Review article
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Nerve injury associated with shoulder surgery

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Abstract

Introduction Progress in shoulder surgery is associated with improved operating rooms equipment, advanced surgical products and minimally invasive techniques. There are rare injuries to nerves and vessels being intersected or pulled into the sutures. However, marginal tears, compression and nerve entrapment of trunks during access retraction, catheterization, inadequate correct of the patient on the operating table and errors in rehabilitation can be common.

The **purpose** was to identify factors predisposing to peripheral nerve injury to the upper limb during shoulder surgery and offer prevention options.

Material and methods Major studies in the field of shoulder anatomy and surgery published between 1984 and 2023 were reviewed to identify anatomical, biomechanical and perioperative factors leading to peripheral nerve injuries. The original literature search was conducted on key resources including GoogleScholar, PubMed, ScienceDirect, RSCI, Scopus. Four approaches were used for structuring and informative presentation of the data to include types of the peripheral nerve injury in the upper limb.

Results and discussion Factors predisposing to the peripheral nerve injury in the upper limb during shoulder surgery were identified in the review. Prevention measures include the patient positioned on the operating table with adequate fixation of the head and torso, regardless of the chosen position; traction of the involved upper limb with a load of not greater than 9 kg using a specialized clamp; preoperative marks of the surgical field and staining of bone landmarks; the arthroscopic ports 1–2 cm to be shifted more distally minimizing the fluid flow into the joint during a long operation. Postoperative consultation with rehabilitation specialists is essential to develop an early activation program and assess the risks of neurological disorders.

Conclusion The shoulder anatomy and the localization of unsafe zones of the shoulder, the risks associated with a particular manipulation were explored for effective preoperative planning and prevention of neurological complications in the treatment of surgical pathology of the shoulder joint.

Keywords: shoulder joint, nerve surgery, nerve injury, arthroscopy, arthroplasty

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INTRODUCTION

Various injuries and surgical procedures about the shoulder are known to place the nerves at risk. Iatrogenic nerve injuries are among the more commonly cited complications associated with shoulder surgery.

The incidence of nerve injury depends on the skill and experience of the surgeon, the type of surgery and the approach used. Neurological symptoms can be detected after 0.2–3 % of arthroscopic procedures, 4 % of arthroplasties, and 8 % of open surgeries performed for shoulder instability [1]. Most of the injuries are paresthesias or hypoesthesias and transient neuropraxia [2]. Severe neurological complications result from injury to the main trunks of the suprascapular (SS), musculocutaneous (MCN), axillary nerves (AS) and cranial nerves (CN) [3]. There are many classifications of nerve injury based on etiology, location, form and degree of damage. Iatrogenic injuries are characterized by pronounced polymorphism and can be caused by compression from retraction or edema, thermal dissection from inadequate ablation/coagulation of surrounding tissues, entrapment in the sutures and anchors, etc.

Nerve trauma is difficult to be detected during surgery and there is no need for intraoperative neuromonitoring in most cases, and there are no obvious visual signs as with intersected blood vessels. Neurological symptoms can be revealed the next day after surgery and often raise doubts for a long time, which may be associated with preoperative plexus blockade. A thorough preoperative preparation and adequate intraoperative and postoperative manipulations are essential for preventing a neurotraumatic factor.

The **objective** was to identify factors predisposing to damage to the peripheral nerves of the upper limb during shoulder surgery and offer options for their elimination.

MATERIAL AND METHODS

Major studies in the field of shoulder anatomy and surgery published between 1984 and 2023 were reviewed to identify anatomical, biomechanical and perioperative factors leading to eripheral nerve injuries. The original literature search was conducted on key resources including GoogleScholar, PubMed, ScienceDirect, RSCI, Scopus. Four approaches were used for structuring and informative presentation of the data to include types of the peripheral nerve injury in the upper limb: placement of the patient on the operating table, arthroscopic surgery of the shoulder, open surgery of the shoulder joint, multifactorial complication of shoulder surgery. Each of them included possible options for damage to the peripheral nerve of the upper limb identifying nerve topography and associated risks of a damage during preoperative, intraoperative manipulations and rehabilitation. Thus, ways to minimize nerve damage could be recommended.

