FORENSIC ASSESSMENT OF ADVERSE OUTCOMES OF ISOLATED DIAPHYSEAL FEMORAL FRACTURES

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https://doi.org/10.35339/ic.7.1.26-32

Abstract

Fractures of the femur diaphysis are one of the most frequent mechanical injuries of the skeleton, however, the frequency and causes of development of complicated post-traumatic period are not well understood. The aim of this work was to study the causes of development of adverse outcomes of isolated diaphyseal femural fractures. **Object and methods** of the work. A retrospective analysis of the protocols of clinical and radiological examination of 21 patients with adverse outcomes of a femoral diaphysis fracture, which, according to the results of the initial expert assessment, did not establish the severity of injuries due to the development of complications in the postoperative period was performed. **Results.** The main cause of fractures in this category of patients is road traffic accidents (90.4% of cases); closed fractures of the femoral diaphysis (85.7%) in the middle third (76.1%) in men (76.2%) prevailed. The following causes of the unsatisfactory results of surgical treatment of the femur diaphyseal fractures were revealed: 1) patient-dependent: a combination of overweight and arthrosis of adjacent (hip and knee) joints – 57.1%; violation of the motor regime in the form of physical inactivity (19.0%) and excessive axial load on the operated leg (19.0%); 2) implant-dependent: a mismatch between the dimensions of the device for immersion osteosynthesis and the anatomical sizes of the corresponding segments of the femur in all cases; 3) surgical-dependent causes: unresolved intraoperative displacement of fragments of the femur (23.8%), violation of the technology of radiation diagnosis (14.3%), violation of the terms of postoperative x-ray monitoring (23.8%) and perioperative antibiotic prophylaxis (14.3%). The consequence of this was a violation of the stability of osteosynthesis in 95.2% with a secondary displacement of bone fragments of the femur (47.6%), delayed consolidation of a hip fracture (61.9%), the formation of pseudarthrosis of the femur (38.1%), and post-traumatic femoral deformity bones (71.4%), development of post-traumatic contracture of the knee joint (81.0%), suppuration of the postoperative wound (23.8%), development of post-traumatic osteomyelitis (14.3%), migration of screws from the osseous plate (47.6%), migration of a distal blocked nail from the intramedullary rust (4.8%), intramedullary rod migration (4.8%).

Key words: *diaphyseal femoral fracture, surgical treatment, perioperative risk factors, postoperative complications, unsatisfactory outcomes.*

Introduction

The fractures of the femur that were not complicated by the damage to the main vessels and nerves, are assessed as bodily injuries of moderate severity. However, in the process of the fracture fusion, regardless of the treatment method (immobilization or various types of osteosynthesis), complications can develop. The most common complication is a defect of reparative processes in the fracture zone (delayed consolidation, non-fusion of bone fragments, pseudarthrosis), as well as persistent contractures of the adjacent joints [1, 2]. Development of complications in the post-traumatic period usually aggravates the outcome of the injury and,

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according to the "Rules of Forensic Medical Determination of the Severity of Bodily Injuries", often leads to severe consequences, as a result of harm to the health.

The frequency and features of complications that develop during the treatment of femoral fractures had been already studied. Errors and complications in the treatment of hip fractures in victims with polytrauma [3, 4], in patients with fractures of particular segments of the femur [5, 6] had been studied as well.

2. Purposes, subjects and methods:

2.1. The purpose of the work was to identify the causes of development of adverse outcomes in isolated femoral diaphyseal fractures.

2.2. Subjects and Methods

Of study were retrospective analysis of protocols of clinical and radiological examination of 21 patients with adverse outcomes of isolated femur shaft fractures, which, according to the results of the initial expert assessment, did not establish severity of bodily injuries due to the development of complications in the postoperative period. All patients were observed at M.I. Sitenko Institute of Spine and Joint Pathology (NAMS of Ukraine) in 2014–2019.

