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SHOULDER AND ELBOW

Nerve injury associated with shoulder surgery

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Axillary;
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Subscapular nerves

Summary
Although generally low, the risk of damage to nerves in the operative field during shoulder surgery still exists. These complications usually occur following surgery for anterior shoulder instability or joint replacement. The risk can be minimized by careful patient positioning, applying a detailed knowledge of shoulder anatomy to the approach and awareness of 'safe-zones'. Certain manoeuvres should be undertaken during the procedure to displace nerves from the operative field. If these measures are incorporated into routine practice, the risk of intraoperative nerve injury will be significantly reduced.

Introduction

Despite a better understanding of the application of shoulder anatomy surgery, there is still a significant intra-operative risk of nerve injury. The nerves in the immediate vicinity of the operative field (Figs. 1—4) which are most frequently damaged are the:

- Axillary
- Suprascapular
- Musculocutaneous
- Subscapular
- [other smaller branches of the brachial plexus]

The incidence of nerve injuries varies with the procedure, the approach utilized and the skill/experience of the surgeon. The reported incidence is 1—2% in patients undergoing rotator cuff surgery, 1—8% in patients undergoing surgery for anterior instability, and 1—4% in patients undergoing arthroplasty.[1,2,3,4] Unpredictable factors, such as anatomical variations and anomalies, influence the magnitude of risk. A three-dimensional knowledge of nerve anatomy is therefore essential in order to avoid injury to these structures.

Anatomy

The **axillary nerve**, composed of fibres from the **5th and 6th cervical nerve roots**, originates from the **posterior cord of the brachial plexus** at the level of the coracoid process, behind the conjoint tendon. It passes anterior to subscapularis and then courses towards its inferior border to enter the quadrilateral space. Here it maintains a close relationship to the inferior capsule, making it susceptible to damage. In the quadrilateral space it is accompanied by the posterior circumflex humeral artery and gives branches to the inferior aspect of the capsule. At posterior aspect of the humeral neck it divides into anterior and posterior trunks. The posterior trunk gives motor branches to teres minor and posterior deltoid, and cutaneous branches to the skin overlying the posterior deltoid before

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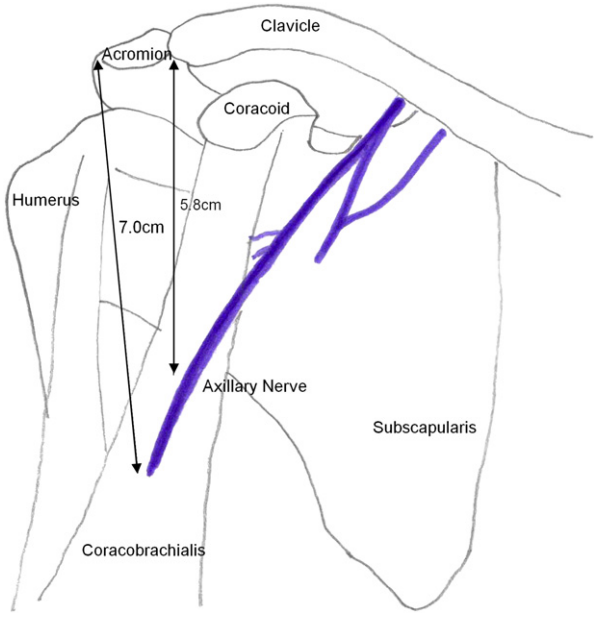

Figure 1 The Axillary nerve is located an average of 5.5 cm from the posterior corner of the acromion, 8 cm from the mid-portion of the acromion, 7 cm from the anterolateral corner of the acromion and 5.8 cm distal to the acromioclavicular joint. These distances tend to be even shorter in women and those with shorter arms.

terminating as the lateral brachial cutaneous nerve of the arm. The anterior branch continues to wind around the surgical neck of the humerus and extends to the anterior border of the deltoid, giving motor branches to the anterior and middle deltoid as well as a number of small cutaneous branches to the skin overlying the deltoid.

