Outcome after pin fixation of supracondylar humerus fractures in children: postoperative radiographic examinations are unnecessary

A retrospective study of 252 Gartland-III and 12 flexion-type supracondylar humerus fractures

Noora TUOMILEHTO [1], Reetta KIVISAARI [2], Antti SOMMARHEM [2], and Aarno Y NIETOSVAARA [2]

[1] Helsinki University, Helsinki; [2] Children's Hospital, Helsinki University Central Hospital, Helsinki, Finland.
Correspondence: noora.tuomilehto@hus.fi
Submitted 2016-02-23. Accepted 2016-08-28.

Background and purpose — The quality of pin fixation of displaced supracondylar humerus fractures in children has not been assessed, and the clinical value of radiographic examinations after pin fixation is unclear. We evaluated pin configuration, quality of osteosynthesis, and outcome in 264 supracondylar fractures. The clinical significance of postoperative radiographs was analyzed.

Patients and methods — 252 Gartland-III and 12 flexion-type supracondylar humerus fractures were pin-fixed in the periods 2002–2006 and 2012–2014. During 2012–2014, staff were intructed that postoperative radiographs should not be taken. Quality of reduction was assessed by measuring Baumann and lateral capitellohumeral angles (LCHA) and also by recording the crossing point of the anterior humeral line (AHL) with bony capitellum. Rotatory alignment was registered as normal or abnormal. Pin configuration and quality of osteosynthesis were evaluated. The clinical significance of postoperative radiographs was analyzed.

Results — Postoperatively, Baumann angle was normal in 66% of the fractures, AHL crossed the capitellum in 84%, and no malrotation was evident in 85% of the fractures. Crossed pins were used in 89% of the cases. 2 or more pins fixed both fracture fragments in 66%. Radiographic examinations were inadequate for assessment of LCHA in 13%, of Bauman angle in 8%, of AHL in 2%, of rotation in 1%, and of pin fixation in 2% of the cases. Postoperative radiographs did not give useful information except in 1 patient who had corrective osteotomy. All 94 patients with follow-up (97%) who were treated during 2012–2014 were satisfied with the outcome.

Interpretation — Despite pin fixation being deemed unsatisfactory in one-third of the cases, significant malunion was rare. Postoperative radiography did not alter management or outcome.

There is common consensus that Gartland grade-III extension-type and flexion-type supracondylar humerus fractures should be reduced and pin-fixed, either by percutaneous or by open means. Satisfactory treatment includes restoration of coronal, sagittal, and rotatory alignment of the distal humerus and fixation with 2 pins piercing both fracture fragments that do not cross at the fracture line (Otsuka and Kasser 1997, Omid et al. 2008, Flynn et al. 2015).

Alignment of distal humerus is assessed in radiographs from the Baumann angle and lateral capitellohumeral (LCHA) angle, and also by using the anterior humeral line. The Baumann angle is defined as the angle between long axis of the humeral shaft and the growth plate of the lateral humeral condyle, with reported normal values between 64° and 81° (Williamson et al. 1992, Dai 1999, Omid et al. 2008, Shank et al. 2011) (Figure 1B). The lateral capitellohumeral angle (LCHA) is defined as the angle between the humeral shaft and capitellum, with reported normal values between 45° and 57° (Zenios et al. 2007) (Figure 1C). The anterior humeral line (AHL) passes through the anterior or middle third of the ossification center of capitellum in normal elbows (Otsuka and Kasser 1997, Omid et al. 2008, Herman et al. 2009, Flynn et al. 2015). Rotatory alignment cannot be determined exactly in plain radiographs. Quality of reduction can also be evaluated clinically by measuring the carrying angle and the range of motion of the elbow (Zenios et al. 2007, Smajic et al. 2013). Stability of osteosynthesis can be assessed by a rotation test intraoperatively (Zenios et al. 2007).

We analyzed the quality of reduction and osteosynthesis in extension type-III and flexion-type supracondylar humerus fractures. The clinical significance of postoperative radiographs and the usefulness of Baumann and LCHA angles in 2 series of children, to define alignment, were also assessed.

