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Auxiliary Kirschner wire technique in the closed reduction of children with Gartland Type III Supracondylar humerus fractures

Liangchao Dong, MD, Yichen Wang, MD, Muyu Qi, MD, Sun Wang, MD, Hao Ying, MD, Yang Shen, MD*

Abstract

This study aimed to investigate the effect of auxiliary Kirschner wire (K-wire) technique in the closed reduction of children with Gartland type III supracondylar humerus fractures by comparing with manual reduction alone.

Retrospective analysis was performed on the clinical data of 68 cases of supracondylar humerus fractures. Thirty-six patients received closed reduction and percutaneous fixation with auxiliary K-wire technique (group A). Thirty-two patients received conventional manual reduction and percutaneous pin fixation (Group B).

In group A, the average operation time was 20.5 ± 8.5 minutes, the average frequency of intraoperative radiographic observations was 4.3 ± 1.1, the average fracture healing time was 6.2 ± 1.8 weeks, and the complication rate was 3/36, 8.3%. The mean operation time was 36.1 ± 10.2 minutes, the average frequency of intraoperative radiography was 8.9 + 1.7 times, the average fracture healing time was (6.1 ± 1.6) weeks, and the complication rate was 2/32, 6.3%. The operation time in group A was significantly shorter than that in group B. The difference between the 2 groups was statistically significant ($P = .012$). The frequency of radiography in group A was significantly less than that in group B ($P = .001$).

Compared with manual reduction, auxiliary K-wire technology can significantly shorten the operation time, reduce the radiant quantity of the surgeon, improve the efficiency of closed reduction of children with Gartland type III supracondylar humerus fractures, and reduce the risk of developing postoperative complications. And meanwhile, there is no significant effect on the imaging and functional outcomes of affected extremities, which is worthy of respect.

Keywords: children, closed reduction, Kirschner wire, supracondylar humerus fracture

1. Introduction

Owing to complete perforation of the front periosteum, posterior bone cortex discontinuous, and even extremely rotational instability, Gartland type III humerus supracondylar fractures must receive surgical reduction (Fig. 1).[1] Closed reduction with percutaneous Kirschner wire (K-wire) fixation is currently preferred, which is minimally invasive, fracture healing for blood supply protection, reducing the risk of infection and complications, such as an open reduction causing an elbow joint dysfunction. Most follow-up studies have confirmed the effectiveness of closed reduction with percutaneous K-wire fixation treating children with Gartland III supracondylar fracture of the humerus.[2] During closed reduction, it is relatively easy to correct the anterior and posterior angulation and the ulnar deviation of the fracture, but it is difficult to achieve a satisfactory rotational displacement with manual reduction alone. To improve the success rate and efficiency of closed reduction and to compare with the conventional manual reduction, the author uses a 1.6-mm K-wire inserting from the upper part of the proximal end of the fracture into the posterior cortical bone of the humerus for temporary fixation to make the rotational displacement better reduced and finally evaluate the complications and efficacy of both reduction methods.

2. Patients and methods

2.1. Patients

A total of 68 cases of children with Gartland type III supracondylar humerus fractures were admitted in department of orthopedics, Shanghai Children's Hospital, China, from August 2014 to August 2016 to receive surgical treatment. They were randomly divided into two groups according to the order of admission. Auxiliary K-wire technique in which the patients with even inpatient numbers were assigned in Group A, whereas the odd inpatient number patients were allocated in Group B, which were treated with manual reduction alone. The inclusion criteria for this study were fresh closed fractures, significantly displaced Gartland III fracture, surgery by the same group of doctors. Patients with open, comminuted, old, and pathological fractures, combined with neurovascular injury, ipsilateral elbow congenital malformations, were excluded from the study. All patients were

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Department of Orthopedics, Shanghai Children's Hospital, Shanghai Jiao Tong University, China.

