

## The scope of upper limb surgery for tetraplegics: Role of tendon transfers and Universal Cuff



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### ABSTRACT

**Objective:** The aim of this study was to evaluate the role of tendon transfers and universal cuff in restoring hand function in tetraplegic patients.

**Methods:** Twenty-one upper limbs on 12 tetraplegic patients (9 males and 3 females); mean age: 42.2 years (range 22–58 years) with a spinal cord injury at or distal to C6, were included in this study. Key pinch was restored using Brachioradialis to Flexor Pollicis Longus transfer and hook using Pronator Teres to Flexor Digitorum Profundus transfer. The gains achieved were measured objectively at six months and at final follow up, the average follow up being 26 months. The functional outcome was assessed using the Modified Lamb and Chan score.

**Results:** Average value was 1.67 kg for key pinch and 2.58 kg for hook grip at final follow up. The Modified Lamb and Chan score revealed good to fair outcome in 75% of patients. Complications resulted from stretching of transfer and mal-tensioning and were salvaged by the use of a 'Universal Cuff'.

**Conclusion:** Surgery should be routinely offered to tetraplegic patients with deficient hand function in whom no recovery is expected after six months following spinal cord injury. Universal Cuff is a good salvage method for patients who refuse re-surgery.

**Level of evidence:** Level IV, Therapeutic study.

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### Introduction

Tetraplegia is a devastating complication resulting from spinal cord injury (SCI). The greatest challenge to a tetraplegic patient is loss of independence. Rehabilitation of such patients primarily involves non-surgical measures but surgery can be an important adjunct in suitable candidates.<sup>1</sup> However, surgical treatment for improving function of upper limb in tetraplegic patients is not commonly done and most textbooks provide very little information on this topic.<sup>2</sup> Moreover, to the best of our knowledge, very little work has been done in this area especially in developing nations like ours owing to limited resources, lack of patient motivation and ignorance among medical practitioners regarding the outcome of these procedures. The objective of this study was to reconstruct important hand functions viz. lateral pinch and hook grip in suitable patients and describe the functional outcome, complications and salvage by the use of a Universal Cuff.

### Methods

This prospective study involved a total of 21 upper limbs in 12 patients with tetraplegia, nine having consented for bilateral surgery and three consenting to get operated only on dominant side. Informed consent was taken pre-operatively from all patients. There were nine males and three females with a mean age of 42.2 years (range 22–58 years). Only those tetraplegics with cervical spine injury at or distal to C6 spinal cord level and with a reasonably preserved elbow function (MRC grade  $\geq$  4/5) and wrist extension (MRC grade  $\geq$  4/5), were offered surgery. An elapse of 6 months after injury was ensured to allow spontaneous recovery of any useful hand function.

Each upper limb was classified into appropriate International Classification group and examined meticulously for the strength of Pronator teres (PT) and Brachioradialis (BR) and the sensibility of the hand.<sup>1–7</sup> Every patient underwent extensive pre-operative physiotherapy to ensure supple joints as joint contractures severely jeopardize the results.<sup>2–4</sup> Thorough patient counseling was done to ensure high level of motivation and avoid dropouts during the long post-operative rehabilitative phase.<sup>5,6</sup>

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In all 21 upper limbs both pinch and hook were restored. Transferring BR to Flexor Pollicis Longus (FPL) restored lateral pinch. Thumb inter-phalangeal (IP) joint was stabilized by using split FPL transfer to A1 pulley.<sup>4,8</sup> Empowering the Flexor Digitorum Profundus (FDP) with the tendon of PT restored Hook grip.

All procedures were carried out under general anesthesia and tourniquet control in a single stage and those undergoing bilateral surgery had the procedures performed simultaneously by two separate teams, each headed by a senior surgeon. Post-surgery, all patients were given above elbow Plaster of Paris casts for 4 weeks. After cast removal, patients were subjected to an intensive physiotherapy protocol similar to the one described by Lo and Turner et al.<sup>9</sup>

