



Risk factors for ischemic osteonecrosis of the femoral head after internal fixation with multiple cannulated screws for Pauwels type III femoral neck fracture

Faktori rizika od ishemijske osteonekroze glave femura posle unutrašnje fiksacije višestrukim kanuliranim zavrtanjima za frakturu vrata femura tipa III po Pauelsu

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Abstract

Background/Aim. Numerous factors lead to hip fractures that are common and often devastating in the geriatric population. The aim of the study was to determine the risk factors for ischemic osteonecrosis of the femoral head (ONFH) in patients after internal fixation with multiple cannulated screws for Pauwels type III femoral neck fracture (FNF). **Methods.** A total of 212 patients with Pauwels type III FNF, who underwent internal fixation with multiple cannulated screws from January 2019 to September 2022 and received one-year follow-up after surgery, were selected. Based on their clinical data and the incidence of ONFH, they were divided into two groups: the group with ischemic ONFH occurrence ($n = 30$) and the ischemic ONFH non-occurrence group ($n = 182$). Logistic regression analysis was conducted to analyze the risk factors for postoperative ischemic ONFH. **Results.** Age, body mass index (BMI),

time from injury to surgery, partial weight bearing (PWB) time after surgery, and preoperative diabetes mellitus (DM) were significantly different between the ischemic ONFH occurrence and ischemic ONFH non-occurrence groups ($p < 0.05$), while other clinical data showed no significant differences ($p > 0.05$). The results of logistic regression analysis revealed that age (> 55 years), PWB time after surgery (≤ 3 months), BMI (≥ 24 kg/m²), time from injury to surgery (> 2 days), and preoperative DM were independent risk factors for postoperative ischemic ONFH ($p < 0.05$). **Conclusion.** The incidence of postoperative ischemic ONFH can be prevented by effectively controlling the following factors: age, BMI, PWB after surgery, and preoperative DM.

Key words:

bone screws; femoral neck fractures; femur head; fracture fixation, internal; orthopedic procedures; osteonecrosis; risk factors.

Apstrakt

Uvod/Cilj. Mnogobrojni faktori dovode do preloma kuka, koji je u gerijatrijskoj populaciji učestao i često razoran. Cilj rada bio je da se utvrde faktori rizika od ishemijske osteonekroze glave femura (ONGF) posle unutrašnje fiksacije višestrukim kanuliranim zavrtanjima kod bolesnika sa frakturom vrata femura (FVF) tipa III po Pauelsu. **Metode.** Izdvojeno je ukupno 212 bolesnika sa FVF tipa III po Pauelsu, koji su bili podvrgnuti unutrašnjoj fiksaciji pomoću kanuliranih zavrtanja od januara 2019. do septembra 2022. godine i praćeni tokom jedne godine. Na osnovu kliničkih podataka i uočene incidencije ishemijske ONGF, bolesnici su raspoređeni u dve grupe: grupu sa pojavom ishemijske ONGF ($n = 30$) i grupu bez pojave ishemijske ONGF ($n = 182$). Za

analizu faktora rizika od postoperativne ishemijske ONGF korišćena je logistička regresiona analiza. **Rezultati.** Životno doba, indeks telesne mase (ITM), vremenski interval od povrede do operacije, period parcijalnog opterećenja težinom tela (POT) posle operacije i preoperativni dijabetes melitus (DM) značajno su se razlikovali između grupe sa pojavom ishemijske ONGF i one bez pojave ishemijske ONGF ($p < 0,05$), dok nije bilo značajne razlike u ostalim kliničkim podacima ($p > 0,05$). Rezultati logističke regresione analize ukazuju na to da su životno doba (> 55 godina), period POT posle operacije (≤ 3 meseca), ITM (≥ 24 kg/m²), vremenski interval od povrede do operacije (> 2 dana) i preoperativni DM bili nezavisni faktori rizika od nastanka postoperativne ishemijske ONGF ($p < 0,05$). **Zaključak.** Incidencija

postoperativne ishemijske ONGF može biti snižena efikasnom kontrolom sledećih faktora rizika: životnog doba, vremena od povrede do operacije, perioda POT posle operacije i prisustva preoperativnog DM.

Ključne reči:

zavrtnji za kost; femur, prelomi vrata; femur, glava; prelomi, fiksacija, unutrašnja; ortopedske procedure; osteonekroza; faktori rizika.