* Correspondence: Yang Shen, Department of Orthopedics, Shanghai Children's Hospital, 355 Luding Road, Shanghai 200062, China (e-mail: shenyangshanghaitj@163.com).

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Figure 1. Preoperative anteroposterior (left) and lateral (right) radiographs of an extension-type Gartland III supracondylar humerus fracture.

surgical treated within 24 hours of injury. The age, sex, side, interval from injury to operation, and other factors of the 2 groups were tested. The results showed that there was no statistical difference (Table 1). This study has been approved by the Ethic Committee of Children's Hospital of Shanghai.

2.2. Operative technique

All patients were kept in a supine position under general anesthesia with the injured limb extended and off the bed under C-arm for closed reduction. Longitudinal traction was applied with the elbow in half-extension and the forearm in supination. Although the traction was maintained, the surgeon applied a valgus or varus force at the fracture site. The posterior displacement of the distal fragment was then corrected by applying a force to the posterior aspect while the elbow was gently hyperflexed and the reduction was confirmed by the C-arm. As how to treat with residual rotational displacement, the patients in group A were temporarily percutaneously inserted a 1.6-mm K-wire from backward to forward at 1 cm above the proximal of fracture fragment (Fig. 2). Be careful not to penetrate the anterior cortex of the humerus, and then the assistant adjusted the direction of the K-wire to correct the rotational displacement by rotating the bone shaft (Fig. 3). In group B, the assistant fixed the affected upper limb, and the surgeon finely corrected rotational displacement by forearm pronation or supination. After confirming that the reduction was successful, 3 K-wires were percutaneously inserted from the lateral aspect of elbow across the lateral cortex to engage the medial cortex. After the C-arm machine was again in perspective, there was no loss of reduction, and the pins were bent and cut. The temporary K-wire was removed at last. After the elbow was bent 90 degrees, the forearm pronation was plastered. The x-ray examination was performed at 3 or 4 weeks after surgery to observe the growth of the callus. Once the callus grows satisfactorily, the K-wire and plaster were removed and the elbow flexion and extension exercises were started. Success criteria of closed reduction: the difference between the Baumann angle and the healthy side of the elbow anteroposterior plate does not exceed 4 degrees (Fig. 4); the lateral line of the humerus cortex extends across the central one-third of the capitellum, and the distal humerus remains essentially " X" shape (Fig. 5).

Comparisons included operative time (starting closed reduction until the end of the cast immobilization), radiography frequency (the frequency of C-arm machine used during the operation), and fracture healing time (x-rays showed the time of bone union). x-ray imaging evaluations were performed at the time of immediate postoperative pluster fixation and the last follow-up, and the standard anteroposterior and lateral radiographs of the elbow joint were photographed and read by the same radiologist to evaluate whether there was a loss of reduction and a Baumann angle change. Intraoperative and postoperative complications were recorded, with or without neurovascular injury, compartment syndrome, nail tract infection, delayed union, and nonunion. The elbow range of motion was measured in the final follow-up and Flynn criteria was used to evaluate the function of the affected extremity.[3]

Table 1

The comparison of general states between the 2 groups.

			Sex		Side		Frature type		
Group	Number	Age, y	Male	Female	Left	Right	Flexion	Extension	Interval from injury to operation, h
A	36	4.0±2.5	26	10	21	15	2	34	4.0±5.5
B	32	4.6±2.3	22	10	20	12	1	31	5.1±4.8
P		.397	.822		.564				.567

