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ORIGINAL ARTICLE

Procedural Outcomes of Double Vs. Single Fluoroscopy for Fixing Supracondylar Humerus Fractures in Children: A Case–Control Study

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Abstract

Background Supracondylar humerus fractures (SHFs) are frequently seen in the pediatric population. The aim of this study was to compare single- and double-fluoroscopy methods for the closed reduction and percutaneous pinning (CRPP) of Gartland type 2 and type 3 SHFs.

Materials and Methods Forty patients who underwent surgery between March 2016 and April 2018 were evaluated retrospectively. Twenty-one patients (group 1) who received double fluoroscopy and 19 patients (group 2) who had single fluoroscopy were evaluated. The preparation period, surgical duration, radiation exposure time, fracture types, sex distributions, distribution of sides, radiologic results at the third month, cosmetic and functional results, and the incidence of complications were recorded.

Results The mean age of the patients in group 1 and group 2 was 4.76 and 4.68 years, respectively. The mean preparation time of group 1 was 11.3 min; whereas in group 2, it was 8.7 min ($p < 0.01$). The mean surgical duration was 31.76 min in group 1, and 40.47 min in group 2 ($p < 0.01$). The mean radiation exposure time in group 1 and group 2 was 41.19 and 47.36 s, respectively ($p = 0.04$). There were statistically significant differences between the two groups in terms of the preparation period, surgical duration, and radiation exposure time. Radiation exposure time and surgical duration were significantly shorter in group 1; the preparation period was shorter in group 2.

Conclusions The double-fluoroscopy technique can significantly reduce surgical duration and radiation exposure time during surgery while treating SHFs of children.

Keywords Supracondylar humerus fracture · Percutaneous pinning · Closed reduction · Double fluoroscopy

Introduction

The most common elbow fractures, especially in children under the age of 7 years, are supracondylar fractures [1]. Pediatric elbow fractures account for approximately 60% of upper extremity fractures and more than 13% of all paediatric fractures [2].

Supracondylar humerus fractures (SHFs) of paediatric patients may be difficult to treat for an inexperienced orthopedist [3]. These fractures are divided mainly into two types as extension and flexion [4]. Extension type fractures

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are seen in 95–98% of patients, and in the remaining 2–5%, flexion type fractures are seen [4]. SHFs are classified as three types according to the Gartland classification system [5]. Type 1 is the stable and minimally displaced fractures; whereas, types 2 and 3 are displaced fractures. The treatment of SHF type 1 is closed reduction and plaster application; percutaneous pinning is preferred after either open or closed reduction in the treatment of type 2 and type 3 fractures [4].

Recently, double fluoroscopy began to be used during surgical procedures [6–8]. In orthopedic practice, double fluoroscopy was used in the nailing of intertrochanteric femoral fractures [6]; Boszczyk et al. stated that using double fluoroscopy in kyphoplasty cases reduced the radiation exposure time [7]. Similarly, Peng et al. also stated that patients with pelvic trauma had less radiation exposure time during sacroiliac screw applications with the use of double fluoroscopy [8]. There is insufficient information about the use of double fluoroscopy in the treatment of pediatric SHFs.

We hypothesized that the surgical duration and radiation exposure time should be shorter with the use of double fluoroscopy. In the study, we aimed to compare the functional and cosmetic results, radiologic results, preparation period, surgical duration, fracture types, sex distributions, distribution of sides, and also the radiation exposure time of groups with SHF who were treated using single or double fluoroscopy.

Materials and Methods

Ethical committee approval was obtained for this retrospectively designed study (date 27/12/2018, no. 2018/152/11/02). Between March 2016 and April 2018, 137 patients were treated with a diagnosis of pediatric SHF in a single medical center. The inclusion criteria were as follows: patients who were treated with closed reduction and percutaneous pinning, and patients with a full documentation of surgical information (e.g., fluoroscopy time, preparation time, surgery duration). The exclusion criteria were as follows: patients with type-1 fractures, patients with a fracture older than 2 days, patients with open fractures, patients who required open reduction, patients with flexion-type fracture, patients with additional fractures of the same extremity, patients with preoperative nerve injury, and patients without adequate follow-up.