DOI 10.1080/17453674.2016.1250058

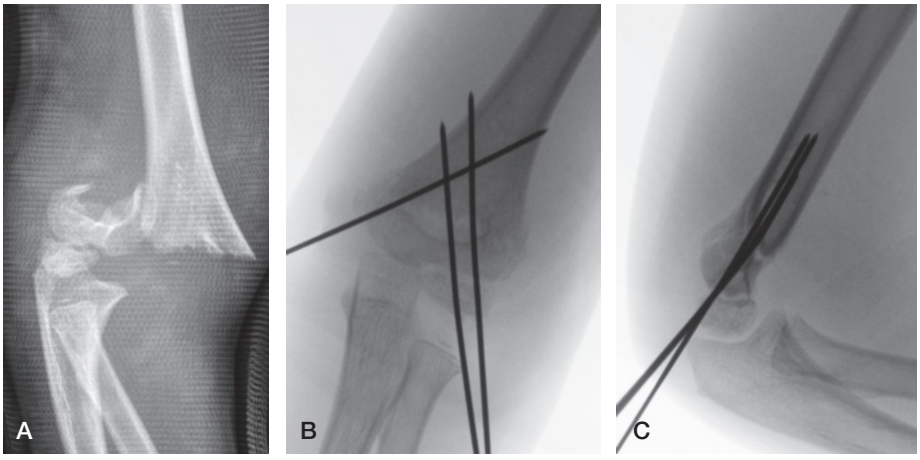

Figure 1. A. A 6-year-old boy with a Gartland grade-III extension-type supracondylar fracture. B and C. Satisfactory reduction and pin fixation in both the frontal plane (Baumann angle) (B) and the sagittal plane (C) (AHL crosses ossification center of capitellum).

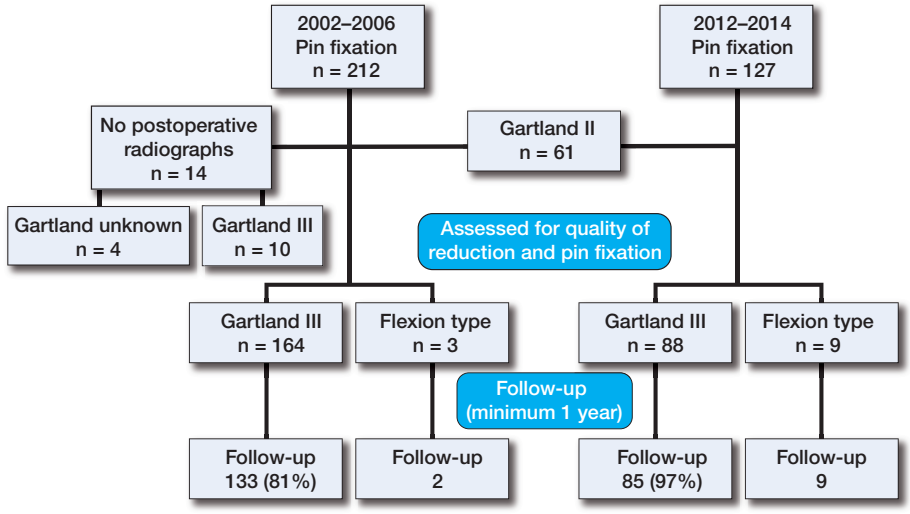

Figure 2. Pin-fixed supracondylar humerus fractures at the Children's Hospital, Helsinki.

Patients and methods

339 supracondylar humerus fractures were pin-fixed at the Children's Hospital, Helsinki, during 2 separate study periods: 2002–2006 inclusive (5 years) and 2012–2014 inclusive (3 years). 61 patients with extension type-II fractures were excluded. 14 other patients were excluded because they had further treatment elsewhere, and no intraoperative fluoroscopic images or postoperative radiographs were available at our institution (Figure 2). The latter part of the study was planned after we realized (during assessment of long-term outcome of displaced supracondylar humerus fractures in children treated at our institution during 2002–2006) that postoperative radiographs had little value in clinical decision-making. Thus, during the second study period, postoperative radiographs were not taken after clinically stable pin fixation with satisfactory alignment. Intraoperative fluoroscopic images were stored. A follow-up visit for pin removal 3–4 weeks after the fracture was scheduled, in contrast to the first study period when a follow-up visit with radiography at 1 week was routine.