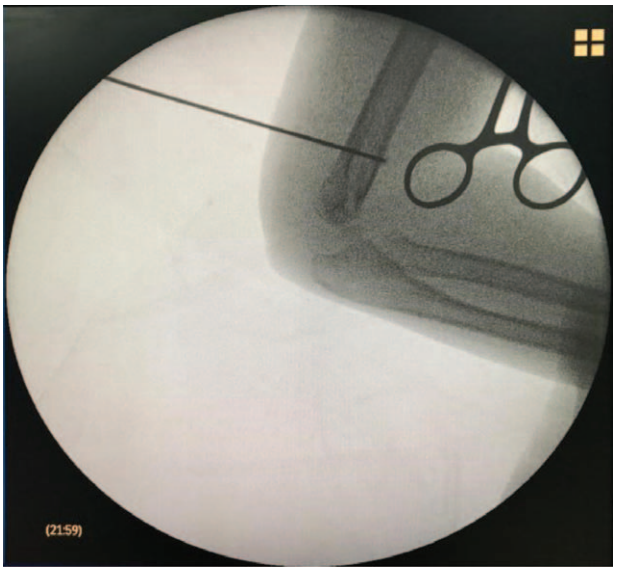

Figure 2. A K-wire was inserted from back to front at 1 cm above the proximal of fracture fragment.

Figure 4. Anteroposterior radiographic images of fracture reduction and fixation with 3 K-wires inserted percutaneously from the lateral sides.

2.3. Statistical analysis

The results were expressed as mean with standard deviation. SPSS 14.0 statistical software was used in the statistical analysis (SPSS Inc, Chicago, IL). The Fisher exact test and paired *t* test were applied to assess the outcome variables between the 2 groups. The *P* value $< .05$ was considered to be significant.

3. Results

All patients were followed up. The mean follow-up time was 22.5 $\pm$4.7 months in group A, and 23.7$\pm$2.8 months in group B. In group A, the average operation time was 20.5$\pm$8.5 minutes, the average fracture healing time was 6.2$\pm$1.8 weeks, and the average frequency of radiography was 4.3$\pm$1.1 times. The average operation time of group B was 36.1$\pm$10.2 minutes, the average fracture healing time was 6.1$\pm$1.6) weeks, the average frequency of radiography was (8.9+1.7) times. The difference in average operation time between the 2 groups was statistically significant. There was a statistically significant difference in the average frequency of radiography. The difference in healing time was not statistically significant. The Baumann angles in group A were (75.5$\pm$5.5)degree and (73.8$\pm$5.7)degree in operation and the last follow-up, and were (74.6$\pm$6.4)were and (72.5$\pm$5.9)° in group B, respectively. Cubitus varus deformity was not seen in both two groups. Complications: In group A, there were two cases of nail tract infection, one case of median nerve injury. One

Figure 3. The assistant holds the forearm with one hand, whereas the other hand corrected the rotation of proximal humerus by swinging the pin.

Figure 5. Lateral intraoperative radiograph showed the anterior humeral line extended across the central one-third of the capitellum.

Table 2

The comparison of intraoperative and postoperative indicators between the 2 groups.

Group	Average follow-up, mo	Average operation time, min	Frequency of radiography	Healing time, wk	Baumann angle, degree		Complication rates	Flynn criteria (excellent ratio)
					Intraoperative	Last follow-up		
A	22.5±4.7	20.5±8.5	4.3±1.1	6.2±1.8	75.5±5.5	73.8±5.7	3/36	26/36
B	23.7±2.8	36.1±10.2	8.9+1.7	6.1±1.6	74.6±6.4	72.5±5.9	2/32	24/32
P	.42	.012	.001	.68	.477	.467	.552	.617

case of nail tract infection and one case of median nerve injury occurred in group B. There were no complications such as vascular injury, delayed union, nonunion, compartment syndrome, etc. The difference in the total incidence of complications between the 2 groups was also not statistically significant. A group of Flynn elbow function scores: excellent in 26 cases, good in 10 cases, fair in 0 cases, poor in 0 cases, excellent rate was 72.2%. The Flynn elbow function score in group B was excellent in 24 cases, good in 8 cases, fair in 0 cases, poor in 0 cases, and excellent in 75%. There was no significant difference between the 2 groups. Table 2).

