Intrafocal joystick technique for closed reduction and percutaneous fixation of late-presenting supracondylar fractures of the humerus

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ABSTRACT

Background:
Pediatric supracondylar humeral fractures are common and challenging injuries. The preferred approach is early closed reduction and percutaneous pinning; however, this fails in up to 25% of patients, and conversion to open reduction, especially in late-presenting patients, has been reported in 3% to 46% of patients due to severe swelling or skin problems around the elbow. This study presents a reduction technique that uses a temporary intrafocal Kirschner wire to allow indirect and more effective manipulation of the distal fragment, facilitating closed reduction in difficult situations.

Methods:
This study retrospectively evaluated the results of an intrafocal joystick technique that was used to aid closed reduction in 15 patients with late-presenting, displaced supracondylar humeral fractures with unfavorable soft-tissue conditions around the elbow. The mean patient age was 6.2 ± 2.7 yr and the mean injury-to-surgery interval (delay) was 4.2 ± 2.7 days. Baumann’s angle, humerocapitellar angle, the anterior humeral line-capitellum relationship were used for radiographic evaluation of the initial reduction and throughout the follow-up that lasted for a mean of 9.4 ± 3.6 mo. The functional and cosmetic outcomes were assessed according to Flynn’s criteria and the Mayo Elbow Performance Index.

Results:
None of the patients could be successfully treated with the standard method. The intrafocal joystick technique succeeded in achieving acceptable closed reduction in 12 of 15 patients; the remaining three patients required open reduction and internal fixation. All fractures united, and wires were removed at a mean of 5.4 ± 1.6 wk. Functional range of motion was regained after a mean period of 7.2 ± 3.5 wk, while full elbow range of motion was regained after a mean period of 12.2 ± 3.5 wk. According to Flynn’s criteria and the Mayo Elbow Performance Index, all patients had an excellent result.

Conclusions:
The intrafocal joystick technique for closed reduction and percutaneous fixation of irreducible supracondylar fractures of the humerus in certain difficult situations can effectively and safely achieve satisfactory radiographic and functional outcomes and decrease the need for conversion to an open reduction. Open reduction and internal fixation are essential in some patients but should only be used after all techniques of closed reduction and percutaneous fixation have failed.

Level of Evidence:
Level III retrospective.

Key Words
Late-presenting, irreducible supracondylar humeral fracture, intrafocal joystick technique, closed reduction, satisfactory radiological and clinical outcomes

INTRODUCTION

Supracondylar humeral fractures represent the most common fractures around the pediatric elbow.¹ Displaced pediatric supracondylar humeral fractures are challenging injuries to treat and entail technically difficult procedures for orthopaedic surgeons.²,³ A displaced fracture usually is treated as an emergency in children, and the preferred approach is closed reduction and percutaneous pinning; this technique requires experience and is not free of complications or partial failure.⁴ Severe swelling and skin problems around the elbow are the common accepted causes that delay surgical intervention of supracondylar humeral fractures.⁴ Closed reduction and percutaneous pinning fail in up to 25% of patients,⁵,⁶ and the rate of conversion to open reduction has been reported to range from less than 3% to around 46%, especially in late-presenting patients.⁷ Open reduction has more potential morbidity than a percutaneous pinning method, including elbow stiffness, scarring, iatrogenic neurovascular injury, longer hospital stay, and worse functional results.⁸

To the best of our knowledge, little was written in the literature about closed reduction for late-presenting displaced supracondylar fractures of the humerus in children and adolescents. This study retrospectively evaluated the results of an aiding closed reduction technique for displaced supracondylar humeral fractures with soft-tissue problems around the elbow for which the standard method of closed reduction failed to achieve satisfactory reduction. The technique uses...
an intrafocal smooth Kirschner wire inserted percutaneously into the fracture site to indirectly and more effectively manipulate the distal fragment, facilitating closed reduction. This technique can be used to avoid the more hazardous and time-consuming open reduction and internal fixation (ORIF) in difficult situations.

**MATERIALS AND METHODS**

This study was performed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975. All patients’ parents gave informed consent before inclusion in the study; the study was authorized by the institutional review board. This study was carried out in the Orthopaedic Department at Benha University Hospital between September 2016 and August 2018 and included 15 patients with closed, late-presenting (more than 2 days), displaced (Gartland II and III) extension type supracondylar humeral fractures.

A retrospective analysis of the results of an intrafocal joystick technique to aid in closed reduction and percutaneous fixation of certain pediatric supracondylar humeral fractures was carried out. This technique was used to avoid open reduction in difficult situations if the standard method of closed reduction failed to achieve a satisfactory reduction. This technique was used for all neglected fractures or in patients with unfavorable soft-tissue conditions around the elbow, provided that there was no visible mature callus detected on radiographs.

