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## Case Report

# Intramedullary nailing for floating knee injury complicated by pulmonary fat embolism: A case report and literature review

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## ABSTRACT

A 28-year-old man involved in a serious motorcycle accident was admitted to our hospital with comminuted fractures of the ipsilateral femoral shaft and tibial shaft, as well as multiple fractures of the right lower limb, including the proximal fibula, medial malleolus, and the third and fourth distal metatarsals. In addition, the patient suffered a skin contusion and laceration of the right foot. On the first day of admission, this patient suddenly developed tachycardia, pyrexia, and tachypnoea, and was immediately transferred to the ICU for further treatment due to a CT-diagnosed pulmonary fat embolism (FE). As a symptomatic treatment, he received a prophylactic dose of low-molecular-weight heparin for 10 days, after which his condition improved. A Doppler ultrasound of the lower leg and a follow-up chest CT angiography were performed, which excluded any remaining thrombus and verified that the pulmonary FE had improved without deterioration. Closed-reduction and retrograde intramedullary nailing were performed for the femoral shaft fractures, while antegrade intramedullary nailing was performed for the tibial shaft fractures under general anaesthesia. In the three-year follow-up, the patient had recovered with good function of the right limb, without any respiratory discomfort. Both the femoral and tibial shaft fractures finally resolved without any further treatment. Ipsilateral femoral and tibial shaft fractures should undergo surgical stabilisation as early as possible to avoid pulmonary FEs. It is still controversial whether intramedullary nailing is suitable for floating knee injuries complicated by pulmonary FEs. However, if patients with pulmonary FEs require intramedullary nailing, we suggest that surgery should be performed after at least one week of anticoagulant use, when patient vital signs are stable and there is no sign of dyspnoea. In addition, patients should try to avoid reaming during the operation to prevent and decrease “second hit” for the lung.

## Introduction

Ipsilateral fractures of the tibia and femur, also known as the “floating knee injury”, are high-energy injuries often associated with other severe injuries to the body. The most common cause is a motor accident. Mortality has been reported to be as high as 8.6% [1,2], with amputation rates of up to 27% [2–5]. Timing and management of ipsilateral shaft fractures are essential, and early fracture stabilisation reduces fat embolism syndrome (FES), deep vein thrombosis (DVT), and pulmonary complications [6]. There are few previous reports concerning intramedullary nailing for “floating knee injury” of patients with pulmonary FEs [7]. In this study, we

