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CLINICAL COMMENTARY

REHABILITATION FOLLOWING STERNOCLAVICULAR JOINT RECONSTRUCTION FOR PERSISTENT INSTABILITY

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ABSTRACT

Background: Sternoclavicular (SC) joint instability is a rare injury, but one with profound implications given its proximity to vital structures and function as the only true articulation between the upper extremity and axial skeleton. The majority of SC joint instability can be treated non-operatively; however, there is a role for reconstruction in the presence of instability that results in pain and dysfunction that is refractory to conservative management or deformity resulting in functional impairment. Given the lack of inherent osseous stability at the sternoclavicular joint and the role of ligaments as primary stabilizers, surgical intervention with emphasis on ligament reconstruction may be recommended. Safe and effective rehabilitation is conducted through phase progression, with avoidance of premature stress to the healing soft tissue graft. The purpose of this clinical commentary is to provide the senior author's rehabilitation protocol, which utilizes the available scientific literature to inform phase content and progression.

Key words: clavicle, reconstruction, rehabilitation, return to sport, sternoclavicular joint

Level of Evidence: 5

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INTRODUCTION

Sternoclavicular (SC) joint injury is rare and comprises 0.5% to 3% of shoulder girdle injuries.[1-3] Given its proximity to vital neurovascular structures immediately posterior and the SC joint's function as the only true articulation between the upper extremity and axial skeleton, the potential for serious complication and long-term disability exists if the injury is missed. In the acute setting, posterior dislocations of the SC joint are potentially severe and occasionally life-threatening.[4,5] Management of sternoclavicular joint pathology mandates a working knowledge of regional anatomy, particularly the soft tissue stabilizers, for appropriate management and rehabilitation. The purpose of this clinical commentary is to provide the senior author's rehabilitation protocol, which utilizes the available scientific literature to inform phase content and progression.

ANATOMY

The sternoclavicular joint is diarthrodial in nature, characterized by an articulation of the medial clavicle with the manubrium of the sternum (Figure 1). The articular surface area of the clavicle is much larger than that of the sternum and both ends are covered with hyaline cartilage.[6] Lee et al [7] performed a detailed quantitative anatomical description of the sternoclavicular joint. Approximately 67% of the medial clavicle contains articular cartilage and even less articulates with the angle of the sternum[7]. The intraarticular disk, a thick and fibrous structure, is interposed between the surfaces of the clavicle and the sternum. Despite the saddle-type joint created by the bulbous, convex medial clavicle and the clavicular notch of the sternum, there is very little osseous restraint given the shallow socket and often incongruent articulation.

Given the inherent incongruity of the joint, the sternoclavicular joint relies primarily on a network of ligamentous attachments for strength and stability. The costoclavicular ligament is the largest ligament of the sternoclavicular joint with a reported average length of 1.3 cm and a maximum width of 1.9 cm.[7,8] The costoclavicular ligament extends from the inferior surface of the medial end of the clavicle, the rhomboid fossa, to provide a point of attachment to the first rib adjacent to its synchondral attachment to the sternum.[9] The interclavicular ligament connects the superior capsular ligaments of the sternum with the superomedial borders of the clavicles. This ligament serves as a restraint against superior translation of the clavicle during shoulder adduction and extension.[10] The costoclavicular and interclavicular ligaments are thought to be auxiliary stabilizers of the SC joint with little effect on anterior or posterior translation.[11]

The capsular ligament extends from the anterosuperior to the posterior aspect of the joint and represents a thickening of the joint capsule. The posterior sternoclavicular ligament and the costoclavicular ligaments are the strongest.[11,12] A post-mortem anatomic study by Bearn et al[12] suggests that the capsular ligament is the most important ligament for maintaining

