Trauma and bone metabolism of magnetic navigation intramedullary nail and traditional intramedullary nail fixation treatment of femoral shaft fracture

Shao-Hui Zhang

Department of Orthopaedics, People's Hospital of Longxian Shaanxi Province, Baoji 721200, China

ARTICLE INFO

Article history:
Received 7 Jul 2016
Received in revised form 17 Jul 2016
Accepted 12 Jul 2016
Available online 24 Jul 2016

Keywords:
Femoral shaft fracture
Magnetic navigation intramedullary nail for femoral shaft fracture
Traditional intramedullary nail fixation
Trauma
Bone metabolism

ABSTRACT

Objective: To analyze the trauma and bone metabolism of magnetic navigation intramedullary nail and traditional intramedullary nail fixation treatment of femoral shaft fracture. Methods: 58 patients with femoral shaft fracture treated in our hospital between December 2011 and December 2015 were divided into observation group and control group by random number table (n=29). Control group received conventional intramedullary nail fixation treatment, and observation group received magnetic navigation intramedullary nail fixation treatment. 24 h after surgery, blood coagulation indexes, enzymology indexes, bone metabolism indexes and angiogenesis indexes were determined; 6 months after surgery, bone mineral density levels were determined. Results: 24 h after surgery, peripheral blood thrombin time (TT), prothrombin time (PT), and activated partial thromboplastin time (APTT) levels of observation group were significantly higher than those of control group, and serum fibrinogen (FIB), D-Dimer (D-D), lactate dehydrogenase (LDH), creatine kinase (CK), creatine kinase isoenzyme (CKMB), glutamic oxalacetic transaminase (GOT), sex hormone-binding globulin type I (SHBG), collagen cross-linked carboxyl-terminal telopeptide (CTX) and deoxypyridinoline (DPD) content were lower than those of control group while bone gla protein (BGP), insulin-like growth factor (IGF-1), hypoxia-inducible factor-1α (HIF-1α), angiogenin 1 (Ang-1), recombinant basic fibroblast growth factor (bFGF) and vascular endothelial growth factor (VEGF) content were higher than those of control group; 6 months after surgery, fracture end bone mineral density (BMD) value of observation group was higher than that of control group. Conclusions: Magnetic navigation intramedullary nail treatment of femoral shaft fracture can more effectively reduce the surgical trauma, improve bone metabolism and increase bone mineral density.

1. Introduction

Femoral shaft fractures are mostly caused by violent injury, external fixation for such patients is difficult to reach anatomical reduction and causes poor blood supply and even necrosis in fracture end, and therefore, the early surgery is the best treatment for femoral shaft fractures[1-2]. Intramedullary nail fixation treatment is the most common clinical means for femoral shaft, but the increase of applied cases gradually exposes that the success rate of distal locking is not high. Studies have reported that the distal locking success rate of traditional intramedullary nail fixation treatment is only 36% or so, it may lead to repeated drilling during surgery, and long-term nail-loosening and -breaking rate rise accordingly[3,4]. Magnetic navigation intramedullary nail has the advantages of accurate positioning and high distal locking success rate, and is expected to break the plight of the current fracture treatment. In the study, both magnetic navigation intramedullary nail and traditional intramedullary nail fixation treatment were applied in patients with femoral shaft fracture in our hospital, and the damage of the two kinds of treatment to patients and the effects on bone metabolism, etc were mainly elaborated.
2. Materials and methods

2.1. General information

58 patients with femoral shaft fracture treated in our hospital between December 2011 and December 2015 were selected as the research subjects. Inclusion criteria: (1) diagnosed with femoral shaft fracture by X-ray; (2) not in accordance with the standard of conservative treatment; (3) could tolerate surgical trauma; (4) did not accept surgery one month before operation; (5) signed informed consent. Exclusion criteria: (1) with long-term use of aspirin, warfarin and other drugs that could affect blood coagulation function; (2) with basic coagulation dysfunction; (3) with malignant tumor diseases; (4) with pathological fracture; (5) with severe heart, liver and kidney dysfunction.