The **suprascapular nerve**, composed of fibres from the **5th and 6th cervical nerve roots** (with a variable contribution from the 4th cervical nerve root), originates from the **upper trunk of the brachial plexus**. It runs laterally, crossing the posterior triangle of the neck, parallel and deep to the omohyoid and trapezius muscles. It enters the supraspinatus fossa through the suprascapular notch, bridged by the thick transverse scapular ligament It then passes beneath the supraspinatus and curves around the lateral border of the scapular spine, the spinoglenoid notch, to enter the infraspinatus fossa. It gives off two motor branches to the supraspinatus muscle, then passes laterally within the fossa, providing sensory branches to the posterior capsule. In the infraspinatus fossa it gives off two motor branches to the infraspinatus muscle and some filaments to the shoulder joint and scapula.

The **musculocutaneous nerve**, composed of fibres of the **5th, 6th and 7**th **cervical nerve roots**, originates from the **lateral cord of the brachial plexus**, opposite the lower border of the pectoralis minor muscle. It penetrates the coracobrachialis muscle and passes obliquely between the biceps brachii and the brachialis to the lateral side of the arm. Just above the elbow it pierces the deep fascia lateral to the biceps tendon and continues into the forearm as the lateral antebrachial cutaneous nerve. Its gives motor branches to coracobrachialis, biceps brachii and brachailis. It also gives a small branch to the bone,

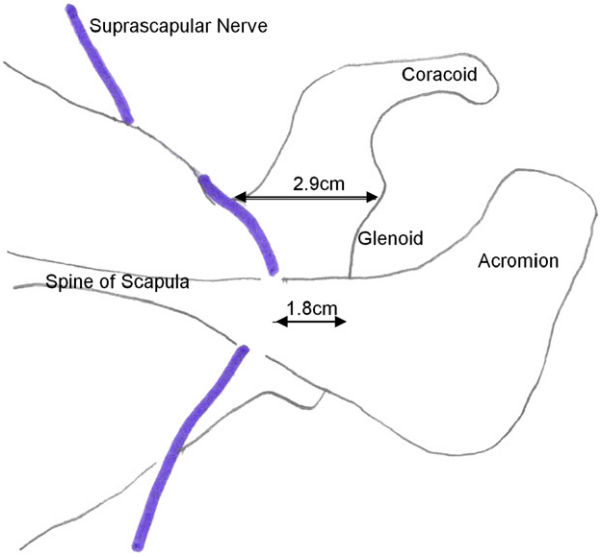

Figure 2 The suprascapular nerve lies on the undersurface of the supraspinatus and infraspinatus tendons, approximately 2.9 cm from the superior glenoid rim and 1.8 cm from the spine of the scapula. Therefore when dissecting the shoulder capsule on the inferior aspect of the rotator cuff, one should avoid dissection medial to the glenoid rim.

which enters the nutrient foramen with the accompanying artery.

The **subscapular nerves**, consisting of fibres from the **5th and 6th cervical nerve roots**, originates from the

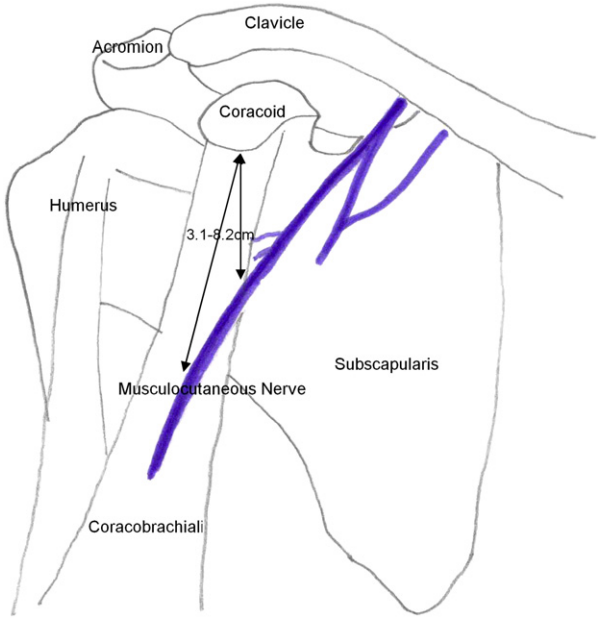

Figure 3 The musculocutaneous nerve is vulnerable in its proximal course where it lies on the subscapularis muscle. This is because the entry point of nerve into coracobrachialis is unpredictable and sometimes the nerve bifurcates. The distance between the coracoid and the entry point of the nerve into coracobrachialis muscle ranges from 3.1—8.2 cm.

