Original Article

Observation of the clinical efficacy of percutaneous reduction by leverage combined with intramedullary nail internal fixation in the treatment of irreducible femoral intertrochanteric fracture: a retrospective single-arm cohort study

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Background: There are few reports on the efficacy and safety of percutaneous lever reduction combined with intramedullary nailing in the treatment of irreducible functional intertrochanteric fracture. This study was designed to investigate the clinical effect of percutaneous reduction by leverage combined with intramedullary nail internal fixation in the treatment of irreducible femoral intertrochanteric fracture.

Methods: A total of 26 patients with irreducible femoral intertrochanteric fracture admitted to Qilu Hospital were included in this study, including 10 males and 16 females. All fractures were reduced through an incision made at the insertion point of the intramedullary nail head or the main nail with the aid of auxiliary equipment such as a periosteal dissector or a bone-holding forcep. Indicators such as operative time, blood loss, and complications were recorded, and the quality of fracture reduction was evaluated by the Baumgaetner modified method. All the patients were followed up regularly for 3 months, 1 year, and 2 years postoperatively, and the Zuckerman Functional Recovery Scale (FRS) for Hip Fracture was utilized to evaluate the hip function of the patients. The Euro-Quality of Life-5 Dimension (EQ-5D) was used to evaluate the quality of life of patients. Hip pain was assessed by the visual analog scale (VAS) at the last follow-up.

Results: According to the Evans-Jensen classification of fractures, 12 cases were classified as type III, 10 as type IV, and 4 as type V. The mean operation time was 67.9±16.4 min and the intraoperative blood loss was 165.8±58.3 mL. All fractures healed completely. In terms of fracture reduction quality, 14 cases were excellent and 11 cases were good. At the last follow-up, the FRS scores decreased from 93.3±5.7 preoperatively to 81.5±18.5 postoperatively, and the EQ-5D index decreased from 0.95±0.05 preoperatively to 0.86±0.14 postoperatively.

Conclusions: With mini-incision assisted reduction combined with intramedullary nail internal fixation to treat of irreducible femoral intertrochanteric fracture, favorable clinical results can be obtained, and the walking ability and quality of life of the patients can be improved postoperatively.

Keywords: Femoral fracture; fracture internal fixation; reduction; clinical efficacy

Submitted Mar 08, 2022. Accepted for publication Jun 30, 2022.
doi: 10.21037/atm-22-2846
View this article at: https://dx.doi.org/10.21037/atm-22-2846

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Introduction

Femoral intertrochanteric fracture is a common extremity fracture, accounting for approximately 43% of hip fractures (1). In the wake of the acceleration of global aging in recent years, the incidence of intertrochanteric fractures has increased remarkably. It has been reported in the literature that the risk of intertrochanteric fractures is significantly increased in the population over 65 years of age, while those between 75–80 years old have the peak age of fracture onset. The total number of patients with intertrochanteric fractures is expected to double in the next 25 years (1,2). In view of the poor recovery of hip function, high complication rate, and high mortality in patients with intertrochanteric fractures after conservative treatment, patients are advised by most doctors to undergo surgery as soon as possible, among which closed reduction and intramedullary nail internal fixation is the most widely used surgical method in recent years (3-6). The majority of intertrochanteric fractures can be reduced and fixed satisfactorily with intramedullary nail technology. However, some fractures are of complex types, and blind pursuit of closed reduction may result in poor fracture reduction and further lead to unsatisfactory internal fixation position, internal fixation failure, and other complications. Therefore, for intertrochanteric fractures that are difficult to reduce, consideration should be given to the utilization of surgical instruments to assist the reduction, followed by fixation with intramedullary nails (5-8). According to literature review, closed reduction and intramedullary fixation are often used for unstable intertrochanteric fractures, such as proximal femoral nail antirotation (PFNA), and the curative effect is acceptable (7). However, there are few reports on the treatment of the irreducible femoral intertrochanteric fracture, and it is not detailed enough. In this study, the irreducible fractures of patients were reduced and fixed through a surgical incision made at the insertion point of the intramedullary nail head or the main nail between December 2013 and March 2015, and favorable clinical results were achieved. The details are reported as follows. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-2846/rc).

