# EVALUATION OF FUNCTIONAL GAIN OF THE ELBOW FOLLOWING STEINDLER SURGERY FOR BRACHIAL PLEXUS INJURY

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## ABSTRACT

Objective: To evaluate the gain in strength and range of motion after modified Steindler surgery of the elbow in patients with lesions of the upper trunk of the brachial plexus. Method: From 1998 to 2007, eleven patients with traumatic closed upper trunk lesion of the brachial plexus were studied. All the patients had development of at least 1 year of injury and degree of strength of elbow flexion ranging from M1 to M3. The patients underwent Steindler surgery with at least 6 months of follow-up. Pre- and post-operative assessments were carried out to determine gain in muscle strength, range of motion of the elbow, and DASH scale score. Results: Of the eleven patients studied, nine (82%) achieved a level of strength equal to or greater than M3 (MRC) with good functional recovery. Two (18%) reached strength level M2 (MRC). We observed that the patients had an average post-operative gain in range of motion of the elbow of 43.45 degrees. The average elbow flexion after surgery was 88 degrees. There was an improvement in elbow function, as demonstrated in the DASH Scale, in 81% of the patients studied. Conclusion: Modified Steindler surgery was effective in the treatment of patients with injuries of the upper trunk of the brachial plexus, with statistically significant gains in range of motion. In all the cases studied, there was some degree of gain in strength and range of elbow flexion, the gain being correlated with the initial muscle strength. Level of Evidence: Level II, prospective clinical trial.

**Keywords:** Reconstructive surgical procedures; Brachial plexus; Elbow.

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## INTRODUCTION

Upper trunk lesions of the brachial plexus (C5 and C6) generally occur due to high-energy mechanisms (car accidents, firearm injuries, stab wounds, falls from heights and sports trauma), mainly affecting people in a young and productive age bracket. The incidence of this kind of lesion has increased, coinciding mainly with the use of motorcycles as a means of transport particularly in large cities. At the beginning of the 70s, Narakas[1,2] and Millesi[3] published the outcome of their work on the surgical repair of brachial plexus lesions. Nerve transfers represented a major advance in the treatment of these lesions. Oberlin *et al*.[4] described the nerve transfer technique where one or more ulnar nerve fascicles are transferred to the musculocutaneous nerve branch for gain of elbow flexion, and later on MacKinnon *et al*.[5] described the double transfer technique, in which besides transferring an ulnar nerve fascicle to the biceps brachii muscle, they transfer a median nerve fascicle to the brachialis muscle. In cases of impossibility of neurological reconstruction, failure in nerve transfers or insufficient return of muscle strength for elbow flexion, the tendon transfers for reestablishment of active elbow flexion are procedures to be indicated.[6]

As a rule, we should attempt nerve reconstruction first, and when it does not present a good result or is no longer indicated, we can resort to muscle transfer surgeries, when possible, where the muscles used most often are: latissimus dorsi[7-8], pectoralis major[9], triceps[10,11], flexor-pronator muscles of the forearm[2,12,13] and microsurgical free tissue transfers.[4,14,15]

The proximal transfer of the flexor-pronator muscles of the forearm to the medial intermuscular septum of humerus (brachial fascia), was described by Steindler[16]. Bunnell[17] suggested radial fixation to decrease the pronator effect of this transfer. Mayer and Green[13] modified the original technique, proposing fixation on the anterior side of the humerus, allowing firmer fixation and decreasing contracture in flexion, described as complications in the original technique.

The Modified Steindler transfer is classically indicated in cases of

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paralysis of the biceps and brachialis muscles, where the presence of functional hand and strength greater than or equal to M4 of the flexor-pronator muscles of the forearm is essential.[5,16,18,19] Our study is aimed at evaluating functional gain after Modified Steindler surgery, in patients with brachial plexus upper trunk lesion with initial elbow flexion force ranging from M1 to M3 (MRC).

## METHODS

The patients selected had traumatic lesions of the upper trunk of the brachial plexus (C5 and C6 with or without impairment of C7) suffered between 1998 and 2007 (Table 1), all with elbow flexion force between M1 and M3 (MRC).

