate exposure of the underlying ribs. The ipsilateral posterior iliac crest is also prepped and draped.

Superficial Exposure

The incision is made between the medial border of the scapula and the spine (Fig. 1). The incision is extending longitudinally and curves over the supraspinatus fossa.

FIGURE 1. Prone position. *D* indicates distal; *P*, proximal.

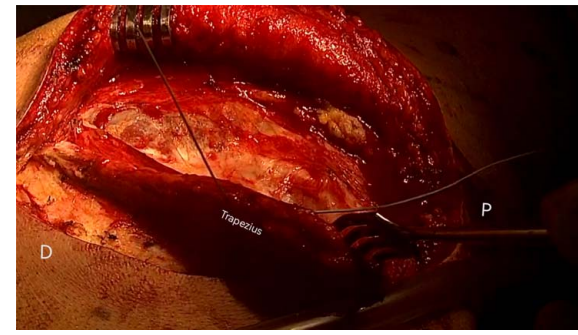

FIGURE 2. Trapezius muscle opening. *D* indicates distal; *P*, proximal.

FIGURE 3. Disinsertion of the rhomboid muscles. *D* indicates distal; *P*, proximal.

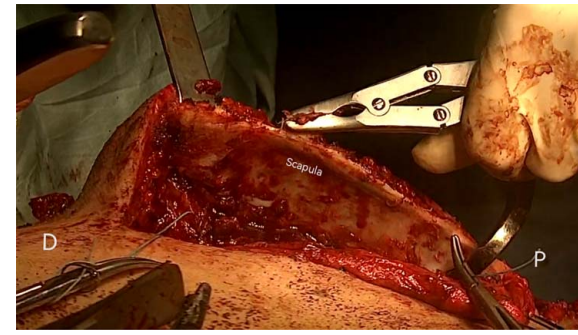

FIGURE 4. Dissection and release of the subscapular from the scapular fossa. *D* indicates distal; *P*, proximal.

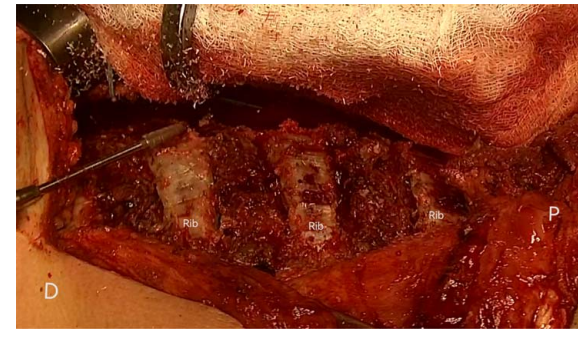

FIGURE 5. Abrasion the posterior surfaces of the ribs. *D* indicates distal; *P*, proximal.

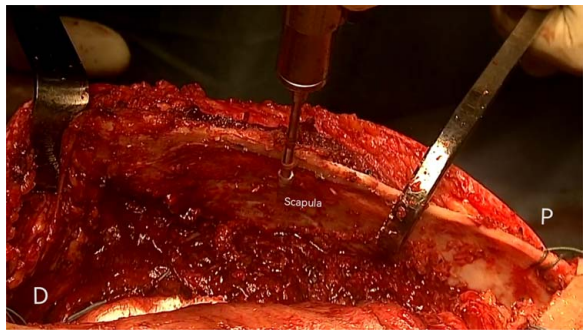

FIGURE 6. Abrasion the anterior surface of the scapula fixation. *D* indicates distal; *P*, proximal.

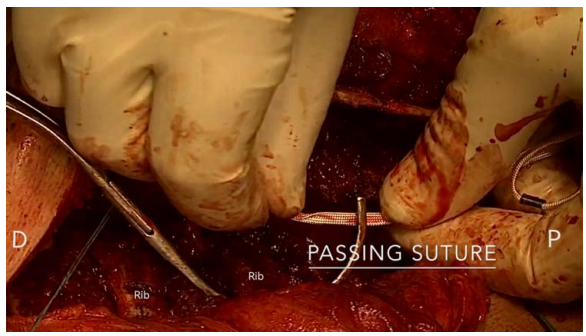

FIGURE 7. A blunt circular clamp is passed around each rib in direct contact with the bone to avoid injury to the intercostal vascular-nervous bundle or iatrogenic. *D* indicates distal; *P*, proximal.

