Research on Correlation between Fluoroscopy at Anteroposterior and Lateral Position in Operation for Intertrochanteric Femoral Fracture

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Abstract

Objective: To explore and summarize the relationship between neck-shaft angle (NSA) of guide pin at anteroposterior film and anteversion angle of guide pin at lateral film under guidance of fluoroscopy by the conventional C-arm X-ray. To design personalized position distribution table of femoral neck guide pin. To guide the adjustment of femoral neck guide pin position.

Methods: Intraoperative imaging data of 50 patients with intertrochanteric fracture were analyzed. The angle between femoral intramedullary nail with femoral neck screw guide pin at anteroposterior film was defined as NSA of guide pin, while the angle between femoral intramedullary nail with femoral neck screw guide pin at lateral film was defined as anteversion angle of guide pin. NSA and anteversion angle were measured respectively. And SPSSv19.0 was used to statistically analyze their relationship. Based on CT data, Mimics10.0 (image processing software) was used to analyze the anatomic features of proximal femur and to establish the 3D model of proximal femur. According to the relevant parameters, Pro/E software was used to establish the models of main intramedullary nail and the guide pin. Surgery was simulated on Pro/E software platform. Intramedullary nail and the guide pin were placed into the best location of the femur to establish an idealized operation model. According to the relative position relations of the femur and intramedullary nail model, solid geometry analysis was used to analyze and calculate the correlation between NSA and anteversion angle. NSA-anteversion correlation curve and personalized position distribution table of femoral neck guide pin were designed.

Results: NSAs and anteversion angles of 50 patients with intertrochanteric fracture were measured under anteroposterior and anteversion position respectively. The results were statistically analyzed to prove the relationship between NSAs and anteversion angles. The 3D model was realistic and the three-dimensional visualization effect was good. Virtual surgery design was consistent with the actual intraoperative situation. The positions of intramedullary nail and guide pin were ideal. And the geometric parameters related with the computations were extracted. Within the perspective, O-XYZ coordinate system, NSA and anteversion angle were calculated. According to its relevance, simple position distribution figure of guide pin is formulated.

Conclusion: Through the analysis on the clinical cases and 3D model, it was found that there was a relationship between intraoperative neck-shaft angle of guide pin at anteroposterior film and intraoperative anteversion angle of guide pin at lateral film. Intraoperative axial rotation of femoral intramedullary nail was used to adjust the position of femoral neck screw guide pin. The neck-shaft angle was increased with the increase of anteversion angle. When the anteversion angle was decreased, the neck-shaft angle was also reduced. Therefore, we develop a personalized position distribution table of femoral neck guide pin to guide the adjustment of intraoperative femoral neck guide pin position.
Keywords: Intertrochanteric Fracture; 3D Modeling; Internal fixation; Guide pin

Introduction

Intertrochanteric femoral fracture is the most common hip fracture, which is often seen in middle and elder people. With the improvement of living standards, increased traffic accident and human life extension, the incidence of intertrochanteric femoral fractures is rising, and patients put forward higher requirements for fracture recovery [1]. There are two main treatments for intertrochanteric femoral fracture: conservative treatment and surgical treatment. The conservative treatment with poor curative effect is prone to developing complications such as infection, bedsore, pulmonary embolism, etc. and the patient’s mortality rate is higher, so it has almost been renounced in clinical. Conservative treatment will be given to only a few of patients with very poor general condition, who can’t tolerate anesthesia and surgery treatment. Surgical treatment is the preferred treatment for intertrochanteric femoral fracture [2]. Intramedullary nail fixation represented by PFNA and InterTan is the most commonly used surgical treatment by far, and the curative effects are also affirmed [3]. It seems simple to treat intertrochanteric femoral fracture by intramedullary nail fixation; however, the entry position and spatial distribution of screw in femoral neck are stringently required [4]. It has certain difficulty to accurately drive a screw into the narrow femoral neck. So, C-arm machine for repeat fluoroscopy or a wide range of stripping and exposure is often needed to obtain satisfactory position. How to accurately place a screw guide pin into the femoral neck under fluoroscopy has been the problem faced by the orthopedic surgeons. We find in clinical work that there is a certain rule to adjust femoral neck guide pin under fluoroscopy at anteroposterior and lateral position during the operation. The angle between the axis of the main femoral intramedullary nail with the axis of the screw guide pin of the femoral neck at the anteroposterior position is defined as the neck shaft angle (NSA), and the angle at the lateral position is defined as the anteversion [5].

