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Research article

Existing hip joint disease is associated with an increased incidence of hip fracture in adults: A retrospective survey of 9710 individuals from a single center

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ABSTRACT

Objective: In hip disease patients, pain and movement restrictions might cause changes in bone strength and increase the likelihood of falls, finally leading to hip fracture. The aim of this study was to identify the incidence of, characteristics of and risk factors for hip fracture in patients with existing hip disease.

Methods: This was a retrospective cohort study. Patients with existing hip disease treated at both outpatient and inpatient departments of our institute were identified by searching the electronic medical record system and followed retrospectively for the occurrence of hip fracture. Demographic and clinical characteristics, such as age, sex and kind of primary hip disease, were collected from the electronic medical record system. The incidence and timing of hip fracture were estimated, and a Cox regression model was built to identify the independent risk factors for hip fracture in these patients.

Results: A total of 9710 eligible patients were included. After a mean follow-up of 3.97 years, hip fractures were identified in 95 patients, for an estimated incidence of hip fracture of 978.37 per 100,000 patients. The femoral neck was involved in 49 fractures (51.58 %), and the femoral trochanter was involved in 45 fractures (47.37 %). Four independent risk factors and one protective factor for hip fracture in patients with hip diseases were identified: age (HR = 1.116, 95 % CI = 1.094–1.138), the presence of osteonecrosis of the femoral head (HR = 2.201, 95 % CI = 1.217–3.980), a lower Harris hip score (HR = 0.966, 95 % CI = 0.949–0.982), a history of previous hip surgery (HR = 2.126, 95 % CI = 1.304–3.466) and the use of walking aids (HR = 0.588, 95 % CI = 0.354–0.975). A scoring system with a total score of 20 points was built, which included all of the above risk factors. The predictive scores for a low risk (estimated incidence of hip fracture ≤30 %), a moderate risk (estimated incidence of hip fracture 31 %–69 %), and a high risk (estimated incidence of hip fracture ≥70 %) of hip fracture were ≤8.5 points, 9.0–13.0 points and ≥13.5 points, respectively.

Conclusion: The incidence of hip fracture in the special population of patients with existing hip disease was determined. Elderly patients, patients with a history of hip surgery, patients with osteonecrosis and patients with poor Harris hip scores were at increased risk of hip fracture. In

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patients with a predictive score greater than 9 points, indicating a moderate to high risk of hip fracture, the use of a walking aid might reduce the risk of hip fracture.

1. Introduction

Hip fracture is a serious health problem due to its high incidence, high mortality, high costs and frequent adverse outcomes [1]. Paspati et al. [2] reported that the incidence of hip fracture was 107.30/100,000 overall and was 314.07/100,000 among those aged over 50 years. The average cost per patient was 9097 USD(3), and the one-year mortality rate was 20 % [4]. Worse still, only 30 %–40 % of patients recover their previous functional status [5]. Therefore, the prediction and prevention of hip fractures are crucial.

Currently, it is well established that hip fracture is a fragility fracture that is closely related to two factors: osteoporosis and falling [1,6]. For instance, Yang et al. [7] suggested that over 95 % of hip fractures in older adults were caused by falls. A meta-regression [8] found that with a 2 % or 6 % improvement in total hip bone mineral density, a 16 % or 40 % reduction in hip fracture risk might be expected. Hip disease, such as osteonecrosis or osteoarthritis, might cause pain and movement restriction in the affected hip joint, which can cause bone mass loss in both the acetabulum and proximal femur [9–11] and can increase the incidence of falls from a standing height due to movement limitations [12–15], so there is reason to suspect that existing hip disease might also make hip fracture more likely.

Unfortunately, the link between existing hip disease and hip fracture is still unclear. This study is novel in enrolling only patients with existing hip disease rather than healthy individuals. By investigating the incidence, characteristics and risk factors for hip fracture in these patients, the relationship between existing hip disease and hip fracture was then determined. Specifically, the aims of this study were as follows [1]: to estimate the incidence of hip fracture in adult patients with existing hip disease [2]; to determine their fracture types and causes [3]; to determine their risk factors for hip fracture; and [4] to build a scoring system to evaluate the risk of hip fracture in these patients.

2. Patients and methods

2.1. Study design

This was a retrospective cohort study. Patients with primary hip disease were identified and followed retrospectively for the occurrence of hip fracture.

2.2. Participants

The electronic medical record inquiry system and picture archiving and communication system at our institute (the Third Hospital of Hebei Medical University) were used to identify the study population. From 2010 to 2019, adult patients without previous trauma who were diagnosed with hip diseases were included. Specifically, the following hip diseases with acetabular, proximal femoral or articular surface bone lesions were included, based on their International Classification of Diseases-10 (ICD-10) codes: osteoarthritis (ICD-10 codes: M13 and M16); osteonecrosis of the femoral head (ICD-10 code: M87); hip dysplasia (ICD-10 codes: M16 and Q65); and other diseases, such as sepsis, tuberculosis, unreduced dislocation, impingement syndrome, rheumatoid and ankylosing spondylitis (ICD-10 codes: M00-M16, M19, M24-M25, M45, A18, S73, and T03). The exclusion criteria were as follows: age less than 18 years; a follow-up time of less than 1 year; isolated soft-tissue disease without changes in bone structure, such as gluteus contracture and piriformis syndrome; history of hip fracture or other serious lower limb trauma prior to the onset of hip disease; malignant tumor; genetic, metabolic or malformative bone disease; and missing medical records or radiological data.

This study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University and was conducted in accordance with the Declaration of Helsinki. As this was a retrospective study and all patient information was deidentified before analysis, informed consent was required only for the patients whose radiological images were selected for publication. This exemption from requiring informed consent was granted by the Ethics Committee of the Third Hospital of Hebei Medical University.

2.3. Baseline and follow-up data collection

Demographic and clinical information, such as sex, age, body mass index, affected side, smoking and alcohol status, steroid use and comorbidities, was retrieved from the medical records at baseline and the final follow-up. In addition to demographic characteristics, information on the patients' primary hip disease, treatment history and lifestyle behaviors was investigated. The parameters assessed included whether the patient used analgesics, used a walking aid, lived alone, received anti-osteoporosis treatment and had a history of hip joint surgery, such as core decompression for osteonecrosis, periacetabular osteotomy for developmental dysplasia, and arthroscopy for osteoarthritis. If a patient developed hip disease successively rather than simultaneously on the two sides, he or she was considered a patient with bilateral hip disease unless a hip fracture occurred prior to the onset of the second hip disease. If a patient had bilateral hip disease and underwent unilateral arthroplasty, he or she was included in the "unilateral hip disease" category.

