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# A Single Lateral Rectus Abdominis Approach for the Surgical Treatment of Complicated Acetabular Fractures: A Clinical Evaluation Study of 59 Patients

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**Background:** This study aimed to evaluate outcome following a single lateral rectus abdominis surgical approach for complicated acetabular fractures, involving anterior and posterior columns.

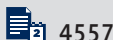
**Material/Methods:** From January 2012 to March 2016, 59 patients, including 36 anterior column hemitransverse fractures, 18 two-column fractures, and five T-type complicated acetabular fractures, were treated with a single lateral rectus abdominis approach and fixed by plates and cannulated lag screws. Anterior column fractures were fixed with 3.5 mm reconstruction plates; posterior column fractures were fixed with 6.5 mm cannulated lag screws. The quality of surgical reduction (using the Matta criteria), functional outcome (using the modified Merle d'Aubigné and Postel scoring system), and postoperative complications were assessed with 24-month follow-up.

**Results:** Fifty-nine patients (mean age, 45 years; range, 18–64 years) including 39 men and 20 women underwent surgery. Mean intraoperative blood loss was 514.6 ml (range, 150–830 ml) and mean operating time was 86.3 min (range, 42–145 min). Anatomical reduction was good in 40 cases (67.8%), fair in 15 cases (25.4%), and poor in four cases (6.8%). The modified Merle d'Aubigné score was excellent in 39 cases (66.1%), good in 14 cases (23.7%), fair in five cases (8.5%), and poor in one case (1.7%). At follow-up, there were five cases of peritoneal damage, eight cases of obturator nerve dysfunction, and four cases of postoperative traumatic arthritis.

**Conclusions:** The single lateral rectus abdominis surgical approach for the treatment of complicated acetabular fractures was minimally invasive with good anatomical exposure and good outcomes.

**MeSH Keywords:** **Fractures, Bone • Hip Fractures • Postoperative Complications • Treatment Outcome**

**Full-text PDF:** <https://www.medscimonit.com/abstract/index/idArt/911009>



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## Background

Surgical correction of complicated acetabular fracture is one of the most challenging procedures performed by orthopedic surgeons. Clinical outcomes of acetabular fractures are variable and are associated with the severity of the initial injury, iatrogenic injury, the quality of the surgical reduction, and available postoperative functional rehabilitation [1–3]. The anatomy of the acetabulum is complex and surrounded by many delicate and important neurovascular structures, making it particularly difficult for surgeons to perform reduction and fixation of acetabular fractures. Also, traditional surgical techniques for acetabular fractures are complex and may be associated with an increased risk for iatrogenic injuries and complications. As a consequence, clinical outcomes of surgical treatment for acetabular fractures are currently relatively unsatisfactory [2,4].

Complicated acetabular fractures always involve both the anterior and posterior acetabular columns. For this reason, some authors have suggested using a simultaneous ilio-inguinal and Kocher-Langenbeck approach to treat these complicated acetabular fractures [5,6]. Although combined approaches have some advantages, they necessitate a longer operating time, resulting in increased blood loss and a higher rate of surgical complications [7–10]. Therefore, there is a current consensus that a single surgical approach might be a better choice for treating complicated acetabular fractures [11,12]. Conventional surgical procedures for treating complicated acetabular fractures involving both anterior and posterior columns include the ilio-inguinal approach and the modified Stoppa approach. The ilio-inguinal approach is not able to provide direct visualization of the quadrilateral plate, and it also requires increased time for the isolation of neurovascular structures, which often leads to unsatisfactory reduction and a higher rate of iatrogenic injury. The modified Stoppa approach can expose the quadrilateral plate for direct visualization but requires an additional incision for reduction and fixation of the iliac fossa fractures and high anterior column fractures.

To overcome the limitations of these conventional approaches, we designed a novel single lateral rectus abdominis surgical approach capable of exposing a large part of the ipsilateral hemipelvis. This aim of this study was to assess the efficacy and safety of the single lateral rectus abdominis open reduction and internal fixation approach for the surgical treatment of complicated acetabular fractures, to identify relevant clinical outcomes, establish rates of postoperative complications and identify advantages of this surgical approach.

## Material and Methods

### Patients included in the study

This study was approved by the Local Ethics Committee of our institution. All procedures involving human participants were in accordance with the ethical standards of the Local Institutional and National Research Committee and with the 1964 Helsinki Declaration and its later amendments. Informed consent was obtained from all participants included in the study.