## Results

The results attained were evaluated both objectively and subjectively. Objective evaluation included measurements of strength and range of motion. Strength of key pinch was measured using spring balance and hook and was recorded using a hand held dynamometer in position most comfortable to the patient. Pre-operatively, the pinch and grasp strength in all our patients was zero. The post-operative record was taken at 6 months after surgery and at the final possible follow up, the mean follow up being 26 months (range 18–38 months). The average value of key pinch (in kg) attained after 21 reconstructions was 1.71 (range 0.7–2.3) at 6 months and 1.67 (range 0.6–3.0) at the final follow up while for hook reconstructions these values were 2.56 (range 1.1–3.8) and 2.58 (range 1.4–4.0) respectively. The short term results at 6 months, when compared with results at mean follow up of 26 months demonstrated a statistically significant correlation (p value-0.0010 for pinch and p value-0.0015 for hook), strengthening the fact that gains achieved are maintained over a considerable period of time.<sup>10,11</sup> However, we must mention that although when choosing only one side to operate, we preferred operating the dominant side, no significant difference was observed in gains achieved on operating either right or left upper limb (p value-0.3739 for pinch and p value-0.7400 for hook), implying that the procedures on either were equally efficacious.

Post-operatively, range of motion at wrist and elbow remained essentially unchanged in all subjects. The strength of pronation of forearm was unchanged in 15 upper limbs and decreased one grade in 6 upper limbs, but none of the patients reported that this resulted in any kind of decreased function. For hook evaluation, excursion of finger flexion was measured by recording the distance between the pulp of the tip of finger and the distal palmar crease. As a result of the gain, evaluation at final follow up revealed average distance from tip of pulp of finger to distal palmar crease to be as follows: 1.4 cm (range 0.6–3.2) for the index finger, 1.6 cm (range 0.8–3.4) for the middle finger, 1.2 cm (range 0.6–2.8) for the ring finger and 1.0 cm (range 0.4–2.2) for the little finger. The point of contact of the thumb on to the index finger was used to evaluate the lateral pinch. It was at proximal IP joint in 5 upper limbs, middle of middle phalanx in 13 upper limbs and distal IP joint in 3 upper limbs.

The functional outcome was assessed by Lamb and Chan score, modified by Mohammed et al.<sup>2,4,12</sup> Our results were good in 4 patients, fair in 5, and poor in 3. However, no patient reported that his functional capacity had diminished in any way. Universal Cuff was used in patients with poor results who refused re-surgery.

## Discussion

Loss of independence is a major catastrophe for a patient with tetraplegia. Restoration of hand function is a foremost priority in

these patients. It is quite obvious that even if minor benefits could be provided by reconstructive surgery of upper limb, it would not only make them more independent but also facilitate the development of personal interests, hobbies, sports and recreational activities.<sup>13</sup> With this objective we offered surgery to tetraplegics who were appropriate candidates for it.

We excluded patients with lesions above C6 vertebrae as operations to improve digital function are seldom indicated in this group.<sup>14</sup> In tetraplegics who have a lesion at the sixth or seventh cervical level, various combinations of tenodesis, arthrodesis, and tendon transfer have been recommended. Some surgeons have relied on tenodesis that are activated by movement of the wrist, while others have used multiple tendon transfers to improve function of the hand.<sup>1,4,15</sup> General principles of tendon transfers must be adhered to. However, at times one may need to be creative enough to bend some of the rules as per requirement.<sup>1</sup> A good idea is to classify the upper limb to be operated into appropriate International Classification group and then choose appropriate donors based upon available functioning muscle groups. Generally FCR, PT, BR and ECRL are the suitable motors available in such patients. Active wrist extension of approximately 60° is ideal, but a minimum of 45° is a pre-requisite for the success of these procedures.<sup>14</sup> Although some surgeons have reported preliminary good results after transfer of the tendon of the Extensor Carpi Radialis Longus (ECRL) to the tendons of the FDP, many patients who have good function of the ECRL may not have equally good function of the Extensor Carpi Radialis Brevis (ECRB) and hence we refrained from using this donor. Additionally, the function of ECRL and ECRB is not easy to isolate and test separately before operation.<sup>14</sup> Thereby, we preferred transfer of the BR tendon to the FPL tendon for restoring lateral thumb pinch and used PT as the second donor to power FDP for restoring hook. Both one and two-stage procedures have been advocated. Lipscomb et al. and House and Shannon, described a two-stage procedure; the extensor phase is performed first, followed two to six months later by the flexor phase.<sup>16,17</sup> However, Lamb and Chan believed that restoration of both active flexion and active extension of the fingers is too ambitious. Their recommendation was to provide grasp by active finger flexion and to allow release to be accomplished by wrist flexion with the natural tenodesis-like effect of the extensors.<sup>2</sup> Since most of the centers in developing nations lack adequate in patient facilities and these patients may need long periods of post-operative care and follow up, we also recommend single staged bilateral procedures to maximize rehabilitation.<sup>1,4,16</sup>

