Title: The influence of proximal femur geometry in identifying femoral neck fractures and intertrochanteric fractures in senile patients

Abstract

Purpose: The purpose of this study was to find the effect of proximal femur geometry in identifying the femoral neck fracture and intertrochanteric fracture in senile patients by using a new measurement method.

Methods: A total of 298 patients with acute hip fractures were included in this study and was divided into two groups: femoral neck fracture group (n=155) and intertrochanteric fracture group (n=143). The total hip bone mineral density and morphological parameters such as femoral neck width (FNW), femoral neck length (FNL), femoral head height (FHH), femoral head diameter (FHD), neck-shaft angle (NSA) and offset were measured and compared. Multiple logistic regression analysis was conducted among these parameters. The receiver operating curve (ROC) analysis was performed to evaluate the predictability of each index.

Results: Patients with intertrochanteric fractures were significantly older than patients with femoral neck fractures. Longer FNL (88.94 versus 86.45), larger FHD (45.55 versus 44.30), shorter offset (29.18 versus 30.32) and larger NSA (131.49 versus 128.32) were found in femoral neck fracture group ($P<0.05$). In multiple logistic regression analysis, age, FNL and NSA were independent factors in identifying fracture types (OR=1.056, 1.089 and 1.262, respectively, $P<0.001$). The ROC analysis showed that NSA was a good discriminator with an area under the curve value of 0.721.

Conclusions: This study showed that morphological discrepancy existed between the two types of hip fractures. A larger NSA was considered as the best predictor for the occurrence of femoral neck fractures.

Key words: geometry, proximal femur, femoral neck fracture, intertrochanteric fracture

Text

The osteoporotic hip fracture in senile patients was associated with high rates of morbidity and mortality [1-2]. With the increasing aged population, patients with hip fractures increased rapidly, resulting in a public healthcare problem with enormous socioeconomic costs [3-5]. The osteoporotic hip fractures consisted of femoral neck factures and intertrochanteric fractures. However, these two kinds of fragility fractures had different characteristics, treatment and prognosis [6-7]. Thus, it was essential to evaluate the risk factors for identifying different types of hip fractures.

Currently, the bone mineral density (BMD) was regarded as a useful method for predicting hip fractures and identifying fracture types [8-9]. Moreover, one study revealed that the simple measurement of proximal femoral geometry could predict hip fractures independently of BMD[10]. Various studies had reported that proximal femur geometry was associated with the occurrence of different types of hip fractures, whereas controversial results were shown [11-14]. The cause of this inconsistency might be the different measurement methods, different ethnics and diverse study design[15].

One of the most important factors was that most of previous studies measured geometric parameters by using 2-dimensional images, such as DXA or X-ray radiograph, which might be influenced by patients' position. Therefore, we presented a new method for the geometric measurement, which was performed in computed tomography (CT) images after three-dimensional reconstruction in Mimics software to minimize the effect of the patient's position. The purpose of this study was to find the effect of proximal femur geometry on identifying the femoral neck fracture and intertrochanteric fracture in senile patients.

Materials and Methods

Source of Patients

The clinical database of our hospital was retrospectively reviewed from May 2015 to May 2016. Patients with acute hip fractures caused by low-energy injury were included and all participants were older than 65 years. Patients with following conditions should be excluded: 1, patients combined with metabolic bone disease (osteomalacia, Paget disease, or primary hyperparathyroidism); 2, the cause was high-energy injury, such as car crash; 3, patients who were taking drugs or had a history of drug use, such as bisphosphonates, steroid medicines and selective estrogen receptor modulators (SERMs); 4, pathological fractures (secondary to tumor or primary hyperparathyroidism). 332 patients were included according to above criteria and 34 patients with incomplete record data or inadequate CT images for three dimensional (3D) reconstruction were excluded. Finally, a total of 298 patients with acute hip fractures were included in this study. Patients were divided into two groups according to the fracture type: 155 patients were combined with femoral neck fractures (FN group), 143 patients were combined with intertrochanteric fractures (IT group). The research was permitted by the ethics committee of the institute.

Measurements

The CT scan was performed by a TOSHIBA CT scanner (TOSHIBA, Tokyo, Japan) for all patients after being admitted to the hospital. The CT was set to 120kVp and 125 mAs to produce an image matrix of 512×512 pixels. The thickness of each slice was 1.0mm. The healthy leg was placed in the position with the patella facing forward and with 0º of extension during imaging. All CT scan data were numbered and deposited to a personal computer with the Digital Imaging and Communications in Medicine (DICOM) format. Then CT images were imported into the reverse engineering software Mimics 17.0 (Materialise, Belgium) software for three dimensional reconstruction and geometrical measurement.

