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Surgical treatment of traumatic lesions of the axillary nerve
A retrospective study of 33 cases

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The purpose of this study was to evaluate the recovery of muscular strength after surgical intervention in axillary nerve injuries. Surgery was elected when no signs of recovery were noted after three months of conservative treatment. Between 1980 and 1996, 46 traumatic lesions of the axillary nerve were surgically treated. Thirteen patients were excluded from the study for various reasons. Among the remaining 33, 20 with interruption of the nerve trunk were treated with nerve grafts and 13 lesions with the nerve in continuity underwent neurolysis.

After a mean follow-up of more than two years, deltoid muscle strength was good or fair in 18 patients and poor in 15 cases.

The outcome seemed to be better in isolated lesions than in complex nerve lesions with a favourable outcome in 6/10 patients vs 8/14, in patients younger than 25 years compared to older patients (8/14 vs 8/19), in patients treated with neurolysis (9/13) compared to grafting (9/20), and when graft length was limited (4/4 patients with a graft 6cm or less, 5/8 with a graft over 6cm in length). The outcome was less favourable when associated osteoarticular lesions were present (8/23 versus 8/10) and most convincingly, when surgery was delayed beyond six months (10/22 versus 8/11).

INTRODUCTION

With advances in microsurgical techniques (*1, 3*), surgical repair has become the treatment of choice for lesions of the brachial plexus. Injuries to the axillary nerve may occur in shoulder trauma particularly after anterior dislocation, during shoulder surgery or as part of a brachial plexus palsy. Except in the latter, an axillary nerve injury usually occurs in the quadrilateral space (*1, 12, 23, 34, 39*). The results of surgical treatment of axillary nerve injuries with neurolysis, repair or grafting are reportedly good (*1, 7, 15, 40, 42*). However, the experience in our institution has been less favourable. We decided to perform a retrospective study of 33 surgically treated lesions, in order to analyse the prognostic factors affecting the outcome.

MATERIALS AND METHODS

Between 1980 and 1996, 46 traumatic lesions of the axillary nerve were surgically treated at Jeanne d'Arc Hospital in Toul. We report the results of 33 lesions with a mean follow-up of more than two years. Thirteen

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patients were excluded for various reasons : the follow-up was too short in 11 patients, one was lost to follow-up, and another one had an iatrogenic lesion of the terminal branches of the axillary nerve.

Thirty- three patients (26 males and 7 females), with an average age of 30 years (range : 13 to 70 years) were included in the present study. The left side was involved in 18 patients and the right side in 15.

The initial injury was a motor vehicle accident in 19 patients, a sports accident in two, an occupational injury in two, a fall in six, an automobile crash in two and a positional anomaly in one. The mechanism was extreme abduction of the arm in 9 cases, anterior dislocation of the shoulder in 10, and a direct blow to the shoulder with a heavy object in one case ; the mechanism was unclear in 13 patients.

Clinical paralysis of the deltoid muscle was documented in all cases. Hypoaesthesia or anaesthesia was noted in 18 patients. Some patients presented paraesthesias over the lateral side of the forearm. Five did not have any sensory alteration in the shoulder region.

The injuries were classified according to the presence or absence of combined nerve lesions. The lesion of the axillary nerve was isolated in 16 patients (group 1), it was combined with a superior scapular nerve injury in 5 patients (group 2), with a lesion to the infraclavicular plexus in 11 patients (group 3), and with a supraclavicular plexus lesion in one patient (group 4)

Osteoarticular injuries were present in 23 patients : shoulder dislocation (10 cases), acromioclavicular dislocation (3 cases), fracture of the scapula (5 cases), fracture of the greater tubercle (3 cases), fracture of the humeral diaphysis (3 cases), fracture of the forearm (2 cases), multiple rib fractures with a flail chest (3 cases), clavicular fracture (2 cases), and two patients presented with cervical spine fracture, head trauma and multiple peripheral fractures.

Osteoarticular injuries were more frequent in the third group (9/11) and fourth group (1/1), than in the other two groups (9/16 in group 1, and 3/5 in group 2).

A rotator cuff lesion was diagnosed in one case ; however, arthrography of the shoulder was performed in only three patients. No vascular injuries were encountered.

Surgery was elected when complete paralysis of the deltoid persisted after three months from the time of injury, without EMG improvement. Due to late referral, the average time elapsed between injury and surgery was 10 months (range : 3 to 36 months) : 6 to 8 months in cases with paralysis of the deltoid, 9 months in cases with an associated lesion of the superior scapular nerve, and 16 months in cases with involvement of the infraclavicular plexus.

At surgery, rupture of the axillary nerve was found in 19 cases : the lesion was situated in the quadrangular space in 9 patients, and proximal to it in 10.

