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Abstract

Study Design Retrospective cohort study.
Objective Supination deformity in obstetric brachial plexus injury can have debilitating consequences for the functionality of the hand. Surgical treatment by a forearm osteotomy has a recurrence rate of 20 to 42%. As a complement to forearm osteotomy, a biceps rerouting may improve outcome.
Methods Children with residual brachial plexus injury, who had a forearm osteotomy for a supination contracture and had a postoperative decrease of pronation to 50 degrees or less, were indicated for a biceps rerouting. Shoulder, elbow and hand function, biceps strength, Mallet score, and Raimondi score were assessed with a minimum follow-up of 2 years.
Results Five patients (median age: 8 years; range: 4–10) underwent biceps rerouting between 2008 and 2012. Median follow-up time was 6.8 years (range: 3.2–7.0 years). Passive pronation increased in all cases (median 0 degree at baseline to 80 degrees at final follow-up). Active pronation also increased. Active median wrist extension was –30 degrees at baseline and 45 degrees at follow-up. Biceps strength and grip strength improved in two cases. No recurrences were present.
Conclusion The sequentially planned surgical treatment of forearm osteotomy and biceps rerouting should be considered in the treatment of severe supination deformity, as it is effective in improving pronation of the forearm and hand function, without recurrence at follow-up.
Level of Evidence/Type of Study Level III, case series, therapeutic study.

Keywords
- brachial plexus
- obstetric palsy
- supination deformity
- forearm osteotomy
- biceps rerouting
- recurrence

Introduction

In obstetric brachial plexus injury, residual deficits are reported to be present in 30% of the cases. When C5–C6 innervated functions (biceps and supinator muscles) are partly restored and there is a poor recovery of the distal roots, a supination deformity can occur resulting in an active and/or passive pronation deficit. It has an incidence of up to 23% in residual plexus palsy, depending on the severity of nerve injury. Supination deformity results from imbalance between recovered function of the biceps and supinator, that are not antagonized by weak pronators. Also, contractures due to growth retardation of poorly innervated muscles and shortening of the interosseous membrane, which is shortest in pronation, can contribute to the development of the

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deformity.[1,2] This supinated "beggar's hand" position is associated with poor upper limb function.[3–5] Pronation of the forearm, in the presence of a functional hand, is used in more daily activity tasks than supination, such as writing, drinking, and most playing activities.

Various surgical techniques have evolved to obtain a pronation position of the hand, of which biceps rerouting eventually combined with a interosseous membrane release and forearm osteotomies are the most widely used techniques. Biceps rerouting alone may be used in mild cases with almost normal passive forearm rotation but absence of active pronation.[6] In severe cases, with a passive pronation deficit, forearm osteotomy is indicated, but recurrence rates are reported to be 20 to 40%, due to muscle imbalances across the forearm. We therefore hypothesized that in cases with a decrease in pronation in the first postoperative months after forearm osteotomy, a biceps rerouting is indicated to prevent recurrence.[7–9] So far, no outcome studies have been published on this sequentially planned surgical strategy. Here we present the long-term clinical follow-up of severely affected patients who underwent biceps rerouting after forearm osteotomy for a supination deformity.

Methods

Patients

Between January 2008 and December 2015, 22 patients with a supination contracture had undergone a forearm osteotomy at our specialized brachial plexus unit at the Leiden University Medical Center, Leiden, The Netherlands. Of these, five consecutive patients were identified who had a decrease in pronation within 1 year after forearm osteotomy. The medical ethical commission approved the study, and patients and/or their parents provided written informed consent (protocol nr. p12.013).

Patients were considered for biceps rerouting after forearm osteotomy if a passive pronation of 50 degrees or less was present within 1 year after surgery. Indications for the initial forearm osteotomy were no passive and active pronation beyond neutral, or a recurrence after prior forearm osteotomy (passive pronation of 50 degrees or less). When shoulder deformities were present, these were preferably treated before the forearm surgery. Furthermore, active wrist and finger extension and flexion were required preoperative, eventually achieved by flexor to extensor tendon transfer.