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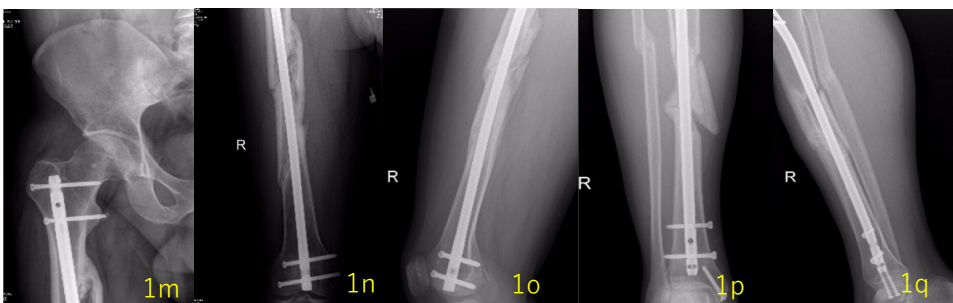
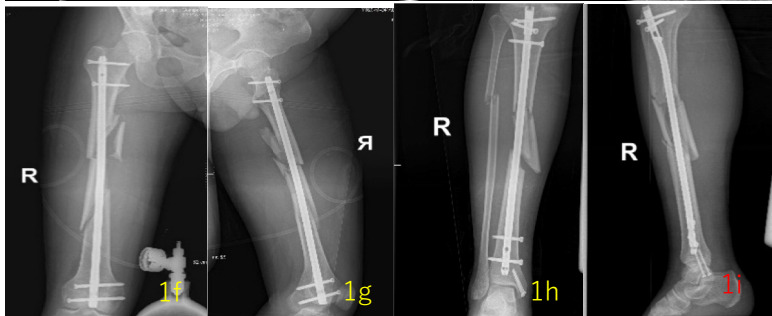
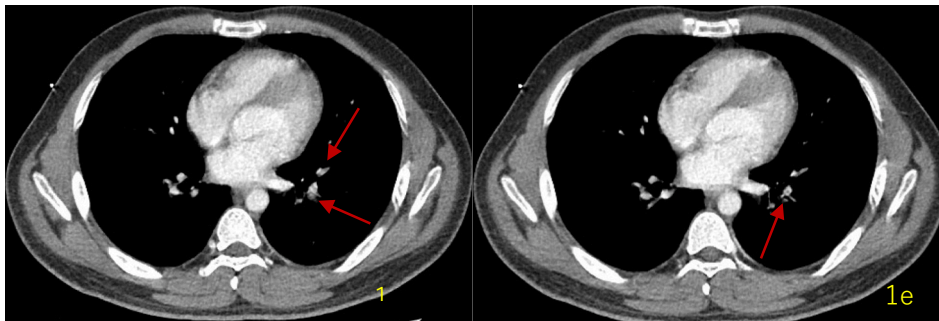
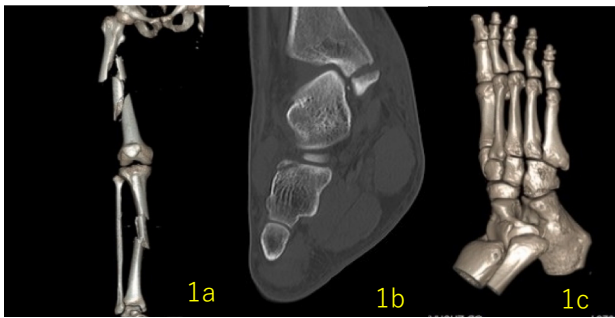
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**Fig. 1.** Male 28 years old, a. ipsilateral comminuted femoral shaft and tibial shaft fracture of right side (a float knee injury) b. 3D reconstruction CT of the right lower extremity after injury showed medial malleolus fracture and talus fractures c. 3D reconstruction CT of the right foot after injury showed the third and fourth distal metatarsus fracture.

d-e. Chest CT angiography of one day after inpatient showed peripheral pulmonary embolism with both inferior lobar artery filling defect (as show by deep red arrow).

f-i. X-ray of one day post-operation show good alignment of femoral shaft and tibial shaft fracture following close reduction and intramedullary nail fixation.

j-l. Outlook of right lower limb one week post-operation show well healing without sign of infection.

m-q. X-ray of one year post-operation show good heal of femoral shaft and tibial shaft fracture following close reduction and intramedullary nail fixation.

report a case of a patient with ipsilateral tibial and femoral fractures with a pulmonary FE that recovered substantially after intramedullary nailing.

## Case report

A 28-year-old male involved in a motorcycle accident presented with multiple injuries and deformities of the right lower limb, including: skin contusions and lacerations on the right foot; and skin abrasions on the face, right elbow, and right heel. We immediately transferred the patient to our emergency department. X-ray examination diagnosed ipsilateral comminuted femoral shaft and tibial shaft fractures, proximal fibula fractures, medial malleolus fractures, talus fractures, and the third and fourth distal metatarsal fractures of the right limb (Fig. 1 a–c). A computed tomography (CT) examination of the head, chest, abdomen, and pelvis showed no other body-related injuries. A Doppler ultrasonography of both lower extremities showed no thrombosis. Neurovascular injury and acute limb compartment syndrome were also not found. He was in good clinical condition (haemoglobin: 11.0 g/dl) with stable vital signs. Splints with skeletal traction were applied, and the soft tissue of the right thigh and foot was subjected to debridement and sutured in an emergency operating room (OR). He was then transferred to the inpatient department to receive cefazolin to prevent infection, and nadroparin calcium by hypodermic injection to prevent thrombus, at a prophylactic dose of 0.4 ml/4100 U, once a day. Paracetamol and tramadol were taken twice a day to relieve pain. A preoperative examination was performed for the selection and stabilisation of the fractures by intramedullary nailing.