Forty patients who met the inclusion criteria were included in the study. Twenty-one patients (group 1) who underwent surgery with the use of double fluoroscopy and 19 patients (group 2) who had single fluoroscopy were evaluated.

Pre-operative and Operative Protocol

When patients presented with type-2 SHFs with only sagittal plane deformity, closed reduction was attempted in the emergency room by simply flexing the elbow under procedural sedative anesthesia (ketamine 1 mg/kg) if there was no contraindication. If the fracture of the patient was displaced in two or three planes, like with type-3 SHF and proper alignment could not be achieved after the closed reduction in type-2 SHF, the patient was taken to the operation room as soon as possible [9]. The patients underwent closed reduction and percutaneous pinning (CRPP) [4, 10]. In this procedure, a single- and double-fluoroscopy method was used by an orthopedist experienced in SHF with CRPP. In patients who received the double-fluoroscopy technique, anteroposterior (AP) and lateral views were obtained at the same time, but anteroposterior and lateral images were taken sequentially (Fig. 1). If the appropriate reduction was not achieved with closed reduction, open reduction was performed and these patients were excluded from the study.

All patients underwent surgery under general anesthesia. The appropriate position was given to the patient. The C-arm fluoroscope was placed in the appropriate position. The two sides of the C-arm fluoroscope were draped as sterile. Then, the patient's arm was cleaned with a betadine solution and started the surgery. After the reduction, in the classic (single-fluoroscopy) method, the limb was placed in a position that provided appropriate images of the elbow. In the double-fluoroscopy method, the patient's arm was kept in a constant position after the reduction maneuver without moving because the AP and lateral views were taken sequentially. Afterwards, CRPP was performed. The position of the fluoroscopies in the double-fluoroscopy method is shown in Fig. 2. A demonstration of CRPP while using the double-fluoroscopy technique is shown in Fig. 3.

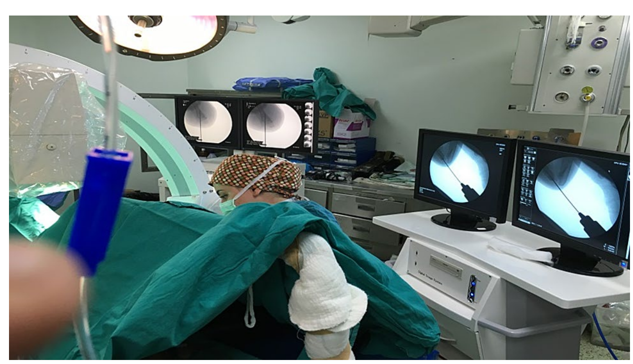

Fig. 1 Acquisition of AP and lateral image at the same time in the double-fluoroscopy technique

Fig. 2 Installation of the fluoroscopes in the double-fluoroscopy technique

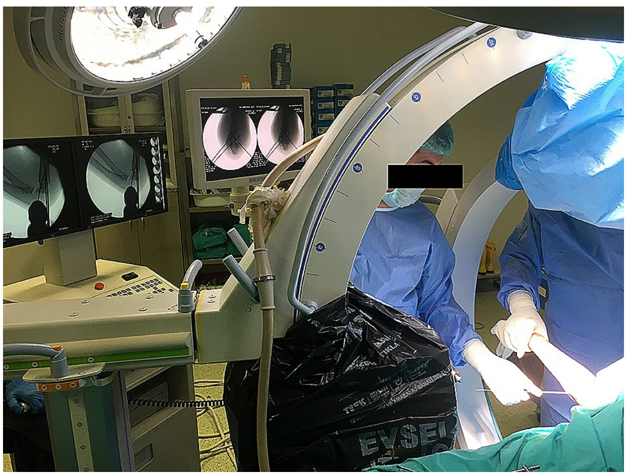

Fig. 3 Percutaneous pinning with the double-fluoroscopy technique and AP and lateral images taken simultaneously

Study Protocol

Preoperative preparation times, surgical times, time for reduction, and time for pinning were recorded. The preoperative preparation time included the time for preparation of anesthesia team, fluoroscopy machine(s) positioning, and patient positioning. Surgical times were evaluated as the time between from the beginning of the surgical procedure to the end of plaster application. The age, sex, fracture types (flexion and extension), and Gartland grades of the patients were evaluated.