A lesion in continuity of the nerve was present in 14 patients ; it was proximal to the quadrilateral space in 13, and in that space in one patient. Ruptures were treated by resection of the proximal and distal nerve stump and replacement of the defect by a saphenous nerve graft. Lesions in continuity were treated with neurolysis in 13 patients, and with a nerve graft in one. Thus, a total of 20 nerve grafts were performed : four of these were done through an anterior approach, and 16 using a combined anterior deltopectoral and posterior approach. The posterior approach allowed access to the proximal part of the nerve via the quadrangular space. The graft consisted of two or three bundles ; its length ranged from 2 to 11 cm (mean length : 6.8 cm). Graft length was noted with some precision in only 12 cases. Neurolysis of the axillary nerve was done through an anterior approach.

Lesions of the superior scapular nerve were treated by neurolysis in two cases ; the lesion was beyond repair in one patient, and in two others spontaneous recovery had occurred before surgery (group 2). Lesions of the infraclavicular plexus (group 3) recovered spontaneously in six patients, neurolysis of the secondary anterolateral trunk or the secondary posterior trunk was done in four patients and grafting with the ulnar and radial nerve in one patient. The shoulder was immobilised for three weeks in patients who had a nerve graft, and for one week in those patients who underwent a simple neurolysis procedure.

Patients were followed up for a minimum of two years after the operation (range : 24 to 53 months). They were evaluated for the presence of sensory disturbances of the shoulder area or amyotrophy of the deltoid muscle. To evaluate the strength of the three parts of the deltoid, testing included abduction, abduction with slight antepulsion (30°), and abduction with slight retropulsion (30°). Strength was graded from M0 to M5 according to the Nerve Injuries Committee of the British Medical Research Council (*47*). However, it proved difficult to evaluate the degree of recovery of each of the three parts of the deltoid. In almost all cases we assessed the global strength of the muscle, which constitutes the most essential element. Evaluation of fatigue on exertion was tested according to a fixed protocol and proved unreliable.

Clinical results were compared to EMG results to eliminate any false impression caused by compensatory muscle action, and to obtain a more precise judgment about the progression of regeneration of the nerve.

The results were considered favourable when the deltoid strength was equal to or better than M3 and unfavourable when equal to or less than M2.

Statistical analysis was done using the Chi-square test with Yate's correction when indicated. The p value was calculated for each table ; $p < 0.05$ was taken as the level for statistical significance.

RESULTS

The earliest signs of recovery were seen as early as two months following neurolysis, and as early as three months following nerve grafting ; in cases with a favourable evolution, recovery could be completed within 6 to 12 months. In cases with an unfavorable evolution, the recovery stagnated despite early signs of regeneration on EMG.

Initially, sensory disturbances of the shoulder were noted in 28 patients and were absent in 5 patients. Five patients recovered completely, 19 had a persistent area of hypoaesthesia or anaesthesia which regressed in size in 7 of them. Four patients were not further evaluated. Dysaesthesias and paraesthesias eventually disappeared over time in all patients.

Complete amyotrophy involving the three heads of the deltoid muscle was noted in 20 patients. It was very severe in seven, severe in ten and moderate in three patients ; the deltoid showed no wasting in five patients. Amyotrophy of the deltoid muscle was dissociated, involving one or two heads of the muscle, in eight patients : five had amyotrophy limited to the anterior part of the muscle, two had amyotrophy of the posterior part, and one had amyotrophy of both the anterior and posterior parts. Isolated amyotrophy of the middle part was not seen in any patient.

The result was favourable in 18 patients (M3 : 5, M4 : 5, M5 : 8) and not favourable in 15 patients (M0 : 5, M1 : 3, M2 : 7).

The following correlations are documented in tables I to VII. Statistically significant differences were only found regarding associated osteoarticular lesions and the type of these lesions (tables IV and V : $p < 0.05$). This may be related to the small number of patients, which limits the power of the statistical comparisons.

Table I. — Recovery of deltoid muscle strength according to the type of intervention performed : neurolysis or nerve grafting

	NEUROLYSIS 13 patients	NERVE GRAFTING 20 patients
< M3	4 patients	11 patients
≥ M3	9 patients	9 patients

$0.1 < p < 0.2$ (N.S.D. = non significant difference).

Table II. — Recovery of deltoid muscle strength according to the type of lesions

	GROUP 1 16 patients	GROUPS 2 + 3 17 patients
< M3	6 patients	9 patients
≥ M3	10 patients	8 patients

$0.3 < p < 0.5$ (N.S.D.).

Table III. — Recovery of deltoid muscle strength according to the time interval between the injury and the surgical intervention

	< 6 MONTHS 11 patients	> 6 MONTHS 22 patients
< M3	3 patients	12 patients
≥ M3	8 patients	10 patients

$p = 0.1$ (N.S.D).

Neurolysis gave a favourable outcome in 9 out of 13 patients, nerve grafting in 9 out of 20 patients (table I).