According to the random number table, the 58 patients were divided into observation group and control group ($n=29$), control group included 17 male cases and 12 female cases that were 34–70 years old, and fracture typing was: 12 cases with 32-A type, 14 cases with 32-B type and 3 cases with 32-C type; observation group included 18 male cases and 11 female cases that were 33–71 years old, and fracture typing was: 11 cases with 32-A type, 14 cases with 32-B type and 4 cases with 32-C type. The two groups of patients were not statistically different in the distribution of gender, age and fracture typing ($P<0.05$).

2.2. Treatment methods

Control group received conventional intramedullary nail fixation treatment, specifically as follows: after epidural anesthesia, patients took lateral position, the hip joint was in slight adduction and fixed in 30° internal rotation position, and the traction and closed reduction of fracture end were conducted. Arc incision (6–8 cm long) was made in femoral greater trochanter tip to expose the oval fossa, the mouth gag was placed on the anteroposterior and lateral femoral medullary cavity centerline under the perspective, and the opening and reaming were conducted (slowly and gently, avoiding cortex splitting caused by forced reaming). After the completion of reaming, proper intramedullary nail was imbedded, and repeated drilling should be avoided in case of difficult distal medullary nail imbedding, and unarmed locking was adopted under early perspective. Observation group of patients received magnetic navigation intramedullary nail treatment for fracture, specifically as follows: patients received epidural anesthesia and took supine position, continuous affected limb traction was conducted, and anteroposterior and lateral fracture reduction was conducted under perspective until satisfactory. Magnetic navigation interlocking intramedullary nails were disinfected, then the main nail, locating rod, distal sighting device were pre-installed, magnetic blocks corresponded to the distal second hole of interlocking intramedullary nail, distal hole of sighting device was in line with the distal of the main nail, and then pointer scale was recorded. Conventional operative approach was adopted, a longitudinal incision about 6 cm was made in about 2 cm above the femoral great trochanter, guide pin was pierced (in pyriform sinus) after traction and reduction until satisfactory under perspective, then medullary cavity was expanded to fracture end and the long guide pin was inserted, with auxiliary fracture traction and manual reduction. The main nail was screwed in medullary cavity and through the fracture end, and the distal was adjusted to avoid rotating shift. Locating rod was installed on the main nail, distal skin and femoral fascia were incised, and the lateral femoral periosteum was stripped. Detector and the distal locking guide sleeve were installed, the fine adjustment screw on positioning rod was adjusted and the pointer scale was determined. Distal first main nail hole was drilled, the detector in the second hole was removed, guide sleeve was imbedded, the second hole was drilled, and then the drill was taken out and fixed with nail. The first distal drill was taken out, locking nail was screwed in for fixation and should be through the main nail, the locking nail was screwed in the second hole in the same way, and the locking nail of the distal second hole should be through the main nail. Under C-arm perspective, the locking nail and fracture reduction position were confirmed and the distal rotating shift was adjusted, fracture end was compressed, proximal sighting device was used to lock proximal locking nail, tail pin was screwed in, and the operation was completed.

2.3. Haematological indexes

24 h after surgery, 3 mL of fasting cubital venous blood was collected from the two groups of patients at the same point in time, 1 mL was directly used to determine the levels of coagulation indexes by automatic coagulometer, specifically including: the thrombin time (TT), prothrombin time (PT), activated partial thromboplastin time (APTT), D-Dimer (D-D) and fibrinogen (FIB). The rest 2 mL was added in sodium citrate for anticoagulation and then centrifuged (2 500 r/min, 5 min) within 30 min to take the supernatant, and the specific detection indexes were as follows: (1) the enzymology indexes: lactate dehydrogenase (LDH), creatine kinase (CK), creatine kinase isoenzyme (CKMB) and glutamic oxalacetic transaminase (GOT); (2) bone metabolism indexes: bone gla protein (BGP), insulin-like growth factor (IGF-1), sex hormone-binding globulin type I (SHBG), collagen cross-linked carboxyl-terminal telopeptide (CTX) and deoxypyridinoline (DPD); (3) angiogenesis indexes: hypoxia-inducible factor-1α (HIF-1α), angiogenin 1 (Ang-1), recombinant basic fibroblast growth factor (bFGF) and vascular endothelial growth factor (VEGF).
2.4. Bone mineral density

