Clinical Research Report

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2019, Vol. 47(11) 5497–5507

DOI: 10.1177/0300060519825990
journals.sagepub.com/home/imr
SAGE

Percutaneous leverage reduction with two Kirschner wires combined with the Métaizeau technique versus open reduction plus internal fixation with a single Kirschner-wire for treating Judet IV radial neck fractures in children

Xiangping Du[1], Lirong Yu[2], Zhigang Xiong[1], Gan Chen[1], Jun Zou[1], Xinle Wu[1], Bin Xiong[1] and Baoli Wang[1]

Abstract

Objective: To compare the clinical effectiveness of a novel approach, percutaneous leverage reduction using two Kirschner-wires (k-wires) combined with the Métaizeau technique, versus open reduction plus internal fixation with k-wire for the treatment of Judet IV radial neck fractures in children.

Methods: Thirty-four patients with Judet IV radial neck fractures were treated either with percutaneous leverage reduction using two k-wires and the Métaizeau technique (n = 16) or open reduction plus internal fixation with k-wire (n = 18). Patient data including sex, age, time from trauma to surgery, fracture type, follow up, postoperative healing time, X-ray studies, elbow function, and complications were collected.

[1]Department of Orthopaedics, Jiangxi Provincial Children's Hospital, Nanchang, China
[2]Department of Endocrinology, Jiangxi Provincial Children's Hospital, Nanchang, China

Corresponding author:
Lirong Yu, Jiangxi Provincial Children's Hospital, No.122, Yangming Road, Nanchang 330006, China.
Email: ylrss@163.com

Results: There were no significant differences in patient characteristics between the two treatment groups. In postoperative elbow function assessment, 93.8% of patients in the group that underwent the novel treatment approach had a score of excellent or good, compared with 83.3% of patients in the open reduction and internal fixation with k-wire group. Furthermore, no postoperative complications were reported in patients in the novel treatment group, compared with 5 patients in the open reduction and internal fixation with k-wire group. All patients in both groups were classified as excellent or good according to Métaizeau criteria in postoperative X-ray assessment.

Conclusions: Compared with the open reduction and internal fixation with k-wire approach, percutaneous leverage reduction using two k-wires combined with the Métaizeau technique can significantly increase the minimally invasive reduction rate, and represents an attractive strategy for the treatment of Judet IV radial neck fractures in children.

Keywords

Children, radial neck fracture, percutaneous reduction, intramedullary nail, k-wire, Métaizeau technique, closed reduction, open reduction

Date received: 12 August 2018; accepted: 28 December 2018

Radial neck fracture is common in children, accounting for approximately 1%–2.7% of all children's fractures and 5%–10% of elbow fractures.[1–5] Severely displaced Judet IV radial neck fractures are not easy to treat using minimally invasive methods such as the Métaizeau technique and single Kirschner (k)-wire percutaneous leverage reduction,[2,4–7] while open reduction may aggravate the elbow injury, increase the risk of radial necrosis and non-union, and decrease treatment effectiveness.[3,8,9] Furthermore, some researchers have suggested that open reduction does not influence the overall treatment effectiveness of radial neck fracture.[2] In the present study, we adopted the combination of percutaneous leverage reduction with two k-wires and the Métaizeau technique to treat radial neck fractures in children, and changed k-wire tail to perform leverage in an attempt to enhance the recovery rate and reduce postoperative complications in comparison with the standard treatment of open reduction plus internal fixation with k-wire.

Methods

Patients

Patients who met the following inclusion criteria were eligible for enrolment: age $\leq$ 14 years; X-ray finding of Judet IV radial neck fracture; consented to combination treatment of percutaneous leverage reduction with two k-wires and the Métaizeau technique or open reduction and internal fixation with k-wire; follow-up period of at least 1 year.

Patients who met the following criteria were excluded from participation: other fractures, including elbow fractures, with the exception of olecranon fractures; presence of vessel and nerve injury; inability to complete Mayo Elbow Performance Score (MEPS) functional assessment.