Outpatient Clinic Follow-Up Protocol

The patients were discharged after 1 day. The extremity of the patient was kept in a long arm cast at 70°–90° of flexion until the wires were removed after both methods. After 3–4 weeks, the union was assessed in radiographs; union was determined if there was callus formation at three of the four cortices. Joint range of motion exercises was started after the removal of pins and the cast. The patients were called for monthly follow-up examinations at the outpatient clinic. At the 3-month follow-up, the patients were evaluated according to Flynn's criteria [11]. AP and lateral elbow radiographs were taken. The complications seen in patients were recorded.

Radiologic Evaluation

The preoperative radiographs of the patients were used to classify the humeral supracondylar fractures according to the Gartland classification system. AP and lateral elbow radiographs were taken on the first postoperative day, at 3–4 weeks, and at 3 months.

Criteria for Determination of Reduction Loss

Baumann's angle was measured on AP radiographs at the third-month follow-up and compared with the contralateral side. In this way, postoperative reduction quality was evaluated. In this measure, as described by Kocher et al., the changes in Baumann angle were found to be moderate (mild) below 6°, and major between 6° and 12° [12]. In the evaluation of reduction in the sagittal plane, a lateral radiograph was evaluated as an inability of the anterior humeral line to interfere with the middle one-third of the capitellum's ossification center, according to Skaggs et al. [13]. Additionally, the humerocapitellar angle on lateral radiographs [14] and the humeroulnar angle on AP radiographs were evaluated at the postoperative third-month follow-up.

Statistical Analysis

Statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS) for Windows software package, version 24.0 (IBM Corp., Armonk, New York, USA). In addition to descriptive statistical methods, the independent sample t test or Mann–Whitney U tests were used to compare continuous data according to the normality test (Shapiro–Wilk). $p < 0.05$ was considered as statistically significant.

Results

The mean age of the patients in group 1 and group 2 was 4.76 ± 1.75 (range 2–9) and 4.68 ± 2.21 (range 2–10) years, respectively. Among the patients in group 1, seven were women and 14 were men. There were four female and 15 male patients in group 2. There were no statistically significant differences between the two groups according to age and sex distributions ($p = 0.90$ and $p = 0.60$, respectively)

Table 1 The types of patients treated while using double fluoroscopy and single fluoroscopy according to age, sex, sides, and Gartland classification according to the groups

	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Age (year)	4.76 ± 1.75 (2–9)	4.68 ± 2.21 (2–10)
Gender		
Female	7 (33.3%)	4 (21.1%)
Male	14 (66.7%)	15 (78.9%)
Side		
Left	10 (47.6%)	9 (47.4%)
Right	11 (52.4%)	10 (52.6%)
Classification (Gartland)		
Type 2	7 (33.3%)	5 (26.3%)
Type 3	14 (66.7%)	14 (73.7%)

(Table 1). The fractures of 10 patients in group 1 were on the left side, and 11 patients had fractures on the right side. In group 2, 9 patients had fractures on the left side, and 10 patients had fractures on the right side (Table 1). The side distribution of the two groups was not evaluated to be statistically significant ($p = 0.98$).

Among the patients in group 1, seven had Gartland type-2 fractures and 14 patients had type-3 fractures. In group 2, five patients had Gartland type-2 fractures and 14 had type-3 fractures (Table 1). The fracture types of the two groups were not evaluated to be statistically significantly different ($p = 0.62$).

