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Role of External Rotation Osteotomy of the Humerus in Patients with Brachial Plexus Injury

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Background: A deficit of external rotation of the shoulder is a common sequelae of brachial plexus injury (BPI). This internally rotated posture of the limb becomes more apparent and functionally limiting once the patient recovers elbow flexion resulting in the hand striking the abdomen on attempted flexion ('tummy flexion'). This precludes hand-to-mouth reach, resulting in an inability to eat with the involved hand. The aim of this study is to present the outcomes of an external rotation osteotomy of the humerus in adult BPI.

Methods: All BPI patients who underwent an external rotation osteotomy of the humerus at our institution over a 5-year period from January 2015 to December 2020 were included in this study. Data with regard to the age, gender, type of BPI, time from injury to nerve surgery and from nerve surgery till external rotation osteotomy, degree of pre- and postoperative external rotation, time to union, patient satisfaction and complications were recorded.

Results: The study included 19 patients (18 men and one woman) with an average age of 30 years (range 20–58). The average time interval from the injury to the nerve surgery was 3.8 months, and between the nerve surgery and the external rotation osteotomy was 29.5 months. No patient had any preoperative external rotation and all attained a resting posture of 15°–20° of external rotation, were able to reach the mid-line of the body, and none complained of loss of internal rotation. There was an implant failure in one patient that was managed with splinting till union and removal of implants later.

Conclusions: External rotation osteotomy of the humerus is a simple and effective procedure to place the limb in a better aesthetic and functional position.

Level of Evidence: Level IV (Therapeutic)

Keywords: *Brachial plexus, Adult brachial plexus injury, Derotation osteotomy humerus, Tummy flexion, Internal rotation deficit, Brachial plexus palsy*

INTRODUCTION

External rotation osteotomy of the humerus is a common operation done for children with birth brachial plexus palsy, with well-established indications and functional benefits.[1–5] However, its role in patients with adult brachial plexus injury is uncertain and the literature dealing with it is sparse.[6] Though nerve surgery is the mainstay of treatment in patients with brachial plexus injury (BPI), timely secondary surgeries can substantially augment the function and add to the patient's overall satisfaction.

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A deficit of external rotation at the shoulder is one of the common sequelae in patients who have undergone nerve reconstruction after BPI (Fig. 1A). It results from the paucity of donors to innervate the shoulder external rotators (infraspinatus and teres minor) during the nerve surgery or due to inadequate recovery of the external rotators. This inadequate recovery can be attributed to the external rotators being placed farther and beyond the abductors in their innervation by the suprascapular nerve (infraspinatus) and the axillary nerve (teres minor). In either situation, when the patient has recovered elbow flexion, this internal rotation posture gets accentuated and revealed. Severe internal rotation posture leads to the flexing elbow striking the abdomen ('tummy flexion') and may even hamper the range of elbow flexion and biceps strengthening exercises (Fig. 2A). Also, in patients with good hand function, lack of external rotation precludes hand-to-mouth reach, resulting in an inability to eat with the involved hand. The aim of this study is to present the outcomes of an external rotation osteotomy of the humerus in adult BPI.

METHODS

All adult BPI patients who underwent an external rotation osteotomy of the humerus at our institution over a 5-year period from January 2015 to December 2020 were included in this study. This is a retrospective study. Data with regard to the age, gender, type of BPI, time from injury to nerve surgery and from nerve surgery till external rotation osteotomy, degree of pre- and postoperative external rotation, time to union, patient satisfaction and complications were recorded.