Methods

General information

A total of 26 patients with irreducible femoral intertrochanteric fracture admitted to Qilu Hospital from December 2013 to July 2015 were included in this study, including 10 males and 16 females, with an average age of 64.5±14.1 years. The current sample size is sufficient to answer clinical questions. Patients were included in this study according to the following criteria: (I) patients whose treatment time from injury to hospitalization did not exceed 48 h; (II) patients aged 18–85 years; (III) patients mainly diagnosed with femoral intertrochanteric fractures; (IV) patients whose fractures were radiologically proven to be type III–V according to the Evans-Jensen classification; (V) patients with unsatisfactory fracture reduction after multiple closed reductions; (VI) patients who could walk independently before surgery. The case exclusion criteria were as follows: (I) patients whose treatment time exceeded 48 h after injury to hospitalization; (II) patients complicated with fractures or multiple system injuries in other parts; (III) patients with previous limited hip movement; (IV) patients with old or pathological fractures; (V) patients with subtrochanteric fractures. All fractures were reduced through an incision made at the insertion point of the intramedullary nail head or the main nail with the aid of auxiliary equipment such as a periosteal dissector or a bone-holding forcep. This study obtained approval from the Ethics Committee of Qilu Hospital (Qingdao), Cheeloo College of Medicine, Shandong University (approval No. 20131164), following the principle of the Declaration of Helsinki (as revised in 2013). The patients have signed informed consent.

Surgical methods

After anesthesia took effect, all patients were supine on the traction table, with the uninjured hip and knee flexed and abducted. The affected limb was pulled axially under C-arm fluoroscopy, with hip adduction and internal rotation of 10°–15°. Routine disinfection was performed on the surgical sheet, and a longitudinal incision of about 4–6 cm was made along the outer and upper part of the greater trochanter. Subsequently, the skin was incised and the subcutaneous tissue was bluntly separated to reach the apex of the greater trochanter. All fractures were reduced by leverage with a periosteal dissector through a proximal incision or by fixation of the broken end with a bone-holding forcep. If the greater trochanter fracture was complicated and the reduction by the instrument might have affected the nail insertion, the intramedullary nail would be placed in the front of the thigh. After determining the position of

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the head nail under fluoroscopy, the skin was cut open to separate the subcutaneous tissue, and a periosteal dissector was used to assist the reduction. After the fracture reduction was satisfactory, a hole was opened at the apex of the greater trochanter and a guide pin was inserted. After confirming that the guide pin was located in the center of the femoral medullary cavity through lateral fluoroscopy, a hollow drill was utilized to ream the medulla along the guide pin, and an appropriate type of intramedullary nail was selected for insertion into the medullary cavity. After the position of the intramedullary nail was satisfactory, the guide pin was drilled along the femoral neck under the guidance of the sighting device. The proximal locking nail of appropriate length was inserted, the nut at the end of the nail was tightened, and then the distal locking screw was screwed. After the fracture reduction and internal fixation were satisfied by fluoroscopy again, the wound was washed and sutured layer by layer, and the surgery was completed. InterTAN or PFNA were selected as internal fixators in this group. Typical cases are shown in *Figures 1*,*2*.

Postoperative management

Antibiotics and anticoagulants were routinely applied postoperatively. On the first day postoperatively, the patients were encouraged to sit up in bed and perform functional exercises on their knee and ankle joints. Two days later, the patients stood with full weight bearing with the assistance of a walking aid, and began walking with partial weight bearing within 1 week according to their respective conditions. Re-examinations were performed at regular intervals postoperatively, and patients gradually moved from partial weight bearing to full weight bearing walking depending on their fracture healing.