Criteria for inclusion in the study were adverse outcomes of the fracture of the femur diaphysis (non-fusion of bone fragments, pseudarthrosis, post-traumatic shortening and/or deformation of the femur, post-traumatic contracture of the knee joint). Criteria for exclusion from the study were hip fractures with fractures of several bones, combined injuries, fractures of the proximal or distal femur epimetaphysis.

All patients underwent surgical treatment using various methods of internal fixation of fragments of the femur using metal structures. When studying the features of the adverse results of femoral diaphysis fractures, an EFORT classification was used, according to which patient-dependent, implant-dependent and surgery-dependent causes and/or risk factors for complications after surgical treatment of orthopedic and traumatic patients were distinguished [7].

The Quetelet body mass index was calculated using the formula 'm/h2',

where m – body weight in kilograms, h – height in meters.

In the statistical processing of the material methods of descriptive statistics were used.

Conflict of interests. There is no conflict of interests.

3. Results

Among the patients included in this study, men predominated (76.2%). All patients were of working age. The main causes of fractures in this category of patients were traffic accidents (90.4% of cases); closed femoral diaphysis fractures (85.7%) in the middle third (76.1%) predominated. Only 2 primary open fractures were revealed (gunshot and due to a fall from a height) and 1 – secondary open as a result of an accident (*Table 1*).

Table 1

Distribution of patients by gender, age and some features of femoral diaphysis fractures

Options	N (%)
Sex	
Male	16 (76.1)
Female	5 (23.8)
Average age 32.12 ± 14.33 years old (18–48 years old)	
Cause of fracture	
Traffic accident	19 (90.4)
Fall from height	1 (4.8)
Gunshot wound	1 (4.8)
Fracture localization	
Top 1/3	3 (14.3)
Middle 1/3	16 (76.1)
Bottom 1/3	2 (9.6)
Type of fracture	
Open	3 (14.3)
Closed	18 (85.7)

It should be noted that osteoporosis or cases of hormone therapy, which are significant risk factors for delayed fracture consolidation, were not detected before the surgery.

Examination of primary radiographs made it possible to establish that only one patient with an open gunshot hip fracture in the middle third, by features of bone-traumatic injuries (defect of the femoral diaphysis up to 4 cm long) initially had a complicated and prolonged postoperative period with delayed fracture consolidation, the need for recovery the anatomical length of the damaged segment, a high risk of developing post-traumatic osteomyelitis. In all other cases, features of fracture did not affect the development of postoperative complications with a worsening treatment outcome.

When studying the causes of unsatisfactory results of surgical treatment of diaphyseal fractures of the femur, the following patient-related, surgery-related and implant-related causes were identified (*Table 2*).

Table 2

The causes of the unsatisfactory results of the surgical treatment of femoral diaphysis fractures

No.	The causes of the unsatisfactory results of the surgical treatment of femoral diaphysis fractures	N (%)
	Patient-related causes	
1	Alcohol intoxication at the time of injury (light degree)	3 (14.3)
2	_ _ _	8 (38.1)
3	History of coxarthrosis (Ist degree)	2 (9.6)
4	History of gonarthrosis (Ist degree)	6 (28.6)
5	Violation of the orthopedic regime in the immediate postoperative period	4 (19.0)
6	Violation of the orthopedic regime during the rehabilitation period	4 (19.0)
	Implant-related causes	
7	Inconsistency of the length of the intramedullary shaft and the length of the bone marrow canal of the femur	1 (4.8)
8	Inconsistency between the diameter of the intramedullary shaft and the width of the bone marrow canal of the femur	1 (4.8)
9	Discrepancy between the length of the distal blocking nail and the anteroposterior diameter of the distal femur metaphysis	2 (9.6)
10	Inconsistency of the length of cortical screws with the diameter of the femoral diaphysis	9 (42.9)
	Surgeon-related causes	
11	Violation of x-ray technology	3 (14.3)
12	Violation of the terms of postoperative x-ray monitoring	5 (23.8)
13	Violation of the terms of postoperative antibiotic therapy	3 (14.3)
14	Untreated intraoperative displacement of femur fragments	5 (23.8)

