Biceps to Triceps Transfer in Tetraplegic Patients: Our Experience and Review of the Literature

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Abstract

Background: Management and indications for surgery in the tetraplegic patient are highly complex because of the substantial functional deficits that they present and their effect on their daily activity. Our purpose was to evaluate the functional outcome in tetraplegic patients who underwent biceps-to-triceps transfer surgery according to Zancolli's modified technique. **Methods:** This is a retrospective study of 6 biceps-to-triceps transfers using Zancolli's modified technique in 4 patients. Mean follow-up was 45 months. We evaluated each patient's DASH (Disabilities of the Arm, Shoulder and Hand) score before surgery and 12 months later. **Results:** In the 6 arms that underwent surgery, full and active elbow extension against gravity at 12 months after surgery was achieved. The mean DASH score was 73.2 preoperatively and 20.8 twelve months postoperatively. One complication occurred. One patient reported loss of elbow flexion preventing thigh lift for transfers. This was resolved with a program of rehabilitation and specific muscle strengthening. **Conclusions:** Zancolli's modified technique is simple and effective, with few complications, whereby we can provide more autonomy for the tetraplegic patient.

Keywords: elbow, extension, tendon, tetraplegia, transfer, Zancolli

Introduction

The annual incidence of spinal injuries is estimated at 40 new cases per million population.⁶ Fifty-five percent of the patients are 16 to 30 years at the time of injury and 80% are male. The most common causes are traffic accidents and falls from height, and the most affected body regions are the cervical and lumbar columns by virtue of their greater mobility.²³

Management of the tetraplegic patient is highly complex because of the substantial functional deficits that they present and their effect on their daily activity. Indications for surgery in the tetraplegic patient are also complex. It is essential to classify exactly the functional deficit of each individual patient. Often, the relationship between the level of skeletal injury and level of neurological impairment is not accurate, and this level can also vary between the 2 upper limbs.⁷ Muscle strength at the injury level can improve. Usually, this improvement is completed by 1 year after the injury, so we should not consider surgery before this time.²⁴

Patients who lack active elbow extension due to spinal cord injury have profound functional loss.¹⁴ Elbow extension

is necessary to dressing and undressing, self-propelling in a wheelchair, making transfers between the chair and the bed, relieving pressure on the ischial bone, and reaching objects above shoulder level.¹² To restore active extension of the elbow in patients with high or medium tetraplegia, the most commonly used techniques are the deltoid-to-triceps transfer and the biceps-to-triceps transfer.

Our purpose was to evaluate the functional results in tetraplegic patients who underwent biceps-to-triceps transfer surgery according to Zancolli's modified technique in our center.

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Table 1. Patients Characteristics.

Patient	Age at injury (years)	Level	Classification	AIS	Time to surgery (months)
Patient 1 (right)	16	C6	G2	B	23
Patient 1 (left)	16	C6	G2. Useful S	B	35
Patient 2 (right)	27	C6	G3. T 1/5 ^a	A	40
Patient 2 (left)	27	C6	G3. T 1/5 ^a	A	57
Patient 3 (right)	40	C6	G3. T 2/5 ^a	A	31
Patient 4 (left)	26	C6	G4. T 2/5 ^a	A	14

Note. S = spasticity; T = triceps; AIS = ASIA Impairment Scale.

^aScoring at Medical Research Council Scale.¹⁹

Materials and Methods

We conducted a retrospective study of 6 biceps-to-triceps transfers, carried out using the modified Zancolli's technique^{14,20,25} in 4 tetraplegic patients who underwent surgery in our center between 2006 and 2012. All of the patients were male, with an average age of 28.2 (18-43) years at the time of surgery. Three right and 3 left elbows underwent surgery. In 2 of these patients, a bilateral transfer was carried out. The average time from injury to the first intervention was 27 (14-57) months and the follow-up was 45 (18-92) months.

The patients were assessed and followed at our center by a multidisciplinary specialized spinal cord injury team. We carried out multiple clinical interviews in the acute phase of the process and, also, during the follow-up. We carried out detailed medical examinations and, also, documented the social and family support available, motivation and adaptation of the patient, and his environment to his new physical reality.

The lesions were classified according to the International Classification of Tetraplegia modified by Allieu^{2,16} and the Classification of the American Spinal Injury Association (ASIA Impairment Scale)⁸ (Table 1).

In various interviews, we studied the overall muscle balance and the specific muscular balance for tetraplegia. We recorded the presence of an active pectoralis major that means a stable shoulder.²³ We also recorded the availability of active triceps, active elbow flexion, active wrist extension, active finger flexion, and active extension of the fingers. We also studied the presence of sublesional segment spasticity. Uncontrollable spasticity is a contraindication for surgery; however, useful spasticity¹ with tone of the finger flexors can provide some ability to grip.

The indications for surgery were individualized according to the degree of tetraplegia, the functional limitations, the needs and motivation of the patient, and the temporal stability of the motor examination, so that no patient underwent surgery before 1 year of the injury.²⁴

This retrospective study was approved by the institutional review board (IRB), and all patients signed the informed consent document for surgery prior to operation.