Efficacy evaluation

All the patients were followed up regularly for 3 months, 1 year, and 2 years postoperatively, and the Zuckerman Functional Recovery Scale (FRS) for Hip Fracture was utilized to evaluate the hip function of the patients (9). The FRS scale includes three aspects: activities of daily living, instrumental activities of daily living, and walking ability, and scores are calculated by weight. The Euro-Quality of Life-5 Dimension (EQ-5D) was used to evaluate the quality of life of patients (10). The EQ-5D includes five aspects: mobility, self-care, usual activities, pain or discomfort, and anxiety or depression. The EQ-5D index is calculated according to the population and ranges from negative 0.594 to 1 (full health). Each question on the scale is graded on three levels: not difficult, partially difficult, and extremely difficult. Postoperatively, the quality of fracture reduction was evaluated by the Baumgaetner modified method. Criterion 1: 120°–135° of orthographic X-ray neck shaft angle, <20° of lateral X-ray angle; criterion 2: <4 mm of fracture mass displacement on anteroposterior and lateral X-rays; excellent: the above two criteria are met at the same time; good: only one criterion is met; poor: both criteria are not met. Hip pain was assessed by the visual analog scale (VAS) at the last follow-up (11).

Statistical analysis

Statistical analysis was performed using SPSS16.0 software. The measurement data (mean ± SD) were examined by *t*-test. Repeated measures analysis of variance was used to compare the FRS score and EQ-5D index at each follow-up time point preoperatively and postoperatively. $P<0.05$ indicates a statistically significant difference.

Results

General information

A total of 29 patients were included in the study according to the inclusion criteria, of which 3 patients withdrew from the study due to death or loss to follow-up. Therefore, a total of 26 patients (89.7%) completed follow-up. Among the 26 patients, there were 10 males and 16 females, with an average age of 64.5±14.1 years, and 18 patients (69.2%) with complicated medical diseases. In terms of the causes of injury, there were 15 cases of fall injuries, 4 cases of falling from heights injuries, and 7 cases of traffic accidents. According to the Evans-Jensen classification, 12 cases were type III, 10 cases were type IV, and 4 cases were type V.

Surgical indicators and efficacy

All the patients had an incision of 7.9±2.1 cm, an operative time of 67.9±16.4 min, intraoperative blood loss of 165.8±58.3 mL, and an average hospital stay of 10.3± 2.8 days. During hospitalization, 1 patient developed a pulmonary infection, which improved after symptomatic treatment. Three patients developed lower extremity venous thrombosis and were treated with anticoagulation and venous mesh placement. One elderly patient developed

