Axillary nerve injury associated with sports

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Object. The aim of this retrospective study was to present and investigate axillary nerve injuries associated with sports.

Methods. This study retrospectively reviewed 26 axillary nerve injuries associated with sports between the years 1985 and 2010. Preoperative status of the axillary nerve was evaluated by using the Louisiana State University Health Science Center (LSUHSC) grading system published by the senior authors. Intraoperative nerve action potential recordings were performed to check nerve conduction and assess the possibility of resection. Neurolysis, suture, and nerve grafts were used for the surgical repair of the injured nerves. In 9 patients with partial loss of function and 3 with complete loss, neurolysis based on nerve action potential recordings was the primary treatment. Two patients with complete loss of function were treated with resection and suturing and 12 with resection and nerve grafting. The minimum follow-up period was 16 months (mean 20 months).

Results. The injuries were associated with the following sports: skiing (12 cases), football (5), rugby (2), baseball (2), ice hockey (2), soccer (1), weightlifting (1), and wrestling (1). Functional recovery was excellent. Neurolysis was performed in 9 cases, resulting in an average functional recovery of LSUHSC Grade 4.2. Recovery with graft repairs averaged LSUHSC Grade 3 or better in 11 of 12 cases

Conclusions. Surgical repair can restore useful deltoid function in patients with sports-associated axillary nerve injuries, even in cases of severe stretch–contusion injury. (DOI: 10.3171/2011.8.FOCUS11183)

Key Words • axillary nerve • stretch–contusion injury • sports • deltoid muscle

Contact and low-intensity sports can result in axillary nerve injury,16 resulting in loss of deltoid function. This muscle is the major abductor of the shoulder. The axillary nerve arises from the posterior cord of the brachial plexus and contains fibers derived from C-5 and C-6 spinal nerve roots via the posterior division of the upper trunk. It passes through the quadrilateral space along with the posterior circumflex artery just distal to the shoulder joint. The nerve then curves around the posterolateral surface of the humerus deep to the deltoid and divides into anterior and posterior branches, both of which innervate that muscle. The nerve is tethered posteriorly as a result of the overlying muscle, making it susceptible to stretch. Etiologies include not only fracture and dislocation of the humerus, but less frequently compensation due to prolonged pressure arising from common sports-related activities. The purpose of this paper is to analyze indications for surgical repair and to access outcomes in patients with solitary axillary nerve injury associated with sports.

Abbreviation used in this paper: LSUHSC = Louisiana State University Health Science Center.
times MR imaging of the shoulder. In addition, these patients were often evaluated by orthopedists to rule out conditions resulting in comparable functional impairments, such as rotator cuff injury. In this way, a definitive diagnosis of axillary nerve injury could be established.

Surgical Procedure

An anterior infraclavicular surgical approach was used in all of our patients. In those cases in which the lesion was determined to extend significantly distally, a posterior approach was added to the anterior approach so that adequate exposure could be achieved. The patients were positioned supine and anesthetized with general endotracheal anesthesia. The table was then inclined to place the patient in an approximately 20° reverse Trendelenburg position. The patient’s arm was abducted approximately 10°–20°.

The mildly curvilinear incision extended from the level of the clavicle to the axilla. At the deltopectoral groove, the pectoralis major muscle was incised and split in the direction of its fibers. A self-retaining retractor was used to hold the muscle edges apart. Laterally and medially, bundles of split pectoralis major were set aside for subsequent repair.

The deltopectoral vein and associated vascular branches were ligated at the superior aspect of the wound, and the underlying pectoralis minor muscle was divided transversely. The self-retaining retractor was then repositioned to a deeper level and placed along both edges of the pectoralis minor.

After the lateral cord was identified and dissected free from adipose and scar tissue, it was traced distally to and through its contribution to the median nerve. Next, the cord was followed past its branches to the coracobrachialis, and finally, on to its continuation as the musculocutaneous nerve. The latter was freed up several inches to the radial nerves. By retracting the more distal axillary artery medially, and by displacing the musculocutaneous nerve superiorly and either medially or laterally, access to the deeper axillary nerve, including that in the quadrilateral space, could be gained.

On occasion, posterior circumflex vessels were encountered and had to be ligated and divided. At this level, the axillary nerve passes lateral to the profundus branch of the axillary artery, whereas the radial nerve is located on its medial side (Fig. 2).