Figure 1. Anterior incision: musculocutaneous nerve was identified and protected throughout the surgery.

The operation was performed under general anesthesia, with the patient in the supine position, without tourniquet, and with the arm positioned on a surgical hand table. We did an anterior longitudinal incision over the medial aspect of the biceps muscle belly, and the musculocutaneous nerve was identified and protected throughout the surgery (Figure 1). The lacertus fibrosus was transected distally. A posterior longitudinal incision was made over the distal third of the triceps tendon but lateral to the olecranon to avoid a medial skin bridge. A subcutaneous tunnel was fashioned along the

Figure 2. Pulvertaft suture keeping the elbow fully extended.

medial aspect of the arm, through the medial intermuscular septum and connecting both incisions. The biceps muscle and tendon are delivered into the posterior incision through this subcutaneous tunnel.^{14,20} The tendon is passed superficial to the ulnar nerve. Finally, through the posterior incision, the biceps tendon is woven in a Pulvertaft fashion into the distal triceps tendon, and the tendons sutured with a nonabsorbable suture keeping the elbow fully extended, with the triceps in maximum contraction (Figure 2). The elbow was immobilized using a brachio-palmar plaster splint with the elbow in full extension and supination for 2 weeks. Between the second and the fifth week, we used an articulated elbow brace in extension adjusting the orthosis to allow 15° of flexion each week without an extension lag, and we also started the active reeducation up to 45° of flexion. From the fifth week, functional activities of daily living were also associated to the therapy, and active flexion rehabilitation above 45° was progressively initiated maintaining a nighttime extension splint until 3 months after surgery.

Muscle strength assessment was done according to the scale proposed by the Medical Research Council (MRC).¹⁷

We recorded the results before surgery and 12 months after using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire.²² We have chosen the DASH questionnaire

because, although it is not specifically validated for the tetraplegic patients, its preoperative results were available at our center database.

Statistical analysis of data was performed using the non-parametric Wilcoxon test and considering a significance level of $P = .05$.

Results

In the 6 arms that underwent surgery, full and active extension of the elbow against resistance (M4 of the MRC Scale) was achieved. All 4 patients were able to use their arms above head level (Figures 3 and 4), transfer between wheelchair and bed independently, and relieve ischial pressure to avoid decubitus ulcers.

One complication occurred in 1 patient, who reported a loss of elbow flexion that prevented elevation of the ipsilateral thigh for transfers to and from the wheelchair. This problem was noted 6 months after surgery and solved by specific program of rehabilitation and muscle strengthening. In this patient, a biceps-to-triceps transfer in the contralateral upper limb achieved good results without this complication.

On objective testing, all 4 patients obtained good active elbow extension, substantial functional improvement of activities above their heads, and independence of transfers.

The mean DASH questionnaire before surgery was 73.2 points with a standard deviation of 7.8. Twelve months postoperatively, DASH questionnaire was 30.8 points with a standard deviation of 13.4. We obtained a mean decrease of 42.5 points with a standard deviation of 6.3 and a P value of .068 (Table 2).

In addition, proper function of the biceps and the possibility of elbow extension in all of the patients allowed us to continue to a second procedure to restore hand function.

Discussion

Patients who lack active elbow extension due to spinal cord injury cannot use their hands reliably above shoulder level because of the difficulty of holding the elbow extended against gravity. The lack of an active antagonist to active elbow flexion creates imprecision to position the hand in space. This is particularly important when coordinated movement is needed, such as with writing or using a key.¹⁴

The main goal of surgery in treatment of tetraplegic patients is to provide them with independence and rebuild a thumb-index pinch usable in a wide range of possible space.¹⁸ Active elbow extension is essential for it. Therefore, we strategically prefer to reanimate the elbow and, at a second procedure, perform further surgery to achieve movement in the hand, as the availability of active elbow extension improves considerably to the pinch strength obtained by

Figure 3. Active elbow extension above the head level after the surgery in the right upper limb.

Figure 4. Active elbow extension above the head level after the surgery in both upper limbs.

Table 2. DASH Score Before Surgery and 12 Months After.

Patient	DASH before	DASH after	Reduction	
Patient 1 (bilateral)	61.5	11.7	49.8	
Patient 2 (bilateral)	77.5	35	42.5	
Patient 3 (right)	76.7	33.3	43.4	
Patient 4 (left)	77.5	43.2	34.3	
Average	73.3	30.8	42.5	$P = .068$

Note. DASH = Disabilities of the Arm, Shoulder and Hand.

transferring the Brachioradialis to Flexor Pollicis Longus⁵ and other muscle for active, or passive, grip.

According to the International Classification,^{2,16} tetraplegies are classified into 3 groups: high (G0, G1, and G2), medium (G3, G4, and G5), and low (G6, G7, G8, and G9). High tetraplegia is characterized by a continuous paralysis of the Triceps Brachii (radial nerve, C7 root), and most of these patients also do not have a functional Pectoralis Major,^{3,4} which means a deficit of anterior shoulder stabilization. In medium, deltoid and Pectoralis Major are active and, in most of them, the Biceps Brachii (musculocutaneous nerve, C5 and C6 roots) is also active, but not the Triceps Brachii. Finally, in low tetraplegia, an active elbow extension is preserved, as the Triceps Brachii is functional as in peripheral paralysis.