Of the remaining 264 patients (median age 6.8 (1.4–14.1) years), 161 (61%) were boys. 13 patients (5%) had an open fracture. 17 senior pediatric orthopedic surgeons performed 188 of these operations (median 11 (1–26)) and 35 orthopedic or pediatric surgical registrars performed 76 (median 2 (1–8)) (Table 1).

All available radiographs and stored fluoroscopic images were analyzed by a pediatric radiologist (RK) and an orthopedic registrar (NT). Fracture alignment was assessed by measuring both Baumann angle and lateral capitellohumeral (LCHA) angle. The intersection point of the anterior humeral line with the ossification center of capitellum was measured and divided into 5 zones (Figure 3). Rotatory alignment was analyzed on radiographs and on stored fluoroscopic images by assessing symmetry of reduction of the medial and lateral columns. Malrotation was registered if reduction was asymmetric, but its degree could not be measured. Quality of the osteosynthesis was evaluated by analyzing the penetration, number, and configuration of the pins. Fracture alignment was analyzed from postoperative radiographs with the exception of 34 patients treated during the second study period who did not have any postoperative radiographs taken.

Baumann and LCHA angles were recorded as an average of the 2 separate measurements performed by RK and NT. Inter- and intraobserver reliability of the Baumann angle and LCHA was calculated using a Pearson correlation coefficient (Silva et al. 2010).

Reduction technique (closed vs. open) was recorded. Pin-track infections and permanent nerve injuries were recorded. Time and setting of pin removal were assessed. The number of corrective osteotomies was recorded. Patients were followed up until satisfactory recovery of elbow motion and hand function—either in outpatient clinics or through contact by mail or phone. Patients or their parents assessed elbow range of motion (extension and flexion) and carrying angle (symmetrical or asymmetrical).

Table 1. The quality of reduction and pin fixation

	Registrars (n = 35)	Consultants (n = 17)	p-value
No. of patients	76	188	
Open reduction, n (%)	0 (0)	20 (11)	
AHL crossing capitellum, n (%)	66 (87)	157 (84)	0.4
Baumann angle, mean	78	76	0.1
LCHA, mean	53	55	0.8
Malrotation, n (%)	9 (12)	30 (16)	0.4
No. of pins crossing both fracture fragments, n (%)			0.2
0	5 (7)	1 4 (7)	
1	26 (34)	43 (23)	
2 or more	43 (57)	128 (68)	

Figure 3. The intersection point of the anterior humeral line with the ossification center of capitellum divided into 5 different zones.

The quality of reduction and pin fixation was compared between patients in 2002–2006 and patients in 2012–2014 and also between patients who were operated by consultants or by registrars. The quality of reduction or pin fixation between the follow-up and non-follow-up patients was analyzed. Statistical analysis was performed using Fisher's exact test.

Results

426 postoperative radiographs and 90 stored intraoperative fluoroscopic images were analyzed. The median number of postoperative radiographs per patient was 2 (1–7) in 2002–2006 and 1 (0–3) in 2012–2014 (Tables 2 and 3).

Baumann angle (median 77° (49–105)) was within normal range in 174 of the 264 patients (66%), less than 10° outside the normal range in 57 patients (22%), more than 10° outside the normal range in 12 patients (5%), and unmeasurable in 21 patients (8%) because of closed growth plates (11/21) or inadequate coronal plane radiographs (10/21). The percentage of patients with a Baumann angle of more than 10° outside the normal range was greater in patients operated in 2002–2006 (7% vs. 1%) (p = 0.06). The intraobserver reliability (r = 0.91 and 0.91) and interobserver reliability (r = 0.92) were considered excellent.

