Risk Factors for Loss of Fixation in Pediatric Supracondylar Humeral Fractures

Thananit Sangkomkamhang MD*,
Udomsin Singjam MD*, Duangjai Leeprakobboon MD*

* *Department of Orthopedic Surgery, Khon Kaen Regional Hospital and Academic Center, Khon Kaen, Thailand*

Objective: *The aim of this study was to determine the risk factors for loss of fixation in pediatric supracondylar humeral fractures.*

Material and Method: *The data were analyzed regarding assessed loss of fixation in 256 supracondylar fractures from January 2010 to December 2012, all of which were treated by closed or open reduction and Kirschner wire fixation. The confounding factors that were thought to cause loss of reduction were collected. Multivariate logistic regression analysis was performed to predict risk factors.*

Results: *Reduction was lost in 14.8% of the patients. Poor surgical technique was significantly higher in the cases with lost reduction (odds ratio: 15.21). Additionally, cases with only lateral pins placement (odds ratio: 2.57), Gartland type 3 fractures (odds ratio: 2.38), and, obesity with a BMI ≥25 (odds ratio: 14.35) had a significantly higher risk of losing reduction and fixation. Other factors including age, energy type of injury, time of surgery, and time to surgery were not associated with risk.*

Conclusion: *The loss of reduction following fracture fixation is associated with poor surgical technique, fixation with lateral pinning only, Gartland type 3 fractures, and pediatric obesity (BMI >25). The stability of fracture fixation in pediatric supracondylar fractures is largely dependent on the use of effective fixation techniques. Cross pinning provides a more stabile fixation than lateral pinning.*

Keywords: *Supracondylar fracture, Humerus, Risk factor, Failure, Fixation*

J Med Assoc Thai 2014; 97 (Suppl. 9): S23-S28
Full text. e-Journal: *http://www.jmatonline.com*

Supracondylar humeral fractures are common fractures in children younger than 10 years of age[1,2]. Most of the Gartland type 2 supracondylar fractures and the Gartland type 3 displaced fractures are stabilized with Kirschner wire fixation after closed or open reduction[1,3]. The incidence of loss of reduction after fixation varies from 1.6% to 33.3%[10]. There are many factors that affect the outcomes of surgical treatment; for example, stability after reduction, configuration of wire fixation, time of surgery, medial or lateral entry of wire fixation, number of wires, and open reduction results in the increased morbidity associated with open procedures[4,5]. Errors in surgical technique play a major role in determining surgical results, especially regarding poor reduction and wire fixation[5,6]. There are many articles that advocate different types of supracondylar fracture stability after fixation, but there is limited evidence regarding the risk factors for loss of reduction after fixation in the patients with supracondylar fracture. In this study, we analyzed case data in order to determine the risk factors that affect fracture stability following fixation and the loss of fixation.

Correspondence to:
Sangkomkamhang T, Department of Orthopedic Surgery, Khon Kaen Regional Hospital and Academic Center, Khon Kaen 40000, Thailand.
Phone: 08-1910-6376
E-mail: sktris@hotmail.com

Material and Method

Institutional review board approval was obtained before the present study was started. This retrospective case study analyzed 256 consecutive supracondylar fractures of the humerus in children that were admitted from January 2010 to December 2012. The patients were operated upon by 17 different surgeons and residents. All patients with open growth plates and those aged below 12 years who were treated for a supracondylar humerus fracture during the study period were included. Patients with open fractures were excluded from the study. For the selection of control subjects, a matched case-control analysis was performed by matching age, gender, configuration of

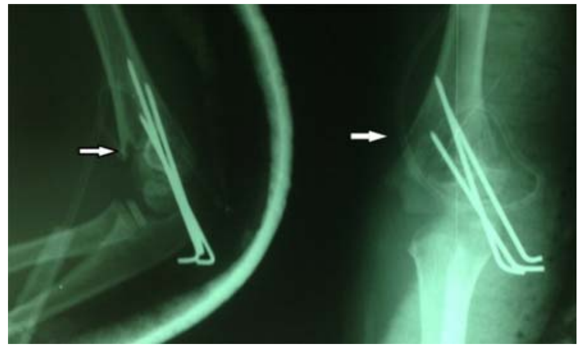

Fig. 1 Anteroposterior and lateral radiograph of the right elbow; the arrow shows rotational malalignment after fixation with three lateral K-wires.