Among the patient-dependent causes, the most significant risk factors for complications after an open reposition of a femoral diaphysis fracture were a combination of obesity, arthrosis of adjacent (hip and knee) joints in 12 (57.1%) patients. Even with initial changes (Ist degree obesity, Ist degree coxarthrosis, Ist degree gonarthrosis), inadequate motor regime in the form of physical inactivity in the postoperative period potentiated the development of persistent restriction of movements in the knee joint with the formation of extensor contracture, relative (functional) shortening of the lower limb, and violation of the motor stereotype in 4 (19.0%) patients. These patients also had a significant reduction in the dosed load on the damaged lower limb in early stages of primary fibrocartilage callus formation in the fracture zone, which was accompanied by inhibition of reparative regeneration processes with a delayed formation of secondary fibrocartilage callus. Violation of the motor regime with excessive axial load on the operated limb during the rehabilitation period was also accompanied by delayed consolidation in the fracture zone (another 4 (19.0%) observations) - see *tables 2, 3*.

The study of implant-dependent causes showed that in all cases of development of postoperative complications, a mismatch was found between the standard size of the metal structure used for immersion osteosynthesis and the anatomical sizes of fractured femur's fragments. Migration of a short intramedullary rod was observed in one (4.8%) case. In another case (4.8%) of blocked intramedullary osteosynthesis of the hip diaphysis fracture in the lower third, the use of a narrow intramedullary nail and a short distal blocked nail was accompanied by migration of the blocked nail and rod's breakage at the level of the femoral fracture, secondary displacement

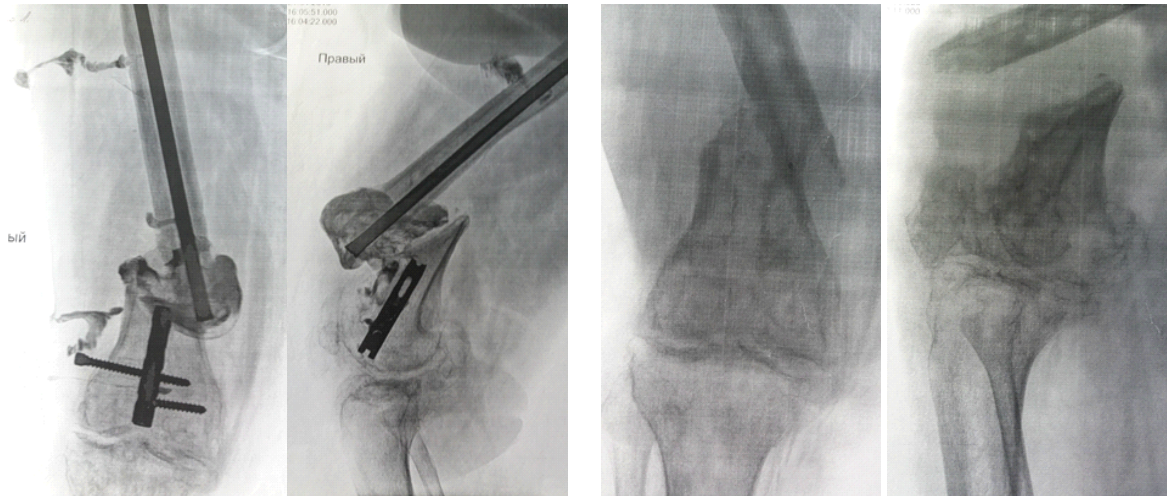
of bone fragments and the absence of fracture consolidation signs. Unstable fracture osteosynthesis in this patient potentiated development of chronic post-traumatic osteomyelitis (*Fig. 1, a, b, tables 2, 3*).

The use of short cortical screws for bone osteosynthesis, especially in conditions of comminuted fracture of the femoral diaphysis, caused migration of screws with impaired stability of bone fragments fixation, delayed fracture consolidation (4 patients; 19.0%), and the formation of a false joint (5 patients; 23.8 %).