To reach the quadrilateral space, the axillary nerve follows a slightly oblique course laterally and posteriorly. Exposure of the nerve down to the level of the quadrilateral space was sometimes assisted by deep placement of 1 or 2 small self-retaining retractors. Just distal to the inferior shoulder joint capsule, the nerve passes through the quadrilateral space along with the posterior circumflex humeral artery. The quadrilateral space is bounded by the teres minor above, the long head of the triceps medially, the teres major and latissimus dorsi muscles below, and the humeral neck laterally. Posteriorly, the axillary nerve divides into anterior and posterior branches. The posterior branch supplies the posterior portions of the deltoid muscles, and a small branch from this posterior division innervates the teres minor. The posterior branch of the axillary nerve also supplies sensation to the skin overlying the deltoid muscle. The anterior branch curls around the surgical neck of the humerus under the deltoid muscle and branches as it extends to the anterior border of the deltoid. The branches further divide to innervate this muscle (Fig. 3). The deltoid is composed of 3 bundles of muscle fibers that contract in concert to raise the arm laterally. Contraction of the anterior bundles, however, provides a more significant contribution to anterior or forward abduction. This motion is aided by the pectoralis major muscle and sometimes by the long head of the biceps, depending on its relationship to the glenohumeral joint.

### TABLE 1: Sports associated with axillary nerve injury in 26 cases

<table>
<thead>
<tr>
<th>Sport</th>
<th>No. of Cases (%)</th>
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<tbody>
<tr>
<td>skiing</td>
<td>12 (46)</td>
</tr>
<tr>
<td>football</td>
<td>5 (19)</td>
</tr>
<tr>
<td>rugby</td>
<td>2 (8)</td>
</tr>
<tr>
<td>baseball</td>
<td>2 (8)</td>
</tr>
<tr>
<td>ice hockey</td>
<td>2 (8)</td>
</tr>
<tr>
<td>soccer</td>
<td>1 (4)</td>
</tr>
<tr>
<td>weightlifting</td>
<td>1 (4)</td>
</tr>
<tr>
<td>wrestling</td>
<td>1 (4)</td>
</tr>
</tbody>
</table>

### TABLE 2: The LSUHSC grading scale for axillary nerve palsy and deltoid muscle weakness*

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no deltoid contraction</td>
</tr>
<tr>
<td>1</td>
<td>trace of deltoid contraction</td>
</tr>
<tr>
<td>2</td>
<td>some abduction of shoulder beyond 30° w/ gravity eliminated</td>
</tr>
<tr>
<td>3</td>
<td>abduction of shoulder against gravity &amp; mild pressure; lateral abduction usually 60°–90°</td>
</tr>
<tr>
<td>4</td>
<td>abduction of shoulder against gravity &amp; moderate pressure; lateral abduction usually &gt;90°</td>
</tr>
<tr>
<td>5</td>
<td>abduction of shoulder against gravity &amp; great amount of pressure; lateral abduction usually &gt;110°</td>
</tr>
</tbody>
</table>

Axillary nerve injury

Intraoperative nerve action potential recordings guided the method of surgical repair of the nerve. If a nerve action potential was recorded through and distal to the stretch–contusion injury, then the epineurial scar was removed, but the lesion in continuity was not resected. If the lesion was irregular, neurolysis was performed along the full extent of the lesion. The skeletonized nerve was then examined. If a portion of that nerve on cross-section appeared worse than the rest, that specific portion was resected across the lesion. The nerve was subsequently repaired, usually with grafts, leaving the rest of the nerve intact. If there was no action potential conducted across the lesion, the lesion was resected and the gap was usually repaired by means of grafts—either sural or antebrachial cutaneous nerves—using a technique similar to that described by Millesi. If a lesion in continuity was not significantly long, then suture repair was performed.

**Follow-Up**

Postoperatively deltoid function was again assessed by means of both clinical examination and electromyography. All patients were evaluated at least once during the follow-up period (range 16 months–6 years, mean 20 months).

**Results**

Twenty-six cases were surgically explored via an infraclavicular approach. After a mean follow-up of 20 months, functional recovery appraised by means of the LSUHSC grading system was quite satisfactory. Nine patients with partial nerve loss Grade 1 or 2 preoperatively, underwent exploratory surgery. In this subset of patients, neurolysis was performed on the axillary nerves.
Postoperatively, the nerves recovered satisfactorily, and a mean grade of 4.2 was attained. Another subset of 3 patients with stretch injuries in continuity were found to have complete nerve loss preoperatively. Intraoperatively, nerve action potentials were able to be conducted across the lesion. These nerves were treated with neurolysis alone and eventually a grade of 3–4 was attained in each of these cases (Table 3). In 2 patients, resection and suture repairs were performed for relatively focal lesions. Nerve action potentials could be conducted across the lesions. The mean outcome grade in these cases was 3–4. In 12 patients, graft repairs were made for lengthier lesions in continuity that required resection; the mean outcome grade was 3 in 3 patients, 3.5 in 8 patients, and 4 in 4 patients. Specifically, outcomes of neurolysis from partial loss (1 case) and resection with graft from complete loss (1 case) revealed extraordinarily good results with post-operative grades of 4.2 and 4, respectively.