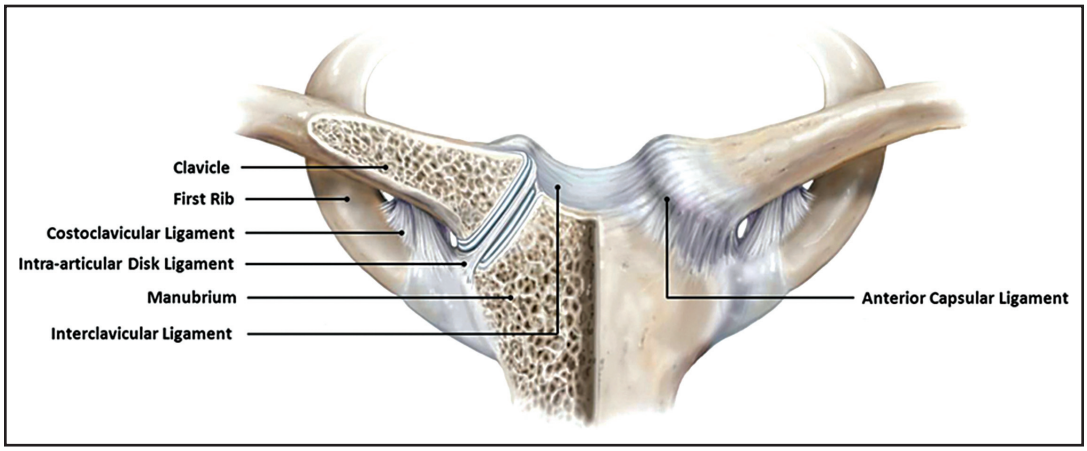

Figure 1. *Native anatomy of the sternoclavicular joint. Used with permission of SAGE Publications, from Martetschlager F, Warth RJ, Millett PJ. Instability and degenerative arthritis of the sternoclavicular joint: a current concepts review. Am J Sports Med. 2014;42(4):999-1007, doi: http://journals.sagepub.com/doi/abs/10.1177/0363546513498990.*

the position of the clavicle. In this study, sectioning of the capsular ligament alone resulted in inferior displacement of the clavicle, while division of the other ligaments did not influence clavicle position. Another study demonstrated that the posterior capsule is a major stabilizer against both anterior and posterior translation while the anterior capsule acts as a secondary stabilizer against anterior translation alone.[11] The subclavius muscle has been proposed as an important stabilizer of the sternoclavicular joint.[12,13] These observations suggest that preservation of the subclavius muscle warrants special attention during surgery of the SC joint as it contributes to additional stability in the presence of ligamentous injury.

Biomechanics

The lack of osseous constraint contributes to a free range of motion of the SC joint through all planes, including rotation. Motion through the SC joint has been described as 30-35 degrees of elevation with a combined range of 35 degrees anterior and posterior translation.[14] The SC joint acts as the hinge and the clavicle as a lever for the shoulder girdle. Accordingly, patients with a short clavicle will experience significantly more torque across the SC joint.[15] These combined movements allow 45-50 degrees of rotation along the long axis.[16-18] It is important to remember that all forces placed through the joints of the shoulder girdle, especially during above head activity, are transferred proximally through the SC joint. The clavicle elevates approximately four degrees for every 10 degrees of arm forward flexion.[19]

DIAGNOSIS

Patient Presentation

Ligamentous injury to the SC joint may occur secondary to direct impact to the anteromedial clavicle or from an indirect force to the ipsilateral shoulder or arm. The patient with acute injury of the SC joint often has severe pain localized to the sternoclavicular joint, increased with any movement of the arm. Posterior dislocation of the SCJ may be caused by a direct impact to the anteromedial aspect of the clavicle or through an indirect force to the posterolateral shoulder, while anterior dislocation is usually due to a lateral compressive force to the shoulder girdle.