Indications: A procedure to improve external rotation was offered to patients who lacked active external rotation at the shoulder and desired to improve the posture of the limb, which tended to flex 'into the chest' on performing elbow flexion. Humerus external rotation osteotomy was performed for these 19 patients who lacked full passive external rotation at the shoulder whereas lower trapezius (ipsilateral or contralateral) transfer was performed for patients who had full passive external rotation. Five of the 19 patients who had good hand function also complained of the inability to eat because of the limited reach of the hand to the mouth, whereas the remaining 14 patients

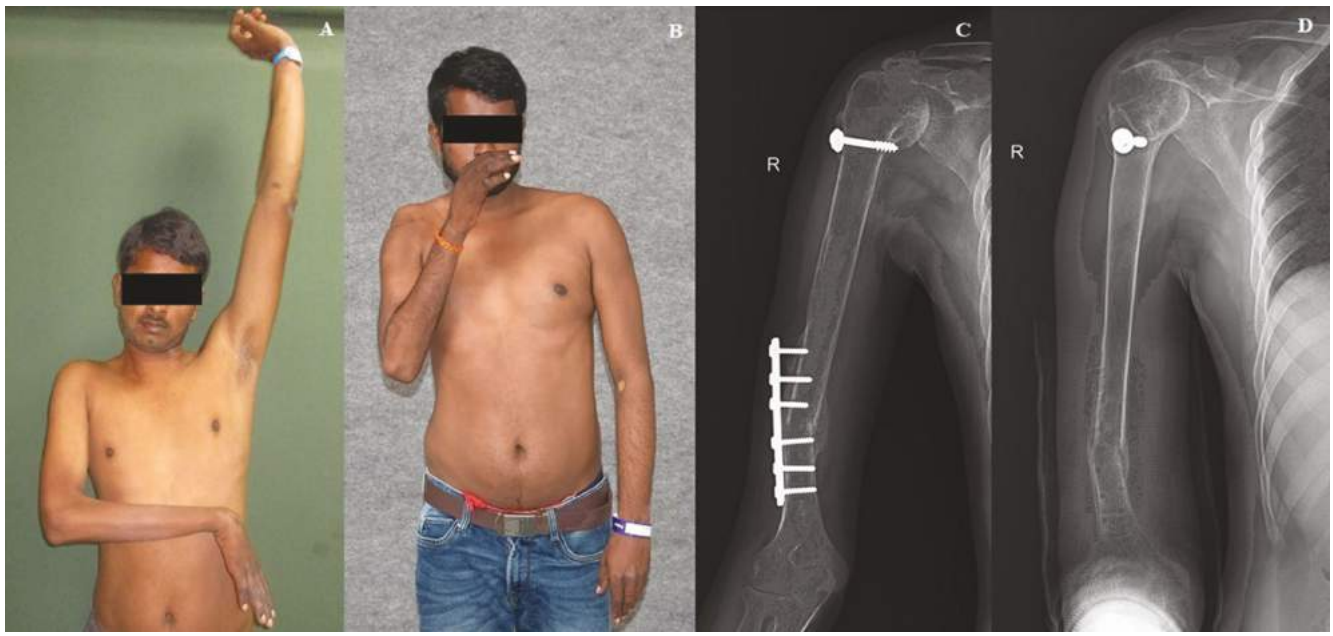

Fig. 1. A 28-year-old male with right-sided global brachial plexus palsy. After the spinal accessory to musculocutaneous nerve transfer, patient had good elbow flexion but the limb was internally rotated. A. External rotation osteotomy of the humerus places the hand in an aesthetically better position which is well appreciated by the patient as it corrects the 'paralysed look' of the limb. B. This patient had an implant failure. However, the osteotomy site has untied well. C. Implant was removed at the time of his subsequent surgery, one year after the osteotomy. D.

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Fig. 2. A 47-year-old male with left-sided global brachial plexus palsy. He recovered grade 4 elbow flexion after Spinal accessory to Musculocutaneous nerve transfer. However, severe internal rotation posture led to the flexing elbow striking the abdomen – 'tummy flexion'. A. Precluding strengthening and a full range of elbow flexion. Postoperatively, 'tummy flexion' got corrected allowing a full range of elbow flexion. B.

with complete palsy did not have any hand function at the time of this surgery.

The angle of external rotation osteotomy was decided with an aim to achieve about 10°–20° of external rotation while still retaining enough internal rotation to reach the centre of the body (umbilical region). Patients who had full internal rotation (able to reach the sacral region) were planned for 60° of rotation, whereas anyone with some limitation were considered for 40°–50° of rotation with eventual confirmation during the surgery so as to allow the reach of hand to the centre of the body.