Whether the internal fixation for intertrochanteric fractures smoothly largely depends on the placement technique of femoral neck guide pin. This process seems simple but it has certain difficulty to accurately drive a screw into the narrow femoral neck, and it often needs multiple fluoroscopy’s to insert the proper guide pin. Currently, most of the surgeries are performed guided at anteroposterior and lateral position. The positioning technologies of femoral neck guide pin used in clinical include [6]: 1. The empirical method: the pin is posited based on the operator’s experience. This method has the disadvantages of rough positioning, high failure rate and aggravated injury due to repeat needling. 2. Direct vision method: The femoral neck and head are fully exposed under the direct vision. This method destroys the joint capsule with large trauma, large amount of bleeding and many postoperative complications. 3. Assist with locator: Direct needle puncturing is performed with the aid of all kinds of positioning devices, which is a popular issue in the research in recent years. But affected by the design of the internal fixation system, there is certain difficulty to develop the locator. Most of the locators used in the clinical now are manual controlled, with blindness and randomness. In addition, in the traditional surgery, the doctors need to establish abstract 3D images on the basis of 2D images through a comprehensive spatial thinking. Because of the patient’s individual differences and the different individual thinking ways of the surgeons, the understanding on the position of the guide pin may have some deviation and differences, thus producing adverse effects to the accuracy of the operation. During the operation, it often requires repeated attempts to achieve a satisfactory position of guide pin, and sometimes the guide pin even may be mistakenly inserted into the joint cavity, thus damaging the normal joint. So, we need a method that can accurately adjust the spatial position of the guide pin by anteroposterior and lateral film, so as to improve the operation efficiency and reduce the intraoperative vice injury.

There is correlation between NSA and anteversion when the main femoral intramedullary nail is rotated along the axis during the operation to adjust the location of femoral neck screw guide pin. This research quantizes the correlation between NSA and anteversion through multiple fluoroscopy’s analysis (such as analysis on clinical cases, 3D simulation operation and geometry processing) on the clinical phenomenon. And based on this phenomenon, personalized distribution map of femoral neck guide pin is established, to guide the location adjustment of femoral neck guide pin.

Materials and Methods

Analysis on clinical cases

Research objective: Inclusion criteria: (1) Patients with intertrochanteric femoral fracture were enrolled in this study, all of whom were admitted in our hospital from March 2007 to October 2013. (2) Patients were all undergone closed reduction and internal fixation with femoral intramedullary nail under 2D fluoroscopy. (3) Intraoperative fracture end was well reset that basically achieved the anatomical repositioning. (4) The position of the guide pin in femoral neck was adjusted through changing entry point by axial rotation of the main intramedullary nail, and the image data was completed and conformed to the clinical criteria. Exclusion criteria: (1) Femoral fracture at other parts of the same side; (2) Pathological intertrochanteric femoral fracture; (3) Old intertrochanteric femoral fracture. 50 cases of patients were included in this study, where 30 cases were male and 20 cases were female; the age ranged from 60 to 85 years old, with an average of 76 years old; all of the patients were with intertrochanteric femoral fracture, where 28 cases were with fracture on the left side and 22 cases were with fracture on the right side. It seems simple to treat intertrochanteric femoral fracture by intramedullary nail fixation; however, the entry position and spatial distribution of screw in femoral neck are stringently required [4]. It has certain difficulty to accurately drive a screw into the narrow femoral neck. So, C-arm machine for repeat fluoroscopy or a wide range of stripping and exposure is often needed to obtain satisfactory position. How to accurately place a screw guide pin into the femoral neck under fluoroscopy has been the problem faced by the orthopedic surgeons. We find in clinical work that there is a certain rule to adjust femoral neck guide pin under fluoroscopy at anteroposterior and lateral position during the operation. The angle between the axis of the main femoral intramedullary nail with the axis of the screw guide pin of the femoral neck at the anteroposterior position is defined as the neck shaft angle (NSA), and the angle at the lateral position is defined as the anteversion [5].

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on the right side. Causes: 8 cases of traffic injury, 35 cases of fall injury and 7 cases of high falling injury. All of the fractures were fresh closed fractures.

