A localization method for guide pin insertion points in the treatment of femoral neck fracture with closed reduction and percutaneous cannulated screw fixation

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Background: Closed reduction and percutaneous cannulated screw fixation is the preferred surgical method for treating femoral neck fractures in elderly patients under 70 years old. The key to the operation is the precise insertion of the guide pin after the successful reduction. However, there is no universally accepted standard for the localization of the guide pin insertion point. This study introduces our invention of a localization method for guide pin insertion points.

Methods: We used fluoroscopic frequency, operative time, union rates, and complications to retrospectively evaluate the treatment and outcome of femoral neck fractures using our localization method for guide pin insertion points. The study included ten patients treated at Affiliated Hospital of Shandong University of Traditional Chinese Medicine between 2010 and 2014 for femoral neck fracture using our localization method for guide pin insertion points.

Results: Our results showed that the mean number of fluoroscopies was 5 (range, 4–8), and the mean operative time was 32 minutes (range, 25–51 minutes). All 10 patients achieved union at an average of 3.4 months (range, 2.8–6.2 months) without complications after the operation. The average follow-up time was 13.2 months (range, 12.2–16 months). The treatment of femoral neck fracture with our localization method for guide pin insertion points resulted in satisfactory curative efficacy without complications.

Conclusions: Our localization method offers distinct advantages, including the accuracy and simplicity of the operation, a low rate of complications, and adequate biomechanical stability. As such, it provides a feasible method for clinical treatment.

Keywords: Localization method; guide pin insertion points; femoral neck fracture

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Introduction

Femoral neck fracture is a common injury in elderly patients. The incidence of femoral neck fracture accounts for approximately 3–4% of all fractures and 50–60% of hip fractures. The incidence is rising due to an increase in traffic accidents and an aging population (1-3). Surgical treatment is the best choice for those with displaced femoral neck fractures. The use of the three-flange nail was a milestone in the history of femoral neck fracture treatment, marking an era of internal fixation in treating femoral neck fractures (4). As a result of recent advances in surgical expertise and equipment, numerous internal fixation methods and

Table 1 Selected patient demographics and operative outcomes

Variable	Value
Total number of patients	10
Average age [range]	67 [61–70] years
Sex	
Male	4
Female	6
Affected side	
Left	5
Right	5
Garden type	
Type II	4
Type III	6
Average length of follow-up [range]	13.2 [12.2–16] months
Mean fluoroscopic frequency [range]	5 [4–8] times
Mean operative time [range]	32 [25–51] minutes
Average time to healed X-ray [range]	3.4 [2.8–6.2] months
Complications (%)	0
Nonunion	0
Infection	0
Vascular nerve injury	0
Necrosis of femoral head	0

materials are available (5). Among them, closed reduction and percutaneous cannulated screw fixation, using three parallel cannulated screws placed in an inverted triangle configuration, is the preferred surgical method for elderly patients under the age of 70 (6-11). Precisely locating the insertion point of the guide pin after successful reduction is the key to successful surgery. However, there is no literature available on the precise localization method of the guide pin insertion points. Only a few studies have reported that the lower guide pin insertion point was located within 3–5 cm of the greater trochanter of the femur or at the level of the lesser trochanter of the femur (12-14); the upper two guide pin insertion points were located based on the doctor's experience and the location of the lower points. But these localization methods are relatively vague and do not consider the patient's personal characteristics. Meanwhile, repeated fluoroscopy and drilling is required to verify the location of the guided needle during the insertion process. This can cause increased radiation damage to the doctors and patients and extends the surgery time. Once again, these localization methods are inaccurate, and the scope of the insertion point is too large. These methods require repeated drilling to optimally adjust the guide pin position during screw placement, which inevitably affects the strength of the underlying bone. Therefore, we designed a localization method for guide pin insertion points and achieved satisfactory curative efficacy in our clinical practice. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-937/rc).