A group of eleven patients formed by 10 males and 1 female with age averaging 34.5 years (24-56 years). Mean time from injury of 4.7 years (1 year minimum, 12 years maximum). (Table 2)

Nine patients had been submitted to previous surgical treatment, five to plexus exploration with nerve transfers, three to microsurgical free transfer of the gracilis muscle for elbow flexion and one patient to conventional transfer of the triceps muscle for elbow flexion. (Table 1)

**Table 1**. *Data on the operated patients.*

| N | Age | Gender | Time of lesion | Level of lesion | Previous surgery |
|---|---|---|---|---|---|
| 1 | 27 | M | 3years | C5/6 | Plexus exploration with reconstruction + OBERLIN |
| 2 | 35 | M | 1year | C5/6 | Plexus exploration + OBERLIN |
| 3 | 32 | F | 4years | C5/6 | Plexus exploration + neurotization AC>SE + radial > axillary |
| 4 | 34 | M | 7years | C5/6/7 | Microsurgical transfer gracilis pro biceps |
| 5 | 43 | M | 5years | C5/6 | Plexus exploration + neurotization AC>MC with graft |
| 6 | 56 | M | 4years | C5/6/7 | Plexus exploration |
| 7 | 31 | M | 3years | C5/6 | No previous surgery |
| 8 | 40 | M | 3years | C5/6 | Microsurgical transfer gracilis pro biceps |
| 9 | 24 | M | 12years | C5/6 | Muscle transfer triceps pro biceps |
| 10 | 31 | M | 2years | C5/6 | No previous surgery |
| 11 | 27 | M | 7years | C5/6 | Microsurgical transfer gracilis pro biceps |

All the patients were operated by specialists from the Hand-Microsurgery group of the Orthopedics and Traumatology Institute of HCFMUSP and rehabilitated by the same Occupational Therapist in the postoperative period. The functional evaluations were carried out in the pre- and postoperative periods after 7, 15, 30 and 60 days and in the sixth month after surgery. The same assessor was responsible for applying all the evaluations of the patients from the survey protocol.

The functional evaluations were performed by measuring the elbow flexion arc with a goniometer, degree of muscle strength and DASH (Disabilities of Arm, Shoulder and Hand) score before and after the Steindler surgery.

**Table 2.** *Results of gain of range of motion in elbow flexion, gain of muscle strength (MRC) and DASH of the operated patients*.

| N | Preop. MRC | Preop. elbow flexion | Preop. DASH |
|---|---|---|---|
| 1 | M1 | 0 º | 28.33% |
| 2 | M2 | 0 º | 60% |
| 3 | M3 | 90 º | 56.66% |
| 4 | M2 | 13º | 20% |
| 5 | M1 | 0º | 19.17% |
| 6 | M2 | 1º | 63.33% |
| 7 | M3 | 97º | 33.33% |
| 8 | M2 | 50º | 15% |
| 9 | M1 | 0º | 2.5% |
| 10 | M2 | 23º | 58% |
| 11 | M2 | 27º | 52% |

Inclusion criteria: traumatic closed upper trunk lesion of the brachial plexus (C5-C6, with or without C7 lesion); patients with one year or more of lesion; total passive amplitude of elbow; strength of flexor-pronator muscles of the forearm and wrist/hand greater than or equal to degree M4.

Exclusion criteria: open or non-traumatic lesion of brachial plexus upper trunk; complete lesion of the brachial plexus; patients with less than one year of lesion; stiffness upon passive movement of the elbow.

## TECHNIQUE

In the surgical procedure the patient is placed in the horizontal supine position with the upper limb in external rotation on a "hand table". The upper limb is exsanguinated with an elastic band. The incision is started in the medial part of the arm approximately eight centimeters proximal to the medial epicondyle, extending distally, passing behind the medial epicondyle and continuing towards the forearm lengthwise in relation to the pronator teres muscle. (Figure 1)

The medial cutaneous nerve of the forearm was identified and isolated. This was followed by the opening of the forearm muscle fascia, with dissection and identification of the ulnar nerve up to its branches to the flexor musculature. (Figure 2)