Table 2. The number of patients and number of postoperative radiographs per patient

Year	No. of patients	No. of postoperative radiographs per patient 0	1	2	3	4–7
2002	28	0	15	8	5	0
2003	32	0	9	8	8	7
2004	35	0	8	11	4	12
2005	40	0	21	11	2	6
2006	32	0	21	6	1	4
2012	34	6	19	5	4	0
2013	33	7	19	5	2	0
2014	30	21	8	1	0	0

Table 3. Timing of postoperative radiography

Postoperative radiography	2002–2006	2012–2014
Before discharge	46	5
After discharge < 3 weeks	61	24
3–6 weeks	167	52
> 6 weeks but < 1 year	56	5
> 1 year	10	0

Table 4. The intersection point of the anterior humeral line with the ossification center of the capitellum in 5 different zones

Point of intersection of AHL with the capitellum	2002–2006 (n = 166)	2012–2014 (n = 94)
–2	14	7
–1	31	30
0	86	30
1	24	22
2	11	5

LCHA (median 53° (26–93)) was within normal range in 106 patients (40%), less than 10° outside the normal range in 95 patients (36%), more than 10° outside the normal range in 30 patients (11%), and unmeasurable in 33 patients (13%) because of inadequate sagittal plane radiographs (22/33) or closed growth plates (11/33). The intraobserver reliability (r = 0.80 and 0.84) and interobserver reliability (r = 0.83) reliability were considered good.

The AHL crossed the ossification center of the capitellum in 223 patients (84%), bypassed it in 37 patients (14%), and could not be recorded in 4 patients (Table 4). The ratio of patients with AHL bypassing the ossification center decreased from 15% in 2002–2006 to 13% in 2012–2014 (p = 0.7). In 16 cases, there was disagreement between the observers about the exact zone (anterior, middle, or posterior) at which the AHL crossed the bony capitellum. Rotatory malalignment was seen in 39 patients (15%) and could not be recorded in 2 patients. The incidence of malrotation decreased from 17% in 2002–2006 to 10% in 2012–2014 (p = 0.2) (Figure 4).

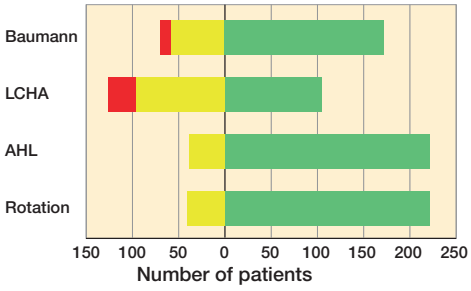

Figure 4. Quality of reduction of supracondylar humerus fracture in 264 children. Green: satisfactory alignment; yellow and red: unsatisfactory alignment; red: 10˚ outside normal values.

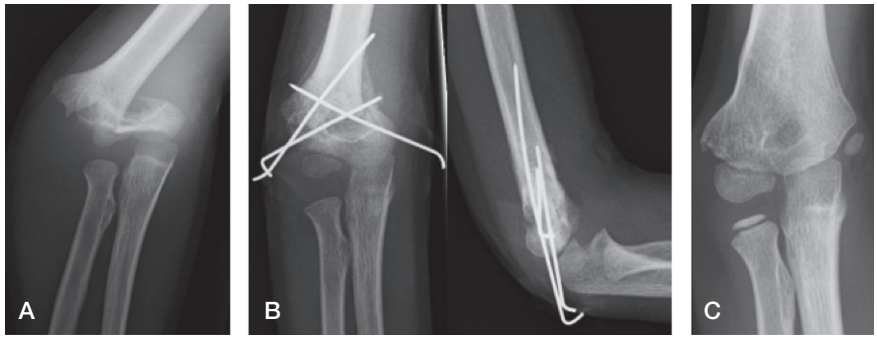

Figure 5. A. AP elbow radiograph of a 6-year-old boy with Gartland grade-III extension-type supracondylar fracture. B. Malunion at 3 weeks after unsatisfactory reduction and pin fixation in AP and sagittal planes. C. Corrective osteotomy was scheduled 3 years later after 7 postoperative radiographs.

