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# **Axillary nerve injury in young adults - an overlooked diagnosis?**

## **Early results of nerve reconstruction and nerve transfers**

Short running title: Axillary nerve injury in young patients

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## **Abstract**

An injury to the axillary nerve from a shoulder trauma can easily be overlooked. Spontaneous functional recovery may occur, but occasionally reconstructive surgery is required. The time frame for nerve reconstruction procedures is from a neurobiological view crucial for a good functional outcome. We present a group of operatively and non-operatively treated young adults with axillary nerve injuries caused by motorcycle accidents, where the diagnosis was set late.

Ten male young adults (median age at trauma 13 years, range 9-24) with an axillary nerve injury were diagnosed by examination of shoulder function and electromyography (EMG). The patients had either a nerve reconstruction procedure or were treated conservatively and their recovery was monitored.

The axillary nerve was explored and reconstructed at a median of eight months (range 1-22 months) after trauma in 8/10 patients. Two patients were treated non-operatively. In 4/8 cases, a reconstruction with sural nerve graft was performed and in 1/8 case only exploration of the nerve was made (minor neuroma). In 3/8 cases a radial nerve branch transfer to the axillary nerve was chosen as the procedure. The shoulder was mobilized after three weeks with physiotherapy and the patients were monitored regularly. Functional recovery was observed in 9/10 cases (median follow up 11 months, range 7-64) with EMG signs of reinnervation in 7 patients.

Axillary nerve function should not be overlooked in young patients with a minor shoulder trauma. Nerve reconstruction can successfully recreate function.

**Key Words:** Axillary nerve, nerve injury, nerve reconstruction, nerve transfer, sural nerve, shoulder trauma

## **Introduction**

The axillary nerve, a terminal branch from the posterior fascicle of the brachial plexus, passes posteriorly through the quadrangular space together with the posterior circumflex humeral artery. It divides into two branches; one posterior and one anterior. The posterior branch innervates the teres minor and the posterior deltoid muscles and gives rise to a sensory nerve branch innervating the skin over the deltoid muscle. The anterior branch passes anteriorly around the surgical neck of the humerus and innervates the middle and anterior parts of the deltoid muscle [1-4].

A blunt trauma to the shoulder, with or without a dislocation of the gleno-humeral joint, has been suggested as the most frequently reason for an axillary nerve injury, particularly in connection with motorcycle accidents [5-7]. The nerve injury can be either minor with spontaneous functional recovery or it may be substantial and require nerve reconstruction to regain function [2]. An axillary nerve injury with associated impaired deltoid function is easily overlooked during the initial clinical examination at the emergency ward [8,9].

Therefore, such an injury may not be diagnosed directly after the trauma; instead the diagnosis is often set after an extensive amount of time when deltoid muscle has atrophied and the patient show subsequent shoulder weakness [10].

Previous studies, focusing on timing of nerve repair [11,12], have shown that time between trauma and surgery is an important factor for successful recovery. The success rate increases when reconstructive surgery is performed early after trauma [5]. However, the praxis of indication for surgery today is to wait three to six months, evaluate any spontaneous nerve recovery and operate if no recovery is found [9,10,13], although favorable results have also been shown when nerve reconstruction is further delayed [1,2,9,14,15].

Previous studies have only included adults and elderly patients[5,6]. However, based on results from peripheral nerve injuries in the hands [16], one may suspect that outcome may be

better in younger patients. Here, we present ten young males, with axillary nerve injury due to a shoulder trauma sustained by motorcycle accidents, where diagnosis was set late after the trauma.

## **Material and Methods**

### *Patients*

Ten male patients, were referred, examined and treated for an injury to the axillary nerve in Umeå and Malmö, Sweden between 2004 and 2010. All patients had received a direct trauma to the shoulder through motor vehicle accidents and were initially after the trauma examined either at their local hospital or by their GP. They were later referred, or went by own initiative, to a specialist for evaluation. Eight patients had a motocross accident on enclosed tracks; one patient was in a motorcycle accident abroad and one patient was in a snowmobile accident. We excluded patients who had received similar injuries from other type of traumas and patients who did not fall into the age group (i.e. > 25 years). The median age of the study population at the time of the accidents was 12.5 years (range 9-23 years), with three patients older than 15 years (Table 1). The patients were examined and diagnosed when they came in contact with the specialist. The median time from trauma to diagnosis was 8 months (range 1-22 months).

