Influence of bone mineral density and hip geometry on the different types of hip fracture

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ABSTRACT

The aim of this study was to assess the influence of bone mineral density and hip geometry on the fragility fracture of femoral neck and trochanteric region. There were 95 menopausal females of age ≥ 50 years with fragility fracture of hip, including 55 cases of femoral neck fracture and 40 cases of trochanteric fracture. Another 63 non-fractured females with normal bone mineral density (BMD) were chosen as control. BMD, hip axis length, neck-shaft angle and structural parameters including cross surface area, cortical thickness and buckling ratio were detected and compared. Compared with control group, the patients with femoral neck fracture or trochanteric fractures had significantly lower BMD of femoral neck, as well as lower cross surface area and cortical thickness and higher buckling ratio in femoral neck and trochanteric region. There were no significant differences of BMD and structural parameters in the femoral neck fracture group and intertrochanteric fracture group. Hip axis length and neck-shaft angle were not significantly different among three groups. The significant changes of BMD and proximal femur geometry were present in the fragility fracture of femoral neck and trochanteric region. The different types of hip fractures cannot be explained by these changes.

KEY WORDS: Bone mineral density; hip; fragility fracture; proximal femur
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INTRODUCTION

Fragility hip fracture is the most critical complication of osteoporosis. There are about 1,500,000 patients with fragility hip fracture in the world in 2000. It is estimated that this number may soar to 6,260,000 in 2050, of which over 50% will be in Asia [1,2]. The morbidity of hip fracture in China is ascending. It ascended at a rate of about 10% each year in 2002-2006 [3]. As patients are usually elder and accompanied by many medical problems, and the surgery is delayed, the mortality of the surgery is relatively high [4,5]. The known risk factors for hip fractures are low bone mineral density (BMD) and change in the hip geometry. The risk of hip fracture increases by 2.6 times with every decrease of one standard deviation in the BMD of femoral neck [6]. The structures of proximal femur such as hip axis length, neck axis length, neck width, neck-shaft angle and cortical thickness are related to type of hip fracture [7-10]. Hip fracture can be classified into femoral neck fracture and femoral trochanteric fracture. Femoral neck is within the articular capsule, while the femoral trochanteric region is outside the articular cap sule. The trochanteric region has more cancellous bone than femoral neck, thereby the fracture mechanism may be different in femoral neck fractures and trochanteric fractures. Do the risks mentioned above have same influence on different types of hip fractures? Hip structure analysis (HSA) is a method to obtain certain structural parameters from dual-energy X-ray absorptiometry (DXA) images [11]. Based on DXA, we compared the BMD and structural parameters of HSA between the cervical fractures and trochanteric fractures of femur in our study.

MATERIALS AND METHODS

Study population

From March 2013 to July 2014, a total of 95 postmenopausal women of age ≥ 50 years with fragility hip fracture received BMD check and HSA. The age ranged from 53 to 91 years, with the average of 76.60±9.36 years. The average menopausal age of these cases was 48.67±3.60 years. Body mass index (BMI) was 13.3-32, with the average of 20.88±3.72.

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There were 55 cases of femoral neck fractures and 40 cases of trochanteric fractures. Another 63 non-fractured postmenopausal women of age ≥ 50 years, with normal BMD of hip and lumbar vertebrae, were selected as controls. The age ranged from 50 years to 74 years with the average of 57.24±5.65 years. BMI of the control group was 20.1-38.2, with the average of 26.56±4.82.

BMD check and HSA

DXA Bone densitometer (Hologic Inc., USA. Discovery A) was used, with precision of ≤ 1%. The precision error defined as % coefficient of variation (%CV) was 0.25%. The BMD of hip and lumbar vertebrae was detected at standard position to obtain the BMD of femoral neck. According to the WHO definitions based on BMD, the T-scores were divided into normal group, osteopenia group, and osteoporosis group ($T \geq -1.0$, $-2.5 < T < -1.0$, and $T \leq -2.5$). Meanwhile, the strength of hip structure was detected. Hip axis length (HAL), neck-shaft angle (NSA) and the structural parameters of femoral neck and trochanteric region were determined, including cross surface area (CSA), cortical thickness (CT) and buckling ratio (BR) [11].