**Discussion**

*Incidence in Various Sports*

Most axillary nerve injuries described to date in the literature have been part of a combined brachial plexus injury. In 1999, however, Oberle et al. presented a case of axillary nerve paralysis after excessive squash playing. In 2003, repair of axillary nerve–associated shoulder injury either with or without fracture/dislocation was reported by the senior authors in our group (D.G.K. and D.H.K.). For the first time, isolated axillary nerve palsy was credited with a dominant role in shoulder dysfunction. Previously, our senior authors showed that tailoring the surgical repair to restore the axillary nerve yielded satisfactory results. This current paper takes the repair of the axillary nerve one step further by categorizing the nuances of the surgical repair and assigning them to be applied to specific subsets of patients, as determined from nerve action potential measurements across the lesion.

In our series, skiing and football were the sports most often associated with axillary nerve injury—involves, respectively, in 46% and 19% of the injuries in our case series. Krivickas and Wilbourn reported a very large series of over 200 sports-related nerve injuries. Wrestling, football, rugby, and weightlifting were the 4 sports in which the highest numbers of peripheral nerve injuries were identified. The absolute number of injuries seen as a result of participation in a particular sport suggests that the risk of nerve injury is higher in certain sports and that the risk is also influenced by a specific referral base for a particular patient population. The most common upper-extremity injuries were cervical radiculopathies and brachial plexopathies, usually the result of severe burners (also referred to as stingers) sustained while wrestling or playing football. A related study by Hirasawa also reported some cases of nerve palsies, but the causes were limited to injuries sustained during mountain climbing, gymnastics, and baseball. The reported prevalence of nerve injury after anterior dislocation of the shoulder ranges from 5% to 25%, and it tends to increase with advancing age. In adolescents and young adults who have already had one shoulder dislocation, the prevalence of recurrent shoulder dislocation is about 40%.

Another sport deserving of attention is ice hockey. The peripheral nerves of the upper extremity are exposed

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**TABLE 3: Outcome of axillary nerve repair in 26 cases**

<table>
<thead>
<tr>
<th>Condition &amp; Treatment</th>
<th>No. of Cases</th>
<th>Mean Postop Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>partial loss &amp; positive NAP†</td>
<td>9</td>
<td>4.2</td>
</tr>
<tr>
<td>neurolysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete loss &amp; positive NAP‡</td>
<td>3</td>
<td>3–4</td>
</tr>
<tr>
<td>neurolysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>resection &amp; suture</td>
<td>2</td>
<td>3–4</td>
</tr>
<tr>
<td>resection &amp; graft</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

* NAP = nerve action potential.
† The mean preoperative grade was in the range of 1–2.
‡ The preoperative grade in each case was 0.
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to acute and chronic mechanical injuries in ice hockey players. This is due to frequent repetitive motions, large muscular forces, and extreme shoulder positions. Colak et al.5 evaluated the effect of ice hockey playing on the axillary, musculocutaneous, and radial nerves crossing the upper arm region. In this study, the values of distal motor latency of the axillary, musculocutaneous, and radial nerves were found to be significantly prolonged in ice hockey players compared with controls. Hence, ice hockey and similar sports can repetitively stress the upper extremity through repeated hard throwing motions

Mechanism of Injury

Axillary nerve injuries occur both with and without shoulder dislocation. When the shoulder is not dislocated, blunt trauma to the anterior aspect of the shoulder has been implicated in causing axillary nerve injury. This occurs in sports such as football, wrestling, and ice hockey as a result of blows from helmeted heads of other players to the shoulder.3,11,16 A more frequent athletic injury, however, is nerve injury resulting from anterior shoulder dislocation (Fig. 4).4,11 The incidence of nerve palsy after acute dislocations of the shoulder ranges from 9% to 18%.5,23 The prevalence of electrophysiologically documented nerve damage associated with closed shoulder trauma is reported to be up to 62% and most frequently involves the axillary nerve.10 Occasionally, the axillary nerve is damaged during reduction of a shoulder dislocation. After glenohumeral dislocation, transient axillary numbness is often noted. This usually reflects neurapraxia rather than a more severe nerve injury.