Surgically dependent causes that could lead to development of complications of osteosynthesis of diaphyseal hip fractures were noted throughout the perioperative period, but mainly after surgery. Most often, the terms of postoperative x-ray monitoring of the operated segment and unrepaired intraoperative displacement of the fragments of the femur – in 5 (23.8%) of observations were violated. Violation of the technology of x-ray diagnosis by performing x-ray of the femur only in the lateral projection, as well as only in the area of the diaphyseal fracture without adjacent joints, was noted in 2 (9.6%) and 1 (4.8%) cases, respectively.

In one of the clinical cases with osteosynthesis of comminuted hip fracture, violation of the x-ray diagnostic technology (performing only one projection of the damaged segment) did not allow intraoperative visualize if there was a completely insufficient fixation of femur fragments (*Fig. 2a*), which was revealed only after 4 months after open reduction (*Fig. 2, b, c*) and led to delayed consolidation of the fracture with a tendency to false joint formation and post-traumatic deformation of the femoral diaphysis (*Fig. 2, d*).

In 3 (14.3%) patients, antibiotic therapy was started only after development of inflammatory changes in the postoperative wound area.



A *B*

Fig. 1 – *A* – fistulograms of a femoral fracture in the lower third, during surgical treatment, with the development of fistulous type of post-traumatic osteomyelitis: breakage of the intramedullary blocking rod, migration of the upper distal screw, fistulous passages filled with contrast; *B* – the absence of reparative fusion in the fracture area after removal of the intramedullary shaft

Table 3

Types of adverse outcomes of osteosynthesis of diaphyseal fractures of the femur

No.	Types of adverse outcomes of osteosynthesis of diaphyseal fractures of the femur	N (%)
1	Fracture of the intramedullary nail	1 (4.8)
2	Intramedullary rod migration	1 (4.8)
3	Migration of a distal blocked nail from an intramedullary nail	1 (4.8)
4	Migration of screws from the bony plate	10 (47.6)
5	Secondary displacement of bone fragments of the femur	10 (47.6)
6	Suppuration of a postoperative wound	5 (23.8)
7	Development of post-traumatic osteomyelitis	3 (14.3)
8	Development of post-traumatic contracture of the knee	17 (81.0)
9	Slow hip fracture consolidation	13 (61.9)
10	Formation of pseudarthrosis of the femur	8 (38.1)
11	Post-traumatic femoral deformity	15 (71.4)

A *B* *C* *D*

Fig. 2 – radiographs of a comminuted femoral fracture in the middle third during surgical treatment: *A* – (on the day of the injury, anteroposterior view) – insufficient (short) fixation of the proximal fragment, diastasis between the proximal, distal and comminuted fragments; *B* (anteroposterior view), *C* (lateral view) c in 4 months after the operation, the osteoporosis zone is visualized around the distal screws (b), diastasis between the distal fragment and the osseous plate (c); *D* (anteroposterior view) 6 months after the injury – removal of the osseous plate; diastasis between the proximal and distal fragments of the femur is observed

4. Discussion

Femur diaphysis fractures are one of the most common skeletal injuries. The total frequency of this injury, taking into account femoral diaphysis fractures during multiple and combined injuries, has been kept at a practically constant level in recent years: for 1 year, the average number was 20.8 per 100,000 adult population in 2018 [8] and 21 per 100,000 adult population in 2013 [9]. The frequency of isolated fractures of the femoral diaphysis within 1 year reaches an average of 10 per 100,000 adult population [10]. Since the femur is the largest in the skeleton, surrounded by the largest muscle mass, and one of the main supporting bones of the lower limb, isolated hip fractures are accompanied by significant blood loss, the development of traumatic shock, and lead to long-term disability regardless of the level of (high or low) kinetic energy traumatic factor [11].

