The humerus is the best place for bone lengthening

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Abstract The aim of this study was to examine the effectiveness of lengthening the humerus in children and young adults. Between 1984 and 2005, the Orthopaedic Department of Semmelweis University elongated 11 humeri (ten patients) for reasons of congenital hypoplasia (four cases), osteomyelitis (three cases), epiphyseolysis, growth plate closure after irradiation and obstetrical paralysis (one case each). The study cohort consisted of five females and five males, with an average age at the time of surgery of 17.8 years (range: 12–31 years). In every case, the lengthening was performed with a unilateral Wagner fixator. The lengthening protocol was 1 mm distraction daily (callotasis) after a 7-day latency period. The fixator was removed after total bone healing. Plate fixation or bone transplantation was not used. The average rate of lengthening was 6.2 cm (4.5–10.5 cm), and the achieved lengthening was 27% (range: 16–44%). The average healing index was 32 day/cm. One patient who suffered from temporary radial paresis, and temporary flexion contracture of the elbow was regarded as a complication following placement of the fixator. Based on our results, humeral shortening can effectively be treated with the unilateral Wagner fixator. The main difference between the original Wagner method and our approach is that we were able to leave the fixator in the humerus until total bony reconstruction so there was no need for plate fixation or bone transplantation.

Résumé Le but de cette étude est d'examiner le devenir des allongements de l'humérus chez les enfants et les adultes jeunes. Entre 1984 et 2005, 11 humérus (10 patients) ont été allongés selon la technique de Wagner. Ces interventions ont eu lieu au Département de Chirurgie Orthopédique de l'Université Semmelweis. La répartition fille/garçon a été de 1 pour 1. L'étiologie des pathologies était dans quatre cas une hypoplasie congénitale de l'humérus, dans trois cas une séquelle d'ostéomyélite, une épiphysiolyse, une fermeture prématurée du cartilage de croissance après irradiation et une séquelle de paralysie obstétricale. L'âge moyen des patients à l'intervention a été de 17,8 ans (12–31). Dans chaque cas l'allongement a été unilatéral avec l'appareil de Wagner. La vitesse de l'allongement a été de 1 mm par jour (callotasi) après une période de latence de 7 jours en post-opératoire. Le fixateur a été retiré après consolidation osseuse. Il n'y a jamais eu de nécessité d'ostéosynthèse par plaques ni greffes. L'allongement moyen a été de 6,2 cm (4,5 à 10,5 cm) et le pourcentage d'allongement de 27% (16–44%). L'index de consolidation a été de 32 jours par centimètre. Un patient a présenté une parésie radiale transitoire et une raideur du coude en flexion. Nous pensons que les raccourcissements de l'humérus peuvent être traités de façon bénéfique pour les patients avec cette technique d'allongement par Wagner. La différence principale avec la méthode de Wagner originale et notre pratique est, l'utilisation du fixateur jusqu'à la consolidation osseuse sans ostéosynthèse par plaques ou greffes.

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Introduction

Humeral lengthening in comparison to femoral or tibial lengthening is very rare. In 2003 we reported that of 302

extremity lengthenings carried out in our department only eight were done on the humerus [13]. One of the factors possibly explaining the rarity of humeral lengthening may be that a minor shortening of the humerus rarely constitutes either a functional or cosmetic handicap to the patient. Only a few reports on lengthening of the humerus can be found in the body of international orthopaedic literature, while reports on humeral shortening are more prevalent [1, 5, 7–9, 14]. The most common reason for humeral shortening is osteomyelitis or growth plate closure caused by a tumour [2, 10, 12]. We have successfully carried out tibial/femoral lengthening in 14 achondroplastic patients; none of these patients wanted to correct their severe arm shortening. The development of the callotasis method and improved lengthening apparatus has provided us with the technology to successfully correct length discrepancies of the upper extremity [3, 6].

Material and methods

Between 1984 and 2005, 11 humeri (ten patients; five males and five females) were elongated using the Wagner fixator at the Orthopaedic Department of Semmelweis University. The average age of the patients at the time of surgery was 17.8 years (range: 12–31). The average amount of shortening was 8.4 cm (range: 4.5–13.5 cm). The most common reason for humeral shortening was congenital in origin in this group of patients (Table 1). The lengthening was performed with Wagner midi or normal equipment. Following insertion of the fixator, we sought and carefully isolated the radial nerve, followed by osteotomy in the middle of the humeral diaphysis. The lengthening protocol was a 7-day latency period, followed by 0.5-mm twice daily distraction. The patients learned how to handle the fixator, to take care of the area surrounding the pins and the exercises. The patients were

discharged on postoperative day 12–14, and the lengthening procedure was continued in their homes. Range-of-motion tests at the elbow and shoulder were carried out every 2 to 4 weeks, and the axis of the humerus and bony remodelling were checked every 2 to 6 weeks. We left the fixator in the humerus until total bony reconstruction was complete, and there was no need for plate fixation or bone transplantation (Fig. 1a–d).

Results

The average amount of lengthening was 6.2 cm (range: 4.5–10.5 cm), and the proportion of achieved lengthening was 27% (range: 16–44%). The average healing index was 32 day/cm (range: 25–40 day/cm).