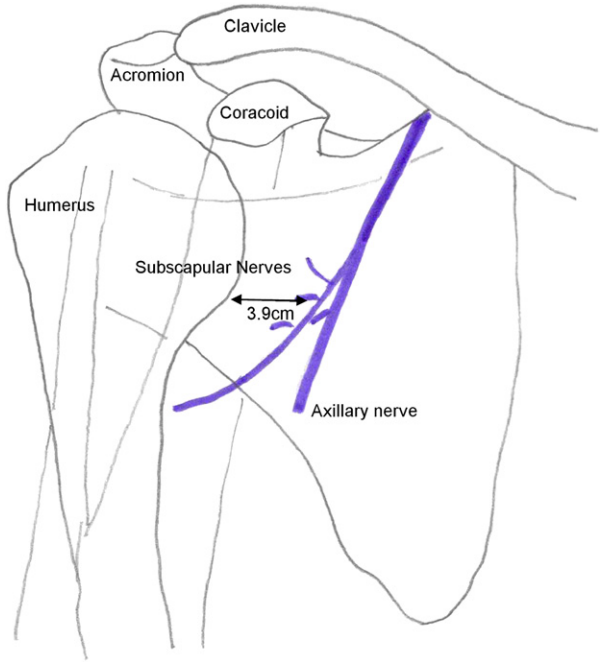

Figure 4 Dissection of subscapularis may damage the subscapular nerve as it enters the muscle as close as 1 cm medial to the border of the glenoid. The mean distance of the main upper subscapular nerve from the border of the glenoid is 3.9 cm with the shoulder in internal rotation, 3.3 cm with the shoulder in neutral, and 2.5 cm with the shoulder in external rotation. All the nerve branches are no closer than 1.5 cm medial to these land-marks for all positions of humeral rotation with the arm at the side.

posterior cord of the brachial plexus on the costal surface of subscapularis. The upper subscapular nerve passes directly into the upper part of the subscapularis muscle whereas the lower subscapular nerve divides into two branches, one entering the lower part of the subscapularis muscle and the other continuing into the teres minor.

Mechanisms of injury

There are a variety of mechanisms accounting for nerve injury during shoulder surgery, although recent advances in surgical technique coupled with better intra-operative awareness have significantly reduced the incidence of **direct laceration** or **incorporation of nerve in a suture repair**. Nowadays **traction**, **compression** and **contusion** are more common mechanisms of nerve injury. Nerve damage through any of these mechanisms can occur with inappropriate positioning of the patient, with anaesthesia, during the approach, with a change in the position of the patient, poor instrument placement or inappropriate manipulation of the arm.[1]

Positioning

Careful positioning of the patient is of paramount importance and there is much debate about the optimum position for surgery. The patients' position will usually depend upon the operation being performed and the surgeon's preference. In the beach chair position the head is particularly susceptible to misplacement. Keeping the head aligned during surgery is difficult because the body is generally out of view and access for adjustment is not easy. Not only can excessive head rotation directly damage nerves and other tissues, but it can also cause disruption of small blood vessels leading to bleeding and nerve compression. As a result, several shoulder-specific operating tables have been designed to improve patient comfort and improve body alignment, therefore improve safety.

Anaesthesia

The muscle relaxants used in general anaesthesia reduce muscle tone making head movement more likely during surgery. Some therefore advocate keeping the patient conscious throughout the procedure so that they can maintain a comfortable head position voluntarily. Advances in regional anaesthesia have meant that interscalene blocks are now more frequently employed and have reduced the need for deep anaesthesia and postoperative analgesia.[5] Although nerve injury associated with interscalene block anaesthesia is uncommon, it has been reported, most commonly affecting the superior laryngeal nerve, vagus nerve, the sympathetic chain (Horner's syndrome), phrenic nerve (precluding bilateral use of this technique) and cervical sympathetic nerves.