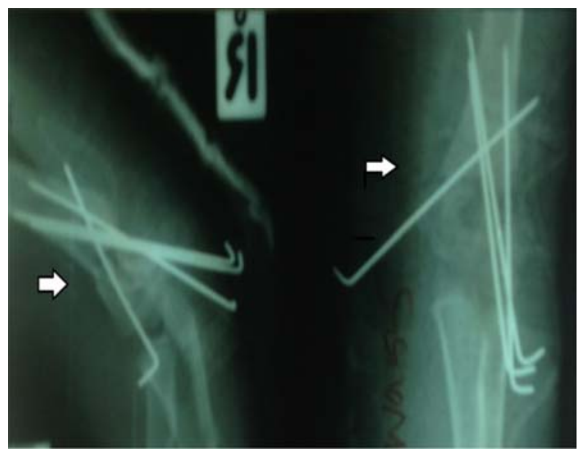

Fig. 2 Anteroposterior and lateral radiograph of the right elbow; the arrow shows translational malalignment after fixation with three lateral K-wires and one medial K-wire.

fracture, and type of fracture. Clinical data and radiographs were reviewed to confirm correct documentation of data related to age, gender, body mass index (BMI), side of injury, energy type of injury, fracture type, surgical details, pin configuration, presence of associated injuries, time from injury to operation, and timing of surgery. The main outcome was the frequency of loss of reduction after treatment with open or closed reduction and fixation with K-wires that required re-operating from immediately after surgery to 4 weeks after surgery. Loss of reduction was defined as excessive rotation or translation of bone fragment. Rotational mal-alignment was defined on a lateral radiograph as the anterior humeral line not bisecting on the capitulum at the fracture site, between the proximal and distal fragments[7] (Fig. 1). Translational mal-alignment was defined on a lateral radiograph of the elbow as minimal cortical contact between the proximal and distal fragments after reduction and fixation[7] (Fig. 2). The pin configurations were divided in two groups. The first group involved inserting lateral pins only, to include either two lateral pins or three lateral pins. The second group involved the use of both medial and lateral pins, included crossed pins with one medial and one lateral entry pin and two laterals and one medial entry pin. Poor surgical technique was defined as inadequate fixation of either the distal or the proximal fragment, convergence of the wires in the cortex of bone, and wires crossing each other around the fracture[8]. For a good quality of fixation, the patient had to present with fixation of the four cortices, both in the proximal and distal fragments, with adequate distance for fixation of the medial and lateral columns[8]. Two surgeons reviewed postoperative radiography to evaluate and classify the quality of surgical technique and determine cases as having good or poor results. The data were tested for inter-rater reliability using the Kappa statistic. The loss of reduction group was compared with the acceptable reduction group using collected variables. Categorical variables were tested using the Chi-squared test and continuous variables were tested using t or the Wilcoxon rank sum test, depending on the distribution. The effect of the quality of the initial reduction and pinning of the fragment on the loss of reduction were analyzed by logistic regression. All significant factors were further evaluated with logistic multivariate regression analysis to eliminate the effect of confounding factors. Final modeling results are reported with odds ratios (OR) and 95% confidence intervals (CIs). STATA 11 (Stata Corp., College Station, TX, USA) statistical software was used for analysis.