The mean preparation time was 11.3 ± 1.59 (range 9–14) min in group 1 and 8.78 ± 1.35 (range 7–11) min in group 2. The mean surgical time was 31.76 ± 7.78 (range 15–45) min in group 1 and 40.47 ± 8.7 (range 23–55) min in group 2. The mean radiation time was 41.19 ± 9.43 (range 20–53) s in group 1 and 47.36 ± 8.86 (range 28–62) s in group 2 (Table 2). There was a statistically significant difference between the two groups in terms of the preparation time ($p < 0.01$), surgical time ($p < 0.01$), and radiation time ($p = 0.04$). In group 1, the preparation time was longer than in group 2, but the surgical time and the radiation exposure time were shorter than in group 2.

According to the Flynn criteria, cosmetic and functional results were found to be similar between the two groups at the third-month outpatient follow-up (Tables 3, 4). The mean range of motion (ROM) for group 1 was 140.9 ± 6.44° (range 130°–150°), and the mean ROM for group 2 was 142.1 ± 6.93° (range 130°–150°).

Table 3 Cosmetic distribution of patient groups according to the Flynn criteria

	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Excellent	15 (71.4%)	12 (63.2%)
Good	5 (23.8%)	5 (26.3%)
Fair	1 (4.8%)	2 (10.5%)
Poor	–	–

Table 4 Functional distribution of the patient groups according to Flynn criteria

	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Excellent	19 (90.5%)	17 (89.5%)
Good	2 (9.5%)	2 (10.5%)
Fair	–	–
Poor	–	–

Complete union was achieved in all patients. The mean Baumann's angle of the fractured side was 73.8 ± 5.6° (range 65°–85°) in group 1 and 74.05 ± 7.38° (range 64°–84°) in group 2. The mean difference in Baumann's angle between the two elbows in group 1 was − 5.9 ± 7.8° (− 17° to 6°) and − 6.05 ± 7.68° (− 17° to 9°) in group 2. The mean difference between the two humerocapitellar angles of both elbows was found as 31.6 ± 8.64° (range 21°–50°) in group 1, and 30.8 ± 8.52° (range 19°–4°) in group 2. According to the anterior humeral line, which was evaluated on lateral radiography, one patient in group 1 and one patient in group 2 had a loss of reduction (Table 5). Reduction loss was detected early in the patient in group 2 and reduction was attempted again; open reduction was required because closed reduction was unsuccessful. In group 1, loss of reduction was observed in the fourth week. No additional maneuver was performed for this patient because the fracture was considered to be healed.

There was no statistically significant difference between the two groups in terms of the Baumann's angle ($p = 0.9$), the difference of both elbow Baumann angles ($p = 0.96$), the lateral humerocapillar angle ($p = 0.76$), and the lateral humerocapillar angle between both elbows ($p = 0.95$). The

Table 2 Mean preoperative duration, surgical time, duration of radiation exposure of patient groups during double fluoroscopy and single fluoroscopy

	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Preparation period, mean (± SD), min	11.3 ± 1.59 (9–14)	8.78 ± 1.35 (7–11)
Surgical duration, mean (± SD), min	31.76 ± 7.78 (15–45)	40.47 ± 8.7 (23–55)
Total Surgical duration, mean (± SD), min	43.09 ± 7.9 (27–57)	49.26 ± 8.65 (31–64)
Radiation time, mean (± SD), s	41.19 ± 9.43 (20–53)	47.36 ± 8.86 (28–62)

Table 5 Measurement results of radiographies of the patient groups

	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Baumann's angle of the fractured side	73.8 ± 5.6 (65–85)	74.05 ± 7.38 (64–84)
Baumann's angle difference of both elbow	1.19 ± 5.01 (− 7 to 11)	1.26 ± 6.33 (− 6 to 12)
Fractured arm's lateral humerocapitellar angle	31.6 ± 8.64 (21–50)	30.8 ± 8.52 (19–4)
Lateral humerocapitellar angle difference of both elbow	− 5.9 ± 7.8 (− 17 to 6)	− 6.05 ± 7.68 (− 17 to 9)
Number of patients with loss of reduction according to anterior humeral line	1 (4.8%)	1 (%5.3)

