CLINICAL ARTICLE

# Treatment of Delayed Acetabular Fractures by Periacetabular Osteotomy through the Lateral-Rectus Approach

Haibo Xiang, MD[1#], Xiaodong Yang, MM[1,2#], Zhuobin Huang, MM[1], Wenquan Xu, MM[1], Yuhui Chen, MD[1], Tao Li, MM[1], Hai Huang, MD[1], Shicai Fan, MD[1]

[1]*Department of Traumatic Surgery, Center for Orthopaedic Surgery, The Third Affiliated Hospital of Southern Medical University and* [2]*Department of Orthopaedic, Huadu District People's Hospital of Guangzhou, Guangzhou, China*

**Objective:** There has been a controversy in the surgical approach for delayed acetabular fracture. The objective of the present study is to investigate the feasibility, surgical techniques, safety, and efficacy of periacetabular osteotomy using the single lateral-rectus approach (LRA) for the surgical treatment of delayed acetabular fracture.

**Methods:** The retrospective study included 22 patients (16 males and six females, with an average age of 45 years) with delayed acetabular fractures from June 2012 to June 2019. For all cases, periacetabular osteotomy was performed through the single LRA. Fracture classification, mechanism of injury, associated injury, time to surgery, operation time, intraoperative blood loss, and complications were recorded and analyzed. The quality of the reduction was assessed based on Matta radiographic criteria. Potential impact factors affecting the quality of reduction were analyzed. Functional outcome was evaluated at the final follow-up according to a modified Mere D'Aubigne-Postel scoring system for each patient.

**Results:** All patients were followed up for at least 12 months. The duration of surgery was 140 min on average (110–205 min) and the mean intraoperative blood loss was 1250 ml (500–2100 ml). According to Matta radiographic criteria, the accuracy of reduction was "anatomical" in seven patients, "imperfect" in 11 patients, and "poor" in four patients, with an excellent and good rate of 81.8%. The time to surgery in poor reduction group was significantly longer than anatomical or imperfect reduction group ($p < 0.05$). All the acetabular fractures united after 8–12 weeks. The average modified Merle D'Aubigne-Postel score evaluated at the final follow-up was 14.6 (6–18), and the clinical outcomes were rated as excellent in six patients, good in 10 patients, fair in four patients, and poor in two patients, with an excellent and good rate of 72.7%. There were two cases of osteonecrosis of the femoral head (9%). No other complication was found for all cases.

**Conclusion:** The LRA is an effective and minimally invasive approach in the treatment of delayed acetabular fractures excluding posterior wall fracture and posterior dislocation.

**Key words:** acetabular wing-plate; delayed acetabular fracture; lateral-rectus approach; periacetabular osteotomy

**Address for correspondence** Shicai Fan, MD, Department of Traumatic Surgery, Center for Orthopaedic Surgery, The Third Affiliated Hospital of Southern Medical University, Guangzhou 510630, Guangdong Province, China Tel: 020-62784311; Email: 553924952@qq.com

#Haibo Xiang and Xiaodong Yang contributed equally to this work.

**Grant sources**: National Natural Science Foundation of China (82072411). Innovation fund cultivation project of national clinical research certer for orthopaedics sports medicine & rehabilitation (2021-NCRC- CXJJ-PY-06). Clinical Research Startup Program of Southern Medical University by High-level University Construction Funding of Guangdong Provincial Department of Education (LC2016ZD032).

**Disclosure**: The authors declare that they have no conflicts of interest.

Received 18 May 2021; accepted 25 August 2022



**Orthopaedic Surgery** 2022;14:3233–3241 • DOI: 10.1111/os.13509

## Introduction

Surgical treatment of acetabular fracture more than 3 weeks old is challenging for most orthopaedic surgeons. For these cases, traumatic arthritis and femoral head necrosis may occur at a very early stage due to the mismatch of acetabulum and head[1]. The surgical treatment of delayed acetabular fracture seems like a deformity correction rather than a traditional fracture reduction and primary total hip arthroplasty is recommended in some severe cases[2,3]. However, because of the bone malunion, scar formation, and soft tissue contracture, the reduction of delayed acetabular fracture is difficult, and the anatomical landmarks cannot usually be distinguished during operation[4,5]. Therefore, an appropriated surgical approach is one of the keys to cope with delayed acetabular fracture. However, the surgical approach for delayed acetabular fracture is still controversial.

Currently, there are anterior, posterior, extended, or combined surgical approaches. The ilioinguinal approach is primarily used for fractures of the anterior column, anterior wall of the acetabulum, and upper posterior column[6]. With this approach, however, the complex anatomy, high complication rate, and steep learning curve are inhibiting disadvantages[7]. The Stoppa approach has good exposure of the quadrilateral plate, although it is difficult to manage a fracture involving the iliac wing. The Kocher–Langenbeck approach remains the standard approach to the dorsal aspect of the acetabulum, but it is associated with a high incidence of complications, particularly heterotopic ossification[6]. Furthermore, the anterior ilioinguinal approach combined with the posterior Kocher–Langenbeck approach is widely used due to good exposure. However, there are obvious disadvantages, including longer surgery duration, severe surgical trauma, increased intraoperative blood loss, and a higher rate of surgical complications[8–10].

Recently, the lateral-rectus approach (LRA) has been widely used in acetabular fractures. This novel intra-pelvic approach has good exposure of anterior column, medial aspect of the posterior column, quadrilateral plate, wing of the ilium, and sacroiliac joint[11–13]. This allows for removal of the fractured callus, release of contracted tissue, and osteotomy under direct vision. Ipsilateral enterostomy is contraindicated for the LRA, while the incision of exploratory laparotomy has no effect on LRA. Options to use this approach have been seen in the anterior column with or without posterior hemi-transverse, both column, T-shaped, transverse, or anterior wall fractures[14]. With this in mind, we hope that this approach can be favorable for periacetabular osteotomy and make operations less invasive in the treatment of delayed acetabular fracture.