Results

256 children with displaced supracondylar fractures were included in this study. There were 152 boys and 104 girls. The mean age was 8.4 years (range: 2-12). There were 205 Gartland type 3 and 51 Gartland type 2 fractures. Fifty-six of the children underwent open reduction followed by pinning due to the failure of closed reduction, nerve injury, vascular compromised and open fracture. Loss of reduction occurred in 38 (14.8%) of patients (Table 1). Loss of reduction was also analyzed in relation to fracture patterns. Reduction was lost in 26 (65.8%) of the Gartland type 3 and 12 (34.2%) of the Gartland type 2 cases. This difference was statistically significant (p = 0.02). Regarding lateral entry pin insertion, two lateral

Table 1. Patient and fracture associated characteristics and univariate analysis of risk factors for loss of reduction

Patient characteristics	Accept reduction n = 218	Loss of reduction n = 38	*p*-value
Age (years) mean $\pm$ SD	7.7$\pm$4.6	8.4$\pm$4.2	0.45
Gender (n/%)			0.76
Male	130 (60)	22 (58)	
Female	88 (40)	16 (42)	
BMI (kg/m^2) (n/%)			<0.01*
$\geq$25	20 (9)	25 (65)	
<25	198 (91)	13 (35)	
Side (n/%)			0.33
Right	153 (70)	24 (63)	
Left	65 (30)	14 (37)	
Gartland type (n/%)			0.04*
II	39 (18)	12 (34)	
III	179 (82)	26 (66)	
High energy injury (n/%)	131 (60)	27 (72)	0.10
Time to surgery hours (hours $\pm$ SD)	6.5$\pm$3.1	7.2$\pm$2.4	0.17
Time of surgery (n/%)			0.64
Day	48 (22)	12 (31)	
Night	170 (78)	26 (69)	
Pin entry (n/%)			0.03*
Lateral pinning	153 (80)	33 (87)	
Cross pinning	65 (20)	5 (13)	
Surgical technique (n/%)			<0.01*
Good	177 (81)	8 (21)	
Poor	41 (19)	30 (79)	

*Statistically significant

pins were used in 152 cases and three lateral pins in 54 cases. Of these 206 children with lateral entry pins, 33 (17.0%) showed postoperative loss of fixation. Configurations with at least one medial pin with crossed pins occurred in 55 cases and two lateral pins with one medial pin in 15 cases. In the groups that included at least one medial pin, 5 (7.0%) out of 65 cases lost reduction. This represented a statistically significant difference (*p*<0.01). Seventy-nine cases were identified with poor surgical techniques, with 30 (38.9%) of those patients showing postoperative loss of reduction. In the 177 cases that were categorized as technically good surgery, 8 (4.5%) cases resulted in loss of reduction. This difference was statistically significant (*p*<0.01). An analysis was performed to determine the effects of obesity on postoperative loss of reduction. A body mass index (BMI) of more than 25 represents obesity in children. Forty-five cases with a BMI >25 were identified and 25 (55.5%) of these showed postoperative loss of reduction. In the 211 cases with a BMI less than 25, 13 (6.1%) cases had loss of reduction. This difference was statistically significant (*p*<0.01). Multivariate logistic regression analysis showed that lateral pinning (odds ratio: 2.57; 95% confidence interval; 1.10-8.24; *p* = 0.03), poor surgical technique (odds ratio: 15.21; 95% confidence interval; 5.43-35.62; *p*<0.01), BMI (body mass index) of more than 25 (odds ratio: 14.35; 95% confidence interval; 4.15-15.45; *p*<0.01), and Gartland type 3 fracture (odds ratio: 2.38; 95% confidence interval; 1.12-3.15; *p* = 0.04) were all associated with a greater risk of postoperative loss of reduction (Table 2). Sex, age, number of pins, timing of surgery, time to surgery, and level of energy injury were not significantly associated.

