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Iatrogenic Nerve Injuries During Shoulder Surgery

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Investigation performed at the Mayo Clinic, Rochester, Minnesota

Introduction: The current literature indicates that neurologic injuries during shoulder surgery occur infrequently and result in little if any morbidity. The purpose of this study was to review one institution's experience treating patients with iatrogenic nerve injuries after shoulder surgery.

Methods: A retrospective review of the records of patients evaluated in a brachial plexus specialty clinic from 2000 to 2010 identified twenty-six patients with iatrogenic nerve injury secondary to shoulder surgery. The records were reviewed to determine the operative procedure, time to presentation, findings on physical examination, treatment, and outcome.

Results: The average age was forty-three years (range, seventeen to seventy-two years), and the average delay prior to referral was 5.4 months (range, one to fifteen months). Seven nerve injuries resulted from open procedures done to treat instability; nine, from arthroscopic surgery; four, from total shoulder arthroplasty; and six, from a combined open and arthroscopic operation. The injury occurred at the level of the brachial plexus in thirteen patients and at a terminal nerve branch in thirteen. Fifteen patients (58%) did not recover nerve function after observation and required surgical management. A structural nerve injury (laceration or suture entrapment) occurred in nine patients (35%), including eight of the thirteen who presented with a terminal nerve branch injury and one of the thirteen who presented with an injury at the level of the brachial plexus.

Conclusions: Nerve injuries occurring during shoulder surgery can produce severe morbidity and may require surgical management. Injuries at the level of a peripheral nerve are more likely to be surgically treatable than injuries of the brachial plexus. A high index of suspicion and early referral and evaluation should be considered when evaluating patients with iatrogenic neurologic deficits after shoulder surgery.

More than 50,000 shoulder arthroplasties and 400,000 shoulder arthroscopic procedures are performed each year in the United States. There is potential for neurologic injury during these surgical procedures as the brachial plexus and its terminal nerve branches are in close proximity to the glenohumeral joint. However, the literature indicates that severe nerve injuries rarely occur[1-7]. Neurologic symptoms are present after approximately 0.2% to 3% of shoulder arthroscopic procedures, 4% of arthroplasties, and 8% of open surgery for the treatment of instability[1,2,5,6]. The majority of these injuries are minor cutaneous nerve lesions and transient neurapraxias[3,4,8,9]. Permanent sequelae and injuries that require secondary surgical intervention are rare, and the long-term outcomes of patients with nerve injury from shoulder surgery have been rarely reported.

At our institution's Brachial Plexus/Peripheral Nerve Injury Clinic, we have treated patients with severe neurologic injuries resulting from shoulder surgery. The purpose of this study was to critically review this patient population to draw attention to the possibility of nerve injures during shoulder surgery, to identify potential mechanisms of injury, and to define the long-term outcomes of patients with these injuries.

Materials and Methods

After institutional review board approval was obtained, a retrospective review of the Brachial Plexus/Peripheral Nerve Injury Clinic database from 2000 to 2010 was undertaken to identify all patients who had a nerve injury associated with any type of shoulder surgery. Sixty-three patients were identified, and their medical records were reviewed. To be included in the study, patients had to have been neurologically intact previously, been treated with an open or arthroscopic shoulder procedure, and had a postoperative nerve-related injury.

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

Patients were excluded when it was documented that the neurologic injury had preceded their shoulder operation; they had undergone a tumor resection with excision of involved nerves, biopsy of lymph nodes, treatment of a clavicle fracture, or closed manipulation of the shoulder for treatment of adhesive capsulitis; or they had a diagnosis of Parsonage-Turner syndrome (idiopathic brachial plexus neuritis).

Twenty-six patients who met the inclusion and exclusion criteria were identified. There were eighteen male and eight female patients. All patients were referred to our unit, and none were referred from our own shoulder/trauma division. The average age was forty-three years (range, seventeen to seventy-two years). Seven patients had undergone an open operation to address instability; four, total shoulder arthroplasty; nine, an arthroscopic procedure; and six, combined open and arthroscopic procedures. In the combined-procedure group, the open portion consisted of subpectoral biceps tenodesis (five) and suprascapular cyst excision in combination with a distal clavicle excision (one).