Between January 2012 and March 2016, 622 patients with pelvic and acetabular fractures were treated surgically in our trauma center by open reduction and internal fixation (ORIF). There were 59 patients with complicated acetabular fractures selected from this cohort for inclusion in the study, who fulfilled the following inclusion criteria: an acute acetabular fracture within the previous 21 days; complicated acetabular fractures involving both the upper and lower columns; a minimum of a 24-month follow-up period. Exclusion criteria included: patients age <18 years or >65 years of age at the time of the injury; patients with associated posterior wall fractures or femoral head fractures; patients with bilateral acetabular fractures, pre-existing ipsilateral hip disease, or with fracture-related nerve damage.

### Imaging studies and classification of acetabular fractures

Before surgery, radiographic examinations including anterior-posterior (AP) and Judet oblique view X-ray projections of acetabular fractures, and computed tomography (CT) with three-dimensional (3D) reconstructions were obtained.

Based on the Judet–Letournel system of classification of fractures, of the 59 cases included in this study, 36 cases were of anterior column with posterior hemitransverse fractures (61.0%), 18 fractures were of both-columns (30.5%), and five were T-type fractures (8.5%). Thirty-two cases presented with associated ipsilateral pelvic ring fractures. Nineteen patients had associated extremity fractures requiring surgical intervention, including 12 ipsilateral lower extremity fractures, six bilateral lower extremity fractures, and one ipsilateral upper and lower extremity fracture. Multiple injuries were found in 33 patients, and seven patients suffered multiple life-threatening injuries. These data, as well as mechanisms of injury and the time between acetabular fracture and surgery, are shown Table 1.

### Surgical technique: Patient preparation for single lateral rectus abdominis approach

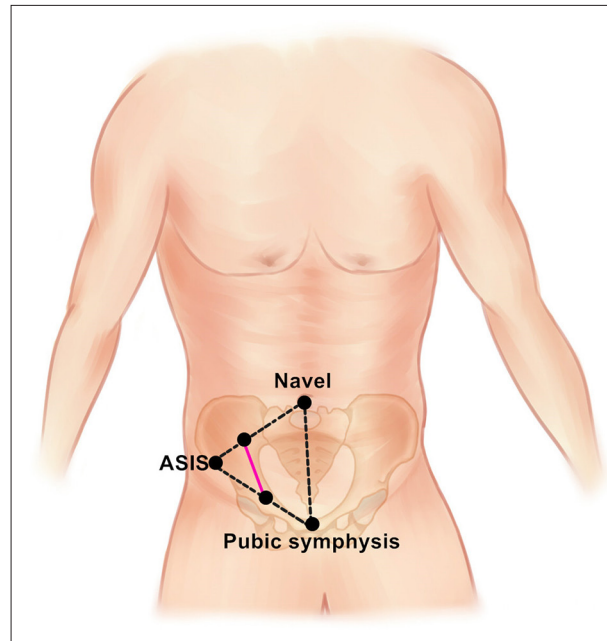
Fifty-nine patients with acetabular fractures were treated via a single lateral rectus abdominis surgical approach with fixation of the anterior column using 3.5 mm reconstruction plates, and

**Table 1.** Patient demographic and injury data.

Variable	Value	Percent
Gender		
Male	39	66.1
Female	20	33.9
Mean age (years)	45 (range: 18–64)	
Acetabular fracture type		
Both columns	18	30.5
Anterior column and posterior hemitransverse	36	61.0
T-type	5	8.5
Ipsilateral pelvic ring fracture	32	54.2
Extremity fractures	19	32.2
Ipsilateral lower extremity fractures	12	20.3
Bilateral fracture lower extremity fractures	6	10.1
Ipsilateral upper and lower extremity fractures	1	1.7
Mechanism of injury		
Fall from a height	43	72.9
Motor vehicle accident (MVA)	12	20.3
Falls from standing height	4	6.8
Mean delay to surgery (days)	8.1 (range: 1–20)	

fixation of the posterior column using 6.5 mm cannulated lag screws. All surgical procedures were performed by the same senior surgeon, using a similar surgical technique.

All patients received antibiotic cover with cefazolin sodium pentahydrate (2 g) 30 min prior to induction of general anesthesia. Patients were placed in a supine position on a radiolucent operating table. The feasibility of obtaining anteroposterior (AP) and Judet oblique views using C-arm fluoroscopy was verified for each patient before surgical draping. The principal surgeon stood on the opposite side to the hip being treated. Exposure was facilitated by flexion of the hip and knee in a triangle to relax the psoas muscle and neurovascular structures. Landmarks for the incision were the navel and the anterior superior iliac spine (ASIS), as shown in Figure 1.



**Figure 1.** The surgical skin incision used in the single lateral rectus abdominis approach.

#### Surgical technique: Caveats of the surgical procedure

The surgical incision started cranially at the junction of the lateral and the middle-third of the line connecting the navel with the ASIS, continuing in a line towards the midpoint of the line connecting the ASIS with symphysis pubis. The length of this incision was about 6–10 cm. The pararectus approach consisted of a curve that began at the junction of the lateral and the middle-third of the line connecting the navel with the ASIS and ended in the junction of the middle-third of a line connecting the ASIS with the symphysis, which is parallel to the lateral border of the rectus abdominis. Compared with the pararectus approach, the location of our surgical approach was lateral to the rectus abdominis.