The status of the primary hip disease was also investigated by considering the radiological findings and pain and functional assessment results. The Kellgren–Lawrence classification system was used to evaluate the radiological data collected from these patients [16]. The visual analog scale (VAS) score was applied as a measure of the severity of pain in these patients [17]. The Harris hip score was applied as a measure of function [18]. Note that for patients with bilateral hip disease, the Harris hip score (as well as the VAS score) was evaluated independently for each side, and the two scores were averaged. For all of these indices, if a patient had bilateral hip disease and underwent unilateral hip arthroplasty, the patient's information and data recorded before the last follow-up

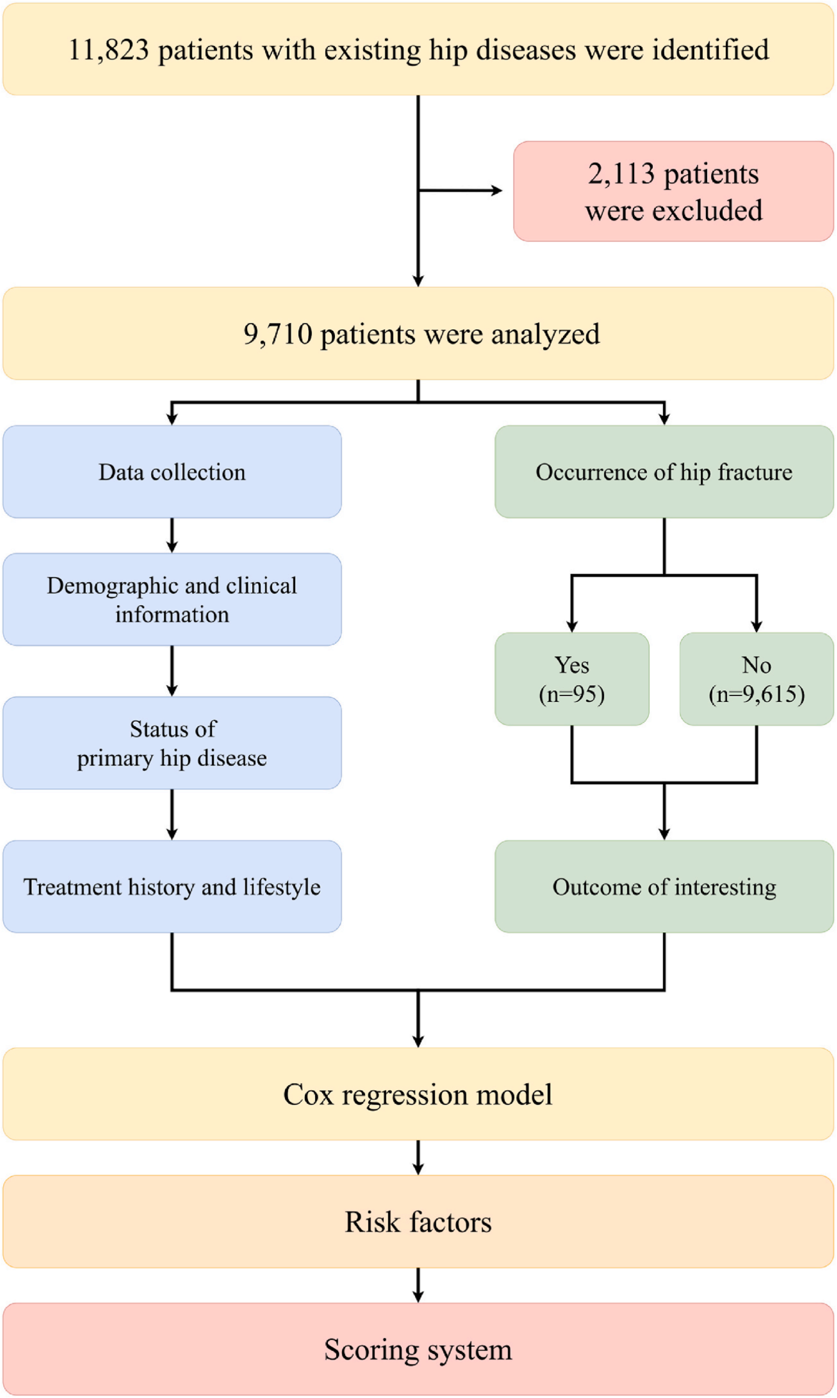

Fig. 1. Flow chart outlining the patient inclusion process and study methods.
Figure Legend: Patients with existing hip disease (n = 11,823) treated at both outpatient and inpatient departments of our institute were identified. A total of 2113 patients who met the exclusion criteria were excluded, leaving 9710 eligible patients to be analyzed. Demographic and clinical characteristics, such as age, sex and kind of primary hip disease, were collected from the electronic medical record system. The incidence and timing of hip fracture were estimated, and a Cox regression model was built to identify the independent risk factors for hip fracture in these patients.

were analyzed. However, if hip arthroplasty was performed bilaterally, the patient's information before the last hip arthroplasty was analyzed.

2.4. Outcomes of interest

The occurrence of hip fracture (including femoral neck fracture, intertrochanteric fracture or subtrochanteric fracture; ICD-10: S72) was considered the primary endpoint event in this study. The corresponding time-to-event outcome variable (disease duration) was calculated as the time from the primary hip disease diagnosis to the occurrence of hip fracture, hip arthroplasty or the last follow-up. Patients were censored at the date of the last follow-up if all diseased joints were replaced by artificial joints or no fractures were identified. The incidence of hip fractures in this population was estimated. The fracture side, affected femoral site (classification) and cause of fracture were also investigated. Note that in patients with bilateral primary hip disease, either the initial unilateral hip fracture or concurrent bilateral hip fracture was considered the ipsilateral fracture in this study.

2.5. Statistical analysis

Statistical analyses were performed using SPSS, version 19.0, statistical software for Windows (IBM, Armonk, New York). Continuous variables are expressed as the mean ± standard deviation, and categorical variables are expressed as frequencies. The Mann−Whitney *U* test was performed for comparisons between continuous variables. The chi-square test was performed for the comparison of categorical variables and estimation of odds ratios. A Kaplan−Meier survival curve was drawn using SPSS software. Cox proportional hazards regression analysis was used to assess the associations between potential risk factors and the onset of hip fracture. Because the occurrence of major trauma might be difficult to predict, only hip fractures caused by minor trauma and spontaneous hip fractures were included in this analysis. The stepwise regression method was used to determine the final independently associated variables. After identifying the initial risk factors, receiver operating characteristic (ROC) curves were created for continuous variables. Then, two cutoff points were made at the estimated risk of 30 % and 70 % for hip fracture from the coordinate points of the ROC curve. Another Cox regression model was built to establish the diagnostic model including the converted categorical variables. According to the β-coefficient, a weighted scoring system was built to help predict the occurrence of hip fracture in patients with existing hip disease. The total score of the system was 20 points. Note that the weight of each factor could be slightly adjusted according to the clinical significance and convenience of calculation. The ROC curve for this scoring system was drawn, and the area under the ROC curve (AUC) was calculated to estimate its predictive accuracy. Some cutoff points were also identified to estimate the risk of hip fracture. The risk of hip fracture was considered to be low if the risk was less than 30 % and high if the risk was greater than 70 %. A P value less than 0.05 was considered to be significant in this study.