Patient's charts were reviewed to ascertain the British Medical Research Council (BMRC) grades (see Appendix) determined with manual motor examinations performed serially by one of three senior authors (A.Y.S., A.T.B., and R.J.S.). Nerve conduction studies, electromyograms (EMGs), and operative notes were reviewed. The following data were recorded: (1) operative procedure; (2) type of anesthesia including peripheral nerve blocks; (3) location of the brachial plexus or peripheral nerve injury based on examination, EMG, and operative findings; (4) time to presentation (time elapsed from injury to evaluation at our facility); (5) findings on physical examination at presentation and the time of follow-up; (6) treatment (either surgical or nonoperative); and (7) duration of follow-up. The physical examination findings were reported as the strength of affected muscles (BMRC grade) and neurologic findings such as paresthesia, pain, and the Tinel sign. The active range of shoulder motion was assessed by measuring forward flexion and abduction, which are reported as the angle between the humerus and thorax.

Patients were followed until maximum medical improvement was reached. When patients did not return for their appointments, attempts were made to contact them by telephone to assess functional status. The average duration of follow-up was seventeen months (range, two to seventy-two months). Seventeen of the twenty-six patients were included in the clinical outcome analysis. Nine patients were excluded. Five had been lost to follow-up and four had been followed for less than one year and had not reached maximal medical improvement.

The percentage of patients who required surgery or had a structural nerve injury was determined. A "structural nerve injury" was defined as an intraoperative finding of physical discontinuity of the nerve, such as a laceration, or suture entrapment. The decision for and timing of a surgical exploration of the nerve injury was individualized and was based on the surgical history, results of serial clinical examinations, EMG findings, and degree of suspicion for a structural injury. In general, surgery was performed if the patient did not demonstrate clinical or EMG signs of reinnervation within six months after injury.

Source of Funding
No external source of funding was used for this study.

Results

There was a total of twenty-nine neurologic injuries in twenty-six patients. The location of these injuries is diagrammatically presented in Figures 1-A and 1-B. Sixteen injuries were to a terminal nerve branch, including the axillary nerve (nine), suprascapular nerve (one), median nerve (two), radial nerve (three), and musculocutaneous nerve (one). Thirteen injuries involved the brachial plexus at various levels, including the cervical nerve roots (one), trunks (nine), and cords (three). Structural nerve injuries were present in nine (35%) of the patients; five had suture entrapment and four, nerve laceration.