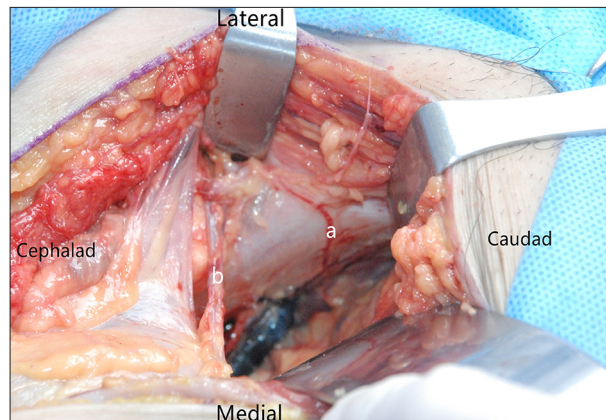
Following subcutaneous dissection, the anterior lamina of the rectus sheath, obliquus externus abdominis, superficial inguinal ring and the funiculus spermaticus in men, or the round ligament in women, could be identified. The subcutaneous incision began at the medial border of the superficial inguinal ring, continuing in a line towards the initial skin incision. The avoidance of damage to the superficial inguinal ring was essential to avoid the development of an inguinal hernia. The subcutaneous incision split part of the anterior lamina of the rectus sheath, the abdominal external oblique muscle, the abdominal internal oblique muscle, and the transverse abdominal muscle. Next, the funiculus spermaticus (or the round ligament) was retracted laterally to expose the arcuate line and the inferior epigastric vessels. The extraperitoneal space was then entered via an incision in the transversalis fascia in line with the subcutaneous incision, with

care not to perforate the parietal peritoneum. The peritoneum was freed from its surroundings and was then gently retracted medially to expose the pelvis, and to facilitate further dissection within the extraperitoneal space.

The subcutaneous incision of the pararectus abdominis approach required transection of the rectus sheath at the lateral border of the rectus abdominis, which is the weakest point of the anterior abdominal wall, to create an extraperitoneal space. This incision had a risk of causing postoperative abdominal hernia. This surgical approach involved an incision in a line lateral to the lateral border of the rectus abdominis muscle, and for this reason we termed the procedure the 'lateral rectus abdominis approach.'

After entering the extraperitoneal space and conducting further dissection, the iliac and psoas muscles, the external iliac vessels and nerves, the obturator vessels and nerve as well as the corona mortis (an anastomosis between the epigastric or external iliac vessels and obturator vessels) were identified. In order to ensure safe retraction, the neurovascular structures were mobilized and encircled with a silastic sling. The dissection proceeded with the lateral retraction of the iliac and psoas muscles and the external iliac vessels, while the ilio-inguinal, femoral, lateral femoral cutaneous, and genitofemoral nerves were protected. The ipsilateral hemisacrum, the sacro-iliac (SI) joint and the posterior part of the iliac crest were exposed, and the bifurcation of the internal iliac vessels and the lumbar plexus was identified. To expose the medial surface of the iliac crest, the iliacus muscle was detached from the iliac fossa. Then, the crest, the superior ramus of the pubis, and the iliopectineal eminence were exposed via lateral retraction of the iliopsoas muscle and the neurovascular structures and medial retraction of the obturator vessels and nerve. It is important to note that the corona mortis between the epigastric and obturator vessels must be identified and ligated to ensure safe placement of a plate on the pubic rami. Our approach eliminates the need to cut into the iliopectineal fascia or to partially release the pectineus muscle, unlike the pararectus approach to exposure of the external iliac vessels. After these steps, the false pelvis and SI joint were exposed.

To further expose the true pelvis, the obturator nerve and vessels were dissected under direct visualization. Then the bladder, intraperitoneal structure, and obturator neurovascular structures were gently medially retracted using a blunt retractor placed over the bundle and into the sciatic notch. The quadrilateral plate was exposed by detaching the obturator internus muscle and relocating it to the level of the ischial spine. The dislocation and fractures of the quadrilateral plate were then reduced under direct visualization using reduction clamps or ball-spiked pushers with footplates. This process completed the exposure of the false and true pelvis.



**Figure 2.** The first 'window' of the single lateral rectus abdominis approach. a – The corona mortis, an anatomical variant including anastomosis between the external iliac, obturator, or inferior epigastric arteries or veins. b – The inferior epigastric artery. The surgery was performed on the left pelvis, and the photograph was taken from the contralateral side of the surgical field.