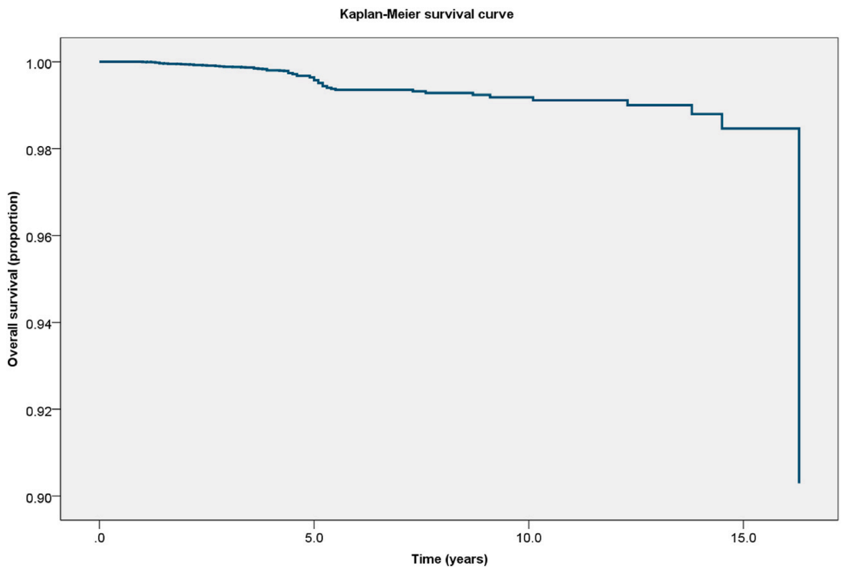

Fig. 2. Kaplan−Meier survival curve for patients with existing hip disease.
Figure Legend: The endpoint event was the occurrence of hip fracture. Patients were censored at the date of the last follow-up if all diseased joints were replaced by artificial joints or no fractures were identified. The corresponding time-to-event outcome variable was calculated as the time from primary hip disease diagnosis to the occurrence of hip fracture, hip arthroplasty or the last follow-up.

3. Results

3.1. Patient characteristics

A total of 11,823 patients met the inclusion criteria (Fig. 1). Among them, 2113 patients were excluded due to missing information in the medical records (n = 982), insufficient radiological data (n = 865), or meeting other exclusion criteria (n = 266). Finally, a total of 9710 patients were analyzed after a mean follow-up of 3.97 years (range, 1 year to 16.3 years).

3.2. Incidence of hip fracture

Hip fractures were identified in 95 patients, all of them unilateral. The incidence of hip fracture in patients with hip disease was 978.37 per 100,000 patients (Fig. 2). A total of 108 proximal femoral fractures were identified in 512,187 healthy individuals in the previously reported China National Fracture Study [19]; these data were retrieved for this analysis. Compared with the incidence in this healthy population, the estimated odds ratio for hip fracture was 46.40 (95 % CI = 35.19–61.17, $\chi^2 = 2223.744$, $p < 0.001$) in this cohort of patients with hip disease. Note that since these two samples came from different sources and the cohorts were not standardized by age or sex, this estimated odds ratio may not be accurate.

3.3. Characteristics of patients who did and did not experience hip fracture

The demographic characteristics, types and stages of primary hip disease, patient lifestyle behaviors and methods used to treat primary hip disease were compared between patients who did and did not experience a hip fracture event during the follow-up period. Among patients who experienced a hip fracture event, the proportion of female patients (45.26 % vs. 33.19 %, P = 0.013) and the average age (64.27 ± 13.65 vs. 50.10 ± 14.44, P < 0.001) were higher than among patients who did not experience a hip fracture event (Table 1). Patients with hip fractures showed lower Harris hip scores (66.96 ± 10.79 vs. 71.63 ± 13.32, P < 0.001) and higher VAS scores (3.49 ± 1.46 vs. 3.24 ± 1.72, P = 0.044) than patients without hip fractures (Table 2). The distribution of Kellgren–Lawrence grades was also different between the two groups (Table 2, P = 0.042). Finally, patients with a surgical history had a higher risk of suffering from hip fracture (Table 3, 30.53 % vs. 18.56 %, P = 0.003).

3.4. Fracture types and causes

Among all 95 patients with hip fractures, 70 (73.68 %) had ipsilateral fractures, and 25 (26.32 %) had contralateral fractures (Table 4, Fig. 3). In terms of the fracture site, the femoral neck was involved in 49 fractures (51.58 %), and the femoral trochanter was involved in 45 fractures (47.37 %). In one patient, a periprosthetic femoral fracture was identified after unilateral hip arthroplasty. The majority of hip fractures observed in this population of patients with hip disease were caused by minor trauma (low-energy trauma, 67.37 %). Other causes were spontaneous fractures due to femoral head necrosis (11.58 %, Fig. 4) and major trauma (high-energy

Table 1
Demographic information of the patients with hip disease included in this study.

Patients characteristics	Patients with hip fracture (n = 95)	Patients without hip fracture (n = 9615)	Total (n = 9710)	Test statistics	P
Sex					
Male	52 (54.74 %)	6424 (66.81 %)	6476 (66.69 %)	6.175[b]	0.013
Female	43 (45.26 %)	3191 (33.19 %)	3234 (33.31 %)		
Age (years)	64.27 ± 13.65	50.10 ± 14.44	50.23 ± 14.50	−8.844[a]	<0.001
Body mass index	23.96 ± 5.53	24.79 ± 5.81	24.78 ± 5.81	−1.359[a]	0.174
Laterality					
Unilateral	28 (29.47 %)	3636 (37.82 %)	3664 (37.73 %)	2.786[b]	0.095
Bilateral	67 (70.53 %)	5979 (62.18 %)	6046 (62.27 %)		
Smoking					
No	56 (58.95 %)	5071 (52.74 %)	5127 (52.80 %)	1.454[b]	0.228
Yes	39 (41.05 %)	4544 (47.26 %)	4583 (47.20 %)		
Alcohol consumption					
No	68 (71.58 %)	6010 (62.51 %)	6078 (62.60 %)	3.307[b]	0.069
Yes	27 (28.42 %)	3605 (37.49 %)	3632 (37.40 %)		
Steroid use					
No	89 (93.68 %)	8656 (90.03 %)	8745 (90.06 %)	1.407[b]	0.236
Yes	6 (6.32 %)	959 (9.97 %)	965 (9.94 %)		
Diabetes					
No	89 (93.68 %)	9190 (95.58 %)	9279 (95.56 %)	0.797[b]	0.372
Yes	6 (6.32 %)	425 (4.42 %)	431 (4.44 %)		
Osteoporosis					
No	84 (88.42 %)	8259 (85.90 %)	8343 (85.92 %)	0.495[b]	0.482
Yes	11 (11.58 %)	1356 (14.10 %)	1367 (14.08 %)		

[a] Mann−Whitney *U* test.
[b] Chi-square test.

Table 2
Types of primary hip disease, stage, hip pain and hip function in patients with hip disease.