### *Methods*

Patients were examined clinically, which included examination of shoulder function (abduction, flexion), presence of sensation and/or atrophy of the deltoid muscle. Function of the suprascapular nerve, i.e. function of the supra- and infraspinatus muscles, was evaluated. Electromyography (EMG) was performed to confirm the injury in 9/10 patients more than six weeks after trauma and within two weeks after trauma in one patient (inconclusive) [9].

The decision of surgical or conservative treatment was based on the results from the clinical examination and EMG results as well as the time elapsed between trauma and diagnosis.

Different nerve reconstruction methods were used; nerve transfers of one branch of the radial nerve to the axillary nerve (n=3) [2,3,17], sural nerve graft to reconstruct a defect of the axillary nerve (n=4) or only neurolysis of the axillary nerve (n=1) [14]. A dorsal exploration was chosen when a nerve transfer was performed (Figure 1). Reconstruction of the axillary nerve with sural nerve graft, two nerve grafts of 6-7 cm each were used, was performed by an anterior incision and exploration [1,10].

Clinical recovery was graded as: *poor*-minimal or no activity in the deltoid (MRC scale M0-M2), *moderate*-intermediate activity and muscle weakness (MRC scale M3), *good*-muscle activity, some deltoid function and some atrophy (MRC scale M4) or *very good*-full activity, good deltoid function and no or minor atrophy (MRC scale M5).

## **Results**

### *Preoperative findings*

An overview of the patients is given in Table I. All patients had, in connection with a motorcycle accident (in one case snowmobile), suffered a blunt trauma to the shoulder and an axillary nerve injury. One patient had both axillary and suprascapular nerve injuries. Four out of 10 patients had history of a shoulder dislocation; out of them one had a tuberculum majus fracture and one had an axillary artery injury in their shoulder. Furthermore, one patient each had a clavicular fracture (and a Hill-Sachs fracture; observed late due to trauma abroad) and an acromio-clavicular dislocation. The remaining four patients did not have any other accompanying injuries.

Examination of the shoulder function showed deltoid muscle atrophy with loss of sensation in the area innervated by the axillary nerve in all patients, and four patients also had allodynia. One patient had a weakness of his biceps brachii and triceps brachii muscles. Furthermore, the examination showed that 6/9 (there are no results for one patient) patients had full range of movement of abduction and flexion in their shoulder joints, 2/9 had full flexion, but could only abduct 90 degrees and 1/9 had no active range of movement at all. The latter patient with no active movement was found to have a suprascapular nerve injury in addition to the axillary nerve injury.

All patients but one (examined within two weeks; inconclusive results) had a preoperative EMG, where 7/10 patients showed denervation activity in the deltoid muscle, 1/10 showed moderate denervation and 1/10 showed a moderate denervation in the anterior part of the deltoid, while the posterior part seemed normal. Furthermore, EMG results showed no voluntary activated motor end plate units in the 7 patients with denervation activity and some active units in the two patients with moderate denervation (Table I).

Severely impaired shoulder function and EMG findings showing no function in motor end plate units were the deciding factors for reconstructive surgery. Two out of 10 patients had good enough shoulder function and some active motor units. Therefore, they were treated conservatively with follow-ups to observe recovery. The remaining eight patients filled the criteria for surgery and underwent nerve reconstruction (Table I).

#### *Intraoperative findings*

The median time between trauma and surgery was 8 months (range 1-22 months). Three patients underwent surgery 14, 19 and 22 months after their trauma. Because previous studies using nerve graft reconstruction after more than 12 months after trauma have shown poor outcome, we choose to do radial nerve transfer procedures in those patients. These

patients all had successful surgery with satisfactory adaptation of a branch from the radial nerve to the axillary nerve (Figure 1). The other five patients were operated 9 months or less after their trauma. Therefore, they were selected for exploration of the axillary nerve and sural nerve grafting if possible. One of these patients was found to have a mild neuroma not requiring nerve grafting. Three patients were found to have a ruptured axillary nerve a few centimeters distally to the branching from the posterior fascicle. They were treated with a sural nerve graft reconstruction. The fifth patient had a hard scar at the same location in and around the axillary nerve, which was resected and a sural graft reconstruction was performed.