Statistical analysis

Data analyses were performed using SPSS statistical software (SPSS, version18.0; SPSS Inc, Chicago, Illinois). Measurement data were expressed as mean ± standard deviation. All parameters of groups were compared with ANOVA, and LSD test was applied for pairwise comparison. $P < 0.05$ was considered as statistically significant.

RESULTS

BMD

BMD of the femoral neck in femoral neck fracture group was 0.228-0.671 g/cm², with T at -1.6~-5.6. Eleven cases were in osteopenic range and 44 cases were in osteoporosis. BMD of the femoral neck in trochanteric fracture group was 0.279-0.671g/cm², with T score at -1.6~-5.1. Two cases were in osteopenic range and 38 cases were in osteoporosis. BMD of the femoral neck in control group was 0.734-0.966 g/cm², with T score at -1~1.11.

Hip geometry

NSA was 121-140° in the femoral neck fracture group, with the average of 129.73±4.16°; NSA was 123-140° in the trochanteric fracture group, with the average of 130.05±4.52°; NSA was 118-138° in the control group, with the average of 129.38±4.85°. There was no significant difference between the groups.

HAL was 102.24±5.90 mm in the femoral neck fracture group, 101.90±6.02 mm in the trochanteric fracture group, and 102.02±4.88 mm in the control group. There was no significant difference between these groups (Table 1).

Cross surface area and cortical thickness: CSA and CT of the two fracture groups showed significant decrease in femoral neck and trochanteric region compared with the control group (p=0.000); There was no significant difference between the parameters of femoral neck fracture group and intertrochanteric fracture group (Table 1).

Buckling ratio

BR of the two fracture groups showed significant increase in femoral neck and trochanteric region compared with the control group (p=0.000). There was no significant difference between the parameters of femoral neck fracture group and trochanteric fracture group (Table 1).

DISCUSSION

We proved in this study that in the fragility femoral neck fracture group and trochanteric fracture group, the BMD of femoral neck was significantly lower compared with the normal group; the CSA and CT of femoral neck and trochanteric region were lower, but the BR was significantly higher. There was no significant difference in both NSA and HAL in femoral neck fracture group and trochanteric fracture group compared with the control group. There was no significant difference in the BMD of femoral neck and hip structure parameters (including NSA, HAL, CSA, CT and BR) in femoral neck fracture group and trochanteric fracture group.

Femoral neck fractures and trochanteric fractures are both common types of hip fracture. The age of patients with femoral trochanteric fractures was about 5 years older than the patients with femoral neck fracture. BMD decreased with the increasing age in the patients aged ≥ 50 years. The BMD reduction rate of femoral neck is 0.64% before the age of 65 years and 0.36% after this age [12]. Low BMD was closely related to hip fracture. The risk for hip fracture increases by a 2.6-fold for each standard deviation decrease in bone mineral density [6]. BMD of the femoral neck is the most sensitive index for predicting hip fracture. As reported by Greenspan SL et al [13], the trochanteric BMD was 13% lower in women and 11% lower in men for patients with trochanteric fracture than in those with femoral neck fracture. In this study, the BMD of femoral neck significantly decreased in the femoral neck fracture group and trochanteric fracture group compared with the control group. However, there was no significant difference between the BMD of the two fracture groups. This means that the decrease in BMD is not the factor influencing the types of hip fracture in our study. Hip geometry also changes with the increasing age. The increase of age in

TABLE 1. Comparison of BMD and structural variables among three groups (femoral neck fracture, trochanteric fracture and normal control)

