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Original article

Surgical factors contributing to nonunion in femoral shaft fracture following intramedullary nailing

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ABSTRACT

Purpose: To explore the possible surgical factors related with nonunion in femoral shaft fracture following intramedullary nailing.
Methods: We retrospectively analyzed totally 425 patients with femoral shaft fracture in level I urban trauma center, including 254 males and 171 females, with an average age of 37.6 (ranging from 21 to 56) years old. The inclusion criteria included: (1) traumatically closed fracture of femoral shaft, with pre-operative films showing non-comminuted fracture, such as transverse fracture, oblique fracture or spiral fracture; (2) closed reduction and fixation with interlocking intramedullary nail at 3–7 days after trauma; (3) complete follow-up data available. The relationship between the following factors (fracture site, reduction degree, direction of nail insertion and nail size) and nonunion was studied.
Results: The incidence of femoral nonunion was 2.8% in patients with closed simple fracture undergoing interlocking intrameduallary nailing, including 11 cases of hypertrophic nonunion. Nonunion was related significantly to distal fracture, unsatisfactory reduction and unreamed nail ($p < 0.05$). There was no significant difference between antegrade nail and retrograde nail ($p > 0.05$).
Conclusions: Nonunion in femoral shaft facture following interlocking intramedullary nailing is related to fracture site, fracture reduction and nail diameter. The choice of reamed nails or unreamed nails depends on the fracture site and reduction degree.

Introduction

Interlocking intramedullary nailing is a widely accepted treatment for the patients with femoral shaft fracture, with the union rate reported from 85% to 100%.[1–3] Nonunion is a common problem for orthopaedic surgeons. Though with a low incidence, it usually requires multiple procedures to achieve union, which increases the cost and is disadvantageous to the recovery. Recent studies have attempted to identify possible risk factors leading to nonunion following intramedullary nailing in femoral shaft fracture in order to reduce nonunion.[4,5]

Open fracture or open reduction is associated with diaphyseal nonunions owing to local blood damage. Closed reduction followed by intramedullary nail fixation is one of ideal surgical methods because it can provide strong internal fixation with a mini-incision but not interfering with local blood supply at the fracture site. Nonunions, however, do occur in these conditions, even in patients with simple femoral fracture, which indicates that other factors, such as the stability of the nail construct, act on fracture healing. The purpose of this study in a series of patients with simple femoral shaft fracture was to evaluate the role of unstable fixation in femoral nonunion, and to find surgical factors resulting in nonunion. Fracture site (proximal or distal), reduction degree (anatomic reduction or unsatisfactory reduction), nail insertion (antegrade or retrograde) and nail size (reamed or unreamed) are considered as relevant factors in the stability of internal fixation. A thorough understanding of these factors and their influence on bone healing may guide us to achieve better operative outcomes and prevent nonunion.

Materials and methods

Six hundred and seventy-two femoral shaft fractures in skeletally mature patients were treated with intramedullary nailing in our department from August 2004 to August 2011. To evaluate the

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effect of nail stability on union, two doctors were asked to screen the cases from all these patients with medical records and X-ray films available. The inclusion criteria were as follow: (1) traumatically closed fracture of femoral shaft, with preoperative films showing non-comminuted fracture, such as transverse fracture, oblique fracture or spiral fracture; (2) closed reduction and fixation with interlocking intramedullary nail 3–7 days after trauma; (3) complete follow-up data available.

Totally 425 patients were included according to the above-mentioned standard, 254 males and 171 females, with an average age of 37.6 (ranging from 21 to 56) years old. Twelve cases among them were diagnosed with diaphyseal nonunion, 3 women and 9 men. Nonunion was defined as a clinically and radiographically unhealed fracture that required additional procedures as determined by the attending surgeon at post-operative 8 months. There was 1 atrophic nonunion and 11 hypertrophic nonunions. Two other doctors who were blind to the study design were asked to read the preoperative and post-operative films and analyzed the condition of the nailing, including fracture site, reduction degree, direction of nail insertion and nail size. Proximal fracture was defined as the fracture between 2 cm distal to lesser trochanter and femoral isthmus; distal fracture was defined as the fracture distal to the femoral isthmus. Satisfactory reduction referred to anatomical reduction; unsatisfactory reduction referred to over 2 mm separation or angulation displacement. Nail size meant reamed nail or unreamed nail.

Fisher's exact test and χ^2 test were used to evaluate the significance of the independent variables. $p < 0.05$ was considered significantly different.