Methods

Closed reduction and percutaneous cannulated screw fixation with three parallel cannulated screws placed in an inverted triangle configuration is the first choice for treating femoral neck fractures. In all surgical procedures, precise guide pin insertion is the key to successful surgery. It can reduce the number of fluoroscopies required and the radiation damage to doctors and patients. At the same time, it can effectively avoid damage to the sclerotin and blood supply of the femoral neck caused by repeated needling. In our clinical treatment, we designed a new localization method for guide pin insertion points using C-arm fluoroscopy. We conducted a retrospective review of 10 patients treated at Affiliated Hospital of Shandong University of Traditional Chinese Medicine between 2010 and 2014 for femoral neck fracture using our localization method for guide pin insertion points. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Affiliated Hospital of Shandong University of Traditional Chinese Medicine (No. 2022-017-KY). Individual consent for this retrospective analysis was waived. The patients' demographics are summarized in *Table 1*. Patient operative records and radiographs were reviewed to identify patients treated with our localization method. Fluoroscopic frequency and operative time were recorded during the operation. Moreover, union rates and postoperative complications were recorded during the follow-up period. Union was defined as radiographic evidence of healing in three out of four cortices and clinical ambulation without any pain.

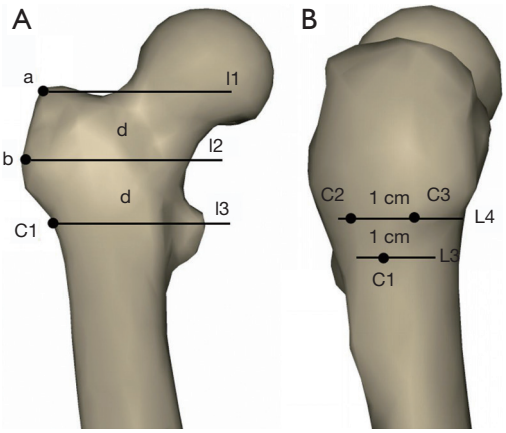

Figure 1 The localization method of the guide pin insertion point. (A) Diagram of the lower guide pin insertion point (the intersection point C1 of line l3 and the lateral cortex of proximal femoral head); (B) diagram of the upper two guide pin insertion points (points C2 and C3).

The localization method of the lower guide pin insertion point

Firstly, we determined the apex point (a) and the highest lateral point (b) of the greater trochanter by palpating the hip. Two horizontal lines (l1 and l2) with a vertical distance of (d) were drawn through points (a) and (b) using the guidance of the anteroposterior radiographs. The horizontal line l3 was then drawn with a vertical distance of (d) from point (b). The intersection point (C1) of line l3 and the lateral cortex of the proximal femoral head was the lower guide pin insertion point (*Figure 1A*). Because the guide pin must penetrate the skin and soft tissue to arrive at point C1, and the direction of the guide pin is parallel to the femoral neck with anteversion of the guide pin controlled at about 10 degrees, the thickness of the soft tissue should be considered when determining the guide pin insertion point on the skin, which should be lower than point C1. Lastly, we placed the guide pin close to the inferior cortical bone of the femoral neck, penetrating through the femoral calcar and compression trabeculae to the cortical bone of the femoral head. For the convenience of manipulation and before fluoroscopy, a Kirschner wire was placed on the front of the hip and located at the central axis of the femoral neck in accordance with the above requirements. The position of the Kirschner wire was adjusted according to the fluoro-images.

The localization method of the upper two guide pin insertion points

The upper two guide pins should be implanted after the successful implantation of the lower guide pin. They were located on horizontal line L4, with a vertical distance to L3 of approximately 1 cm. The horizontal distance between the two insertion points marked as C2 and C3 was approximately 1 cm (*Figure 1B*). As with the lower guide pin, the thickness of soft tissue should also be considered when determining the guide pin insertion points on the skin. Additionally, the guide pins were placed close to the posteroposterior cortical bone and the superoanterior cortical bone of the femoral neck. The three guide pins were placed evenly in an inverted triangle configuration in the femoral neck.

Screw implantation method

Three guide pins were implanted at points C1, C2, and C3, parallel to the direction of the femoral neck. The distance between the anterior end of the guide pins and the cortical bone of the femoral head was approximately 5–10 mm. Three 0.5 cm guide pin-centric skin incisions were made carefully. Finally, three cannulated screws of moderate length were implanted along the guide pins at a 110-degree neck-shaft angle. The screw position was evaluated to determine correct parallelism and positioning in the femoral head and neck. The three cannulated screws should pass through the fracture line simultaneously to gain the dynamic compression needed to reduce the gap at the fracture site and enhance stability.

Statistical analysis

All data are shown as mean ± standard deviation ($\bar{x}$±s) and were calculated using the SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). A P value <0.05 was considered statistically significant.