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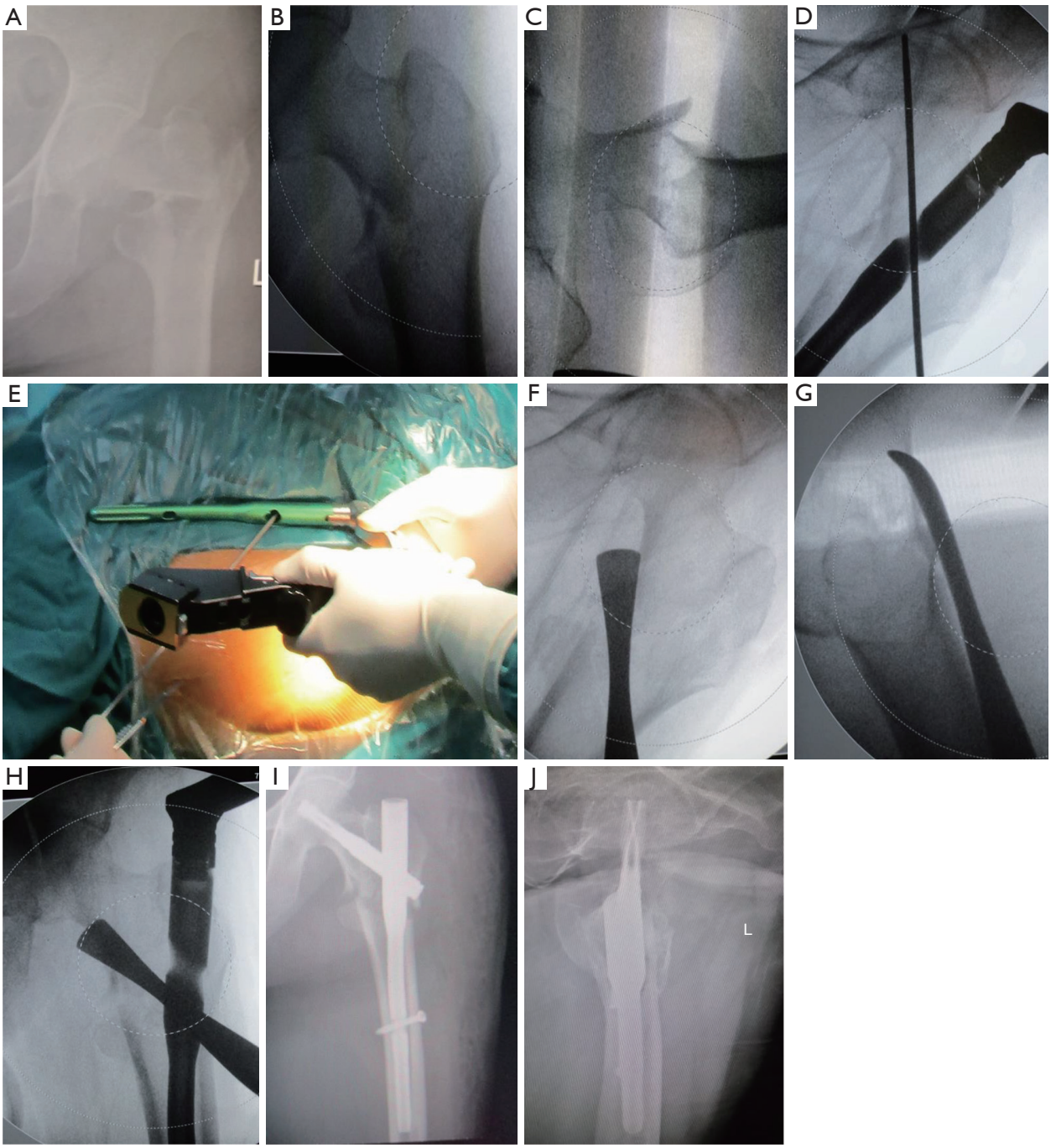

Figure 1 A 78-year-old woman with a left intertrochanteric fracture. (A-C) Preoperative X-rays showed that the proximal fracture was not involved with the lesser trochanter, which was attached to the distal end of the fracture. Intraoperative fluoroscopy showed satisfactory reduction of the proximal fracture, and the lateral view showed anterior displacement of the fracture with difficulty in reduction. (D-H) After determining the position of the head nail under fluoroscopy, a longitudinal incision was made and the main nail was inserted. The reduction was performed with the aid of a periosteum dissector. (I,J) Postoperative X-ray examination showed a satisfactory reduction and fixation position. L, left.