6 months after surgery, dual-energy X-ray absorptiometry was used to detect the fracture end bone mineral density (BMD) values of two groups of patients.

2.5. Statistical methods

Statistical software SPSS23.0 was used to input and analyze the data in the study, measurement data analysis between two groups was by $t$ test and $P<0.05$ indicated statistical significance in differences.

3. Results

3.1. Blood coagulation indexes

24 h after surgery, comparison of blood coagulation indexes PT, TT, APTT, FIB and D-D between two groups of patients is as follows: peripheral blood PT, TT and APTT levels of observation group were significantly higher than those of control group while FIB and D-D content were significantly lower than those of control group ($P<0.05$), shown in Table 1.

3.2. Enzymology indexes

24 h after surgery, comparison of serum LDH, CK, CKMB and GOT content between two groups of patients is as follows: serum LDH, CK, CKMB and GOT content of observation group were significantly lower than those of control group ($P<0.05$), shown in Table 2.

3.3. Bone metabolism indexes

24 h after surgery, comparison of serum bone metabolism indexes BGP, IGF-1, SHBG, CTX and DPD content between two groups of patients is as follows: serum SHBG, CTX and DPD content of observation group were significantly lower than those of control group while BGP and IGF-1 content were significantly higher than those of control group ($P<0.05$), shown in Table 3.

3.4. Angiogenesis indexes

24 h after surgery, comparison of angiogenesis indexes HIF-α, Ang-1, bFGF and VEGF content between two groups of patients is as follows: serum HIF-α, Ang-1, bFGF and VEGF content of observation group were significantly higher than those of control group ($P<0.05$), shown in Table 4.

3.5. Bone mineral density

6 months after surgery, comparison of fracture end bone mineral density value between two groups of patients is as follows: fracture end BMD value of observation group was (0.89±0.09) g/cm$^3$ and fracture end BMD value of control group was (0.78±0.08) g/cm$^3$. 6 months after surgery, fracture end BMD value of observation group was higher than that of control group, and differences were statistically significant ($P<0.05$).

| Table 1 | Comparison of blood coagulation index levels after surgery ($n=29$, $\bar{X} \pm s$) |
|------------------|------------------|------------------|------------------|------------------|
| Groups           | PT (s)           | TT (s)           | APTT (s)         | FIB (g/L)        | D-D (g/L)        |
| Observation group| 10.73±1.89       | 27.16±3.43       | 23.41±2.83       | 3.41±0.39        | 842.91±90.34    |
| Control group    | 9.28±0.91        | 24.38±3.12       | 21.05±2.75       | 4.62±0.53        | 1102.52±130.98  |
| t                | 5.372            | 6.192            | 6.842            | 5.893            | 9.283           |
| P                | <0.05            | <0.05            | <0.05            | <0.05            | <0.05           |

| Table 2 | Comparison of enzymology index content after surgery ($n=29$, $\bar{X} \pm s$) |
|------------------|------------------|------------------|------------------|------------------|
| Groups           | LDH (mmol/L)     | CK (U/L)         | CKMB (U/L)       | GOT (U/L)        |
| Observation group| 201.74±25.84     | 56.38±6.17       | 69.73±7.49       | 1.18±0.17        |
| Control group    | 362.55±40.28     | 119.84±13.75     | 101.52±14.68     | 2.05±0.23        |
| t                | 11.384           | 9.384            | 9.742            | 5.182            |
| P                | <0.05            | <0.05            | <0.05            | <0.05            |