Approaches to the shoulder & 'safe zones'

The anterior approach (delto-pectoral)

This explores the interval between the deltoid (axillary nerve) and pectoralis (medial and lateral pectoral nerves) muscles. The cephalic vein is dissected and retracted laterally with the deltoid, thus exposing the underlying conjoint tendon formed by the coracobrachialis tendon and short head of biceps. Subscapularis is exposed after retraction of the conjoint tendon medially. This is then divided to access the capsule, preserving the most inferior fibres in order to protect the **axillary nerve**. The inferior border of subscapularis can be found by identifying 3 small vessels (often known as the 3 Sisters), which run transversely across; these require cauterisation prior to division.

The **musculocutaneous nerve** is protected by avoiding vigorous retraction of the conjoint tendon and any dissection medial to coracobrachialis. This nerve usually penetrates the biceps/coracobrachialis 5—8 cm below the coracoid but enters these muscles proximal to this 5 cm safe zone almost 30% of the time. **Adduction and external rotation of the arm will help displace the axillary nerve away from the operative field.**[6]

The lateral approach

This involves splitting the deltoid muscle or subperiosteal dissection of it from the acromion. The deltoid is not split more than 5 cm beyond the acromion to avoid injury to the **axillary nerve**. If dissection extends more than 5 cm below the acromion, denervation of the deltoid can occur anterior

to the muscle split because of the posterior origin of the innervation of the muscle.[7]

The posterior approach

This involves exploiting the plane between infraspinatus (suprascapular nerve) and teres minor (axillary nerve). The deltoid is detached from the spine of the scapula or split directly (Rockwood's). The posterior capsule of the shoulder lies immediately beneath it. The **axillary nerve** together with the posterior circumflex humeral artery both run in the quadrilateral space below the teres minor, so it is prudent to stay above teres minor. Excessive medial retraction of the infraspinatus can injure the **suprascapular nerve**.[7]

During arthroscopy, trochar direction and portal placement can endanger nerves if performed incorrectly. The posterior portal is usually established first by palpating the soft spot. The landmark for the skin incision is approximately 2 cm inferior and 1 cm medial to the posterolateral corner of the acromion. Once the skin is incised, the trochar should be directed towards the coracoid. If the portal is made too low, the **axillary nerve** is at risk. If the portal is made too medial, the suprascapular nerve may be in danger. The anterior portal can be established using an inside-out technique using a Wissenger rod or by puncture of the anterior skin under direct vision from the posterior portal. The **musculocutaneous nerve** is at risk if the anterior portal is placed too medial. A portal which is placed superior and lateral to the coracoid process is relatively safe. Injury to individual nerves during shoulder arthoscopy may also come about through a variety of other causes including over-distension of the joint with fluid, excessive traction and extravasation of fluid.[8]

Most surgical approaches to the shoulder split the deltoid muscle putting the **axillary nerve** at risk. It is therefore extremely important to be aware of the precise location of the axillary nerve within the operative field. The nerve is located an average of 5.5 cm from the posterior corner of the acromion, 8 cm from the mid-portion of the acromion, 7 cm from the anterolateral corner of the acromion and 5.8 cm distal to the acromioclavicular joint. These distances tend to be shorter in women and those with shorter arms. Abducting the shoulder to 90 degrees brings the nerve closer to the edge of the acromion by approximately 30%[9] The proximity of the axillary nerve to subscapularis and the inferior capsule makes it vulnerable during procedures in this area (e.g. capsular shift procedure, particularly when the inferior flap is being detached from the humeral neck). Minimising traumatic retraction by using an appropriately flat/blunt retractor will help, as will externally rotating the humerus. Not only does this provide better exposure of the capsule but it also reduces tension on the nerve.[10] When making a posterior stab wound for shoulder arthroscopy, the trochar is in close proximity to the axillary nerve, anywhere between 0.5—4.0 cm. The axillary nerve is held to the shoulder capsule by loose areolar tissue between the 5 and 7 o'clock position (considering the superior aspect of the glenoid as the 12 o'clock position).[11] However, its position changes with that of the arm. Consequently, in anterior (and to some extent posterior) approaches to the glenohumeral joint, adduction, external rotation, and perpendicular traction, the axillary nerve moves away from the glenoid and therefore further from the operative field. Identifying and then protecting the nerve is possible. A 'tug test' has been described, during which the axillary nerve is gently palpated on the anterior aspect of the subscapularis and simultaneously palpated as it courses from the posterior aspect of the neck of the humerus to the deltoid muscle. By gently balloting the nerve in each area, one can sense the course and ensure it is not damaged.[12]