In the present study, we identified patients with delayed acetabular fracture who underwent periacetabular osteotomy through the single LRA. The aims of this study were to (i) analyze the safety and efficacy of the periacetabular osteotomy through the single LRA; (ii) investigate the surgical techniques of the periacetabular osteotomy through the single LRA; (iii) identify the potential impact factors affecting the quality of reduction of delayed fractures.

## Materials and Methods

This work was approved by our local institutional ethics committee (201803004). Informed consent was obtained from all included participants.

### *Inclusion and Exclusion Criteria*

Inclusion criteria included (i) patients with delayed acetabular fracture (>21 days) and without involving the posterior wall fracture or posterior dislocation; (ii) patients suffering from hip pain and limited mobility; (iii) patients with displacement of fracture (>5 mm); and (iv) use of a single LRA to perform periacetabular osteotomy, reduction, and fixation.

Exclusion criteria included (i) patients with chondral lesions of the femoral head or acetabulum; (ii) incomplete follow-up data (<1 year); (iii) patients with severe systemic diseases, unstable vital signs, and inability to tolerate anesthesia or surgery.

### *Preoperative Treatment*

After admission, routine preoperative examinations were performed for all patients. Patients who had undergone cystostomy, enterostomy, or who had medical diseases were treated systemically by relevant departments. In order to prevent the deep vein thrombosis, Rivaroxaban (10 mg, qd) was given to all patients and the vascular ultrasound of lower extremity was performed 1 day before the surgery. A broad-spectrum antibiotic prophylaxis was administered intravenously 30 min before surgery.

All patients were examined with a standard pelvic x-ray (anteroposterior and Judet positions of the pelvis) and CT scan (Siemens, Germany). The original CT data in Dicom format were imported into Mimics software (Materialize, Belgium) for 3D reconstruction. The 3D printing technology (Stratasys Dimension 1200es, USA) was used to print a 1:1 ratio simulated pelvic model (Figure 1), which facilitated understanding of the displacement direction, growth of the callus, and malunion pattern so that a treatment plan could be formulated. Based on such models, simulated osteotomy, reduction, and fixation were carried out *in vitro*. In addition, the location, direction, and length of the screws were also determined. Finally, a pre-shaped reconstruction plate (Shandong Weigao Orthopedic Device, China) or acetabular wing-plate (Double Medical Technology Inc., China) was sterilized for intraoperative use.

### *Surgical Procedure*

#### Anesthesia and Position

After tracheal intubation and general anesthesia, patients were positioned supine on a radiolucent operating table with the ipsilateral extremity draped freely.

#### Approach and Exposure

The incision of the LRA started cranially at the junction of the lateral and middle thirds of the line connecting the umbilicus with the anterior superior iliac spine and ended at

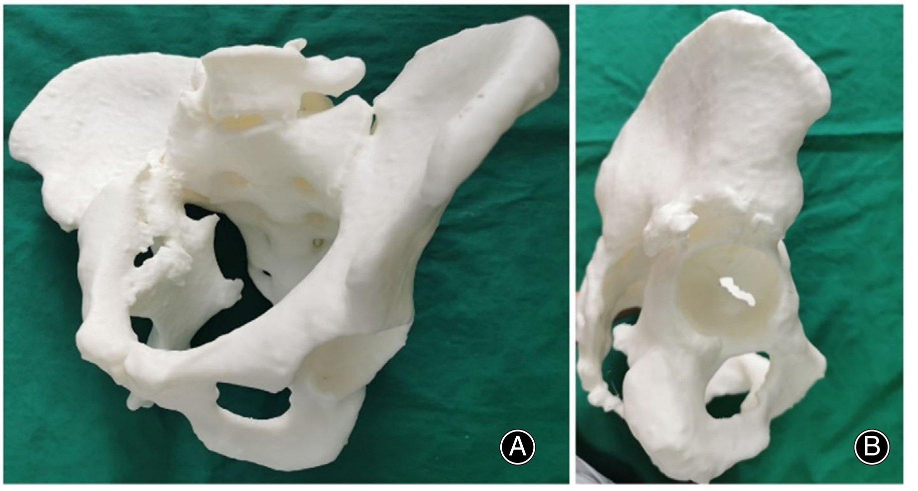


**Fig. 1** The detail of the fracture is shown in the 1:1 simulated 3D pelvic model. (A) Medial view. (B) Lateral view.

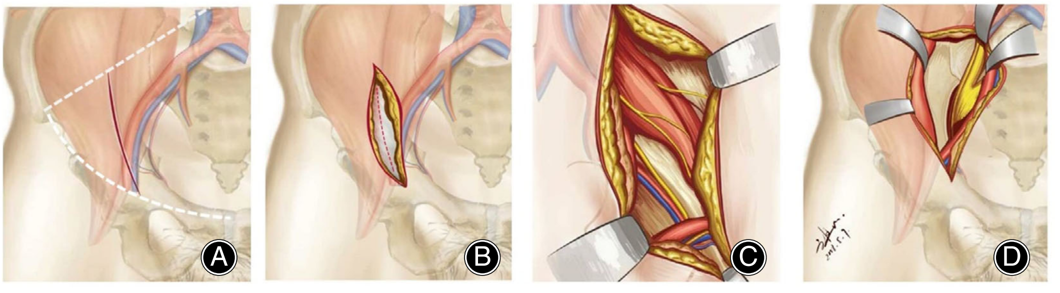


**Fig. 2** Schematic diagrams of the lateral-rectus approach (LRA). (A) The incision of the LRA started cranially at the junction of the lateral and middle thirds of the line connecting the umbilicus with the anterior superior iliac spine and ended at the midpoint of the inguinal ligament. (B) Full thickness incision of the abdominal muscle and subperiosteal dissection to expose the fracture surface. (C) The medial window of the LRA. (D) The middle window of the LRA.

the midpoint of the inguinal ligament as described previously[13] (Figure 2). Extraperitoneal space was exposed by dissection of the subcutaneous fatty tissue and incision of the obliquus externus abdominis, obliquus internus abdominis, transverse abdominis, and transversalis fascia. Special attention was given to identify the iliopsoas muscle, the external iliac vascular bundle, the vas deferens in males or the round ligament in females, and the peritoneum. Next, three windows of the LRA were developed[13]. In the medial window, the anterior column, anterior wall, obturator foramen, quadrilateral plate, and pubic tubercle were exposed clearly. The greater sciatic notch, internal aspect of posterior column, quadrilateral plate, and iliac fossa were exposed through the middle window. The lateral window exposed the iliac wing where the high anterior column fracture was seen or if osteotomy was required.