#### *Postoperative procedures and outcome*

All operated patients were immobilized in a collar and cuff for three weeks after surgery where after rehabilitation began. The patients were followed regularly and longtime evaluation is still going on. In the present study, the median follow up time was 11 months (range 7-64) with 2 patients less than 12 months. All patients regained full passive shoulder movement. Poor outcome was seen in 1/10 patient, moderate in 1/10, good in 7/10 and very good in 1/10 (Table I). Postoperative EMG was performed in 8/10 patients. Of these patients, seven showed reinnervation and activity in the deltoid muscle, while one patient, clinically graded as poor, showed no signs of reinnervation.

The two patients that were treated conservatively had their follow-ups at 22 and 27 months after their diagnosis and had a recovery classified as good and moderate, respectively. The three patients that had a radial nerve transfer were lastly followed-up at 11, 12 and 14 months, respectively, after surgery. Their recovery was good with selective deltoid muscle activation (e.g. examined by the patient bending forward and with slightly flexed elbow and abducted shoulder pulling the elbow posteriorly by extension in shoulder; thus, clear activation by palpation of the posterior part of the deltoid muscle) and less atrophy. The patient that had a



simple axillary exploration was followed-up 23 months after surgery. This patient showed good recovery with fresh reinnervation and muscle activity at EMG. The remaining four patients that had nerve graft reconstruction were lastly followed-up at 7, 12, 16 and 64 months, respectively, after surgery. The patient with the longest follow up had a very good recovery. The two patients with follow-ups at 12 and 16 months post surgery were classified as having a good recovery. The recovery of the patient with his latest follow-up at 7 months was evaluated to be poor with no deltoid activity or function and no reinnervation at EMG.

## **Discussion**

The present study included a homogenous group of young males, some very young, with a history of shoulder trauma due to motorcycle accidents, particularly on enclosed tracks. Practically, all earlier studies on axillary nerve injuries have not included children. The regenerative capacity after nerve injuries in children, particularly as in our youngest patients, is considered to be better for at least two reasons, e.g. fast peripheral nerve regeneration with shorter distance to target and superior cerebral adaptability, plasticity, in the young brain. The prominent feature of the present study was that all patients, except two, did not get a diagnosis of an axillary nerve injury during the initial examination performed in connection to their trauma. It was not until the patients or their parents observed sufficient weakness and even atrophy of the deltoid muscle, which created problems in every day life, that they sought medical attention. Thus, an axillary nerve injury may easily be overlooked, which negatively affects the prognosis for a good recovery. Why is this diagnosis commonly overlooked? The axillary nerve controls the deltoid muscle, which performs mostly abduction and flexion of the shoulder joint. If other muscles that support the same movements are functioning, like the supraspinatus muscle innervated by suprascapular nerve, they will compensate for the loss of the deltoid, which will hide the symptoms. Another factor that contributes to the difficulty

diagnosing an axillary nerve injury is that these patients often have concomitant injuries caused by trauma leading to pain and immobilization of the shoulder. Therefore, a proper examination may be difficult to perform in the acute stage. However, the present study shows that even patients with a minor shoulder trauma, in worst case a dislocated shoulder joint, should be examined properly with respect to axillary nerve function even though it may be difficult due to pain and immobilization of the shoulder.

Earlier studies have focused on the type of reconstructive nerve surgery that is favorable and the importance of timing of surgery. Our study indicates that active surveillance of the nerve function after an injury is crucial to identify signs of recovery with the purpose to avoid any unnecessary delay of nerve reconstruction. Particularly, a clinical examination should be performed to detect any signs of improvements. Active surveillance of the patients is important and if no recovery is expected, early exploration should be considered.