Initially, the mechanism of axillary nerve injury in sports was described by Bateman,2 in 1967, as being the result of an upward driving force directly into the armpit. A traumatic insult such as this has the ability to crush the posterior cord against the inferior aspect of the glenohumeral joint, resulting in axillary nerve palsy. An alternative mechanism was also described that attributed falling backward to result in traumatization of the axillary nerve. As far as sports such as baseball, skiing, ice hockey, and football are concerned, stretch injuries of the nerve rank highest on the list of causes of axillary nerve injury. This is mainly due to the repetitive motions specific to individual sports, which engage the same, distinct muscles repeatedly, leading to overuse of particular muscles or muscle groups and adverse effects on the associated nerves.

Many proposed mechanisms of injury are described in the literature in regard to blunt trauma to both the shoulder and the deltoid muscle. Perlmutter and colleagues described compression of the axillary nerve by a helmeted head blow as it travels on the deep surface of the deltoid.24-26 Direct blunt trauma to the anterolateral aspect of the shoulder via the same mechanism has also been noted to cause axillary nerve injury. There may also be a traction component associated with this injury, as scarring of the axillary nerve distal to the quadrilateral space, as well as scarring to the intramuscular portion of the nerve, has been identified.

A direct blow to the anterior lateral deltoid muscle is another main cause of the injury for athletes playing contact sports.3 The proximity and route of the axillary nerve along the deltoid muscles make it vulnerable to the injuries sustained from contact sports. Furthermore, the short length of the axillary nerve renders it vulnerable to stretch injuries, especially during shoulder dislocation.11

Quadrilateral space syndrome represents a chronic compression syndrome of the axillary nerve in athletes whose sports of choice require repetitive throwing motions.11,18,28 Teres minor is the superior margin of the quadrilateral space. If fibrous bands develop at the inferior edge of the teres minor, they can compress both the axillary nerve and the posterior humeral circumflex artery. Quadrilateral space syndrome can cause complete denervation of the deltoid and teres minor muscles by compressing the axillary nerve. Compression could be more severe in the abducted, externally rotated (throwing) position.28 Cheung et al.7 described the effects of shoulder position on axillary nerve positions during the split lateral deltoid approach.

Clinical Presentation and Examination

Surprisingly, many patients with axillary nerve injury may be asymptomatic even though they have sustained complete or incomplete lesions.29 Pain is not a prominent complaint, and deltoid weakness is often masked by compensation from surrounding muscle groups.1 In the acute setting, the athlete classically presents with weakness in abduction, decreased sensation along the deltoid muscle insertion, progressive atrophy of the deltoid muscle, and subluxation of the glenohumeral joint.

When affected athletes exercise, however, they may fatigue quickly. This is especially noted with overhead activity and heavy lifting. Affected persons may also notice reduced strength with abduction or an inability to raise the arm. Furthermore, numbness of the lateral arm may be noted. The presence of trauma, dislocation, or fracture should be documented. The physical examination of athletes with axillary nerve injury should include evaluation for range of motion (passive and active) and strength in all planes. External rotation strength is important to assess, because 45% of external rotation strength is from the teres minor. This is an important distinction, because global strength, especially abduction and forward elevation, is predominantly provided by the deltoid, the prime mover of the shoulder. When a patient is seen late in the course of the affliction, muscular atrophy, particularly of the deltoid and teres minor, should be noted, as it is of

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**Fig. 4.** Schematic illustration of the axillary nerve being stretched across the humeral head following shoulder dislocation. The capsule is represented as completely disrupted or greatly elongated. **A:** Intact shoulder joint and axillary nerve. **B:** Shoulder joint dislocation and stretched axillary nerve.
great importance in localizing the lesion. If the posterior deltoid and teres minor are spared, then the lesion is distal to the quadrilateral space. A complete neurovascular examination should be performed to assess sensation over the upper lateral arm and to rule out other lesions such as thoracic outlet syndrome and brachial plexus and cervical spine lesions. It is also important to note that complete deltoid muscle deficit may occur in the presence of normal sensation to the upper lateral arm and shoulder. Several reports have documented the unreliability of sensory changes after injury.

Axillary nerve injury resulting from a direct blow to the anterolateral shoulder, however, has a less optimistic prognosis. Perlmutter et al. noted persistent paralysis of the deltoid with such injuries in 11 athletes at 2.5–23 years after injury.

Acute axillary nerve palsy is often seen in the athletic setting, and careful physical examination and EMG evaluation are necessary to make an accurate diagnosis. Evaluation of strength is typically hampered by pain. The injured athlete can often elevate the arm using the pectoralis and supraspinatus muscles, and subluxation can be prevented by the supraspinatus and long head of the biceps muscles. Active arm elevation by compensatory muscles is seen in up to 60% of athletes after axillary nerve injury.