The lengthening procedure was well tolerated by all the patients. The patients' co-operation was favourable, and all could maintain their normal daily activities – with slight restrictions (Fig. 2). Pin tract infection was found in every second patient, but after local treatment and oral antibiotics, suppuration stopped. Two temporary elbow flexion contractures developed (20° and 45°, respectively); however, after the contracture had been recognised, physiotherapy was initiated, with a subsequent complete return of the range of motion. One patient had neuropraxis that resolved within 3 months of commencing physiotherapy. The planned lengthening was achieved in every case. Non-union or other major complications were not observed.

Discussion

Dick and Tietjen published the first case of humeral lengthening in 1978 [4], and since then more than 100 humeral lengthening cases have reported in the literature. Most of the reported series – as with our study – have

Table 1 Patients' data

Case	Age (years)	Shortening (cm)	Length achieved (cm)	Increased lengthening(%)	Etiology
P.G.M.	31.9	4.5	4.5	18.8	Congenital
S.Sz.	19.0	8	6	26.1	Postirradiation
K.F.	16.5	10	5	20.8	Congenital
B.R.	19.6	13.5	8	44.4	Laes plex.brach
K.F.	17.7	5	4.5	16.1	Congenital
H.A.	13.1	10	6.5	36.1	Osteomyelitis
M.M.	14.9	5	5	19.6	Congenital
B.Á.	18.2	5.5	5	20.4	Epiphyseolysis
B.J.	12.6	10	6.5	20.3	Osteomyelitis
C.P.	12.6	10.5	10.5	43.8	Osteomyelitis
B.M.	20.1	10	6.5	32.5	Congenital
Average	17.8	8.4	6.2	27.2	

Fig. 1 X-rays of a 12.5-year-old boy's humerus. **a** A 10.5-cm shortening remained after infantile osteomyelitis, **b** 6 weeks after the lengthening has started, **c** after the 10.5-cm shortening has equalised, **d** 10 months after the lengthening has started, the fixator was removed

consisted of fewer than 20 humeral lengthening procedures. Cattaneo et al. reported the largest study which consisted of 30 bilateral humeral elongations on achondroplastic dwarfs. The aetiology of the more than 70 humeral length discrepancies reported elsewhere included post-traumatic hypoplasia, unicameral bone cyst, septic arthritis and congenital or idiopathic length discrepancies. Congenital deformities were the most common underlying causes in most of our cases. In the lower extremity there seems to be an increasing number of complications when the lengthening exceeds 20%. This phenomenon does not occur on the humerus. In our study, the average rate of lengthening was 27%, and in two patients, it was more than 40%. The usual age of the patients undergoing lengthening is 12–14 years,

at a time when growth has become stable and osteogenic forces are still optimal [2, 7, 8].

We used the Wagner apparatus in all of our cases, but Italian authors prefer the Ilizarov apparatus [1]. Our experiences with the unilateral Wagner apparatus are very favourable. It gives adequate stability to the non-weight bearing humerus and is easy to handle. This unilateral fixator on the humerus can be applied similarly to the Ilizarov fixator – i.e. no plate has to be implanted – and in this way the patient is spared two additional operations. The Wagner fixator is more comfortable to wear than the Ilizarov type. Spongiosaplasty was not necessary due to the effectiveness of the callus distraction method. The tendency towards luxation did not appear, even in the case

Fig 2 The lifestyle of most patients did not change during the lengthening of the humerus

of a displastic glenoid fossa. Janovec et al. [7] and Poul et al. [9] also reported good results after using the Wagner fixator for humeral lengthening.

We found that the humerus had almost the same healing index (range: 25–40 day/cm) as the bones of the lower extremity, but patients who had humeral lengthening had a faster functional recovery. Functional recovery following tibial or femoral lengthening takes about 32 months; this is in contrast with humeral lengthening, which takes only 8 months. The determination of the healing index is considered to be finished when the fixator is removed, but this does not mean the return of function of the extremity in all cases. A plate implantation is necessary after removal of the fixator from the tibia and the femur; this is not required after a humeral lengthening procedure as the fixator is removed only after total bone reconstruction. This is why the healing index can be the same. Tanaka et al. published a comparative study in which they reported that the humerus shows significantly faster bony reconstruction than the tibia [11].

Drainage from the pin tracts was a common complication in our patients, but this healed after proper pin care management. We found flexion contracture in two elbows,

but interruption of the lengthening procedure was not necessary; however, these elbows resolved only following removal of the apparatus. Radial paresis is a serious complication of humeral lengthening. Based on published recommendations, we did not stop the lengthening procedure when the complication appeared and despite signs of paralysis, the lengthening was allowed to proceed; ultimately each case improved and the patient recovered.

We believe that this method is a suitable treatment of humeral shortening as the lengthening procedure is well tolerated, and the risk of complication is small. The use of the Wagner apparatus for osteosynthesis or spongiosaplasty was not necessary, which is the reason why – in our opinion – circular fixators have no advantage over unilateral fixators in lengthening the humerus. With the adequate use of unilateral fixators, total humeral reconstruction can be achieved with a low risk of complication and without the loss of joint movement.

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