RESULTS

Placing the patient on the operating table

J.R. Andrews et al. [4] concluded that improper port placement can damage neurovascular structures and identified the main complicating factors to include inadequate patient positioning and traction greater than 9 kg. Shoulder surgery can be performed with two main positions: the beach-chair position and the lateral decubitus position [4].

Beach-chair position

Nerve injury is uncommon with beach-chair position with the upper limb being lowered due to the mass, and the brachial plexus is not stretched and maximally displaced downwards to the axillary region, and therefore damage to the MCN and AS is the least likely scenario [5].

The beach-chair position has a disadvantage of providing instability to the head. There is evidence of postoperative neurological symptoms due to compression of the lesser occipital and greater auricular nerves due to head supports [6] and mid-cervical quadriplegia [7]. Other iatrogenic nerve damage can be associated with the use of a belt to hold the head, the assistant or surgeon relying on the neck area with compression to the angle of the lower jaw, excessive lateral flexion and excessive head movements during muscle relaxation with loss of fixation (compression of the XII cranial nerve) [8]. A. Cogan et al. [9] suggested that any change in the angle formed by the torso and head other than 180° increases the risk of injury to the XII cranial nerve.

Recommendations

The head in the beach-chair position must be carefully secured with side supports or a specialized fixator to protect the neck. It is important to monitor the location throughout the operation, as well as any touch at the site [10].

Lateral decubitus

Another position, lateral decubitus, has the advantages of a better cerebral perfusion with no greater risk of hypotension and bradycardia. Bubbles in the joint fluid from coagulation move away from the field of view providing free access to the posterior and upper regions of the shoulder, better visualization of the subacromial space [eleven]. Most of the benefits are due to lateral traction of the upper limb securing the patient in a lateral position. Tension in the brachial plexus can increase the risk of damage to the MCN and AS performing arthroscopic ports, and the traction force leads to compression of soft tissues, vessels and nerves, and the load on the contralateral shoulder can lead to compression injuries.

Recommendations

Lateral decubitus suggests a traction of 9 kg at most, the patient positioned with a dorsal rotation of the body up to 30°, abduction of the arm of 45° to be reduced when working in the subacromial space [12].

Arthroscopic shoulder surgery

Arthroscopic surgery minimizes soft tissue dissection compared to open shoulder surgery. However, placement of ports is associated with the risk of direct nerve injury [4]. The incidence of intraoperative or iatrogenic nerve injury is directly correlated with several factors. First, a lot depends on the experience of the surgeon, the number of operations performed, the knowledge and skills acquired during cadaver courses. Second, the anatomy of the patient is essential [13]. Maldevelopments, abnormalities post-traumatic conditions can cause the complications. The risk of nerve injury can be minimized through the knowledge of the anatomy of the nerve trunks described in the literature.

Formation of accesses

Marking is to be produced first (Fig. 1) to facilitate an adequate access. The landmarks may become erroneous in the case of a long procedure. With the tissues filled with water the markers move and can lead to various complications. In this case, it is more appropriate to consider previous ports as a starting point [14].

Posterior port

The posterior port is usually placed first by palpating and puncturing the soft spot. The landmark for the skin incision is approximately 2 cm inferior and 1 cm medial to the posterolateral angle of the acromion [15].