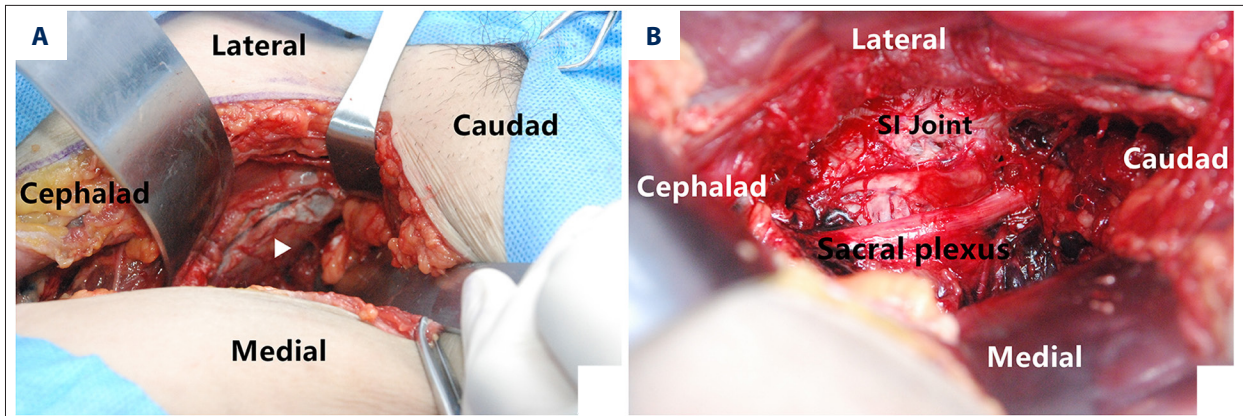
### Surgical technique: The three surgical 'windows'

In the pararectus approach, the area that had been exposed is divided into five operative 'windows,' whereas our approach required only three. The first 'window,' which exposed the area from the iliopectineal eminence to symphysis pubis, was situated between the external iliac vessels and the obturator neurovascular structures (Figure 2). Surgeons were able to reduce and fix the fracture of the superior ramus of the pubis and anterior acetabular wall in this 'window' after ligating the corona mortis (an anastomosis between the epigastric or external iliac vessels and obturator vessels). The second 'window' was located between the iliopsoas muscle and the external iliac vessels (Figure 3). This second 'window' exposed the sacrum, the SI joint, the medial aspect of posterior column and the quadrilateral plate via lateral retraction of the iliopsoas muscle and medial retraction of the external iliac vessels, lumbar plexus and obturator nerve and vessels. This 'window' was used to treat fractures of the posterior pelvic ring and posterior column as well as dislocations and fractures of the quadrilateral plate. The third 'window' was located between the psoas muscle and the iliac muscle (Figure 4). To expose the third 'window,' the iliac muscle was retracted laterally while the psoas muscle and neurovascular structures were gently retracted medially. Through this third 'window,' fractures of the iliac crest were reduced and fixed following the detachment of the iliac muscle.

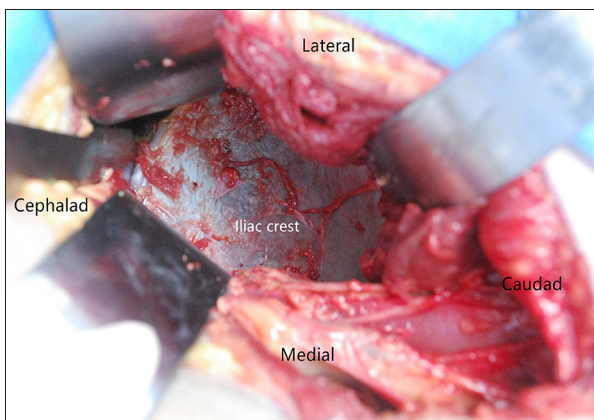
### Surgical technique: Fixation of the acetabular fracture and wound closure

To fix fractures, it was first necessary to reduce the medial dislocation of the femoral head by lateral traction with a Schanz

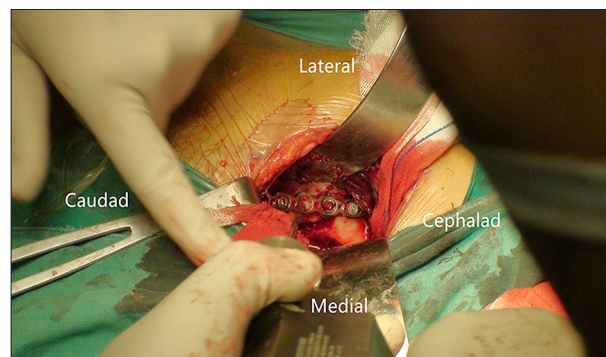




**Figure 3.** The second 'window' of the single lateral rectus abdominis approach. (A) The quadrilateral plate (white arrow). (B) The SI vertebral joint and sacral plexus. The surgery was performed on the left pelvis, and the photograph was taken at the contralateral side of the surgical field.



