

The posttraumatic proximal cross-union of the forearm in childhood: what is recommended?

Marcel Dudda, Tobias Fehmer,
Thomas A. Schildhauer,
Christiane Kruppa

Department of Surgery, University
Hospital Bergmannsheil, Ruhr-University
of Bochum, Germany

Abstract

The posttraumatic proximal cross-union of the forearm in childhood is a rare complication after radial head, neck or proximal forearm fractures and elbow dislocations. There is no standardized treatment. Several surgical procedures with or without interposition techniques are described in the literature. The aim of this study was to analyze all children with cross-unions who underwent surgery over the last 15 years. From 1998 to 2013, 8 children with a posttraumatic proximal cross-union of the forearm (Type 3 according to Vince and Miller) received surgical treatment with resection of the cross-union or radial head. Mean age at the time of initial trauma was 9.0 ± 2.56 years (range 6-14 years), age at the time of surgery was 11.9 ± 3.09 years (range 7-16 years). Mean time of resection of the cross-union was 23.2 months. Follow-up time was 10.6 months (range 1-36 months). Five patients had a resection of the cross-union without any interposition techniques, in 2 cases with an additional arthrolysis of the elbow. One patient had an interposition of a local fascia flap. In 2 cases, a primary excision of the radial head, six and seven years, respectively, after trauma, was performed. All patients, except one, had non-steroidal anti-inflammatory drugs therapy after surgery. A post-operative irradiation was performed in 3 cases. The mean postoperative range of motion for pronation/supination was $36/0/53^\circ$. Controversy remains about the best procedure to adopt for posttraumatic cross-union in childhood. After analysis of our data and the literature, we recommend the resection of the cross-union within 6-24 months of occurrence without necessarily using any interposition techniques. All patients reported an improvement with regard to ordinary activities. In cases of long-term cross-union for several years with ankylosis of the elbow and bony deformities of the proximal radius, an excision of the radial head as salvage procedure is recommended.

Introduction

The posttraumatic proximal cross-union of the forearm in childhood is a rare complication after radial head and neck or proximal forearm fractures and elbow dislocations.¹⁻³ This uniting callus between radius and ulnar, which makes pronation and supination of the forearm impossible, was first described in adults by Gross *et al.* in 1864.⁴ The first report in children was performed by Mouchet *et al.* in 1900.⁵ In the existing literature, cross-unions are often described in case reports and small cases series.⁶⁻⁸ In 1987, Vince and Miller reviewed 10 children with cross-union after fracture or osteotomy of the forearm.⁸ Prior to this, these authors had carried out a study on cross-union in adults; they reported an incidence of 2% in a population of 2318 adults with fractures of the forearm. Furthermore, they developed a classification system with regard to the location of the cross-union. Type 1 (distal) is located in the distal intra-articular part of the forearm, Type 2 (diaphyseal) in the middle and non-articular distal third of the forearm, and Type 3 (proximal) in the proximal third, determined by the length of the ulnar.⁹ Jupiter and Ring developed a subclassification of the Vince and Miller Type 3 cross-union classification. They described Type A cross-union at the location distal to the tuberosity radii and Type B up to the region of the proximal radioulnar joint. A Type C cross-union shows an additional ankylosis of the elbow and humeroulnar ossifications.¹⁰ There is no standardized treatment and several surgical procedures with or without interposition techniques are described in the literature.^{8,10-14} Furthermore, the timing of treatment is included in the discussion. Vince and Miller described an increased rate of recrudescence after an early resection of the cross-union, but on the other hand they mentioned that delayed resection might be complicated by scarring of the soft tissue and bony deformities following osteophyte development.⁸ Compared to the adult population, they reported worse results in pediatric diaphyseal (Type 2) cross-unions.⁹

We retrospectively analyzed all children who underwent surgery for a cross-union in our institution over the last 15 years to determine treatment for cross-unions, complications and range of elbow motion.