Table 5. The quality of reduction and pin fixation in follow-up patients and non-follow-up patients during the 2 study periods (2002–2006 and 2012–2014)

	2002–2006 follow-up				2012–2014 follow-up			
	Yes		No		Yes		No	
	n	%	n	%	n	%	n	
Total	135	81	32	19	94	97	3	
Baumann angle								
Mean, degrees	77		78		75		70	
Unmeasurable	9	7	1	3	11	12	0	
Normal over 10°	87	64	19	59	65	69	3	
Normal	9	7	2	6	1	1	0	
LCHA								
Mean, degrees	56		55		53		34	
Unmeasurable	10	7	2	6	19	20	0	
Normal	54	40	16	50	36	38	0	
over 10° Normal	17	13	3	9	9	10	1	
AHL								
Crossing capitellum	111	82	30	94	81	86	1	
Not diagnostic	1	1	0	0	2	2	1	
Rotation								
Yes	22	16	7	22	10	11	0	
Pins crossing both fracture fragments								
0	11	8	6	19	2	2	0	
1	50	37	9	28	11	12	0	
2 or more	72	53	17	53	79	84	3	
Not diagnostic	2	1	0	0	2	2	0	

Fractures were fixed with 2 pins in 195 patients (74%), 3 pins in 63 patients (24%), 4 pins in 5 patients (2%), and 5 pins in 1 patient. Crossed pins were used in 235 patients (89%) and unilateral pins in 29 patients (11%). 2 or more pins fixed both fracture fragments in 171 patients (65%). Pin fixation was unsatisfactory in 88 patients (33%) (1 adequate pin in 69 patients, 0 adequate pins in 19 patients). Pin penetration could not be assessed in radiographs from 5 patients. Reduction was somewhat compromised during follow-up in 10 patients—because of inadequate pin fixation of the medial column in 9 patients, 3 of whom also had unsatisfactory reduction of the fracture (malrotation). 1 patient's pins were accidentally removed 7 days after surgery, but the Baumann angle remained normal and the AHL crossed the capitellum. 1 patient's Baumann angle was > 10˚ outside the normal range and the AHL did not cross the capitellum, leading to 15˚ extension deficit and 4˚ cubitus varus deformity, but he was fully satisfied with the functional and cosmetic outcome. 1 patient's AHL did not cross the capitellum, but in spite of this normal elbow range of motion was restored. The Baumann angle of the remaining 7 patients was < 10˚ outside the normal range, and the AHL crossed the capitellum. None of them wanted to have any further surgery. The rate of satisfactory pin fixation increased from 53% in 2002–2006 to 85% in 2012–2014.

Fracture alignment worsened during radiographic follow-up in 8 of 188 patients operated by consultants, as compared to 2 of the 76 patients operated by the registrars. 6 patients had pin-track infections that healed uneventfully with antibiotics.

Pin removal was performed at median 27 (7–49) days in 2002–2006 and at median 25 (18–36) days in 2012–2014. Anesthesia was required in 19 children (8%), 16 of whom were in the first part of the study. In 4 patients, pin removal was postponed because delayed healing was suspected in radiographs. In restrospect, all of these fractures were radiologically healed and pins could have been removed as planned.

Follow-up ranged from 7 to 12 years in 135 of 167 patients (81%) treated in 2002–2006 and from 1 to 4 years in 94 of 97 patients (97%) from 2012–2014. The quality of reduction was similar between the follow-up patients and the non-follow-up patients (Table 5). Of the 229 patients (87%) with at least 1 year of follow-up, 185 (81%) had symmetrical extension, 212 (93%) had symmetrical flexion, and 194 (85%) had symmetrical carrying angle. None of these patients reported functional disability of the fractured elbow and all had received no further treatment, except for 1 child who had a corrective osteotomy. This patient's primary reduction and pin fixation was unsatisfactory and he would have been better treated by a reoperation the next day (Figure 5).

Of the 32 patients treated in 2002–2006 with no long-term follow-up, 10 had clinical check-ups 2–30 months after operation due to restricted elbow ROM (6 patients) or to nerve palsy (4 patients). 1 of the 4 patients with nerve palsy had partial laceration of the ulnar nerve by the ulnar fixation pin, which was removed 2 days after the primary operation. Another patient's median nerve had been entrapped between fracture fragments, and exploration and partial nerve repair was performed. 17 patients had no follow-up, and could not be contacted after pin removal. 5 other patients who had follow-up elsewhere after pin fixation at our institution could not be contacted. 3 patients treated during the second study period could not be contacted after treatment at our institution. 2 out of 3 patients with complications of treatment were operated by 1 senior surgeon.