Isolated lesions of the axillary nerve achieved a favourable score in 10 of 16 patients, and combined nerve lesions in 8 of 17 patients (table II).

When the time interval between injury and surgery was less than 6 months, 8 out of the 13 patients had a favourable score, versus only 10 of 22, if more than 6 months (table III). The difference is not statistically significant ($p < 0.1$)

Table IV. — Recovery of deltoid strength according to the presence or absence of associated osteoarticular lesions

	NO ASSOCIATED LESIONS 10 patients	ASSOCIATED LESIONS 23 patients
< M3	2 patients	15 patients
≥ M3	8 patients	8 patients

$p < 0.05$ (S.D = significant difference).

Table V. — Recovery of deltoid muscle strength according to the type of associated osteoarticular lesions

	DISLOCATIONS 10 patients	FRACTURES 13 patients
< M3	4 patients	9 patients
≥ M3	6 patients	4 patients

$p < 0.05$ (S.D).

Table VI. — Recovery of deltoid muscle strength according to the patients' ages

	< 25 YEARS 14 patients	≥ 25 YEARS 19 patients
< M3	6 patients	11 patients
≥ M3	8 patients	8 patients

$P < 0.1$ (N.S.D).

Table VII. — Results according to the length of the nerve graft used

	Nerve graft ≤ 6 cm 4 patients	Nerve graft > 6 cm 8 patients
< M3	0 patient	3 patients
≥ M3	4 patients	5 patients

$P = 0.45$ (N.S.D).

The success rate dropped from 80% (8/10 patients) to 34% (8/23 patients) when associated osteartícular lesions were present (table IV). Dislocations appeared less harmful than fractures : favourable outcome in 6/10 patients versus 4/13 patients (table V).

Eight of 14 patients younger than 25 years had a favourable result, versus only 8 of 19 patients older than 25 years (table VI).

If graft length needed to bridge the gap was less than 6 cms, 4/4 patients evolved favourably, versus only 5/8 patients when the length was greater (table VII).

DISCUSSION

Petrucci (42) and Alnot *et al* (*1, 2*) obtained excellent results with a muscle strength recovery of M3 or better in 100% and 94% respectively of their patients with axillary nerve injury. Coene and Narakas reported M3 or better recovery in 70% of their patients (*15*).

Since the outcome obtained in our series was poorer, we tried to analyse the factors affecting outcome. The factors investigated were the type of lesion of the axillary nerve and the ensuing treatment (neurolysis or nerve grafting), the presence of associated nerve injuries or osteoarticular lesions and the time interval between the injury and the surgical intervention.

Paralysis of the deltoid muscle causes not only a cosmetic problem as a result of amyotrophy, but also a severe limitation in active motion of the shoulder joint, especially abduction and antepulsion. The absence of a functional deltoid may lead to early damage and a possible rupture of the rotator cuff muscles (*1, 44*), and consequently to early degenerative arthritis of the shoulder joint (*14, 44*).

Most lesions of the axillary nerve are part of a brachial plexus lesion in a traction-elongation injury. Four main pathogenic mechanisms seem to be responsible (*1, 14, 25, 34, 39, 42, 46, 51*).

The axillary nerve is the most exposed element of the brachial plexus owing to its anatomic location directly beneath the capsule of the glenohumeral joint in the quadrilateral space, when a shoulder dislocates or a humeral neck fractures. Damage to the suprascapular or musculocutaneous nerves may also occur with these lesions.

In motorcycle accidents, extreme abduction and internal rotation of the arm and the ensuing opening of the scapulohumeral angle, cause wedging of the infraclavicular part of the plexus and the vascular elements over the humeral head and are the main mechanism of injury of the infraclavicular plexus and particularly of the nerves in the vicinity

of the scapulohumeral joint (axillary, musculocutaneous and radial nerves) (*14, 32*).

The third pathogenic mechanism is internal rotation seen in opening of the cervicoscapular angle (*1, 14, 25, 39, 42, 45, 46*) and this occurs while the shoulder is being pulled down. The motor branches coil around the surgical neck of the humerus while the sensitive branch of the axillary nerve remains intact.

A last pathogenic mechanism of lesser importance seen in axillary nerve injuries is direct blunt trauma to the lateral aspect of the shoulder.

The decision whether or not to operate on these patients was not always easy. Two anatomical peculiarities of the axillary nerve support direct surgical repair when possible : the simple fascicular structure of the axillary nerve and its proximity to the effector muscle which plays a crucial role in shoulder movements. Nonoperative treatment (physiotherapy and rehabilitation) aims at the development of compensatory muscles (*14, 50*). In late cases or when direct surgical repair of the axillary nerve has failed, salvation is by muscle flap transposition (trapezius, latissimus dorsi or long biceps) (*26, 28, 31, 50*), or arthrodesis of the shoulder joint. Such a treatment does not nearly give a normal shoulder joint, neither anatomically nor functionally ; results are always inferior to those of direct surgical repair of the axillary nerve (*15, 42, 46*). Therefore surgical repair is to be done whenever it is possible. It should be performed within three to four months after injury, if no signs of clinical or electrical regeneration are noted (*1, 7, 14, 42, 50*).