Surgical technique: Surgery was performed by surgeons of Level 4 expertise. The surgical approach and level of osteotomy were chosen based on the previous nerve surgery and any concomitant secondary surgery being done along with the humerus external rotation osteotomy. Since most of the patient had undergone nerve surgery for restoration of elbow flexion, osteotomy was done in the lower humerus level, as opposed to the proximal humerus in children with birth brachial plexus palsy, to prevent an inadvertent injury to previously reconstructed nerves. One patient underwent osteotomy through anterior approach (first case), whereas in the rest, all the osteotomy was done through the posterior approach. The posterior approach not only provided a better and easier bone exposure but also a flatter bone in the distal part for suitable plate placement. Moreover, as most of the patients underwent concomitant trapezius transfer, posterior approach osteotomy could be accomplished without a position change. Whenever the posterior approach was used, the radial nerve was encountered at the proximal extent of the incision and was safely

secured. Irrespective of the approach, osteotomy level was planned so as to allow fixation of the osteotomy with a six-holed plate. The flatter surface (distal bone in the posterior approach) was chosen as a reference and a reference wire was placed in the last hole of the intended plate. The correction wire was placed in the most proximal hole site of the intended plate at a desired angle of rotational correction (discussed previously) with help of an angle guide. The osteotomy site was marked to allow three screw placements on either side. Osteotomy was done by first making multiple drill holes with a 2 mm K-wire and then completing it with an osteotome. The distal segment was externally rotated at the osteotomy site to have the reference and correction wires parallel to each other. While maintaining this corrected position, the osteotomy site was fixed with a six-holed 4.5 narrow locking compression plate. The plate was first secured to the flat surface of the bone (distal bone in posterior approach) with a cortical screw and then the next screw was put in the compression mode so as to achieve compression at the osteotomy site. The reach of the hand to the mid-line of the body (umbilical region) was confirmed and the remaining four screws were placed in the locking mode. In our initial cases,we used a dynamic compression plate (DCP) but later changed to locking compression plate (LCP) as the latter provides a better fixation in patients who may have disuse osteopenia. Moreover, the LCP allows placement of the plate and fixation in the non-flat areas of the bone as well. None of the patients required any concomitant soft tissue release at the shoulder.

All the patients were immobilised in an arm pouch sling if osteotomy was the only operation. In others, the concomitant secondary procedure determined the immobilisation. For instance, when accompanied by trapezius transfer, the limb was immobilised in an abduction and external rotation splint for 2 months. At 1 month, the patient was allowed to mobilise the limb except in cases, where trapezius transfer was done along with osteotomy. Union was assessed with radiographs at 6 months.

RESULTS

The study included 19 patients (18 men and one woman) with an average age of 30 years (range 20–58) (Table 1). All had sustained the BPI in a road traffic accident. A total of 14 patients had a complete BPI (C5-T1), three extended upper BPI (C5-7) and two upper BPI (C5-6). Eighteen patients had nerve surgery done at an average time interval of 3.8 months from the injury. All recovered MRC $\geq$ 3 elbow flexion. In 14 patients, the severity of nerve injury precluded the re-innervation of the external rotators and in four patients, though the external rotators were reinnervated, their function did not recover. One patient (case no. 1) spontaneously recovered elbow flexion after an initial global BPI without external rotation. Thus, all 19 patients had a complete absence of external rotation and recovery of at least grade-3 elbow flexion prior to the humerus external rotation osteotomy. All patients desired to improve the posture of the limb, which tended to flex 'into the chest'. Five of them complained of inability to eat because of the limited reach of the hand to the mouth, whereas the remaining 14 patients with complete palsy did not have any hand function at the time of this surgery. All these patients had limited passive external rotation and were not suitable candidates for external rotation tendon transfer. Hence, external rotation osteotomy was planned. None required any additional soft tissue release.