This study was approved by the ethics committee at our hospital.

Treatment groups

A total of 16 patients (11 male, 5 female) were enrolled in the group that received

treatment with percutaneous leverage reduction with two k-wires combined with the Métaizeau technique. The patient characteristics were as follows: trauma: left side in 9 patients and right side in 7 patients; age: range of 6 years and 7 months to 12 years and 10 months, with mean age of 10 years and 1 month; cause of trauma: fall in 11 patients, bicycle accident in 4 patients, and skateboarding accident in 1 patient; time from injury to surgery: 2–7 days, mean of 3.7 days; associated injury: complicated with olecranon fracture on the same side in 3 patients; Judet subtype[2]: Judet IVa in 8 patients and Judet IVb in 8 patients.

A total of 18 patients (12 male, 6 female) were enrolled to the group that received treatment with open reduction and internal fixation with k-wire. The patient characteristics were as follows: trauma: left side in 9 patients and right side in 9 patients; age: 4 years and 2 months to 13 years and 10 months, with mean age of 9 years and 1 month; cause of trauma: fall in 13 patients, bicycle accident in 3 patients, fall from a double pole in 1 patient, and accidental injury in 1 patient; time from injury to surgery: 1–9 days, mean of 3.8 days; associated injury: complicated with olecranon fracture on the same side in 3 patients; Judet subtype: Judet IVa in 11 patients and Judet IVb in 7 patients.

Treatment procedures

Percutaneous leverage reduction using two k-wires combined with the Métaizeau technique. Prior to surgery, the narrowest internal diameter of the radial marrow cavity on the affected side was measured using X-ray imaging, and the elastic intramedullary nail was selected as being 1/2–2/3 of the internal diameter. Patients were placed in a supine position under general anesthetic or brachial-plexus anesthetic, and routine sterilization and positioning of surgical drapes was performed.

Reduction fixation (RF) comprised four steps: first, the location of the distal radius epiphyseal plate was determined by C-arm X-ray and a small incision was made in the lateral and proximal 2–3 cm to protect the superficial radial nerve. After drilling and pulping the metaphysis, the elastic intramedullary nail was inserted into the marrow cavity and gradually pushed to reach 1 cm of the fracture line (Figure 2). Second, the needle insertion position of k-wire leverage reduction was localized with a no. 16 needle. The position was parallel to the fracture line (Figure 3). Another 2.0 mm (or 1.5 mm for younger children) k-wire needle was obliquely inserted from the posterolateral elbow. After the needle had pierced the muscular fasciae, the blunt needle tail of the k-wire was inserted along the route of the original needle. After the needle reached the posterolateral radialis diaphysis, the needle tail was positioned along the radialis diaphysis to reach the proximate end and allow detection of the displaced caput radii. The needle tail was used to penetrate the caput radii; it was partially penetrated initially (Figure 4A), to ensure that the k-wire could be inserted into the gap at the fracture end (Figure 4B); next, the distal fracture surface was regarded as a foothold and the caput radii was pushed upwards (Figure 4C) to further correct the angular deformity. Third, another k-wire was used to further achieve fracture reduction, and the needle insertion position was 0.5–1 cm from the proximal end and lateral side of the first needle, respectively. The same method was used to detect the displaced caput radii. The needle was not inserted into the fracture gap, but the needle tail was instead used to push or press the caput radii (Figure 5A, 5B) to correct the lateral displacement of the caput radii and collaborate with the initial k-wire to correct the angular deformity. Fourth, where the two k-wires had already achieved