Parameters items	Normal	Trochanteric fracture	Femoral neck fracture	p_1 (0.05)	p_2 (0.05)	p_3 (0.05)
Number of cases no	63	40	55			
Age (mean±S.D)	57.24±5.65	79.25±7.94	74.67±9.90	0.000	0.000	0.006
Menopausal age (mean±S.D)	50.63±4.67	48.25±3.06	48.98±3.95	0.004	0.030	0.390
Body mass index (mean±S.D)	26.98±3.75	21.07±4.26	20.74±3.30	0.000	0.000	0.703
Bone mineral density of femoral neck (mean±S.D)	0.826±0.064	0.446±0.091	0.466±0.104	0.000	0.000	0.260
T value (mean±S.D)	−0.21±0.57	−3.48±1.36	−3.45±0.94	0.000	0.000	0.896
Cross surface area of femoral neck (mean±S.D)	3.09±0.31	1.75±0.33	1.88±0.40	0.000	0.000	0.076
Cortical thickness of femoral neck (mean±S.D)	0.204±0.019	0.107±0.021	0.110±0.022	0.000	0.000	0.405
Buckling ratio of femoral neck (mean±S.D)	8.55±1.52	18.36±4.87	18.58±4.95	0.000	0.000	0.794
Cross surface area of intertrochanter (mean±S.D)	5.58±0.60	3.08±0.98	3.13±0.79	0.000	0.000	0.729
Cortical thickness of intertrochanter (mean±S.D)	0.462±0.048	0.246±0.072	0.251±0.069	0.000	0.000	0.741
Buckling ratio of intertrochanter (mean±S.D)	6.89±0.86	14.21±3.72	14.57±5.21	0.000	0.000	0.636
Neck-shaft angle (mean±S.D)	129.38±4.85	130.05±4.52	129.73±4.16	0.467	0.680	0.733
Hip axis length (mean±S.D)	102.02±4.88	101.90±6.02	102.24±5.90	0.918	0.830	0.771

p_1: Comparison between the normal BMD group and IT fracture group, p_2: Comparison between the normal BMD group and FN fracture group, p_3: Comparison between IT fracture group and FN fracture group

the patients aged ≥ 50 years may cause the thinning of cortex of proximal femur and the increasing of medullary cavity [8], as well as changes in the hip structure strength [14,15]. The hip structure parameters such as HAL and NSA are related to hip fracture [7,10]. Are they the reasons causing different types of hip fracture? Duboeuf F et al [16] hold that HAL can only predict the femoral neck fracture. Gnudi S et al [17] indicated that women with trochanteric fractures had relatively small HAL and NSA. Pulkkinen P et al [18] indicated that NSA is the best factor to predict the type of hip fracture as patients with femoral neck fractures usually have more than 3 times bigger NSA than the patients with trochanteric fractures. However, it was also reported that there is no significant difference between the NSA in the patients with femoral neck fracture and normal people [8]. Panula J et al [19] also believed that there is no material difference in the NAL and NSA for the female or male patients with femoral neck fracture and intertrochanteric fracture; the two indexes cannot explain the mechanisms of femoral neck fracture and intertrochanteric fracture. In this study, we found no significant difference in the HAL and NSA in femoral neck fracture group and intertrochanteric fracture group, as well as the control group. The result also did not support the idea that the HAL and NSA are the factors leading to different types of hip fracture. In the femoral neck fracture group and trochanteric fracture group, the structural strength parameters such as CSA and CT of the femoral neck, trochanteric region and femoral shaft evidently decreased, while the BR evidently increased. This indicated the increase in the fragility of proximal femur and the decrease in the BMD. However, there was no statistical difference between these parameters in the two fracture groups which indicated that CSA, CT and BR are not the factors leading to different types of hip fracture. Pulkkinen P et al [18] performed mechanical test on the proximal femur of cadavers and discovered that the one with lowest structural mechanical strength was vulnerable to femoral neck fracture, while the trochanteric fractures usually occurred under relatively high load. Clinically, the patients with trochanteric fractures were elder. The structural mechanical strength of their bone should be lower theoretically. This suggests that the type of hip fracture was not related with the decrease of BMD. The factors causing different types of hip fracture may not be related to the hip. Tal S et al [20] reported that female sex, frailty, falls, low calcium and low hemoglobin status are significant risk factors for the prediction of trochanteric fractures and that the patients with Parkinson's disease are at a lower risk for trochanteric fractures compared with cervical fractures, with an odds ratio of 0.6. Because of the non-skeletal factors such as advanced age, the patients make different protective responses to falls. The differences in the violence and conduction direction of the impact force on hip or the greater trochanter lead to different types of hip fractures.

CONCLUSION

Our objective in this study was to find the internal factors of hip related to difference in the types of hip fracture, and it confirmed that the femoral neck BMD and structural parameters such as CSA, CT and BR were all related to hip fracture. However, these parameters are unable to explain the reason for different types of hip fracture, which may be caused by the non-skeletal factors like advanced age and falls etc.

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DECLARATION OF INTERESTS

The authors declare no conflict of interests

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