Materials and Methods

Between 1998 and 2013, 8 children with a posttraumatic proximal cross-union of the forearm (Type 3 according to Vince und Miller) who received surgical treatment with a resection of the cross-union or the radial head were

Correspondence: Marcel Dudda, Department of Surgery, BG-University Hospital Bergmannsheil Bochum, Bürkle-de-la-Camp Platz 1, 44789 Bochum, Germany.
Tel. +49.234.3020 - Fax: +49.234.6956.
E-mail: marcel.dudda@ruhr-uni-bochum.de

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retrospectively analyzed. X-rays and clinical data of all patients were reviewed. Cross-union treatment, pre-, intra- and postoperative elbow range of motion (ROM) for pronation and supination, recrudescence occurrence and further surgical intervention, as well as non-operative additive therapies such as drugs and radiation, were recorded. Initial trauma causing the cross-union were fractures of the radial head and neck, or fractures of the proximal forearm. Patients were 4 (50%) girls and 4 (50%) boys. Three right (37.5%) and 5 left (62.5%) arms were affected. Average age at the time of initial trauma was 9 ± 2.56 years (range 6-14 years), average age at the time of surgery was 11.9 ± 3.09 years (range 7-16 years). The earliest excision of the cross-union was performed five months after fracture, the latest excision after five years. One non-union of the radial neck with an additional cross-union was observed in one patient. Mean follow up was 10.6 months (range 1-36 months).

Results

Five patients were treated with resection of the cross-union without any interposition techniques (Figures 1 and 2). Two had an additional arthrolysis of the elbow and one an addi-

tional reinsertion of the biceps tendon. One of these patients had an arthrolysis of the elbow initially after a healed radial neck fracture and a cross-union developed which was resected one year after initial trauma. In one patient, an interposition of a local fascia flap after resection was performed. In 2 patients, a primary excision of the radial head with additional elbow arthrolysis, six and seven years after trauma was accomplished (Figures 3 and 4, Table 1.)

In our study, all patients except the one with the additional non-union, received non-steroidal anti-inflammatory drugs (NSAIDs), and 3 patients underwent postoperative irradiation.

One patient with the initial elbow arthrolysis after a radial neck fracture developed a cross-union and the resection was performed one year after primary trauma. In one case, no further treatment after recrudescence was performed and the patient who was diagnosed for a cross-union five years after trauma underwent a resection of the radial head with additional elbow arthrolysis six months after initial resection of the cross-union due to a fulminant ankylosis of the elbow. The patient who underwent a resection of the cross-union and an additional interposition of a local fascia flap

required a sedated mobilization of the elbow one month later because of decreasing mobility. An improvement in the range of motion for pronation and supination intraoperatively, based on the pre-operative appearance, was observed in all patients. Also, all patients showed a loss of range of motion for pronation and supination postoperatively compared to the intraoperative appearances, even without radiological signs of a recurrent cross-union. Mean range of motion for pronation and supination was 36/0/53° (Table 2).

Discussion

The proximal radial cross-union, defined as uniting callus between radius and ulna, is rare. Cross-union is reported as the most common serious complication which can occur after radial head and neck fractures, and occurrence after open reduction of severely displaced fractures has been described.^{2,15-23} Nenopoulos *et al.* reported an incidence of 9% cross-union in their study population of 45 children, which occurred in dislocated fractures;²¹ Newman *et al.* described a frequency of 10%.² Häßle *et al.* analyzed 116 fractures of the proximal forearm

in children and found 2 cross-unions. In all cases of non-reduced side dislocation, they reported 2-5 mm deformities of the radial head, radioulnar cross-union or intra-articular callus.¹ This was also reported by Newman *et al.* who, in 4 of 5 cross-unions, found a non-reduced side dislocation greater than 2 mm.² Vocke *et al.* reported that, after radial neck fracture, a radiolunar synostosis developed in 1 of 38 cases.²⁴ In our patient group, development of cross-union occurred after proximal forearm fractures, radial head fractures and elbow dislocation. Besides fracture dislocations, periosteal interpositions,²⁵ surgical trauma,^{26,27} and repeated manipulation are described as possible causes.⁷ However, since the cause has not been investigated specifically, there is no consensus about treatment or the best timing of treatment. In adults, Vince and Miller suggested resection of the cross-union at least one year after trauma in order to ensure complete callus formation. But on the other hand, in the pediatric population, they reported that delayed resection might be complicated by soft tissue contractions and these might compromise recovery of a good range of motion.⁹ Ogden *et al.* suggested the resection within six months.²⁸

In our patient group, the time of diagnosis

Table 1. Patients and treatments.