Discussion

We have assessed the quality of reduction and pin fixation in displaced supracondylar humerus fractures at our institution. The quality and clinical significance of postoperative radiographic examination was also evaluated. This was a retrospective intervention study, and comparison of the results from the 2 study periods should be done with caution.

The study had certain limitations to be considered. Although the follow-up rate (87%) can be considered high, we do not know the outcome in the remaining patients who could not be contacted. In addition, one might question whether patient satisfaction regarding the appearance or function of the fractured elbow could worsen in time. Malunion in the coronal plane usually results in cubitus varus, which does not remodel or worsen (Guven et al. 2015). In our experience most of our patients with subjectively unsatisfactory alignment in the coronal or sagittal plane searched treatment soon after the injury, with clinically evident deformity. This is line with the literature, since the corrective humerus osteotomies reported have been done in pediatric orthopedic clinics (Rane et al. 2012).

During the second (3-year) study period, the number of postoperative radiographs gradually decreased, but even in 2014 approximately one-third of the patients still had unnecessary imaging studies performed (i.e. they had no effect on the treatment of the patient). New regulations take time to be put into practice in an effective way.

Alignment of the distal humerus in the frontal plane can be registered in radiographs by calculating the Baumann angle and, clinically, by measuring the carrying angle (Dai 1999, Shank et al. 2011, Silva et al. 2010, Smajic 2013, Williamson et al. 1992). The reliability of radiographic evaluation has been questioned due to the relatively wide degree of normal variation in the Baumann angle in children (almost 20°), and errors in measurement of Baumann angle (of up to 7°) (Silva et al. 2010). In our opinion, Baumann angle has little predictive value on outcome, and the quality of reduction in the frontal plane might therefore be better evaluated clinically by comparison of the carrying angles of the elbows. Our study supports the importance of clinical evaluation. Despite the fact that an abnormal Baumann angle was measured in almost one-third of our patients' elbows after pin fixation, no reoperations were done and only 1 corrective osteotomy was performed for gun-stock deformity. In addition, Baumann angle was not measurable in 8% of the cases.

The quality of reduction in the sagittal plane can be assessed in radiographs from the AHL or from LCHA, and clinically by recording elbow range of motion (Otsuka and Kasser 1997, Omid et al. 2008, Herman et al. 2009, Shank et al. 2011, Flynn et al. 2015). No comparisons between the 2 radiological methods have been reported. According to the present study, the crossing point of the AHL with the ossification center of the capitellum is a more useful tool than LCHA for estimation of alignment of the distal humerus in the sagittal plane. The AHL and its relation to the bony capitellum were almost always assessable (98%), and its correlation to clinical results was far better than that of the LCHA (with AHL passing capitellum 84% vs. normal LCHA 40%), with no corrective osteotomies performed for sagittal plane malunions. Reduction can probably be considered to be satisfactory if the AHL crosses the bony capitellum at any part, although the AHL has been shown to pass through the anterior or middle thirds of the capitellum in normal elbows (Herman et al. 2009). Sagittal alignment of the fracture should be recorded by the AHL method in image-intensifier views, since complete elbow range of motion can be difficult to attain intraoperatively—partly because of swelling and partly because of the fixation pins.

Loss of reduction has been reported to occur in 4% of patients with lateral pins only and in 2% of patients treated with crossing pins (Woratanarat et al. 2012, Pennock et al. 2014). Partial loss of reduction in 4% of our patients is in accordance with these earlier studies, despite pin fixation being deemed unsatisfactory in almost half of the 167 patients operated during 2002–2006. This result is not good enough, even considering that reduction and osteosynthesis of a displaced supracondylar fracture of the humerus can be challenging. The quality of pin fixation increased in patients operated between 2012–2014, 85% of whom had 2 or more pins purchasing both fracture fragments ($p = 0.02$). Changes in our staff might explain part of this improvement in the standard of osteosynthesis. It is also possible that surgeons pay more attention to satisfactory reduction and stable pin fixation if postoperative radiographs are not being taken (Berthelot 2011).