Introduction

Femoral neck (FN) fracture (FNF) is a common hip fracture found between the femoral head and the base of the FN, also known as intracapsular hip fracture, since the fracture line lies in joint¹. Epidemiological data indicate that FNF accounts for about 3.66% of all fractures. In the young population, it is mainly attributed to high-energy forces, whereas in the elderly, it is mostly associated with osteoporosis, same-level falls, and other low-energy forces^{2,3}. Pauwels type III (PTIII) FNF refers to fractures with an angle of $\geq 50^\circ$ between the distal fracture line and the horizontal line, having a large vertical shear force and many complications after surgery. The surgical treatment of FNF includes internal fixation (IF) and artificial hip replacement. Currently, IF with multiple cannulated screws (CSs) is often used to treat PTIII FNF, which can provide relatively satisfactory outcomes. However, such treatment leads to a fairly high incidence rate of long-term complications and disability rate due to the anatomical and blood supply characteristics of the femoral head and neck. As a severe complication, ischemic osteonecrosis of the femoral head (ONFH) has an incidence rate of about 8–40% after IF with multiple CSs for PTIII FNF³. In addition, it has been proven that ischemic ONFH is difficult to treat, resulting in varying degrees of femoral head collapse accompanied by impaired walking and joint movement, which seriously affects the quality of life⁴. Therefore, ischemic ONFH is currently a major problem in PTIII FNF treatment. Defining the risk factors for ischemic ONFH following multiple IF with multiple CSs for PTIII FNF is of great significance in preventing such a complication and decreasing its incidence.

Methods

This retrospective analysis included 212 patients with PTIII FNF. IF was performed on all patients with multiple CSs at our hospital from January 2019 to September 2022, and they were followed up for one year after surgery. This study was approved by the Jiangsu Integrated Chinese and Western Medicine Hospital on January 4, 2019.

The patients were divided into two groups based on the incidence of ischemic ONFH: an ONFH occurrence group ($n = 30$) and an ONFH non-occurrence group ($n = 182$).

The inclusion criteria were set as follows: age > 18 years, relevant criteria of FNF in the "Clinical Guidelines for Diagnosis and Treatment: Orthopedics"⁵, IF with

multiple CSs, unilateral FNF, and fracture time < 3 weeks. The exclusion criteria were incomplete clinical data, associated fractures, or severe diseases.

Patient data included gender, mechanism of injury, injured side, conducted or not conducted traction, duration of surgery, age, body mass index (BMI), time from injury to surgery (TIS), partial weight bearing (PWB) time after surgery, preoperative diabetes mellitus (DM), and preoperative hypertension.

Statistical analysis

A Statistical Package for the Social Sciences (SPSS) software version 26.0 was adopted for data processing and analysis. Descriptive data were analyzed, and the Chi-squared χ^2 test was used to compare the occurrence and non-occurrence groups. Logistic regression was performed to find the risk factors for postoperative ischemic ONFH in patients with PTIII FNF. The difference was considered statistically significant if $p < 0.05$.

Results

Thirty (14.15%) patients suffered from ischemic ONFH out of the 212 patients with PTIII FNF who performed IF with multiple CSs.

The comparisons of clinical data between the two groups shown indicated no statistically significant differences regarding gender, mechanism of injury, injured side, traction conducted performance, duration of surgery, and preoperative hypertension presence ($p > 0.05$). The numbers of patients older than 55 years, with $BMI \geq 24 \text{ kg/m}^2$, $TIS > 2$ days, PWB time after surgery ≤ 3 months, and preoperative DM showed a statistically significant difference between the ischemic ONFH occurrence and ischemic ONFH non-occurrence groups ($p < 0.05$) (Table 1).

Logistic regression analysis was performed using the incidence of ischemic ONFH after IF with multiple CSs for PTIII FNF as the dependent variable (ONFH occurrence group = 1, ONFH non-occurrence group = 0) and the factors with statistically significant differences (age, BMI, TIS, PWB time after surgery, and preoperative DM) as the independent variables (Table 2). It was found that age > 55 years, $BMI \geq 24 \text{ kg/m}^2$, $TIS > 2$ days, PWB after surgery ≤ 3 months, and the presence of preoperative DM were confirmed as the risk factors for postoperative ischemic ONFH (odds ratio > 1 , $p < 0.05$) (Table 3).