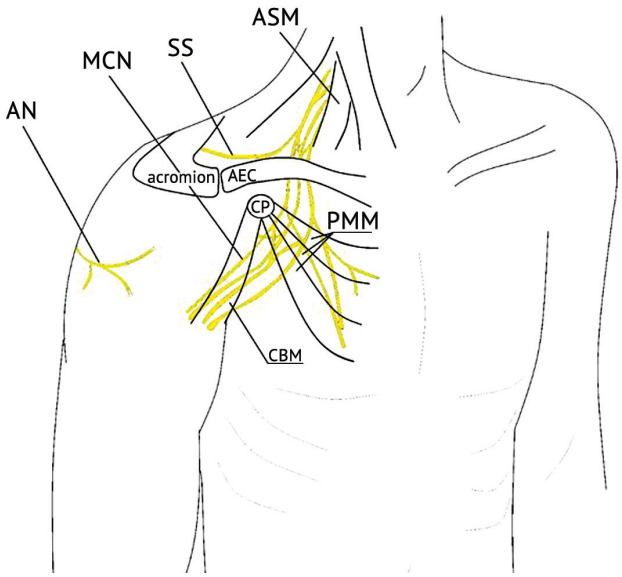

Fig. 1 Schematic representation of preoperatively marked musculoskeletal landmarks of the shoulder for identifying the location of the nerves. Abbreviations: AN, axillary nerve; MCN, musculocutaneous nerve; SS, suprascapular nerve, AEC, acromial end of the clavicle; CP, coracoid process; CBM, coracobrachial muscle; PMM, pectoralis minor muscle; ASM, anterior scalene muscle (illustrated by the author)

Description of the technique

With the skin cut, the trocar is directed towards the coracoid process. If the port is too low and/or the trocar is directed below the shoulder joint, there is a high risk of injury to the AN. If the port is too medial, the SS is likely to be affected. For the adequate trocar placement, the following technique can be used. The first finger of the right or left hand to be placed near the entry site, depending on which shoulder is being operated on. The second finger is to be placed at the apex of the coracoid process. The direction of the instrument placement will be controlled based on the effect of a palpable and easily visualized vector [14]. The port can be 1 cm more proximal in some cases. This technique is used when the main manipulations occur in the subacromial space. The arthroscope is placed subacromially, almost parallel to the acromion, which will not interfere with the movement of the instrument increasing the viewing area [16]. The port is more practical for a short procedure (within 1 hour). Longer procedures will result in extravasation and the approach will be ineffective.

Posterior port

The next port is formed at the anterior aspect. The procedure must be performed with extreme caution to avoid complications [3].

Anatomy

There is a risk of damage to the AN and MCN with placement of the anterior port. A greater traumatic risk for AN is associated with the placement of ports during arthroscopy in an anterior-inferior position: the transsubscapular port used in labral complex reconstruction, can be located at a distance of 1.5 cm from the AN [17]. Therefore, surgeons are advised to maintain a minimum “safe zone” distance of 1 cm from the glenoid applying capsular sutures. The MCN is vulnerable proximally lying on the subscapularis muscle. The nerve entry point into the coracobrachialis muscle is unpredictable and the nerve can bifurcate [18]. The distance between the CP and the nerve entry point into the muscle ranges from 3.1 to 8.2 cm. Placement of any anterior ports medial to the CP and the conjoined tendon can result in traumatic injury to the MCN and the lateral trunk of the brachial plexus. A permanent injury to the nerves is rare with experienced surgeons during shoulder arthroscopy (< 0.1 %) [3].

Technique

The anterior port is used with inside-out technique and a Wiesinger rod or by puncturing the skin anteriorly under direct arthroscope view from the posterior port. MCN can be at risk with the anterior port placed too medially and low from the coracoid process. The port, which is located superior and lateral to the CP and the lateral edge of the short head of the biceps tendon, is relatively safe [3].

Lateral port

The lateral port is installed next in most surgical interventions with the knowledge of the location of the final branches of the AN [19].

Anatomy

The AN is located on average 5.5 cm inferior to the posterior angle of the acromion, 8 cm from the middle part of the acromion, 7 cm from the anterolateral angle of the acromion, and 5.8 cm distal to the acromioclavicular joint. Abduction in the shoulder joint to 90° brings the nerve closer to the edge of the acromion by approximately 30 % [20]. Violation of the boundaries can lead to inadequate placement of the lateral port and is associated with damage to the sensory branches of the AN in 10 % of cases [21]. The SS lies on the undersurface of the supraspinatus and infraspinatus tendons being close to the surgical site, approximately 2.9 cm from the superior border of the glenoid and 1.8 cm from the spine of the scapula. The SS can be damaged by compression from anchors located in the superior part of the glenoid during SLAP operations [22]; the SS is usually located at a distance of 2 cm from the insertion points of the anchors [23].