On the morning of the first day of admission (28 h after injury), the patient presented with sudden pyrexia of 38.2° without other discomfort, and his vital signs were stable. Therefore, no special treatment was administered. Five hours later, this patient developed a sudden pyrexia of 39.0°, tachycardia at 144 times/min, tachypnoea at 30 times/min, and air oxygen saturation dropped to 95 %. He was immediately transferred to the ICU for further treatment. Other examinations, such as routine blood tests, indicated a haemoglobin value of around 7.3 g/dl. Moreover, a routine urine test was normal. A follow-up chest CT angiography showed peripheral pulmonary embolism involving the superior lobe of the left lung and both inferior lobes of the lung (Fig. 1d and e). He received nadroparin calcium by hypodermic injection at 0.4 ml/4100 U, twice a day for 10 days.

After 10 days of treatment, the patient's condition had improved. Oxygen saturation was 99 % without dyspnoea or cardiac dysfunction. Moreover, a lower leg Doppler ultrasound excluded any remaining thrombus, and a new chest CT angiography showed that the pulmonary FE had improved without deterioration. Haemoglobin was stable at 8.7 g/dl, and surgical incisions on the right thigh and foot were healing without any signs of infection.

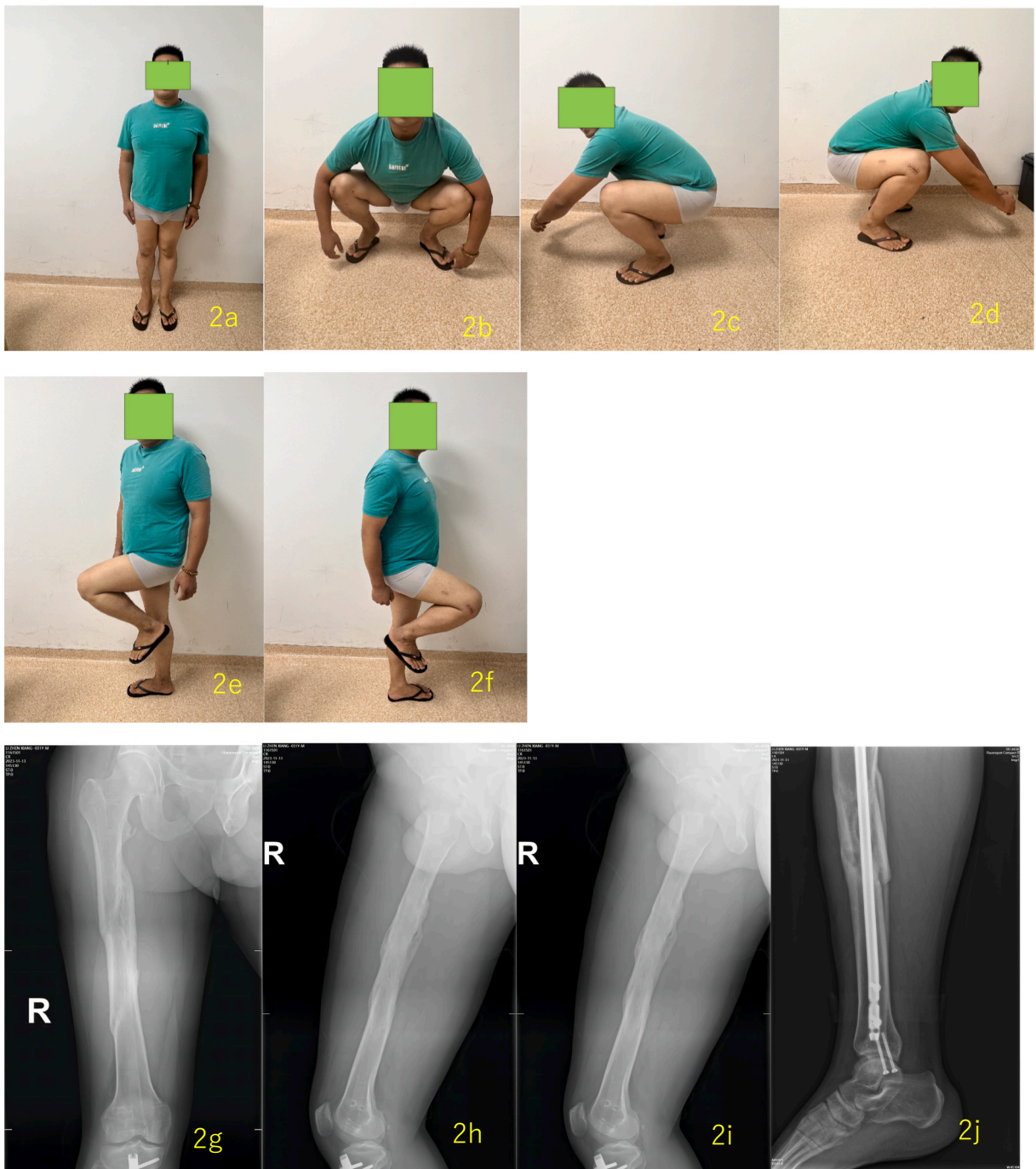
The patient underwent a closed reduction and retrograde nailing fixation of the comminuted femoral shaft fracture, and closed reduction and anterograde nailing fixation of the comminuted tibial shaft fracture. In addition, an open reduction and cannulated screw fixation under general anaesthesia was performed (Fig. 1f–i). After the operation, he was returned to the ICU for the next 7 days, and then transferred to the orthopaedic trauma ward without signs of infection (Fig. 1j–l). One month after the initial trauma, the patient was discharged from the hospital. He demonstrated continuous bone healing and rapid clinical recovery. In the 5th month post injury, he recommenced daily activities. After 12 months, his injuries were completely healed, as indicated by radiological examinations (Fig. 1m–q). He recovered substantially with a good level of function of the injured limb (Fig. 2–f). He had no symptoms of respiratory discomfort, and demonstrated union of the ipsilateral comminuted femoral and tibial shaft fractures. In the three-year follow-up, there was no need for a second operation (Fig. 2g–j).