Table 6 Complications of the patient groups

Complications	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Nerve injury	2 (9.5%)	2 (10.5%)
Pin tract infection	1 (4.8%)	2 (10.5%)
Reduction loss	1 (4.8%)	1 (5.3%)
Reoperation	–	1 (5.3%)

Table 7 Wire configuration distributions of the patient groups

Wire configuration	Group 1 (*n*: 21)	Group 2 (*n*: 19)
Crossed wires (lateral 1, medial 1)	2 (9.5%)	5 (26.3%)
Crossed wires (lateral 2, medial 1)	8 (38%)	7 (36.9%)
Double lateral wires	4 (19%)	5 (26.3%)
Three lateral wires	7 (33.5%)	2 (10.5%)

radiographic measurement results of the two groups were not statistically significantly different.

One patient had ulnar nerve lesion, one patient had anterior interosseous nerve lesion, two patients had pin tract infections, and one patient had a loss of reduction in group 1. Two patients had ulnar nerve injury, two patients had pin tract infections, and one patient had a loss of reduction in group 2 (Table 6). In patients with ulnar nerve injuries, medial pins were removed and nerve examinations of all patients were found to be normal at the final follow-up. Pin tract infection was found to be improved after the removal of wires in both groups.

The configurations of the wires used for percutaneous pinning were variable (Table 7) and this was one of the limitations of the study.

No statistically significant differences were found in the statistical evaluations of the patients in terms of sex, fracture side and fracture types, the incidence of complications, preoperative preparation time, total surgical time, and radiologic measurement results. There were statistically significant differences between the two groups in terms of the preparation period, the surgical time, and radiation exposure time. The duration of radiation exposure and surgical times was significantly shorter in group 1.

Discussion

CRPP is the preferred treatment for displaced pediatric SHFs, but this may be difficult for an inexperienced orthopedist [3]. Double fluoroscopy can be advantageous in terms of, shorter radiation exposure time, and shorter surgical time. However, this technique has disadvantages such as longer preparation time. This current study has confirmed these advantages and disadvantages precisely. Our double fluoroscopy method's most important advantage is that during CRPP, we keep the patient's elbow in the same position without having to turn the elbow or the fluoroscope device during the procedure. However, it should be kept in mind that keeping the elbow in a fixed position during surgery is advantageous in terms of protection of the initial reduction but not moving the elbow can also prevent the control of rotational stability of the fracture during surgery.

Closed reduction is attempted first in the surgical treatment of SHF. Closed reduction has several advantages over open reduction in terms of biology [15]. It has been reported that open reduction may result in joint stiffness because of iatrogenic soft tissue damage [16, 17]. In Papavasiliou and Beslikas' study, open reduction resulted with much more flexion contracture and valgus deformities compared with closed reduction with percutaneous pinning [18]. In a study comparing radiation exposure times in open reduction and closed reduction, it was observed that exposure time to radiation was three times more in patients who underwent closed reduction and percutaneous pinning [19].

Double fluoroscopy is used during various surgical procedures, especially in fractures [6–8]. Boszczyk et al. stated that radiation exposure times were reduced with the use of double fluoroscopy [6]. In another study, Peng et al. compared the efficacy and safety of percutaneous placement of iliosacral screws for unstable pelvic ring injuries and performed a comparison between single and double C-arm fluoroscopy use. They found that double fluoroscopy provided a faster technique with less radiation exposure for percutaneous placement of iliosacral screws than the use of single fluoroscopy [7].

