The LACS Procedure for Multidirectional Instability of the Shoulder

An Honors Thesis (HONRS 499)

by

Karey L. Claywell

Dr. Thomas Weidner

Ball State University

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Purpose of Thesis

Lasers are becoming more and more useful in the field of orthopedic medicine. This thesis paper deals with a surgical procedure known as the Laser-Assisted Capsular Shrinkage, or LACS procedure for multidirectional instability of the shoulder. A complete discussion of the anatomy of the shoulder, an injury evaluation of the shoulder, the history and development of lasers, and a detailed case study of an intercollegiate athlete with shoulder instability are included in this thesis. After reading this paper, you will have a full understanding of the shoulder anatomy and evaluation, as well as the use of lasers to shrink collagen tissue and to improve stability in the shoulder joint.
The shoulder is a very complicated and diverse joint of the body. It is comprised of many muscles, bones, ligaments, and nerves, as well as other supportive structures. The purpose of this paper is to investigate the shoulder and discuss a new surgical procedure, the Laser Assisted Capsular Shrinkage, or LACS procedure on an athlete with multidirectional instability. A complete anatomical review of the shoulder will be outlined, as well as a complete evaluation, the history of lasers and their use in orthopedics, a discussion of shoulder instability, and a case study of an athlete who had the LACS procedure done to prevent instability.

ANATOMY

The shoulder joint is a very complicated ball-and-socket joint that is very similar to the hip joint. However, unlike the hip, the socket ("glenoid") in the shoulder is very shallow while the humeral head is relatively large in proportion. The hip joint is a very deep acetabular socket and allows a great amount of stability but a lot less mobility. The shoulder is very unstable from a bony standpoint, and functional stability is almost completely dependent upon the synergism of the musculotendinous units.¹

Bony:

The bony structures of the shoulder include the humerus, scapula (shoulder blade), and clavicle. The sternum is not directly related to the shoulder, but indirectly related as it forms an articulation with the clavicle. The clavicle, or collar bone, is a long, slender "S" shaped bone that supports the anterior portion of the shoulder. This bone extends from the sternum to the tip of the shoulder where it joins the acromion process of the scapula. The lateral third of the clavicle is concave and primarily flat-shaped while the medial two-thirds is convex and primarily circular in shape. This change in shape and contour presents a structural weakness in the clavicle and increases the risk of injury to this area. The clavicle is stabilized by three muscles, the
deltoid, trapezius, and subclavian, which all attach to it and help maintain its position. The scapula, or shoulder blade, is a flat, triangular-shaped bone that lies on the posterior thoracic wall. It primarily serves as an attachment site for many muscles, including the rotator cuff muscles. The main articulation of the scapula is with the humeral head at the glenohumeral joint. The scapula has three prominent projections: the spine, the acromion, and the coracoid process.

The humerus is the long bone of the upper arm that articulates at the proximal head with the glenoid fossa to form the glenohumeral joint and at its distal end to the elbow joint. The head of the humerus is spherical and articulates with the shallow glenoid fossa of the scapula (see glenoid fossa in Appendix 1). The anatomical neck of the humerus serves as an attachment for the articular capsule of the glenohumeral joint. The humerus also has a greater and lesser tuberosity which are located adjacent and immediately inferior to the humeral head. These two tuberosities form a deep groove known as the bicipital groove, which retains the long tendon of the biceps brachii muscle. These three bones together form the four basic articulations, or joints, of the shoulder which are the glenohumeral (GH) joint, the acromioclavicular (AC) joint, the scapulothoracic (ST) joint, and the sternoclavicular (SC) joint.

The coracoclavicular joint is not a true joint articulation but is sometimes categorized as one. The glenohumeral joint is maintained by both a passive and active mechanism, the passive mechanism relating to the glenoid labrum and capsular ligaments and the active mechanism relating to the deltoid and rotator cuff muscles. The glenoid labrum is a fibro-cartilaginous rim which acts to deepen the glenoid cavity and offer more stability. The labrum (see labrum in Appendix 2) deepens the glenoid fossa by 50% and serves as the attachment site for ligaments.
The superior attachment of the labrum is loose, and the inferior attachment is firm and unmoving.\textsuperscript{5} The glenoid’s articular surface is pear shaped, with an inferior half 20\% larger than the superior half. The articular cartilage of the glenoid fossa is thickest in the periphery and thinnest in the center.\textsuperscript{5} Only 25\% to 30\% of the humeral head is covered by the glenoid in any position of rotation.\textsuperscript{4} This joint has been compared to a golf ball sitting on a tee. The capsule that surrounds the entire joint structure is further stabilized by the musculotendinous bundle of the rotator cuff muscles. The capsule contains discrete capsular ligaments that are important in understanding shoulder instability. The capsule is attached medially to the margin of the glenoid fossa and laterally to the circumference of the anatomical neck, descending about 1.3 cm onto the shaft of the humerus.\textsuperscript{7} It is thin and large, allowing 2 to 3 mm of distraction of the head from the glenoid.\textsuperscript{8} The joint capsule is composed of multilayered collagen fiber bundles of different strengths and orientations.\textsuperscript{7} The anterioinferior capsule is the thickest and strongest portion of the capsule due to the densely organized collagen fibers.\textsuperscript{7} The orientation of collagen fibers provides and absorbs tension, which leads to a centering or stabilizing of the joint.\textsuperscript{5} There are three main ligaments in the anterior (front) part of the shoulder, which help prevent subluxation or dislocation. These ligaments are known as the “superior glenohumeral ligament (SGHL), the middle glenohumeral ligament (MGHL), and the inferior glenohumeral ligament complex (IGHLC).\textsuperscript{9} The acromioclavicular joint is a gliding articulation formed by the junction of the clavicle and the acromion process off of the scapula (see acromion above in Appendix 1). This is a rather weak junction and is surrounded by a thin, fibrous capsule. The two articulating surfaces of the joint are separated by a fibro-cartilaginous disk. Joint stability is maintained by the ligaments rather
than the strength of the interlocking joint surfaces. The primary ligaments of the joint are the acromioclavicular and coracoclavicular ligaments (see ligaments on Appendix 3). The coracoclavicular ligament branches into two distinct portions, the coronoid and the trapezoid. The scapulothoracic joint is not a true joint; however, the movement of the scapula on the wall of the thoracic cage is critical to shoulder joint motion. Contraction of the scapular muscles, which attach the scapula to the axial skeleton, is critical in stabilizing the scapula, thus providing a base on which a highly mobile joint can function. Finally, the sternoclavicular joint is the junction of the clavicle and the sternum. This saddle joint is the only direct connection between the upper extremity and the trunk. Thus, this complete structure is called the clavicular strut and functions much like the front suspension of a car. A fibro-cartilaginous disk separates the two articulating surfaces and functions as a shock absorber against the medial forces and also helps prevent any displacement upward. This disk allows the clavicle to move up and down, forward and backward, in combination, and in rotation. Therefore, the clavicle moves on the disk and the disk moves separately on the sternum.