## Discussion

Floating knee injury is a high-energy injury, and is often associated with other severe and potentially life-threatening injuries. Firstly, we must exclude other injuries and the risk of systemic complications. There are previous reports regarding “floating knee injury” patients with pulmonary FEs [6]. However, the suitability of reamed intramedullary nailing in treating patients with pulmonary embolisms or lung injuries is controversial. Since it is convention to avoid intramedullary nailing in patients with pulmonary injuries in order to prevent and decrease pulmonary “second hits” during reaming, surgical indications and treatments are rarely mentioned in the literature [7].

1. The following reasons may explain the apparent pulmonary embolism in this patient with a floating knee injury:

Firstly, the floating knee injury in this case was the result of a high-impact collision, resulting in ipsilateral tibial and femoral



**Fig. 2.** a-f. 3 years postoperations follow-up show good function of right hip and knee joint.  
g-j. X-ray of 3 years postoperations showed good union of ipsilateral comminuted femoral shaft and tibial shaft fracture of right side.

fractures, medial malleolus fractures, and multiple fractures of the right foot. It was a serious injury with significant blood loss, with haemoglobin levels dropping from 11.6 g/dl to 7.3 g/dl in only one day. Hypothermia would lead to pachyemia, which increases thrombus complications. FEs are found in 95 % of femoral shaft fractures. FEs in isolated femoral fractures have been reported as between 1 and 10 % [8,9]; however, it is suspected to be higher [10] in bilateral fractures.

Secondly, we did not carry out orthopaedic damage control on this patient. Rather, only an external cast and skeletal traction were applied. The patient was surgically stabilised with an external fixator immediately after admission. Given that the literature suggests that external braces or casts and bone traction should not be considered preventive measures against FEs, surgical stabilisation of the



fracture within 24 h can decrease, but not exclude, an FEs [11,12]. FEs has also been reported in cases of immediate nailing of bilateral femoral fractures [13].

## 2. Perioperative treatment for pulmonary embolism in this floating-knee injured patient:

The patient's oxygen saturation improved immediately, and he was shifted to the normal ward after supplemental oxygen was provided (initially, 4 l/min through the nasal passage) when he suffered from a pulmonary FE. The first reason was that chest CT angiography revealed a partial peripheral pulmonary embolism involving only the left upper and lower lobes. The second reason was that he was a young man, which meant that he possessed strong compensatory abilities for pulmonary function. This is why his oxygen saturation immediately improved, returning to normal without the need for intubation. He received low-molecular-weight heparin at a therapeutic dose of 4100 U, delivered via hypodermic injection twice a day for 10 days. Common heparin therapy was not recommended in to reduce bleeding and blood transfusions in this case, as high-energy injuries lead to frequent hidden blood loss after 2–3 days of injury. Bleeding should be reduced to avoid complications and blood transfusions. Oxygen saturation in the air was maintained at 99–100 % without dyspnoea or cardiac dysfunction. A Doppler ultrasound of the leg ruled out any residual thrombus, and new chest CT angiograph showed improvement in the filling defect of the right inferior lobar artery, with no change in the filling defect of both inferior lobar arteries. This indicated improvement in pulmonary FE without worsening. Thus, we decided to perform the surgery.