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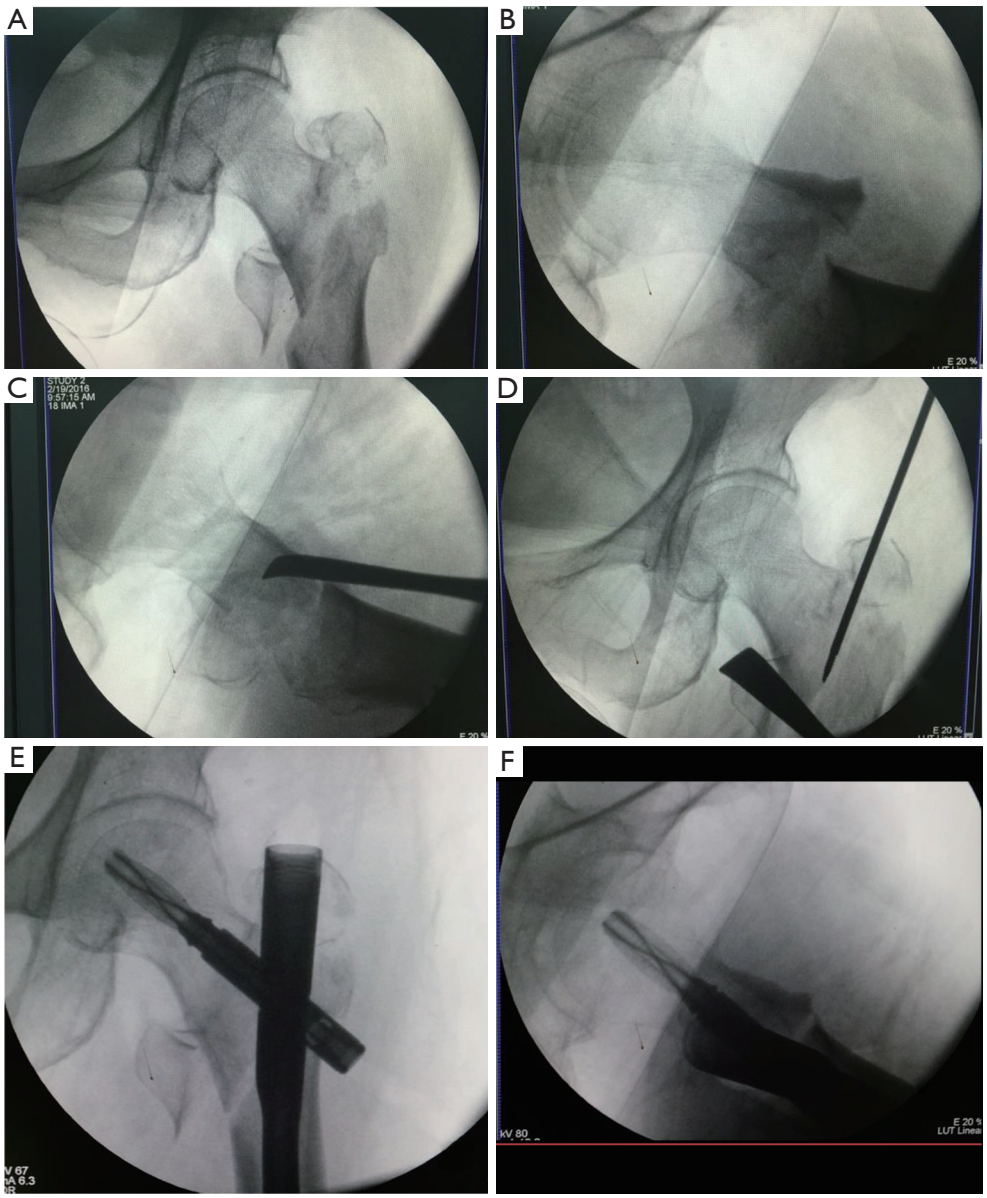

Figure 2 A 77-year-old woman with a left intertrochanteric fracture. (A,B) Preoperative X-ray showed the disassociation of the greater and lesser trochanter, and the lateral view showed anterior displacement of the proximal fracture. (C,D) A surgical incision was made along the lateral side of the greater trochanter. The reduction was performed with the aid of a periosteum dissector. (E,F) Postoperative X-ray examination showed a satisfactory reduction and fixation position.

a cerebral infarction 2 weeks after discharge and was hospitalized again for treatment. All the wounds healed well without suppuration or exudation. All fractures healed completely and no patients experienced delayed union, nonunion, or complications such as hip varus and femoral head dissection. In terms of fracture reduction quality postoperatively, 17 cases were excellent, 8 cases were good, and 1 case was poor. The tip-apex distance (TAD) was 19.8±6.3 mm.