Patient characteristics	Patients with hip fracture (n = 95)	Patients without hip fracture (n = 9615)	Total (n = 9710)	Test statistics	P
Disease duration (years)	4.11 ± 2.81	3.97 ± 2.63	3.97 ± 2.63	−0.753[a]	0.452
Primary hip disease					
Osteoarthritis	16 (16.84 %)	1862 (19.37 %)	1878 (19.34 %)	6.176[b]	0.103
Osteonecrosis	73 (76.84 %)	6737 (70.07 %)	6810 (70.13 %)		
Hip dysplasia	6 (6.32 %)	505 (5.25 %)	511 (5.26 %)		
Other	0 (0.00 %)	511 (5.31 %)	511 (5.26 %)		
Kellgren–Lawrence grade					
Grade 0	3 (3.16 %)	515 (5.36 %)	518 (5.33 %)	9.892[b]	0.042
Grade 1	33 (34.74 %)	3099 (32.23 %)	3132 (32.26 %)		
Grade 2	32 (33.68 %)	2517 (26.18 %)	2549 (26.25 %)		
Grade 3	24 (25.26 %)	2270 (23.61 %)	2294 (23.63 %)		
Grade 4	3 (3.16 %)	1214 (12.63 %)	1217 (12.53 %)		
Visual analog scale score (points)	3.49 ± 1.46	3.24 ± 1.72	3.24 ± 1.72	−2.014[a]	0.044
0–3	47 (49.47 %)	5411 (56.28 %)	5458 (56.21 %)	5.319[b]	0.070
4–6	47 (49.47 %)	3803 (39.55 %)	3850 (39.65 %)		
>7	1 (1.05 %)	401 (4.17 %)	402 (4.14 %)		
Harris hip score (points)	66.96 ± 10.79	71.63 ± 13.32	71.59 ± 13.30	−3.933[a]	<0.001
Excellent	0 (0.00 %)	688 (7.16 %)	688 (7.09 %)	23.656[b]	<0.001
Good	8 (8.42 %)	2318 (24.11 %)	2326 (23.95 %)		
Fair	35 (36.84 %)	2575 (26.78 %)	2610 (26.88 %)		
Poor	52 (54.74 %)	4034 (41.96 %)	4086 (42.08 %)		

Note: A Harris hip score of 90–100 was considered to indicate excellent hip function; 80–89, good; 70–79, fair; and less than 70, poor.
[a] Mann−Whitney *U* test.
[b] Chi-square test.

Table 3
Treatment history and life behaviors of patients with hip disease.

Patients characteristics	Patients with hip fracture (n = 95)	Patients without hip fracture (n = 9615)	Total (n = 9710)	Test statistics	P
Analgesic use					
No	79 (83.16 %)	7652 (79.58 %)	7731 (79.62 %)	0.740[a]	0.390
Yes	16 (16.84 %)	1963 (20.42 %)	1979 (20.38 %)		
Walking aid use					
No	61 (64.21 %)	5714 (59.43 %)	5775 (59.47 %)	0.893[a]	0.345
Yes	34 (35.79 %)	3901 (40.57 %)	3935 (40.53 %)		
Live alone					
No	87 (91.58 %)	8837 (91.91 %)	8924 (91.91 %)	0.014[a]	0.907
Yes	8 (8.42 %)	778 (8.09 %)	786 (8.09 %)		
Anti-osteoporosis treatment					
No	89 (93.68 %)	8927 (92.84 %)	9016 (92.85 %)	0.100[a]	0.752
Yes	6 (6.32 %)	688 (7.16 %)	694 (7.15 %)		
Surgical history					
No	66 (69.47 %)	7830 (81.44 %)	7896 (81.32 %)	8.860[a]	0.003
Yes	29 (30.53 %)	1785 (18.56 %)	1814 (18.68 %)		

[a] Chi-square test.

trauma, 21.05 %). Cardiovascular diseases and cerebrovascular diseases were identified in 11 fracture patients (11.58 %) and 6 fracture patients (6.31 %), respectively. Another 3 fracture patients (3.16 %) had both cardiovascular disease and cerebrovascular disease. Detailed information regarding the fracture types and causes is shown in Table 4.

3.5. Risk factors for hip fracture

To minimize bias, only patients with hip fractures caused by minor trauma and spontaneous hip fractures (n = 75) were included in the Cox regression model. Five independent risk (protective) factors were identified (Table 5). Age was the foremost risk factor: every 1-year increase in age increased the hazard ratio of hip fracture by 11.6 % (HR = 1.116, 95 % CI = 1.094–1.138). The type of primary hip disease was the second risk factor for hip fracture. Compared with patients with osteoarthritis, patients with osteonecrosis of the femoral head were more likely to fracture a hip (HR = 2.201, 95 % CI = 1.217–3.980). Additionally, the hazard ratio for hip fracture decreased by approximately 3.4 % for every 1-point increase in the Harris hip score (HR = 0.966, 95 % CI = 0.949–0.982). The last risk factor for hip fracture in patients with hip disease was a history of hip surgery (Fig. 5). Compared with patients with no history of hip surgery, patients with a history of hip surgery had approximately twice the risk of hip fracture (HR = 2.126, 95 % CI = 1.304–3.466). Apart from these risk factors, a protective factor was also found in this study: Hip fracture was less likely in patients who used walking

Table 4
Incidence, characteristics and causes of hip fracture in patients with hip disease.

Patient characteristics	Count	Proportion	Incidence (per 100,000 patients)
Total	95	100 %	978.37
Fracture side			
Ipsilateral	70	73.68 %	720.91
Contralateral	25	26.32 %	257.47
Fracture classification			
Femoral neck fracture	49	51.58 %	504.63
Trochanteric fracture	45	47.37 %	463.44
Periprosthetic hip fracture	1	1.05 %	10.30
Fracture cause			
Major trauma	20	21.05 %	205.97
Minor trauma	64	67.37 %	659.11
Spontaneous	11	11.58 %	113.29
Comorbidity			
None	75	78.95 %	772.40
Cardiovascular diseases	11	11.58 %	113.29
Cerebrovascular diseases	6	6.31 %	61.79
Both	3	3.16 %	30.90

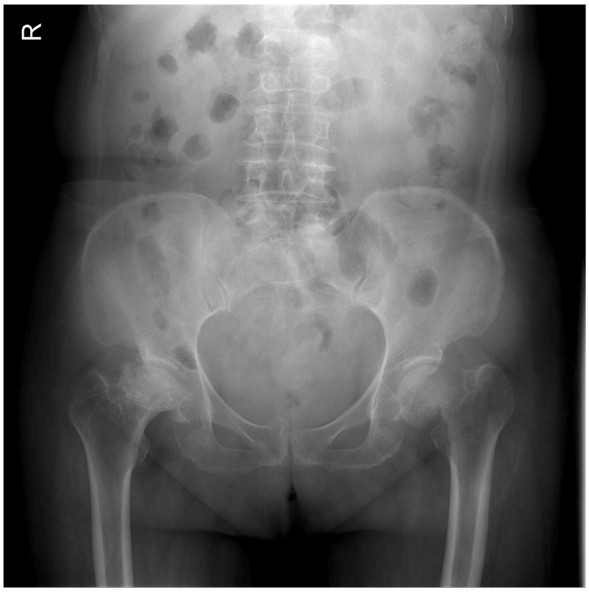

Fig. 3. Contralateral hip fracture in a patient with unilateral hip disease.
Figure Legend: A 65-year-old female patient with osteonecrosis of the right femoral head. The patient had pain and movement restrictions in the right hip. Her left hip was pain-free and functioned well until she fell from a standing height and developed a left femoral neck fracture.

aids (HR = 0.588, 95 % CI = 0.354–0.975).