*Osteotomy Procedure*

For fractures between 21 days and 12 weeks, most fractures of the acetabular rim had cartilaginous healing. Therefore, the callus was removed after identifying the primary fracture line. Most of the pubic ramus and iliac wing fractures achieved osseous healing, which could be cut off directly and then the fragment surfaces were debrided of scar tissue and callus. For fractures longer than 12 weeks, there was healing with malunion. Osteotomy was usually performed based on the preoperative plan. Specifically, multiple Kirschner wires were inserted into the osteotomy site in a direction from front to back (Figure 3). The osteotomy was performed along the Kirschner wires under fluoroscopic guidance. The osteotomy plane was determined based on the displacement and malunion pattern (Figure 4). The soft tissue around the osteotomy site was completely released and the sacrospinous ligament was cut off if necessary (Figure 5). For some complex cases, it was necessary to open the acetabular roof whereafter an osteotomy along the primary fracture line was performed. If the fracture could not be reduced after the osteotomy, a wedge osteotomy was required for the excess bone.

*Reduction and Fixation*

The Trochanteric Schanz screw or ipsilateral lower extremity provided with axial traction during the reduction maneuvers.

Combined with the Schanz screw in the anterior superior iliac spine, reduction was obtained by the means of rotation or lifting. The fracture was temporarily stabilized by multiple Kirschner wires. C-arm fluoroscopy (Siemens) was used to evaluate reduction prior to completion of the osteosynthesis. Either pre-contoured reconstruction plate or acetabular wing-plate was used for fracture fixation (Figure 6). Finally, the bones following osteotomy were replanted into the osteotomy site or bone defect.

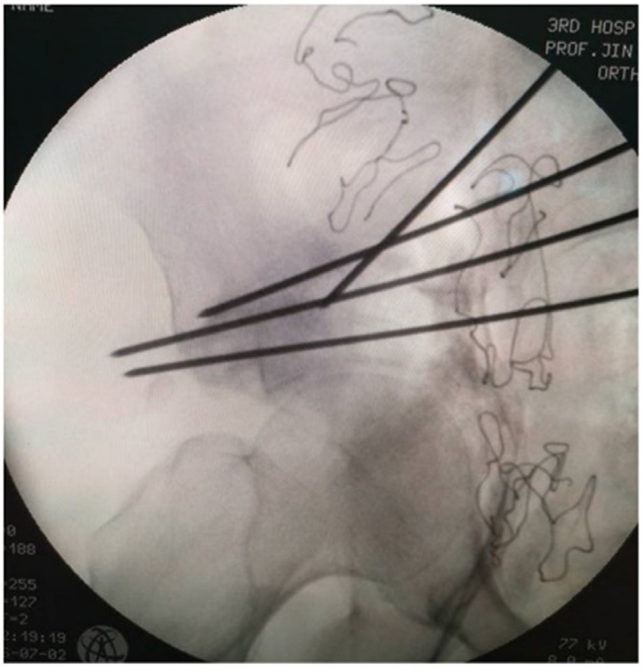


**Fig. 3** Multiple Kirschner wires were inserted into the osteotomy site from front to back.

### *Postoperative Management*

Intravenous prophylactic antibiotics were administered for 24 h postoperatively. As prophylaxis against venous thromboembolism, low-molecular-weight heparin was provided daily for at least 2 weeks. Drainage was removed when the fluid was less than 50 ml/day or within 48 h. Active and passive exercises started gradually for all patients on the first day after operation. Patients were permitted toe-touch weight-bearing for the first 3 months while full weight-bearing depended on the patient's general condition and fracture healing state.