Results

The study included 10 patients (4 males and 6 females) treated at Affiliated Hospital of Shandong University of Traditional Chinese Medicine between 2010 and 2014 for femoral neck fracture using our localization method for

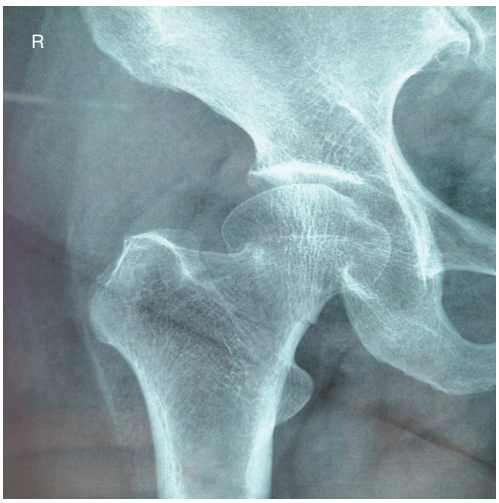

Figure 2 Preoperative radiograph of a left displaced Garden III femoral neck fracture (R: right limb).

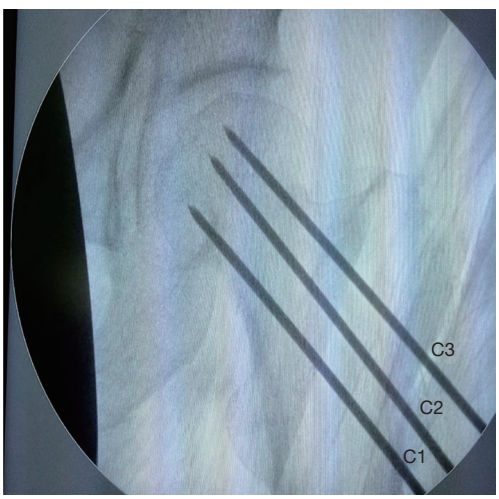

Figure 3 The three guide pin insertion points (C1, C2, and C3) are identified with our localization method.

guide pin insertion points. The average age was 67 years (range, 61–70 years). Four were type II, and six were type III based on the Garden Index. They all had fresh closed fractures caused by direct violence. We conducted regular postoperative follow-ups and recorded the fluoroscopic frequency, operative time, union rates, and postoperative complications.

The 10 patients received an average of 13.2 months (range, 12.2–16 months) of postoperative follow-up. The mean number of fluoroscopies was 5 (range, 4–8), and the mean operative time was 32 minutes (range, 25–51 minutes).

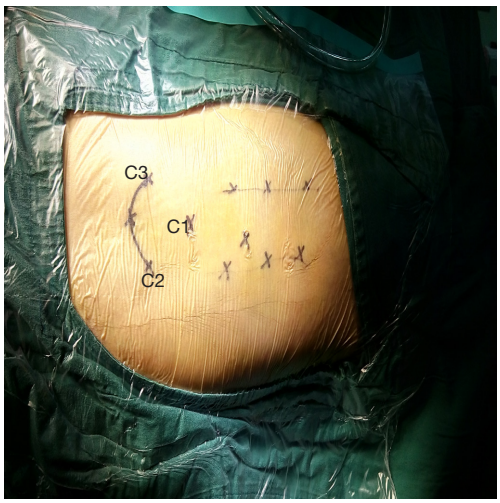

Figure 4 The three guide pins are inserted through the three guide pin insertion points.

On average, all 10 patients achieved union at 3.4 months (range, 2.8–6.2 months) without infection, vascular nerve injury, nonunion, or other postoperative complications. Union was identified by the treating surgeon by observing clinical ambulation without pain and radiographically by healing in three out of four cortices.

Patient case presentation

The patient was a 63-year-old male worker, previously fit and well, who fell and hurt himself by accident. He felt severe pain in his left hip and was sent to Affiliated Hospital of Shandong University of Traditional Chinese Medicine immediately. We found external rotation deformity of his left limb and performed an X-ray examination. Unfortunately, we found a left femoral neck fracture (Garden Index III) (*Figure 2*). Due to the significant displacement, the patient was treated surgically with closed reduction and percutaneous internal fixation using three parallel cannulated screws placed in an inverted triangle configuration. The three guide pins were inserted (*Figure 3*) into the three guide pin insertion points (C1, C2, and C3) that had been located with our localization method (*Figure 4*). Then three parallel cannulated screws were implanted to fix the fracture (*Figure 5*). Postoperative follow-up was performed periodically over 12 months to evaluate the hip function and observe complications. Overall, we achieved a satisfactory therapeutic outcome without complications (*Figure 6*).