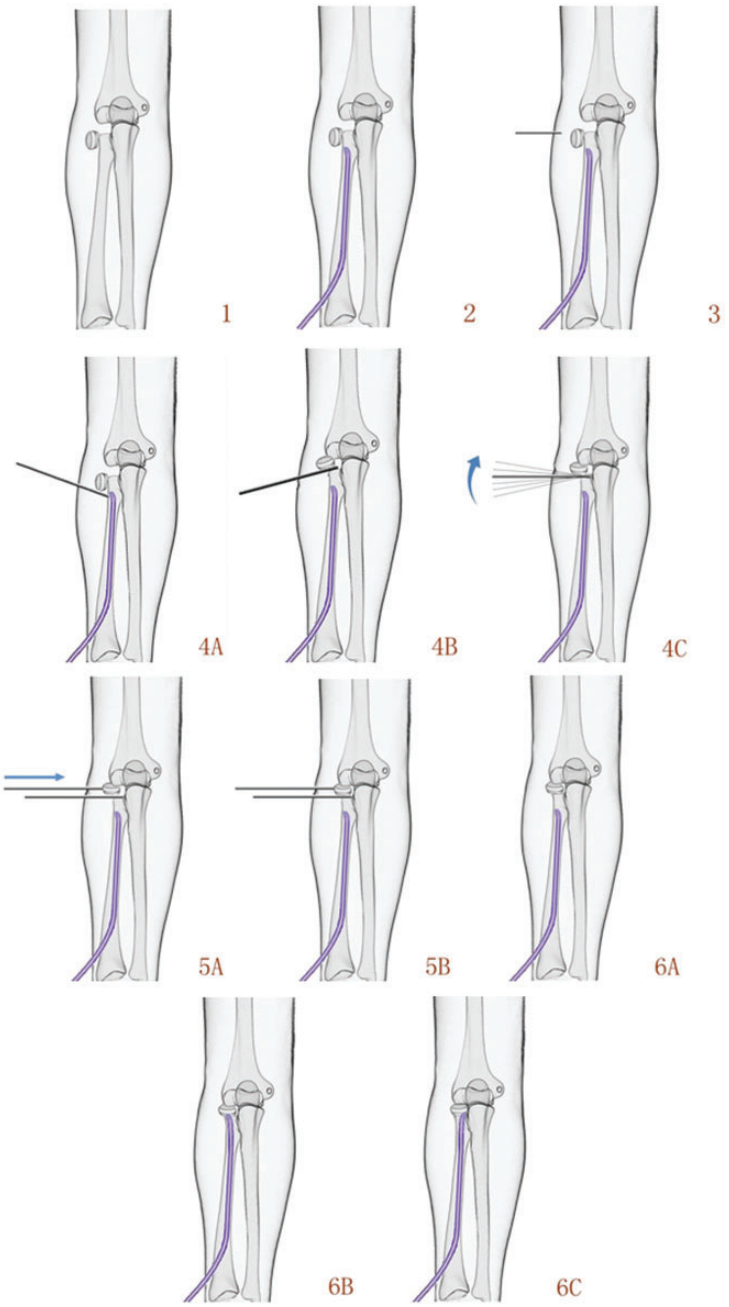

Figure 1. Surgical procedures.
(1) preoperative condition; (2) insertion of the elastic intramedullary nail into the radial marrow; (3) localization of a no.16 needle during surgery; (4A) poking the caput radii via the needle tail; (4B) insertion of k-wire through the gap in the fracture end; (4C) the distal fracture surface as a foothold and poking the capitulum radii upwards; (5A, 5B) pushing or pressing another needle tail to the caput radii; (6A) reduction condition following the use of two k-wires; (6B, 6C) correcting the lateral displacement of the capitulum radii.