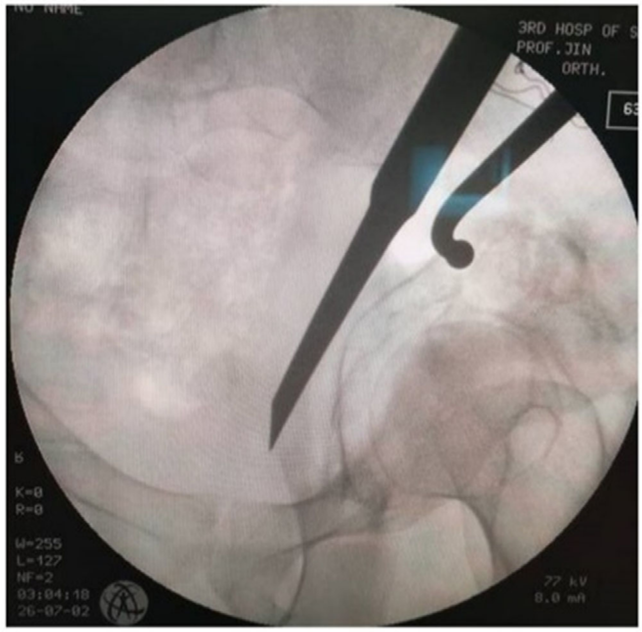


**Fig. 5** The sacrospinous ligament was cut off with the osteotome.

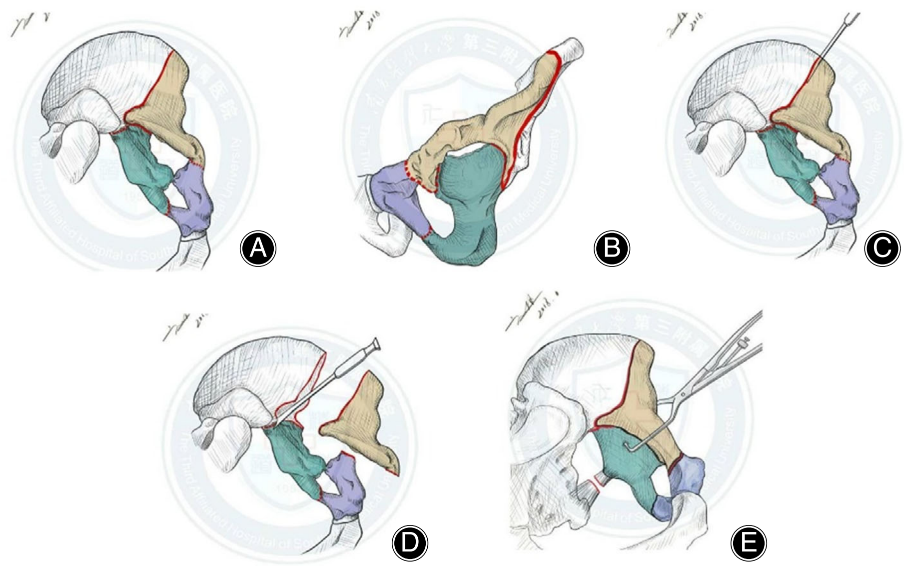


**Fig. 4** Scheme diagrams of preoperative osteotomy plaining. (A, B) The osteotomy plane was determined according to deformity pattern. (C) The anterior column was removed. (D) After the osteotomy, the fracture gap was debrided. (E) A reduction clamp was used to reduce the fracture.

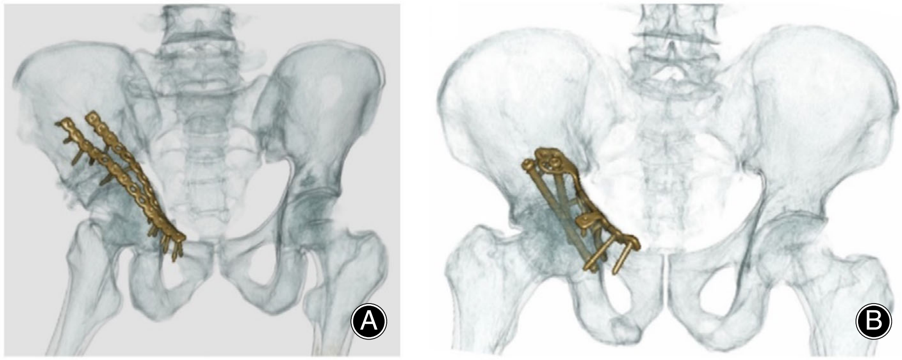


**Fig. 6** The fracture was fixed with multiple reconstruction plates (A) or acetabular wing-plate (B).

### Radiographic Evaluation and Follow-Up

Anterior posterior (AP), Judet oblique view X-rays, and CT scans with 3D reconstruction were performed 72 h after surgery to evaluate the quality of reduction and position of implant. All patients received routine postoperative follow up at 1, 2, 3, 6, 12 months and yearly thereafter.

### Outcome Measures

Patient demographics and characteristics, including gender, age, mechanism of injury, fracture classification, combined injury, and time to surgery were recorded and analyzed. All surgical data, including blood loss, duration of surgery, and intraoperative complications, were recorded. Fracture healing, clinical function, and postoperative complications were recorded during the follow-up period.

#### *Matta Grading Score*

Postoperative fracture reduction quality of the acetabulum was evaluated according to Matta's scoring system[9]. It was evaluated by measuring the postoperative residual displacement using AP and Judet oblique view X-rays. Displacement of 1 mm or less was defined as anatomic reduction; displacement between 2 and 3 mm was defined as imperfect reduction and displacement of more than 3 mm was considered poor reduction. Furthermore, Matta's research also suggested that a displacement of less than 3 mm had an excellent or good clinical result[9]. Therefore, in the present study, all patients were divided into two groups according to the quality of the reduction: anatomical or imperfect reduction group and poor reduction group. All potential impact factors affecting the quality of reduction were further analyzed.

**TABLE 1 Patient demographic data**

| Variable | Value | Percent |
|---|---|---|
| Gender | | |
| Male | 16 | 72.7 |
| Female | 6 | 27.3 |
| Mean age (years) | 45 (22–61) | |
| Mechanism of injury | | |
| Motor vehicle accident | 9 | 40.9 |
| Fall from height | 12 | 54.5 |
| Heavy object injury | 1 | 4.6 |
| Fracture classification | | |
| Both column | 16 | 72.7 |
| Anterior column with posterior hemitransverse | 4 | 18.2 |
| T-type | 2 | 9.1 |
| Combined injury | | |
| Enterostomy | 5 | 22.7 |
| Pelvic fracture | 6 | 27.3 |
| Multiple fracture of limbs | 7 | 31.8 |
| Time to surgery (days) | | |
| 21–120 | 17 | |
| >120 | 5 | |

#### *Modified Merle D'Aubigné Score*

A modified Merle D'Aubigné score was used to evaluate the progress in hip function after acetabular fracture surgery[9,15]. This system consists of three parts, including pain, walking, and range of activity. Each of the three items had a total score of 6 points. The finally total score was the sum of three items, with the functional outcome rated as excellent (18 points), good (15–17 points), fair (14 or 13 points), and poor (<13 points).