Proper radiographic and clinical evaluations for soft-tissue conditions and edema around the elbow, neurovascular injury, and/or associated injuries were performed. Patients with associated vascular injuries necessitating open vascular repair, open fractures, associated ipsilateral arm or forearm injuries, or with clearly detected mature callus were all excluded from this study. This study comprised twelve boys and three girls. The left elbow was affected in seven and right side was affected in eight patients, and the injury-to-surgery interval ranged from 2 to 9 days.

**Technique**

Under complete aseptic conditions, the procedure was carried out with the patient under general anesthesia without a tourniquet. All patients were placed supine with their shoulders close to the edge of the operating table. Closed reduction under image intensification was attempted in the standard way through sequential steps: (1) sustained traction was applied to the forearm with the elbow extended while applying countertraction to disengage the fractured fragments and to correct rotation; (2) medial or lateral displacement was corrected by applying a laterally or medially directed force, respectively; (3) the posterior displacement and angulation were then corrected by applying an anteriorly directed force from the posterior aspect of the distal fragment while flexing the elbow to about 90 degrees. If acceptable reduction could not be achieved because of marked edema or delayed presentation for surgery, a Kirschner wire was used to aid reduction. A thick K-wire (1.8 to 2.5 mm according to age of the patient, the size of displaced fragment and severity of displacement) was introduced from the back of the arm through the triceps muscle at the level of the fracture site (Figure 1) and passed under C-arm guidance between the two fragments resting and hinging under the lower border of the proximal fragment as a joystick (Figure 2) correcting a posteriorly displaced, non-rotated distal fragment by progressive bending of the wire acting as a tool for indirect reduction to push and manipulate the distal fragment anteriorly achieving an accepted reduction if introduced in the midline, or introduced either medially or laterally in relation to the midline of the back of the arm for correction of a posteriorly displaced and rotated distal fragment.

Once acceptable reduction was achieved (Baumann’s angle about 75 degrees, anterior humerul line passing through the middle third of the humeral capitellum, and a humerotrochlear angle around 40 degrees),9 percutaneous fixation using various pinning techniques under C-arm guidance (Figure 3) was performed. The Kirschner wire was used to maintain reduction during change in elbow position, rendering fixation easier. A well-padded, above-the-elbow protective slab with the forearm in a neutral position was applied and worn for 2 wk.

Vascular and neurological assessment was performed postoperatively. Anteroposterior and lateral radiographs of the operated elbow were obtained immediately postoperatively and after 1 wk to assess reduction and wire position. The above-elbow slab was removed after 15 to 21 days, depending on fracture configuration, adequacy of reduction, stability of fixation, and patient and parent compliance, allowing early progressive active and active-assisted elbow range of motion with wires in place.

**FIGURE 1.** A thick Kirschner wire introduced from the back of the arm through the triceps muscle at the level of the fracture without application of a tourniquet in two different cases.
Once healing was radiographically detected, usually between 3 and 5 wk, the Kirschner wires were removed. At the last follow-up, anteroposterior and lateral radiographs of both elbows were taken to assess Baumann’s angle and humerocapitellar angle. Range of motion and carrying angle of both elbows were assessed using a goniometer. The functional and cosmetic outcomes were assessed according to Flynn’s criteria10 and the Mayo Elbow Performance Index (MEPI) described by Turchin et al.,11 which is composed of four parameters: pain, arc of motion, stability, and activities of daily living.

Statistical analysis was performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). Statistical analysis was done using a two-tailed Student T test, and $P<0.05$ was considered statistically significant.

RESULTS
This study comprised twelve boys and three girls. Their ages ranged from 3 to 16 yr, with a mean age of $6 \pm 2.7$ yr. The left elbow was affected in seven patients and the right side was affected in eight. The injury-to-surgery interval ranged from 2 to 9 days, with a mean delay of $4 \pm 2.7$ days.

None of the patients had successful reduction to an acceptable position after two trials of closed reduction with the standard method. The intrafocal joystick technique of closed reduction

FIGURE 2. A thick Kirschner wire introduced as a joystick under C-arm guidance between the two fragments, resting and hinging under the lower border of the proximal fragment correcting the posteriorly displaced distal fragment in two different patients. Progressive bending of the wire acts as a tool for indirect reduction to push and manipulate the distal fragment anteriorly.