Table 1**General data of patients with Pauwels type III femoral neck fractures who underwent surgery**

Parameter	Group		χ^2	<i>p</i>
	ONFH occurrence (n = 30)	ONFH non-occurrence (n = 182)		
Gender			1.428	0.232
male	15 (50.00)	112 (61.54)		
female	15 (50.00)	70 (38.46)		
Age, years			21.310	< 0.001
> 55	20 (66.67)	45 (24.73)		
≤ 55	10 (33.33)	137 (75.27)		
Body mass index, kg/m ²			11.996	0.001
≥ 24	18 (60.00)	51 (28.02)		
< 24	12 (40.00)	131 (71.98)		
Injury cause			0.002	0.963
falls	12 (40.00)	72 (39.56)		
car accidents	18 (60.00)	110 (60.44)		
Injured side			1.322	0.250
left	14 (46.67)	65 (35.71)		
right	16 (53.33)	117 (64.29)		
Traction			2.640	0.104
yes	13 (56.67)	52 (28.57)		
no	17 (43.33)	130 (71.43)		
Duration of surgery, hrs			1.205	0.272
> 2	11 (36.67)	49 (26.92)		
≤ 2	19 (63.33)	133 (73.08)		
TIS, days			21.220	< 0.001
> 2	17 (56.67)	33 (18.13)		
≤ 2	13 (43.33)	149 (81.87)		
PWB time, months			17.641	< 0.001
≤ 3	14 (46.67)	26 (14.29)		
> 3	16 (53.33)	156 (85.71)		
Preoperative diabetes mellitus			28.984	< 0.001
yes	18 (60.00)	29 (15.93)		
no	12 (40.00)	153 (84.07)		
Preoperative hypertension			2.110	0.146
yes	12 (40.00)	52 (28.57)		
no	18 (60.00)	140 (71.43)		

ONFH – osteonecrosis of the femoral head; TIS – time from injury to surgery; PWB – partial weight bearing. All values are given as numbers (percentages).

Table 2**Variable assignment methods**

Variable	Meaning	Assignment	
		1	0
X1	Age, years	> 55	≤ 55
X2	Body mass index, kg/m ²	≥ 24	< 24
X3	TIS, days	> 2	≤ 2
X4	PWB time after surgery, months	≤ 3	> 3
X5	Preoperative diabetes mellitus	yes	no
Y	Ischemic ONFH	yes	no

ONFH – osteonecrosis of the femoral head; For other abbreviations, see Table 1.

1 – ischemic ONFH occurrence group; 0 – ischemic ONFH non-occurrence group.

Table 3

Logistic regression analysis results of multiple risk factors for ischemic ONFH after internal fixation with multiple CSs for Pauwels type III FNF

Variable	β	Standard error	Wald	<i>p</i>	Odds ratio	95% confidence interval
Age	1.806	0.424	18.178	< 0.001	6.089	2.654–13.970
Body mass index	1.349	0.408	10.951	0.001	3.853	1.733–8.565
TIS	1.776	0.416	18.251	< 0.001	5.904	2.614–13.334
PWB	1.658	0.423	15.379	< 0.001	5.250	2.292–12.025
Preoperative DM	2.069	0.424	23.785	< 0.001	7.914	3.446–18.173

DM – diabetes mellitus; CSs – cannulated screws; FNF – femoral neck fracture. For other abbreviations, see Table 1.

Discussion

The incidence of FNF is gradually increasing because of transportation development and the acceleration of the aging process⁶. FNF is caused by external forces on the FN. It is highly related to osteoporosis. The fracture can occur when FN is under a slight torsional force, and it is more likely to be found in middle-aged and elderly people since such populations are the most vulnerable to osteoporosis. Displacement of the FNF damages the basilar artery ring outside the joint capsule, which compromises the main blood supply to the femoral head, thus resulting in avascular ONFH⁷. Moreover, FNF leads to changes in neck-shaft angle and FN anteversion and destroys the balance between structure and function, which results in stress concentration in the joint and remodeling of the femoral head bone trabecular microstructure. Bone trabecular degeneration and collapse may occur if the remodeled structure fails to adapt to the new compressive stress and biomechanical environment, inducing further malformation and obstruction of peripheral blood vessels. Eventually, ONFH occurs after FNF surgery, reflecting on the postoperative quality of life⁸. PTIII FNF is followed by a large vertical shear force, poor stability, and relatively high risk of IF failure or fracture displacement after surgical reduction, easily causing severe damage to the femoral head blood supply and consequent fracture nonunion and ONFH^{9,10}. Studies have manifested that the IF approach of inserting multiple CSs into FN is the most stable^{11,12}. Various studies have demonstrated that despite the high clinical value, IF with multiple CSs still leads to ONFH. If not detected on time and if not treated actively, ONFH is followed by painful and dysfunctional hip joint, inducing socioeconomic problems and even requiring artificial joint replacement^{13,14}. For this reason, actively preventing the ONFH after IF with multiple CSs for PTIII FNF is a crucial measure for effectively improving the prognosis of these patients.