3.6. Scoring system for predicting hip fracture in patients with hip disease

We built a new scoring system for surgeons to rapidly screen for patients with existing hip disease who have a high risk of hip fracture caused by minor trauma and spontaneous hip fractures (Table 6). Five factors are included in this scoring system. For each factor, one or two weighted scores are assigned. The total score of each factor is the final score of the patient, and the maximum score is 20 points. The AUC of this scoring system was 0.824 (95 % CI = 0.779–0.868). According to the previously described standards, the predictive scores for a low, moderate, and high risk of hip fracture were ≤8.5 points, 9.0–13.0 points, and ≥13.5 points, respectively. When the cutoff point was set at 13.5 points (including 13.5 points), the sensitivity and specificity of this scoring system were 0.773 and 0.708, respectively.

4. Discussion

There are some key points that distinguish this study from previous studies. First, in previous studies, the study population was

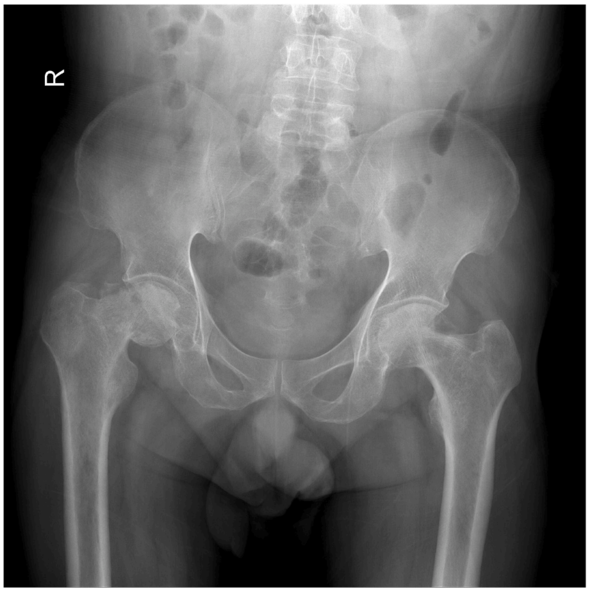

Fig. 4. Pathological fracture due to osteonecrosis.
Figure Legend: A 49-year-old male patient with bilateral osteonecrosis of the femoral head. Acute hip pain and movement restrictions occurred when he was sitting in a chair without any trauma. He was sent to the hospital, where X-rays showed a right femoral neck fracture. After other diseases were excluded, the patient was diagnosed with a pathological fracture of the right femoral neck due to osteonecrosis.

Table 5
Independent risk factors for hip fracture in patients with hip disease.

Risk factors	Hazard ratio	95 % confidential interval for hazard ratio	P
Age (years)	1.116	1.094–1.138	<0.001
Primary hip disease			
Osteoarthritis (ref.)	–	–	–
Osteonecrosis	2.201	1.217–3.980	0.009
Hip dysplasia	1.670	0.600–4.649	0.326
Other	–	–	0.951
Harris hip score (points)	0.966	0.949–0.982	<0.001
Walking aid use			
No (ref.)	–	–	–
Yes	0.588	0.354–0.975	0.040
Surgical history			
No (ref.)	–	–	–
Yes	2.126	1.304–3.466	0.003

ref., reference.
Note: Cox proportional hazards regression analysis was used to estimate these hazard ratios, confidential intervals, and P values. All potential risk factors, including demographic characteristics, primary disease characteristics, lifestyle behaviors, treatment history and hip function (i.e., all variables reported in Tables 1–3), were initially included in the regression models. The stepwise regression method was used to determine the final independent variables in the equation. Variables with $P > 0.1$ were removed from the equation.

healthy individuals of different ages or healthy elderly individuals. In this study, regardless of age, all the participants were patients with existing hip disease. The incidence of hip fracture in this study was 978.37/100,000 patients, which was higher than the incidence in some other studies, suggesting that the occurrence of hip fracture is worth considering in these special patients. The second innovation was that some new independent risk factors for hip fracture, including the type of existing hip disease, hip function (Harris hip score) and surgical history, were identified in this study. This indicated that the types and severity of existing hip disease could affect the occurrence of hip fracture. Previously, this has not been discovered since all the participants were healthy individuals. Therefore, in these previous studies, only demographic characteristics (such as age and female sex) and parameters reflecting osteoporosis and the risk of falls (bone mineral density, cardiovascular and cerebrovascular diseases) were commonly identified as risk factors for hip fracture. Finally, in this study, a new prediction system was built that could help estimate the hip fracture risk in each individual with existing hip disease. This could not only prompt patients at high fracture risk to take some preventive measures, such as using walking aids, but more importantly it can help with clinical decisions such as whether a patient should undergo hip arthroplasty soon, to avoid a passive treatment situation if hip fracture occurs.

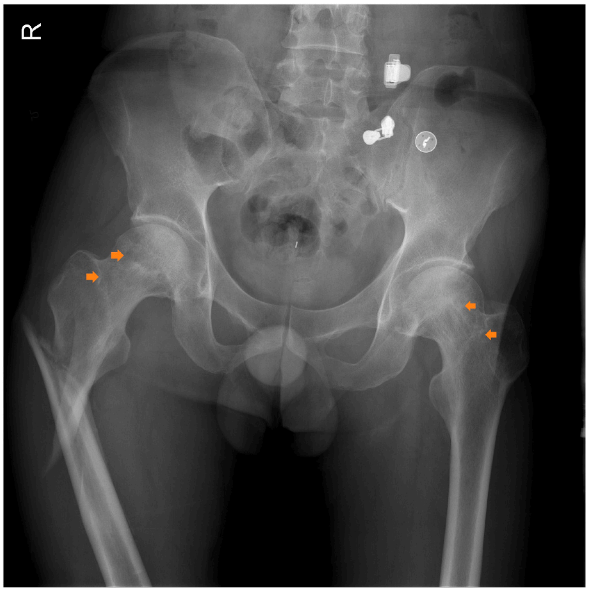

Fig. 5. Hip fracture in a patient with surgical history.
Figure Legend: A 56-year-old male patient with bilateral osteonecrosis of the femoral head. He had undergone core decompression and bone grafting 1.5 years prior. After a traffic accident, a right subtrochanteric fracture was identified in this patient. The arrows show the passages of core decompression.

Table 6
Scoring system for predicting hip fracture in patients with hip disease.