**Operation process and angulation:** All of the patients were undergone reduction and internal fixation for intertrochanteric femoral fracture. The main intramedullary nail was placed into the proper location in the femoral shaft according to the standard surgical procedures. For the first-time guide pin was placed into the femoral neck, and poor location of the guide pin was seen under fluoroscopy at anteroposterior and lateral position during the operation; the main nail was rotated along its longitudinal axis to adjust the entry point of guide pin, and the guide pin was replaced, then fluoroscopy was performed again at anteroposterior and lateral position. The angle between the axis of the main femoral intramedullary nail and the axis of the screw guide pin of the femoral neck at the anteroposterior position is defined as the neck shaft angle (NSA), represented as α. And the angle between the main axis of the femoral intramedullary nail and the axis of the screw guide pin of the femoral neck at the lateral position is defined as the anteversion, represented as β. The intraoperative imaging data of 50 mentioned cases were collected. Professional drawing software was used to measure the NSA and anteversion of the guide pin at anteroposterior and lateral position before and after adjustment of guide pin, respectively, namely α1, α2, β1 and β2. SPSS v19.0 was used for statistical research, and the correlation between NSA of guide pin at anteroposterior position and anteversion of the guide pin at lateral position was analyzed.

**Model establishment**

**Equipment and software:** CT: 64 slice spiral CT (GE company, USA); Computer: CORE i7, 8G memory, 635MNVIDIA graphics card and 48.26 cm (19 inch) LCD; Software: medical modeling software Mimics10.01 (Materialize company, Belgium), and Pro/E software 3.0.

**Modeling of femur and intramedullary nail:** One patient was randomly selected from 50 cases of patients to extract raw CT data. Data requirements: the patient was given postoperative CT scan, with the scan scope from hip to lower 1/3 of the femur; the slice gap of each scan was 1 mm, the density of pixel matrix was 512×512 and each pixel was assigned 2 bytes in CT image. The obtained CT images were stored in Dicom format.

**Femoral geometric model was set up:** patient’s data in Dicom format was imported into Mimics10.01. Through image positioning, threshold setting, dynamic area growth and hole repair, the redundant data was removed, and the 3D visualization model of femur was rebuilt finally and exported in lis format. Geometry model establishment of intramedullary nail: according to PFNA intramedullary nailing data provided by SYNTHES, Pro/e software was applied to establish intramedullary nail model and guide pin model, which was derived in the lis format. And femoral model and intramedullary nail model were shown in (Figure 1).

![Figure 1: Femoral and intramedullary nail model.](image)

**Measurement on curvature radius of femoral shaft**

Femoral shaft was bended to the anterolateral direction. Mimics10.01 was used to draw axis of femoral marrow cavity, and the physical radian of marrow cavity axis from the site of 2 cm under femoral intertrochanteric to lower 1/3 of femur was measured, presented with curvature radius (R) (Figure 2).

![Figure 2: Measurement on curvature radius of femur.](image)

**Simulation operation**

1. Data file of femur, main intramedullary nail and guide pin in lis format was imported into software Pro/E 3.0, and respectively saved as Pro/E components;
2. In model of femoral component, axis of femoral neck \(L_2\), axis of proximal femoral shaft \(L_3\) and axis of distal femoral shaft \(L_4\) were found and established through measurement. In model of main intramedullary nail, axis of main nail \(L_1\) was found and established through measurement. In model of guide pin, axis of guide pin \(L_5\) was found and established through measurement.
3. New assembly was established in software Pro/E, and the model of femoral component was imported and fixed on the acquiescent default location; component model of main intramedullary nail was inserted along the axis of proximal femoral shaft \(L_1\), to recombine \(L_1\) and \(L_5\) and adjust the main nail to the appropriate depth. The positions of main intramedullary nail and guide pin of femoral neck were fixed with the angle of 130°. Guide pin of femoral neck screw was placed; the guide pin and main intramedullary nail component were set as a whole, called intramedullary nail composite. With
axes $L_1$ and $L_5$ as well as $L_2$ and $L_4$ as reference, the position of intramedullary nail composite in femoral model was adjusted until meet the clinical standards.

**Mathematical analysis**

1) With the lower endpoint of the axis of distal femoral shaft ($L_3$) as the origin of coordinates (O), and the axis of distal femoral shaft ($L_5$) as the Zaxis, the plane through Z axis and parallel with axis of femoral neck ($L_1$) was defined as plane XOZ, and fluoroscopy coordinate system O-XYZ was established according to the right-hand rule. Anteroposterior fluoroscopy was defined as positively along the Y axis (XOZ plane projection), while lateral position fluoroscopy was defined as reversely along the X axis (YOZ plane projection).