Technique

The lateral port is positioned under visualization from the posterior port, approximately 4 cm distal to the midportion of the lateral edge of the acromion [21]. We recommend a needle test puncture to understand the cutting point. It is performed in the direction of the lower surface of the acromion.

Time factor

Extravasation is another intraoperative factor that can cause a nerve damage. Large incisions for an access in the capsule and synovial membrane creating prerequisites for the fluid releasing into the surrounding tissue and resulting in edema. This is not only an imprudent approach to port placement that leads to this. Extravasation can be aggravated by increased operating time, increased pressure in the joint cavity for better visualization, and arthroscopy in conditions of acute injury and severe inflammation. Decreased extensibility of the joint cavity can be the most negative consequence of extravasation limiting operating capacity of the instruments preventing adequate placement through the ports with a risk to the neurovascular structures [24]. The difficult to predict intraoperative phenomenon requires more attention to the anatomical structures near the ports. The ports can be relocated with a risk of extravasation in a prolonged surgery.

Open shoulder surgery

Open shoulder surgery is associated with a risk of peripheral nerve injury because of the use of retractors located anterior to the glenoid near the brachial plexus extending 10–25 mm medial to the glenoid [25]. As mentioned earlier, intraoperative positioning of the hand can cause stress to the brachial plexus creating preconditions for an injury. Open shoulder surgeries include rotator cuff repair, shoulder stabilization, total or partial joint replacement, and osteosynthesis of fractures. Adequate surgical access is practical in avoiding complications [26].

Anterior approach

is common in surgery of the anterior shoulder joint, anterior instability, osteosynthesis of the proximal humerus and joint replacement [27].

Technique

The anterior (deltopectoral) approach involves widening the interval between the deltoid and pectoral muscles. The cephalic vein is retracted superiorly and laterally along with the deltoid muscle to expose the conjoined tendon formed by the coracobrachialis tendon and the short head of the biceps. The subscapularis muscle is located underneath it. Divided or transected fibers of the subscapularis muscle allows access to the joint capsule. Open operations stabilizing the shoulder joint are more common using the deltopectoral approach and modifications. The reported incidence of neurological injury varies from 0.8 to 8.2 % [28]. A deltopectoral approach is associated with minimally displaced conjoined tendon with the MCN penetrating in the muscle fibers below. The MCN is at risk due to compression by the retractors located under the conjoined tendon. Caution is recommended when retracting muscles. The AN passes under the subscapularis muscle and is directed through the quadrangular space, therefore it is recommended to preserve the lowest quarter of the subscapularis muscle to protect this nerve. The Bristow-Latarjet operation is indicative in terms of the risks of damage to several nerves using the approach [29]. The bone autoplasty of a defect in the articular surface of the scapula is used to stabilize the shoulder joint. An osteotomy of the coracoid process is performed and the joint tendon attached is shifted to the anteroinferior glenoid defect [28]. A systematic review published in 2013 showed 21 cases of nerve injury with 1904 operations (1.2 %): MCN was the most commonly injured nerve followed by AN and diffuse brachial plexopathy [29]. There were reports of injury to the glenoid due to screws passing through the glenoid impinging on it as it is guided along the posterior edge of the articular process of the scapula, or due to excessive penetration during drilling. Medial deviation of the glenoid screws should be avoided according to anatomical studies [30].

Lateral approach

The lateral approach suggests an incision parallel to the lateral edge of the acromion to allow wide visualization of the subacromial space. Other approaches include Neer (anterolateral), Mackenzie (more laterally displaced), Bigliani incisions starting from the acromioclavicular joint and including split variants [31, 32]. They can be used for rotator cuff injuries, impingement syndrome, for joint replacement and osteosynthesis of the proximal humerus. Minimally invasive plate osteosynthesis (MIPO) techniques are performed through a delta split in case of proximal humerus fractures. An intact position of the AN is essential for a low-traumatic plating [33].

Anatomy

It is not recommended to cut the deltoid muscle 5 cm below the acromion to avoid damage to the AN. Yildirim et al. reported an influence of the upper limb length to the phenomemon with a safe range being at least 5.5 cm [34]. The distance between the acromion and the anterior ramus of the AN can vary [35] and decrease with abduction [36]. Wilkinson et al. reported 755 MRIs of the shoulder joints showing the lower articular edge of the humeral head as a horizontal landmark for the passage of the axillary neurovascular bundle and a window measuring 22 mm below this projection being the most dangerous zone [37].