In this study, 30 patients had postoperative ischemic ONFH, with an incidence rate of 14.15%, which is in line with that reported in previous literature¹⁰. In the face of the high incidence rate of ONFH in patients undergoing surgery for PTIII FNF, age has always been a key research issue. Kim and Kim¹⁵ pointed out that a higher incidence rate of postoperative ONFH is found in older patients with

PTIII FNF. The reason may be the fact that older patients experience greater calcium loss, gradual decline in body functions, and progressive failure of organ functions, thus developing osteoporosis. Besides, Zhao et al.¹⁶ reported that PTIII FNF patients with BMI ≥ 24 kg/m² had a higher incidence rate of postoperative ONFH, which is in accordance with our study. Excessive BMI usually suggests higher blood viscosity, which increases the risk of thrombosis and microcirculation supply disorder, further inducing postoperative ONFH. In addition, the incidence of postoperative ischemic ONFH is related to TIS. A higher number of patients with TIS > 2 days in the ischemic ONFH occurrence group, as found in our study, can be explained by the state that earlier surgery can cure vascular distortion, compression, and spasm after quick fracture reduction. This leads to a decrease of the pressure in the joint capsule (previously increased by the fracture) and improves or eliminates the effect of packing, which thereby reopens the temporarily closed blood vessels and restores the remaining blood supply. However, regarding the time of > 2 days from injury to surgery, the bone structure undergoes great changes, and joint stability becomes worse, leading to a higher incidence rate of postoperative ischemic ONFH. Furthermore, the incidence rate of ONFH rises significantly in patients with PWB time after surgery ≤ 3 months¹⁷. The results of this study revealed that the proportion of patients with PWB time after surgery ≤ 3 months was remarkably larger in the ischemic ONFH occurrence group than in the ischemic ONFH non-occurrence group. A higher incidence of ischemic ONFH when PWB time after surgery is ≤ 3 months can be explained by the fact that within three months after surgery, the patient's fractures are not fully healed, and premature PWB will cause considerable stress on the FN. As a result, IF screw loosening and cutting easily occur, making IF ineffective and thereby resulting in unstable immobilization, shortening, and *varus* deformity. Eventually, nonunion occurs, further increasing the incidence rate of ONFH¹⁸. Moreover, patients with preoperative DM are more susceptible to postoperative ONFH¹⁹. It was indicated in our study that the ischemic ONFH occurrence group had more patients with preoperative DM than the ischemic ONFH non-occurrence group. Patients with preoperative DM suffer from a multi-system dysfunction caused by impaired glucose metabolism

in the body. Abnormal glucose metabolism will directly cause vascular endothelial proliferation and thicken the capillary basement membrane, narrowing the vascular lumen, reducing the elastic function of the wall, and impairing the blood supply capacity. However, the femoral head has a greater demand for blood supply due to its specific blood supply. The remodeling of blood vessels after FNF directly impacts the blood supply to the femoral head. In patients with preoperative DM, blood vessels have undergone different degrees of damage before the injury, and the blood supply to the femoral head suffers secondary damage caused by FNF. As a result, the risk of ONFH in such patients is greatly increased.

Conclusion

In summary, age > 55 years, body mass index $\geq 24 \text{ kg/m}^2$, time from injury to surgery > 2 days, partial weight bearing time after surgery ≤ 3 months, and preoperative diabetes mellitus presence are considered the risk factors for ischemic osteonecrosis of the femoral head after internal fixation with multiple cannulated screws for Pauwels type III femoral neck fracture.

Conflict of interest

The authors declare no conflict of interest.

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