Journal of Orthopaedic Surgery and Research

RESEARCH ARTICLE

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Minimally invasive techniques utilizing the "Joy Stick" method for managing irreducible flexion-type supracondylar fractures of the humerus in older children

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Abstract

Objective In this study, we investigated the efficacy of percutaneous poking reduction and Kirschner wire fixation in older children with irreducible supracondylar flexion-type fractures of the humerus.

Methods This retrospective investigation included 27 children, comprising 15 males and 12 females, aged between 10 years and 3 months to 14 years and 11 months, all diagnosed with a flexion-type supracondylar fracture of the humerus within one week of trauma. All patients underwent surgery under general anesthesia. Following unsuccessful manual reduction, percutaneous poking reduction with Kirschner wires was performed under C-arm fluoroscopy to achieve fracture reduction. Following successful reduction, three 2.0 mm Kirschner wires were inserted in a cross pattern to secure the fracture ends. Postoperatively, the elbow joint was immobilized in a functional position with a plaster cast for four weeks.

Results Follow-up in the outpatient department ranged from 9 to 36 months. Clinical functional assessment using Flynn's criteria rated 24 cases as excellent, 2 as good, and 1 as fair, yielding an overall efficacy of 96.3%. No cases of fracture re-displacement, fracture fragment necrosis, or other complications such as nonunion, iatrogenic nerve injury, myositis ossificans, or long-term elbow joint dysfunction were observed during the postoperative follow-up.

Conclusion The percutaneous poking reduction and Kirschner wire fixation technique is a simple and reliable procedure for treating irreducible flexion-type supracondylar fractures of the humerus in older children, with minimal trauma. This technique offers substantial stability for the fracture and results in excellent long-term recovery of joint function.

Keywords Flexion type, Joy stick, Older children, Percutaneous reduction, Supracondylar fracture of the humerus

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Introduction

The most prevalent type of elbow joint injury in children is a supracondylar fracture of the humerus [1]. For displaced supracondylar fractures of the humerus, closed reduction followed by percutaneous Kirschner wire fixation is the current consensus in pediatric orthopedics worldwide [2–4]. However, with the improvement in socio-economic conditions and the rise in sports activities among teenagers, there has been an increase in the incidence of supracondylar fractures of the humerus in older children with excessive body weight. Although flexion-type supracondylar fractures of the humerus are less common, they present greater treatment challenges and exhibit a higher rate of complications compared to extension-type fractures [5]. Improper treatment can easily lead to complications such as nerve damage, elbow joint deformities, and functional impairments [6].

Apart from lateral external fixation [7], it is challenging to achieve closed reduction using only manual reduction for older children with flexion-type supracondylar fracturs of the humerus due to swelling of the affected limb. Open reduction, Kirschner wire, or plate fixation may be necessary [8]. However, these traditional treatment methods have significant drawbacks: significant surgical trauma, suboptimal recovery of joint function in the later stages, and potential psychological trauma caused by residual surgical scars in children, all of which contradict the basic principle of minimally invasive treatment in pediatric orthopedics [9].

In recent years, new minimally invasive treatment techniques for unreducible flexion-type supracondylar fractures of the humerus have been summarized and reported [10, 11]. There have been increasing reports on the use of the "Joy Stick" technique for the reduction of supracondylar fractures of the humerus in children. In our clinical practice, we have adopted this technique for managing refractory supracondylar fractures in older children, achieving satisfactory results. The summary of our findings is as follows.

Materials and methods

Clinical data

In this retrospective study, 27 cases of non-reducible flexion-type supracondylar humerus fractures in older children treated by the orthopedics department between September 2017 and September 2020, were included. The cohort included 15 males and 12 females, ranging in age from 10 years and 3 months to 14 years and 11 months. All fractures were the result of falls, classified as Gartland type III-IV flexion-type supracondylar fracture of the humerus.

The inclusion criteria were children aged 10 years or older with flexion-type supracondylar humerus fractures. The exclusion criteria were: (1) patients with open fractures; (2) fractures with minimal displacement or successful closed reduction; (3) complicated with severe vascular or nerve injuries; and (4) complicated with fractures in other body parts. This study was approved by the ethics committee of Anhui Provincial Children's Hospital, and all patients and their legal guardians were informed and provided written informed consent.