ID	Age at therapy for cross-union	Treatment time after trauma	Treatment	Relapse	Further treatment
1	10 years	5 months	Resection + interposition fascia flap	No	Sedated mobilization
2	10 years	30 months	Resection + elbow arthrolysis	No	No
3	10 years	10 months	Resection	Yes	No
4	16 years	5 years	Resection + elbow arthrolysis	Yes	Radial head resection
5	14 years	2 months	Elbow arthrolysis	Persisted	Cross-union resection
6	7 years	22 months	Resection + biceps tendon reinsertion	No	No
7	15 years	6 years	Radial head resection + elbow arthrolysis	No	No
8	3 years	7 years	Radial head resection + elbow arthrolysis	No	No



Figure 1. Ten-year old boy after radial neck fracture with proximal radioulnar cross-union after 10 months (A, B).

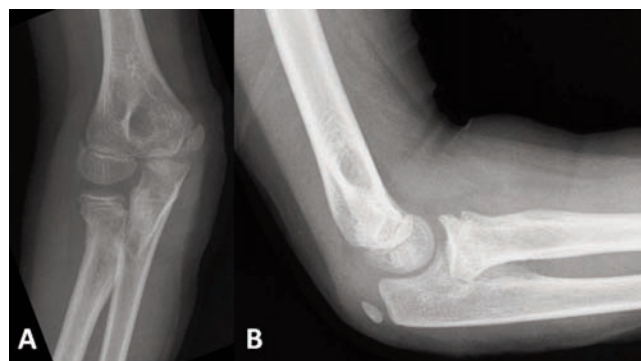


Figure 2. Ten months after trauma resection of the cross-union (A, B).

of the cross-union was between five months and seven years. All patients undergoing surgery within 60 months after trauma received a cross-union resection. But acceptable results could only be achieved in patients who underwent resection within 30 months after trauma. The patient who underwent resection after five years had to have a radial head resection due to a recrudescence. The patient who underwent cross-union resection with flap interposition required a sedated elbow mobilization one month later because of decreased mobility. Therefore, we had better results with a simple resection without interposition techniques. In 2 of 3 cases treated six and seven years after trauma, a primary resection of the radial head with elbow arthrolysis was performed with good intraoperative ROM. None of these patients experienced a recrudescence and, therefore, in cases with a delayed treatment of the cross-union a resection of the radial head may be a long-term option. However, this should only be considered a salvage procedure. Treatment with resection of the radial as salvage procedure is reported to show good results.^{29,30} After reviewing the literature and our results, we suggest the resection of the cross-union within 6-24 months after occurrence. We agree with Ogden *et al.*²⁸ that, at this point, formation of the callus should be complete and any delay in treatment might be complicated by soft tissue contractions and difficulties in achieving a good ROM, as suggested by Vince and Miller.^{8,9,28}

Treatment options are usually described in case reports or small case series.^{3,8,11,13,31} Aner *et al.* reported 2 cases of cross-union: one resection without interposition techniques after 33 months with pronation/supination 45°/0°/70°, and the other with resection of the cross-union after eight months with interposition of a Gore-Tex-Vascular-Graft with an pronation/supination of 80°/0°/90°. They reported an increase in risk after the age of ten years

and an extensive fracture dislocation.¹¹ Interposition of free vascularized fascia fat grafts or silicon membrane after resection of the cross-union are described.^{13,31} Von Laer *et al.* mentioned that the success rate in treatment of posttraumatic cross-union is higher than in congenital cases, and that interposition of vascularized transplants may provide an opportunity for surgery.³² The technique of these interpositions has been reported by various authors in adults.^{31,33,34} Wierer *et al.* reported good results with a method developed by Kamineni *et al.*¹² with resection of 1 cm radius with no further manipulation of the cross-union.¹⁴ Jupiter and Ring used bone wax as interposition material as well as soft tissue such as fat.¹⁰