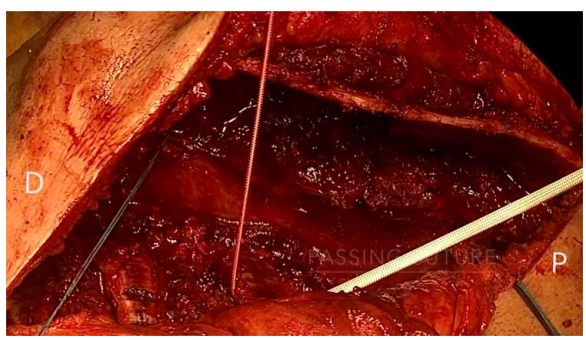

FIGURE 8. Cables passing around the ribs. *D* indicates distal; *P*, proximal.

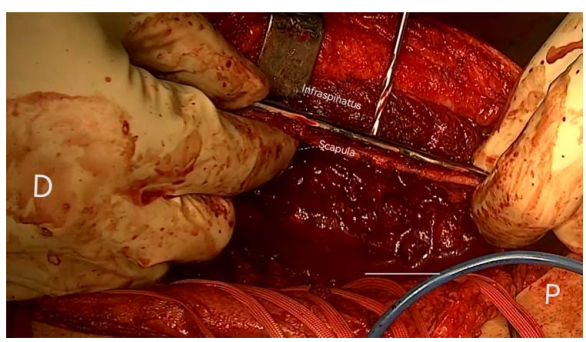

FIGURE 9. Placement of the plate in the infraspinatus fossa and drilling of the 3.5 mm holes in the scapula. *D* indicates distal; *P*, proximal.

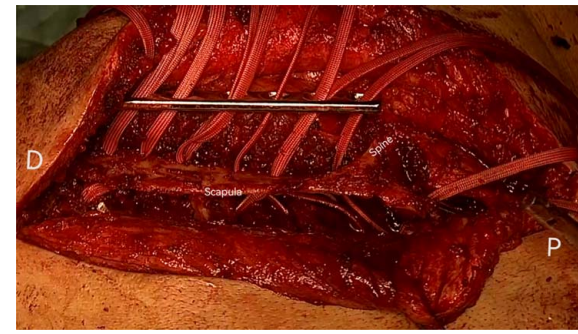

FIGURE 10. Passage of the tapes through the holes in the scapula and plate. *D* indicates distal; *P*, proximal.

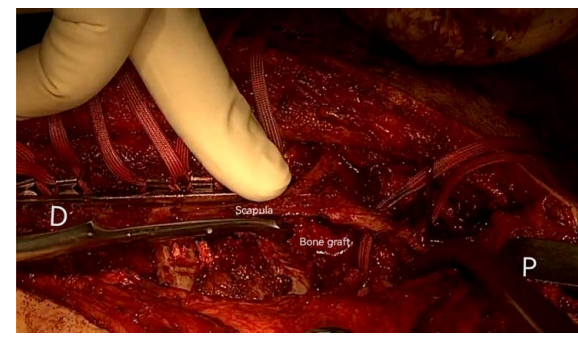

FIGURE 11. Placement of a cancellous bone graft between the scapula and the ribs. *D* indicates distal; *P*, proximal.

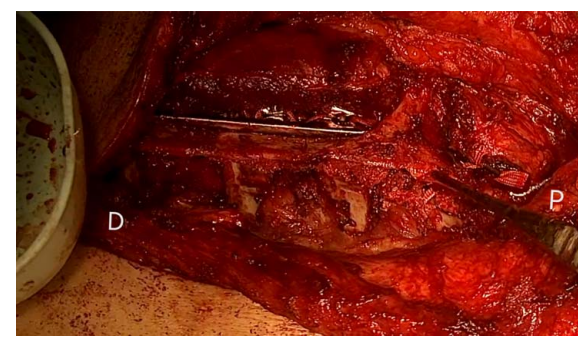

FIGURE 12. Final osteosynthesis. *D* indicates distal; *P*, proximal.

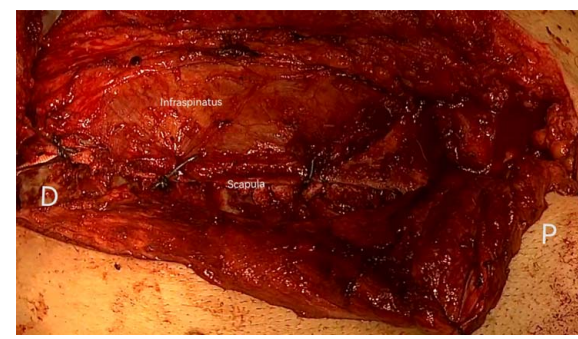

FIGURE 13. The plates are covered by the reinsertion of the supra and infraspinatus muscles. *D* indicates distal; *P*, proximal.