Discussion

The incidence of loss of reduction after fixation for supracondylar fracture surgery varies in the literature from 1.6% to 33.3%[10]. In the current study overall, 14.8% of cases experienced a loss of fixation. The present study describes the experience at a rural tertiary referral center and a large number of patients, using a multivariate logistic model to determine which factors were independently associated with an increased incidence of loss of reduction after fixation for supracondylar fractures. Multiple factors, such as

Table 2. Multivariable prediction risk factors for loss of reduction

Risk factor	Entire cohort n = 256 Crude ORs	Adjusted for age, sex, configuration of fractures		
		Adjusted ORs	95% CI	*p*-value
Obesity BM I≥25	19.03	14.35	4.15-15.45	<0.01
Gartland type 3	2.11	2.38	1.12-3.15	0.04
Lateral pinning	2.80	2.57	1.10-8.24	0.03
Poor surgical technique	16.19	15.21	5.43-35.62	<0.01

timing of the surgery, quality of reduction, pin configuration, pin placement, and surgeon experience have been reported to be associated with poor outcomes[4,5,9]. Many studies have shown the importance of stability, which is dependent on the Gartland type, loss of an intact periosteal, and comminution of bone[8]. In the present study, there was no high risk of loss of reduction found in relation to sex, age, timing of surgery, time to operation, and level of energy injury. We did find a significant difference in the loss of reduction between Gartland type 2 and Gartland type 3 fractures. This may be due to greater instability and comminution in Gartland type 3 fracture patterns.Consistent with many previous studies, we found no difference in outcome between cases receiving care immediately vs. cases receiving delayed treatment[11,14]. But in a child with swelling and ecchymosis around the elbow, impending compartment syndrome, or neurovascular complication should be operated as soon as possible[12,13]. There was no significant difference in the loss of reduction between the groups, which had been operated upon during the day vs. during the night in the present study, similar to previous studies[15,16]. Many studies have shown the benefit of cross pinning as compared with lateral entry pinning for the maintenance of reduction[8,9]. But some systematic review has shown risk for iatrogenic ulnar nerve injury in cross pinning[20]. This current study also showed a significantly higher loss of reduction in the patients who only had lateral entry pins. Achieving adequate lateral entry pin placement is technically difficult due to the need for pin alignment that engages both columns[17,18]. Many series have suggested stability testing after lateral pin fixation and, if found to be unstable, if it is suitable to add a third pin on the lateral or medial side[2,5]. However, we had no data regarding cases where a stability test was performed intra-operatively. The data indicated that poor surgical technique and K-wire placement were the major causes for loss of reduction after fixation. This study lacked data regarding surgeon experience, which may have played a major role in poor surgical technique results and further research to clarify this will be required. A fracture treated with surgical technique errors had an increased likelihood of losing reduction. This is especially the case in Gartland type 3 fractures, in which poor placement of the pins in either the proximal or the distal fragment resulted in rotational or translation instability[17]. The other noted error was the convergence of lateral entry pins. Surgical technique shortfalls were found in this series regarding loss of reduction, findings similar to previous studies[4,5,8]. The effect of obesity did increase the level of incidence of postoperative loss of reduction. In patients with a BMI of more than 25 (pediatric obesity) an increased incidence of postoperative loss of reduction was found, again similar to previous studies[19]. This may be due to a complex fractures configuration after extremity injury in obesity children[19]. The limitation of the present study is that it was a retrospective study and important data regarding intra-operative details, such as stability of the fracture after reduction, reasons for choosing type of pin fixation, surgeon's experience, and the results of tests for stability after fixation was in most cases not available. The present study also did not follow the loss of reduction group that did not require reoperation. Therefore, there is no information regarding long-term outcome at last follow-up about possible deformity of the elbow or other complications. Finally, a selection bias was likely present because patients with more difficult fracture patterns would have been sent to our referral center and may need to open reduction.

Conclusion

The present study was a large series, which successfully identified risks relating to a loss of reduction in pediatric supracondylar fractures. The loss of reduction after fracture fixation was associated in most cases with poor surgical technique. Cross pinning was found to be appropriate for fixation. Gartland type 3 fractures showed a trend towards higher loss of reduction due to the unstable nature of this type of fracture. Obese children with a BMI >25 were also at risk for higher rates of loss of reduction. In cases presenting with these conditions, surgeons must treat supracondylar fracture cases with good operative technique and effective fixation. Additionally, intra-operative clarification of the fracture configuration may help in achieving a more successful outcome. Other factors such as the age, gender, side of fracture, high-energy injury, time to operation, and timing of surgery were not associated with risk of loss of reduction and fixation.