**Soft Tissues:**

The ligaments of the shoulder complex differ at each articulation. The glenohumeral articulation includes the superior, middle, and inferior glenohumeral ligaments as well as the tough coracohumeral ligament, which all strongly reinforce the loose articular capsule of the joint. The glenohumeral ligaments appear to produce a major restraint in shoulder flexion, extension, and rotation. The ligaments of the acromioclavicular joint consist of the anterior, posterior, superior, and inferior portions (see ligaments in Appendix 3). The coracoclavicular ligament, as previously mentioned, helps maintain the position of the clavicle relative to the acromion. The acromioclavicular ligament along with the acromion forms the coracoacromial
arch. Finally, the sternoclavicular ligaments are very strong because of the support they must provide to the extremely weak joint. These ligaments tend to pull the clavicle downward and toward the sternum in effect anchoring it. The main ligaments of this articulation include: the anterior sternoclavicular, sternoclavicular, interclavicular, and costoclavicular ligaments. These ligaments play very important roles in the attachments to the sternum and clavicle. Without these connections, the joints would not be able to function properly and effectively.

**Musculature:**

The muscles that cross glenohumeral joint produce dynamic motion and establish stability to compensate for a bony and ligamentous arrangement that allows for a great deal of mobility. In addition, the muscles that attach to the shoulder blade (scapula) are important to shoulder instability. The shoulder socket is actually part of the shoulder blade and the muscles which attach to the shoulder blade provide a stable pedestal for arm motion and stability. The movements of the glenohumeral joint include flexion, extension, abduction, adduction, and rotation. There are two groups of muscles that act on the glenohumeral joint. The first group of muscles originate on the axial skeleton and attach to the humerus and the second group originates on the scapula and attach to the humerus. The first group consists of the latissimus dorsi and the pectoralis major and the second group consists of the deltoid, the teres major, the coracobrachialis, the subscapularis, the supraspinatus, the infraspinatus, and the teres minor. The last four muscles are known as the rotator cuff muscles (or SITS). The tendons of these four muscles adhere to the articular capsule and serve as reinforcing structures. A third group of
muscles attach the scapula to the axial skeleton and includes the levator scapula, the trapezius, the serratus anterior and posterior, the rhomboids. The biceps and triceps, and the pectoralis minor are also involved in the shoulder complex. The table below shows the major muscles of the shoulder complex followed by their primary action.

**Appendix 4.**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latissimus dorsi</td>
<td>Adduction, extension, and internal rotation</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>Adduction, flexion, and internal rotation</td>
</tr>
<tr>
<td>Deltoid</td>
<td>Anterior fibers: flexion, internal rotation, &amp; abduction</td>
</tr>
<tr>
<td></td>
<td>Posterior fibers: extension, external rotation, &amp; abduction</td>
</tr>
<tr>
<td></td>
<td>Middle fibers: abduction and flexion</td>
</tr>
<tr>
<td>Teres major</td>
<td>Extension, internal rotation of scapula, and adduction</td>
</tr>
<tr>
<td>Coracobrachialis</td>
<td>Flexion and adduction</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Internal rotation and stabilizes humeral head</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>Abduction and stabilizes humeral head</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>External rotation and stabilizes humeral head</td>
</tr>
<tr>
<td>Teres minor</td>
<td>External rotation, extension, and stabilizes humeral head</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Elevation and downward rotation</td>
</tr>
<tr>
<td>Trapezius</td>
<td>Elevation, depression, and retraction of scapula</td>
</tr>
<tr>
<td>Serratus anterior and posterior</td>
<td>Depression, protraction, upward rotation, and elevation</td>
</tr>
<tr>
<td>Rhomboid major and minor</td>
<td>Elevation, depression, and retraction of scapula</td>
</tr>
<tr>
<td>Biceps</td>
<td>Flexion and abduction of arm</td>
</tr>
<tr>
<td>Triceps</td>
<td>Extension and adduction of arm</td>
</tr>
<tr>
<td>Pectoralis minor</td>
<td>Upward rotation and forward tilting</td>
</tr>
</tbody>
</table>

**Range of Motion:**

The combination of these muscles and joints allow for maximal rotation with minimal rotational stress on the proximal fixation point. The muscles of the shoulder girdle are the largest and strongest muscles in the body. However, they can easily be disrupted because of their complexity. All of these muscles act to stabilize the shoulder complex as well as provide movement in several different motions, which include the following:

**Appendix 5.**

- **Flexion:** 170-180 degrees
- **Extension:** 50-60 degrees

6
Abduction: 170-180 degrees
Adduction: 40-50 degrees
External rotation: 80-90 degrees
Internal rotation: 90-100 degrees

Scapulohumeral rhythm describes the movement of the scapula relative to the movement of the humerus throughout a full range of abduction. As the humerus elevates to 30 degrees there is no movement of the scapula; however, from 30 to 90 degrees, the scapula abducts and upwardly rotates 1 degree for every 2 degrees of humeral elevation. From 90 degrees to full abduction, the scapula abducts and upwardly rotates 1 degree for each 1 degree of humeral elevation. In addition, the clavicle will move at both the sternoclavicular and acromioclavicular joints to compensate for the movements of the humerus and the scapula.