All patients must be subjected to a strict and closely supervised post-op rehabilitative physiotherapy protocol.<sup>9</sup> Generally such patients need long period of inpatient treatment as most centers in developing world lack adequate outpatient facilities for tetraplegic post-operative care.<sup>18</sup>

Comparing results of different studies is difficult because of difference in neurological deficits, type of surgery and methods of measurements used by various authors.<sup>19</sup> Additionally, objective results may correlate poorly with functional outcome and hence may not be ideal mode for comparison.<sup>4</sup> Nevertheless, our achievements coincide well with the reported literature. Using BR to FPL transfer Lo and Turner et al. reported 1.2 kg of average key pinch post-operatively after 12 reconstructions while Mohammed et al. and Gansel et al. claimed an average of 2.1 kg and 2.2 kg respectively.<sup>4,9,14</sup> Vastamaki et al. found average pinch strength of 1.1 kg attained after 10 reconstructions to dip by 21% after a mean follow up of 21 years.<sup>10</sup> A meta-analysis of 37 studies by Hamou et al. revealed an average of lateral pinch to be 2 kg.<sup>8</sup> Forner-Cordero et al. employed a different method of measurement and reported an average value of 17.2 kPa of pinch and 18.8 kPa of hook strength after 14 each reconstructions.<sup>7</sup> Gansel et al. reported hook

strength of 21 mm Hg after 11 reconstructions employing PT to FDP transfer.<sup>14</sup> However, House et al. and Kelley et al. have each reported average hook strength of 3.5 kg and 2.81 kg after 12 and 24 reconstructions respectively.<sup>11,17</sup> The heterogeneity of objective measurement methods makes comparisons extremely difficult. Subjective assessment hence seems to be more reliable and more closely related to functional outcome.<sup>4</sup> Using the Modified Lamb and Chan score, Mohammed et al., Lo and Turner et al. and Forner-Cordero et al. have each reported excellent to good results in 70%, 75% and 71.4% cases respectively.<sup>4,7,9</sup> Our results were good to fair in 75% of cases. Most of our patients documented a high level of satisfaction after undergoing surgery. Their improvements primarily surfaced in the form of being able to navigate by self-driving a wheel chair, being able to self-feed and by having the ability to self-dress and self-toileting (Fig. 1). Additionally, we employed simple but useful innovations like advising most patients to use special deep surfaced cup like spoons to ease in self-feeding (as shown in Fig. 2), thereby making their life more comfortable.

One study has shown that BR and PT are equally efficacious in restoring key pinch, whereas hook was better restored by PT to FDP transfer rather than FDP tenodesis.<sup>20</sup>

Although in our study 25% of patients had poor results as per modified Lamb and Chan score, none reported a decrease in functional capability in any way. All but one patient agreed that they had benefitted in some form from the procedures. Even though objective gain may be minimal, even minor degree of increased independence brings in great degree of mental satisfaction. In fact, all patients made a remark that there is a great need to offer these procedures to all tetraplegics as for them there is no other ray of hope for a better future.

Complication were few but notable. Two patients had thumb hyperflexion on dominant side owing to mal-tensioning of the BR to FPL transfer. These patients were instructed to hold the thumb out against the side of a table or a wheel chair while fingers were being flexed, then bringing the thumb against the side of the index finger.<sup>2</sup> Any surgical intervention was fortunately not required. Another patient had bilateral failure of hook reconstruction. The poor result was directed to a poor pre-operative strength of PT in addition to some joint contractures and a poor level of motivation of this patient. Another one had a loss of hook power on dominant limb after post-operative physiotherapy, where rupture of



Fig. 2. 52 year old male who had bilateral hook and lateral pinch reconstruction, demonstrating his ability to hold a specially designed spoon made for easing self feeding in such patients.