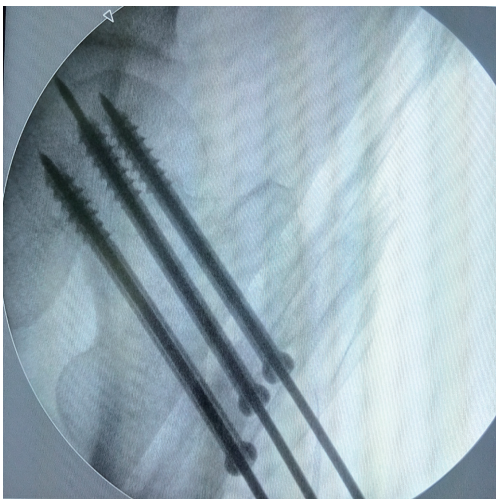

Figure 5 Three parallel cannulated screws are implanted according to the guide pins to fix the fracture.

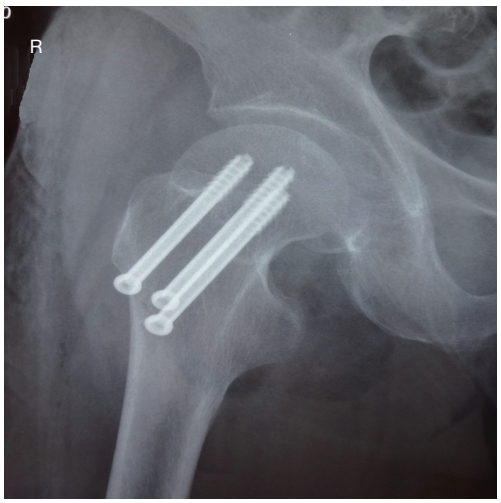

Figure 6 Postoperative radiograph. The fracture is fixed with three parallel cannulated screws placed in an inverted triangle configuration (R: right limb).

Discussion

There is a high incidence of femoral neck fracture in elderly patients because of osteoporosis, degeneration of hip muscles, bone fragility in Ward's triangle area, and changes in bone structure (6). Displaced femoral neck fractures have a significant rate of poor outcomes due to a high incidence of complications, among which nonunion and osteonecrosis of the femoral head are the two most commonly encountered and intractable (15). On the one hand, it is because of significant damage to the blood supply to the femoral head and femoral neck; On the other hand, it is due to the considerable shear stress and the comminution of the posteromedial cortex at the fracture site, which result in the loss of the buttressing effect against lateral rotation. In this study, with C-arm fluoroscopy guidance, we used closed reduction and percutaneous cannulated screw fixation, which has the advantages of less trauma, simplicity of operation, minimal damage to the blood supply of the femoral head, good anti-rotation ability, and strong compression ability at the fracture end; thus, it is the preferred surgical method for the treatment of femoral neck fractures in elderly patients. Overall, this procedure includes three important steps: (I) close reduction; (II) guide pin insertion; and (III) screw fixation. Of these, ideal or anatomical closed reduction is the premise, precise guide pin insertion is the key, and strong screw fixation is the guarantee.

Closed reduction surgery is a well-established and widely used clinical treatment for femoral neck fracture. We performed closed reduction based on the principle of traction along the limb's vertical axis with reduction to reverse the trauma mechanism. Then, Garden's alignment index (16) was used to evaluate the reduction quality, where grade I was optimal, grade II was acceptable, and grades III and IV were considered failures. Lastly, many scholars (10,17) have emphasized the importance of the selection and placement of the internal fixators in stabilizing femoral neck fractures. To avoid overdrilling, internal fixation using three parallel cannulated screws placed in an inverted triangle configuration was implemented in our study. This screw configuration can sustain high shearing stress, provide bending resistance and anti-torsional strength, and withstand greater axial stress. Furthermore, the incidence of complications such as subtrochanteric fracture, nonunion, and osteonecrosis of the femoral head is very low using this configuration. Additionally, after much discussion and biomechanical experiments, this configuration shows a good biomechanical effect (9,10,18,19). Thus, it has been widely implemented in clinical practice. We also used this screw configuration and gained a satisfactory curative outcome in our clinical treatment.