Results

The incidence of femoral nonunion was 2.8% in patients with closed simple fracture undergoing interlocking intrameduallary nailing. Eleven cases of them had hypertrophic nonunions, characterized by evident callus formation but with clear fracture line. Patients' distribution related to various studied factors is shown in Table 1. Nonunion was correlated significantly with distal fracture, unsatisfactory reduction and undreamed nail ($p < 0.05$). There was no significant difference between antegrade nail and retrograde nail ($p > 0.05$).

Surgical characteristics of all 12 patients with nonunion are demonstrated in Table 2. Among all 12 patients, 9 suffered from distal femoral fracture, 10 underwent antegrade nailing, 8 presented unsatisfactory reduction and 7 received unreamed nail fixation.

Discussion

Nonunion of the femoral shaft facture represents a challenge for orthopaedic surgeons and a serious socioeconomic problem for the patients mainly due to blood supply damage or inadequate fracture stability.[6] Avascular change at the fracture site resulted from open fracture or open reduction leads to atrophic nonunion occasionally, while unstable fixation contributes to hypertrophic nonunion. In this study, 425 patients with closed femoral shaft fracture underwent close reduction and intramedullary nailing. As a result, nonunion occurred in 12 cases, including 11 cases of hypertrophic nonunions, which suggested that unstable fixation attributed a lot to this kind of nonunion following nailing.

Diameter of the nail is usually a key issue with regard to the stability of intramedullary nail. Reaming allows the insertion of a larger nail, which provides a greater stability, but may induce a greater periosteal reaction. The literature reported a fewer nonunions associated with reamed nailing than with unreamed nailing.[7,8] Two hundred and twenty-four patients were enrolled in a multicenter, prospective, randomized clinical trial by Canadian Orthopaedic Trauma Society.[9] Eight of 107 fractures (7.5%) in the group without reaming had a nonunion compared with two of 121 fractures (1.7%) in the group with reaming. They concluded that intramedullary nailing of femoral shaft fractures without reaming resulted in a significantly higher rate of nonunion compared with intramedullary nailing with reaming. Despite the clinical success achieved by intramedullary nailing after reaming, several concerns have been proposed on the biological consequences of reaming. Reaming disrupts the cortical blood flow, causing various extent of thermal necrosis in cortical bone. Elevated intramedullary pressures associated with reaming can also result in marrow embolization, which may trigger the development of adult respiratory distress syndrome.[10,11] These limitations prevent reaming technique from a wide application.

Totally 243 simple fractures accepted a reamed nail in our study, and 5 patients were found with nonunion. Interestingly, all the fractures of the 5 cases were at the distal femur. This suggested that reamed nailing can provide a strong enough stability for a proximal fracture, but it sometimes fails for the fractures distal to isthmus. For a distal fracture, a large antegrade nail can stabilize the proximal and the isthmus. But the distal femoral medullary cavity is bigger, and the two distal locking screws can not limit the nail, which decreases the stability of this construct. Thus the micromotion across the fracture gap prevents bone healing. A blocking screw helps to control the nail, and is used for reduction as well as treatment of nonunion.[12,13]

Retrograde nailing is effective for stabilization of femoral shaft fractures. It was once thought to provide a higher healing rate than antegrade nail, especially in cases of distal fracture. Papadokostakis et al[14] evaluated the efficacy of retrograde nailing in the treatment of distal femur fractures and femoral shaft fractures with a systematic review of the literature. He found that the patients with femoral shaft fractures had a mean time to union of 3.2 months, while the union rate was 94.2%; the rate of knee pain, malunion and re-operation was 24.5%, 7.4% and 17.7%, respectively. So he concluded that retrograde intramedullary nailing be a reliable treatment option mainly for distal femoral fractures. However, in the management of diaphyseal fractures, retrograde intramedullary nailing was associated with high rate of knee pain and low rate of fracture union.[15] In our research, there was no significant difference in nonunion rate between antegrade nail and retrograde nail.

We demonstrated a typical case who suffered from the same fracture in similar sites of both femurs and underwent the same

Table 1
Case distribution by different surgical factors (n).

Item	Fracture site		Fracture reduction		Direction of nail		Pattern of insertion	
	Proximal	Distal	Satisfactory	Unsatisfactory	Antegrade	Retrograde	Reamed	Unreamed
Fracture	146	279	270	155	334	91	243	182
Nonunion	3	9	4	8	10	2	5	7
p	<0.05		<0.05		>0.05		<0.05	