2) With the lower endpoint of the axis of main intramedullary nail as the origin of coordinates (O$_1$), and the axis of main intramedullary nail ($L_4$) as the Z$_1$axis, the plane of the axis of main intramedullary nail and the axis of guide pin was defined as plane X$_1$O$_1$Z$_1$, and guide pin trajectory coordinate system O$_1$-X$_1$Y$_1$Z$_1$ was established according to the right-hand rule, as shown in (Figure 3).

3) After assembly, the main intramedullary nail and the femoral neck guide pin were considered as a whole. Through axial rotation of the main intramedullary nail, position of guide pin in the femoral neck was changed. When the main nail was rotated along its axis, the trajectory of the endpoint of the guide pin was a period of circular arc. The coordinate of the endpoint of guide pin can be determined based on the relative positions of femur and intramedullary nail with the sizes of femur and intramedullary nail. Then the changes of the angle between axis of main intramedullary nail and axis of guide pin under fluoroscopy at anteroposterior and lateral position can be determined, namely the changes of NSA and anteversion, as shown in (Figure 4).

Figure 3: Fluoroscopy coordinate system O-XYZ, guide pin trajectory coordinate system O$_1$-X$_1$Y$_1$Z$_1$.

Figure 4: The plane of the femoral neck guide pin is within the scope of the red line.

4) Fluoroscopy coordinate system O - XYZ was the fixed coordinate system. Based on the measured data, the origin of coordinate system O$_1$ of the guide pin trajectory coordinate system O$_1$-X$_1$Y$_1$Z$_1$ was ($x_1$, $y_1$, $z_1$) = (0,0,200 mm) at coordinate system O-XYZ. Rotation angle of coordinate system O$_1$-X$_1$Y$_1$Z$_1$ relative to coordinate system O – XYZ was $(\alpha_x, \alpha_y, \alpha_z) = (-10^\circ,4^\circ,t)$ (where t referred to the axial rotation angle of the main r intramedullary nail, with the change range from $-20^\circ$ to $20^\circ$; the positive direction was external rotation while the negative direction was internal rotation). The coordinate transformation matrix of coordinate system O$_1$-X$_1$Y$_1$Z$_1$ to coordinate system O – XYZ was matrix C.

$$C = \begin{bmatrix} \cos \theta_2 \cos \theta_3 & -\sin \theta_2 \sin \theta_3 & \sin \theta_3 & x_3 \\ \sin \theta_2 \cos \theta_3 + \cos \theta_2 \sin \theta_3 & -\cos \theta_2 \sin \theta_3 + \cos \theta_3 \cos \theta_2 & -\sin \theta_3 \sin \theta_2 & y_3 \\ \cos \theta_2 \sin \theta_3 + \sin \theta_2 \sin \theta_3 & \sin \theta_2 \cos \theta_3 + \sin \theta_3 \cos \theta_2 & \cos \theta_3 & z_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Note: In matrix C, $\theta_3 = t$, as the variable. The values of the transformation matrix were different due to different values of t.

According to measured data, in the coordinate system O$_1$-X$_1$Y$_1$Z$_1$, if the length of the guide pin was 100mm and the angle between guide pin and main nail was $130^\circ$, the coordinate of the endpoint of guide pin in the coordinate system O$_1$-X$_1$Y$_1$Z$_1$ would be $(-100 \times \sin(30^\circ),0,170) = (76.60,0,170)$. And when the main nail was in axial rotation, the coordinate of the endpoint of guide pin O$_3$ would be $(x_3,y_3,z_3)$ in the coordinate system O-XYZ, thus $[x_3,y_3,z_3,1]^T = C \times [-76.60,0,170,1]^T$, namely coordinates of O$_3$ were as follows:

$$x_3 = \cos \theta_2 \cos \theta_3 x_1 + \cos \theta_2 \sin \theta_3 x_2 + \sin \theta_3 y_1 + z_3$$

$$y_3 = \sin \theta_2 \sin \theta_3 x_1 + \cos \theta_2 \sin \theta_3 x_2 + \cos \theta_3 y_1 + z_3$$

$$z_3 = (-\cos \theta_2 \sin \theta_3 x_1 + \sin \theta_2 \sin \theta_3 x_2 + \cos \theta_3 y_1 + z_3) \times \cos \theta_3 + \sin \theta_3 \sin \theta_2 + \cos \theta_2 \cos \theta_3 x_3$$

Where $(x_3,y_3,z_3) = (-76.60,0,170)$

In the fluoroscopy coordinate system O-XYZ, the coordinate of O₁, O₂, and O₃ were (0,0,200 mm), (7.37, 18.31, 303.87), and (x₃, y₃, z₃). According to the coordinate values of O₁, O₂, and O₃, NSA of guide pin was calculated from plane XOZ and anteversion of guide pin was calculated from plane YOZ.