Kara et al. compared single and double-fluoroscopy methods in intramedullary (IM) nailing of femur intertrochanteric fractures [8]. In this study, the preoperative preparation time was found as 19.6 min with single-fluoroscopy and 21.2 min with the double-fluoroscopy method. The mean surgical time was 48.7 min with the single-fluoroscopy method and 32.8 min with double fluoroscopy. The radiation exposure mean time was 65.9 s for single fluoroscopy and 40.2 s for double fluoroscopy. In conclusion, it was emphasized that the double-fluoroscopy method could be safely used in IM nailing for intertrochanteric femur fractures.

In this study, the mean preparation time was 11.3 (range − 914) min with the double-fluoroscopy method and 8.78 (range 7–11) min with single fluoroscopy. The mean surgical time was 31.76 (range 15–45) min with double fluoroscopy and 40.47 (range 23–55) min with single fluoroscopy. The mean duration of radiation exposure was 41.19 (range 20–53) s with double fluoroscopy and 47.36 (range 28–62) s with single fluoroscopy. There was a statistically significant difference between the two groups in terms of preoperative preparation time ($p < 0.01$), surgical time ($p < 0.01$), and duration of radiation exposure ($p = 0.04$). Double fluoroscopy extends the preparation period but it decreases the surgical time and the duration of radiation exposure compared with single fluoroscopy. When we compared the double-fluoroscopy method with single fluoroscopy, we found that the surgical time decreased by 23% and the radiation exposure period decreased by 13%.

In the classic method in which single fluoroscopy is used, the surgeon has to give the position to either the patient's elbow or to the C-arm to confirm the reduction in both AP and lateral views. However, if the patient's elbow is turned, there is a risk of loss of obtained initial reduction, and if the C-arm is turned, there is a risk of contamination. In the double-fluoroscopy method, the patient's arm is kept in a fixed position except for taking an image in the full flexion position, the Jones position. Accordingly, percutaneous pinning can be applied in this way without moving the patient's arm or the C-arm to see the reduction quality and Kirschner wire positioning in antero-posterior and lateral views. This is one of the most important advantages of the double-fluoroscopy technique during the surgery.

Radiation exposure has many adverse effects to both the surgical team and the patient [20]. The prevalence of cancer was found as 29% in orthopedic surgeons who were exposed to radiation for more than 24 years [21]. There are also reports of a high risk of developing breast cancer among female orthopedists [22, 23]. In our study, it was determined that exposure to radiation was reduced with double fluoroscopy compared with single fluoroscopy.

There are several limitations to the study. The first is the limited number of patients, the different numbers of wires used, and the variety of configurations of wires in the surgeries. Second, the study was performed retrospectively. The final limitation is about the measurement method of radiation exposure time but not the exact radiation exposure in terms of Sieverts.

Conclusions

Double fluoroscopy is a simple method to perform if there are two fluoroscopy devices in the hospital. The functional results of patients who underwent double fluoroscopy were similar compared with the patients who had single fluoroscopy, but double fluoroscopy decreased surgical and radiation exposure time. It should be kept in mind that double fluoroscopy can be used safely during closed reduction and percutaneous pinning in displaced pediatric supracondylar humeral fractures.

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Compliance with Ethical Standards

Conflict of Interest The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper. I(we) affirm that I (we) have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript. Any other conflict of interest (i.e., personal associations or involvement as a director, officer, or expert witness) is also disclosed in an attachment. Burak Gunaydin, Ali Turgut, Abdulkadir Sari, Yasar Mahsut Dincel, Cagatay Tekin, Yavuz Selim Kabukcuoglu declare that they have no conflict of interest. The manuscript has been read and approved by all the authors. The manuscript represents honest work. All submissions and previous reports regarded as redundant publication of the same or very similar work. Any such work referred to specifically and referenced in the new paper.

Ethical Standard Statement This study "Procedural outcomes of double vs. single fluoroscopy for fixing supracondylar humerus fractures in children" has been registered retrospectively by a registration number ChiCTR1900023885. The study was approved by the Local Ethical Committee dated 27/12/2018 and numbered 2018/152/11/02. Informed consent was obtained from all individual participants included in the study.

Informed Consent The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity can not be guaranteed.

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