Another structure located within the shoulder complex is bursa. Several of these structures are located within the shoulder joint and the most important one is the subacromial bursa. It is located between the coracoacromial arch and the glenohumeral capsule. These bursae are easily subjected to trauma and injury when another structure puts pressure on the bursae.

Neurological:

Finally, the neurological anatomy of the shoulder must be included to gain a complete understanding of the entire shoulder. The shoulder involves the cervical nerve roots and the brachial plexus, which contribute to the complexity of the shoulder joint. The brachial plexus supplies the upper portion of the shoulder, deltoid, and arm and is formed by the C5 through C8 and T1 nerve roots. There are five segmental areas of the brachial plexus and these include: roots, trunks, divisions, cords, and branches. These five segments give rise to the nerve supply to the arm and shoulder. The nerves branching off of the brachial plexus include: the deep subscapular, suprascapular, lateral pectoral, musculocutaneous, axillary, radial, median, ulnar, subscapular, medial pectoral, medial brachial cutaneous, medial antebrachial cutaneous, long
thoracic, and thoracodorsal nerves. Below (in Appendix 6) you will see the nerve root levels (C5-T1), as well as sensory, motor, and reflex testing for the shoulder.

Appendix 6.

<table>
<thead>
<tr>
<th>Nerve Root Level</th>
<th>Sensory Testing</th>
<th>Motor Testing</th>
<th>Reflex Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Axillary nerve</td>
<td>Axillary nerve</td>
<td>Biceps brachii</td>
</tr>
<tr>
<td>C6</td>
<td>Musculocutaneous nerve</td>
<td>Musculocutaneous nerve</td>
<td>Brachioradialis</td>
</tr>
<tr>
<td>C7</td>
<td>Radial nerve</td>
<td>Radial nerve</td>
<td>Triceps brachii</td>
</tr>
<tr>
<td>C8</td>
<td>Ulnar nerve (mixed)</td>
<td>Median &amp; palmer interosseous nerve</td>
<td>None</td>
</tr>
<tr>
<td>T1</td>
<td>Medial brachial</td>
<td>Deep branch of ulnar nerve</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>cutaneous nerve</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The dermatomes, which is an area of skin innervated by a single nerve root, are:

Appendix 7

- C4 – trapezius
- C5 – lateral are (axillary nerve)
- C6 – lateral forearm, thumb, index finger and half of middle finger (sensory branches of musculocutaneous nerve)
- C7 – middle finger (radial nerve)
- C8 – ring and little finger, medial forearm (ulnar nerve)
- T1 – medial arm (medial brachial cutaneous nerve)
- T2 – axilla
- T3 – axilla to nipple
- T4 – nipple to pectoralis major

Circulation:

The blood supply to the shoulder is from the subclavian artery. It lies distal to the sternoclavicular joint, arches upward and outward, passes the anterior scalene muscle, and then moves downward laterally behind the clavicle and in front of the ribs. This artery continues on to become the axillary artery and then the brachial artery, which continues to branch down the arm and into the fingers.

EVALUATION

The shoulder complex is one of the most difficult regions of the body to evaluate. A thorough assessment of the shoulder complex involves all of the steps of an injury evaluation.
including: history, observation / inspection, palpation, active and passive range of motion, strength testing, neurological testing, laxity and special tests, and functional testing.

**History:**

The first step in the evaluation is the history. This is an essential step to find out as much about the injury as possible. During this time, the examiner must ask the athlete questions regarding their injury that will help the examiner determine the severity and cause of injury as well as the next steps to take in the evaluation process. It is necessary to know if the injury was caused by sudden trauma or was of slow onset. If the injury was caused by sudden trauma, it must be determined if the precipitating cause was from external and direct trauma or from some other type of force. Questions regarding the athlete’s complaints that can help the evaluator determine the nature of the injury include:

- What happened – obtain specific details including the mechanism?
- What position was the body part in at the time of injury?
- Have you ever experienced this pain before? If so, what was done for it and did the treatment help to decrease the pain?
- What is the level (pain scale) and duration of the pain?
- What causes the pain to increase or decrease (activity or not activity)?
- Where is the pain located and what kind of pain are you experiencing – sharp, dull throbbing, aching, tingling, numbness, or burning?
- Did you hear any unusual noises such as a pop, tear, or rip at the time of injury?
- Is there any crepitus or “creaking” during movement?
- Is there a feeling of weakness or sense of fatigue?
- What movements or positions seem to aggravate or relieve the pain?
- Does your pain radiate to any other areas?
- Do you have pain at rest or at night?

After a thorough history, the evaluator should have a good understanding of the injury and the onset of the symptoms. The next step, inspection, will allow the evaluator to observe anything unusual about the injury.
Inspection:

A careful examination of the shoulder joint begins with a visual inspection of the athlete’s head, neck, shoulders, scapulae, and upper thorax with their entire body exposed above the breast line. A systematic approach should be taken by starting at the head and working down both shoulders looking for asymmetry between contralateral bony and soft tissue contours, the attitude of the shoulder and how they are holding it, deformity, atrophy, or any obvious scars or marks.\textsuperscript{11,12} The entire joint must be compared bilaterally and checked from anterior, posterior, and lateral aspects. When inspecting the shoulder, the bony and soft tissues that have previously been discussed, must all be inspected to notice any deformities or abnormalities. It is also important to notice any swelling or inflammation, ecchymosis, or bleeding as a result of the injury. Once this step is complete, the evaluator can move on to the next step, palpation.