The medial epicondyle osteotomy was performed with an oscillating saw respecting the location of the medial collateral ligament of the elbow (Figure 3). The dimension of the epicondyle fragment accompanying the muscle mass measures approximately 1cm in depth by 2cm in width. (Figure 3)

After isolating the brachial artery and the median nerve with its branches to the round pronator muscle and superficial flexor muscle of the fingers, the musculature was released enough to shift the epicondyle fragment and the entire origin of the flexor-pronator muscles proximally. The bone fragment is fixed approximately four centimeters proximal to the distal edge of the humerus. The humerus and the fragment were irrigated with blood for the fragment to be fixed. The elbow was flexed 120 degrees for fixation of the fragment with a 3.5mm screw. The fixation position in the humerus was chosen as radially as possible, decreasing the pronating action of the transfer. (Figure 4)

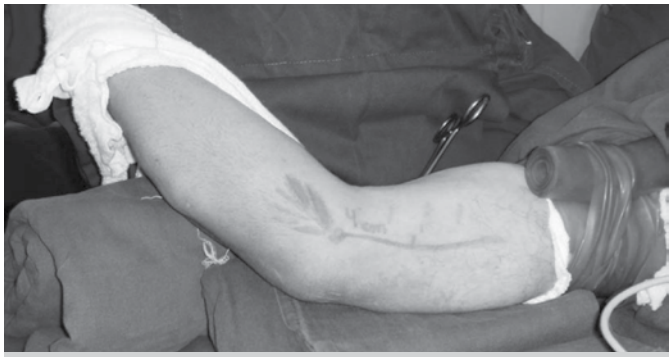

**Figure 1**. *Positioning of the upper limb in abduction and external rotation and surgical approach.*

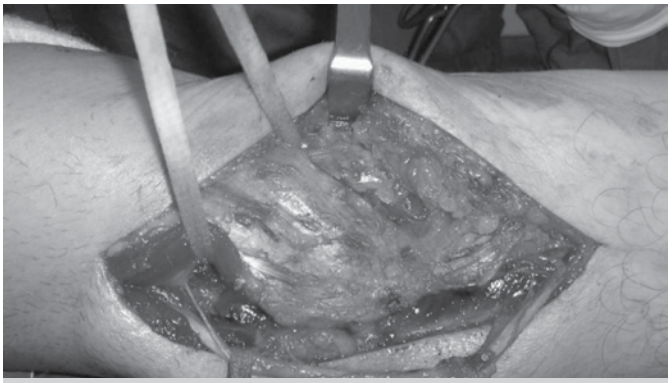

**Figure 2.** *Release of the flexor-pronator muscles and isolation of the ulnar nerve.*

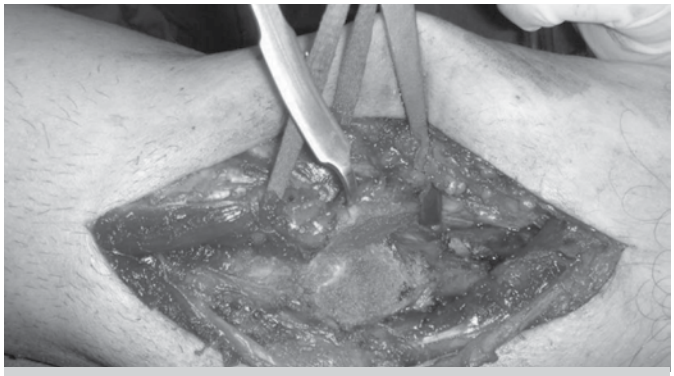

**Figure 3.** *Medial Epicondyle Osteotomy.*

**Figure 4.** *Fixation of the medial epicondyle segment with 3.5mm screw, with transfer of flexor-pronator muscles 4cm proximal to elbow joint.*

The planes of soft parts were brought together and the limb was immobilized with a long upper limb plaster cast at 90 degrees of elbow flexion with forearm supination.

## REHABILITATION

The occupational therapy rehabilitation protocol started in the 4th postoperative week. The baycast splint was replaced by a canvas splint supporting the entire forearm and wrist, and the elbow was kept at approximately 120˚of flexion.[20]

Active movement of fingers and passive movement for elbow flexion were begun in the 4th week, with extension blocking.