FIGURE 3. Percutaneous fixation in two different patients. The joystick wire is kept in place to maintain the achieved reduction making pinning easier.
achieved acceptable closed reduction in 12 of 15 patients, meanwhile the remaining three patients required ORIF. All clinical and radiographic results of the three patients in whom ORIF was performed were excluded from this study. In the 12 patients in whom closed reduction was successful (Figures 4 and 5), the mean Baumann’s angle was 17.6 degrees (range 12-21 degrees), the mean humerotrochlear angle was 39.8 degrees (range 36-43 degrees), and the anterior humeral line passed through the middle third of the capitellum in eight patients, in the anterior third of the capitellum in three patients, and anterior to the capitellum in one patient. Splints were removed at the beginning of the third postoperative week, and elbow range of motion was encouraged while wires were still in place. All fractures united, and wires were removed at a mean of 5.4 ± 1.6 wk (range 4-8 wk).

The mean follow-up period was 9.4 ± 3.6 mo (range 6-18 mo), and all patients and parents expressed appreciation and satisfaction with the outcome, specifically functional recovery (Figures 4 and 5). The functional range of motion was regained after a mean period of 7.2 ± 3.5 wk, while the full elbow range of motion was regained after a mean period of 12.2 ± 3.5 wk, and at the last follow-up an excellent result was obtained according to Flynn’s criteria and the Mayo Elbow Performance Index in all 12 patients.

Three patients (representing 25% of the studied cases) developed superficial pin track infections that began after slab removal with the beginning of active range of motion; this was managed simply by pure alcohol and oral antibiotics. One patient developed intraoperative superficial thermal abrasive injury around the site of application of the intrafocal wire, with progressive healing over the next 4 wk and complete healing at the time of wire removal (Figure 6). No patient had iatrogenic nerve injury or vascular insult. No patient developed deep wound infection, wire loosening, or migration.

**DISCUSSION**

Supracondylar humeral fractures represent one of the most common skeletal injuries in children. Once unstable and displaced, the standard approach is early closed reduction and percutaneous Kirschner wire fixation. However, between 10% and 20% of patients present late, with the elbow still tense and swollen and possibly with abrasions or scabs. The delay is either due to lack of medical facilities or social and financial constraints. Tiwari et al. considered open surgical intervention the best option for such late-presenting fractures despite concerns regarding elbow stiffness, myositis ossificans, unsightly scarring, and iatrogenic

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**FIGURE 4.** (A) Nine days old, displaced supracondylar fracture in a 18-year-old male patient with marked elbow edema. (B) Percutaneous intrafocal Kirschner wire inserted under C-arm, facilitating closed reduction and percutaneous pinning. (C) Healing fracture in an acceptable position with medial and lateral wires for more stable fixation. (D) Active elbow range of motion after 2 wk with wires still in place. (E) Range of motion at the time of wire removal by the fifth postoperative week. Fracture has completely healed in an acceptable position. (F) Final clinical result 3 mo postoperatively showing excellent functional and cosmetic results.
neurovascular injury. Another situation in which ORIF is necessary is failure to get an acceptable closed reduction (Baumann’s angle of 75 degrees, anterior humeral line passing through the middle third of the humeral capitellum, a humerotrochlear angle about 40 degrees, and intact medial and lateral columns on oblique views). The rationale behind using intrafocal Kirschner wire to aid closed reduction was to try and avoid ORIF in patients with irreducible fractures or fractures that could not be reduced to a satisfactory position because of marked elbow swelling or delayed presentation for surgery.

In reviewing the literature regarding closed reduction and percutaneous fixation of late-presenting displaced supracondylar humeral fractures in children and adolescents, three main studies were found on this topic. Herzog et al., Parmaksizoglu et al., and Slongo developed different techniques to aid reduction in certain irreducible fractures when closed reduction via the standard method failed, with the goal to avoid the hazardous, and more time consuming, ORIF.

Reduction aids included a percutaneously placed 2.5-mm Schanz pin drilled into the posterior humeral diaphysis and

FIGURE 5. (A) Three days old, displaced supracondylar fracture in a 3.5-year-old male patient with elbow edema and skin blisters. (B) Percutaneous intrafocal Kirschner wire inserted under C-arm guidance facilitating closed reduction and percutaneous pinning. (C) Healing fracture by the third postoperative week in an acceptable position using medial and lateral wires for more stable fixation. (D) Completely healed fracture after wires removed 5 wk postoperatively, with the anterior humeral line (AHL) passing anterior to the capitellum. (E) Final clinical result 2 mo postoperatively showing excellent functional and cosmetic results.

FIGURE 6. Intraoperative superficial thermal abrasive injury caused by unnoticed overheating of the intra-focal wire resulting from metal friction between it (when used as a blocking wire maintaining reduction) and the wires used for fixation; progressive healing was noted over the next 4 weeks with complete healing by the time of wire removal.
used as a joystick to reduce anterior and posterior, varus and valgus, and rotational deformity, a temporary Kirschner wire inserted into the proximal part of the humerus to be used as a joystick to have a better control of the proximal fragment, and the use of a small lateral external fixator.