**Figure 4.** The third 'window' of the single lateral rectus abdominis approach. The surgery was performed on the left pelvis, and the photograph was taken from the contralateral side of the surgical procedure.



**Figure 5.** Suprapectineal plates used in the single lateral rectus abdominis approach. The surgery was performed on the right pelvis, and the photograph was taken from the contralateral side of the surgical field

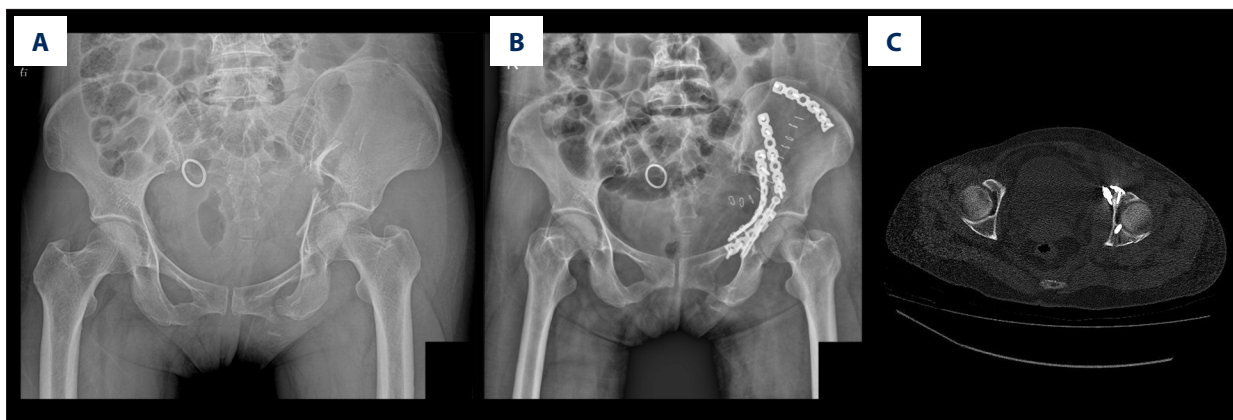
pin in the lateral trochanter or by manual reduction. This procedure allowed the anterior column and anterior wall fractures to be addressed. There were 3.5mm reconstruction plates and cortical screws placed on the pelvic brim, which were used to stabilize the anterior columns (Figure 5). In patients with medial displacement of the quadrilateral plate, the infrapectineal plate was used as a buttress to fix the quadrilateral plate following its reduction via reduction clamps or ball-spiked pushers with footplates [13,14].

To prevent the screws from penetrating the hip joint, screw insertion was directed based on the previously recommended safe zones for screw placement [15,16]. Reduction of the posterior column was achieved using a reduction clamp or bone lever, followed by the insertion of a guide wire in the pelvic brim oriented towards the ischial spine. In patients with low posterior column fracture, this guide wire was inserted towards the ischial tuberosity. After the guide wire was appropriately

inserted without reduction loss (confirmed by fluoroscopy), it was used to direct insertion of the 6.5mm lag screw. Fractures of the adjacent SI joint and the iliac crest were fixed using plates and/or percutaneous screws. Fluoroscopy was used to check fracture reduction and implant position before wound closure. The wound was closed in layers with the insertion of drains. The drains were removed when the drainage volumes were less than 50 ml per day.

#### Postoperative imaging and physical therapy

X-ray examinations and CT scans with 3D reconstruction were conducted in all patients postoperatively. Prophylactic intravenous antibiotics were administered for 48 h. To prevent deep vein thrombosis (DVT), low-molecular-weight heparin was administered daily until the patient was discharged from hospital. Physiotherapy, including range of motion (ROM) exercises and muscle strengthening exercises, was initiated as early in recovery as appropriate. Weight bearing was not permitted for the first eight weeks after surgery, after which progressive



**Figure 6.** Pre-operative and postoperative anteroposterior (AP) radiographs and postoperative computed tomography (CT) imaging of a 47-year-old woman with dual anterior and posterior column fracture of the acetabulum who underwent the single lateral rectus abdominis approach for open reduction and internal fixation. **(A)** Anteroposterior (AP) radiograph of a 47-year-old woman who fell from a height and sustained dual anterior and posterior column fracture of the acetabulum, medial displacement of the quadrilateral plate, central displacement of the femoral head, high iliac crest fracture and a calcaneus fracture on the left side. **(B, C)** Postoperative anteroposterior (AP) radiograph and computed tomography (CT) scan of the acetabulum shows the outcome of reduction of the fracture. The high iliac crest fracture was reduced and fixed with a 3.5 mm reconstruction plate using the single lateral rectus surgical approach.

weight bearing was recommended provided there was radiological evidence of fracture consolidation.