From the 6th week on the splint could be removed for short periods during the day; elbow flexion training was initiated with assisted flexion of the wrist without resistance, and elbow extension without the action of gravity.

The splint was removed in the 8th week, when elbow flexion against gravity was started, and if flexion control was still precarious the splint was kept on for another two weeks for walking.[21]

## FUNCTIONAL EVALUATION

### Goniometry

Goniometry was performed using a standardized goniometer. The active range of motion of the elbow was evaluated with measurements in degrees (flexion and extension).

### Degree of muscle strength (TMM)

The muscle test is an important part of the physical exam, providing information on the degree of muscle strength that the patient is capable of reaching. This evaluation was carried out to scale the evolution of elbow flexion force. Muscle strength was scaled according to its ability to act against gravity or the resistance offered by the examiner. (Appendix 1)

**Appendix 1.** *Muscle Strength Evaluation Scale (MRC-Medical Research Council)[20].*

| | |
|---|---|
| 0 | No contraction is perceived |
| 1 | Trace of contraction, without production of movement |
| 2 | Weak contraction, producing movement with the elimination of gravity |
| 3 | Executes movement against gravity, yet without additional resistance |
| 4 | Executes movement against moderate external resistance and gravity |
| 5 | Is capable of overcoming a greater quantity of resistance than at the previous level |

### DASH (Disabilities of Arm, Shoulder and Hand)

Subjective questionnaire that makes it possible to observe the patient's pre- and postoperative functional evaluation.[22]

## RESULTS

The data were obtained by evaluating 11 patients pre- and postoperatively. (Table 3)

In the study, considering elbow flexion strength, all the patients obtained an improvement of the initial level. The best result was 2 points and was reached by 54% of the patients. The group with greatest gain was that presenting initial muscle strength M2, where 80% evolved 2 levels of strength. The group that initially presented M1 strength evolved with gain of 1 or 2 points

**Table 3**. *Postoperative results.*

| N | Postop. MRC | Postop. Elbow flexion | Postop. DASH |
|---|---|---|---|
| 1 | M2 | 30º | 23.33% |
| 2 | M4 | 127º | 41.67% |
| 3 | M4 | 126º | 54.17% |
| 4 | M3 | 90º | 18.33% |
| 5 | M2 | 16º | 22.5% |
| 6 | M3 | 95º | 50.83% |
| 7 | M4 | 116º | 25.0% |
| 8 | M4 | 108º | 40% |
| 9 | M3 | 96º | 1.72% |
| 10 | M4 | 121º | 41.67% |
| 11 | M4 | 109º | 46.67% |

(50% each). In the group of initial strength M3, all the patients achieved gain of 1 point. Therefore, generally speaking, there was an improvement in elbow flexion strength gain in all the patients after the procedure. Moreover, we obtained a Kendall's coefficient of 0.757, which indicates that the relationship between pre- and postoperative force is strong. The results are demonstrated in Figure 5.

Range of motion had mean variation of 43.45 degrees, where the greatest variation was 96 and the least variation, 2 degrees. The difference between the pre- and postoperative values appeared statistically significant (p=0.003). Once again the group with initial strength M2 obtained the best results, averaging 60.6 degrees. The group of initial strength m1 had mean gain of 40.5 degrees. In the initial group of degree 3 strength the mean gain was 6.5 degrees.

DASH also obtained variation in all the patients, with a negative result in 81% of the patients, which corresponds to a functional improvement. The mean variation was -4.49. This variable did not obtain any statistical relationship in the study (p=0.091). The variation of results did not differ among the study groups. All the osteotomized fragments were consolidated as evidenced in the control radiography at 12 months after surgery.