Palpation:

Once again, the bony landmarks and soft tissues previously discussed must be palpated during this step. The evaluator must palpate the athlete from both the front and the behind, as well as the injured and uninjured sides to make comparisons between the two sides. The athlete’s shoulder is palpated bilaterally for areas of tenderness, obvious deformities, and temperature changes. Beginning anteriorly and moving laterally:\textsuperscript{13}

- the sternoclavicular joint is palpated for signs of possible dislocation
- the shaft of the clavicle for signs of possible fracture
- the AC joint for partial or total separation
- the pectoralis muscles for deformity or increased tone (indicating spasm or trigger points)
- the biceps tendon / bicipital groove
- supraspinatus muscle
- scapular spine and infraspinatus fossa indicating rotator cuff tears, possible neurological involvement, or tenderness involving infraspinatus tendinitis, excessive swelling, or fracture of the scapular spine
- vertebral border of the scapula for increased tenderness and / or spasm

Once these palpations are finished, the fourth step is range of motion testing.
Active and Passive Range of Motion (ROM):

Active movements (AROM) are assessed first when checking range of motion and are usually done in a way so that the painful movements are performed last. The active movements that should be evaluated are forward flexion, extension, abduction, adduction, internal rotation, external rotation, horizontal abduction, and horizontal adduction. The normal ranges of motion for these measurements have been addressed previously in this paper (see normal ranges of motion in Appendix 5). It is also possible to address these motions in combination. An example is the Apley's scratch test which combines internal rotation with adduction on one arm and external rotation with abduction on the other arm. However, some of these movements may be restricted when dealing with an injured shoulder. Another important thing to note when assessing AROM is the painful arc, which is tested while the patient abducts the arm. According to Mullin, if pain is elicited between about 45 and 120 degrees but not at the beginning or end ranges, then a positive painful arc is present. This happens as a result of impinging tissue on the acromial arch and the coracoacromial ligament and is usually indicative of subacromial bursitis, tendinitis of the rotator cuff, or impingement syndrome. If a consistent click is noted during certain movement patterns, then it is possible that the athlete has a tear of the glenoid labrum or glenohumeral capsule. Scapulohumeral rhythm is monitored for signs of guarding or compensating, which may be a result of frozen shoulder or a rotator cuff tear. Passive range of motion (PROM) is assessed with the patient lying supine and the evaluator checking all ranges of motion for pain, restrictions (noting end point of movement), or excessive motion (hypermobility, instability, and laxity). A couple of general guidelines are if there is limited AROM and PROM, then one should suspect a frozen shoulder, fracture or chronic bursitis.
Limited AROM but full PROM is indicative of a rotator cuff tear. AROM and PROM but problems with one restricted movement is a sign of tendinitis.

**Strength Testing:**

Strength testing helps the evaluator determine if there are any muscular imbalances between the injured and uninjured sides. The movements tested isometrically are the same as those tested for AROM with restricted elbow flexion and extension added. The examiner must carefully note any movements which cause pain in order to determine the muscles involved with the injury. It is also important to note which motions are guarded and / or weak. A general guideline for patterns of pain and weakness are as follows:\(^{13}\)

- *strong and painful: tendinitis*
- *weak and painful: serious*
- *weak and painless: rotator cuff tear or nerve root*
- *all strong and painful: hysteria*
- *all strong and painless: normal*
- *pain with repetition: vascular*

Once the strength is assessed, the evaluator will have a better understanding of the athlete’s severity and the degree of the injury.

**Neurological Testing:**

Neurological testing should include all of the sensory, motor, and reflex tests discussed previously in Appendix 6. A neurological examination is very important when assessing the shoulder joint because portions of the cervical nerve roots and brachial plexus may be impinged or involved in the injury. The following table (Appendix 8) will present three neurological special tests that should be included in the neurological examination. These include the Adson’s, Allen, and Military Brace Position tests all for thoracic outlet syndrome. These tests are used to evaluate vascular or circulatory problems (with the radial artery) in the upper and lower arm.
Special Tests:

Each joint in the shoulder complex must be evaluated for any instability or laxity and compared to the uninjured side. Laxity tests should be specific to the ligaments being tested. The joints should be assessed for any movement and the amount of movement if any. An end point should be felt to assure that there is no tear of the ligament. The special tests that are included in a shoulder evaluation are listed in the table below. Some of the tests can be eliminated if the signs and symptoms of the injury do not deal with that injury. However, any tests that are positive must be examined carefully and noted in the evaluation report.

Appendix 8.