It can be seen from *Table 1* that at the last follow-up, the FRS scores decreased from 94.3±5.7 preoperatively to 82.4±10.8 postoperatively (P<0.05), and the EQ-5D index decreased from 0.95±0.05 preoperatively to 0.85±0.10 postoperatively (P<0.05). Significant recovery was seen in

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Table 1 Surgical efficacy of patients at different follow-up time points before and after surgery

Items	FRS score, mean ± SD	EQ-5D score, mean ± SD
Preoperative	94.3±5.7	0.95±0.05
3 months after surgery	61.0±13.3*	0.57±0.16*
1 year after surgery	80.9±11.5*	0.82±0.13*
2 years after surgery	82.4±10.8*	0.85±0.10*

*, compared with preoperative P<0.05. FRS, Functional Recovery Scale; EQ-5D, Euro-Quality of Life-5 Dimension.

the hip function and quality of life of the patients 1 year after injury, but the changes were not obvious after 1 year. At the last follow-up, the patients had a hip VAS score of 1.1±0.7, and 88.5% (23/26) had recovered the ability to walk independently postoperatively.

Discussion

In the wake of the development of internal fixation materials and surgical techniques, the closed reduction intramedullary nail technique has been extensively applied in the treatment of femoral intertrochanteric fractures. Intramedullary fixation [such as dynamic hip screw (DHS)] is superior to extramedullary fixation (such as DHS) due to its characteristics of being more consistent with the anatomical structure and mechanical properties of the proximal femur, and taking into consideration the principles of Arbeitsgemeinschaft für Osteosynthesefragen (AO) and minimally invasive and biological osteosynthesis (BO), which is especially suitable for intertrochanteric fractures with incomplete lateral walls (12,13). It has been reported in the literature that intramedullary nails demonstrate various benefits such as effectively reducing the load on the proximal femur (especially the posterior medial), moving the arm inward, reducing the stress at the internal fixation joint, and diminishing the risk of internal fixation fracture (12-14). Furthermore, intramedullary fixation effectively reduces surgical trauma and is more conducive to the early functional exercise of patients. New fixation systems developed in recent years such as PFNA and InterTAN have made up for the deficiencies of previous intramedullary nails (12-14). Despite the fact that most patients with intertrochanteric fractures can achieve a favorable reduction via internal rotation, adduction, and other methods, there are still 11–17% of fractures that cannot achieve satisfactory alignment through closed reduction (15,16). Such fractures are sometimes not significantly comminuted, but are difficult to reduce due to mechanisms of injury (rotational compression) and traction of surrounding muscles and tissues. Clinically, intertrochanteric fractures with difficulty in reduction are mainly sagittal irreducible fractures, that is, the fractures show fair reduction under orthographic X-ray but obvious displacement under lateral X-ray. This type of fracture mainly includes two types: (I) proximal fractures are anterior while distal fractures are posterior; (II) proximal fractures are posterior while distal fractures are anterior, of which the former type is more common. Most of the fracture lines of sagittal irreducible fractures run from posterior superior to anterior inferior, and are distributed along the intertrochanteric line, which usually involve the anteromedial femoral talus rather than the posterior medial talus. The lesser trochanter of the proximal anteriorly displaced fracture can be attached to the proximal or distal fracture, or it can be separated and displaced (see *Figures 1*,*2*). Its occurrence mechanism may include the following aspects: (I) soft tissues in front of the femur are destroyed and cannot limit the proximal fracture; (II) proximal fractures are displaced forward under the traction of the iliofemoral ligament, iliopsoas muscle, and pectineus muscle, and are abducted and externally rotated under the action of the tensor fascia lata and gluteus medius muscle; (III) distal fractures are located behind the proximal end due to contraction of the posterior femoris muscle and adductor muscle. It is worth noting that some scholars believe that the anterior displacement of proximal fractures can be mainly attributed to the iliopsoas muscle. However, since most of the anterior displacement of proximal fractures is often combined with fracture and dissociation of the lesser trochanteric muscle, and the insertion point of the iliopsoas muscle is just located in the lesser trochanteric muscle, the role of the iliopsoas muscle in proximal fracture displacement may not be obvious in such a case. Consequently, the iliofemoral ligament and the pectineus muscle may be more vital factors causing proximal anterior displacement. Fractures with proximal posterior displacement are relatively rare. Patients with such proximal fractures usually have no or partial involvement in the lesser trochanter and sometimes still have a distal attachment to the lesser trochanter. The mechanism of these fractures has not been definitively determined. It may have a close bearing on a distal fracture with a complete or partial lesser trochanter fracture displaced anteriorly under muscular traction, and a proximal fracture with a cortical tip