Appropriate placement of the guide pins is crucial for treating femoral neck fractures with cannulated screws. However, it is not easy to insert the guide pin at the correct position and drill straight along in the right direction. Precise guide pin insertion is the key to successful surgery

in the entire surgical procedure. It can reduce the number of fluoroscopies required and the radiation damage to doctors and patients. At the same time, it can effectively avoid damage to the sclerotin and blood supply of the femoral neck caused by repeated needling. To reduce fluoroscopy and drilling frequency and obtain the best screw configuration, it is necessary to improve the localization methods in surgical techniques, just as corresponding matching apparatus for treating fractures are constantly updated with the rapid development of medical technology.

Special instruments, such as a novel guidewire aiming device (20), a self-designed femoral neck guide pin locator (21), a new adjustable parallel drill guide (22), and robot navigation (23,24) have reportedly been used for the placement of guiding needles. They are believed to have the potential to improve the precision of guide pin insertion. Although these have achieved satisfactory results and are operationally convenient, they have not been promoted in clinical practice because of their relatively high cost and complications. On this basis, we constantly assess and summarize our experiences in clinical practice and have consequently designed a localization method for guide pin insertion points. This method guided our operations, and satisfactory curative efficacy was achieved. In our study, we observed a 100% union rate without complications after surgery.

Our localization method for guide pin insertion points has many advantages. Firstly, the lower guide pin insertion point was based on the distance between the apex and the highest lateral point of the greater trochanter, measured by the anteroposterior radiographs. This method locates the guide pin insertion points quite precisely and avoids the impact of the patient's personal characteristics. Secondly, the distance between the upper two guide pins and between the upper and lower guide pins was measured by the lateral radiographs. These two distances are both 1 cm. The three guide pins should be placed close to the posteroposterior cortical bone, the superoanterior cortical bone, and the inferior cortical bone of the femoral neck in proper sequence. They are distributed in the shape of an inverted isosceles triangle and parallel to each other. Biomechanical experiments have shown that this distribution provides a stronger biomechanical effect, better torsional and anti-rotational effects, and greater axial stiffness and axial failure load (25). Thirdly, the guide pins were uniformly distributed in the femoral neck, and the distance between them is large enough using our localization method. It can significantly decrease the incidence of complications, such as nonunion and necrosis of the femoral head (8,26).

Our localization method of guide pin insertion points is suitable for patients under 70 years old with fresh, closed Garden I, II, or III type femoral neck fractures. But it cannot be used in patients with severe osteoporosis. All 10 patients in our study conformed to these criteria.

In our clinical practice, we have found that our localization method for guide pin insertion points has contributed to improved operation quality and has reduced intraoperative injury. Additionally, the accuracy of the guide pin insertion has improved with the help of the pre-located Kirschner wire, which has allowed for the initial judgment on the insertion points, the collodiaphyseal angle, and the anteverted angle. We insert the lower guide pin first because an appropriate lower guide pin insertion can lay a good foundation for the upper two guide pins. In addition, our localization method reduces the frequency of guide pin drilling because it can accurately adjust the position and direction before any drilling attempts. Furthermore, our localization method reduces the surgery difficulty, shortens the operation time, and improves the surgical outcome.

In conclusion, our localization method is accurate, simple to operate, and has sufficient theoretical support. However, although we have achieved satisfactory clinical outcomes, biomechanical experiments have yet to be performed to verify the reliability of our method. Moreover, there is little literature on this treatment plan, and future prospective studies with larger sample sizes are needed to confirm our results. Therefore, we can only provide a clinical reference for the localization of guide pin insertion points. Further experiments will be performed to confirm the scientific robustness and reliability of our method.

Conclusions

We designed a localization method for guide pin insertion points to assist surgeons in inserting cannulated screw guide pins accurately when treating femoral neck fractures with closed reduction and percutaneous cannulated screw fixation. Furthermore, this localization method can enhance the accuracy of cannulated screw guide pin insertion without increasing operative time or iatrogenic injury. Therefore, the localization method is suitable for clinical application and deserves to be promoted.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-937/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-937/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-937/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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Affiliated Hospital of Shandong University of Traditional Chinese Medicine (No. 2022-017-KY). Individual consent for this retrospective analysis was waived.

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