Surgical Procedure

The osteotomy of the forearm was performed by an open proximal osteotomy of the ulna through a dorsomedial approach, just proximal to the insertion of the interosseous membrane to the ulna. After plate fixation of the ulna, an open osteotomy of the middistal radius through a dorsolateral approach was performed, and a dorsal distal third radial osteotomy was fixed with a plate as well. Both osteotomies were fixed in maximum pronation by a small fragment four-hole compression plate (►**Fig. 1**).

Biceps rerouting was performed by the procedure described by Zancolli.[1] A volar elbow approach was used to reach the biceps tendon, which was then Z-shaped lengthened and rerouted around the radial head, and fixed to its own end to become an active pronator. At the same session, plate removal of the forearm osteotomies was performed. ►**Fig. 2** shows the scar from both biceps rerouting and osteotomy. Postoperative, an upper arm cast in 90 degrees of pronation and 50 degrees of elbow flexion was applied. After 6 weeks of cast treatment, physical therapy started to perform active and passive pronation and supination of the forearm to obtain maximum range of motion.

Fig. 1 Radiographic picture after double forearm pronating osteotomy (case 4).

Clinical Evaluation

Patients were followed at 3 monthly periods in the first year and then on a half-yearly to yearly basis until maturity. All procedures were performed by the senior author (R. N.). All functional and clinical data were collected prospectively and entered in the departments ProMISe database (Medical Research Data Management, Leiden University Medical Center, The Netherlands). Data on gender, sex, age, Narakas classification,[10] primary neurosurgical repair, and secondary surgery were obtained. One of two examiners (both orthopaedic surgeons part of the specialized brachial plexus unit) evaluated the patients with a handheld goniometer. Passive and active glenohumeral

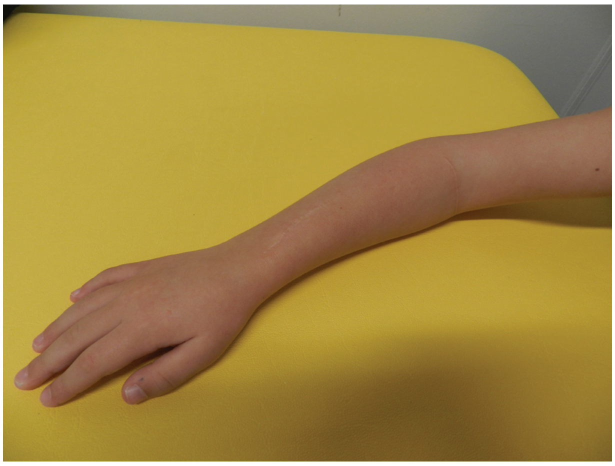

Fig. 2 Scar after biceps rerouting and forearm osteotomy (case 4; scar from ulna osteotomy not visible).

abduction and external rotation were assessed. In addition, the Mallet score was obtained to estimate the overall functionality of the affected shoulder. It includes active abduction, active external rotation, and the (in) ability to reach the mouth, neck, and back and ranges from 5 (poor) to 25 (excellent).[11]

Elbow function was assessed by passive flexion and extension. Furthermore, passive and active pronation and supination were measured in 90 degrees of elbow flexion with 0 degree of shoulder abduction. We used the Medical Research Council motor scale to measure biceps strength, which ranges from 0 (no muscle contractions) to 5 (normal muscle strength).[12,13] Hand function was assessed by active wrist extension and flexion, and by extension and flexion strength of the wrist. Also, the grip strength and the finger extension strength were recorded. Furthermore, the Raimondi score was collected to assess overall hand function. This score ranges from 0 (poor) to 5 (excellent) and is based on the active wrist extension and finger movement, and abduction and opposition of the thumb together with the rotational position of the forearm.[14] For this study, we report clinical data at baseline and at last follow-up visit.

Results

Baseline characteristics are shown in ►**Table 1**. Median age at baseline was 8 years (range: 4–10 years) and median follow-up was 6.8 years (range: 3.2–7.0 years). The included patients all had a lesion of C5–C7 or worse (Narakas classification II, III, or IV). A neurosurgical repair was performed in the first year after birth in four patients. In one patient, a latissimus dorsi and teres major transfer was performed to restore impaired active external rotation of the shoulder. One patient received a flexor-to-extensor transfer to improve wrist extension prior to the forearm osteotomy. One patient was treated before by a forearm osteotomy and had recurrence. This patient was the first to be treated by the new strategy: forearm osteotomy and during follow-up decision for biceps rerouting.