Upon examination, the patient commonly supports the injured upper extremity in a position of adduction across the trunk, supported with the uninjured arm. The affected upper extremity may appear shortened compared to the contralateral extremity and thrust forward, and the patient commonly experiences increased discomfort when lying in the supine position. With anterior dislocation, the medial end of the clavicle may be visibly displaced and more pronounced on the injured side. With posterior displacement, the usual fullness of the anteromedial chest may be less pronounced. In patients with partially preserved function after discloation, positions of discomfort may include the cocking position of throwing, particularly with anterior instability. Pain secondary to posterior instability of the SC joint may be less easily reproduced and the deformity may be obscured by swelling. The index of suspicion for the treating clinician to recognize an anterior or posterior SC joint dislocation must be high, as the only presenting symptom may be subtle pain in the area of the SC joint, mild shortness of breath, hoarseness, or tightness in the throat; however these may portend more significant issues including tracheal or esophageal compression,[20,21] pneumothorax,[22] compression of the great vessels, and thoracic outlet syndrome.[23] On rare occasions, a posterior SC joint dislocation may result in more severe dyspenia, dysphagia, paresthesias and/or neurologic deficits of the affected extremity compared to an anterior SC joint dislocation. [23]

The osseus development of the medial clavicle must be considered when evaluating injuries to the SC joint. The clavicle is the first long bone in the body to ossify (fifth intrauterine week). The epiphysis at the medial end of the clavicle is the last of the long bones to ossify (18^{th} -21^{st} year) and does not fuse with the shaft of the clavicle until the 23^{rd} to 25^{th} years.[24,25] Other authors suggest an even later age of bony union.[26] Accordingly, the possibility of dislocation through the medial clavicle physis should be considered in the evaluation of younger patients.

IMAGING

Traditional anteroposterior (AP) or posteroanterior (PA) radiographs of the chest and sternoclavicular joints may suggest injury, but are often hard to interpret given the overlay of the clavicle, sternum, and the first rib. CT is the preferred imaging modality to assess problems of the SC joint (Figure 2). CT is

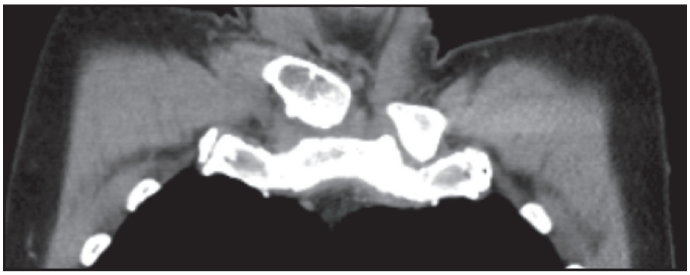

Figure 2. *CT Scan of the Sternoclavicular Joint*
This coronal slice of a CT scan demonstrates an anterior dislocation of the right sternoclaviular joint. Used with permission of SAGE Publications, from Martetschlager F, Warth RJ, Millett PJ. Instability and degenerative arthritis of the sternoclavicular joint: a current concepts review. Am J Sports Med. 2014;42(4):999-1007, doi: http://journals.sagepub.com/doi/abs/10.1177/0363546513498990.

most sensitive and specific for distinguishing injuries to the joint from injuries of the medial clavicle as well as revealing instability manifesting in subtle subluxation of the joint.[27,28] Given the incongruent nature of the osseous anatomy of the SC joint, it is essential to obtain CT imaging through both SC joints and the medial half of both clavicles for comparison. This imaging can be combined with dynamic stress testing to further describe sternoclavicular joint disease.[29]

MRI may be useful in the diagnosis of injury to the soft tissues surrounding the joint as well as injury to the intraarticular disc. Given the relatively late ossification of the medial clavicle and the potential for physeal injury in patients under 30 years of age, MRI may also play a role in determining if the epiphysis has been displaced with the clavicle or is still adjacent to the sternum following trauma. Furthermore, the use of MRI to limit radiation exposure in children with suspected sternoclavicular joint injury has been advocated.[30]

SURGICAL MANAGEMENT

Numerous surgical techniques have been used to treat sternoclavicular joint instability. The senior author prefers reconstruction using hamstring tendon graft in a figure-of-eight fashion since this technique has been shown to be biomechanically superior to other methods when comparing graft integrity, load to failure, and translation of the medial clavicle.[31,32] Martetschläger et al. has previously described this method in detail.[32] After confirming