<table>
<thead>
<tr>
<th>Special Test</th>
<th>Indication</th>
<th>Positive Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty Can / Centinela Test</td>
<td>Supraspinatus impingement</td>
<td>Pain and/or weakness</td>
</tr>
<tr>
<td>Speed’s Test / Biceps Test</td>
<td>Biceps strain or bicipital tendinitis</td>
<td>Pain and/or weakness</td>
</tr>
<tr>
<td>Yergason’s Test</td>
<td>Biceps Tendon irritation</td>
<td>Pain in bicipital groove</td>
</tr>
<tr>
<td>Subluxing Biceps Tendon and Bicipital Tendinitis Test</td>
<td>Indication of tear of transverse humeral ligament</td>
<td>Pain in bicipital groove (tendinitis); biceps tendon pops out of groove</td>
</tr>
<tr>
<td>Drop Arm Test</td>
<td>Rotator Cuff tears (especially supraspinatus)</td>
<td>Unable to lower arm, pain/weakness, and shoulder hiking</td>
</tr>
<tr>
<td>Shoulder Impingement Test</td>
<td>Impingement of rotator cuff (especially supraspinatus)</td>
<td>Reproducible pain at subacromial space, especially near end range of motion</td>
</tr>
<tr>
<td>Modification of Shoulder Impingement</td>
<td>Impingement of rotator cuff or long head of biceps brachii tendon</td>
<td>Pain with motion, especially near end ROM</td>
</tr>
<tr>
<td>Cross Adduction Test</td>
<td>Possible subcoracoid bursitis or labral/capsular tear</td>
<td>Pain elicited at anterior shoulder</td>
</tr>
<tr>
<td>Apprehension Test (Crank test)</td>
<td>Joint mobility/obvious laxity (looseness) compared to opposite side</td>
<td>Look of apprehension or alarm on patient’s face; may feel that shoulder will dislocate;</td>
</tr>
<tr>
<td>Relocation Test (follows apprehension test)</td>
<td>Anterior or posterior force; check for humeral head pressing on static stabilizers of shoulder</td>
<td>Increased pain</td>
</tr>
<tr>
<td>Glenohumeral Glide Test</td>
<td>Laxity of shoulder stabilizers</td>
<td>Pain or increased motion compared to opposite side</td>
</tr>
<tr>
<td>Test</td>
<td>Description</td>
<td>Findings</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Load and Shift Test (Glenohumeral translation)</td>
<td>Assess amount of joint play in glenohumeral joint (uni- or multi-directional instability)</td>
<td>Humeral head excessively translates compared to contralateral side</td>
</tr>
<tr>
<td>Sternoclavicular Joint Test</td>
<td>Sternoclavicular Joint Instability</td>
<td>Increased pain or instability</td>
</tr>
<tr>
<td>Piano Key Sign</td>
<td>Trauma to coracoclavicular ligament</td>
<td>Resemblance of piano key</td>
</tr>
<tr>
<td>Acromioclavicular Traction Test</td>
<td>Integrity of acromioclavicular and costoclavicular ligaments</td>
<td>Humerus and scapula move inferior to clavicle (step deformity)</td>
</tr>
<tr>
<td>Acromioclavicular Compression Test (spring test)</td>
<td>Acromioclavicular Joint Instability</td>
<td>Increased pain or instability; excursion of clavicle over acromion process</td>
</tr>
<tr>
<td>Sulcus sign</td>
<td>Excessive inferior translation</td>
<td>Widening of space between acromion process and humeral head (“sulcus”)</td>
</tr>
<tr>
<td>Serratus Anterior Test</td>
<td>Serratus Anterior muscle weakness</td>
<td>Winging of scapula with wall push-up</td>
</tr>
<tr>
<td>Anterior Scalene Syndrome Test (Adson’s test)</td>
<td>Compression of subclavian artery as it enters into outlet canal between heads of anterior and middle scalene muscles</td>
<td>Pulse depressed or stopped completely in testing position</td>
</tr>
<tr>
<td>Thoracic Outlet Syndrome Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costoclavicular Syndrome Test (Military Brace Position)</td>
<td>Compression of subclavian artery between first rib and clavicle</td>
<td>Radial pulse obliterated partially or totally</td>
</tr>
<tr>
<td>Hyperabduction Syndrome Test (Allen Test)</td>
<td>Compression of subclavian and axillary vessels and brachial plexus move behind pectoral muscle and beneath coracoid process</td>
<td>Diminished radial pulse</td>
</tr>
</tbody>
</table>

**Functional / Sport-specific Tests:**

Upon completion of the special tests, the evaluator may wish to do any functional or sport-specific tests depending on the structures involved and severity of the injury. This completes the initial evaluation and the examiner should at this time have a pretty good idea of which structures are involved and which ones are not involved. Some of the special tests can be eliminated if a structure or injury is ruled out from the previous steps in the evaluation. For example, the Allen, Adson’s, and Military Brace Position tests can all be eliminated if there is no
sign of neurological damage (Thoracic Outlet Syndrome). It is important to remember that only the relevant special tests are necessary as there are too many to perform routinely and they may further aggravate the injury.

**LASERS**

The rest of this paper will focus in the history and use of lasers in the medical field as well as with a particular shoulder surgical procedure. The Laser Assisted Capsular Shrinkage, or LACS procedure, for shoulder instability will involve a case study of an athlete who experienced multidirectional instability.

**History:**

Lasers are becoming more and more common in every area of medicine. They have been around since the early 1960s, however they are very recent in medicine. "Laser" is an acronym for Light Amplification by Stimulated Emission of Radiation, a unique type of light energy produced by man. Laser light is different than visible light in its characteristics of collimation (all emitted light is almost perfectly parallel), coherent (light waves are all in phase in both time and space), and monochromatic, one specific wavelength. The development of the laser followed Neil Bohr's description of the atom in 1913 and Albert Einstein's hypothesis of stimulated versus spontaneous emission of radiation in 1917. According to Nottage, the laser, however, was created in 1960 by Maiman, while employed in the aerospace industry. The CO₂ laser was first applied in arthroscopy in the early 1980s which led to considerable controversy as to both efficacy and benefit beyond the normal mechanical techniques. Today the laser has proven to be
very beneficial as well as cost efficient. In 1987, the Holmium 2.1 nanometer laser was introduced experimentally as the first fiber optic delivered free energy laser beam for arthroscopic application in a water medium. The FDA approved the Holmium 2.1 laser in 1989 for all peripheral joint applications. The laser is also highly used today in optometry for corrected vision.

The laser light is created in a lasing cavity which must contain a lasing medium, such as a Holmium doped crystal rod of yttrium, aluminum, and garnet (Ho:YAG). The crystal rod is excited by high intensity flash lamp, commonly Krypton, causing the release of photons which become trapped in the lasing cavity. This “optical resonator” is composed of the rod internally at and each end a precisely aligned parallel mirror. One mirror is 100% reflective of the wavelength while the opposite mirror reflects a predetermined amount of photons (light energy) allowing a percentage of the impinging photons to pass through the mirror and become the usable output or “laser beam”. The principle phenomenon of lasers is the ability of photons to stimulate the emission of other photons, each having the same wavelength and direction of travel. As the photon passes close to an excited electron, the electron will become stimulated as well and emit a photon that is identical in wavelength and phase to the impinging photon. This process can then be amplified between the two mirrors of the optical resonator. Therefore a photon is an energy or particle packet released by excited electrons.

**Elements:**

The laser must consist of three fundamental elements which include a lasing medium (such as carbon dioxide or a Holmium doped YAG crystal) to provide the source of photons that support the light amplifications, an energy source to excite the medium (commonly Krypton flash lamp), and an optical resonator, or chamber containing parallel mirrors to amplify the laser
effect. The wavelength produced by the laser can be altered by changing the lasing medium. The specific properties, characteristics, and tissue effects of each wavelength are generally determined through experimentation.