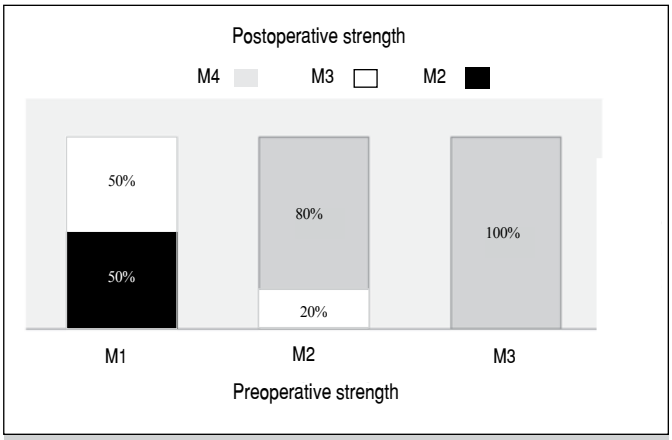


**Figure 5.** *Evaluation of strength gain according to initial strength*.

### Complications

All the cases showed a certain degree of loss of elbow extension, averaging 7 degrees. The worst results were loss of 28 and 23 degrees respectively. There was one case of postoperative superficial infection, which was treated effectively with oral cephalosporin.

## DISCUSSION

The increase in the incidence of plexus lesions caused by car accidents gives rise to concern among members of society and creates a legion of patients with severe limitations of their work and everyday functions. A fact that increases the importance of studies targeting their recovery.

Modified Steindler surgery is indicated in patients that do not have functional elbow flexion strength. The indication of this surgery is performed for patients with total passive amplitude of the elbow, functional hand and flexor-pronator muscles with strength of at least M4 (MRC).[23,24]

All the patients analyzed in this clinical series presented some degree of increase of active amplitude and gain of elbow flexor muscle strength.

Of the eleven patients analyzed, nine (82%) reached a level of strength greater than or equal to M3 (MRC) with good recovery of elbow function. Two (18%) reached strength level M2 (MRC), in which clinical recovery was unsatisfactory. Prior to surgery these presented a degree of muscle strength equal to M1 (MRC). When we analyzed the remaining patients, the better evolution of those that initially had strength in degree 2 or 3 and obtained the best results, was clear. In addition, we have a Kendall's coefficient equal to 0.757 that indicates strong relationship between pre- and postoperative strength. This fact reinforces the considerations of Teboul[(15)] who consider that only patients with flexion strength equal to M2/M3 are eligible for performance of modified Steindler surgery.[25]

In the surgical technique we observed that good dissection of the proximal forearm muscles is essential to manage to reach the 4cm of elbow articulation desired for fixation of the osteotomized fragment. An attempt was made to position the medial epicondyle fragment as radially as possible in the humerus, decreasing the pronating action of the transfer.[7,10,14] The fixation planned at 4cm from the distal humeral articulation appeared to avoid excessive flexion contracture, common in the original technique where the advocated fixation averaged 6 to 7cm,5[,23] the result shown in the study with average loss of extension of 7 degrees, lower than that of the classical series such as Dutton and cols. (30-60 degrees),[26] Steindler (60 degrees)[16] and Mayer and Green (below 15 degrees).[13]

We observed that the patients presented mean gain of postoperative range of motion of the elbow of 43.45 degrees, a statistically significant data (p:0.003). The mean postoperative elbow flexion was 88 degrees, comparable to the series described by Dutton[26] who found 95 degrees of mean postoperative flexion, while Liu[25] obtained higher mean postoperative flexion of 114 and 107 degrees respectively. We can infer that this series presented results compatible with similar reports in literature.[3,7,8]

Considering the more distal fixation of the insertion of the flexor-

pronator muscles (fixation of the fragment 4cm from the joint) we noticed less restriction of elbow extension with a mean value lower than that found in literature (7 and 15 degrees respectively)[7,14] and on the other hand a slightly lower gain of elbow flexion (88 and 95 degrees respectively),[3,7] as shown previously. The study shows a small difference between the extension deficit and the gain of flexion that does not alter the final range of motion. The more distal fixation appears advantageous as it requires smaller dissection and generates less restriction on the extension.

The DASH functional test showed an improvement in the scores of most patients (81%). Yet this data was not statistically significant (p 0.091). Considering the clinical satisfaction demonstrated by the patients, most of whom declared they were satisfied with the procedure, we believe that a larger group of patients could demonstrate statistical significance for this data.

## CONCLUSION

Modified Steindler surgery proved effective for gain of elbow strength and flexion in patients with high lesion of the brachial plexus, especially those that presented an initial degree of elbow flexion strength of at least M2.

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