Despite the fact that one-third of fractures were fixed with 1 or no pins crossing both fracture fragments, reduction was compromised in only 10 cases. All of them were fixed with an inadequately placed medial pin. As previously suggested by Moseley (2012), this could mean that only one adequately placed medial pin would be enough to stabilize a well-reduced fracture in an above-elbow cast. However, pins that do not penetrate bone in both fracture fragments might also give some stability, especially if partially placed under the periosteum.

Only 3 senior pediatric orthopedic surgeons performed operations during both study periods. Registrars change at 3- to 6-month intervals. Despite the very small numbers of operations performed alone by individual registrars, their performance was not significantly inferior to that of consultants (Table 1). This suggests that the quality of teaching is acceptable at our institution. Registrars are at first assisted by consultants at our institution, to ensure that they have adequate technical skills before being allowed to operate alone. Consultant help is always available when needed.

Complications of treatment have been reported to occur in 1% of distal humerus fractures in Finland (Vallila et al. 2015), the risk being smallest in hospitals treating the highest number of patients. Complication rates cannot be reduced by radiographic follow-up (Ponce et al. 2004). In our study, the only clinically significant malunion and 1 of the 2 permanent iatrogenic nerve injuries happened to patients who were treated by one and the same senior surgeon. The number of complications of treatment in distal humerus fractures could probably be reduced by concentrating surgery to a fewer hospitals, and also by continuous internal institutional assessment of treatment quality, which should be a part of modern fracture treatment.

Karamitopoulos et al. (2012) concluded that mild changes and pin migration in postoperative radiographs have little effect on clinical management or long-term outcome. The results of our study support these findings. Firstly, only 10 patients' fracture alignment appeared to be compromised before pin removal. Secondly, these findings never affected the treatment or led to a reoperation. Thirdly, none of these 10 patients' fractures healed in subjectively significant malunion. In addition to this, in 9 of these patients the primary reduction and/or pin fixation was done insufficiently and should have been recognized already in image-intensifier pictures. These findings are well in line with our current routine not to take any radiographs to monitor fracture alignment after satisfactory reduction and stable pin fixation. This policy protects the patients against unnecessary ionizing radiation of 0.01 mSv, which is comparable to the natural background radiation for 1 day (Radiation and Nuclear Safety Authority in Finland). Furthermore, 1 outpatient visit for the patient, 1 workday for the parent(s), and the costs to the community of an outpatient visit and radiography are saved.

Non-union of supracondylar humerus fractures is very rare. We did not find a single case in our earlier study of 7,000 distal humerus fractures (Vallila et al. 2015). In the present study, 4 removals of patients' pins were delayed during 2002–2006 because of suspected delay in radiological ossification. In retrospect, all 4 fractures were radiologically healed and pin removal could have been performed as scheduled. Furthermore, no non-unions or early refractures have occurred in patients treated between 2012 and 2014. This supports our current belief that radiographs are of little or no value at the time of pin removal.

The only patient in this series who had a corrective osteotomy for gun-stock deformity had 6 unnecessary postoperative elbow radiographs taken. This patient should have been followed up clinically by recording elbow carrying angle and range of motion. 1 set of elbow radiographs would have been enough for planning purposes after the decision about corrective surgery had been made.

In summary, reduction of a displaced supracondylar humerus fracture is acceptable when the AHL crosses the ossification center of capitellum in the sagittal plane, and the carrying angle is restored within 10° of the contralateral side. Stability of pin fixation should be tested intraoperatively and recorded. Pins can be safely removed after 3–4 weeks. The routine use of postoperative radiographs does not appear to be justified. Particularly if following reduction, the fracture can be shown to be well aligned, and has stable fixation. However, further studies are needed to define what the satisfactory limits of radiographic alignment are. By reducing unnecessary postoperative radiographs, we can reduce the exposure of a patient to unwanted ionizing radiation, costs, and consumption of patients', families', doctors', and hospitals' time.

NT participated in preparing the study protocol, was responsible for collection of patient data, analyzed all radiographs, and stored fluoroscopic images together with pediatric radiologist RK. RK analyzed all radiographs, stored fluoroscopic images, and proofread the manuscript. AS participated in preparing the study protocol and proofread the manuscript. AYN participated in preparing the study protocol and was the main writer of the manuscript together with NT.