The mechanism and location of the femoral fracture depend on the age of the victims. At the age of 40–45 years, femoral diaphysis fractures usually occur due to high-energy injuries [12]; the most common type of injury is an accident (up to 75%), a fall from a height (up to 7.3 – 10.0%), gunshot injuries (2.3 – 4.5%) [13, 14]. In older people, the proximal part of the femur is mainly damaged due to low-energy injuries, more often as a result of a fall from a small height [15].

Despite the advantages of surgical treatment of mechanical damage to the skeleton (stable fixation of the damaged segment, early motor activation of patients and early initiation of active rehabilitation treatment), the use of open fixation for fractures of the femur is still a matter of discussion [16, 17]. Such a restrained approach to choosing a surgical method of treatment is associated with a rather high frequency of postoperative complications, especially provided that such complications in patients with a fracture of the femur are more common and more difficult than with fractures of long tubular bones of a different location [18], which not only leads to lengthening of the disability period of the patients, but also – to their disability [19].

It should be noted that the internal fixing metal structures, which are used in the surgical treatment of skeleton bone fractures, during their usage can be damaged by loads exceeding the strength of

both the device structure itself and the bone to which they are fixed [20, 21]. This problem can be: 1) iatrogenic (the result of a violation of preoperative preparation, osteosynthesis technology or postoperative management) [22, 23]; 2) associated with the patient, when, due to violation of limits regime concerning the operated limb loads, these loads exceeded the durability of the implant or bone [24]; 3) due to the manifestation of a latent structural defect, which can lead to the fixator fracture in the absence of obvious external causes and full compliance with both surgical technology and recommendations for the postoperative regime [25, 26].

The most common cause of complications of submersible osteosynthesis of fractures of long tubular bones is violation of the technology of internal fixation of the bone fragments [27–29]. The first step to successful consolidation of the fracture is an open reduction with the restoration of the anatomical relationship in the damaged bone [27, 30, 31]; in the process of open reduction, it is necessary to avoid extensive skeletalization of the fragments [32, 33], which allows to save the maximum possible vascularization of the fracture zone. Important aspects of prevention of complications are preoperative planning with indications for the method of internal fixation, the correct operation with the optimal use of fixing structures [34], long and short screws depending on the fracture type (comminuted, non-fragmented) and the fracture location [35, 36], an early active development of movements in adjacent joints and a dosed load on the operated limb.

In our study, unstable fixation of the diaphyseal femoral fracture, due to various reasons, was detected in 20 (95.2%) cases. This led to a significant restriction of the motor regime in the postoperative period and potentiated development of knee joint contractures in 17 (81.0%) patients and impaired consolidation in all cases with a slower fracture fusion in 13 (61.9%) patients, and the formation of a false joint in 8 (38.1%) patients (*Table 3*).

Such outcomes of diaphyseal fractures of the femur are assessed as a serious injury to health by a forensic medical examination. At the same time, a thorough study of the causes of the unfavorable outcome of this fracture with a differentiated approach and taking into account the influence of patient-related, implant-related and surgery-related factors on given treatment outcome is necessary.

Conclusions

1. Isolated femoral diaphysis fractures are mostly closed (85.7%), localized mainly in the middle third (76.1%), and occur more often in men (76.1%) due to road accidents (90.4%).

2. The main causes for development of postoperative complications are unstable fixation of the fracture area (95.2%) and untreated displacement of femur fragments (71.4%) which lead to development of knee joint contractures in 17 (81.0%) patients with a delayed fracture fusion in 13 (61.9%) and the formation of a false joint in 8 (38.1%) cases.

3. The factors that potentiate development of postoperative complications in patients with hip diaphysis fractures are patient-dependent causes: obesity (38.1%), coxarthrosis (9.6%) and a history of gonarthrosis (28.6%), impaired orthopedic regimen the immediate postoperative period (14.3%) and the rehabilitation period (19.0%).

Research prospects. The revealed causes of complications after surgical treatment of femoral diaphysis fractures allow development of a set of organizational and therapeutic measures aimed at improving the results of open osteosynthesis of these fractures.

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Received: 21-Nov-2019
Accepted: 13-Feb-2020