5) Calculation on NSA of guide pin:
To calculate the NSA of guide pin, the projection of O₁, O₂, and O₃ in the fluoroscopy plane at anteroposterior position XOZ should be calculated and recorded as O₁₁, O₁₂, O₁₃. Then the NSA of guide pin was the vertex angle \( \angle O₁O₁₁O₁₁ \).

(1) The coordinate of O₁ in the coordinate system O-XYZ was measured, as \((x₁, y₁, z₁) = (0, 0, 200)\)

(2) The coordinate of O₂ in the coordinate system O-XYZ was measured, as \((x₂, y₂, z₂) = (7.37, 18.31, 303.87)\)

(3) The coordinate of O₃ in the coordinate system O-XYZ was calculated, and the values were different for different rotation angles \( \theta \):
\[
\begin{align*}
\tau₁ &= \cos \theta₁ \cos \theta₂ \cos \theta₃ \cos \theta₂ \cos \theta₁ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \\
\tau₂ &= \cos \theta₁ \cos \theta₂ \cos \theta₃ \cos \theta₂ \cos \theta₁ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \\
\tau₃ &= \cos \theta₁ \cos \theta₂ \cos \theta₃ \cos \theta₂ \cos \theta₁ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \sin \theta₂ \\
\end{align*}
\]

Where \((x₁, y₁, z₁) = (-7.60, 0.170)\) and \(\theta₁ = -10^\circ, \theta₂ = 4^\circ\)

(4) The coordinate values of projection points \(O₁₁, O₁₂, O₁₃\) were \((0.0, 200), (7.37, 0, 303.87)\) and \((x₃, y₃, z₃)\) respectively.

(5) NSA of guide pin \( \theta₁ \) was obtained by triangle cosine theorem:
\[
\cos \theta₁ = \frac{a² + b² - c²}{2ab} \quad \Rightarrow \quad \theta₁ = \arccos \left(\frac{a² + b² - c²}{2ab}\right)
\]

Where \(a = \sqrt{(x₂-x₁)² + (y₂-y₁)² + (z₂-z₁)²} \), \(b = \sqrt{(x₃-x₂)² + (y₃-y₂)² + (z₃-z₂)²} \), \(c = \sqrt{(x₃-x₁)² + (y₃-y₁)² + (z₃-z₁)²} \)

Results

1. NSA \( \alpha \) and anteversion \( \beta \) of guide pin were measured in 50 clinical cases. The data was performed correlation analysis by SPSS19.0, and the results were shown as in (Figure 7). It can be seen from the correlation analysis results that there was significantly positive relationship between NSA and anteversion, and correlation coefficient of 0.0302 (P<0.05) showed statistical significance.

2. Curvature radius of the 3D femoral model - the curvature radius of medullary cavity was 90.02 cm. The virtual surgery was realistic with good 3D visual effects. The design of virtual surgery was in accordance with the actual intraoperative situation. The axis of main intramedullary nail was coincided with the axis of upper femur. The depth of insertion was proper. The guide pin of tension screw was located at the axis of femoral neck, and the tip apex distance was 22 mm.

3. When the main intramedullary nail was externally rotated and internally rotated of 20° at the standard location. The trajectory of endpoint of guide pin was curved. Under the fluoroscopy coordinate system O-XYZ, with the axial rotation angle of main intramedullary nail(t) as the variable, the changes of NSA of guide pin at anteroposterior position and anteversion of the guide pin at lateral position were observed through calculation, as shown in (Figure 7).
When the main intramedullary nail was externally rotated, as the \( t \) value was increased, the NSA of guide pin at anteroposterior position and anteversion of the guide pin at lateral position were both increased; when the main intramedullary nail was internally rotated, as the \( t \) value was decreased, the NSA of guide pin at anteroposterior position and anteversion of the guide pin at lateral position were both decreased.

4. According to the correlation between NSA and anteversion of guide pin, the personalized position map of femoral neck guide pin was designed and developed, as shown in (Figure 8).