Figure 3. *Sternoclavicular Joint Reconstruction*
The graft is shuttled through passing sutures in the tunnels in a figure-of-eight fashion and secured with non-absorbable, high strength sutures through the tendon knot.

the hypermobility of the medial clavicle during the examination under anesthesia, the SC joint is exposed along with the medial third of the clavicle. A medial clavicle excision is performed if the SC joint is arthritic.[33,34] The hamstring autograft (usually gracilis tendon) is harvested using standard technique, whip-stitched at both ends with non-absorbable, high strength suture and measured to determine the appropriate drill tunnel diameter. Following careful dissection of the retrosternal space and placement of a malleable retractor beneath the medial clavicle and sternum to protect mediastinal structures, two bone tunnels are drilled each in medial clavicle and sternum. The graft is shuttled through passing sutures in the tunnels in a figure-of-eight fashion and secured with non-absorbable, high strength sutures through the tendon knot (Figure 3). A recent study by Petri et

al evaluated 21 sternoclavicular joint reconstructions using the above described technique after a mean of two years and showed significant improvement in clinical outcomes, such as range of motion and strength, with high patient satisfaction and no intra- or postoperative complications.[35]

REHABILITATION

There is a lack of well-examined research protocols following SC joint stabilization available in the literature. The post-operative rehabilitation protocol for sternoclavicular joint reconstruction employed at the senior author's institution emphasizes avoidance of scapular protraction and retraction (Appendix 1).[35] Progression of the protocol should be performed under careful supervision of the rehabilitation team, with attention to achieving and maintaining proper scapulothoracic mechanics. Persistent or recurrent pain and/or swelling at the surgical site indicate inappropriate phase progression.

Early Recovery (Weeks 0 to 6)

A sling will be worn for a minimum of six weeks. An active compression cold therapy device, for example the Game Ready® system (Game Ready®, Concord, Georgia U.S.A.), is utilized. The proposed benefits of cryotherapy include edema control, local vasoconstriction and pain reduction.[36-38] Multiple cryotherapy modalities have been shown to be effective for short-term pain reduction.[38] The senior author prefers active compression cold therapy for 30 minutes, followed by 60 minutes off to avoid skin irritation. The on-off cycle is repeated throughout the day while the patient is awake. After reconstruction of the sternoclavicular joint, patients must avoid scapular protraction and retraction, as well as scapular depression and elevation during the initial six weeks.

Lifting or carrying objects with the affected extremity is not permitted, although range of motion of the elbow, wrist, and hand should be initiated immediately to avoid stiffness in distal joints. Cervical range of motion exercises are also encouraged to avoid stiffness and muscular spasm. Glenohumeral joint motion will begin at six-weeks post-operative. While there is a deficiency of data regarding glenohumeral stiffness after sternoclavicular joint reconstruction, one of the most reported complications is stiffness following shoulder immobilization after rotator cuff repair with an incidence of 4.9% to 32.7%. [39-41] Post-operative stiffness following SC joint stabilization is likely multi-factorial and may be secondary to post-operative immobilization, the tear type, presence of capsular adhesions or contractures, as well as patient co-morbidities. Given the duration of immobilization, the authors emphasize passive glenohumeral range of motion.

Isolated hamstrings activation is not permitted for four weeks after surgery to protect and aid in the recovery of the autograft site. Implementation of a walking program is encouraged to both aid in deep venous thromboembolism prevention as well as initiate functional strength recovery in the lower extremities.