The transfer of posterior deltoid-to-triceps¹⁸ consists in transposing the posterior deltoid to the triceps tendon by using other tendons or synthetic ligaments between them. The presence of a stable shoulder, and therefore a functional pectoralis major, is a necessary prerequisite for this technique.^{4,21} The medialization of anterior deltoid as described by Johnstone¹⁰ is an available option for shoulder stabilization before the deltoid-to-triceps transfer in high tetraplegia but, in our opinion, this technique adds major risks to surgery as the possible injury to the subclavian vessels and recovery sometimes takes longer.⁴ Various complications have been reported with the deltoid-to-biceps transfer, including lack of the final 60° of active extension against gravity in 50% of patients, stretching of the tendon repair resulting in decreased strength and extensor lag,^{11,13,19} infection of the

graft,²¹ and development of heterotopic ossification in the posterior deltoid muscle.^{14,18}

The biceps-to-triceps transfer was first described by Mayer in 1951 and Friedenberg in 1954,⁹ and popularized in tetraplegic patients by Zancolli,¹⁴ by performing the transfer by the medial route.^{14,20} This technique does not require a stable shoulder so we can use it in high tetraplegia, and to be feasible there must be other available muscles to supply the biceps functions, flexion and supination of the elbow. So, for this technique, there are some prerequisites, including M5 elbow flexion of the MRC with an active Brachialis (musculocutaneous nerve, C5 and C6 roots), M3 supination with an active Supinator (posterior interosseous nerve arising as a branch from the radial nerve; C6, C7, and C8 roots), and a supple elbow. If either of these muscles are nonfunctional, the patient will lose elbow flexion (supplied by the Brachialis) and forearm supination, respectively.

Furthermore, no tendon grafts are required, it is safe,¹⁴ postoperative follow-up is simple,¹¹ and it has a low rate of complications, the most important of which is decreased flexor strength from 24%²³ up to 47%, although patients do not notice this and there is no considerable functional disturbance.²⁰

The advantages of the biceps-to-triceps transfer over the deltoid-to-triceps transfer are that of removing the deforming force of the unopposed biceps, with correction of the flexion and supination deformities at a single stage with 1 transfer so it is the procedure of choice in patients with fixed elbow flexion contractures of greater than 45°. Meanwhile, the deltoid transfer requires 2 stages, with first stage being to release the elbow flexion contracture by biceps tenotomy.¹⁴ Finally, although not used in this study, the technique can also be used as salvage surgery after failed deltoid-to-triceps transfer.^{13,21}

The good results obtained in our series are similar to those reported in other studies. Kuz et al¹⁴ published a series of 4 medial route transfers, achieving M4 elbow extension against resistance in all arms and considerable functional improvement as we have also obtained. Revol et al²⁰ reported the results of 13 medial route transfers achieving full active extension in all cases. Kozin et al¹² presented the largest series in the literature with 68 arms; they reported active M3 extension in 42 cases and 51 of the 68 cases were able to carry out activities above their head.

Mulcahey et al¹⁹ compared both techniques in a prospective randomized study and found similar results in terms of extension of the elbow after surgery. At 24 months follow-up, 7 of the 8 transferred biceps achieved extension against gravity (M3 or greater), whereas only 1 of 8 deltoid transfers was able to do this. However, the study shows that the loss of elbow flexion at 24 months was greater in the biceps-to-triceps transfer, but patients did not report any functional impairment as a result of this.

This complication occurred in one of our patients and is the main disadvantage of the Zancolli's technique, although most patients do not perceive it and are satisfied with the results.²⁰

Finally, Leclercq et al¹⁵ published a review article of both surgical techniques and concluded that the transfer of biceps-to-triceps by the medial route has clear advantages over Moberg's technique. It is a simple technique, does not require grafts, achieves better results in terms of active elbow extension, and requires fewer restrictions during the postoperative period. Therefore, they, like us, considered the biceps-to-triceps transfer to be the technique of choice to restore active extension in the tetraplegic patient.

Concerning the MRC, our results are similar to those previously reported in the literature. Regarding the DASH questionnaire, in our opinion the postoperative score reduction is totally disproportionate. We believe that it is an inappropriate questionnaire for the assessment of tetraplegic patients.

Our work has limitations. It is a retrospective study and presents a limited number of cases. To assess the results, we used the MRC scale and DASH questionnaire because these were the available preoperative data at our center, but as the DASH questionnaire is not a specific tool for tetraplegic patients, our results could be difficult to interpret correctly.

The management of tetraplegic patients is difficult, and these patients should be evaluated in multidisciplinary units specializing in their treatment. To achieve autonomy for the patient, it is essential to restore active elbow extension and, for that, the biceps-to-triceps transfer is a simple, effective, and with few complications technique that can be used as primary procedure or salvage surgery.

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Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional review board) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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