The mean time between the nerve surgery and the external rotation osteotomy was 29.5 months. In eight patients, humerus external rotation osteotomy was done as a solo operation, and in the remaining, it accompanied other concomitant procedures (Table 1). These additional procedures ($n = 11$) included wrist arthrodesis ($n = 4$), trapezius transfer ($n = 3$), wrist arthrodesis and trapezius transfer ($n = 2$), pronation osteotomy of the forearm ($n = 1$) and triceps to biceps transfer ($n = 1$). None of the patients had any surgical site infections. Union was achieved at all the osteotomies at 6 months follow-ups X-ray (Fig. 3A). However, in one patient who had fixation with DCP, there was evidence of implant failure (Fig. 1C). This implant was removed at the time of his subsequent surgery for restoration of finger flexion, one year after the osteotomy operation. All the patients were satisfied with the surgery in terms of improved posture and the appearance of the limb. They subjectively felt their elbow power had improved (1B). All three patients with upper type BPI with good hand function reported improved hand-to-mouth reach (2B). In fact, two of them were able to use the involved right hand for eating after the surgery and were greatly satisfied. All the patients attained a resting posture of 15°–20° of external rotation (Table 1) and were still able to reach the mid-line of the body, and none complained of loss of internal rotation.

DISCUSSION

In a patient with a BPI, restoring elbow flexion is considered the top priority in reconstruction as this provides positioning of the hand for activities of daily living.

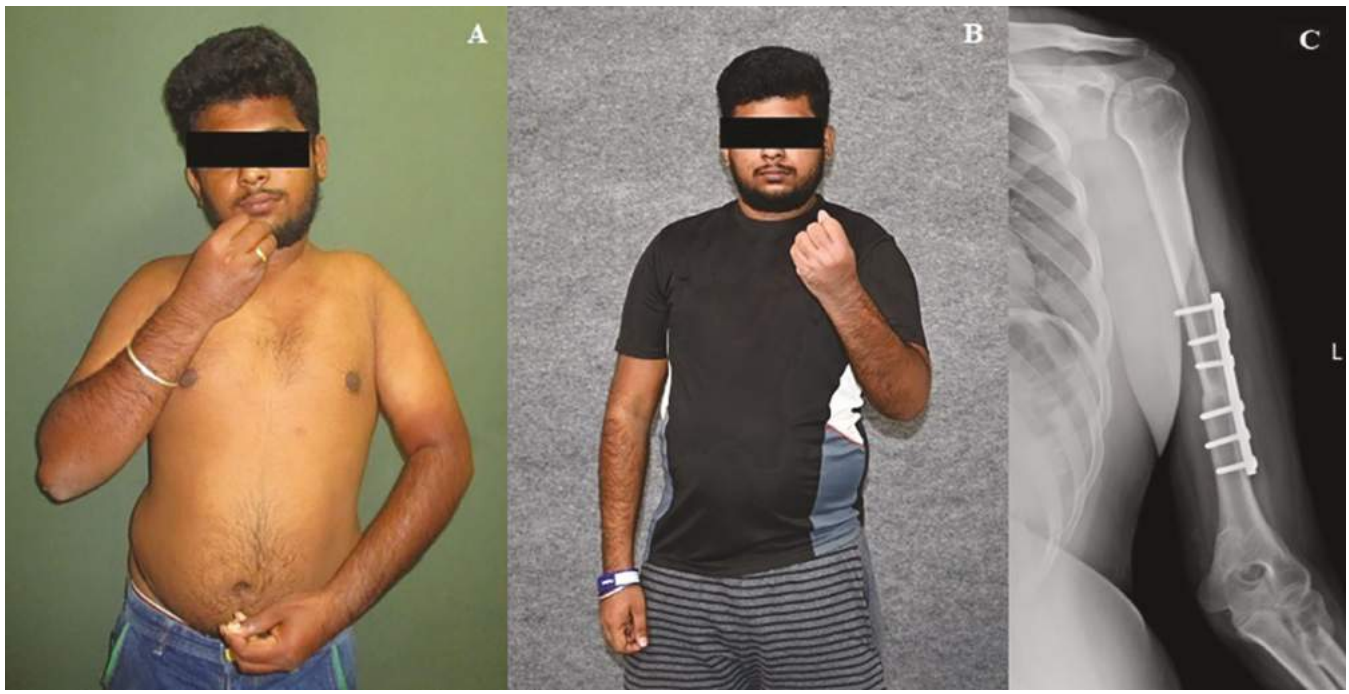

Fig. 3. A 24-year-old male with left sided upper extended brachial plexus palsy. The arm hangs down in an inwardly rotated position. A. Same patient, after external rotation osteotomy of humerus, with improved position of the arm and better hand to mouth and face reach. B. Radiograph showing good union at the osteotomy site. C.