### Statistical Analysis

Statistical analysis of the data was performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). All measurement data were described by mean, standard deviation, or percentage. Two independent sample *t*-tests were used for count data. The Fisher exact test was used for comparison of categorical data. The level of significance was set at $p < 0.05$.

## Results

### Demographics and Characteristics

Twenty-five patients diagnosed with delayed acetabular fractures between June 2012 and June 2019 were screened for eligibility according to our inclusion and exclusion criteria. Three patients were excluded due to the loss to follow-up. A total of 22 patients who had undergone periacetabular osteotomy through the LRA were included in this study. Sixteen patients were male and six were female. Their mean age was 45 years old (range 22–61). The cause of injury was a traffic accident in nine cases, a fall in 12 cases, and a heavy object injury in one case. As for the combined injuries, there were five cases of enterostomy, six pelvic fractures, and seven multiple limb fractures. The time from injury to operation was 3 to 12 weeks ($n = 15$), 3 to 6 months ($n = 5$), 9 months ($n = 1$), and 3 years ($n = 1$), respectively. There were 16 patients with both column fractures, two with T-type fractures, and four anterior columns with posterior hemitransverse fractures as defined by Judet–Letournel classification system[16]. A summary of the general demographics and characteristics of patients was shown in Table 1.

### General Surgical Outcomes

The duration of surgery was 140 min on average (range 110–205 min) and the mean intraoperative blood loss was 1250 ml (range, 500–2100 ml). For fixation, multiple reconstruction plates were used in nine cases while 13 cases were fixed with an acetabular wing-plate. A summary of the general surgical outcomes is shown in Table 1.

### Matta Grading Score

All fractures and osteotomy sites exhibited radiological evidence of fracture union with a healing time of 8 to 12 weeks. According to Matta's scoring system, the accuracy of reduction was "anatomical" in seven patients, "imperfect" in 11 patients, and "poor" in four patients, with an excellent and good rate of 81.8%. Among the 16 both-column fractures, 13 cases had secondary congruence with anatomic reduction in four cases and satisfactory in nine cases. The difference of delay to surgery (≥120 day) in the two groups was statistically significant ($p = 0.024$). No other potential factors affecting fracture reduction were identified (Table 2).

### Modified Merle D'Aubigné Score

The average modified Merle d'Aubigne–Postel score evaluated at the final follow-up was 14.6 (range, 6–18). The functional outcome was rated as excellent in six patients, good in 10 patients, fair in four patients, and poor in two patients, with an overall excellent and good rate of 72.7% (Table 3).

### Complications

All patients had a 12-month follow-up (range, 12–36 months). All incisions healed in one stage without infection. There was no implant loss, breakage, neurovascular bundle damage, or deep vein thrombosis reported during the follow-up. Osteonecrosis of the femoral head was found in two cases (9%) of which one patient was converted to a total hip replacement 17 months after surgery. The other patient reported only mild pain with no trouble in conducting daily activities during the 3-year follow-up period (Table 3).

Typical cases are shown in Figures 7 and 8.

**TABLE 3 Postoperative outcome and complications**

| Postoperative data | Value | Percent |
|---|---|---|
| Mean surgery duration (min) | 140 (110–205) | |
| Mean blood loss (ml) | 1250 (500–2100) | |
| Reduction quality (Matta) | | |
| Anatomical (<1 mm) | 7 | 31.8 |
| Imperfect (1–3 mm) | 11 | 50 |
| Poor (>3 mm) | 4 | 18.2 |
| Merle D'Aubigne–Postel score | | |
| Excellent (18) | 6 | 27.3 |
| Good (15–17) | 10 | 45.4 |
| Fair (13–15) | 4 | 18.2 |
| Poor (<13) | 2 | 9.1 |
| Complications | | |
| Femoral head necrosis | 2 | 9.1 |

**TABLE 2 The potential impact factors affecting the quality of reduction in anatomical or imperfect reduction group and poor reduction group**

| | Anatomical or imperfect reduction group ($n = 18$) | Poor reduction group ($n = 4$) | $p$ value |
|---|---|---|---|
| Age | 46.94 ± 13.18 | 37.75 ± 13.4 | 0.485 ($t = 0.711$) |
| Gender | | | 0.708 |
| Male | 13 | 3 | |
| Female | 5 | 1 | |
| Fracture classification | | | |
| Both column fractures | 13 | 3 | 0.708 |
| T-type fracture | 2 | 0 | 0.622 |
| Anterior column with posterior hemitransverse | 3 | 1 | 0.582 |
| Time to surgery (days) | | | 0.024 |
| 21–120 | 16 | 1 | |
| ≥120 | 2 | 3 | |
| Multiple limb fracture | | | 0.622 |
| Yes | 6 | 1 | |
| No | 12 | 3 | |
| Pelvic fracture | | | 0.292 |
| Yes | 4 | 2 | |
| No | 14 | 2 | |
| Combined with the other organ trauma | | | 0.632 |
| Yes | 10 | 2 | |
| No | 8 | 2 | |