Forearm Rotation

Passive and active pronation increased in all cases. Passive pronation increased from a median of 0 degree (range: –10 to 40 degrees) to 70 degrees (range: 50–90 degrees) at final follow-up (►**Table 2**). Pronation at rest improved from a median of –80 degrees (–90 to –50 degrees) to a median of 50 degrees (30–60 degrees). Active pronation increased from a median of 0 degree (range: –30 to 0 degree) to a median of 70 degrees (range: 40–70 degrees) (►**Fig. 3**). Passive supination decreased in three patients and active supination decreased in all patients. The passive arc of rotation increased in four patients (median: +50 degrees; range: 0 to +80 degrees). The active arc of rotation decreased in three patients and increased in two patients (median: –10 degrees (range: –50 to +20 degrees). No recurrences were seen during follow-up.

Shoulder, Elbow, and Hand Function

Range of motion of the shoulder at baseline and at final follow-up was comparable. Mallet score was 14 (range: 13–19) at baseline, compared with 17 (range: 13–19) at follow-up. Also, extension of the elbow at follow-up (median: –20 degrees; range: –5 to –40 degrees) was comparable with baseline values (–20 degrees; range: –15 to –40 degrees). Biceps strength improved in two cases and was unchanged in three cases. Wrist extension was –30 degrees (range: –6050 degrees) at baseline and 45 degrees (range: 20–60 degrees) at

Table 1 Baseline characteristics

Case	Age (y)	Follow-up (y)	Nerve injury	Narakas classification	Neurosurgical repair	LD/TM transfer	Wrist extension transfer
1	8	6.8	C5–T1	IV	C5–C8		
2	8	7	C5–T1	IV	C5–C7		Yes
3	8	7	C5–C7	II	None		
4	4	5	C5–T1	III	C5–C6		
5	10	3.2	C5–C7	II	C5–C6	Yes	

Abbreviations: LD, latissimus dorsi; TM, teres major.
Note: Age is age at intervention. Nerve injury shows the number of roots involved in the plexus injury. Narakas classification ranges from I (C5 injury, good prognosis) to IV (total injury, worst prognosis). Neurosurgical repair shows the root levels that were treated. LD/TM transfer was performed to improve active external rotation. Wrist extension transfers were performed by a transfer of the flexor carpi radialis to the extensor carpi radialis longus.

Table 2 Follow-up pronation and supination after forearm osteotomy and biceps rerouting

Case	Passive								Active									
	Preop (pro/sup)			Forearm osteotomy		Last FU (pro/sup)			Preop (pro/rest/sup)					Last FU (pro/rest/sup)				
				Perop	3 mo													
1	0	–	90	80	80	90	–	0	0	–	−50	–	50	70	–	60	–	0
2[a]	20	–	60	80	75	90	–	30	0	–	−60	–	60	70	–	60	–	−20
3	0	–	90	80	80	60	–	30	0	–	−90	–	90	60	–	30	–	0
4	0	–	90	90	60	50	–	30	0	–	−90	–	90	40	–	30	–	0
5	−10	–	90	90	80	70	–	20	−30	–	−80	–	80	70	–	50	–	0

Abbreviations: FU, follow-up; perop, pronation at the end of the forearm osteotomy procedure; preop, at baseline; pro, pronation; rest, position in rest; sup, supination.
[a]Case 2 had a recurrence of a prior forearm osteotomy and was the first patient to be treated by the sequential treatment strategy of forearm osteotomy and biceps rerouting.

follow-up. Grip strength improved in two cases and was unchanged in three cases. The Raimondi score improved in one case and was unchanged in the other four cases. No deterioration of hand function measurements was observed.

Complications

There were no complications from the biceps rerouting, with respect to infection, tendon rupture, or neurovascular damage. Also, no complications from the prior osteotomies were reported, that is, no nonunions, malunions, or synostoses were present.

Discussion

In this paper, we report on the long-term follow-up of patients who had a biceps rerouting for a decrease in passive pronation within 1 year after forearm osteotomy, which was performed for severe supination deformity. We showed that this strategy improved pronation in all patients, without recurrence after a follow-up of 6.8 years. Improvement in active wrist extension was observed, as well as in the Raimondi score and grip strength.