Acknowledgement

The authors sincerely acknowledge Professor Robert Mills for his support in manuscript and English review.

Potential conflicts of interest

None.

References

1. Wilkins KE, Aroojis AJ. Incidence of fractures in children. In: Beaty JH, Kasser JR, editors. Rockwood and Wilkins' fractures in children. 6th ed. Philadelphia: Lippincott Williams and Wilkins; 2005: 10-1.
2. Skaggs DL, Sankar WN, Albrektson J, Vaishnav S, Choi PD, Kay RM. How safe is the operative treatment of Gartland type 2 supracondylar humerus fractures in children? J Pediatr Orthop 2008; 28: 139-41.
3. Kaewpornsawan K. Comparison between closed reduction with percutaneous pinning and open reduction with pinning in children with closed totally displaced supracondylar humeral fractures: a randomized controlled trial. J Pediatr Orthop B 2001; 10: 131-7.
4. Bahk MS, Srikumaran U, Ain MC, Erkula G, Leet AI, Sargent MC, et al. Patterns of pediatric supracondylar humerus fractures. J Pediatr Orthop 2008; 28: 493-9.
5. Sankar WN, Hebela NM, Skaggs DL, Flynn JM. Loss of pin fixation in displaced supracondylar humeral fractures in children: causes and prevention. J Bone Joint Surg Am 2007; 89: 713-7.
6. Mangwani J, Nadarajah R, Paterson JM. Supracondylar humeral fractures in children: ten years' experience in a teaching hospital. J Bone Joint Surg Br 2006; 88: 362-5.
7. Beck JD, Riehl JT, Moore BE, Deegan JH, Sartorius J, Graham J, et al. Risk factors for failed closed reduction of pediatric supracondylar humerus fractures. Orthopedics 2012; 35: e1492-6.
8. Balakumar B, Madhuri V. A retrospective analysis of loss of reduction in operated supracondylar humerus fractures. Indian J Orthop 2012; 46: 690-7.
9. Kocher MS, Kasser JR, Waters PM, Bae D, Snyder BD, Hresko MT, et al. Lateral entry compared with medial and lateral entry pin fixation for completely displaced supracondylar humeral fractures in children. A randomized clinical trial. J Bone Joint Surg Am 2007; 89: 706-12.
10. Brauer CA, Lee BM, Bae DS, Waters PM, Kocher MS. A systematic review of medial and lateral entry pinning versus lateral entry pinning for supracondylar fractures of the humerus. J Pediatr Orthop 2007; 27: 181-6.
11. Mehlman CT, Strub WM, Roy DR, Wall EJ, Crawford AH. The effect of surgical timing on the perioperative complications of treatment of supracondylar humeral fractures in children. J Bone Joint Surg Am 2001; 83-A: 323-7.
12. Han QL, Wang YH, Liu F. Comparison of complications and results of early versus delayed surgery for Gartland type III supracondylar humeral fractures in pediatric patients. Orthop Surg 2011; 3: 242-6.
13. Scherl SA, Schmidt AH. Pediatric trauma: getting through the night. J Bone Joint Surg Am 2010; 92: 756-64.
14. Loizou CL, Simillis C, Hutchinson JR. A systematic review of early versus delayed treatment for type III supracondylar humeral fractures in children. Injury 2009; 40: 245-8.
15. Yildirim AO, Unal VS, Oken OF, Gulcek M, Ozsular M, Ucaner A. Timing of surgical treatment for type III supracondylar humerus fractures in pediatric patients. J Child Orthop 2009; 3: 265-9.
16. Ramachandran M, Skaggs DL, Crawford HA, Eastwood DM, Lalonde FD, Vitale MG, et al. Delaying treatment of supracondylar fractures in children: has the pendulum swung too far? J Bone Joint Surg Br 2008; 90: 1228-33.
17. Lee SS, Mahar AT, Miesen D, Newton PO. Displaced pediatric supracondylar humerus fractures: biomechanical analysis of percutaneous pinning techniques. J Pediatr Orthop 2002; 22: 440-3.