In this study, using an intrafocal Kirschner wire to aid closed reduction in certain difficult situations was inspired by the Kapandji technique of closed reduction and percutaneous fixation of distal radial fractures. Pins are inserted into the fracture site and then used as an intra-focal pin leverage to pry the distal fragment into a more optimal position. To pry-literally-means using force to move something or to separate something from something else via a lever inserted at a crucial site. A more distal application for the Kirschner wire as a lever could present more help and better control for a distal fragment in such irreducible fractures compared to the more proximally inserted Kirschner wire in the proximal part of the humerus for better control of the proximal fragment.

Our results regarding patient demographics (age, mechanism of injury, operative time, healing time, time needed for wire removal, and time needed for restoration of full elbow range of motion) were comparable to other studies, while the mean operative delay (injury-to-surgery interval) in this study was longer than that reported by Parmaksizoglu et al. (4 ± 2.7 days vs 1.9 days), rendering closed reduction more difficult. This could to some extent explain why we had three patients (representing 20% of the studied cases) in whom closed reduction using intrafocal pinning failed requiring ORIF, while Parmaksizoglu et al. had no reported failures and no patients requiring ORIF. On the other hand, a mean operative delay (injury-to-surgery interval) of 6 days necessitating ORIF through a medial approach in all the patients was reported in a study presented by Eren et al.

Regarding adequacy of reduction, the anterior humeral line did not pass through the middle third of the capitellum in four patients, passed through the anterior third of the capitellum in three, and passed totally anterior to the capitellum in one. None of the fractures healed with varus malalignment. At the last follow-up, full range of the elbow motion was reported in all the 12 patients, and it was surprisingly found that flexion and extension range was not affected by the relationship of the anterior humeral line (AHL) to the capitellum. This coincides with what was presented by Mohammad et al. and Labelle et al., who reported that there is a controversy regarding the limits of acceptable reduction; a displacement of less than 20% and a rotation-angulation measurement of less than 20 degrees has been reported as acceptable reduction.

In this study, using an intrafocal smooth Kirschner wire (pin) to aid closed reduction could be safer compared to other methods of joystick reduction. A Kirschner wire inserted into the proximal part of the humerus has a potential risk of injuring the neurovascular structures. A posteriorly inserted threaded Schanz pin drilled into the humeral diaphysis could injure the soft tissues, and application of a proximal Schanz pin of a small lateral external fixator has the potential risk of radial nerve injury. Moreover, manipulation of the displaced distal fragment from the nearest point could be more effective in achieving an acceptable reduction compared to other methods of indirect reduction via manipulation of the proximal fragment from a distance, rendering the intrafocal joystick technique more superior compared with other methods of joystick reduction. The intrafocal wire also acts as a blocking pin to keep the distal fragment in an optimal reduced position during position change from extension to flexion and external rotation, allowing easier and faster percutaneous pinning. On the other hand, this technique-unlike others-only exerts its effect on the distal fragment, lacking any control on the long proximal fragment, rendering it ineffective in certain situations. In the three patients in whom closed reduction failed with this technique, prying the distal fragment anteriorly did not achieve an acceptable reduction, and ORIF was necessary. The proximal fragment was found to be tucked-in and buttonholing the brachialis muscle in two of these three patients, a situation for which intrafocal joystick technique could do nothing.

The relatively short follow-up period of the included patients does not represent a limitation in this study; this study was mainly concerned with evaluation of a reduction technique, assessing its efficacy, success, and potential hazards. Herzog et al. followed their patients for an average of 3 mo (range 1-17.5 mo). In this study, a mean follow-up period of 9.4 ± 3.6 mo (range 6-18 mo) was really more useful in detecting an actual relationship between final range of motion and the initially achieved reduction.

The relatively small number of patients, the absence of a control group, including neglected cases treated by ORIF, the absence of an accurate correlation between the injury-to-surgery interval and the success or failure of closed reduction, and using such a technique in supracondylar fractures only of extension type represent the limitations of this study; however, these limitations could not undermine the results achieved by this study.

In conclusion, neglected displaced supracondylar humeral fractures remain a treatment challenge. Intrafocal joystick technique for closed reduction and percutaneous fixation can effectively and safely help in treating such injuries, decreasing the need for ORIF and achieving very satisfactory radiographic and functional outcomes. ORIF is still necessary in certain conditions, but it should only be used after failure of all possible techniques of closed reduction and percutaneous fixation.

REFERENCES