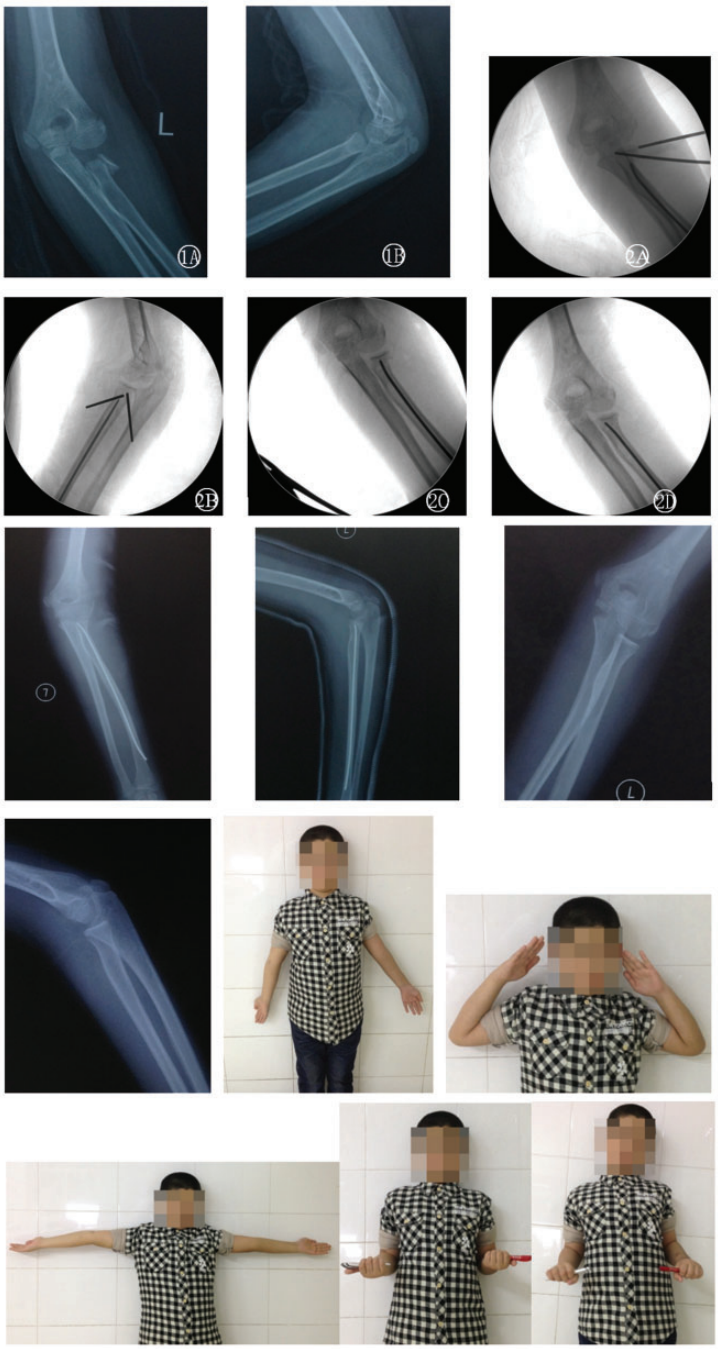

Figure 2. X-ray, image intraoperative observation, and postoperative function following treatment with percutaneous leverage reduction using two k-wires combined with the Métaizeau technique.
The patient (male, aged 11 years), was diagnosed with a left-side Judet IVb radial fracture. (1A, 1B) orthotopic and lateral X-ray image of the preoperative elbow; (2A–2D) method used to treat the radial fracture; (3A, 3B) orthotopic and lateral X-ray image on the first postoperative day; (4A, 4B) orthotopic and lateral X-ray image 2 years after surgery; (5A–5E) postoperative function.

fracture reduction, the elastic intramedullary nail was gently pushed to a position below the epiphyseal plate to fix the fracture. If partial angular displacement persisted, the elastic intramedullary nail was positioned toward the displaced caput radii and gently pushed to a position below the epiphyseal plate, where it underpinned the capitulum radii to further correct the angular deformity (Figure 6B). The elastic intramedullary nail was rotated 180° to correct lateral displacement of the capitulum radii. After ensuring fracture reduction and good fixation, the elastic intramedullary nail was immobilized in situ, the tail was not bent and exposed about 1 cm of the cortical bone of radius, the elastic intramedullary nail was cut off, and the incision was sutured.

Following surgery, anterior and posterior plaster support was used to maintain the elbow and wrist in a functional position. The time until removal of the external plaster fixation and the elastic intramedullary nail was determined according to the fracture recovery condition. In the present study, postoperative external plaster was used to fix the fracture for 3–4 weeks. After removal of the plaster, elbow flexion and extension and forearm rotation function exercises were initiated. The elastic intramedullary nail was removed 2–3 months after surgery.