18. Zamzam MM, Bakarman KA. Treatment of displaced supracondylar humeral fractures among children: crossed versus lateral pinning. Injury 2009; 40: 625-30.
19. Seeley MA, Gagnier JJ, Srinivasan RC, Hensinger RN, VanderHave KL, Farley FA, et al. Obesity and its effects on pediatric supracondylar humeral fractures. J Bone Joint Surg Am 2014; 96: e18.
20. Woratanarat P, Angsanuntsukh C, Rattanasiri S, Attia J, Woratanarat T, Thakkinstian A. Meta-analysis of pinning in supracondylar fracture of the humerus in children. J Orthop Trauma 2012; 26: 48-53.

การศึกษาเปรียบเทียบปัจจัยเสี่ยงของการเกิดภาวะล้มเหลวหลังจากผ่าตัดรักษากระดูกต้นแขนส่วนปลายเหนือปุ่มกระดูกหักในเด็ก

ธนนิตย์ สังคมกำแหง, อุดมศิลป์ สิงห์แจ่ม, ดวงใจ ลี้ประกอบบุญ

วัตถุประสงค์: *เพื่อศึกษาเปรียบเทียบปัจจัยเสี่ยงของการเกิดภาวะล้มเหลวหลังจากผ่าตัด รักษากระดูกต้นแขนส่วนปลายหักเหนือปุ่มกระดูก*

วัสดุและวิธีการ: *ทำการศึกษาผู้ป่วยเด็กที่มีภาวะกระดูกต้นแขนส่วนปลายหักเหนือปุ่มกระดูกและรักษาโดยการผ่าตัดดามโลหะ Kirschner wire ทั้งชนิดเปิดแผลและไม่เปิดแผลผ่าตัดตั้งแต่เดือนมกราคม พ.ศ. 2553 ถึง เดือนธันวาคม พ.ศ. 2555 ด้วยการรวบรวมผู้ป่วยที่มีภาวะล้มเหลวหลังการผ่าตัดและจับคู่กับกลุ่มควบคุมวิเคราะห์หาความสัมพันธ์ระหว่างปัจจัยเสี่ยงของความล้มเหลวหลังการผ่าตัดด้วย multiple logistic regression*

ผลการรักษา: *ผู้ป่วยเด็กที่มีภาวะกระดูกต้นแขนส่วนปลายหักเหนือปุ่มกระดูกจำนวน 256 ราย พบว่ามีภาวะล้มเหลวหลังการผ่าตัดร้อยละ 14.8 มีปัจจัยเสี่ยงคือ เทคนิคการผ่าตัดที่ไม่เหมาะสมลักษณะกระดูกหักแบบ Gartland type 3 การใส่ยึดตรึงด้วย Kirschner wire เฉพาะด้านนอกและเด็กมีน้ำหนักตัวเกินดัชนีมวลกาย ≥ 25 กิโลกรัม/เมตร^2*

สรุป: *ภาวะล้มเหลวหลังการผ่าตัดรักษากระดูกต้นแขนส่วนปลายหักเหนือปุ่มกระดูกในเด็กมีความสัมพันธ์กับปัจจัยเสี่ยงต่างๆ เช่น เทคนิคการผ่าตัดที่ไม่เหมาะสม ลักษณะกระดูกหักแบบ Gartland type 3 การ Kirschner wire เฉพาะด้านนอกและเด็กมีน้ำหนักตัวเกิน การวางแผนการป้องกันภาวะล้มเหลวหลังการผ่าตัดรักษากระดูกต้นแขนส่วนปลายหัก เหนือปุ่มกระดูกในเด็กต้องคำนึงถึงปัจจัยเสี่ยง เช่น การใช้เทคนิคการผ่าตัดที่เหมาะสมและการยึดตรึงกระดูกด้วย Kirschner wire แบบไขว้*