Risk factors	β-coefficient	Predictive score (total = 20 points)
Age (years)		
≤42 (ref.)		0
43–58	2.023	5.5
≥59	3.532	9.5
Primary hip disease		
Other (ref.)		0
Osteonecrosis	0.641	1.5
Harris hip score (points)		
≥80 (ref.)		0
66–79	1.843	5
≤65	1.620	4.5
Walking aid use		
Yes (ref.)		0
No	0.684	2
Surgical history		
No (ref.)		0
Yes	0.733	2

ref., reference.
Note: The area under the curve of this scoring system was 0.824 (95 % confidential interval = 0.779–0.868). The total score was the sum of each item's score. The predictive scores for a low risk (estimated incidence of hip fracture ≤30 %), moderate risk (estimated incidence of hip fracture 31 %–69 %), and high risk (estimated incidence of hip fracture ≥70 %) of hip fracture were ≤8.5 points, 9.0–13.0 points and ≥13.5 points, respectively.

4.1. Incidence of hip fracture in patients with existing hip disease

The incidence of hip fracture was higher in our patients with existing hip disease than in a healthy population described in a previously published study [19]. The survival curve showed that hip fracture could occur at any time after the initial diagnosis of the primary hip disease, with a median time-to-event of 3.90 years. This finding is consistent with our hypothesis that the presence of an existing hip disease is a risk factor for hip fracture. The reason for such a high incidence of hip fracture in this population remains unclear, but we hypothesize that the following factors contribute. In patients with hip disease, pain and movement restrictions can affect their ability to stand normally, walk, and stand up from sitting. These difficulties might increase the likelihood of falls, especially falls from an upright position, which is considered an important cause of hip fracture [13,14]. Pain and movement restrictions can affect the transfer of physical stress to the hip joint, reducing the weight-bearing load on the hip joint and resulting in disuse osteoporosis around the affected hip joint [20]. Bone marrow edema and osteosclerosis of the femoral neck occur in some patients with osteonecrosis [21]. These changes in bone microstructure might also increase the risk of hip fracture.

4.2. Hip fracture characteristics in patients with existing hip disease

In terms of hip fracture characteristics, the fracture classification and cause of fracture in patients with existing hip disease in this study were generally consistent with those in healthy people [19]. For instance, the most common cause of hip fracture was minor trauma in this study, which was also the most common cause in the healthy population studied in the China National Fracture Study [19]. Furthermore, the proportions of femoral neck fractures and femoral trochanter fractures in the current study were the same as those in previous epidemiological studies [19,22]. Some unique characteristics do distinguish hip fractures in patients with existing hip disease from hip fractures in the healthy population. In this study, 11.58 % of hip fractures were spontaneous fractures due to osteonecrosis [23], while in the healthy population, no hip fractures were caused by osteonecrosis. We found that 26.32 % of fractures occurred on the contralateral side. This finding suggests that existing hip disease not only reduces the bone strength of the affected side but also increases the probability of falls and other traumas, which could cause contralateral hip fractures. Hence, we should consider the risk of fracture in both hips even in patients with unilateral hip disease.

4.3. Risk factors for hip fracture in patients with existing hip disease

Age was an independent risk factor in patients with existing hip disease, confirming the findings of many similar studies in which healthy populations were examined [1,22,24–27]. For example, an epidemiological study in Spain showed that the incidence of hip fracture rapidly increased after the age of 65 years [27]. Ramanau et al. reported that the population aged over 50 years had a risk of fragility hip fracture that was two times higher than that of the younger population, and this increased risk was closely related to osteoporosis [25]. All of the above results demonstrate that aging is also a definitive cause of hip fracture, regardless of whether the patient has an existing hip disease.

Osteonecrosis of the femoral head is a particular type of hip disease that was associated with a higher risk of hip fracture than the other types of hip disease in this study. In contrast to other hip diseases (such as osteoarthritis and developmental dysplasia), which are characterized by a chronic onset and slow progression, osteonecrosis of the femoral head can cause severe pain and movement restrictions relatively quicky [11,28]. Furthermore, collapse of the femoral head, which occurs in up to 50 %–79 % of patients with osteonecrosis of the femoral head [29,30], changes the stress distribution of the hip joint and causes severe secondary osteoarthritis, which is often more severe than primary osteoarthritis [11,20]. Hence, compared with patients with primary osteoarthritis, patients with osteonecrosis have a higher risk of hip fracture. Cancellous bone edema of the femoral neck and trochanter is commonly observed in patients with osteonecrosis [21]. Histological examinations have shown serous exudate, focal interstitial hemorrhage, and fibrosis in these cancellous bones [21]. Thus, this condition can reduce the strength and increase the fragility of the femoral neck and trochanter and can even cause pathological fractures [31]. All these factors can make hip fracture more likely. Moreover, most osteonecrosis patients with Ficat stage III-IV disease eventually undergo total arthroplasty [32]. Preventive action should be taken in these patients to reduce the incidence of hip fracture and the difficulty of future hip arthroplasty surgery.

A low Harris hip score, which reflected poor hip function in this study, was another risk factor for hip fracture. Generally, poor hip function severely affects patients' level of physical activity, walking speed, and gait pattern and causes disuse osteoporosis and muscle atrophy [33]. Dargent-Molina et al. reported that a slow gait speed, difficulty performing the tandem walk test and a small calf circumference were predictors of fall-related hip fracture [34,35]. Moreover, the major cause of hip fracture in the current study was falling from a standing height. Accordingly, we believe that the increased likelihood of falls resulting from poor hip function might be an important cause of hip fracture in this population. In addition, since falling from a standing height was the main cause of hip fracture, preventative measures against falling may also prevent hip fracture.

In this study, we found that the use of a walking aid could help reduce the risk of hip fracture. We believe this was mainly because the use of a walking aid could prevent falling, which was the main cause of hip fracture. Graafmans et al. studied involving 694 elderly people aged over 70 years and demonstrated that 40 % of the participants fell at least one time and that 19 % of the participants fell two times or more in one year. They concluded that a high activity level and the use of a walking aid may protect against falls [36]. Stevens et al. also suggested that fall prevention programs, including education regarding the correct and efficient use of walkers, could help reduce the fall risk and hip fracture incidence [37]. Similar to these previous studies, our study demonstrates that this preventive measure, namely, the use of a walking aid, also worked in patients with existing hip disease.

The last risk factor for hip fracture in patients with hip disease was a history of surgical treatment for existing hip disease (except arthroplasty). The most common previous surgical treatment in this study was hip-preserving surgery, especially core decompression (with bone grafting), since most of the patients in this study were diagnosed with osteonecrosis. Berger et al., Amanatullah et al. and Chua et al. each reported the case of a patient with a hip fracture after core decompression and bone grafting [31,38,39]. They noted that core decompression, especially with a thick passage, might reduce the bone strength around the femoral neck and trochanter [31,39]. Some complications or comorbidities of hip surgery, such as infection and steroid use, can cause osteolysis and osteoporosis and reduce bone strength [31,39]. Therefore, additional attention should be paid to reducing the risk of hip fracture in patients with existing hip disease and a surgical history.