Open reduction and internal fixation with k-wire. Patients were prepared for surgery as described above, and a 3.5 cm incision was made in the posterolateral elbow. The joint capsule was cut along the brachioradialis muscle and spatiumintermusculare, to expose the caput radii and radial neck. The fracture was exposed beneath the periosteum and the soft tissue within the fracture was cleaned, ensuring open reduction of the fracture. One 1.5 mm or 2.0 mm k-wire was used to fix the capitellum, caput radii, and radial neck. The pin was bent and cut, the pintail was retained in the outer skin, and the incision was cleaned and sutured.

Following surgery, anterior and posterior plaster support was used to maintain the elbow and wrist in a functional position. The time until removal of the external plaster fixation and the elastic intramedullary nail was determined according to the fracture recovery condition. Postoperative internal fixation with k-wire and external fixation with plaster was used to fix the fracture for 4–6 weeks. Following removal of the internal fixation with k-wire and plaster, elbow flexion and extension and rotation function exercises of the forearm were initiated.

Treatment of associated lesion

Olecranon fractures were treated conservatively by external fixation with a plaster support. The anterior-posterior plaster slab was externally fixed in the functional position of the elbow and wrist.

For open reduction of the olecranon fracture, the fractured limb was flexed 90° and the elbow back was placed in front of the breast. A median incision was made in the elbow back and the fracture was gradually exposed, with the periosteum retained to the greatest extent possible. The joint cavity was examined and cleaned. Drilling through the ulna was performed 2–4 cm from the end of the distal fracture to provide an entry point for wire tension. The reduction was then performed using two k-wires of 1.6 mm to fix the fracture. The wire tension was drilled into the former distal pole and around the entry-point of the two k-wires, and was fixed using an "8" method. C-arm X-ray imaging showed that the fracture had a good contraposition alignment. Finally, the incision was cleaned and sutured.

Assessment of therapeutic effectiveness

Iconographic assessment was performed by evaluating postoperative X-rays according to Métaizeau criteria[10], whereby anatomic reduction was classified as excellent, inclination $<20°$ was good, inclination of 20°–40° was average, and inclination $>40°$ was poor. Assessment of elbow function was according to the MEPS[6], whereby pain was 45, function was 25, radius was 20, and elbow stability was 10, out of a total score of 100. A score of 95–100 was considered excellent, 80–94 was good, 60–79 was average, and 0–59 was poor.

Statistical analysis

Normal measurement data were shown as "$x \pm s$"; a t-test was used for comparisons between groups; and a χ^2 test was used to determine the count rate (%) of data between the groups. Values of $P < 0.05$ were considered statistically significant. SPSS 22.0 software (IBM Corp, Armonk, NY, USA) was used for the statistical analysis of data in both groups.

Results

Percutaneous leverage reduction using two k-wires combined with the Métaizeau technique

Enrolled patients were followed up for 12–39 months, with a mean follow up of 19 months ($P = 19.06 \pm 9.41$). All fractures were primary healing, with a recovery time of 4–10 weeks and mean recovery time of 5.4 weeks (5.43 ± 1.59).

Postoperative X-ray images were evaluated according to Métaizeau criteria, and 12 patients were classified as excellent, 4 patients as good, and 0 patients as average or poor, giving a rate of 100% for the classification of excellent or good. According to the MEPS evaluation of postoperative elbow function, 10 patients were classified as excellent, 5 as good, 1 as average, and 0 patients as poor, representing a rate of 93.8% for the classification of excellent or good.

One patient with a Judet IVb fracture was diagnosed as having a fully displaced caput radii and complication of olecranon fracture. The olecranon fracture received conservative treatment of external fixation with plaster support and the radial neck fracture was treated with percutaneous leverage reduction using two k-wires combined with the Métaizeau technique. RF was not achieved during surgery, however, and open reduction and fixation of the elastic intramedullary nail was subsequently performed. Postoperative fracture reduction was good, but the elbow grading was average. Two other patients that had an olecranon fracture complication received conservative treatment and had good postoperative elbow function.