Progression of Rehabilitation Phases

Weeks 6 to 12

Full passive and active-assisted range of motion (AAROM) exercises begin at approximately six weeks (Appendix 1), with active range of motion commencing at eight weeks. Only passive and AAROM are allowed until eight-weeks post-operative. The goal of this second phase is to restore glenohumeral range of motion and promote proper scapulothoracic motion. A contraindication to progression of the protocol includes persistent or recurrent pain and/or swelling. Correction of underlying scapulothoracic dyskinesia will allow normal biomechanics of the shoulder girdle during upper extremity elevation. Aqua therapy, if able, should be incorporated for gentle AAROM. Examples of independent stretches are also provided (Appendix 1, Figures 4a, 4b).

Active ROM begins at 8 weeks after surgery and focuses on strengthening of the shoulder and scapular stabilizers (Figures 5a, 5b). Light isometrics, including internal and extrernal rotation, elbow flexion and extension are also initiated at the eight-week mark. Clinicians should include both open and closed kinetic chain exercises (Figure 6) beginning at this time as well, as electromyographic activity of shoulder girdle musculature demonstrates significant differences when activated in exercises are performed in an open versus closed kinetic chain conditions.[42,43]

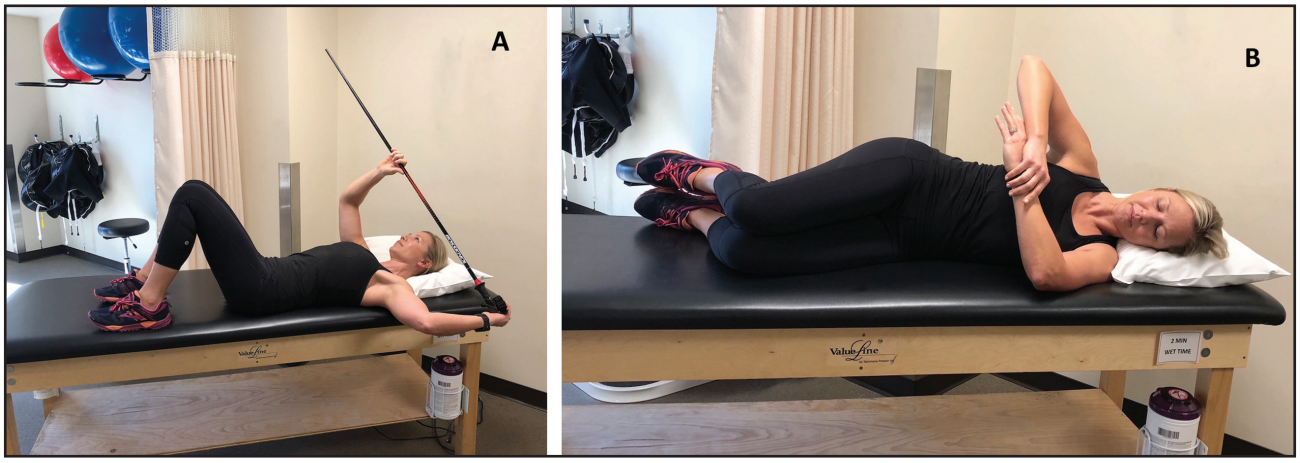

Figure 4a and 4b. *External Rotation Stretch (4a) and Sleeper Stretch (4b)*
Controlled, gentle external rotation stretch with assistance via a ski pole (4a) and modified sleeper stretch to stretch the posterior capsule (4b).