The **suprascapular nerve** lies on the undersurface of the supraspinatus and infraspinatus tendons. It is therefore very close to the operative field, approximately 2.9 cm from the superior glenoid rim and 1.8 cm from the spine of the scapula. Therefore, when dissecting the shoulder capsule on the inferior aspect of the rotator cuff to allow for musculotendinous advancement, one should avoid sharp dissection more than 1 cm medial to the glenoid rim in order to avoid direct contact with the nerve.[13] Furthermore the nerve tends to be tethered to the periosteum of the supraspinous fossa and the suprascapular notch. As a result it is placed under significant tension when advancing supraspinatus laterally. Although medial retraction of the muscle can significantly change the course of the nerve, this too creates tension on the nerve.[14] The suprascapular nerve is most commonly injured during placement of posteriorly directed sutures for repair of a detached anterior labrum and capsule through drill holes in the glenoid neck, supraspinatus and infraspinatus tendon mobilization during massive rotator cuff repairs, or glenoid osteotomy for treatment of posterior instability.

The **musculocutaneous nerve** is particularly vulnerable in its proximal course where it lies on the subscapularis muscle. This is because the entry point of nerve into coracobrachialis is unpredictable and the nerve sometimes bifurcates.[15] The distance between the coracoid and the entry point of the nerve into coracobrachialis muscle ranges from 3.1—8.2 cm.[6] Any surgical procedures involving the anterior aspect of the shoulder therefore risk injuring the musculocutaneous nerve,[1] such as the modified Bristow procedure (for shoulder instability) or shoulder arthroscopy (due to joint distension, excessive traction and extravasation of fluid).[16,17,18]

Dissection of subscapularis, to release it during shoulder reconstruction, may damage its innervation. This is because the nerve enters the muscle as close as 1 cm medial to the border of the glenoid. The mean distance from the main, upper **subscapular nerve** to the border of the glenoid is 3.9 cm with the shoulder in internal rotation, 3.3 cm with the shoulder in neutral, and 2.5 cm with the shoulder in external rotation. The palpable anterior border of the glenoid rim, deep to subscapularis and the medial border of the conjoint tendon, serve as guides to the insertion point of the subscapular nerve. All nerve branches are no closer than 1.5 cm medial to these land-marks for all positions of humeral rotation with the arm at the side. The lower subscapular nerve is immediately posterior to the axillary nerve, which therefore serves as a guide to the insertion point of the lower subscapular nerve. During the anterior approach to the shoulder, injury to the lower subscapular nerve is therefore minimized by locating and protecting the axillary nerve.[19]

Discussion

Intraoperative nerve injuries about the shoulder are generally uncommon. They occur most commonly following surgery for anterior shoulder instability or joint replacement. Preoperatively the patient must be positioned very carefully with a view to maintaining this position throughout the surgery. The surgeon must have detailed knowledge of shoulder anatomy together with an awareness of potential anatomical variations. Care must be taken during the approach, and knowledge of so-called 'safe-zones' must be applied. Furthermore, certain manoeuvres should be undertaken to move nerves at risk away from the operative field, whilst minimising the time that the arm is kept in any extreme position. The patient must have a documented neurological assessment pre and post-operatively (once any interscalence block has worn off) to avoid any confusion. If these measures are incorporated into routine practice, the risk of intraoperative nerve injury will be significantly reduced.

New techniques currently being assessed to manage the risk of nerve injury include the use of intraoperative nerve monitoring devices to identify nerve position, capsule thickness, and provide real-time identification of impending nerve injury and function during shoulder thermal capsulorrhaphy.[20] This is a promising technique, though to date outcome data is not available.

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