No infection, nerve injury, caput radii necrosis, proximate fusion of ulna and radius, or early closure of the radius proximal epiphyseal plate was observed in patients in the group treated with percutaneous leverage reduction using two k-wires combined with the Métaizeau technique.

Open reduction and internal fixation with k-wire

All 18 enrolled patients were followed up for 12–39 months, with a mean follow up of 23 months ($P = 22.75 \pm 4.31$). All fractures were primary healing, with a recovery time of 4–12 weeks and mean recovery time of 6.3 weeks (6.31 ± 2.21).

Postoperative X-ray images were evaluated according to Métaizeau criteria, and 12 patients were classified as excellent, 4 as good, and 0 patients as average or poor, giving a rate of 100% for the classification of excellent or good. According to the MEPS evaluation of postoperative

elbow function, 9 patients were classified as excellent, 6 as good, 2 as average, and 1 patient as poor, representing a rate of 83.3% for the classification of excellent or good.

Three patients had a complication of olecranon fracture. One patient underwent open reduction and tension band fixation, resulting in poor postoperative elbow function. The remaining two patients received conservative treatment of external fixation with plaster support, resulting in good elbow function.

Three patients had a pin tract infection, 1 patient had caput radii necrosis, and 1 patient had heterotopic ossification. There was no nerve injury, proximate fusion of ulna and radius, or early closure of the radius proximal epiphyseal plate reported in the group treated with open reduction and internal fixation with k-wire.

Table 1 Judet fracture classification.

Type	Angulated angle (°)	Displacement (%)
I	No	No
II	>30	<1/2 of transverse diameter
III	30–60	>1/2 of transverse diameter
IV	>60	Total

Judet IVa: angulated angle of 60–80°; Judet IVb: angulated angle >80°.

Comparative analysis

There was no statistical difference in age, sex, affected upper limb, associated lesion, Judet IV subtype, trauma time, postoperative healing time, or duration of follow up between the two treatment groups. Fewer postoperative complications were observed in the group treated with percutaneous leverage reduction using two k-wires combined with the Métaizeau technique compared with the group treated with open reduction and internal fixation with k-wire, with statistical significance ($P = 0.46$, $P < 0.05$). Postoperative X-ray studies showed that both groups had a similar rate of excellent and good Métaizeau classification. However, the rate of excellent and good MEPS postoperative elbow function was higher in the group treated with percutaneous leverage reduction using two k-wires combined with the Métaizeau technique (93.8%) than in the group treated with open reduction and internal fixation with k-wire (83.3%).

Conclusion

Radial neck fracture is a common injury in children, representing the third most prevalent type of elbow fracture and fracture of radius head, which may be because the bend intensity of the ligament is 2–5 times that of cartilage prior to epiphysis maturity. An abundance of cartilage and a narrow

Table 2. Comparison of the outcomes of two methods for the treatment of Judet IV radial neck fractures.

Group	Percutaneous leverage reduction using two k-wires combined with the Métaizeau technique (n = 16)	Open reduction and internal fixation with k-wire (n = 18)
Excellent or good rate of X-ray (%)	100	100
Excellent or good rate of elbow function (%)	93.8	83.3
Complications	0	5

neck in the caput radii contributes to a biomechanical weakness in the radial neck.

Treatment is in accordance with the angulated angle and displacement degree, an approach that remains controversial. Fowles, Kassab et al.[11] believed that indications of conservative treatment include: age < 5, angulated angle $< 50°$; 5–10 years old, angulated angle $< 30°$; girls >12 years old and boys >14 years old, angulated angle $< 15°$. Bemstein et al.[12] believed that children < 6 years old and angulated angle $< 60°$ are acceptable, but >12 years old and angulated angle $>30°$ are not acceptable. The current controversy focuses on whether the fracture of 30–60° requires surgery.[6]

For fractures with angulation $\geq 30°$, standard treatment includes open reduction, percutaneous leverage fracture, and elastic intramedullary nail reduction.