Careful manual muscle testing is important in identifying gross weakness in abduction. Patients with chronic compression of the axillary nerve in quadrilateral space syndrome typically present with tenderness in the posterior shoulder area in the quadrilateral space, which is exacerbated by placing the arm in the throwing position and resisting internal rotation. Symptoms, however, are often vague, consisting of a dull ache in the shoulder with progressive use, and may be difficult to differentiate from the internal impingement also seen in the throwing athlete.

**Treatment**

When electromyography reveals an axillary nerve lesion, the athlete should be reevaluated at monthly intervals for signs of nerve regeneration. Because the axillary nerve is relatively short, in the case of a second-degree injury (axonotmesis), recovery should be seen between the 3rd and 4th month after injury. Surgical exploration and possible nerve grafting are generally recommended if no return of function has occurred by 4–6 months after injury.

In our series, all patients who were deemed to be appropriate surgical candidates did not show adequate signs of spontaneous recovery (greater than LSUHSC Grade 2) even after 6–8 months of conservative therapy. Thus, surgical intervention was believed to be a reasonable treatment option. The patients in our series were further subdivided into 3 groups: neurolysis-only group, resection-and-direct-suture-repair group, and resection-and-graft-repair group; after surgical intervention, patients in all 3 groups showed satisfactory results.

The site of nerve injury is sometimes in the quadrilateral space, requiring both anterior and posterior surgical approaches. Cable grafts are commonly required if the axillary nerve ends cannot be repaired without tension, but despite this, the results of surgery are generally good, with restoration of 3–4/5 strength in the deltoid in more than 90% of patients. Chronic axillary nerve compression in quadrilateral space syndrome generally responds to conservative management, including changing pitching mechanics, which has been reported to be successful in 75%–90% of patients. Surgical intervention for quadrilateral space syndrome is indicated if conservative management fails and involves release of fibrous bands of the teres minor muscle and any aberrant bands crossing the quadrilateral space. Timing of surgery, however, remains controversial. In a thorough review of 146 cases, Bonnard et al. demonstrated a dramatic reduction in the number of successful outcomes with increasing delay between the time of injury and intervention. By contrast, Moor et al. showed the positive results in delayed axillary nerve reconstruction with interposition of sural nerve grafts and concluded that even delayed axillary nerve grafting may lead to satisfactory functional results with a low morbidity and should therefore be done in selected patients.

**Preventive Measures**

Proper conditioning and preventive measures in young athletes are important to avoid axillary nerve injuries around the shoulder. Most of these injuries occur in inexperienced athletes, and poor conditioning plays a large role. Preventing these types of injuries includes the following: adequate preseason examination; matching competitors for age, weight, and skill level; proper conditioning; avoiding excessive training at too early an age; thorough rehabilitation of the injured athlete before return to sports; appropriate and properly maintained equipment and playing fields; adequate supervision; and rule changes as necessary. Although in the US the highest injury rates are noted in adolescents participating in football, basketball, gymnastics, baseball, and roller skating, in Japan nerve injury occurs most commonly from mountain climbing—as a result of excessive backpack weight. Rather than condemning certain sports as unsafe because of a high incidence of injuries, proper training techniques should be emphasized in all sports to reduce the risk of these injuries.

**Conclusions**

Direct attacks and blows to the shoulder area are common for athletes playing contact sports. In addition, the axillary nerve has characteristic anatomical features such as its short length and a specific route beneath the deltoid muscle that predispose it to injury. As such, axillary nerve injury associated with sports has been a relatively common occurrence, with or without humerus fracture and dislocation. Favorable functional outcomes in those with axillary nerve injury are essential, especially for athletes who wish to continue engaging in their sport of choice. Therefore, surgical repair of the axillary nerve by means of neurolysis and nerve grafting should be considered in the management of these cases. In our patient population, surgical intervention appropriate to the extent of nerve injury has proven to be a reliable method of regaining deltoid function in severe cases of sports-related stretch–contusion injuries.
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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Kim, Lee. Acquisition of data: Lee, Saetia. Analysis and interpretation of data: Kim, Lee, Saetia, Saha. Drafting the article: Lee, Saetia. Critically revising the article: Kim, Saha, Kline. Reviewed submitted version of manuscript: Lee, Saha, Kline. Approved the final version of the manuscript on behalf of all authors: Kim. Administrative/technical/material support: Kim, Saetia, Kline. Study supervision: Kline.

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