**Patient evaluation at follow-up**

All surgical data, including time to surgery, blood loss, operating time, intraoperative and postoperative complications were recorded. Patients received routine postoperative follow-up at one, three, six, and 12 months, and every year thereafter. X-ray examination and CT scans established radiographic outcomes, including fracture patterns, reduction quality, and long-term outcomes. The evaluation criteria for reduction quality were derived from the Matta scoring system, with reduction quality classified as anatomic (<1 mm), imperfect (1–3 mm), or poor (>3 mm), based on the postoperative residual displacement. Clinical outcomes were evaluated using the modified Merle d’Aubigné score, ranging from excellent (18 points), good (15–17 points), fair (14 or 13 points), and poor (<13 points) [13].

**Results**

Fifty-nine patients (mean age 45 years; range, 18–64 years), included 39 men and 20 women, were treated successfully with open reduction and internal fixation (ORIF) by the single lateral rectus abdominis surgical approach. The mean time from fracture to surgery was 8.1 days (range, 1–20 days). The mean operating time was 86.3 min (range, 42–145 min). The mean operative blood loss was 514.6 ml (range, 150–830 ml). All surgical incisions healed without infection, and stitches were removed two weeks after surgery in cases of wound non-closure.

**Table 2.** Postoperative outcomes.

Postoperative data	Value	Percent
Mean operating time (min)	86.3 (range: 42–145)	
Mean blood loss (ml)	514.6 (range: 150–830)	
Mean union time (weeks)	11.2 (range: 8–14)	
Reduction quality (Matta)		
Anatomic (<1 mm)	40	67.8
Imperfect (1–3 mm)	15	25.4
Poor (>3 mm)	4	6.8
The modified Merle d’Aubigné score		
Excellent	39	66.1
Good	14	23.7
Fair	5	8.5
Poor	1	1.7

All patients were followed-up for at least 24 months (mean, 28.1 months; range, 24–48 months). All fractures exhibited radiological evidence of fracture union within 14 weeks after surgery (mean fracture union time, 11.2 weeks; range, 8–14 weeks). No patients exhibited loss of reduction at their final follow-up (Figure 6).

**Table 3.** Complications.

Variable	Value	Percent
Peritoneum lesions	5	8.5
Obturator nerve injuries	8	13.6
Enteroplegia	3	5.1
Deep vein thrombosis	4	6.8
Traumatic arthritis	4	6.8

The reduction quality was graded as anatomic in 40 patients (67.8%), fair in 15 patients (25.4%), and poor in four patients (6.8%). According to the modified Merle d'Aubigné scoring system, the clinical outcomes were excellent in 39 patients (66.1%), good in 14 patients (23.7%), fair in five patients (8.5%), and poor in one patient (1.7%) (Table 2).

No significant intraoperative bleeding occurred in any patient. There were five cases of peritoneal lesions and eight cases of obturator nerve injuries. In instances of peritoneal lesions, there were no hernias noted at last clinical follow-up. The eight patients with obturator nerve injuries presented with postoperative temporary weakness and pain of the hip adductor muscles, but eventually recovered in about one month without further medical intervention. Three patients presented with temporary paralytic ileus during the first 24 hours after surgery and returned to normal within 48 hours with enema treatment. Four patients developed DVT in the ipsilateral lower limbs and in these individuals antithrombotic treatment was extended for three months. No cases of pulmonary embolism were noted. At 6-month, 12-month, and 18-month follow-up, one, two, and one patient, respectively were diagnosed with traumatic arthritis. The remission of arthritis symptoms was achieved after taking aminodextran and celecoxib. All of them refused further surgical treatment (Table 3).

## Discussion

Most complicated acetabular fractures are caused by high-energy damage, such as that sustained from falls from a height or motor vehicle accidents [17,18]. As described by Letournel 40 years ago, surgical management of acetabular fractures can significantly improve clinical outcomes, decrease mortality rates and lower the incidence of postoperative complications. Most surgeons currently believe that complicated acetabular fractures are best treated via a single approach, which entails the abovementioned benefits [11,12]. Single approaches for the treatment of complicated acetabular fractures involving both columns are anterior intrapelvic approaches, including the ilio-inguinal approach, the modified Stoppa approach, and the pararectus approach.