Treatment methods

All surgeries were completed within one week of the injury. Following admission, each patient underwent surgery under general anesthesia. When traditional closed reduction failed, the percutaneous poking reduction and Kirschner wire fixation technique was employed. The "Joy-stick technique," a well-established and widely recognized method, was utilized in this procedure. The specific surgical steps were as follows: Under intravenous inhalational anesthesia, the child was placed in a supine position with the affected limb positioned for an X-ray, followed by disinfection and surgical draping of the entire affected upper limb. The affected elbow joint was flexed at a 90° angle. Under C-arm fluoroscopy guidance, a 3 mm-diameter Kirschner wire was employed. After puncturing the skin behind the fracture site with the sharp end of a Kirschner wire, the blunt end was inserted into the fracture site. Using the fracture end as a fulcrum, the Kirschner wire was utilized to reduce the fracture while an assistant slowly extended the child's elbow joint. The fracture was confirmed to be well reduced under C-arm fluoroscopy (if necessary, additional Kirschner wires were used to correct any radial or ulnar deviation on the medial and lateral sides).

Following satisfactory reduction, three 2.0 mm Kirschner wires were inserted into the humeral medial and lateral epicondyles from the distal end of the fracture using an electric drill, while avoiding the ulnar nerve on the medial side. The wires were crossed to achieve fixation of the fracture bone. C-arm fluoroscopy was used to confirm that the crossing point of the wires was above the fracture line, and the elbow joint flexion and extension movements were checked to ensure unrestricted function.

Postoperative treatment: the satisfactory reduction was confirmed under fluoroscopy, the Kirschner wires were fixed, and the excess wire tips were bent and cut; the wire tips were covered with iodine-soaked gauze and gauze pads, and the elbow joint was immobilized in the functional position with a plaster cast.

The postoperative protocol followed traditional guidelines similar to those for extension-type fractures, aligning with international recommendations, involving a four-week duration. An X-ray of the elbow joint was performed four weeks post-surgery to confirm preliminary callus formation around the fracture site. The cast and

the Kirschner wires were then removed. After one month of functional exercises, the elbow joint function was restored. Complete healing of the fracture was observed during the follow-up period of three to six months.

Treatment results

Patients were followed up on the second day, fourth week, third month, and sixth month post-surgery. During follow-up visits, anteroposterior and lateral X-rays of the elbow joint were obtained to evaluate the healing of the fracture. At the most recent follow-up, the recovery of elbow joint function was observed and evaluated clinically using the Flynn criteria. The results were as follows: 24 cases were rated excellent (flexion and extension limited by 0°–5°), 2 cases were rated good (flexion and extension limited by 6°–10°), and 1 case was rated fair (flexion and extension limited by 11°–15°), resulting in an excellent and good rate of 96.3%. These ratings reflect the condition at the last follow-up compared to the unaffected side. Additionally, the comparison of carrying angles between the injured and contralateral limbs showed 24 excellent cases (loss 0°–5°) cases, 3 cases with good results (loss 6°–10°). No fracture re-displacement, necrosis of fracture fragments, or complications such as nonunion, iatrogenic nerve injury, myositis ossificans, or long-term elbow joint dysfunction were observed during the follow-ups (Table 1).

Discussion

Between September 2017 and September 2020, our hospital treated a total of 27 cases involving older children with irreducible flexion-type supracondylar fractures of the humerus. Treatment consisted of percutaneous reduction using Kirschner wires followed by cross fixation with Kirschner wires and subsequent immobilization using plaster splints to ensure stable fracture fixation. After four weeks, follow-up X-ray examinations indicated the formation of callus at the fracture ends. The plaster splints were subsequently removed, and the fixation Kirschner wires were extracted, followed by functional exercise guidance. Throughout the postoperative follow-up period, there were no instances of fracture displacement, absorption of fracture segments, or complications such as nonunion, iatrogenic nerve damage, myositis ossificans, or long-term dysfunction of the elbow joint. Overall, the treatment demonstrated positive therapeutic outcomes.