| Table 3 | Comparison of bone metabolism index content after surgery ($n=29$, $\bar{X} \pm s$) |
|------------------|------------------|------------------|------------------|------------------|
| Groups           | BGP (ng/mL)      | IGF-1 (ng/mL)    | SHBG (ng/mL)     | CTX (μg/mL)      | DPD (nmol/L)    |
| Observation group| 17.74±1.83       | 213.74±25.31     | 41.28±4.77       | 421.28±45.67     | 91.26±10.58    |
| Control group    | 14.18±1.56       | 198.64±21.05     | 50.63±5.83       | 510.93±55.76     | 101.54±14.78   |
| t                | 5.839            | 9.283            | 8.162            | 12.472           | 10.893         |
| P                | <0.05            | <0.05            | <0.05            | <0.05            | <0.05          |
Clinical common operation methods at present, and the comparison of treatment methods for femoral shaft fractures, both magnetic navigation and traditional intramedullary nail fixation are considered the best treatment options. Meanwhile, selecting the right time for surgery is crucial. Early surgery is preferred because timely anatomical reduction and fixation can prevent further bone damage.

4. Discussion

Femoral shaft fracture is a type of clinical severe fracture, and without timely anatomical reduction and fixation, it can lead to poor blood supply and even necrosis of fracture end. Selecting a reasonable surgical procedure and conducting early surgery are the best treatment for femoral shaft fractures, both magnetic navigation and traditional intramedullary nail fixation are the clinical common operation methods at present, and the comparison of their advantages and disadvantages has been controversial[5]. Intramedullary nailfixation technology is relatively mature, but the repeated drilling and locking as well as nail loosening and breaking during operation has become its biggest technical barriers. Magnetic navigation intramedullary nail, after the improvement of existing intramedullary nail, can accurately determine the position of the far end lock hole, and the magnetic detector has high sensitivity, so the frontal plane of locking nail spindle is without deviation during drilling, which significantly reduces the locking failure rate. The current domestic research on magnetic navigation intramedullary nailing is still in its infancy, and there are fewer reports about its application value for patients with femoral shaft fracture. In the study, the above two types of internal fracture fixation were applied in patients with femoral shaft fracture in our hospital, and the differences in surgical trauma, bone metabolism and other aspects were mainly elaborated.

The incidence of venous thrombus is high after orthopaedic operation, which is mainly because that the stress after surgical trauma leads to the activation of massive prothrombin into thrombin, which further activates platelets and blood coagulation factors, hydrolyzes fibrinogen and activates plasminogen, which enhance thrombin further activates platelets and blood coagulation factors, resulting in a hypercoagulable state in patients, leading to a series of tissue and organ damage, which can be specifically characterized by abnormal serum enzyme index content. In the study, the above two types of internal fracture fixation were applied in patients with femoral shaft fracture in our hospital, and the differences in surgical trauma, bone metabolism and other aspects were mainly elaborated.

In the study, peripheral blood PT, TT and APTT levels of observation group were higher, indirectly confirming that the design of magnetic navigation positioning device is without distal inhibiting device, and can avoid mechanical stimulation damage to patients’ knee. But during traditional intramedullary nailing, the distal limit lever is mounted in 2 cm of superior border of patella, it may damage the quadriceps femoris, suprapatellar bursa and other tissues, and at the same time, multiple drilling and locking during surgery may further expand the trauma of fracture. Trauma, shock and other primary attacks may directly activate the inflammatory cells in human body and cause a series of tissue and organ damage, which can be specifically characterized by abnormal serum enzyme index content. In the study, peripheral blood PT, TT and APTT levels of observation group were lower, indicating that the magnetic navigation intramedullary nail treatment causes fewer traumas to the body than traditional intramedullary nail fixation. This may be because that the design of magnetic navigation positioning device is without distal inhibiting device, and can avoid mechanical stimulation damage to patients’ knee. But during traditional intramedullary nailing, the distal limit lever is mounted in 2 cm of superior border of patella, it may damage the quadriceps femoris, suprapatellar bursa and other tissues, and at the same time, multiple drilling and locking during surgery may further expand the trauma of fracture. Trauma, shock and other primary attacks may directly activate the inflammatory cells in human body and cause a series of tissue and organ damage, which can be specifically characterized by abnormal serum enzyme index content. In the study, early postoperative serum LDH, CK, CKMB and GOT are associated with cardiac function, myocardial cells can also be stimulated when acute inflammatory stress response occurs, and intracellular enzymes are released into the peripheral blood and are detected. In the study, early postoperative serum LDH, CK, CKMB and GOT content of observation were lower, indicating that the less traumatic feature of magnetic navigation intramedullary nail treatment again.