The literature reports less use of additional treatment methods such as irradiation and anti-inflammatory agents after cross-union resection, and no valid conclusions can be drawn. Most reports dealing with this are of adults or address heterotopic ossifications in children with neurological issues.³⁵⁻³⁸ Cullen *et*

al. reported 4 cases of post-traumatic cross-union in adults, each of them received postoperative irradiation with 800-1000 cGy and reported no recurrence of the cross-unions.³⁵ Low-dose irradiation can be applied within five days after surgery and has been shown to reduce heterotopic bone in adults.³⁹⁻⁴² A single 800 cGy has been reported to be as effective as 1000 cGy dose given in 5 doses.⁴⁰ In adults, post irradiation sarcoma are not reported with doses less than 3000 cGy.⁴³ Despite these results in adults, other author do not recommend irradiation in children to avoid recurrence of heterotopic ossifications.³⁸ As additional therapy to avoid heterotopic ossification and recurrence of the cross-union, NSAID such as perioperative oral indomethacin have been used, but their effectiveness has not been documented.^{36,37,44} A few positive results have been reported using anti-inflammatory agents in adults to avoid recurrence of heterotopic ossifications.^{45,46} In our study, all patients, except the one with the additional non-union, received NSAIDs and 3 patients had postopera-

Table 2. Range of motion.

ID	Pre-operative ROM	Intraoperative ROM	ROM at last follow up
1	No pronation/supination	20-0-30° Pro/Sup	20-0-30° Pro/Sup
2	No pronation/supination	70-0-20° Pro/Sup	20-0-30° Pro/Sup
3	Pro/sup 30-0-20°	80-0-50° Pro/Sup	80-0-50° Pro/Sup
4	No pronation/supination	30-0-80° Pro/Sup	30-0-80° Pro/Sup
5	No pronation/supination	90-0-60° Pro/Sup	30-0-60° Pro/Sup
6	No pronation/supination	45-0-70° Pro/Sup	45-0-70° Pro/Sup
7	No pronation/supination	80-0-90° Pro/Sup	20-0-70° Pro/Sup
8	Pro/sup 20-0-20°	80-0-60° Pro/Sup	40-0-30° Pro/Sup

ROM, range of motion.



Figure 3. Thirteen-year old girl after radial neck fracture at the age of six years (A,B), presentation at hospital seven years after trauma with cross-union, ankylosis and bony deformity of the proximal radius.

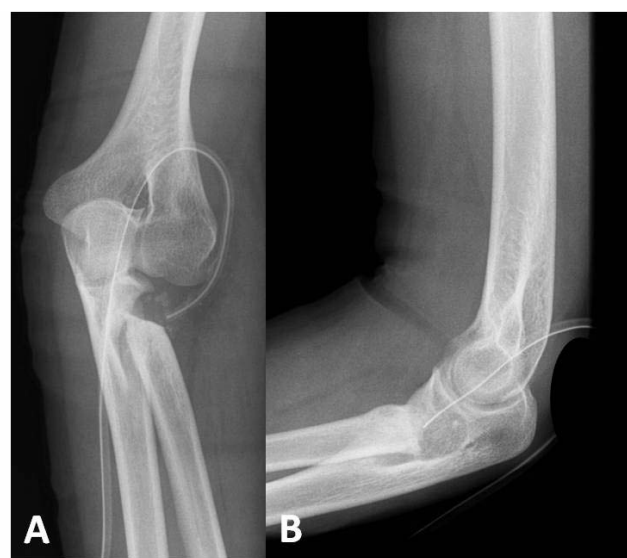


Figure 4. Primary resection of the cross-union and arthrolysis due to fulminant ankylosis and bony deformities (A,B).

tive irradiation.

In all patients, reduced mobility was observed postoperatively with an average ROM of 36°/0°/53° for pro- and supination; this was disappointing in patients with resection of the radial head who clinically showed moderately better results. But the short follow up means valid conclusions can not be drawn and a longer observation period for these patients is required. In comparison to the almost stiff pre-operative pro- and supination, all patients showed an improved ROM postoperatively without experimental surgical procedures. Due to this loss of ROM, an early and aggressive physiotherapy after resection of the cross-union, with regularly and closed meshed control of the result, seems to be a major factor in preventing the loss of motion. This impression is based on the observation that all patients showed decreasing mobility postoperatively, even though they did not show radiological signs for a recurrent cross-union. This might be due to soft tissue contractions and could be addressed with aggressive physiotherapy, although this requires further investigations. A resection of the radial head in delayed diagnosed cross-union with ankylosis of the elbow might still be necessary to reach an acceptable range of motion. The patient's parents should be involved in detailed discussion with medical staff to explain and clarify all the options available and possible outcomes since their child might be handicapped in performing some types of manual work.

The limitation of this study relates to the inherent problems of retrospective evaluations and the small number of patients that makes it difficult to draw reliable conclusions. Furthermore, a longer follow up of these patients to address recurrence of cross-unions and range of motion of the forearm would be beneficial.