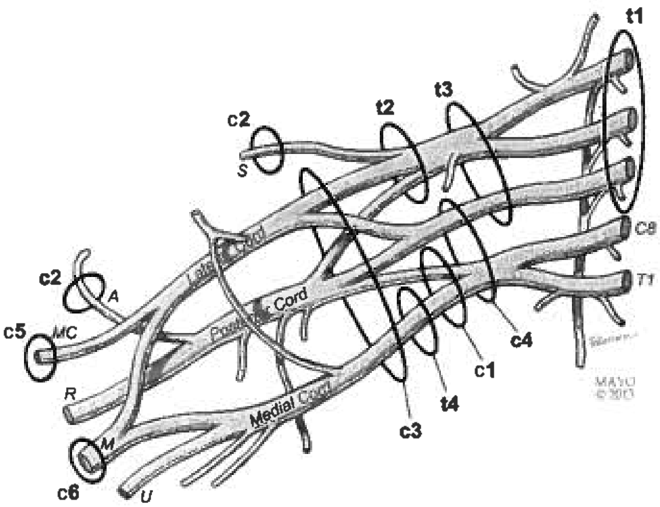

Fig. 1-A

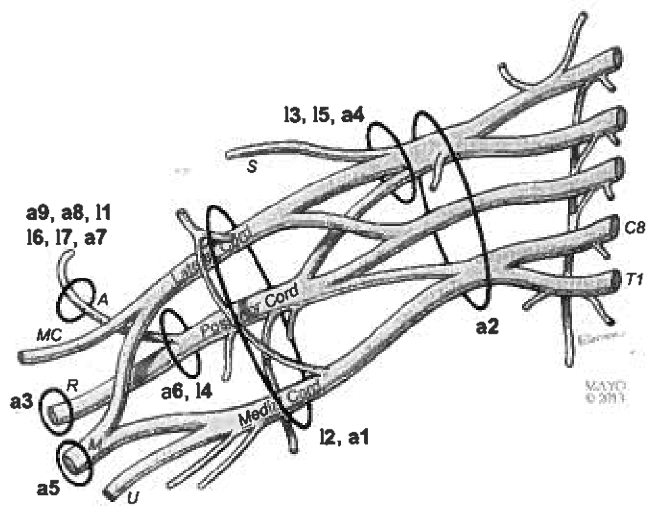

Fig. 1-B

Fig. 1-A Locations of the neurologic injuries following the total shoulder arthroplasties (t) and combined open and arthroscopic procedures (c). The case letter and number (c1, t1, etc.) correspond with those shown in Tables III and IV. S = suprascapular nerve, A = axillary nerve, MC = musculocutaneous nerve, R = radial nerve, M = median nerve, and U = ulnar nerve. (Copyrighted and used with permission of the Mayo Foundation for Medical Education and Research; all rights reserved.) **Fig. 1-B** Location of the neurologic injuries following the arthroscopic procedures (a) and open operations for instability (i). The case letter and number (a1, i1, etc.) correspond with those shown in Tables I and II. S = suprascapular nerve, A = axillary nerve, MC = musculocutaneous nerve, R = radial nerve, M = median nerve, and U = ulnar nerve. (Copyrighted and used with permission of the Mayo Foundation for Medical Education and Research; all rights reserved.)

Of the seventeen patients who were followed for more than one year, three had full recovery. Fourteen patients had persistent motor and/or sensory impairment resulting from their injury. One of these individuals had cutaneous numbness that was a relatively minor deficit. The remaining thirteen had substantial motor and/or sensory deficits that affected their ability to perform activities of daily living. Five patients had

TABLE I Nerve Injuries Following Open Procedures to Treat Instability

Case	Sex, Age *(yr)*	Operation	Plexus Injury	Treatment Course	Findings at Follow-up
i1	F, 17	Open capsular shift	Axillary nerve sutured to inferior capsule	5 mo: nerve repair	2 yr postop.: 3/5 deltoid strength. Active abduction to 35° and chronic pain
i2	F, 21	Open capsular shift (revision), subscapularis repair	Pan brachial plexus and axillary artery sutured at cord level (see Appendix)	1 mo: interpositional nerve grafts. 2 yr: tendon transfers for wrist and finger extension. 3 yr: thumb carpometacarpal and interphalangeal fusion, intrinsic tenodesis	3 yr postop.: difficulty with pinch strength and fine motor use of hand
i3	M, 29	Open Bankart repair, subscapularis advancement	Upper trunk	Observation	7 mo postop.: slight shoulder weakness (deltoid, rotator cuff 4/5) and biceps weakness (4/5). Decreased sensation in C5
i4	F, 34	Open Bankart repair	Axillary and radial nerves sutured to inferior capsule (see Appendix)	5 mo: interpositional nerve grafting, tendon transfers for radial nerve dysfunction	6 yr postop.: poor functional outcome. Shoulder abduction to chest level. Limited use of hand. Was unable to continue working
i5	M, 19	Open Bankart repair, capsular shift	Upper trunk	Observation	5 yr postop.: numbness of superficial branch of radial nerve
i6	M, 19	Open Bankart repair, capsular shift	Axillary nerve	8 mo: neurolysis	Lost to follow-up
i7	M, 21	Open Bankart repair, capsular shift	Axillary nerve sutured	5 mo: neurolysis	Lost to follow-up

shoulder dysfunction that consisted of a reduced range of motion secondary to loss of motor strength. Two patients had loss of elbow flexion strength resulting from biceps and brachialis paralysis. Six patients had weakness of the intrinsic hand muscles, and three had chronic neurogenic pain.