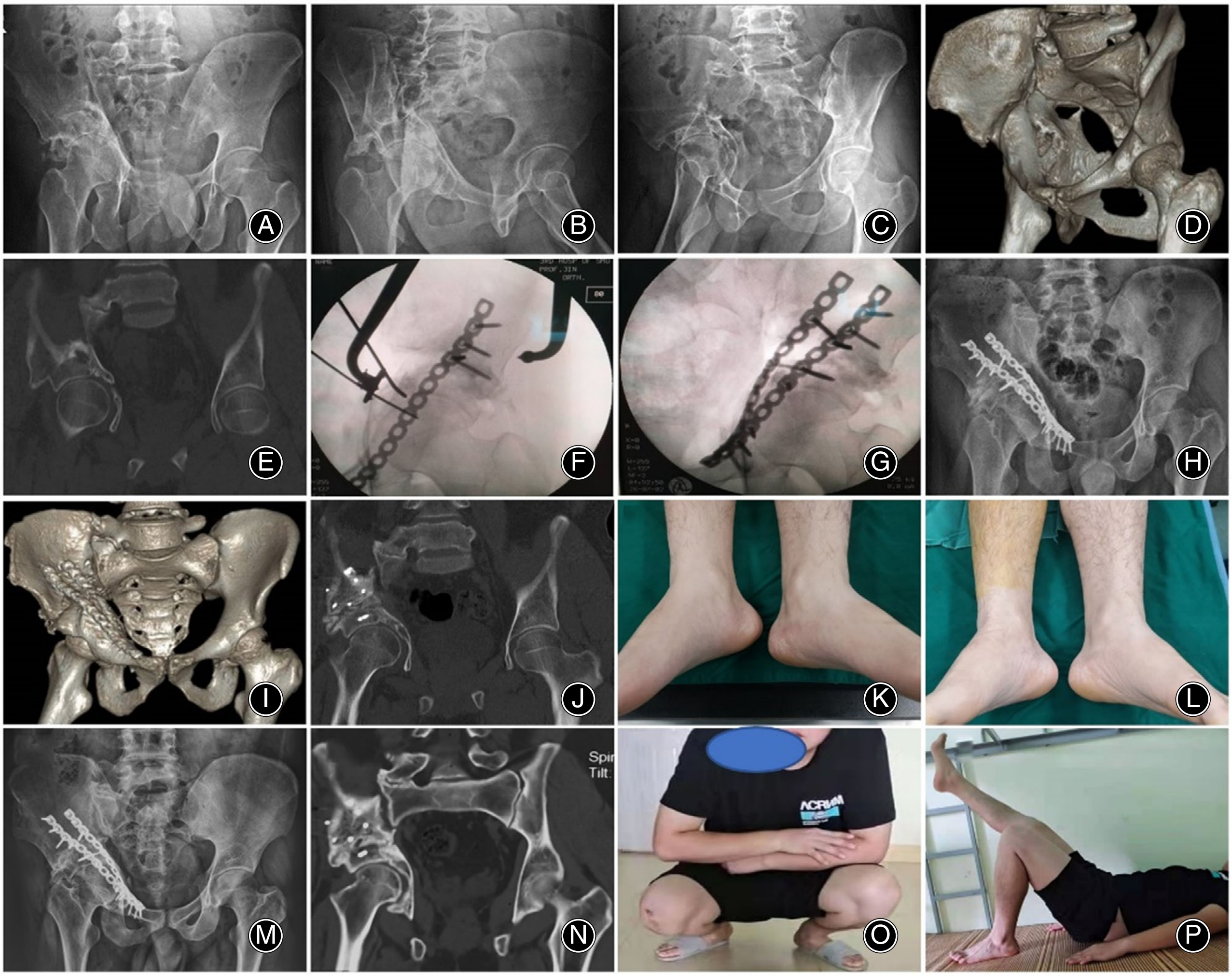


**Fig. 7** A delayed fracture of both columns (male, 20 years old) treated by periacetabular osteotomy through the lateral-rectus approach (LRA) 14 months after the traffic injury. Preoperative anteroposterior radiograph (A), obturator radiograph (B), iliac oblique radiograph (C), three-dimensional (3D) CT reconstruction (D), and CT corona scan (E) showing the malunion. Intraoperative reduction with a clamp (F) and placement of a reconstruction plate (G). Postoperative anteroposterior radiograph (H), CT 3D reconstruction (I), and CT corona scan (J) showing the good quality of the reduction. The inequality of lower extremities (K) achieved significant correction (L). X-ray (M), CT examination (N) and functional performance (O, P) 1.5 years after surgery.

## Discussion

In the current study, our results suggested that the LRA is an effective and minimally invasive procedure for delayed acetabular fractures without involving the posterior wall fracture or dislocation. The main advantage of the LRA is that it can provides good exposure of the ipsilateral hemipelvis ring, thereby shortening operative time, reducing intraoperative blood loss, and minimizing complications.

### *Lateral-Rectus Approach Makes Operations Less Invasive*

In the present study, all of the 22 cases were exposed and osteotomized through a single LRA. The mean duration of surgery was 140 min. This is significantly shorter than previous reports. Johnson *et al.*[17] reported a series of 188 delayed acetabular fractures with a mean operative time of 240 min. Zhu *et al.*[4] reported a mean operative time of 195 min in treating delayed acetabular fractures. Another study with combined approaches reported a mean surgery time of 275 min[5]. One possible reason for less operative time in our study is that conducting an osteotomy and releasing soft tissue in a supine position is relatively safer. Additionally, all of the procedures were conducted under direct vision, which facilitated better management of hemorrhage during the operation. An intraoperative blood loss of 1250 ml in the present study is similar to a recently published study using a three-dimensional (3D) skeleton-arterial model for preoperative planning[18]. However, Johnson *et al.*[17]