anastomosis was suspected. He was offered re-surgery but refused to give consent. This problem is peculiar in a developing set up that motivating failures for re-surgery is almost impossible. The “Universal Cuff” was used to tackle such situations. The cuff is shown in Fig. 3(a) and the patient in Fig. 3(b) is demonstrating the use of the cuff. It consists of a holder attached to a soft padded strap, which can be tied across the palm. The holder is made of elastic material that can be fitted with items of daily routine like tooth brush, spoon etc. thereby enabling the patient to carry out activities of daily routine. Any increase in hook strength contributes in enabling the grip of the cuff to the palm. It can particularly be a salvaging tool

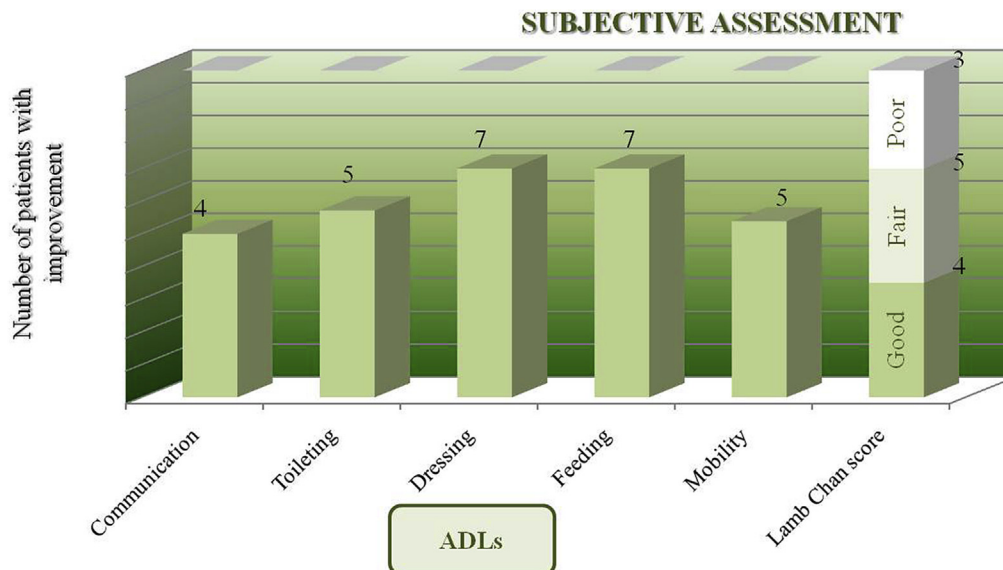


Fig. 1. Graph depicting subjective improvements in patients in various aspects of Activities of Daily Living.

(a)



(b)



**Fig. 3.** (a) The 'Universal Cuff'. (b) 42 year old male with bilateral pinch and hook reconstruction is demonstrating the use of Universal Cuff. This patient had bilateral failure of hook reconstruction and refused for re-surgery.

when the operative results are poor and the consent for re-surgery is not given owing to the dropping morale of the tetraplegic.

The major problems we faced were a small sample size due to lack of motivation among our patients, short survival of tetraplegics owing to lack of medical care facilities, limited patient resources and access to health care and above all, lack of adequate and transparent knowledge among practitioners regarding results of these procedures, precluding them from making appropriate referrals and lack of information amongst patients regarding the outcome and benefits of this surgery, which has also been cited by other authors.<sup>5,6</sup> This is based on their belief that objective gain expected is minimal. But unfortunately, objective assessment in these cases may not correlate with functional gain. Even with minimal objective benefit a good subjective outcome may result.<sup>4,7</sup> Also, proper patient selection is important. It has been suggested that the most important step for surgical rehabilitation of tetraplegic patients is patient selection.<sup>21</sup>

## Conclusion

We would conclude by saying that reconstructive surgery on upper limbs must be routinely offered to all those young patients with traumatic tetraplegia who are motivated enough and are

appropriate candidates for the same. However, the surgeon must refrain from being over optimistic while counseling the patient as this may make the subject set in false functional goals. And the surgeon must understand that surgery is an aid and not a substitute to other rehabilitative measures. The complex process of rehabilitation actually requires a focused team approach with patient's family and the patient himself being an important part of the team.

## Compliance with ethical standards

### Ethical approval

All procedures were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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None.

### Conflict of interest

The authors declare that they have no conflict of interest.

### Consent

Informed consent was obtained from all individual participants included in the study.

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