Open Surgery for Treatment of Instability

Seven patients had nerve injury resulting from an open surgical procedure to treat shoulder instability (Table I). All patients had a general anesthetic, and two received an additional suprascapular nerve block. Three patients had an injury at the level of the brachial plexus (two in the upper trunk and one at the cord level) and four, at a terminal nerve branch (three of the axillary nerve and one combined injury of the axillary and radial nerves). There were four structural nerve injuries, with the nerves entrapped by sutures passed through the capsule in all instances (see Appendix). The medial, lateral, and posterior cords of the brachial plexus were sutured in one instance; the axillary nerve was sutured in two cases; and the radial and axillary nerves were involved in one case.

Five of the seven patients required surgery to remove the incarcerating suture, followed by nerve repair, nerve grafting with sural nerve grafts, and/or subsequent tendon transfers to restore hand function.

Four patients in this group were followed for more than one year. One of them had a minor deficit (numbness of the superficial branch of the radial nerve), and the other three had substantial motor and/or sensory deficits.

Arthroscopic Procedures

Nine patients had nerve injury secondary to arthroscopic procedures (Table II). In addition to general anesthesia, four patients had a suprascapular nerve block. Two procedures were performed with the patient in the lateral position with traction and the remainder, with the patient in a beach-chair position. Three patients had an injury at the level of the brachial plexus (the upper trunk in two and the cord level in one) and six, at a terminal nerve branch (axillary nerve in three, axial and radial nerve in one, radial nerve in one, and median nerve in one). Five of the nine patients had surgical treatment of the nerve injuries. Two of them had nerve transfers, one was treated with nerve graft, one had a tendon transfer for median nerve function, and one had an unrepairable nerve lesion secondary to injury at the neuromuscular junction with severe pain and underwent a proximal axillary neuroma excision. There were two cases of structural nerve damage during an arthroscopic Bankart repair: the anterior division of the axillary nerve was sutured in one patient (see Appendix), and the axillary nerve was lacerated in the other. In the latter patient, the nerve was lacerated at the neuromuscular junction near the posterior portal.

Four patients underwent conservative treatment (observation). Three of them had presented for evaluation more than twelve

TABLE II Nerve Injuries Following Isolated Arthroscopic Procedures

Patient	Sex, Age (yr)	Operation	Plexus Injury	Treatment Course	Findings at Follow-up
a1	M, 65	Arthroscopic mini-open rotator cuff repair	Pan brachial plexus at cord level, axillary artery transection	Observation	3 yr: weakness of intrinsic hand muscles (2/5), difficulty with some fine motor function
a2	M, 72	Arthroscopic subacromial decompression, rotator cuff repair	Pan brachial plexus at trunk level	Observation	1 yr: weak thenar musculature of hand (3/5) with decreased thumb opposition strength
a3	M, 59	Arthroscopic subacromial decompression, distal clavicle excision, subscapularis repair, coracoid decompression, biceps tendon debridement	Radial nerve	Observation	2 mo: full recovery
a4	M, 59	Arthroscopic mini-open rotator cuff repair and subacromial decompression. Lateral position with arm in traction	Upper trunk/lateral cord	Observation (options limited due to delayed presentation at 18 mo)	3 yr: biceps and brachialis strength 2/5, very weak elbow flexion
a5	M, 59	Arthroscopic subacromial decompression and SLAP repair	Median nerve	7 mo: tendon transfers (brachioradialis to flexor pollicis longus and side-to-side tenodesis of flexor digitorum profundus of index, long, and ring fingers)	12 mo: chronic neuropathic pain, hand function restored
a6	M, 27	Arthroscopic Bankart repair	Axillary and radial nerves	6 mo: nerve transfer (triceps branch of radial nerve to axillary nerve)	11 mo: gradually recovering deltoid function. Last seen 5 mo after nerve transfer: had not reached maximal improvement
a7	F, 62	Arthroscopic Bankart repair	Axillary nerve lacerated at quadrilateral space and at muscle insertion	15 mo: axillary nerve exploration, neuroma resection. (Given distal area of injury, nerve transfer not possible)	1 yr: full range of shoulder motion although compensating muscles, function limited by shoulder weakness (deltoid 0/5)
a8	M, 53	Arthroscopic rotator cuff repair	Axillary nerve	5 mo: nerve graft	Lost to follow-up
a9	M, 17	Arthroscopic Bankart repair	Anterior division of axillary nerve sutured to capsule (see Appendix)	7 mo: nerve transfer (triceps branch of radial nerve to axillary nerve)	11 mo: gradually recovering deltoid function. Last seen 3 mo after nerve transfer: not reached maximal improvement

months after injury; had residual ulnar, median, and/or musculocutaneous nerve deficits; and were advised that nerve surgery would not be of benefit secondary to the time that had elapsed since the injury. All chose to be observed. The remaining patient had a radial nerve palsy that resolved by two months after surgery.