The study was supported by the Päivikki and Sakari Sohlberg Foundation and Finska Läkaresällskapet (the Finnish Medical Association).

No competing interest declared.

Berthelot J-M. The Hawthorne effect: Stronger than the placebo effect? Joint Bone Spine 2011; 78: 335-6.

Dai L. Radiographic evaluation of Baumann angle in Chinese children and its clinical relevance. J Pediatr Orthop B 1999; 8(3): 197-9.

Flynn J, Skaggs D, Waters P. Fractures in Children. Rockwood and Wilkins' 2015 8th ed.

Guven M, Kaynak G, Inan M, Caliskan G, Unlu H, Kesmezacar H. Results of displaced supracondylar hmerus fractures treated with open reduction and internal fixation after mean 22.4 years of follow-up. J Shoulder Elbow Surg 2015; 24: 640-6.

Herman M, Boardman M, Hoover J, Chafetz R. Relationship of the anterior humeral line to the capitellar ossific nuleus variability with age. J Bone Joint Surg Am 2009; 91: 2188-93.

Karamitopoulos M, Dean E, Littleton A, Kruse R. Postoperative radiographs after pinning of supracondylar humerus fractures: are they necessary? J Pediatr Orthop 2012; 32: 672-4.

Moseley C F. Evidence-based medicine: Not a slam dunk. J Pediatr Orthop 2012; 32: S111-S113.

Omid R, Choi P, Skaggs D. Current concepts review – supracondylar humeral fractures in children. Bone Joint Surg Am 2008; 90: 1121-32.

Otsuka N, Kasser J. Supracondylar fractures of the humerus in children. J Am Acad Orthop Surg 1997; 5: 19-26.

Pennock A, Charles M, Moor M, Bastrom T, Newton P. Potential causes of loss of reduction in supracondylar humerus fractures. J Pediatr Orhop 2014; 34: 691-7.

Ponce B, Hedequist D, Zurakowski D, Atkinson C, Waters P. Complications and timing of follow-up after closed reduction and percutaneous pinning of supracondylar humerus fractures – follow-up after percutaneous pinning of supracondylar humerus fractures. J Pediatr Orthop 2004; 24: 610-4.

Rane E, Thielen Z, Fregory S, Sobralske M. Complications of supracondylar osteotomies for cubitus varus. J Pediatr Orthop 2012; 32: 232-40.

Shank C, Wiater B, Pace J, Jinguji T, Schmale G, Bittner R, Bompadre V, Stulus J, Krengel W. The lateral capitellohumeral angle in normal children: mean, variation, and reliability in comparison to Baumann's angle. J Pediatr Orthop 2011; 31: 266-71.

Silva M, Pandarinath R, Farng E, Park S, Caneda C, Fong Y-J, Penman A. Inter- and intra-observer reliability of the Baumann angle of the humerus in children with supracondylar humeral fractures. Int Orthop 2010; 34: 553-7.

Smajic N, Smajic J, Sadic S, Jasarevic M, Ahmetovic-Djug J, Hodzic R. Correlation between Bauman's and carrying angle in children with supracondylar fracture of humerus. Med Arch 2013; 67(3): 195-7.

Vallila N, Sommarhem A, Paavola M, Nietosvaara Y. Pediatric distal humeral fractures and complications of treatment in Finland: a review of compensation claims from 1990 through 2010. J Bone Joint Surg Am 2015: 97(6): 494-9.

Williamson D, Coates C, Miller R, Cole W. Normal characteristics of the Baumann (humerocapitellar) angle: an aid in assessment of supracondylar fractures. J Pediatr Orthop 1992; 12(5): 636-9.

Woratanarat P, Angsanuntsukh C, Rattanasiri S, Attia J, Woratanarat T, Thakkinstian A. Meta-analysis of pinning in supracondylar fractures of the humerus in children. J Orthop Trauma 2012; 26: 48-53.

Zenios M, Ramachandran M, Milne B, Little D, Smith N. Intraoperative stability testing of lateral-entry pin fixation of pediatric supracondylar humeral fractures. J Pediatr Orthop 2007; 27: 695-702.