Definition and characteristics of fractures

The predominant type of elbow fracture observed in children is the supracondylar fracture of the humerus, with extension-type fractures constituting more than 95% of cases, while flexion-type fractures represent a smaller proportion, approximately 5%. The literature on flexion-type fractures primarily comprises case reports rather than large-scale studies and summaries [12, 13]. Despite the fact that the fractures occur in the same location on the supracondylar humerus, their mechanisms differ [14]. Flexion-type injuries occur when a child sustains a fall with the elbow joint in a flexed position, causing direct contact between the medial posterior elbow and the ground surface. The force is transmitted from the posterior and inferior directions to the anterior and superior directions, causing the olecranon to impact the distal humerus, resulting in a flexion-type supracondylar fracture of the humerus. During the reduction process, hindrances to successful reduction arise from factors such as the robust and elastic brachialis muscle and fascia enveloping the distal humerus and joints, the taut periosteum on the anterior side of the fractured humeral bone, and impaction of periosteal soft tissues during the reduction procedure [15]. Manual closed reduction can be particularly challenging for elderly patients with high body weight who are in the edema phase. Additionally, the posterior lateral column of the distal humerus is prone to rotation in the event of a fracture, and the small contact surface between the medial column fractures makes it difficult to maintain stability after reduction.

Comparison of treatment options

The incidence of flexion-type supracondylar fractures of the humerus is relatively low [16]. Treatment methods vary, and when repeated attempts at closed reduction fail, open reduction surgery is considered due to the challenging nature of closed reduction [17]. Traditional treatment options frequently involve open reduction, but this surgical procedure is associated with severe trauma, slow long-term recovery of elbow joint function, and

Table 1 Efficacy of surgical treatment

Outcome	Excellent	Good	Fair	Poor
Elbow Joint Function	Flexion and extension are limited by 0° – 5°.	Flexion and extension are limited by 6°–10°.	Flexion and extension are limited by 11°–15°.	Flexion and extension are limited by more than 15°.
Number of Cases	24	2	1	0
Comparison of Carrying Angles Between Affected and Unaffected Limbs	Loss of 0°–5°	Loss of 6°–10°	Loss of 11°–15°	Loss of greater than 15°
Number of Cases	24	3	0	0

the formation of scars, which may not satisfy both children and their parents. Some researchers have reported transforming flexion-type fractures into extension-type fractures using a traction and supination maneuver. However, this technique frequently results in rupture of the anterior periosteum during the violent reduction process, causing instability in multiple directions, such as anterior-posterior and radial-ulnar, making it difficult to maintain reduction. There are also reports indicating that prone positioning may be beneficial for the treatment of flexion-type supracondylar fractures of humerus [18], but it requires special positioning during surgery, which increases the duration of the procedure and anesthetic risks.

Percutaneous poking reduction and Kirschner wire fixation can overcome the drawbacks of the above treatment options, particularly for older children with irreducible flexion-type supracondylar fractures of the humerus. This procedure offers a simple reduction technique that provides effective and stable fixation. Additionally, this method is minimally invasive [19], causing minimal disruption to the blood supply around the fracture site and reducing disturbance to joint structures. It allows for faster fracture healing, optimal recovery of elbow joint function, and minimal scarring, resulting in high patient satisfaction. As depicted in Fig. 1, some cases experienced rotational failure and slight extension, although overall results were satisfactory.

In recent years, European scholars have used a radial external fixator for treating supracondylar humerus fractures [7]. This method offers the advantage of correcting rotational deformities during reduction and maintaining the alignment of forces post-reduction without the need for postoperative plaster fixation [20, 21]. Additionally, in cases requiring delayed treatment, secondary intervention, or severe swelling, as well as those involving vascular or nerve complications, initial treatment with an external fixator is recommended. However, compared to Kirschner wire fixation, this approach entails higher costs, which may deter some parents from opting for this treatment.