Of the nine patients, only one made a full recovery; the remaining eight had debilitating motor/sensory deficits.

Combined Open and Arthroscopic Procedures

Six patients had nerve injury resulting from a combined procedure (Table III). The arthroscopic portions included diagnostic arthroscopy, subacromial decompression, and debridement or repair of the rotator cuff. The open portion was a subpectoral biceps tenodesis in five cases; in the remaining patient, a cyst was excised from the supraspinatus muscle in combination

TABLE III Nerve Injuries Following Combined Open and Arthroscopic Shoulder Surgery

Case	Sex, Age (yr)	Operation	Plexus Injury	Treatment Course	Findings at Follow-up
c1	M, 42	Arthroscopic subacromial decompression, distal clavicle excision, rotator cuff repair. Open subpectoral biceps tenodesis	Lower trunk/medial cord	9 mo: tendon transfers (brachioradialis to flexor pollicis longus, pronator teres opponensplasty, brachialis to flexor digitorum profundus), thumb interphalangeal fusion	13 mo: limited hand function
c2	F, 41	Arthroscopic subacromial decompression. Open distal clavicle excision, removal of ganglion cyst from supraspinatus muscle	Axillary nerve neurapraxia and suprascapular nerve laceration	5 mo: nerve transfer (spinal accessory nerve to suprascapular nerve transfer), axillary nerve neurolysis	4 yr: full recovery
c3	F, 42	Arthroscopic subcoracoid decompression, debridement of partial subscapularis tears. Open subpectoral biceps tenodesis	Pan brachial plexus	Observation	Lost to follow-up
c4	F, 45	Arthroscopic subacromial decompression, distal clavicle excision. Open subpectoral biceps tenodesis	Middle and lower trunks	Observation: surgical options limited by delayed presentation (10 mo) and fixed contractures of hand	2 yr: very limited hand function
c5	M, 56	Arthroscopic rotator cuff repair. Open subpectoral biceps tenodesis	Musculocutaneous nerve lacerated (see Appendix)	8 mo: partial ulnar nerve transfer to musculocutaneous nerve	16 mo: very weak elbow flexion, unable to lift >10 lb (4.5 kg)
C6	M, 29	Diagnostic shoulder arthroscopy. Open subpectoral biceps tenodesis	Median nerve transection	2 mo: nerve grafting	4 mo. Last seen 2 mo after nerve grafting: had not reached maximal improvement

with a distal clavicle excision. In addition to a general anesthetic, two patients received regional nerve blocks. Three patients had an injury to the brachial plexus, and three had a terminal nerve branch injury. A structural nerve injury occurred in three cases.

The open procedure was responsible for three of the nerve injuries. Two nerve lacerations were caused by an open subpectoral biceps tenodesis: the musculocutaneous nerve was lacerated in the region of the tenodesis screw (see Appendix) in one of these cases, and the median nerve was mistaken for the biceps tendon and was stitched and tenodesed into the humerus in the other patient. The third laceration, which involved the suprascapular nerve, occurred during the excision of a cyst from the supraspinatus. We could not ascertain if the nerve injury was secondary to the open or the arthroscopic procedure in three patients treated with a combined procedure.

Four of the six patients required surgical management, and surgery would have been considered for one other patient if she had presented before developing fixed contractures of the hand. Surgery consisted of tendon transfers in one patient, nerve transfers in two, and nerve grafting in one. Four patients had more than one year of follow-up; one made a full recovery, and the other three had substantial functional impairment.

Arthroplasty

Four patients had nerve injuries following a total shoulder arthroplasty (Table IV). In addition to general anesthesia, there were two regional nerve blocks. All of the injuries involved the brachial plexus. There were no structural nerve injuries. One patient required an Eden-Lange tendon transfer because of persistent scapular winging. Three patients were followed for more than a year; one made a full recovery, and the other two had limited shoulder function.