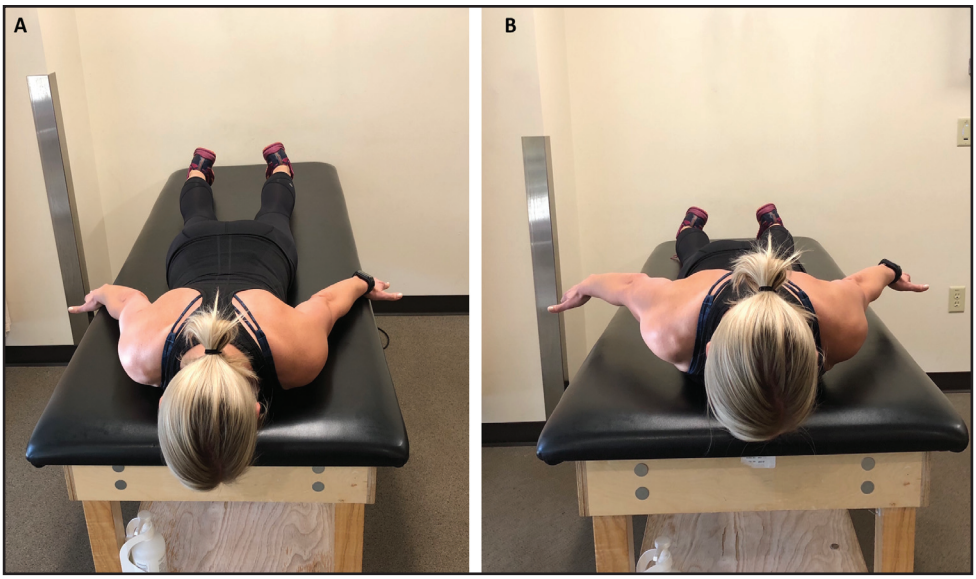

Figure 5a and 5b. *Prone Scapular Stabilization*
Prone strengthening of the scapular stabilizers via shoulder and torso extension.

Weeks 13 to 20

The focus of this phase of rehabilitation is to increase the strength of the shoulder musculature with emphasis on proper scapulothoracic motion. Progression of weight and resistance level of the existing exercises is the focus of weeks 13 to 20, including the incorporation of functional lower extremity exercises. Patients may progress to full upper extremity weight bearing activities of daily living without restriction.

Return to Sport/Activity

Functional movement patterns that incorporate the upper and lower body and core are integrated in the final stages of rehabilitation. For patients who wish to return to sport, sport-specific drills may be designed by the supervising physical therapist. These drills are created with the goal of gradual transition to sport specific movements in order to avoid excessive stress at the sternoclavicular joint. Criteria for return to sports participation include no pain with sport-specific exercises, full and painless range of motion, and strength within 10% of the contralateral upper extremity. While multiple evaluation tests of the upper limb are available for the clinician to ascertain readiness of an individual to return to sport, there are no established tests focused on

Figure 6. *Proprioception*
An example of open kinetic chain proprioception while emphasizing scapular stabilization.

return to sport following sternoclavicular joint reconstruction. It is the duty of the rehabilitation staff to establish return to sport readiness.

SUMMARY

Many sternoclavicular joint injuries are managed non-operatively. In the cohort of patients who suffer chronic, painful instability, however, reconstruction of the sternoclavicular joint may be beneficial for pain reduction and improving function. Successful return to full activities requires protection of the reconstruction during the early phase of rehabilitation followed by supervised progression through a structured post-operative rehabilitation protocol. The senior author's proposed rehabilitation protocol utilizes the available scientific literature to inform phase content and progression in order to enable safe and effective post-operative rehabilitation.

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Appendix 1. *Sternoclavicular Joint Reconstruction Rehabilitation Protocol.*

Phase I	
0 to 6 weeks after surgery	
	Precautions: • No lifting or carrying objects • No scapular retraction or protraction • No scapular depression or elevation • No passive range of motion of the glenohumeral joint • No isolated hamstrings activation (donor graft site) x 4 weeks • Weight bearing as tolerated in bilateral lower extremities
	Goals: • Maintain motion at elbow/wrist/hand • Protect reconstruction/graft site
	Therapeutic Exercises: • Cervical range of motion • Elbow/wrist/hand range of motion • Walking program (DVT prevention)
	Activities of Daily Living (ADL): • Ok to work on computer with supported arm • Elbow motion okay for eating/drinking • Unaffected arm for primary ADL use
	Criterion for Progression: • Absence of persistent or recurrent pain and/or swelling
*DVT: deep vein thrombosis	
Phase II	
6 to 12 weeks after surgery	
	Precautions: • No lifting or carrying objects > 5 lbs until 9 weeks post-operative • No overhead activities (except ROM) until week 8 • No active ROM until 8 weeks
	Goals: • Restore passive and active glenohumeral range of motion • Promote proper scapulothoracic motion