Laser light is a form of energy (photons) that is absorbed by tissue and converted to heat energy much like the sun when illuminating the earth. This, in turn, raises the tissue temperature and causes a thermal effect. The thermal effect of the laser energy ultimately produces the surgical effect rather than a specific unique characteristic of the laser beam itself. Laser tissue interaction may cause reflection, transmission, scattering, conduction or absorption. Therefore, the visible effect of the laser is to cut, coagulate, or vaporize.14 The effect of the laser on tissue that is of most interest medically is that of absorption. Tissue absorption is dependent upon the type of laser utilized and the characteristics of the tissues to which it is exposed. According to Nottage,14 laser impact on tissue can instantly boil the intracellular water by heat transfer, causing a cellular explosion such as seen with tissue ablation. The laser energy, spot size, and exposure time can all be adjusted on the laser to change the effect of the laser beam. The operator controls the exposure time for the desired tissue effect. This time varies among the tissues being corrected. The combination of spot size (beam diameter) and laser energy, is expressed as joules/cm² or “energy density.” The energy density varies directly with the energy level and adversely with the spot size or will vary inversely with the square of the beam diameter. Energy density is one of the most important operating parameters to understand at a given wavelength and reflects the amount of energy actually delivered per unit area.

Development:

The laser has continued to develop throughout the past few decades. The development of the pulsed laser as opposed to the continuous laser has allowed the operator to optimize specific
tissue effects and minimize thermal damage. The pulse frequency can vary from 150 to 350 nanoseconds. This optimizes tissue absorption and minimizes burning by eliminating the amount of heat delivered to the tissue at any one point. The delivery of the laser energy can be via direct contact or noncontact. Direct contact delivery involves the hot tip and noncontact delivery involves the free beam. The most common delivery used is the free beam unit, such as the Holmium YAG laser. The direct contact tips commonly cause problems with the accumulation of debris upon the laser and thus blocks the laser energy and ultimately leads to a cautery tip effect.

**Holmium 2.1 Laser:**

According to Nottage, a common wavelength useful in orthopedics today is that of the Holmium 2.1 laser, an invisible beam of light in the infrared zone of radiation directed by a helium neon visible aiming beam aligned with the treatment beam. The Holmium 2.1 laser is well-absorbed by water and because of this absorption, when the beam is fired a small amount of laser energy at the tip of the free beam will boil immediate water adjacent to it (in an aqueous medium) creating a vapor bubble. This allows the laser energy to pass through the bubble and reach the tissues to be absorbed. Although the Holmium 2.1 laser is used in a contact mode, it is actually a free beam spaced back slightly from the tip of the probe, to operate as described. The common settings used for the Holmium 2.1 laser are: energy level of 0.6-2.0 joules/pulse, repetition rate of 8-20 per second (hertz), pulse power of 0-6 kilowatts, pulse duration of 100-350 nanoseconds, and a spot size of 0.5 mm. The Holmium YAG laser’s thermal energy commonly produces thermal damage in an area of 25-50 microns with an area of adjacent thermal change from 250-300 microns with a normal depth of penetration of approximately 0.5 mm.
Advantages:

There are many advantages of the use of lasers in surgical procedures. Some of these advantages include homeostasis, which is the maintenance of a steady-state in the body’s internal environment, one probe does the work of many instruments, the instrument has a small diameter of approximately 2mm, they are very powerful, they are cost efficient, and they use a fiber optic cable which benefits the surgeon. Lasers are also beneficial for the patient in other ways including “less subjective pain and less apparent bleeding and swelling,” reduction in surgical time, no charring and therefore less irritation and inflammation, safe equipment, and precise surgery.\textsuperscript{10}

Lasers in Orthopedics:

The use of lasers in orthopedics has continued to grow over the past few years. The laser in the shoulder has been applied to the subacromial space and glenohumeral joint for the debridement of labral lesions, release of the coracoacromial ligament and chondroplasty. The LACS (Laser Assisted Capsular Shrinkage) procedure uses a laser to induce change in the morphological characteristics of the shoulder capsule and the effects depend upon the laser used, time exposed and intensity of the heat exposure. The laser energy is transmitted through radiation and heat conduction by photons of light which create a warming effect on the intracellular water. The amount of heat produced as well as the conduction through the tissues becomes very important to the operator.

The shoulder capsule is comprised mostly of type 1 collagen tissue which normally contains a triple helical polypeptide stabilized by intramolecular and intermolecular bonds.\textsuperscript{14} The “shrinkage” occurs when the application of thermal energy to the collagen will disrupt the bonds stabilizing the triple helix and this leads to a decrease in the overall length of the molecule.
The temperature range for tissue shrinkage commonly occurs between 55-80 degrees centigrade and ideally between 60-70 degrees centigrade. Reports have shown that the heat effect and not the laser effect alone produce collagen shrinkage and the shrinkage was precise and dose-related. Other research has shown that tissue shrinkage was dependent upon the temperature and time utilized. Tissue heated below 57 degrees centigrade did not shrink and over 75 degrees for five minutes showed complete loss of fibrillar structure and capsular architecture. The Holmium YAG laser is the current thermal delivery system, however, has no specific feedback mechanism that exists for the surgeon to carefully identify the amount of heat exposure and temperature within the tissue for clear definition of the amount of collagen shrinkage which would be produced. The Holmium YAG laser can also be used to ablate or remove both soft tissue and bone. This type of laser is a pulsed type with various settings for both energy per pulse and pulses per second. At an energy level of 20-30 watts, the laser will ablate soft tissue such as cartilage or a capsule and at higher settings such as 80 watts, bone can be removed. The lower energy setting of 10 watts is used to shrink capsular tissue due to shortening of the collagen molecule.