4.4. Scoring system for predicting hip fracture in patients with hip disease

The final purpose of determining risk factors for hip fracture was to identify patients at a high risk of hip fracture and prevent hip fracture or cure hip disease prior to the occurrence of hip fracture. The occurrence of hip fracture was determined by the risk factors together rather than individually, and the contribution of each risk factor to the occurrence of hip fracture varied. Hence, we built a weighted scoring system to comprehensively consider these risk factors and evaluate the overall risk to a given patient [40]. Clinical decisions could be made based on the patient's score. For a patient with a score ≥13.5 points who is considered to have a possibility of hip fracture (≥70 %), early intervention could be performed to avoid a hip fracture.

4.5. Limitations

There are several limitations to this study. First, as this study was not a population-based survey, the estimated incidence of hip fracture might have been affected by hospitalization and selection bias. Consequently, the incidence of hip fracture in patients with hip disease relative to the incidence in healthy populations may be artificially elevated. Second, the occurrence of hip fracture is affected by many factors. It is impossible for one study to cover all the potential factors simultaneously. Therefore, some relevant factors might have been missed or not searched for in the current study. Finally, only the incidence of, characterization of and risk factors for hip fracture in patients with existing hip disease were investigated; the treatments and prognoses of these patients were not analyzed. Therefore, whether early arthroplasty can truly help reduce the incidence of hip fracture in these particular patients remains unknown.

5. Conclusion

In this study, the incidence of hip fracture in a special population, namely, patients with existing hip disease, was determined. Four independent risk factors and one independent protective factor were identified. Elderly patients, patients with a previous history of hip surgery, patients with osteonecrosis and patients with poor Harris hip scores were at a high risk of hip fracture. A scoring system with a total score of 20 points was built for clinical surgeons to rapidly evaluate a patient's hip fracture risk. If the predictive score is over 9 points, which indicates a moderate to high risk of hip fracture, protective measures such as the use of a walking aid should be taken to reduce the risk of hip fracture.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University (K2021-027-1) and was conducted in accordance with the Declaration of Helsinki. As this was a retrospective study and all patient information was deidentified before analysis, informed consent was only required for patients whose radiological images would be published.

Consent for publication

Written informed consent was obtained from participants whose radiological data have been published in the journal.

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Data availability statement

All data generated or analyzed during this study are included in this article.

CRediT authorship contribution statement

Bo Liu: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Xiao Chen:** Methodology. **Mengnan Li:** Data curation. **Xiaoxuan Zhang:** Data curation. **Binquan Zhang:** Writing – original draft, Writing – review & editing. **Huijie Li:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing.

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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References