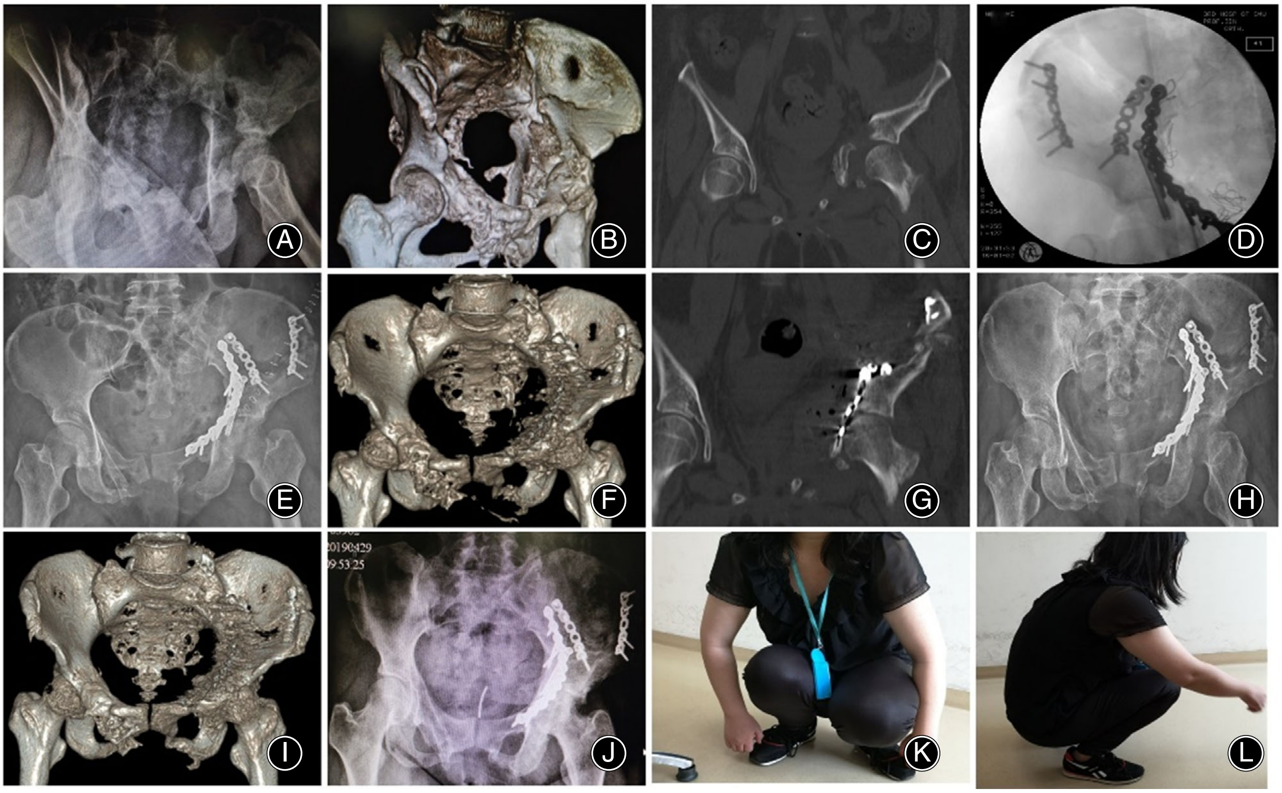

**Fig. 8** A delayed fracture of both columns (female, 32 years old) treated by periacetabular osteotomy through the lateral-rectus approach (LRA) 3 months after the traffic injury. (A) Preoperative iliac oblique radiograph. (B) Preoperative three-dimensional (3D) CT reconstruction. (C) Preoperative CT corona scan. (D) Anterior–posterior fluoroscopy of the pelvis after the fixation. (E) Postoperative pelvic anteroposterior image. (F) Postoperative CT 3D reconstruction. (G) Postoperative CT corona scan. (H) Pelvic X-ray 3 months after surgery. (I) CT 3D reconstruction 3 months after surgery. (J) Pelvic X-ray 1.5 years after surgery. (K, L) Hip function evaluated 1.5 years after surgery.

and Gao *et al.*[5] reported an average intra-operative blood loss of 1600 and 2160 ml, respectively. In the study of Laird and Keating[10], the rate of traumatic arthritis was reported to be 14%.

### *Lateral-Rectus Approach Reduces Postoperative Complications*

In the current study, there were two cases (9%) that developed into osteonecrosis of the femoral head with no heterotopic ossification nor neurovascular complications observed. A longer follow-up study is needed to confirm these results. Additionally, the satisfaction rate of radiological results was 81.8% in our study, which was higher than 67% reported by Johnson *et al.*[17], 70% reported by Zhu *et al.*[4], and 73.8% reported by Gao *et al.*[5]. In this case, it was more convenient to remove callus, release soft tissue, and perform the osteotomy under direct vision through the LRA.

### *Factors Affecting Quality of Reduction*

The factors affecting quality of reduction were also analyzed in the present study. A statistically significant difference was presented in the time to surgery of two groups among all potential impact factors. One possible reason was that with a prolonged time to surgery, the formation of extensive callus and malunion led to a reduced success rate of reduction.

### *Treatment Methods for Delayed Acetabular Fracture*

In addition to the controversy over the surgical approach, there is also no consensus on treatment methods for delayed acetabular fractures. The debate is whether the primary arthroplasty or acetabular reconstruction would make more sense for severely displaced delayed acetabular fractures with the articular cartilage intact[4]. In the present study, we performed one-stage acetabular reconstruction in all patients. Our study demonstrated that ORIF was a good choice for delayed acetabular fractures, especially for young patients, and even if ORIF failed, restoration of the columns was beneficial to the subsequent total hip arthroplasty. This is consistent with previous reports[19–21].

### *Surgical Techniques for Reduction and Fixation*

For acetabular reconstruction, there are several reduction and fixation techniques based on our experience. First, traction of the lower limb or trochanteric Schanz screw will be helpful for correcting the residual vertical displacement. Second, the rotation of the iliac wing along with the anterior column can be corrected using a Schanz screw in the iliac wing. Additionally, using a lag screw with a short plate or anterior–posterior column lag screws may be a useful for separation displacement. Finally, stable fixation can be obtained with multiple pre-contoured reconstruction plates or acetabular wing-plates. It is worth noting that preoperative planning for delayed acetabular fracture is indispensable. Three-dimensional (3D) printing of pelvic model was a good tool for preoperative planning and rehearsal. The position, direction, and angle of osteotomy could be determined by preoperative rehearsal. Further, shaping the reconstruction plate on the 3D pelvic model improved the anatomic reduction rate, shortened the operation time, and reduced the complications.