Recent advances in arthroscopic shoulder surgery have made it possible to reconstruct a loose, unstable shoulder joint without the use of large incisions or disruption of the joint capsule or muscle units. The YAG laser has proven useful in many areas of surgery, and now has reached entirely new applications orthopedic field. Traditionally, a shoulder which presented instability, would involve a two to three inch incision on the anterior portion of the shoulder, dissection of the joint, and tightening of the capsule itself by dividing it, and suturing it to itself.
in a tightened position. The procedure now involves the use of laser energy at low settings to shrink the collagen tissue without destroying the surrounding cells of the shoulder capsule and without creating an incision. The first clinical series of laser assisted capsular shrinkage was reported in 1993/1994 as a combined study of five orthopedic practices using Coherent lasers, the Versa-Pulse O Holmium laser.\textsuperscript{14} Both unidirectional and multidirectional instability were addressed in these cases. The parameters used were as follows: 1 joule, tangential application with a 30 degree probe, and 10 hertz defocused beam. The results of this study six months post-surgery revealed 93\% good or excellent, 5\% fair, and 2\% poor. The results were also better in the younger patients, subluxers rather than dislocators, and nondominant arms compared to the dominant arms. The following case study reveals the use of the lasers and the LACS procedure in a collegiate athlete.

**CASE STUDY**

**Shoulder Instability:**

Shoulder instability may be classified in four different ways. The most important considerations of instability are direction of instability and the cause of instability. According to Lipscomb,\textsuperscript{9} the most common type of instability, by far, is the anterior type. In anterior instability, the ball (humeral head) tends to move abnormally toward the front of the body. The other types of instability are posterior and inferior. In addition, some individuals may suffer from instability in several different directions at one time and this is known as multi-directional instability. Damage to the inferior glenohumeral ligament complex (IGHLC), which supports the bottom part of the shoulder capsule like a hammock is related to most cases of shoulder instability.\textsuperscript{9} Injuries may also occur to the superior glenohumeral ligament (SGHL) and the middle glenohumeral ligament (MGHL). According to Bailey,\textsuperscript{1} males are more prone to
dislocations than females because females have greater shoulder range of motion and flexibility which aids in their avoidance of dislocations and subluxations. However, females do have a higher rate of multi-directional instability than do males. The recurrence of dislocations is well chronicled to approximate percentages of repeat episodes of dislocation which are: patient under 18 years of age – 90%, patient under 30 years of age – 65%, and patient over 35 years of age – 20%. The older the patient, the less likely they are to re-injure the shoulder due in part to the decreased level of sport activity.

Dislocations:

Anterior (forward) dislocations account for more than 98% of all shoulder dislocations. The most common cause of an anterior dislocation is an indirect force applied to the arm in which it is forced away from the body and rotated over the humeral head. However, four percent of anterior dislocations may occur without trauma. Posterior (backward) dislocations constitute only two to four percent of all shoulder dislocations. Because they are so infrequent, this type of dislocation can often be missed on an initial evaluation. These types of dislocations can often be associated with electrical shocks or seizures. The arm is positioned against the side of the body and it is usually rotated against the body.

Individuals with multi-directional instability usually have a large element of inferior (downward) instability in addition to anterior and / or posterior instability. Many of these individuals have laxity in many of their other joints.

Laser Assisted Capsular Shrinkage (LACS) Procedure:

The LACS procedure is a relatively new procedure used to shrink or tighten the capsule of the shoulder in multidirectional instability. Many surgical procedures have been developed
to reduce multidirectional instability, but they require an extensive recovery period.\textsuperscript{18-20} The recovery period to return to activity ranges from 4 to 12 months.\textsuperscript{12,21-24} The immobilization with a LACS procedure is considerably less, approximately 1 week.\textsuperscript{25} According to Wicks,\textsuperscript{10} the LACS procedure is much as described for the arthroscopic repair and then the laser probe is passed in a crisscross pattern over the inside of the capsule and anterior ligaments while watching the capsule shrink. The more passes and tissue affected the tighter the joint becomes. The living cells between the “weals” grow into the denatured collagen matrix and lay down new collagen in the shortened position permanently.\textsuperscript{10}

Case History:

During the fourth game of a match, a 22-year-old intercollegiate volleyball player dove to the right for a ball and hyperabducted her right shoulder.\textsuperscript{7} She complained of weakness, and inability to raise her arm above shoulder height in any plane. She tested positive to the relocation, anterior drawer, apprehension, sulcus, and clunk tests.\textsuperscript{26-27} According to Perkins, she also presented a painful arc of $60^\circ$ to $90^\circ$ of abduction with weakness and no posterior laxity was evident. Upon evaluation, there was no previous history of injury to either shoulder and the uninjured shoulder was normal. The athlete was diagnosed by the team orthopedist with multidirectional instability and a possible labral tear. The athlete was unable to play due to pain and dysfunction and so elected to have arthroscopic surgery.

According to Perkins,\textsuperscript{7} the athlete underwent surgery, which consisted of the LACS procedure to tighten the capsule and eliminate multidirectional instability on November 15. According to the surgical report, the arm was placed in a shoulder traction device with 6.8 kg (15 lb) of weight in manual traction. The Holmium YAG laser as previously discussed was used to shrink the capsule and tighten the joint. A 5-mm, 30\(^\circ\) arthroscope and various accessory
instruments were introduced into the shoulder through anterior and posterior portals. The surgeon was able to detect that the labrum was thin, but had not been torn and would not need any repair. There were no complications during surgery and the athlete was immobilized before leaving the hospital.