From the neurobiological view, the condition of the Schwann cells in the distal nerve segment, with respect to activation, proliferation and apoptosis decreases with time after trauma and the potential for recovery deteriorates over time each day after trauma [11,12].

In the present study two different reconstructive techniques were used depending on time elapsed between trauma and surgery. Reconstruction with sural nerve grafts may be the surgical procedure of choice soon after the trauma and radial nerve transfer for later surgery. Outcome after both types of procedures may be sufficient if the time from trauma to surgery is less than twelve months. Interestingly, our results showed that all patients that had a radial nerve transfer had a promising outcome even though their transfer were performed at 14-22 months after trauma, suggesting that a radial nerve transfer can be successful even in late cases.

However, one may even suggest that it may be justified to consider a radial nerve transfer also in early recognized cases. Such a procedure may reduce the time for reinnervation of the muscle. The ability of the brain to adapt to changes in afferent and efferent nerve impulses allow for a rapid adaptation to the new signal pattern created in the radial nerve transfer. It is well described that this adaptability is present also in older patients. However, younger patients, like the present one, show a remarkable capacity for rapid, within days, cerebral adaptation [18]. The results from the present study show successful reinnervation and useful deltoid function in nine cases although we only had a median follow-up time of 11 months. Some patients are likely to recover even better over the next years since reinnervation and maturation after nerve regeneration may continue for several years.

We conclude that axillary nerve function should not be overlooked particularly in young patients, even if the shoulder trauma is considered to be minor. Follow-up examinations – active surveillance – to rule out an axillary nerve injury are indicated. In established injuries active monitoring for any clinical improvement is crucial. Even if an axillary nerve injury is diagnosed late, a radial nerve transfer should be considered as an optimal treatment strategy.

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Table I. Summary of young patients with an axillary nerve injury, surgical procedure and functional recovery.

Age (years)	Gender	Trauma and concomitant injury	Preop EMG Verifying injury to axillary nerve	Time to surgery (months)	Type of operation	Follow-up (months postop)*	Postop EMG verifying reinnervation	Deltoid muscle – functional recovery
9	Male	Blunt	Yes	19	Radial nerve transfer	14	Yes	Good
13	Male	Blunt	Yes	22	Radial nerve transfer	11	Yes	Good
13	Male	Blunt	Yes	14	Radial nerve transfer	12	Yes	Good
10	Male	Blunt	No		Conservative treatment	27	Yes	Moderate
19	Male	Fracture clavicle Hill-Sachs fracture	Yes	4	Sural nerve graft	64	Yes	Very good
19	Male	Shoulder dislocation Fracture tuberculum majus	Yes	7	Exploration (neuroma)	23	Yes	Good
10	Male	Shoulder dislocation	Yes	6	Sural nerve graft	12	Not done	Good
24	Male	Acromio-clavicular dislocation	Inconclusive results	1	Sural nerve graft	16	Yes	Good
16	Male	Shoulder dislocation Arterial vascular damage	Yes	9	Sural nerve graft	7	No	Poor
11	Male	Shoulder dislocation	No		Conservative treatment	22	Not done	Good

\*For the two patients with conservative treatment follow up has been calculated from trauma.

## Figure legend

Figure 1. Peroperative photos from one of the present cases showing the technique of nerve transfer in late reconstruction of an axillary nerve injury on the left side (i.e. the shoulder is up and the arm is down on the photos). a) The dissection is performed between the deltoid and triceps muscles and is continued to expose the radial nerve and its branches. A branch (arrow) from the radial nerve (star) is transected as far distally as possible. The nerve branch is carefully lifted with a pair of forceps and mobilized proximally approaching the axillary nerve. b) The branch from the radial nerve (arrow) is transferred to the axillary nerve (arrowhead), which is transected as proximally as possible and transferred to the branch of the radial nerve. c) Detail of the nerve transfer (with one suture; arrow) with the proximal branch of the radial nerve attached to the distal axillary nerve. d) The suture of the nerve transfer is reinforced by the use of fibrin glue (arrow; Tisseel®).