The ilio-inguinal approach is the most common anterior intrapelvic approach for the treatment of acetabular fractures, and it has been widely used over the past twenty years as it provides a wide view of the medial surface of the entire ipsilateral hemipelvis for reduction [19]. The primary indication for the use of the ilio-inguinal approach is the appearance of anterior column fractures. This approach can expose the pelvic brim under direct visualization, with the exception of the acetabular dome and the quadrilateral plate, which results in suboptimal reduction in patients presenting with impacted acetabular dome fractures or displacement of the quadrilateral plate [8,20]. Also, this approach is difficult for surgeons unfamiliar with the approach to learn because of the critical anatomical structures in the surgical area. Furthermore, the complicated procedures necessitated by the ilio-inguinal approach are associated with a longer operating time and increased blood loss, increasing the rate of complications [7]. Compared with the ilio-inguinal approach, the lateral rectus abdominis approach can provide a direct view of the quadrilateral plate and equivalent exposure of the medial surface of hemipelvis without isolation of critical anatomical structures in the surgical area, resulting in better quality of reduction of quadrilateral plate fractures and reduced operating time and intraoperative blood loss. Wang et al. [21] reported that 64 patients with dual column fractures were treated via a single ilio-inguinal approach with mean operating times of 241.2 min and mean blood loss of 888.6 ml. Poor quality of reduction in patients was rated as 17.2% (11 cases) and the excellent and good clinical outcomes were rated in 73.4% (47 cases) with three instances of hip joint failure. The analysis of 135 two column fractures that were treated via various approaches by Gänsslen et al. resulted in 24.4% of patients with poor reduction and 60.7% of patients presenting with functionally perfect or good reduction [18]. Compared with this previous study, our study showed a significant decrease in operating time (86.3 min) and blood loss (514.6 ml) with better reduction quality (poor reduction rate of 6.8%) and better clinical outcomes (an excellent or good rate of 89.8%). No joint failure or hip replacement was found at last follow-up. Shazar et al. [22] reported that 84 of 122 patients (68.9%) treated via the ilio-inguinal approach achieved anatomic reduction with a mean operating time of 293.4 minutes, and 11 (9%) instances of incision infection. Our study showed a similar anatomic reduction rate of 67.8% (40 out of 59 patients), but with shorter mean operating time and lower infection rates.

The modified Stoppa approach, as described by Hirvensalo in 1994, is an alternative technique for surgical treatment of the anterior acetabulum [23]. This approach can expose the anterior column, the pelvic brim and the quadrilateral plate surface up to the great sciatic notch under direct visualization via an incision through the rectus abdominis muscle, which makes it possible to reduce and fix the quadrilateral plate with



infrapectineal screws and plates under direct visualization. As a buttress, infrapectineal screws and plates can provide stronger fixation, which can decrease the postoperative medial displacement of the quadrilateral plate. However, the single modified Stoppa approach does not allow surgeons to reduce and fix iliac fossa fractures or high anterior column fractures without the first 'window' of the ilio-inguinal approach [7,8,24]. Gras et al. [25] and Shazar et al. [22] reported, that about 40% (12/30) and 55.3% (57/103) of patients, respectively required additional lateral exposure. The additional incision significantly prolonged the duration of surgery with a mean operating time of 202 min and 240.5min, respectively, potentially increasing the rates of blood loss and infection.

The pararectus approach, as reported by Keel in 2012, was used to treat acetabular fractures predominantly involving the anterior column and the quadrilateral plate [20]. The pararectus approach combines the advantages of the second and third 'windows' of the ilio-inguinal approach with the medial view of the modified Stoppa approach via a less invasive single incision. Bastian et al. reported that the pararectus approach could expose about 42% of the ipsilateral pelvis, significantly more than that exposed by the modified Stoppa approach (29%) [24]. Although the exposure of the pararectus abdominis approach is wider, especially at the surface of iliac fossa, the first 'window' of the para-rectus abdominis approach is still necessary for surgeons to complete the reduction and fixation of high anterior column fractures exiting the iliac crest. Keel et al. [26] reported that 48 patients with acetabular fractures treated via the pararectus approach presented with excellent and good clinical outcomes in 68.8% (33/48) with a mean operating time of 200 minutes. The mean blood loss in this previous study was 1,477 ml, and 23% (11/48) of patients required an additional incision to reduce and fix the fractures of iliac crest [26]. Compared with this previously published study, our surgical approach offered better clinical outcomes with reduced operating time and blood loss. In our case series, the patients were younger (mean age, 45 years) than those in the study reported by Keel et al. (mean age, 62 years) [26]. This reason might explain the better clinical outcomes, with less operating time and blood loss, in the present study. Also, the lack of the use of an additional 'window' in our study also reduced operating time and blood loss.