Fig. 3 Active pronation at final follow-up was 70 degrees in this patient (case 1).

Until recently, patients usually underwent either osteotomy or biceps rerouting, depending on the severity of the supination deformity. A forearm osteotomy is considered the first-choice treatment option in more severely affected children (i.e., passive pronation ≤ 50 degrees), while biceps rerouting was usually applied in case of mild deformity (i.e., passive pronation ≥ 50 degrees).[6] Experts have discussed the value of adding biceps rerouting to a forearm osteotomy in the presence of severe supination deformity to prevent recurrences, but patient data on these combined procedures have not been published and no conclusions could be made.[7,15] Several studies have shown that a successful forearm osteotomy without recurrence may result in a postoperative passive pronation between 46 and 70 degrees.[5,16–18] The rotational position of the forearm was improved in this study and may provide for an increased functionality of the hand, as shown in literature by an improved Raimondi score at final follow-up.[5] Indeed, improved hand function was observed in our study patients. Additionally, a larger increase in maximum passive (50–90 degrees) and active pronation (40–70 degrees) at final follow-up was achieved by combining the two treatments when compared with the 46 to 70 degrees of postoperative passive pronation and the 6 to 49 degrees postoperative active pronation reported in literature.[5,7,9,16–19] These results support the recommendation that in severe supination deformity, combining forearm osteotomy and biceps rerouting may improve outcome.[6]

We did not find any disadvantages, except loss of supination, nor any complications with our strategy. The shoulder function was not affected by any of the surgical procedures of the forearm. Neither increase in elbow flexion contracture nor a decrease in biceps strength was present. In contrast, two patients had improved biceps strength at follow-up, perhaps due to shortening of the tendon or due to a more extensive use of the hand after surgery. No biceps ruptures were present. It is questionable if this sequential strategy should also be performed in younger children with severe deficits, with a high expected recurrence risk. In these cases, perhaps forearm osteotomy and biceps rerouting could also be performed in one surgical session. As we routinely remove hardware after forearm osteotomy, the biceps rerouting is performed in the same session as the hardware removal. By using the sequential strategy, only children with a recurrent pronation deficit will be indicated for biceps rerouting. As such, overtreatment can be prevented by performing biceps rerouting only when a tendency to recurrence during the postoperative period is present.

In our cohort with almost 7 years of follow-up, no recurrences were seen. In the literature, a recurrence rate of 20 to 42% has been reported after forearm osteotomy, even when well-fixed osteosynthesis plates were applied. It has been hypothesized that supinating forces by the biceps or supinator are not antagonized if forearm osteotomy is performed as a single procedure.[8,9] Also, ongoing shortening of the interosseous membrane, biceps muscle. or supinator may lead to osseous remodeling and subsequently to recurrence of deformity.[5,7,20,21] Remodeling of malrotation of the forearm bone fracture can be up to 45 degrees in children below 9 years of age.[22] Our youngest patient (4 years of age) indeed had the most prominent decrease in active arc of pronation, although the deformity did not recur after 5 years of follow-up. Close follow-up after forearm osteotomy and the performance of biceps rerouting when passive pronation deteriorates did prevent recurrence in our patient cohort, although more data are needed to confirm our findings. As the rerouted biceps functions as an active pronator by its strength and as a passive pronator by muscle shortening, unwanted remodeling into a recurrent supination position might be prevented by this sequential treatment approach.

In conclusion, performing a biceps rerouting in cases of pronation deterioration after forearm osteotomy is a successful treatment strategy for severe cases of supination deformity. Patients should be closely followed after forearm osteotomy, especially during the first postoperative year to observe a decrease in passive pronation. If a passive pronation decreases below 50 degrees, a biceps rerouting is performed together with hardware removal. Young patients (i.e., less than 6 years of age), patients with severe passive pronation deficit (<0 degree), patients with a rapidly progressive deformity, patients with a high expected risk of recurrence, and patients after recurrence of a prior forearm osteotomy might benefit from this treatment strategy. This strategy may help in decision-making and prevents overtreatment and recurrence.