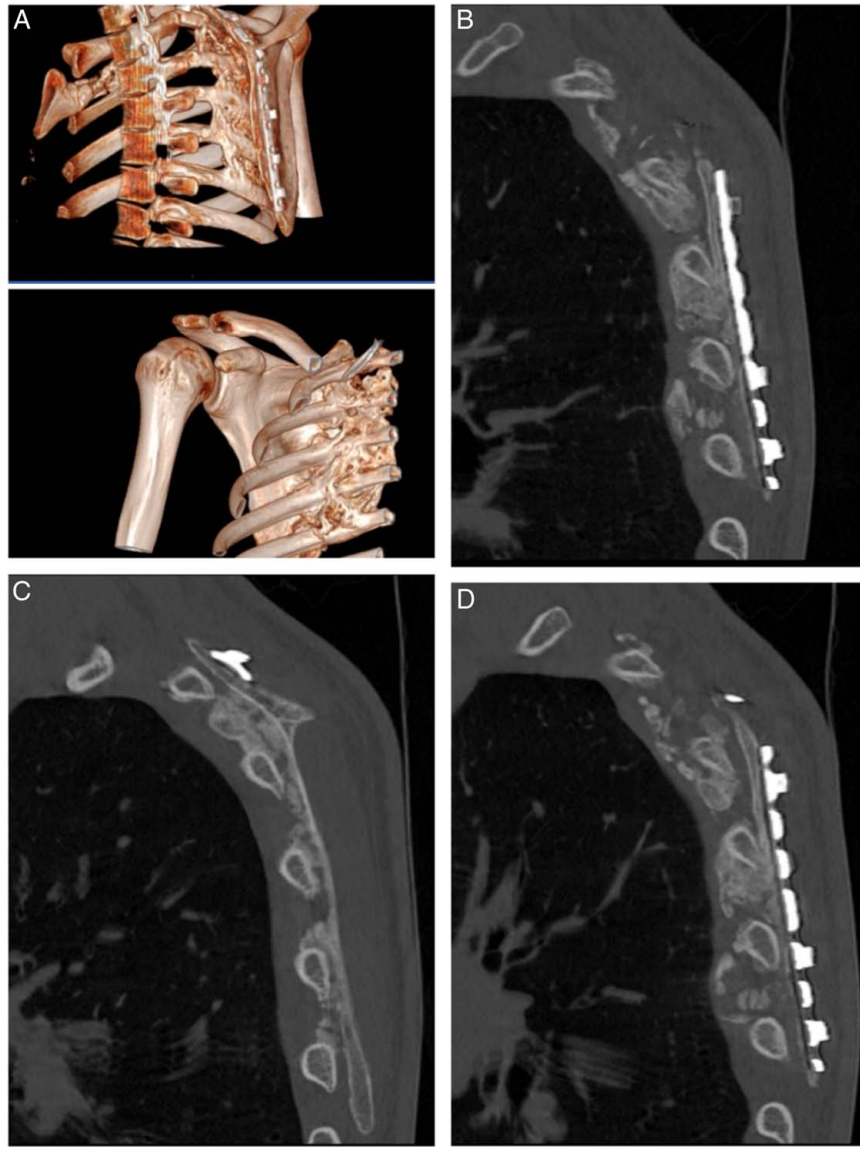

FIGURE 14. Postoperative CT scan after scapulothoracic arthrodesis. A, Three-dimensional CT and sagittal (B–D) cuts demonstrating successful osseous fusion with a solid fusion mass. CT indicates computed tomography.

The trapezius is exposed. In these cases, the muscle is often atrophic and may be difficult to clearly identify.

Deep Exposure

The posterior aspect of the scapula is then exposed by successively detaching the trapezius (Fig. 2) and rhomboids (major and minor) from their scapular insertion. (Fig. 3) Traction sutures are placed in these 3 muscles to allow medial mobilization and expose the underlying supra and infraspinatus fossae. A periosteal elevator is then used to detach the medial origin of the supraspinatus and infraspinatus muscles from the scapula to allow for later positioning of the plates.

The shoulder is then positioned in internal rotation by positioning the patient's hand in their back. This lifts the scapula and facilitates the identification of the serratus anterior, which is completely excised. This muscle is usually atrophic due to the FSHD.

The subscapularis is exposed and 4 cm to 6 cm of the medial muscle belly is excised to prepare the bone of the subscapularis fossa for fusion to the ribs (Fig. 4).