Treatment experience

The affected limbs of all patients exhibited abnormal build-up of fat and swelling. When simple closed reduction failed, a poking reduction procedure was utilized. A 3.0 mm-diameter Kirschner wire was commonly used as a lever, with the insertion point at the back of the elbow. After puncturing the skin with the sharp end of the wire, the blunt end was inserted from the posterior to the

Fig. 1 (**A-B**) Male, 11 years old, left flexion radial deviation supracondylar fracture of humerus; (**C**) percutaneous Kirschner wire poking reduction; (**D-E**) percutaneous Kirschner wire fixation after reduction, reduction is not perfect, but acceptable; (**F-G**) elbow joint anteroposterior and lateral X-ray third month after the reduction; (**H-I-J**) fully recovered elbow joint appearance and function

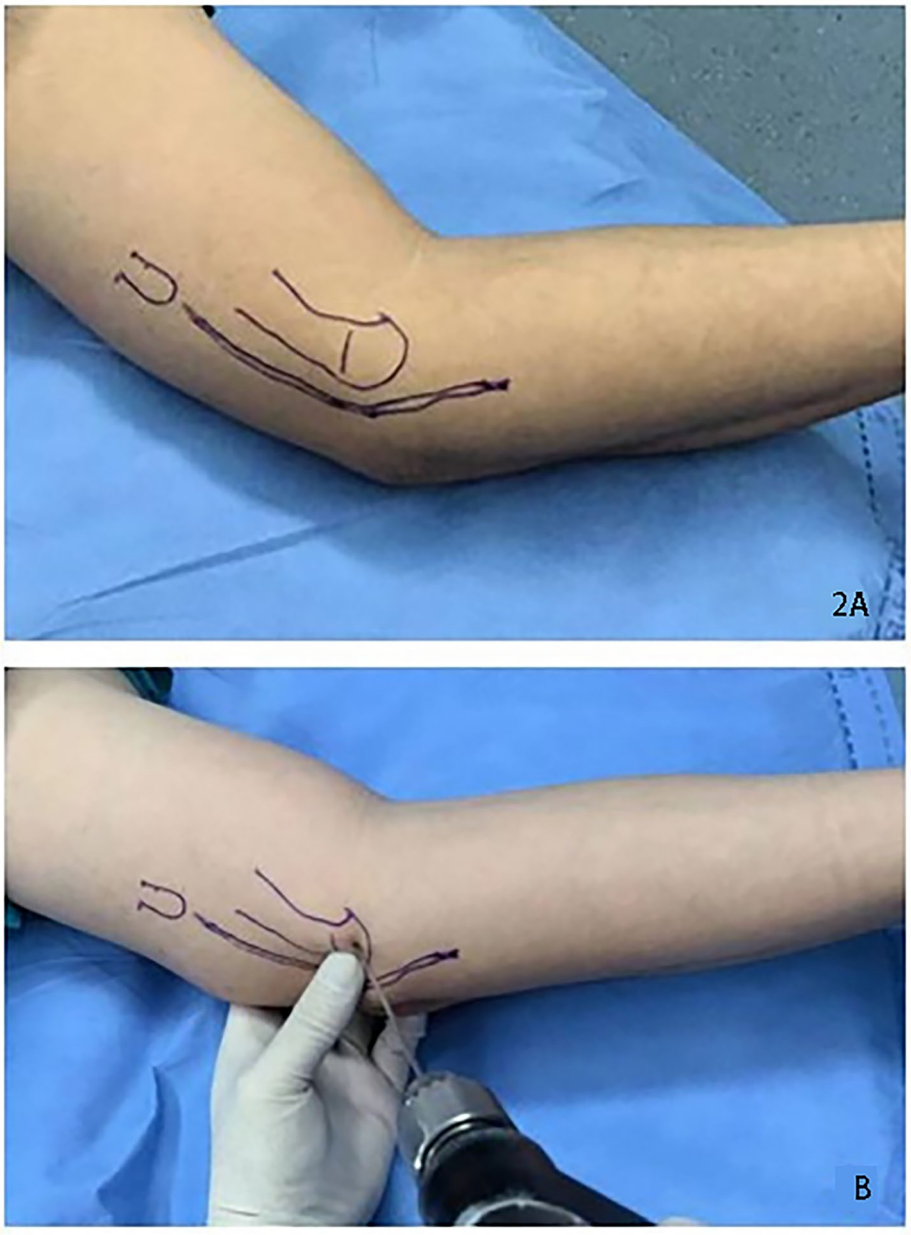

Fig. 2 (**A**) Schematic diagram of the inside of the elbow joint: U represents the ulnar nerve; (**B**) Before resetting the posterior nail, the surgeon used his thumb to press the internal epicondyle and push back the soft tissue to avoid ulnar nerve injury

anterior end of the fracture with care to avoid damaging blood vessels and nerves [22]. The Kirschner wire should not be inserted too deeply, and the integrity of the anterior periosteum should be preserved. The poking force was applied gently, employing leverage principles with the fracture ends as fulcrums to avoid excessive force. The distal fracture end was poked and pushed from the proximal anterior to the distal posterior for reduction. In cases where the fracture failed to maintain stability post-reduction, the initial Kirschner wire used for reduction could be left in place for stabilization. Alternatively, a 2.0 mm diameter Kirschner wire could be inserted through the ulnar olecranon into the medullary cavity of the humerus along its axis to enhance stability [11]. After adequate stability was achieved with the crossed Kirschner wire fixation, the original poking wire was removed.

In this study, the physical examination after admission of the fractures revealed that three cases were accompanied by ulnar nerve injury. However, immediate exploration and release of the ulnar nerve were not performed during closed reduction surgery of the fractures.

Subsequently, the ulnar nerve symptoms completely resolved within three months.

Precautions