Restoring shoulder function is the second reconstructive priority. Shoulder stability and abduction precede external rotation in priority. In the treatment of BPI, restoring shoulder external rotation may enhance outcomes by increasing their ability to perform activities of daily living.[7] If the extent of BPI permits dual nerve transfer for the shoulder, the spinal accessory to suprascapular and the triceps motor branch to the axillary nerve provides the best chance of restoring external rotation at the shoulder. However, the outcomes are variable.[8] Limited improvement in external rotation has been observed by various authors.[9–11] Furthermore, the option of nerve transfer may be severely limited in cases with extended brachial plexus palsies and may not exist in cases with global brachial plexus involvement.

Most activities of daily living require some degree of shoulder external rotation, with the arm being positioned with only 27° of abduction most of the time.[12,13] So, when these groups of patients recover good elbow function in a setting of inadequate or no external rotation, the patient is unhappy with the poor aesthetic appearance of an internally rotated shoulder. In addition, these patients are unable to do proper physiotherapy to strengthen their biceps because every time a patient tries to flex the elbow, he will have 'tummy flexion', where the hand hits the abdomen or chest, and further flexion of the elbow is restricted. Lack of external rotation also prevents the hand from reach to their face or mouth despite recovering good elbow function.

There are three options available for restoring shoulder external rotation, namely, shoulder arthrodesis, tendon transfers and external rotation osteotomy of the humerus. Shoulder arthrodesis is a salvage procedure for a completely paralysed shoulder requiring shoulder stability. Many patients are apprehensive about the thought of the shoulder becoming 'fixed' and do not desire fusion. Moreover, it is a complex operation with substantial implant and bone union-related complications.[14,15] A tendon transfer is generally the first option as it provides an active functional range and does not necessarily limit the movement in the opposite direction.[14–17] However, in extensive brachial plexus injuries, many of the potential donors for performing tendon transfer may be paralysed, weak or not sparable. Moreover, limited passive external rotation, common in this group of patients because of the longstanding paralysis, may preclude the tendon transfer surgery in the first place. All the 19 patients in this series lacked full passive external rotation at shoulder. External rotation osteotomy is a simple and effective technique with minimal negative effects, provided care has been taken to retain the reach of the hand to the mid-line of the body. It immediately places the hand in a cosmetically

Table 1. Patient Demographics

Patient	Sex	Type of palsy	Nerve surgery performed	Nerve surgery for shoulder innervation	Time since injury to nerve surgery (months)	Time since injury to external rotation osteotomy (months)	Approach -site of osteotomy	Combined surgery
1	Male	C5-T1	No*	No	-	36	Anterolateral – Distal	None
2	Male	C5-T1	Yes	No	3	14	Posterior - Distal	Wrist arthrodesis
3	Male	C5-T1	Yes	No	3	19	Posterior - Distal	None
4	Male	C5-T1	Yes	Yes (C6 to Ax. N.)	3	42	Posterior - Distal	None
5	Male	C5-T1	Yes	No	3	40	Posterior - Distal	None
6	Male	C5-T1	Yes	No	6	25	Posterior - Distal	Wrist arthrodesis + Trapezius transfer
7	Male	C5-7	Yes	No	2	26	Posterior - Distal	Trapezius transfer
8	Male	C5-7	Yes	Yes (SAN to SSN)	2	26	Posterior - Distal	Wrist arthrodesis
9	Male	C5-T1	Yes	No	3	23	Posterior - Distal	Wrist arthrodesis
10	Male	C5-T1	Yes	No	1	25	Posterior - Distal	Wrist arthrodesis
11	Male	C5-6	Yes	No	5	33	Posterior - Distal	None
12	Male	C5-T1	Yes	No	2	17	Posterior - Distal	Trapezius transfer
13	Male	C5-T1	Yes	No	5	39	Posterior - Distal	Pronation osteotomy Forearm
14	Female	C5-T1	Yes	Yes (C5 to PDUT)	9	31	Posterior - Distal	Wrist arthrodesis
15	Male	C5-T1	Yes	No	4	28	Posterior - Distal	None
16	Male	C5-T1	Yes	No	3	41	Posterior - Distal	Triceps to biceps transfer
17	Male	C5-T1	Yes	No	2	17	Posterior - Distal	None
18	Male	C5-6	Yes	No	2	27	Posterior - Distal	Trapezius transfer
19	Male	C5-6	Yes	Yes (SAN to SSN)	11	53	Posterior - Distal	None