Time to Presentation

The average time between the injury and evaluation was 5.4 months (range, one to fifteen months; median, five months) in the series overall. In three patients, the clinical outcome was compromised specifically because of treatment delay. These individuals presented at eight, ten, and eighteen months after their injury. In two patients, the opportunity for nerve transfers

TABLE IV Nerve Injuries Following Total Shoulder Arthroplasty

Patient	Sex, Age (yr)	Operation	Plexus Injury	Treatment Course	Findings at Follow-up
t1	M, 56	Total shoulder arthroplasty (revision of hemiarthroplasty)	C4-C7 nerve roots	2 yr: Eden-Lange procedure (transfer of rhomboid and levator scapulae for scapular winging)	4 yr: 100° of forward flexion, 90° of abduction
t2	M, 59	Total shoulder arthroplasty (revision of hemiarthroplasty)	Upper trunk	Observation	1 yr: 90° of forward flexion, 30° of abduction
t3	F, 61	Total shoulder arthroplasty	Upper and middle trunks	Observation	8 mo: full recovery
t4	M, 49	Total shoulder arthroplasty	Medial cord	Observation (nerve transfer for ulnar nerve dysfunction could have been considered if patient were evaluated earlier than 8 mo)	Lost to follow-up

had been lost. In the third patient fixed contractures of the fingers had developed, prohibiting tendon transfers.

Distribution of Severe Injuries

The percentage of patients who had a structural nerve injury or who required surgical intervention varied according to the location of the nerve injury (see Appendix). Individuals presenting with an isolated lesion of a terminal nerve branch were more likely to have a structural nerve injury than patients who had an injury to the brachial plexus. Patients with a terminal nerve branch injury had spontaneous recovery less often and underwent surgical reconstruction more often than those with a brachial plexus injury.

The percentage of patients who sustained a structural injury or required surgical treatment also varied according to the type of index surgery (Fig. 2). The rates of structural injuries and surgical intervention were higher in patients who had undergone an open operation for instability or combined arthroscopic and open operations.

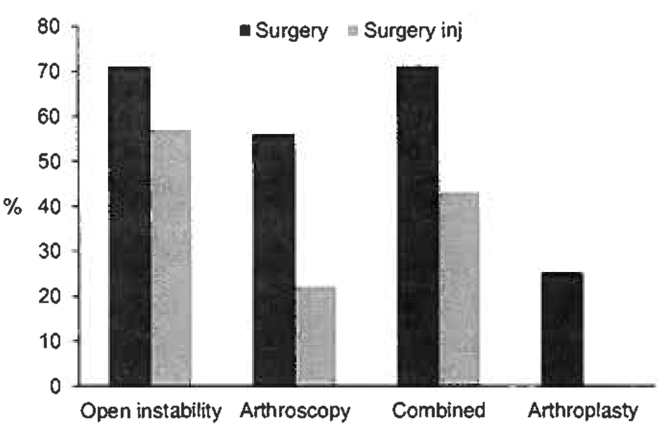

Fig. 2
The percentages of patients with a structural nerve injury were highest in the group with an open procedure for instability and the group treated with combined open and arthroscopic procedures.

Discussion

Patients who have neurologic symptoms following a shoulder surgical procedure may have a severe underlying neurologic injury that could result in permanent deficits. These events can occur after any type of shoulder procedure and may result from several potential injury mechanisms. All patients with postoperative neurologic symptoms should be evaluated with a high index of suspicion to avoid a delay in treatment. Patients who have a complete deficit of a peripheral nerve have a higher likelihood of having a structural nerve injury.