Technique

The lateral approach and delta split involve subperiosteal cut of the deltoid muscle from the acromion or separation of its fibers, respectively. Suturing is important for MIPO access to protect the AN [33]. The suture prevents further separation of the muscle tissue with access retraction.

Posterior approach

The approach is performed during surgery of the posterior part of the shoulder to repair injuries to the posterior portion of the rotator cuff and posterior instability [31].

Technique

The posterior approach involves the use of the space between the infraspinatus muscle and the teres minor muscle. The deltoid muscle is separated from the spine of the scapula or split directly (according to Rockwood) [38]. The posterior capsule of the shoulder lies below them. Excessive medial retraction of the infraspinatus muscle can damage the SS [3].

Multifactorial complication of shoulder surgery

Distal peripheral neuropathy (DPN) is a rare neurological postoperative disorder [39]. The complication can be associated with a surgical shoulder manipulation and is difficult for differential diagnosis of the injury and the level (Fig. 2).

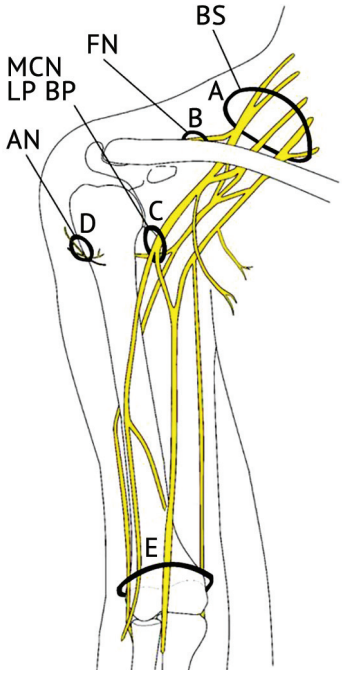

Fig. 2 Schematic representation of common injuries to nerve structures of the upper limb during shoulder surgery: (A) interscalene blockade of the brachial plexus, positioning of the patient on the operating table, intraoperative manipulations and movements of the surgeon with more proximal injuries leading to damage to the X and XII cranial brain nerves; (B) posterior approaches and arthroscopic ports; (C anterior approaches, deltopectoral in particular; (D) lateral approaches and arthroscopic ports; (E) area of the distal peripheral nerves, which can be damaged during intraoperative positioning of the patient and the upper limb, extravasation, tourniquet application, inadequate immobilization and rehabilitation. Abbreviations: BS, brachial plexus; FN, suprascapular nerve, MCN, musculocutaneous nerve; LP BP, lateral fascicle of the brachial plexus, AN, axillary nerve (illustrated by the author)

DPN was identified in 0–0.24 % of anatomical shoulder arthroplasties [39], 0.9 to 5.2 % in reverse arthroplasty [40], and 0 to 2 % after arthroscopic shoulder surgery. Although a direct cause-and-effect relationship with shoulder surgery has not been established there are prerequisites reported for the development of DPN including positioning of the upper limb, interscalene brachial plexus block [41], fluid extravasation, tourniquet application and prolonged immobilization. DPN after shoulder surgery is a multifactorial disease.

Tourniquet application

Tourniquets are inflated to high pressures that can damage nerves through mechanical compression and/or ischemia. Larger nerves are predominantly affected, and high pressure can lead to temporary loss of motor function and deterioration of sensory perception [42].

Prolonged immobilization

Nerve damage can be associated with prolonged immobilization using orthosis. Several cases of anterior interosseous nerve injury have been described in patients wearing a Robert Jones type orthosis or bandage after clavicle osteosynthesis [43]. A follow-up examination at 6 weeks reveals dysfunction of the patient's first finger. T2-weighted MRI shows marked swelling in the forearm muscle innervated by the anterior interosseous nerve. Post-immobilization contracture develops due to a traumatic disease represented by functional and morphological denervation of tissues

and muscle atrophy, leading to shortening of muscle fibers, a decreased elasticity of the joint capsule and rigidity [44]. Compartment syndrome develops in the elbow and the wrist due to swelling, mechanical compression with intrasurgical hand rests or inadequate use of orthosis and lack of early rehabilitation. Typical tunnel syndromes of the radial, ulnar, median nerves and their branches can develop to be treated with conservative treatment or surgical decompression in some cases [38].