4. Discussion

Since Swenson[4] firstly used the closed reduction percutaneous pinning with K-wire in 1948 to treat supracondylar fractures of the humerus, this method quickly obtained extensive promotion and application in clinical practice for its advantages in small surgical trauma, good reduction effect, short fixation time, and satisfactory follow-up results. At present, it has become the preferred surgical method for the treatment of children with Gartland III supracondylar fracture of the humerus. Owing to the limited remodeling ability of the elbow joint, the fracture reduction must reach or approach the anatomical reduction to obtain its normal function, prevent the long-term complications caused by poor restoration, and the joint mechanics anomaly. Although some scholars believe that open reduction can also get good clinical efficacy,[5] More scholars reported that peeling soft tissue during open reduction surgery, exposure of the fractured end, and reduction likely to aggravate elbow injury increase the incidence of myositis ossificans and the possibility of infection, and affect the functional recovery of the elbow at a later stage.[6] We have a cautious attitude toward open reduction. Only open fractures, suspected median nerves, and/or brachial arteries and soft tissues embedded in the fracture site lead to repeated attempts to avoid aggravating injury after multiple failed attempts of reduction. Because the periosteum around humerus supracondyle completely ruptures, the role of soft tissue hinge no longer exists, so Gartland III fracture is extremely unstable. Closed reduction is to reset the fracture end under "non-straight vision." The technical requirements for the surgeon are high. To reset the fracture end, the "locked" state of the fracture should firstly be released. During the repositioning process, the elbow half extension position is first maintained, that is, the flexion is 30 degree, so that the tension of the flexion and extension muscles is reduced, and then the traction along the longitudinal axis of the upper limb is performed to achieve the "locking" state of the fractured end. Afterwards, horizontal displacement of the distal end of the fracture is corrected, and the next step is to correct the anterior–posterior displacement by the degree of elbow flexion, and it is also possible to use the fold-top or manipulation technique.[7] On the contrary, if the front and rear displacements are corrected first, the "locking" state of the broken end of the fracture in nonanatomical alignment will seriously hinder the correction of lateral displacement. In clinical work, we found that correcting the lateral displacement first, and then correcting the front and rear displacement usually can obtain a satisfactory reduction effect.

Usually, when the closed reduction is performed, the distal end of the fracture is generally applied to the proximal end of the fracture. The traditional method of traction is relatively easy to repair the anterior and posterior angulation and lateral displacement. However, it is difficult to effectively restore the rotational displacement. Rotational displacement of the end is often the main reason for the failure of closure and restoration of supracondylar fractures of the humerus. In addition, the force of the reduction technique of conventional traction cannot effectively control the strength of the reduction process. It may be that the strength is not enough or excessive so that the reduction is unsatisfactory. Moreover, the fracture end movement occurs easily during the process of pinning and a change in body position when taking radiograph, which results in failure of reduction. The auxiliary K-wire technique is resetting the proximal end of the fracture to the distal end. The lever principle can be used to control the rotation of the proximal end of the humerus. It can effectively correct the rotational deformity of the fracture. The radiography confirms that the reduction effect is good, and the assistant is allowed maintaining the position of the K-wire and forearm simultaneously. It is then performed by the surgeon to perform percutaneous K-wire fixation. This avoids the loss of the position of the fracture end during pin insertion and can effectively control the force of reduction, thus significantly improving success rate of closed reduction. Such a leverage technique has been reported by foreign scholars; Novais et al[8] recommend that a K-wire or a Steinmann pin be placed at the distal end of the supracondylar fracture of the humerus as a control rod for fracture reduction. Grenn et al[9] recommended a closed reduction method for the supracondylar fracture, the needle was inserted from the olecranon and the distal end of the fracture into medullary cavity of the humerus shaft. The author tried both methods, and realized that the methods of Novais et al and Grenn et al must be guided by the C-arm machine to advance the pin inserting, and it is difficult to ensure a successful needle insertion. Besides, it is not easy to quickly grasp the operating skills, so the doctor's learning curve is extended. And these 2 methods have the risk of epiphysis injury, so we improved the methods of the above. The author's experience is to penetrate a 1.6-mm K-wire at the proximal end of the fracture in the direction from back to front, break through the posterior cortical bone and continue to inject the needle, and after the second resistance, insert the needle 3~4 circles and stop, and then the head of the needle has entered the frontal cortical bone, but not a complete