References

1 Zancolli EA. Paralytic supination contracture of the forearm. J Bone Joint Surg Am 1967;49(7):1275–1284

2 Weekley H, Nikolaou S, Hu L, Eismann E, Wylie C, Cornwall R. The effects of denervation, reinnervation, and muscle imbalance on functional muscle length and elbow flexion contracture following neonatal brachial plexus injury. J Orthop Res 2012;30(8):1335–1342

3 Hoeksma AF, Ter Steeg AM, Dijkstra P, Nelissen RG, Beelen A, de Jong BA. Shoulder contracture and osseous deformity in obstetrical brachial plexus injuries. J Bone Joint Surg Am 2003;85-A(2):316–322

4 Evans-Jones G, Kay SP, Weindling AM, et al. Congenital brachial palsy: incidence, causes, and outcome in the United Kingdom and Republic of Ireland. Arch Dis Child Fetal Neonatal Ed 2003;88(3):F185–F189

5 Yam A, Fullilove S, Sinisi M, Fox M. The supination deformity and associated deformities of the upper limb in severe birth lesions of the brachial plexus. J Bone Joint Surg Br 2009;91(4):511–516

6 Metsaars WP, Nagels J, Pijls BG, Langenhoff JM, Nelissen RG. Treatment of supination deformity for obstetric brachial plexus injury: a systematic review and meta-analysis. J Hand Surg Am 2014;39(10):1948–1958.e2

7 Allende CA, Gilbert A. Forearm supination deformity after obstetric paralysis. Clin Orthop Relat Res 2004;(426):206–211

8 Hankins SM, Bezwada HP, Kozin SH. Corrective osteotomies of the radius and ulna for supination contracture of the pediatric and adolescent forearm secondary to neurologic injury. J Hand Surg Am 2006;31(1):118–124

9 Bahm J, Gilbert A. Surgical correction of supination deformity in children with obstetric brachial plexus palsy. J Hand Surg [Br] 2002;27(1):20–23

10 Narakas A. Surgical treatment of traction injuries of the brachial plexus. Clin Orthop Relat Res 1978;(133):71–90

11 Mallet J. Obstetrical paralysis of the brachial plexus. II. Therapeutics. Treatment of sequelae. Priority for the treatment of the shoulder. Method for the expression of results [in French]. Rev Chir Orthop Reparatrice Appar Mot. 1972;58(Suppl 1):166–168

12 James MA. Use of the Medical Research Council muscle strength grading system in the upper extremity. J Hand Surg Am 2007;32(2):154–156

13 Medical Research Council. Aids to the Investigation of Peripheral Nerve Injuries. 2nd ed. London: Her Majesty's Stationery Office; 1943

14 Raimondi P. Evaluation of results in obstetric brachial plexus palsy: The hand. Presented at the International Meeting on Obstetric Brachial Plexus Palsy. The Netherlands: Heerlen; 1993

15 Waters PM. Obstetric brachial plexus injuries: evaluation and management. J Am Acad Orthop Surg 1997;5(4):205–214

16 van Kooten EO, Ishaque MA, Winters HA, Ritt MJ, van der Sluijs HA. Pronating radius osteotomy for supination deformity in children with obstetric brachial plexus palsy. Tech Hand Up Extrem Surg 2008;12(1):34–37

17 Lipskeir E, Weizenbluth M. Derotation osteotomy of the forearm in management of paralytic supination deformity. J Hand Surg Am 1993;18(6):1069–1074

18 Blount WP. Osteoclasis of the upper extremity in children. Acta Orthop Scand 1962;32:374–382

19 Rühmann O, Hierner R. Z-plasty and rerouting of the biceps tendon with interosseous membrane release to restore pronation in paralytic supination posture and contracture of the forearm [in German]. Oper Orthop Traumatol 2009;21(2):157–169

20 Nikolaou S, Liangjun H, Tuttle LJ, et al. Contribution of denervated muscle to contractures after neonatal brachial plexus injury: not just muscle fibrosis. Muscle Nerve 2014;49(3):398–404

21 Crouch DL, Plate JF, Li Z, Saul KR. Computational sensitivity analysis to identify muscles that can mechanically contribute to shoulder deformity following brachial plexus birth palsy. J Hand Surg Am 2014;39(2):303–311

22 Noonan KJ, Price CT. Forearm and distal radius fractures in children. J Am Acad Orthop Surg 1998;6(3):146–156