A case of bilateral femoral shaft fractures complicated with a fat pulmonary embolism has been reported in the literature. The patient was treated with low-molecular-weight heparin (0.6 ml/d) for 11 days, and intramedullary nailing was performed. The patient recovered significantly without exacerbations of the pulmonary embolism or other complications [14].

## 3. The reasons for fixation with intramedullary nailing in this patient included:

- 1) This patient suffered multiple segmental comminuted fractures of the femoral and tibial shafts. If we used plate fixation, we may have needed an open reduction, which could disrupt the blood supply to the fracture and cause a delayed union or nonunion. Using an external fixator could potentially lead to fracture instability and a delay in union or nonunion. Thus, external fixation is the first appropriate method for femur stabilisation, particularly in cases where injury severity increases (New Injury Severity Score (NISS)) >40 (severe abdominal, pelvic, and chest injuries), in line with orthopaedic principles of injury control [15].
  - 2) Closed reduction with intramedullary nail fixation is less invasive and more complicated for patients with comminuted fractures of the femoral and tibial shafts. It could result in excellent fracture healing rates and good clinical and functional outcomes for most long bone shaft fractures of the lower limb. While experimental studies have indicated that the embolism of marrow contents during reaming could have a harmful effect on pulmonary function [16,17], there are also many contrary cases in the literature. Jiang et al. showed that early intramedullary nailing of femoral fractures in patients with chest injuries was not associated with additional pulmonary complications [18]. Other investigators have also reported no adverse effects of reaming, even in patients with multiple thoracic trauma injuries, and demonstrated only limited and transient effects of embolism on the development of FEs and ARDS [19–21].
  - 3) A case of bilateral femoral shaft fracture complicated by fat and pulmonary FE has been reported in the literature.
- ## 4. What should we do when we operate on a patient with a floating knee injury using intramedullary nailing, when complicated by fat and pulmonary embolisms? It is theoretically possible that such patients would suffer pulmonary “second hits” due to the intramedullary nail fixation. Therefore, we should consider means of preventing and avoiding it during reaming.
- 1) The general anaesthesia was administered using tracheal intubation. Before surgery, we should prepare the external fixator and plate, which enables us to temporarily switch from a nail to a plate or external fixator in the event of pulmonary injury or deterioration of the pulmonary embolism, such as when oxygen saturation levels fall below the normal level during reaming.
  - 2) The length and diameter of the nail were measured accurately using 3D computer software before surgery. We inserted the nail without reaming and avoided changing the nail during the operation. Studies suggest that the intramedullary pressure (IMP) increases during reaming, which could lead to fat intravasation with subsequent dysfunction and a significant increase in ICP, especially in patients with multiple injuries. Reaming is unavoidable, and we recommend regulating intramedullary reaming with a low DS and high RPM, which may reduce IMP alterations and result in less fat intravasation and a lower ICP increase.

## Conclusions

Ipsilateral femoral and tibial shaft fractures should undergo surgical stabilisation immediately to avoid pulmonary FEs. It is still controversial as to whether intramedullary nailing is suitable for floating knee injuries complicated by pulmonary FEs. However, if patients with pulmonary FEs require intramedullary nailing treatment, we suggest that surgery should be performed after anticoagulant therapy for at least one week when patient vital signs are stable, and without any sign of dyspnoea. Moreover, reaming during the operation should be avoided to prevent and decrease “second hits” for the lung.

## Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

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## CRedit authorship contribution statement

**Mei-Ren Zhang:** Writing – review & editing, Writing – original draft. **Kui Zhao:** Data curation. **Hai-Yun Chen:** Supervision. **Jiang-Long Guo:** Data curation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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