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just inserted into the iliopsoas muscle and behind the lesser trochanter. To sum up, irreducible fractures have a complex injury mechanism. Relying solely on repeated closed reduction will not only increase the radiation exposure risk of medical staff, but also increase local tissue damage, increase intraoperative and postoperative blood loss, and prolong the length of surgery. In view of this, doctors are advised to use the traction bed to make the orthostatic reduction satisfactory. If the fracture reduction is shown to be unsatisfactory by lateral fluoroscopy, careful study should be carried out on the fracture type and displacement direction of the patients. If great difficulties are encountered during reduction, auxiliary techniques should be used decisively for reduction. Neither blindly repeated traction or rotation reduction nor reduction with the help of intramedullary nails is advisable.

In the treatment of femoral intertrochanteric fractures, the goals of rebuilding a painless and stable hip joint, restoring walking ability as soon as possible, and reducing complications are expected to be achieved. Studies have found that about 75% of intertrochanteric fractures are not ideally reduced. Poor hip joint function and complication rates have a close bearing on poor reduction (5,17). Based on this, favorable fracture reduction combined with strong osteosynthesis is a prerequisite for patients to obtain satisfactory clinical efficacy. Open reduction has been used by many scholars in the past to treat irreducible fractures. Such a method requires less fluoroscopy, but often requires severing the muscles around the proximal femur, resulting in greater surgical trauma (18). For the purpose of reducing surgical trauma, assisted reduction techniques such as reduction by leverage and clamp reduction combined with intramedullary nails have been adopted in recent years by most doctors to treat irreducible intertrochanteric fractures, and favorable clinical efficacy has been achieved (4,7,14,19). It was found in a study conducted by Chun *et al.* (20) that reduction by the leverage technique is a safe and effective method for the treatment of intractable fractures, which allows the fracture to be reduced satisfactorily, and does not significantly prolong the anesthesia time and postoperative overall recovery time of patients compared with the treatment of reducible fractures. It was demonstrated by Zhang *et al.* (6) that the Steinmann pin assisted reduction method had the advantages of less trauma and satisfactory reduction effect in the treatment of intertrochanteric fractures compared with open reduction, and could achieve favorable clinical efficacy. The above findings are similar to our study results. As found in this study, most of the irreducible fractures could be reduced by reduction by leverage, and no complications related to surgical procedures (such as iatrogenic fractures and vascular and nerve injuries) occurred in the patients. Most of the patients achieved satisfactory recovery of hip function and independent walking ability postoperatively. Regular follow-up showed that the hip function and quality of life of the patients recovered most significantly within 1 year after the operation, but no significant improvement was found after 1 year, indicating that attention should be paid to early functional exercise after injury by doctors and patients. Patients should walk with weight as soon as their condition permits and receive rehabilitation guidance from professional physicians when necessary. Despite the close correlation between fracture reduction and surgical efficacy, the key factor determining the treatment regimen is not the fracture itself, but the comprehensive condition of the patients for the elderly patients (21,22). For patients with poor physical conditions, blind pursuit of anatomic reduction is not desirable. Repeated continuous reduction and prolonged surgery and anesthesia may lead to a significant increase in postoperative hidden blood loss in patients, which in turn leads to an increased risk of complications in patients (23-25). Therefore, priority should be given to the alignment of the fracture rather than complete reduction for frail elderly patients.