The rehabilitation program was designed specifically for the LACS procedure. It was a very aggressive program that allowed for an early return to activity. The program allows patients to progress at their own pace and within their own limitations. Progression to the next phase depends upon active range of motion and the ability to perform the exercises of the phase without pain. The athlete began rehabilitation approximately one week (on November 22) post-surgery. The athlete started with passive range of motion in all ranges and progressed to isometric exercises (see exercises in Appendix 11) with the arm at the side (November 27). Within 12 days after immobilization, the athlete had regained full active and passive range of motion in all ranges of the shoulder. On November 30, she began a closed kinetic progression (see closed kinetic chain progression in Appendix 12), including an upper body exerciser for moderate–to high–speed exercise (phase 3). The athlete rehabilitated at home on her own over semester break. By December 7, she advanced to phase 4, and phase 5 on January 17. The athlete was released from the physician’s care on February 8, 11 weeks postarthroscopy, with full active range of motion, no signs of instability, and good strength. The athlete began sport-specific skills such as passing, setting, serving, blocking, spiking, and digging as tolerated. She also continued the rehabilitation program (phases 7 and 8). The total rehabilitation period lasted for 2.5 months. At 3 years after surgery, she is coaching and playing volleyball without pain or dysfunction.
The athlete's active range of motion measurements increased preoperatively to postoperatively in flexion by 40°, abduction by 70°, adduction by 50°, and internal and external rotation, with the shoulder abducted to 90°, by 53° each. Extension did not increase postoperatively. The pain level decreased from severe (constant discomfort, limits activity) preoperatively, to mild (occasionally, only with activity, does not limit activity) at 11 weeks postsurgery. Many of the activities of daily living such as hair washing and combing, putting on a jacket and finishing with the affected shoulder, opening a car door, and getting clothing from a shelf above shoulder level, that the athlete found difficult before surgery were performed without difficulty after surgery.

Appendix 10
LACS Rehabilitation Protocol

Phase 1
  Immobilized in sling

Phase 2
  Immobilization removed
  Codman / pendulum exercises
  Passive flexion – extension
  Passive abduction – adduction
  Passive horizontal abduction – adduction
  Passive internal – external rotation with shoulder adducted and elbow flexed to 90°
  Wall climbing, table walking
  Isometric exercises: hold 6 seconds with shoulder adducted and elbow flexed to 90°
  Active range of motion (AROM): all ranges except internal – external rotation with abduction to 90°
  Cardiovascular (CV) activity of choice
  Activities of daily living

Phase 3
  Continue Codman / pendulum exercises
  Continue isometric exercises
  Begin active – assisted ROM in same ROM if necessary
  Upper body exercises (UBE) for ROM at moderate to high speed (90°/s to 120°/s)
  Begin closed kinetic chain exercise progression (see Appendix 12)
  Begin elbow, wrist, and hand isotonic exercises
  CV activity of choice
If active ROM almost full, begin isotonics

Phase 4
Continue active -- assisted ROM if needed
Continue closed kinetic chain progression (see Appendix 12)
AROM
Begin AROM internal – external rotation at 90° of abduction
Continue UBE
Begin isotonic dumbbell exercise, all ROMs
  * Flexion – extension
  * Abduction – adduction
  * Horizontal abduction – adduction
  * Internal – external rotation with arm adducted and elbow flexed to 90°
  * Internal – external rotation at 90° of abduction and elbow flexed to 90°
  * Elevation – depression
  * Protraction – retraction
  * Scaption with internal rotation
  * Scaption with external rotation
  * Horizontal abduction with medial rotation at 0°, 30°, and 90°
  * Horizontal abduction with lateral rotation at 0°, 30°, and 90°
CV activity of choice

Phase 5
Begin scapular stabilization exercises (scapular elevation, depression, and adduction)
Progress weight in isotonics as tolerated
Continue closed kinetic chain progression (see Appendix 12)
CV activity of choice

Phase 6
Continue isotonic exercise
Continue closed kinetic chain progression (see Appendix 12)
Continue scapular stabilization exercises
Begin isokinetic exercise at high speed with arm in slight abduction and elbow flexed (180° to 300°)
Begin tubing exercises: flexion – extension, abduction – adduction, and horizontal abduction – adduction
CV activity of choice

Phase 7
Continue above exercises and progress as tolerated
Begin pull-downs (front and back), military, bench press, cleans, and squats if indicated
CV activity of choice

Phase 8
Continue exercises from Phase 6
Begin sport – and activity – related exercises of choice
Proprioceptive neuromuscular facilitation patterns if indicated
Throwing athletes begin throwing protocols
Employ drills that use the shoulder in practice and activity

Cautionary notes
Not all patients will return in 2 months.
Patients should progress at their own pace, reducing weight, exercises, or both, if they develop pain.
Always maintain full active ROM.
No overhead activity until at least 3 weeks postoperatively.
Check with the patient’s physician before implementing this program.

Appendix 12
Closed Kinetic Chain Progression

- Double-arm wall push-aways: short distance, 15.24 cm (6 in)
- Double-arm wall push-aways: long distance, 30.48 cm (12 in)
- Single-arm wall push-aways: short distance, 15.24 cm (6 in)
- Single-arm wall push-aways: long distance, 30.48 cm (12 in)
- Ball toss: chest, single arm, spatial awareness
- Press up from chair
- Rowing
- Bent-knee and bent-arm pushup
- Bent-knee and straight-arm pushup
- Straight-leg pushup, bent arm
- Straight-leg pushup, straight arm
- Wheel barrel pushup
- Catching large balls
- Side-to-side walking on hands
- Slideboard: side to side and circles
- Swedish (Swiss) ball exercises

Notes
* Patients should progress at their own pace.
* Closed kinetic chain exercises were chosen from the above list for the athlete in this case study.
* Other closed kinetic chain exercises can be substituted as long as the patient progresses from beginning to advanced exercises.

CONCLUSION

In conclusion, the LACS procedure may be a fairly new procedure used, however, it has proven to be very beneficial as well as cost efficient. This technique offers an alternative to the previous techniques used, which consisted of open and closed surgical procedures. The LACS
procedure employs a laser to shrink tissue in the shoulder capsule, which allows function and mobility to return.\textsuperscript{17} The results of the LACS procedure have, thus far, proven to be successful and the return of the athlete to participation is considerably less than with an open surgical technique. As the use of lasers continues to be successful in the orthopedic field, we will learn more about the benefits and advantages to reduce shoulder instability, as well as other possible joints that could be surgically repaired with lasers.
References