Percutaneous k-wire leverage reduction internal fixation is minimally invasive and causes little iatrogenic injury to radial proximate blood transportation and elbow peripheral muscle ligaments, but may damage the posterior interosseous nerve and radial proximate epiphysis plate, leading to fusion of the ulna and radius and needle tract infection.[2,4,13] Zwingmann et al.[14]believed that percutaneous k-wire leverage reduction internal fixation can be used in Mason II patients having a displaced and mildly angulated fracture and radial collapse. Tarallo et al.[15] considered that the efficacy of percutaneous k-wire leverage reduction internal fixation was lower than that of the Métaizeau technique.

In 1980, Métaizeau[16] was the first to report the use of a closed reduction of the intramedullary nail to treat the radial fracture in children, with good postoperative efficacy. For radial fracture with severe displacement and angulation, however, it can be difficult to achieve reduction using the Métaizeau technique alone,[5,7,10] and the use of open reduction has therefore been advocated in these cases.[17]

Recently, some researchers have used a Kirschner needle to supplement the Métaizeau method in the treatment of children with radial neck fractures, although this approach is primarily used in Judet type III cases.19 Judet IV fractures are frequently difficult to reset, resulting in a prolonged duration of surgery.

Zimmerman et al.[8] retrospectively analyzed 151 patients treated for radial fracture in 2001–2011 and found that the postoperative efficacy in 67% of patients treated with open reduction was worse than that in those who received treatment with a k-wire and Métaizeau technique. However, in a study of 51 children with radial neck fracture, Gutiérrez-de la Iglesia[17] found that final functional outcome might not be affected by the use of open reduction.

Therefore, we adopted percutaneous leverage reduction using two k-wires combined with the Métaizeau technique to treat Judet IV radial neck fracture in an attempt to enhance the success rate of minimally invasive treatment and compare the clinical outcomes of this novel approach with the open reduction and internal fixation with k-wire method. In the present study, only one patient (12.5%) underwent open reduction and elastic intramedullary nail fixation, which was lower than the 30% reported by Gutiérrez-de et al.,[2] the 26% reported by Kaiser et al.,[18] and the 26% reported by De Mattos et al.[3] MEPS evaluation of elbow function showed that the new technique produced an excellent and good rate of 98.3%, which was significantly better than the rate of 83.3% found in the group treated with open reduction and internal fixation with k-wire and the rate of 78.9% reported by Kaiser et al.[18] Furthermore, no complications were observed in the group treated with percutaneous leverage reduction using

two k-wires combined with the Métaizeau technique, while 5 patients in the group treated with open reduction and internal fixation with k-wire reported complications. In the new technique, a blunt needle tail was used to perform leverage reduction, which can reduce injury to the radial proximate epiphysis plate and articular cartilage. Needle insertion was carried out in the posterolateral radius, thus avoiding the deep radial nerve. No cases of deep radial nerve injury or early closure of the epiphysis plate were reported in the group treated with the new technique.

Compared with open reduction and internal fixation with k-wire, percutaneous leverage reduction using two k-wires combined with the Métaizeau technique may have the following advantages: (1) minimal invasion, less bleeding, smaller incision, and smaller scar; (2) decreased risk of pin tract infection, radial necrosis, and damage to the radial nerve and its branches; and (3) earlier postoperative flexibility and rotation of the elbow, which benefits recovery; and (4) better elbow function.

In summary, percutaneous leverage reduction using two k-wires combined with the Métaizeau technique can significantly increase the minimally invasive reduction rate of radial fracture in children, with the advantages of less trauma, fewer complications, and good efficacy, and thus represents a good strategy to treat Judet IV radial neck fractures in these patients.

Acknowledgments

This study was funded by the Science and Technology Plan of the Jiangxi Provincial Health Commission (No. 20151134).