breakthrough, not only to avoid injuring the nerves and blood vessels in the anterior humerus, but also to maintain adequate control to ensure the reduction. The author's team also found through practice that 1.6-mm K-wire can maintain enough strength for holding the proximal humerus in early-age children, but for high-weight (>25 kg) children, the size of pin should be switched to 2 mm in diameter. Owing to the small number of cases, this group was not included in this study.

The Gartland type III fractures in Group A were significantly reduced in operative time and intraoperative radiographic frequencies by the aid of the auxiliary K-wire technique. This technique can rapidly obtain a fracture reduction and does not affect the rate of fracture healing and complications. Whether auxiliary K-wire technique is with closed reduction or manual traction and closed reduction, it does not destroy the blood flow at the fracture end, which has little interference with the internal environment of the bone, minimizing the damage to the bone and the surrounding soft tissue, and provides beneficial callus growth environment, so there was no significant difference in mean fracture healing time between the 2 groups in this study. In terms of complications, there was no significant difference in the incidence of overall complications between the 2 groups (A/3/36, B/3/32, $P = .891$). In this study, there were no significant differences in radiographic results or elbow function scores between the 2 groups. Therefore, it is proved that this technique is of great importance. With the aid of the K-wire technique, although an additional pin wound existed, it was a minimally invasive procedure that did not cause more trauma to the child and no postoperative wound infection occurred.

For the approach of K-wire fixation, there has been controversy in the academic world.[10] Medial–lateral crossed pin fixation has obvious advantages in antirotation and antilateral displacement; however, there is the possibility of iatrogenic ulnar nerve injury, the incidence of which was from 2% to 6% according to literature.[11] Sharma et al [12] analyzed 2 different methods for treating supracondylar humerus fractures of children and pointed out that lateral and medial-lateral K-wires approaches had no significant difference in postoperative fracture stability and elbow joint function. But in reality, there was a certain possibility of radial nerve injury, studies had reported that the incidence of iatrogenic radial nerve injury by the lateral K-wire method was approximately 0.3%.[13] All of our retrospective cases were treated by lateral 3 K-wires approach. The stability was satisfactory. There was no case lost after follow-up. No cases of radial nerve injury occurred after surgery. Two cases of median nerve injury occurred after surgery in both groups and they were self-recovered within 1 month after surgery. What is gratifying is that through practicing this technology, we have shortened the learning curve of young doctors. On average, senior resident doctors can perform this surgery after training for 3 times.

This study has some limitations. The sample size is relatively small, the follow-up time is not long enough, and the dosage of x-ray is not described. We will strictly design and standardize the study and strive to conduct prospective studies in the future to further verify this method.

In summary, compared with manual traction reduction, auxiliary K-wire technology can significantly improve the success rate of closed reduction of children with Gartland III humeral supracondylar fractures, which can significantly shorten the operation time and the frequency of intraoperative radiographs, and does not increase intraoperative and postoperative complications, which does not affect the healing of fractures, or reduce the final imaging and extremity function results in children. Therefore, for some patients with apparent rotation displacement of the Gartland type III supracondylar humerus fracture, it is recommended that the surgeon attempts a closed reduction with the aid of the auxiliary K-wire technique.

Author contributions

Conceptualization: Liangchao Dong, Yang Shen.
Formal analysis: Yichen Wang, Muyu Qi.
Methodology: Liangchao Dong, Sun Wang, Hao Ying, Yang Shen.
Writing – original draft: Liangchao Dong.
Writing – review & editing: Yang Shen.

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