Conclusions

Postoperative cross-unions are rarely seen in the pediatric population and there is no consensus as to treatment. We suggest resection within 6-24 months without necessarily an interposition technique. For delayed treatment, resection of the radial head as salvage procedure can be performed. We advocate post-operative oral therapy with NSAID in all patients and irradiation in cases of delayed treatment of cross-unions; however, cases must be evaluated on an individual basis. All patients should be treated with intensive physiotherapy and continuative postoperative follow up to prevent a loss of range of motion.

References

- Häße HM. Frakturen des proximalen Radius im Wachstumsalter. *Unfallchirurgie* 1991;17:24-33.
- Newman JH. Displaced radial neck fractures in children. *Injury* 1977;9:114-21.
- von Laer L, Pirwitz A, Vocke AK. [Post-traumatic problem cases involving the elbow in children]. *Orthopäde* 1997;26:1030-6. [Article in German].
- Gross SD. A system of surgery. 3rd ed. Philadelphia: Blanchard & Lea: 1864. p 916.
- Mouchet A. Les fractures du col du radius. *Chirurgie* 1900;21:596-622.
- Fielding JW. Radio-Ulnar crossed union following displacement of the proximal radial epiphysis. A case report. *J Bone Joint Surg Am* 1964;46:1277-8.
- Roy DR. Radioulnar synostosis following proximal radial fracture in child. *Orthop Rev* 1986;15:89-94.
- Vince KG, Miller JE. Cross-union complicating fracture of the forearm. Part II: children. *J Bone Joint Surg Am* 1987;69:654-61.
- Vince KG, Miller JE. Cross-union complicating fracture of the forearm. Part I: adults. *J Bone Joint Surg Am* 1987;69:640-53.
- Jupiter JB, Ring D. Operative treatment of post-traumatic proximal radioulnar synostosis. *J Bone Joint Surg Am* 1998;80:248-57.
- Aner A, Singer M, Feldbrin Z, et al. Surgical treatment of posttraumatic radioulnar synostosis in children. *J Pediatr Orthop* 2002;22:598-600.
- Kamineni S, Maritz NG, Morrey BF. Proximal radial resection for posttraumatic radioulnar synostosis: a new technique to improve forearm rotation. *J Bone Joint Surg Am* 2002;84-A:745-51.
- Proubasta IR, Lluch A. Proximal radioulnar synostosis treated by interpositional silicone arthroplasty. A case report. *Int Orthop* 1995;19:242-4.
- Wierer M, Huber-Wagner S, Mutschler W. [Post-traumatic proximal radioulnar synostosis. Surgical technique and review of the literature]. *Unfallchirurgie* 2012;115:451-6. [Article in German].
- Degreef I, De Smet L. Missed radial head dislocations in children associated with ulnar deformation: treatment by open reduction and ulnar osteotomy. *J Orthop Trauma* 2004;18:375-8.
- Exner GU. Missed chronic anterior Monteggia lesion. Closed reduction by gradual lengthening and angulation of the ulna. *J Bone Joint Surg Br* 2001;83:547-50.
- Koslowsky TC, Mader K, Wulke AP, et al. Operative treatment of chronic Monteggia lesion in younger children: a report of three cases. *J Shoulder Elbow Surg* 2006;15:119-21.
- Powell RS, Bowe JA. Ipsilateral supracondylar humerus fracture and Monteggia lesion: a case report. *J Orthop Trauma* 2002;16:737-40.
- Gao GX, Zhang RY. Radial neck fracture in children. *Chin Med J (Engl)* 1984;97:893-6.
- Lindham S, Hugosson C. The significance of associated lesions including dislocation in fractures of the neck of the radius in children. *Acta Orthop Scand* 1979;50:79-83.
- Nenopoulos SP, Beslikas TA, Gigis JP. Long-term follow-up of combined fractures of the proximal radius and ulna during childhood. *J Pediatr Orthop B* 2009;18:252-60.
- Vahvanen V, Gripenberg L. Fracture of the radial neck in children. A long-term follow-up study of 43 cases. *Acta Orthop Scand* 1978;49:32-8.
- Steele JA, Graham HK. Angulated radial neck fractures in children. A prospective study of percutaneous reduction. *J Bone Joint Surg Br* 1992;74:760-4.
- Vocke AK, Von Laer L. Displaced fractures of the radial neck in children: long-term results and prognosis of conservative treatment. *J Pediatr Orthop B* 1998;7:217-22.
- O'Brien PI. Injuries involving the proximal radial epiphysis. *Clin Orthop Relat Res* 1965;41:51-8.
- Dougall AJ. Severe fracture of the neck of the radius in children. *J R Coll Surg Edinb* 1969;14:220-5.
- Henrikson B. Isolated fractures of the proximal end of the radius in children epidemiology, treatment and prognosis. *Acta Orthop Scand* 1969;40:246-60.
- Ogden JA. Skeletal injury in the child. Philadelphia: Lea and Febiger; 1982.
- Herbertsson P, Josefsson PO, Hasselius R, et al. Fractures of the radial head and neck treated with radial head excision. *J Bone Joint Surg Am* 2004;86-A:1925-30.
- Hresko MT, Rosenberg BN, Pappas AM. Excision of the radial head in patients younger than 18 years. *J Pediatr Orthop* 1999;19:106-13.
- Kanaya F, Ibaraki K. Mobilization of a congenital proximal radioulnar synostosis with use of a free vascularized fascio-fat graft. *J Bone Joint Surg Am* 1998;80:1186-92.
- Van Laer C. Korrekturingriffe am kindli-