### *Limitations*

There are several limitations in the present study, including its retrospective nature, relatively short follow-up time, and limited number of patients. However, despite the above shortcomings, the results presented here suggest a feasible and safe way to manage delayed acetabular fractures through the LRA method.

### *Conclusion*

The LRA, with a clear exposure of the ipsilateral pelvis in an intrapelvic visualization, facilitates periacetabular osteotomy and reduction. Stable fixation can be obtained with multiple reconstruction plates or acetabular wing-plates. Therefore, periacetabular osteotomy through the LRA method is an effective and minimally invasive treatment for delayed acetabular fractures without involving the posterior wall fracture or dislocation.

## Author Contributions

Haibo Xiang and Xiaodong Yang contributed to performing the retrospective study. Zhuobin Huang and Wenquan Xu performed the data analyses. Yuhui Chen and Tao Li wrote the manuscript. Hai Huang provided constructive discussions on the study design. Shicai Fan performed the surgery and provided financial support.

### *Data Availability Statement*

The data used to support the findings of this study are included within the article.

## Ethics Statement

All the procedures were approved by the Ethics Inspection Committee of The Third Affiliated Hospital of Southern Medical University (201803004). All patients signed a General Consent of the Ethical Committee of Third Affiliated Hospital of Southern Medical University for using and publishing their data for scientific use.

## References

**1.** Vallier HA, Cureton BA, Patterson BM. Factors affecting revenue from the management of pelvis and acetabulum fractures. J Orthop Trauma. 2013;27:267–74.
**2.** Tornetta PR. Displaced acetabular fractures: indications for operative and nonoperative management. J Am Acad Orthop Surg. 2001;9:18–28.
**3.** Tannast M, Najibi S, Matta JM. Two to twenty-year survivorship of the hip in 810 patients with operatively treated acetabular fractures. J Bone Joint Surg Am. 2012;94:1559–67.
**4.** Zhu SW, Sun X, Yang MH, Li YN, Zhao CP, Wu HH, et al. Long-term outcome of operative management of delayed acetabular fractures. Chin Med J. 2013; 126:14.
**5.** Gao YS, Zhou ZB, Tang MJ, Yu XW, Chen S, Zhang CQ, et al. Late surgery for acetabular fractures in a Chinese level I trauma centre: surgical experience and outcomes. Int Orthop. 2015;39:1865–71.
**6.** Cutrera NJ, Pinkas D, Toro JB. Surgical approaches to the acetabulum and modifications in technique. J Am Acad Orthop Surg. 2015;23:592–603.
**7.** Pohlemann T, Herath SC, Braun BJ, Rollmann MF, Histing T, Pizanis A. Anterior approaches to the acetabulum: which one to choose? Efort Open Rev. 2020;5:707–12.
**8.** Archdeacon MT. Comparison of the ilioinguinal approach and the anterior intrapelvic approaches for open reduction and internal fixation of the acetabulum. J Orthop Trauma. 2015;29:S6–9.
**9.** Matta JM. Fractures of the acetabulum: accuracy of reduction and clinical results in patients managed operatively within three weeks after the injury. J Bone Joint Surg Am. 1996;78:1632–45.
**10.** Laird A, Keating JF. Acetabular fractures: a 16-year prospective epidemiological study. J Bone Joint Surg Br. 2005;87:969–73.
**11.** Zhang X, Yang XD, Xia G, Li T, Wang H, Xiaong R, et al. Surgical treatment of complex acetabular fractures through the lateral-rectus approach with the pelvic reconstructive plate and antegrade posterior-column lag screw. J Trauma Surg. 2015;2:123–6.
**12.** Chen J, Liu H, Wang C, Lin X, Gu C, Fan S. Internal fixation of acetabular fractures in an older population using the lateral-rectus approach: short-term outcomes of a retrospective study. J Orthop Surg Res. 2019;14:4–8.
**13.** Wang C, Liu H, Lin X, Chen J, Li T, Mai Q, et al. A single lateral rectus abdominis approach for the surgical treatment of complicated acetabular fractures: a clinical evaluation study of 59 patients. Med Sci Monit. 2018;24:7285–94.
**14.** Wenzel L, von Ruden C, Thannheimer A, Becker A, Brand A, Augat P, et al. The Pararectus approach in acetabular surgery: radiological and clinical outcome. J Orthop Trauma. 2020;34:82–8.
**15.** D'Aubigne RM, Postel M. The classic: functional results of hip arthroplasty with acrylic prosthesis. Clin Orthop Relat Res. 1954;467:7–27.
**16.** Judet R, Judet J, Letournel E. Fractures of the acetabulum: classification and surgical approaches for open reduction. Preliminary report. J Bone Joint Surg Am. 1964;46:1615–46.
**17.** Johnson EE, Matta JM, Mast JW, Letournel E. Delayed reconstruction of acetabular fractures 21–120 days following injury. Clin Orthop Relat R. 1994; 305:20.
**18.** Zhou X, Zhang Q, Song W, Zhou D, He Y. Clinical significance of three-dimensional skeleton-arterial model in the management of delayed reconstruction of acetabular fractures. BMC Surg. 2018;18:30.
**19.** Madhu R, Kotnis R, Al-Mousawi A, Barlow N, Deo S, Worlock P, et al. Outcome of surgery for reconstruction of fractures of the acetabulum. The time dependent effect of delay. J Bone Joint Surg Br. 2006;88:1197–203.
**20.** Zhang L, Zhou Y, Li Y, Xu H, Guo X, Zhou Y. Total hip arthroplasty for failed treatment of acetabular fractures: a 5-year follow-up study. J Arthroplasty. 2011; 26:1189–93.
**21.** Gavaskar AS, Gopalan H, Karthik B, Srinivasan P, Tummala NC. Delayed Total hip arthroplasty for failed acetabular fractures: the influence of initial fracture management on outcome after arthroplasty. J Arthroplasty. 2017;32:872–6.