	Therapeutic Exercises:
	• Scapular retraction-depression
	• Aqua therapy for gentle AAROM
	• Passive ROM on glenohumeral joint
	• Active Assist ROM:
	  ○ Internal and external rotation
	  ○ Forward elevation and scaption
	• Light isometrics:
	  ○ Internal and external rotation
	  ○ Biceps and triceps
	  ○ Hamstrings isometrics

Appendix 1. *Sternoclavicular Joint Reconstruction Rehabilitation Protocol. (continued)*

	• Active ROM **(begin at 8 weeks),** examples included below**
	  ○ Sidelying external rotation
	  ○ Forward elevation and scaption
	  ○ Prone horizontal abduction with external rotation
	  ○ Prone lower trapezius to 60 degrees
	  ○ Prone extensions with external rotation
	  ○ Open chain proprioception

	• Low load prolonged stretching
	  ○ Door jam/pectoralis stretch
	  ○ Sleeper stretch
	  ○ 90/90 external rotation stretch
	  ○ Hamstrings doorway stretch

	Activities of Daily Living (ADL): • Ok to work on computer with supported arm • Overhead activities may begin at week **8** • Dressing/Bathing tasks may be performed with affected arm
	Criterion for Progression • Full, painless passive and active range of motion
*ROM: range of motion **Specific exercise examples have been outlined, however, therapists may choose to modify these exercises while maintaining the particular exercise goal.	
Phase III	
13 to 20 weeks after surgery	
	Precautions: • None
	Goals: • Maintain proper scapulothoracic motion • Increase strength of shoulder and peri-scapular musculature

	Therapeutic Exercises:
	• Active ROM → **Progress to with weight/resistance,** examples included below*
	  ○ Sidelying external rotation
	  ○ Forward elevation and scaption
	  ○ Prone horizontal abduction with external rotation
	  ○ Prone lower trapezius to 60 degrees
	  ○ Prone extensions with external rotation
	  ○ Open chain proprioception
	  ○ Functional lower extremity strengthening

Appendix 1. *Sternoclavicular Joint Reconstruction Rehabilitation Protocol. (continued)*

	• Low load prolonged stretching
	  ○ Doorway_pectoralis stretch
	  ○ Cross arm stretch
	  ○ Sleeper stretch
	  ○ 90/90 external rotation stretch
	  ○ Hamstrings doorway stretch

	Activities of Daily Living (ADL): • Full ADLs without restriction
	Criterion for Progression • Proper scapulothoracic mechanics with overhead activities
	• 5/5 strength upon testing of the rotator cuff, deltoid, trapezius (upper/middle/lower), biceps and triceps musculature
Phase IV	
20+ weeks after surgery	
	Precautions: • None
	Goals: • Maintain proper scapulothoracic motion • Return to preferred sport/activities

	Therapeutic Exercises:
	• Maintenance strengthening program (2x/week)
	  ○ Sidelying external rotation
	  ○ Forward elevation and scaption
	  ○ Prone horizontal abduction with external rotation
	  ○ Prone lower trapezius to 60 degrees
	  ○ Prone extensions with external rotation
	  ○ Open chain proprioception
	  ○ Functional lower extremity strengthening
	• Maintenance stretching program (5-7x/week)
	  ○ Door jam/pectoralis stretch
	  ○ Cross arm stretch
	  ○ Sleeper stretch
	  ○ 90/90 external rotation stretch
	• Sport-specific exercises

	Activities of Daily Living (ADL): • Full ADLs without restriction
	Criterion for Progression • Return to sport based on ability of patient to perform sport-specific exercises pain-free and with proper mechanics.
*Specific exercise examples have been outlined, however, therapists may choose to modify these exercises while maintaining the particular exercise goal.	