Next, the arm is positioned in 90 degrees of abduction and 90 degrees of external rotation to determine the ribs, which will be in contact with the scapula in this position (usually the second to seventh rib). The ribs are marked with electrocautery and the shoulder is placed in internal rotation with the hand resting over the lumbar spine. The medial subscapular muscle origin is elevated and resected to allow for bony apposition with the rib cage. The ribs are then exposed, elevating all the soft tissue over the dorsal ribs with electrocautery to allow for direct bony apposition to the ventral scapular body. Care is taken to protect the neurovascular bundle that runs along the deep distal aspect of each rib. The ribs are prepared for suture passage using rib periosteal elevators taking care to also remove parts of the intercostal muscles, which may cause interposition of soft tissue at the fusion site. Distally, the neurovascular bundle is bluntly dissected

TABLE 1. The Range of Motion for Each Patient for Preoperative and Postoperative

Patients mobility (degree)	1		2		3		4 (left)		4 (right)	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Forward elevation	90	130	100	140	90	140	100	130	90	130
Abduction	90	120	80	120	80	110	90	110	80	110
External rotation	80	90	80	80	80	80	90	90	80	80
Internal rotation	L4	L4	L4	L4	L5	L5	L4	L5	L4	L5

away from the rib to prevent entrapment between the tape fixation and the rib itself. The dorsal surfaces of the ribs and the subscapularis fossa of the scapula (from which the subscapularis muscle has been excised) are freshened with a motorized burr to create punctate bleeding (Figs. 5–6). Care must be taken not to burr the scapula excessively as the bone is very thin at this location and it is important to preserve some cortical bone to support plate and tape fixation. A blunt circular clamp (Fig. 7) is passed around each rib in direct contact with the bone from distal to proximal to avoid injury to the intercostal vascular-nervous bundle or iatrogenic pneumothorax. A tape (Strapflex, FH Ortho) is then passed around each of the prepared ribs (second to seventh rib depending on patient height and scapular size) (Fig. 8).

A standard 6-hole 3.5 mm plate (LC-DCP, DePuy Synthes) is contoured and placed in the infraspinatus fossa parallel to the medial border of the scapula just below the scapular spine and a standard 2-hole 3.5 mm plate is positioned in a similar manner in the supraspinatus fossa above the scapular spine. A 3.5 drill bit is then used to create holes through the scapula corresponding to the holes in the plate (Fig. 9). The arm is then placed back in the "superman position" (90 degrees of abduction and 90 degrees of external rotation) to position the scapula against the ribs in the appropriate position of fusion.

The tapes are then passed through the corresponding holes so that they compress the scapula and plate against the ribs when tightened (Fig. 10).

Cancellous bone graft from the ipsilateral posterior iliac crest is harvested and mixed with femoral head allograft. The bone graft is then inserted into the space between the scapula and the ribs, taking care to place as much as possible directly on the decorticated ribs. We do allow the bone graft to overlay the intercostal space as well to provide further osteoinductive effects to encourage a solid fusion mass (Fig. 11).

The tapes are then tightened with a custom-made tensioner (Strapflex, FH Ortho) to allow for even tensioning across all fixation points (Fig. 12). Tension is maintained by compressing a metallic crimp with custom-made pliers (Strapflex, FH Ortho). An additional bone graft is added on the medial border of the scapula and the ribs.

Once the tension on all ribs is satisfactory, the passive range of motion of the GH joint is performed to test the stability of the construct. Saline is then placed to cover the entire wound, and positive pressure is returned to the operative side lung. The wound is then inspected for bubbles, which would indicate a pneumothorax has been created, and which would require the placement of a chest tube.

Closure

The closure is performed first by suturing the medial edge of the supra and infraspinatus transosseous to the medial border of the scapula, thus covering the plates. (Fig. 13). The rhomboids are reinserted on their scapular insertion at the medial border of the scapula through bone tunnels and the remaining trapezius is fixed back in place. The closure is performed over a flat channel drain.

Postoperative Management (Early and Late Stage)

The patient is immobilized for 6 weeks in a standard shoulder sling.

A postoperative chest x-ray allows for documentation of the osteosynthesis material and the arthrodesis position as well as pneumothorax screening.

Pendulum exercises are initiated immediately. Passive range of motion of the shoulder is allowed after 3 to 4 weeks postoperatively.