DISCUSSION

Intraoperative injuries to the nerves of the shoulder are not common, but lead to catastrophic consequences. They can occur during operations performed for instability of the anterior shoulder, joint replacement and during fixation of multi-fragmental fractures of the proximal humerus. Preoperative preparation is essential and includes proper anesthesia and adequate positioning of the patient on the operating table with sufficient fixation of the head and torso. The operating team must have proper knowledge of the shoulder anatomy and specific features of the neurovascular formations. Particular care must be taken when establishing access through “secure areas”. Preoperative palpation of the bony landmarks outlining the contours for safe access, maintaining an “anatomy map” in case of edema are important. Operative time must be carefully monitored, especially during arthroscopy, to reduce the risk of nerve damage from extravasation. Any hand positioning must be physiological and consistent.

Despite advances in surgical technology, including the use of instruments that allow for less invasive procedures, the risk of nerve damage cannot be completely eliminated. Knowledge of the perioperative factors to developing neuropathy remains important. Increased intraoperative awareness and knowledge of anatomy, irrespective of open or arthroscopic surgery, necessitate careful postoperative assessments to determine whether injury has occurred [45]. Continuous intraoperative nerve monitoring is practical for avoiding risky manipulations having knowledge of safe zones. In 2005 A.N. Esmail et al. [46] and 2007 S.H. Nagda et al. [47] used this method for arthroscopy and replacement of the shoulder joint. Episodes of impaired impulse transmission during surgery were recorded in 17 out of 30 patients after arthroplasty. Removal or release of the retractor pressure was ineffective. It was initially assumed that this caused the equipment’s response. The hand returned to a neutral position led to improved condition in 77 % of cases. It was concluded that monitoring may be useful during surgery on a stiff joint or in patients with a history of open shoulder surgery. Pre- and intraoperative careful monitoring avoids the risk of further complications. A peripheral nerve damage is difficult to detect early after surgery due to immobilization with orthosis. An electrophysiological study can be practical in dubious cases. Earlier studies can help to determine whether the injury is electrophysiologically partial or complete with the presence of a single motor unit indicating a partial nerve injury [48]. If an acute nerve injury is suspected, stimulation electroneuromyography is recommended 10–14 days after injury [49]. Examinations performed approximately three months after injury may indicate early reinnervation through the presence of nascent potentials. The peripheral nerve surgery is normally scheduled no earlier than 3–6 months after injury, unless there is clinical or electrophysiological evidence of reinnervation during this period [50, 51]. Surgeons operating on the shoulder have skills in microsurgical nerve suturing. Early repair of nerve injury has been reported to achieve better functional outcomes [52, 53, 54, 55]. A secure fastening and wearing the orthosis is essential for rehabilitation. The patient should be informed by the operating surgeon about the timing of its use, how often it should be removed and how to perform exercises safely. This will reduce the risk of elbow and wrist contractures and minimize the likelihood of creating preconditions for the tunnel syndromes and other neuropathies.

CONCLUSION

The review allowed us to identify factors predisposing to damage to the peripheral nerves of the upper limb during shoulder surgery. Every stage is important, from preparation for surgery to the implementation of the adequate rehabilitation protocol. Adequate fixation of the head and torso is important for the patient in the lateral decubitus or the beach-chair position on the operating table with traction on the operated upper limb measuring 9 kg at most and using a specialized fixator. Careful preoperative marking of the surgical field and staining of bone landmarks should be produced after estimation of the expected length of operation. Arthroscopic ports are advised to move 1–2 cm distally during a long procedure to minimize the flow of intra-articular lavage fluid. An early ambulation programme can be discussed postoperatively with rehabilitation specialists to prevent neurological disorders.

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