[1] N. Veronese, S. Maggi, Epidemiology and social costs of hip fracture, Injury 49 (8) (2018) 1458–1460, https://doi.org/10.1016/j.injury.2018.04.015.
[2] I. Paspati, A. Galanos, G.P. Lyritis, Hip fracture epidemiology in Greece during 1977-1992, Calcif. Tissue Int. 62 (6) (1998) 542–547, https://doi.org/10.1007/s002239900476.
[3] C.M. Koeck, D.L. Schwappach, F.M. Niemann, T.J. Strassmann, H. Ebner, K. Klaushofer, Incidence and costs of osteoporosis-associated hip fractures in Austria, Wien Klin. Wochenschr. 113 (10) (2001) 371–377.
[4] B.Y. Xu, S. Yan, L.L. Low, F.F. Vasanwala, S.G. Low, Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review, BMC Musculoskelet Disord 20 (1) (2019) 568, https://doi.org/10.1186/s12891-019-2950-0.
[5] T.W. O'Neill, D.K. Roy, How many people develop fractures with what outcome? Best Pract. Res. Clin. Rheumatol. 19 (6) (2005) 879–895, https://doi.org/10.1016/j.berh.2005.06.003.
[6] C.M. Peeters, E. Visser, C.L. Van de Ree, T. Gosens, B.L. Den Oudsten, J. De Vries, Quality of life after hip fracture in the elderly: a systematic literature review, Injury 47 (7) (2016) 1369–1382, https://doi.org/10.1016/j.injury.2016.04.018.
[7] Y. Yang, V. Komisar, N. Shishov, B. Lo, A.M. Korall, F. Feldman, et al., The Effect of fall biomechanics on risk for hip fracture in older adults: a cohort study of video-captured falls in long-term care, J. Bone Miner. Res. 35 (10) (2020) 1914–1922, https://doi.org/10.1002/jbmr.4048.
[8] M.L. Bouxsein, R. Eastell, L.Y. Lui, L.A. Wu, A.E. de Papp, A. Grauer, et al., Change in bone density and reduction in fracture risk: a meta-regression of published trials, J. Bone Miner. Res. 34 (4) (2019) 632–642, https://doi.org/10.1002/jbmr.3641.
[9] C.I. Robison, M. Rice, M.M. Makagon, D.M. Karcher, Duck gait: relationship to hip angle, bone ash, bone density, and morphology, Poult Sci 94 (5) (2015) 1060–1067, https://doi.org/10.3382/ps/pev050.
[10] L.A. Tucker, E. Fosson, B.W. Bailey, J.D. LeCheminant, Is the dose-response relationship between body mass and hip bone mineral density in women influenced by diet, physical activity, or menopause? Am. J. Health Promot. 28 (5) (2014) 325–327, https://doi.org/10.4278/ajhp.120921-ARB-460.
[11] R.S. Weinstein, Glucocorticoid-induced osteoporosis and osteonecrosis, Endocrinol Metab. Clin. N. Am. 41 (3) (2012) 595–611, https://doi.org/10.1016/j.ecl.2012.04.004.
[12] S.H. Park, Tools for assessing fall risk in the elderly: a systematic review and meta-analysis, Aging Clin. Exp. Res. 30 (1) (2018) 1–16, https://doi.org/10.1007/s40520-017-0749-0.
[13] C.T. Vottis, E. Mitsiokapa, V.G. Igoumenou, P.D. Megaloikonomos, I.P. Galanopoulos, G. Georgoudis, et al., Fall risk assessment metrics for elderly patients with hip fractures, Orthopedics 41 (3) (2018) 142–156, https://doi.org/10.3928/01477447-20180501-07.
[14] S. Nunan, C. Brown Wilson, T. Henwood, D. Parker, Fall risk assessment tools for use among older adults in long-term care settings: a systematic review of the literature, Australas. J. Ageing 37 (1) (2018) 23–33, https://doi.org/10.1111/ajag.12476.
[15] N. Callis, Falls prevention: identification of predictive fall risk factors, Appl. Nurs. Res. 29 (2016) 53–58, https://doi.org/10.1016/j.apnr.2015.05.007.
[16] M.D. Kohn, A.A. Sassoon, N.D. Fernando, Classifications in brief: kellgren-lawrence classification of osteoarthritis, Clin. Orthop. Relat. Res. 474 (8) (2016) 1886–1893, https://doi.org/10.1007/s11999-016-4732-4.
[17] M.D. Reed, W. Van Nostran, Assessing pain intensity with the visual analog scale: a plea for uniformity, J. Clin. Pharmacol. 54 (3) (2014) 241–244, https://doi.org/10.1002/jcph.250.
[18] H. Weel, R. Lindeboom, S.E. Kuipers, T. Vervest, Comparison between the Harris- and Oxford Hip Score to evaluate outcomes one-year after total hip arthroplasty, Acta Orthop. Belg. 83 (1) (2017) 98–109.
[19] W. Chen, H. Lv, S. Liu, B. Liu, Y. Zhu, X. Chen, et al., National incidence of traumatic fractures in China: a retrospective survey of 512 187 individuals, Lancet Global Health 5 (8) (2017) e807–e817, https://doi.org/10.1016/s2214-109x(17)30222-x.
[20] Y. Kubo, G. Motomura, S. Ikemura, K. Sonoda, T. Yamamoto, Y. Nakashima, Effect of collapse on the deformity of the femoral head-neck junction in osteonecrosis of the femoral head, Arch. Orthop. Trauma Surg. 137 (7) (2017) 933–938, https://doi.org/10.1007/s00402-017-2720-0.
[21] T. Kubo, T. Yamamoto, S. Inoue, M. Horii, K. Ueshima, Y. Iwamoto, et al., Histological findings of bone marrow edema pattern on MRI in osteonecrosis of the femoral head, J. Orthop. Sci. 5 (5) (2000) 520–523, https://doi.org/10.1007/s007760070033.
[22] A.R. Díaz, P.Z. Navas, Risk factors for trochanteric and femoral neck fracture, Rev. Española Cirugía Ortopédica Traumatol. 62 (2) (2018) 134–141, https://doi.org/10.1016/j.recot.2017.09.002.
[23] Y.M. Kim, H.J. Kim, Pathological fracture of the femoral neck as the first manifestation of osteonecrosis of the femoral head, J. Orthop. Sci. 5 (6) (2000) 605–609, https://doi.org/10.1007/s007760070013.
[24] R. Barnea, Y. Weiss, I. Abadi-Korek, J. Shemer, The epidemiology and economic burden of hip fractures in Israel, Isr. J. Health Pol. Res. 7 (1) (2018) 38, https://doi.org/10.1186/s13584-018-0235-y.
[25] H. Ramanau, I. Chernyanin, E. Rudenka, O. Lesnyak, A. Zakroyeva, J.P. Bilezikian, et al., Epidemiology of hip fracture in Belarus: development of a country-specific FRAX model and its comparison to neighboring country models, Arch. Osteoporosis 13 (1) (2018) 42, https://doi.org/10.1007/s11657-018-0454-4.
[26] A. Dubey, K.J. Koval, J.D. Zuckerman, Hip fracture epidemiology: a review, Am J Orthop (Belle Mead NJ) 28 (9) (1999) 497–506.
[27] J.L. Hernández, J.M. Olmos, M.A. Alonso, C.R. González-Fernández, J. Martínez, M. Pajarón, et al., Trend in hip fracture epidemiology over a 14-year period in a Spanish population, Osteoporos. Int. 17 (3) (2006) 464–470, https://doi.org/10.1007/s00198-005-0008-7.
[28] C.G. Zalavras, J.R. Lieberman, Osteonecrosis of the femoral head: evaluation and treatment, J. Am. Acad. Orthop. Surg. 22 (7) (2014) 455–464, https://doi.org/10.5435/jaaos-22-07-455.
[29] K.H. Koo, R. Kim, G.H. Ko, H.R. Song, S.T. Jeong, S.H. Cho, Preventing collapse in early osteonecrosis of the femoral head. A randomised clinical trial of core decompression, J Bone Joint Surg Br 77 (6) (1995) 870–874.
[30] T. Nishii, N. Sugano, K. Ohzono, T. Sakai, Y. Sato, H. Yoshikawa, Significance of lesion size and location in the prediction of collapse of osteonecrosis of the femoral head: a new three-dimensional quantification using magnetic resonance imaging, J. Orthop. Res. 20 (1) (2002) 130–136, https://doi.org/10.1016/s0736-0266(01)00063-8.
[31] Y. Chua, N. Wazir, C. Chiu, B. Kareem, Management of osteonecrosis of the hip complicated with fracture: a case report, Malays Orthop J 6 (SupplA) (2012) 43–45, https://doi.org/10.5704/moj.1211.011.
[32] R.P. Ficat, Idiopathic bone necrosis of the femoral head. Early diagnosis and treatment, J Bone Joint Surg Br 67 (1) (1985) 3–9, https://doi.org/10.1302/0301-620x.67b1.3155745.
[33] T. Blikman, W. Rienstra, J. van Raay, B. Dijkstra, S.K. Bulstra, M. Stevens, et al., Neuropathic-like symptoms and the association with joint-specific function and quality of life in patients with hip and knee osteoarthritis, PLoS One 13 (6) (2018) e0199165, https://doi.org/10.1371/journal.pone.0199165.
[34] P. Dargent-Molina, F. Favier, H. Grandjean, C. Baudoin, A.M. Schott, E. Hausherr, et al., Fall-related factors and risk of hip fracture: the EPIDOS prospective study, Lancet 348 (9021) (1996) 145–149, https://doi.org/10.1016/s0140-6736(96)01440-7.
[35] S. Muraki, [Fall risk and fracture. The association of physical performance with falls in the elderly], Clin. Calcium 23 (5) (2013) 713–718.
[36] W.C. Graafmans, P. Lips, G.J. Wijlhuizen, S.M. Pluijm, L.M. Bouter, Daily physical activity and the use of a walking aid in relation to falls in elderly people in a residential care setting, Z. Gerontol. Geriatr. 36 (1) (2003) 23–28, https://doi.org/10.1007/s00391-003-0143-8.
[37] J.A. Stevens, S. Olson, Reducing falls and resulting hip fractures among older women, MMWR Recomm. Rep. (Morb. Mortal. Wkly. Rep.) 49 (Rr-2) (2000) 3–12.
[38] D.F. Amanatullah, R. Farac, T.J. McDonald, H.D. Moehring, P.E. Di Cesare, Subtrochanteric fracture following removal of a porous tantalum implant, Case Rep Orthop 2013 (2013) 946745, https://doi.org/10.1155/2013/946745.
[39] R.J. Berger, A.A. Sultan, C. Cole, N. Sodhi, A. Khlopas, M.A. Mont, Sub-Trochanteric hip fracture following core decompression for osteonecrosis in a patient with a pre-existing contralateral occult femoral neck fracture, Surg. Technol. Int. 32 (2018) 361–365.
[40] Sr. D'Agostino Rb, S. Grundy, L.M. Sullivan, P. Wilson, Validation of the Framingham coronary heart disease prediction scores: results of a multiple ethnic groups investigation, JAMA 286 (2) (2001) 180–187, https://doi.org/10.1001/jama.286.2.180.