To prevent injury to blood vessels and nerves during poking reduction, gentle insertion is required. In order to prevent extensive skin and soft tissue abrasions, care should also be taken to protect the soft tissues surrounding the pinhole during the reduction. The fracture site can be fixed using Kirschner wires if their position is satisfactory under fluoroscopy during the evaluation of leveraged reduction. During the placement of the wires, attention should be paid to prevent wire breakage due to friction between the fixation Kirschner wires and the poking Kirschner wire. A flexion-type supracondylar fracture of the humerus is often accompanied by an ulnar nerve injury [23]. Preoperative examination should be conducted and the ulnar nerve should be protected during surgery [24]. To prevent iatrogenic ulnar nerve injury, the surgeon should use their thumb to push the subcutaneous tissue, including the ulnar nerve, posteriorly and laterally at the insertion site when placing the Kirschner wire along the medial side of the elbow (Fig. 2) [25]. The needle tips of the crossed fixation Kirschner wires should pierce the cortical bone of the contralateral fracture proximal end, as the most stable fracture fixation can be achieved when the crossing point is above the fracture line.

Conclusion

In conclusion, percutaneous poking reduction and Kirschner wire fixation is a minimally invasive treatment approach for irreducible flexion-type supracondylar fractures of the humerus in older children. It provides minimal surgical trauma, rapid recovery, and extremely satisfying long-term outcomes. The surgical procedure is simple, easy to perform, and requires a short learning curve, making it worthy of clinical promotion.

Author contributions

Li Y and Jun Sun conceived the idea and conceptualised the study. Feng YY, Yuan Y and Chu XJ collected the data. Chu XJ and Yuan Y analysed and interpreted the data. Feng YY and Yuan Yi statistically analyzed the data. Li Y obtained financing. Li Y and Feng YY drafted the manuscript. Li Y, Yuan Yi and Jun Sun reviewed the manuscript. All authors read and approved the final draft.

Funding

This research was supported by Scientific research funding project of Anhui Medical University (No. 2020xkj254).

Data availability

The data and materials used to support the findings of this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of Children's Hospital of Anhui Province (No. EYLL-2020-014). This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from the legal guardians of all participants.

Informed consent

All patient guardians signed a document of informed consent.

Conflict of interest

The authors declare that they have no conflict of interest regarding this work.

Received: 24 January 2024 / Accepted: 15 July 2024
Published online: 27 July 2024

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