The trauma caused by the fracture surgery will affect bone metabolism, thus influencing the fracture healing process and lower limb function rehabilitation. In physiological conditions, BGP can induce bone salt deposition and improve bone strength, it is the osteogenic activity-specific marker, and serum BGP content increases when osteoblast function is enhanced. In the study, early postoperative serum SHBG, CTX and DPD content of observation were lower while BGP and IGF-1 content were higher, which, together with the physiological role of various factors mentioned in this paper, explain that after magnetic navigation intramedullary nail treatment, the osteogenic activity of fracture end is higher while osteoclastic activity is relatively lower, and the fracture healing is more ideal.

Fracture healing process is inevitably accompanied by the angiogenesis in the fracture end, which supplies oxygen and nutrients for osteocytes to promote the fracture healing. Many

Table 4

Comparison of angiogenesis index content after surgery (n=29, x±s).

<table>
<thead>
<tr>
<th>Groups</th>
<th>HIF-α (μg/L)</th>
<th>Ang-1 (ng/mL)</th>
<th>bFGF (ng/mL)</th>
<th>VEGF (pg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td>0.79±0.08</td>
<td>8.29±0.91</td>
<td>12.84±1.92</td>
<td>25.38±3.11</td>
</tr>
<tr>
<td>Control</td>
<td>0.51±0.06</td>
<td>5.76±0.59</td>
<td>7.63±0.84</td>
<td>19.76±2.42</td>
</tr>
<tr>
<td>t</td>
<td>5.382</td>
<td>6.931</td>
<td>7.094</td>
<td>8.293</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

<ref>Shao-Hui Zhang/ Journal of Hainan Medical University 2017; 23(3): 96–100</ref>
studies agree that fracture end angiogenesis activity is consistent with the exuberant degree of fracture healing, and detecting the content of HIF-α, Ang-1, bFGF, VEGF and other angiogenesis-related factors can directly reflect the degree of fracture healing and indirectly reflect the surgical trauma[16]. HIF-α is the most direct regulatory factor for histocytes to induce angiogenesis in hypoxia condition, VEGF is its downstream factor, and study has found that after HIF-α pathway is activated, VEGF is massively expressed and osteogenic property is improved. Ang-1 is expressed in vascular smooth muscle cells, and a lot of studies have confirmed that the Ang-1 can promote vascular lumen formation and prevent vascular leakage[17]. BFGF can promote angiogenesis after fracture and accelerate fracture healing. It was found in the study that serum HIF-α, Ang-1, bFGF and VEGF content of observation group were higher, indicating that after magnetic navigation intramedullary nailing treatment, fracture end angiogenesis and bone formation are more exuberant, and confirming the curative effect of the operation. Finally, bone mineral density values of the two groups of patients were tested 6 months after surgery, and it was found that BMD value of the observation group was higher, which confirms that the long-term curative effect of magnetic navigation intramedullary nail treatment is also significant.

In conclusion, magnetic navigation intramedullary nail treatment of femoral shaft fracture can more effectively reduce the surgical trauma, improve bone metabolism and increase bone mineral density.

References