In this series, neurologic injuries resulted from a wide array of shoulder procedures. Some occurred during operations that are already recognized as having a risk for nerve injury, such as open procedures for instability and shoulder arthroplasties[1,2,10]. Other injuries were sustained during situations that have not been previously reported, and perhaps are not perceived, as being as susceptible to a neurologic injury, such as subpectoral biceps tenodesis and arthroscopic Bankart repair. These cases demonstrate that patients who present with a neurologic deficit following a shoulder operation must be closely followed and evaluated since they may have a permanent injury even if the perceived risk is low. The best example of this is isolated arthroscopic procedures; the risk of neurologic injury has been reported to be as low as 0.1% and there are very few reports of permanent neurologic deficits[3,5,6,9]. Yet five patients in our series had functional deficits at more than one year following shoulder arthroscopy.

Although severe injuries can occur in any setting, their likelihood appears to be higher in certain scenarios. Structural nerve injuries such as lacerations or suture entrapment most often occur when neurologic structures are in close proximity to the operative field while sutures are being placed or structures are divided. For instance, the musculocutaneous, median, and ulnar nerves are at risk during a subpectoral biceps tenodesis; the entire brachial plexus and axillary nerve, during an open operation for instability; and the axillary nerve, during an arthroscopic Bankart repair. Furthermore, a structural injury must be considered if a patient presents with a complete palsy of an isolated peripheral nerve. In contrast, stretch injuries resulting from retraction, such as occurs in shoulder arthroplasty, usually produce incomplete deficits of multiple nerves or a portion of the plexus. This is more likely when the involved nerves were not directly within the operative field, such as in a patient with an incomplete palsy of both cord levels of the brachial plexus affecting the ulnar and radial nerves following a total shoulder arthroplasty. Finally, we have observed that patients with suture entrapment injuries present with excruciating neuropathic pain in addition to loss of motor function immediately postoperatively.

The nerve injuries in this series were the result of multiple causes. Some patients had a structural nerve injury, and in those cases the mechanism of injury could often be clearly defined. In the remaining patients, the injuries had many potential causes. In open surgery, retractors placed anterior to the subscapularis or medial to the glenoid can injure the brachial plexus, which is located just 10 to 25 mm medial to the glenoid[11]. Arm positioning also places strain on the brachial plexus, and intraoperative neuromonitoring studies have demonstrated that nerve dysfunction may occur with extreme positions of the shoulder during arthroplasties and during arthroscopic procedures with the patient in the lateral position when traction is applied[12-14]. Complications of regional anesthesia are also possible but are likely very rare. It is estimated, on the basis of two large prospective studies, that neurologic injury results from three of 10,000 peripheral nerve blocks[15-17]. Furthermore, nearly two-thirds of the patients in this series had not had a block performed.

Regardless of the perceived cause of injury, it is important that patients with postoperative neurologic deficits be thoroughly and promptly evaluated. In this series, there was often a lengthy delay between the time of injury and referral for evaluation by a peripheral nerve surgeon. The average time lapse was 5.4 months. This is a very important point because the treatment options available to these patients are time-sensitive. Following a nerve injury, irreversible changes occur at the motor end plate in a time-dependent manner so that reinnervation procedures are most successful if they are performed before six months[18]. Furthermore, early referral allows the patient to have serial physical examinations and EMGs, which enables the treating surgeon to gauge recovery and assess the need for surgery. We recommend obtaining the first EMG at six weeks postinjury and serially thereafter.

We recognize the limitations of this study, which include its retrospective nature and the biases that are inherent to retrospective studies. Additionally, we have a very specialized referral practice, and the referral bias may reflect more severe injuries. We also recognize that a large majority of nerve injuries associated with shoulder surgery are neurapraxias and often resolve spontaneously. However, despite these limitations, serious nerve injuries do occur, cannot be ignored, and cannot always be attributed to neurapraxia.

In conclusion, although nerve injuries after shoulder surgery are relatively uncommon, severe neurologic injuries can occur. Severe injuries resulting from shoulder surgery are more commonly direct nerve injuries caused by either laceration or suturing and tend to be isolated terminal nerve branch injuries. These injuries may require surgical management and can result in permanent disability. Lengthy delays in evaluation can compromise the final outcome. When evaluating a postoperative neurologic deficit following shoulder surgery, surgeons should maintain a high index of suspicion for nerve injuries that will not resolve spontaneously and may require timely surgical management.

Appendix

eA A table showing the BMRC muscle grading system and figures demonstrating individual cases are available with the online version of this article as a data supplement at jbjs.org. ■

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