The ideal position of screw in femoral head and neck is still controversial, but all the researchers agree that the position should be in the center or slightly posterior and inferior area of the femoral head and neck. Baumgaertner et al [11] have put forward the concept of TAD, and pointed out that in 198 cases of patients with intertrochanteric fracture, when TAD was less than 25mm, there was no one failure due to screw breakdown or piercing. In the simulation operation, the placed position was in the central of the femoral head and neck, namely the axis of the guide pin and the axis of the femoral head and neck were coincided, and TAD was 22mm. With this position as the standard, the main intramedullary nail was internally rotated and externally rotated, respectively. The guide pin swept a sectorial plane in the femoral head and neck, suggesting all the possible positions of the guide pin in the femoral head and neck.

Correlation between NSA and anteversion of guide pin

Through clinical research we found that the main intramedullary nail was rotated along the axis intraoperatively to change the entry point, as the anteversion of guide pin at lateral position was adjusted, the NSA of guide pin at anteroposterior position was also changed. As the anteversion of guide pin at lateral position was increased, the NSA of guide pin at anteroposterior position was also increased. Otherwise, as the anteversion of guide pin was decreased, the NSA of guide pin was also decreased. SPSS was applied to analyze the correlation between NSA and anteversion of guide pin, and the results showed very significant correlation.

In order to further quantify its correlation, 3D simulation operation and geometric analyses were adopted in this study to study the above clinical phenomenon, and the same conclusion was drawn: there was correlation between NSA of guide pin at anteroposterior position and anteversion of the guide pin at lateral position.
guide pin at lateral position was increased, the NSA of guide pin at anteroposterior position was also increased. Otherwise, as the anteversion of guide pin at lateral position was decreased, the NSA of guide pin at anteroposterior position was also decreased.

The author thinks that the reasons for this phenomenon are related with the special anatomical structure of the femur and the projection angle of X-ray. Femur is the longest long tubular bone in the human body, the medullary cavity was bended to the anterolateral direction. Yan Hongwei et al [12], have researched 52 cases of femoral specimens for the anatomical features of the whole exterior femur and the medullary cavity, the results showed that there is a uniform forward bending in the femur with the curvature radius of medullary cavity of (120.68±6.098) cm [7]. Both the length and the radius of medullary cavity play a conditional role in application of intramedullary nailing. When the main intramedullary nailing is placed along the medullary cavity of the proximal femur, the axis is accord with the axis of the medullary cavity at the proximal femur, and goes forward to the anterior and inferior area of the body. Most of the patients ignore the physiological bending of femur in intraoperative fluoroscopy; therefore, there is an angle between the axis of main intramedullary nailing and the projection plane of the anteroposterior film. So, the NSA and anteversion of guide pin will be changed in axial rotation of main intramedullary nailing to adjust the entry point.

Design and application of personalized distribution map of femoral neck guide pin

With the progress of modern medicine, orthopedic surgery is gradually minimally invasive, refined and intellectualized. Computer assisted orthopedic surgery (CAOS) arises at the historic moment. It combines the computer image processing and visualization technology with clinical surgery. So the doctors can build a 3D fracture model before operation, and perform measurement, reduction and fixation, etc. on the models. In addition, intraoperative auxiliary navigation makes many complicated surgeries no longer rely on the performer’s experience, but more depend on the operation specification, thus ensuring the safety and accuracy of the operation, which is regarded as a new revolution in orthopedic industry.

CAOS technology was applied in this study for auxiliary treatment on patients with intertrochanteric femoral fracture. First of all, according to the patients’ preoperative imaging data, a perfect preoperative simulation system was established, to fully assess the preoperative condition, conditions possibly occurring in the operation of the patients and the countermeasures. The specific methods were: reconstruction of bilateral proximal femoral model according to the patients’ preoperative CT scan data, and the femur on the diseased side after anatomical reduction was in contralateral simulation. According to the above research method, through 3D reconstruction, simulation operation, and geometric analysis, finally the correlation curve between NSA and anteverision of guide pin with the rotation angle of main intramedullary nail was obtained, which can be used in clinical after simplified into diagram.

Compared with the other preoperative evaluation system, preoperative 3D simulation system proposed in this research is mainly characterized by the concept of correlation between NSA and anteverision of guide pin in intraoperative 2D fluoroscopy. And personalized distribution map of femoral neck guide pin is formulatied to guide the adjustment of position of femoral neck guide pin.