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Ethical Approval

The ethics approval was obtained from the Ethics Committee of Jiangxi Provincial Children's Hospital (June 6, 2019).

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ORCID iD

Xinle Wu https://orcid.org/0000-0002-0533-2499

References

1. Wang J, Chen W, Guo M, et al. Percutaneous reduction and intramedullary fixation technique for displaced pediatric radial neck fractures. *J Pediatr Orthop B* 2013; 22: 127–132.
2. Gutiérrez-de la Iglesia D, Pérez-López LM, Cabrera-González M, et al. Surgical techniques for displaced radial neck fractures: predictive factors of functional results. *J Pediatr Orthop* 2017; 37: 159–165.
3. De Mattos CB, Ramski DE, Kushare IV, et al. Radial neck fractures in children and adolescents: an examination of operative and nonoperative treatment and outcomes. *J Pediatr Orthop* 2016; 36: 6–12.
4. Choi WS, Han KJ, Lee DH, et al. Stepwise percutaneous leverage technique to avoid posterior interosseous nerve injury in pediatric radial neck fracture. *J Orthop Trauma* 2017; 31: e151–e157.
5. Zhang FY, Wang XD, Zhen YF, et al. Treatment of severely displaced radial neck fractures in children with percutaneous K-wire leverage andclosed intramedullary pinning. *Medicine* 2016; 95: e2346.
6. Gagliardi1 Ida C, Mouraria GG, Funayama B, et al. Evaluation of children with radial neck fractures treated with flexible intramedullary nail. *ActaOrtop Bras* 2016; 24: 81–84.
7. Bither N, Gupta P and Jindal N. Pediatric displaced radial neck fractures: retrospective results of a modified Metaizeau technique. *Eur J OrthopSurgTraumatol* 2015; 25: 99–103.

8. Zimmerman RM, Kalish LA, Hresko MT, et al. Surgical management of pediatric radial neck fractures. *J Bone Joint Surg Am* 2013; 95: 1825–1832.
9. Basmajian HG, Choi PD, Huh K, et al. Radial neck fractures in children: experience from two level-1 trauma centers. *J Pediatr Orthop B* 2014; 23: 369–374.
10. Cossio A, Cazzaniga C, Gridavilla G, et al. Paediatric radial neck fractures: one-step percutaneous reduction and fixation. *Injury* 2014; 45: s80–s84.
11. Fowles JV and Kassab MT. Observations concerning radial neckfractures in children. *J PediatrOrthop* 1986; 6: 51–57.
12. Bemstein SM, Mckeever P and Bersteein L. Percutaneous reduction of displaced radial neck fracture in children. *J Pediatr Orthop* 1993; 13: 85–88.
13. Song KS, Kim BS and Lee SW. Percutaneous leverage reduction for severely displaced radial neck fractures in children. *J Pediatr Orthop* 2015; 35: e26–e30.
14. Zwingmann J, Welzel M and Dovi-Akue D. Clinical results after different operative treatment methods of radial head and neck fractures: a systematic review and meta-analysis of clinical outcome. *Injury* 2013; 44: 1540–1550.
15. Tarallo L, Mugnai R, Fiacchi F, et al. Management of displaced radial neck fractures in children: percutaneous pinning vs. elastic stable intramedullary nailing. *J Orthop Traumatol* 2013; 14: 291–297. [Epub ahead of print]
16. Métaizeau JP, Prévot J, and Schmitt M. Reduction and fixation of fractures of the radiousbecentro-medullary pinning. Original technic. *Rev Chir Orthop Reparatrice Appar Mot* 1980; 66: 47–49.
17. Falciglia F, Giordano M, Aulisa AG, et al. Radial neck fractures in children: results when open reduction is indicated. *J Pediatr Orthop* 2014; 34: 756–762.
18. Kaiser M, Eberl R, Castellani C, et al. Judet type-IV radial neck fractures in children: comparison of the outcome of fractures with and without bony contact. *Acta Orthop* 2016; 87: 529–532.