*Elbow flexion recovered spontaneously in this patient.

**Ax. N.: Axillary nerve, SAN: Spinal Accessory Nerve, SSN, Suprascapular nerve, PDUT, Posterior division of Upper trunk.

better position, which is very well appreciated by the patient.

A mere change in position of the arm makes the elbow flexion look stronger and more functional. Though we are unable to objectively prove the statement, patients felt that their elbow flexion was powerful after the osteotomy placed their limb in a better position. This is the limitation of this study. A better-positioned arm could allow for the better strengthening of the biceps. Above all, in patients with good hand function, externally rotated position allows easy access to the mouth. All of our patients had an uneventful postoperative period with no cases of postoperative infection. One patient experienced an implant-related complication that was discovered during routine radiographic evaluation in the postoperative period. The proximal screws holding the 4.5 mm DCP used for fixation had pulled out (Fig. 1C). Patient denied any trauma; however, the possibility cannot be ruled out. Disuse-related osteopenia in these groups of patients could be another reason. Hence, we now prefer to use LCP for the fixation and would recommend the same. The degree of external rotation to be performed depends on the severity of the internal rotation posture, but in all these cases it was 50°–60°. In particular, one must make sure that after external rotation, the mid-line reach of the hand is still preserved by the surgeon being able to passively touch the patient's palm to the belly 'belt area'. Over-correction must be avoided, as an externally rotated limb is neither aesthetic nor functional. The surgical approach and level of osteotomy can be chosen based on the previous nerve surgery and concomitant secondary surgery being done along with the humerus external rotation osteotomy, as detailed earlier. However, we have found that the osteotomy at the lower third of the humerus through a posterior approach is safe as it does not disturb any of the previous nerve reconstructions. The bone shape at this level is suitable for plate placement and the level of osteotomy allows for a stable fixation with a six-hole 4.5 mm LCP plate. Moreover, the scar resulting does not interfere with any of the future reconstructions patients may need. All the osteotomies in our series healed well.

Brachial plexus injuries are complex in terms of the variable extent of the injury and inconsistent recovery patterns. In addition, patient demands and desires have a great bearing on the surgical plan, especially for secondary surgeries. Most of the patients themselves have expressed that if the limb was placed in an externally rotated position manually, they felt better because the limb is now in a better cosmetic and functional position. This eased our decision-making in the early cases and influenced by the satisfaction reported by these patients, we offer this operation to many more patients now. External rotation osteotomy of the humerus is a simple and effective operation to place the limb in a better cosmetic and functional position. A mere change in position of the limb has a positive impact on the self-esteem of these patients and they are able to flex their elbow without interference against the abdomen. Moreover, in a patient with good hand function, the restored external rotation permits easy reach of hand to mouth.

DECLARATIONS

Conflict of Interest: The authors do NOT have any potential conflicts of interest with respect to this manuscript.

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Ethical Approval: Our study was exempt from institutional review board adjudication per institutional policy regarding small case series.

Informed Consent: There is NO information (names, initials, hospital identification numbers or photographs) in the submitted manuscript that can be used to identify patients.

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