In clinical practice, personalized distribution map of femoral neck guide pin can help the performer to accurately master the fracture end condition and guide pin placement position. In preoperative simulation, the best position of guide pin of femoral neck screw in femoral head and neck is put forward in advanced, and NSA and anteverision of guide pin are calculated under fluoroscopy at anteroposterior and lateral position.

If the guide pin of femoral neck screw is placed for the first time, and the anteverision of guide pin is not ideal under C-arm fluoroscopy and needs adjustment, the 2D image data of intraoperative fluoroscopy can be based on to measure the NSA and anteverision of guide pin. And then the method for guide pin adjustment, that is the axial rotation angle of the main intramedullary nailing, can be searched in personalized position distribution map of femoral neck guide pin.

NSA of guide pin is 135.7°, while anteverision of guide pin is 24°. The coordinates of the red line corresponding to the first position of femoral neck guide line in operation; based on the NSA and anteverision of guide pin measured in the operation, the corresponding positions in the figure are found; the abscissa and the rotation angle of the main intramedullary nailing are found; compared with the abscissa of red and black line, the method to adjust the guide pin location can be obtained.

Through this technology, the positioning of the guide pin is more accurate, and the numbers of insertion and intraoperative fluoroscopy used are decreased, thus reducing the exposure time of doctors and patients and related persons. The contradiction between accuracy and safety of the operation is well solved. At the same time, the successful rate of surgery is increased and the postoperative complications are decreased. In addition, the establishment of personalized distribution map of femoral neck guide pin doesn’t need a new medical device, which can be carried out in ordinary computers, so it can be combined with the traditional medical methods, but not increase the health care costs.

Preoperative establishment of personalized distribution map of femoral neck guide pin is a simple and accurate method for

adjustment of the location of the femoral neck guide pin. It is not only a kind of positioning technology, but also a kind of idea. 1. Subjectivity and blindness operation can be reduced during operation, and these empirical operations can be expressed in exact figures. 2. Positioning technology of femoral neck guide line can be designed personalized according to the actual situation of each patient. This technology can be a positioning device, or a geometric representation, even a simple diagram. 3. Preoperative preparations completed to simulate intraoperative emergency and make the countermeasures.

Limitation and prospects

The advantages of personalized distribution map of femoral neck guide pin are obvious, but its application has some limitations. It must meet the following conditions: 1. The femur at the diseased side achieves the anatomical repositioning. 2. Fluoroscopy plane in preoperative simulation surgery should in accord with the actual fluoroscopy during the operation. 3. It fits for adjusting the position of the guide pin in femoral neck by axial rotation of the main intramedullary nail, but not fit for adjusting the depth of the main intramedullary nail. 4. The anatomical and fluoroscopy position of the patient must not be changed during fluoroscopy.

In addition to the application conditions, the experiment design itself also has some limitations. 1. The 3D femoral model in this paper was established based on the patients with preoperative CT scan data and the projection plane may be deviated to the actual projection. 2. Engineering software commonly used in digital orthopedics is not designed aiming at orthopedics system, but reference to some mechanical engineering software. When dealing with complex skeleton model, this software may develop some error for the measurement data. 3. Preoperative design and simulation work needs time and improved preoperative imaging tests, which are difficult to apply to patients needing emergency surgery.

Through the popularity of 3D C-arm machine in the future, the doctor can carry out continuous multiple level scan and 3D reconstruction with professional software for the patients during the operation. The mentioned preoperative design and simulation can be performed after reduction of hip fracture end, which cannot only shorten the preoperative preparation time, but make the results more accurate.

Although the application and design of personalized distribution map of femoral neck guide pins has certain limitation, these problems may be reduced or avoided as the development of computer assisted orthopedic surgery. It has immeasurable prospects for application in orthopedics.

Conclusion

Through analysis on clinical cases and research on 3D model, it is found that there is a positive correlation between anteversion of femoral neck guide pin at lateral position with the NSA of guide pin at anteroposterior position. When the main intramedullary nail was rotated along the axis intraoperatively to change the position of the guide pin, the anteversion of guide pin was increased, the NSA was also increased. Otherwise, as the anteversion of guide pin was decreased, the NSA was also decreased. Based on this principle, personalized distribution map of femoral neck guide pin is established. It can position and adjust the location of femoral neck guide pin during operation, which is a simple, accurate and practical adjustment technology for femoral neck guide pin.

References