Associated osteoarticular lesions were frequent in this series : there were 10 shoulder dislocations and 13 fractures, which greatly affected the prognosis.

In our series we did not have any associated vascular lesions despite the severity of some of the injuries. In a study of 63 axillary nerve lesions, Coene (*14, 15, 40*) reported 13 arterial lesions in young adults, 11 of which were associated with severe infraclavicular plexus injury. Bonnard *et al* reported 21 vascular lesions out of 146 patients (*7*).

Five patients did not have any sensory alteration in the shoulder area and a few others merely had dysaesthesia. This is most probably due to the anatomic relationship of the sensory and motor branches of the axillary nerve with the surgical neck of the humerus. The sensory branch being more distant, is less vulnerable. Considering the crossing through the quadrangular space, which is a fixed zone, and as a consequence more vulnerable to injuries (*1, 46*), we noted that the lesions occurred proximal to the space in 23 patients and at the crossing in only 10 patients. This was also noted by Coene (*14*) : he had 77% ruptures and 23% lesions in continuity. We had 19 ruptures (58%) and 14 lesions in continuity (42%).

We assigned a minimum of two years follow-up given the delay in recovery. We were often surprised by the good functional recovery despite minor changes in the bulk and electrical activity of the deltoid. This reflects the important role of the compensatory muscles, which were subjected to a well-organised rehabilitation after surgery (*17, 19, 21, 30*). In general, the results obtained in our series were good. Of 33 patients, 18 recovered M3 or better deltoid strength.

We noted that the results seemed to be better following neurolysis, in comparison to nerve grafting. Artico *et al* and Coene and Narakas (*4, 15*) did not note any significant difference between the two types of intervention. We pointed out the importance of the following prognostic factors : high-energy trauma, lesion of the infraclavicular plexus, associated osteoarticular lesions and delay of surgical intervention (9 to 36 months). In some cases, independently from the type of the intervention, violent trauma may be the cause of a poor outcome, possibly because of stretching of the nerve at a distance from the initial insult. These lesions may be overlooked during the initial work up and will affect the outcome and recovery. The association of an axillary nerve lesion and a fracture is a negative prognostic factor for various reasons : the initial insult was severe enough to cause a fracture, the presence of other plexus lesions is frequent, the osteo-articular lesions delay the definitive treatment of the nerve injury, and sequelae of the fracture itself may affect the outcome. For several authors, the time interval between the initial insult

and the intervention appears as the most important factor (*7, 50*). This may explain the modest results in our series, in which the average delay was 10 months. This was most often due to late consultation by the patient, and it reflects by no means a "wait-and-see" policy on our part. All our excellent results (M5) were seen in patients in which the delay was less than 8 months ; there was one exception however, which may indicate that delayed intervention may sometimes give a favourable outcome. We nevertheless advocate early intervention, within three months of the initial insult if there are no EMG signs of nerve regeneration, although we were unable to demonstrate a statistically significant difference between the results of early and late intervention in this study, owing to the limited size of the study group.

Two additional factors affecting the prognosis were the age of the patient, and the length of the nerve graft used (*7, 50*). In our study, the outcome appeared better in patients younger than 25 years and also after grafting less than 6 cms ; no statistically significant differences were demonstrated however, which may be related to the small size of the groups studied.

Finally, persisting segmental amyotrophy of the deltoid was observed in 8 of our patients ; 7 of them however had a positive outcome (≥ M3). Such segmental amyotrophy was not mentioned in previously published series, where the overall recovery of the three parts of the deltoid was always noted. This amyotrophic dissociation seen in our series was more frequently noted in nerve graft cases than in neurolysis cases. It may have been caused by poor approximation of the end of the grafts, or by an atypical anatomic distribution of the terminal branches as demonstrated by Coene, or due to stretching of the nerve roots at the time of injury. In our series we did not have in every instance simultaneous recovery of the three parts of the deltoid muscle.

CONCLUSION

The outcomes following surgical treatment of 33 traumatic lesions of the axillary nerve with neurolysis or nerve grafting are reported. A favourable outcome was obtained in 18/33 patients with a deltoid recovery of M3 or better. Associated osteoarticular lesions represented an important factor leading to an unfavorable outcome. Another important prognostic factor seems to be the time interval between the injury and the intervention. If there are no clinical and EMG signs of recovery of nerve function, surgery should be done three months after the initial insult, particularly if the patient is young and the axillary nerve lesion is isolated.

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