In recent years, with the continuous deepening of research on the mechanism and treatment of refractory intertrochanteric fractures, assisted reduction techniques have been more and more widely applied in clinical practice. Said *et al.* (26) performed reduction by leverage on the broken end of the fracture using a retractor at the incision of the fracture. Carr *et al.* (27) carried out reduction by leverage by inserting the bone hook and dissector through the lateral incision. In case of difficulty in reduction, an anterior lateral incision can be added to assist the reduction. In China, the proximal femur was exposed through an anterolateral incision, and then the proximal femur was reduced by means of a Steinmann pin and reduction forceps (17). Although new approaches are provided by these techniques for the treatment of difficult intertrochanteric fractures, they all require one or more additional surgical incisions, which not only increases the surgical trauma and prolongs the operative time, but may also affect the healing of the fracture by exposing the fracture end. In this study, all fractures were reduced through a surgical incision made at the insertion point of the intramedullary nail head or the main nail. With such a treatment regimen, surgical

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trauma and interference with the fracture site are reduced and favorable clinical outcomes are achieved. Most patients in this group can obtain satisfactory reduction through a greater trochanter incision, but for patients with poor reduction or complex proximal fractures, and for patients whose reduction device interferes with the insertion of the guide pin or main nail, fracture reduction through an incision at the head nail location is required. In addition, accurate insertion of intramedullary nails is also the key to successful surgery. Attention should be paid by doctors to the following: (I) the nail insertion point should be at the tip of the greater trochanter. When the patient is obese or soft tissue obstruction causes the needle insertion point to move out, the incision can be appropriately extended or the jamming bit can move inward; (II) when reaming, attention should be paid to the "fast rotation and slow advance" of the drill bit to prevent the fracture from being displaced again when the drill bit is drilled; (III) when placing the nail or reaming, a periosteum dissector should always be used to lift or repress the fracture end to prevent fracture displacement.

Nevertheless, there were still some shortcomings in this study: (I) there are various types of refractory fractures. Some fracture types, such as simple small trochanteric related refractory fractures, were not studied because fewer cases were included in this group; (II) patients with reverse intertrochanteric fractures were not included in this study, but we believe that the reduction by leverage technique may be suitable for these patients as well; (III) this was a single center study with data only from Qilu Hospital.

In summary, mini-incision assisted reduction combined with intramedullary nail internal fixation boasts various advantages in the treatment of irreducible femoral intertrochanteric fracture. With such a treatment regimen, favorable clinical results can be obtained, and the walking ability and quality of life of the patients can be improved postoperatively. Refractory intertrochanteric fractures are complex in terms of injury mechanism, and the type of fracture should be carefully analyzed by doctors preoperatively. In case of difficulties in the closed reduction by the traction table during surgery, the relevant instruments should be used to assist the reduction in time to reduce the surgery time of patients and improve the quality of fracture reduction.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-2846/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-2846/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-2846/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study obtained approval from the Ethics Committee of Qilu Hospital (Qingdao), Cheeloo College of Medicine, Shandong University (approval No. 20131164), following the principle of the Declaration of Helsinki (as revised in 2013). The patients have signed informed consent.

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(English Language Editor: C. Betlazar-Maseh)

Cite this article as: Jiang T, Gao H, Liu T, Kang S, Bao F, Huang D, Hu Y. Observation of the clinical efficacy of percutaneous reduction by leverage combined with intramedullary nail internal fixation in the treatment of irreducible femoral intertrochanteric fracture: a retrospective single-arm cohort study. Ann Transl Med 2022;10(15):822. doi: 10.21037/atm-22-2846

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