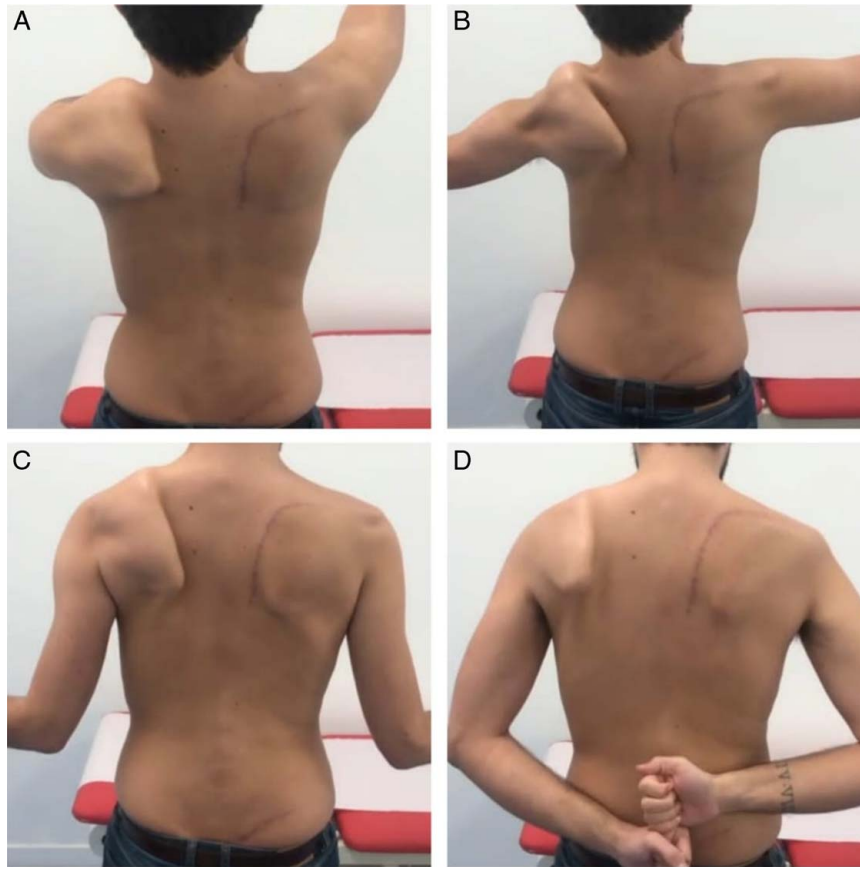

FIGURE 15. Difference in range of motion between the operated right side and the nonoperated left side at 6 months. Left: preoperative movements: (A) forward elevation 90 degrees; (B) abduction 80 degrees; (C) external rotation 80 degrees: (D) internal rotation L4. Right: preoperative movements: (A) forward elevation 130 degrees; (B) abduction 110 degrees; (C) external rotation 80 degrees; (D) internal rotation L5.

Active shoulder motion is initiated after 6 weeks. A computed tomography scan is performed at 6 months postoperatively (Fig. 14) to assess the healing of the arthrodesis before physical activity is authorized.

POTENTIAL COMPLICATIONS

Pulmonary

Pneumothorax is a known complication, which is often minor and reversible without any associated invasive procedure. Large pneumothoraces should be managed with chest tube placement and serial chest radiographs.[14]

Pulmonary atelectasis[14] or pulmonary embolism[15] may also be observed less commonly.

Nonunion

Nonunion is the most common complication and is accountable for 50% of reoperations.[15] Nonunion is caused by high shear and torsional forces on the shoulder girdle that occurs with shoulder motion.

This complication is more frequent when surgeons use weaker one-third tubular plates,[12] allograft instead of autograft,[14] and cables instead of large diameter wires.[15] The use of nonmetallic cerclage may theoretically lower the complication rate as Peeters et al,[7] recently demonstrated in a review paper that nonmetallic cerclages can withstand greater loads to failure compared with metallic cerclages.

Other Complications

Other potential complications include: rib fracture,[6] scapular fracture,[6] intercostal neuralgia,[6] brachial plexus injury,[6] and infection.[15]

EXPECTED OUTCOMES

We operated on 5 shoulders in 4 patients with this technique. The follow-up scans performed at 6 months postoperatively showed healing of the arthrodesis in all patients.

Shoulder Elevation

All patients gained active motion in active forward elevation (+40 degrees on average) and abduction (+25 degrees on average) (Table 1). Internal and external rotations were unchanged (Fig. 15).

The fundamental goal of STA is to improve shoulder elevation and, therefore, quality of life. It is accepted that the ST joint is responsible for one-third of the shoulder range of motion. Although shoulder motion is a combination of ST and GH motions throughout its range, it is practical to assume that the GH joint can only generate an elevation of 120 degrees, when the scapula is fixed.

CONCLUSION

STA is, therefore, the surgical approach of choice for the treatment of scapula alata in facio-scapulo-humeral muscular

dystrophy. It is not risk-free, but it brings amplitude gain, indolence, and esthetic benefits to patients.

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