- chen Ober-und Unterarm. Unfallchirurgie 2004;107:552-62.
33. Friedrich JB, Hanel DP, Chilcote H, Katolik LI. The use of tensor fascia lata interposition grafts for the treatment of posttraumatic radioulnar synostosis. *J Hand Surg Am* 2006;31:785-93.
 34. Muramatsu K, Ihara K, Shigetomi M, et al. Posttraumatic radioulnar synostosis treated with a free vascularized fat transplant and dynamic splint: a report of two cases. *J Orthop Trauma* 2004;18:48-52.
 35. Cullen JP, Pellegrini VD Jr., Miller RJ, Jones JA. Treatment of traumatic radioulnar synostosis by excision and postoperative low-dose irradiation. *J Hand Surg Am* 1994;19:394-401.
 36. Ippolito E, Formisano R, Caterini R, et al. Operative treatment of heterotopic hip ossification in patients with coma after brain injury. *Clin Orthop Relat Res* 1999;130-8.
 37. Ippolito E, Formisano R, Farsetti P, et al. Excision for the treatment of periarticular ossification of the knee in patients who have a traumatic brain injury. *J Bone Joint Surg Am* 1999;81:783-9.
 38. Kluger G, Kochs A, Holthausen H. Heterotopic ossification in childhood and adolescence. *J Child Neurol* 2000;15:406-13.
 39. Anderson LD, Sisk D, Tooms RE, Park WI 3rd. Compression-plate fixation in acute diaphyseal fractures of the radius and ulna. *J Bone Joint Surg Am* 1975;57:287-97.
 40. Ayers DC, Pellegrini VD Jr., Evarts CM. Prevention of heterotopic ossification in high-risk patients by radiation therapy. *Clin Orthop Relat Res* 1991;87-93.
 41. Jang SH, Shin SW, Ahn SH, et al. Radiation therapy for heterotopic ossification in a patient with traumatic brain injury. *Yonsei Med J* 2000;41:536-9.
 42. Abrams RA, Simmons BP, Brown RA, Botte MJ. Treatment of posttraumatic radioulnar synostosis with excision and low-dose radiation. *J Hand Surg Am* 1993;18:703-7.
 43. Kim JH, Chu FC, Woodard HQ, et al. Radiation-induced soft-tissue and bone sarcoma. *Radiology* 1978;129:501-8.
 44. Pellegrini VD Jr., Konski AA, Gastel JA, et al. Prevention of heterotopic ossification with irradiation after total hip arthroplasty. Radiation therapy with a single dose of eight hundred centigray administered to a limited field. *J Bone Joint Surg Am* 1992;74:186-200.
 45. Ritter M, Giobe T. The effect of indomethacin on heterotopic ossification of the elbow following long term coma. *J Bone Joint Surg Am* 1979;61:113-7.
 46. Sodemann B, Persson PE, Nilsson OS. Prevention of periarticular heterotopic ossification following total hip arthroplasty. Clinical experience with indomethacin and ibuprofen. *Arch Orthop Trauma Surg* 1988;107:329-33.