The advantages of the lateral rectus abdominis approach used in this study included the exposure of the quadrilateral plate and a large part of the inner surface of iliac fossa using only a small incision. Surgeons can treat fractures involving both columns associated with high iliac crest fractures via a single and minimally invasive incision. Compared with the ilio-inguinal approach, the lateral rectus abdominis approach has an equivalent exposure via a minimally invasive incision. In the ilio-inguinal approach, surgeons need to dissect the inguinal canal

to isolate the spermatic cord, which can cause postoperative inguinal hernias [27]. In our lateral rectus abdominis approach, there was no dissection of the inguinal canal, which minimized the risk of postoperative inguinal hernia, allowing surgeons to more easily perform reduction and internal fixation of complicated acetabular fractures via an approach that can be more readily learned. Bastian et al. [24] indicated that both the modified Stoppa approach and the pararectus approach had limitations in their ability to expose iliac fossa fractures and high anterior column fractures. Compared with both the modified Stoppa approach and the pararectus approach, the lateral rectus abdominis approach can expose the fractures of iliac crest and high anterior column under direct visualization without an additional lateral 'window,' which can shorten the operating time and reduce intraoperative blood loss (Figure 6B). Traction injuries are the primary complications of surgical treatment of acetabular fractures, and because the lateral rectus abdominis approach is more lateral, prolonged or excessive traction to nerves is less likely to occur. Only transient neurological symptoms were observed in eight patients in the present study, and no lateral cutaneous nerve injuries were observed. The lateral rectus abdominis approach is also likely to be associated with a lower risk of abdominal hernia because there is no need to incise the rectus sheath at the lateral border of the rectus abdominis.

The major complications in patients treated via the lateral rectus abdominis approach are injuries to the peritoneum, and obturator nerve injuries, and are consistent with findings in other previously reported intrapelvic approaches [20,28], five peritoneal perforations were observed in our study. Therefore surgeons must take care to protect the peritoneum and intestine when entering the extraperitoneal space. If peritoneal perforation occurs, repair of the peritoneum must be immediate. We did not observe any cases of hernias as of the last follow-up. Temporary dysfunction of the adductor muscle in eight patients was observed postoperatively, which may be due either to the medial displacement or the iatrogenic stretching of the obturator nerve during exposure of the quadrilateral plate. These patients presented with weakness and pain of the adductor muscle and recovered without further intervention within one month. Surgeons must protect the obturator nerve carefully when detaching the obturator internus muscle to expose the quadrilateral plate, especially in patients with preoperative obturator nerve injuries. Traction injuries of the lateral femoral cutaneous nerve have been reported in 18% of cases treated using the ilio-inguinal approach and 5% treated using the Stoppa approach [29,30]. No traction injuries of the lateral femoral cutaneous nerve were observed in our study. Three patients presented with temporary paralytic ileus 24 hours after surgery, which may be due to the excessive traction of the intraperitoneal tissue, but these patients returned to normal after 48 hours, following the use of an enema.



In the present study, DVT occurred in four patients. Antithrombotic treatment was extended for three months in the patients studied, and no cases of pulmonary embolism occurred. Fracture union was related to several factors, including hormone levels, intestinal microbiota, and other factors. Nonunion or malunion was not observed in this study [31,32]. Some surgeons have suggested that the incision used in our approach could damage the nerves controlling the rectus abdominis muscle, resulting in muscle dysfunction, but this was not found at last follow-up in the cases in the present study.

Four patients presented with traumatic arthritis during follow-up. In general, clinical outcomes for patients with acetabular fractures are positively correlated with reduction quality. In the present study, four patients had poor reduction quality but only two of them ultimately presented with unsatisfactory outcomes. The other two patients achieved good clinical outcomes, as their acetabular fractures only involved the low acetabulum, which was not the main weight bearing area of the hip and had no significant impact on hip function [33]. However, three patients with anatomic reduction quality presented with traumatic arthritis at last follow-up. These patients presented with the 'gull sign' in initial radiographic examinations, which indicated dome impaction of the acetabulum. According to some authors, dome impaction of acetabulum always results in a relatively poor clinical outcome, even when the impacted fragment had been reduced [34–37].

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This study had several limitations. The study was of small size from a single center and included low statistical power due to the small number of cases and lack of a historical comparison group. This study also had a relatively short follow-up duration, which might have been insufficient to evaluate the progression of postoperative osteoarthritis.

## Conclusions

The single lateral rectus abdominis surgical approach for complicated acetabular fractures can facilitate a wide exposure of the ipsilateral pelvis with a single and minimally invasive incision, especially in patients associated with fractures of the high anterior column or the iliac crest. Stable fixation can be achieved by the plates fixing the anterior column, and by the quadrilateral plate and a lag screw fixing the posterior column. Using this lateral rectus abdominis approach, the reduction and fixation of complicated acetabular fractures might be a more straightforward approach when compared with previously described surgical techniques.

## Conflict of interest

None.

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