The measurement was performed on the healthy side. 3D proximal femur models were established via masks creating, region growing and calculation. The femoral head was separated and simulated to a ball. The center of the close-fit ball was deemed as the center of the femoral head[16]. The transverse slice at the level of apex of the lesser trochanter was defined as slice T0. Slices 10mm and 30mm distal to the end of the lesser trochanter were defined as Slice T10 and Slice T30. Then the circle was drawn in Slice T10 and T30 which was best fitting with the inner contour of a section plane. Then a line was drawn along the center of the Slice T10 and T30. The line was defined as the central axis of the proximal medullary canal. The plane defined by the central axis of the proximal femur and the center of the femoral head was named as the central coronal plane of the proximal femur[17]. Geometrical measurements were performed on the plane.

Measured parameters were as followed: 1) Femoral neck width (FNW): The narrowest femoral neck width. 2) Femoral neck length (FNL): A line was drawn through the midpoint of the FNW and the center of the femoral head, which intersected with the cortex of the proximal femur and the femoral head at a point. The length between the above two points was defined as the FNL. 3) Femoral head height (FHH): the vertical distance between the center of the femoral head and the slice T0. 4) Femoral head diameter (FHD). 5) Neck-shaft angle (NSA): The angle was formed between the axis of the femoral neck and the axis of the proximal femur. 6) Offset: The perpendicular distance from the centre of the femoral head to the central axis of the proximal medullary canal. (Figure 1)

Bone Mineral Density

Areal BMD (g/cm2) of the total hip were measured by dual-energy x-ray absorptiometry with Lunar DPX(GE; Fairfield, Connecticut, USA) in the array (fan beam) mode.

Statistical analysis

The SPSS 17.0 software was used for statistical analysis (SPSS, Chicago, Illinois, USA). For quantitative data, the one-sample Kolmogorov-Smirnov test was used to test the normal distribution. The Student t-test or the Mann–Whitney test was used to compare continuous variables between groups as appropriate. For qualitative data, the Chi-square test was used. Then the multiple logistic regression analysis was applied to evaluate the independent determinant of fracture type. In addition, the receiver operating curve (ROC) analysis was performed to evaluate the predictability of each index. The area under the curve (AUC) and the cut-off value were calculated. A P value <0.05 was considered statistically significant, and all tests were two-sided.

Results

Patients in IT group were significantly older than patients in FN group (80.92 VS 77.63, $P<0.001$). The mean length of FNL in FN group was (88.94±5.78)mm, which was significantly longer than (86.45±5.81)mm in IT group($P<0.001$). The FHD in FN group was significantly larger than IT group (45.55 VS 44.30, $P=0.002$). Furthermore, patients in FN group had significantly larger NSA than patients in IT group (131.49 VS 128.32, $P<0.001$). The offset in IT group was significantly longer than that in FN group (30.32 VS 29.18, $P=0.005$). The total hip BMD in IT group was slightly higher than FN group, while no statistical difference was found (0.826 VS 0.819, $P=0.684$). The other parameters didn't have significantly statistical difference, including gender, height, weight, BMI, smoker, drinker, history of fracture, FNW and FHH. (Table 1)

In multiple logistic regression analysis, three parameters were independent factors in identifying fracture types, including age (OR=1.056, 95%CI=1.017~1.097, $P=0.005$), FNL (OR=1.089, 95%CI=1.038~1.143, $P<0.001$) and NSA (OR=1.262, 95%CI=1.172~1.359, $P<0.001$). BMI, FHD and offset were not associated with the occurrence of fracture types (P=0.782, 0.222 and 0.132, respectively). (Table 2)

To identify better predictors for identifying types of hip fractures, ROC analysis and AUC values were performed for related predictors. The NSA had a good AUC value (0.721). The cut-off value of NSA was 129.99, with a sensitivity of 67.1% and specificity of 69.9%. The age, FNL and offset had poor AUC values (0.642, 0.606 and 0.596, respectively). (Figure 2)

Discussion

Femoral neck fractures and intertrochanteric fractures were most common types of osteoporotic hip fractures in senile patients. However, numerous differences were found between two types of fractures [6, 18]. Therefore, it was of great concern to predict the occurrence of fracture types. Previous studies revealed that both BMD and proximal femur geometry were associated with the occurrence of fracture types [19-21]. However, conflicting geometrical results were found owing to different measurement setups or diverse study design. In present study, we applied the Mimics software to reconstruct CT images of the proximal femur, which will minimize the effect of patients' position and improve the accuracy of measurement.

In accordance with previous studies, we found that patients with intertrochanteric fractures were 3 years older than patients with femoral neck fractures in this study. After adjusting for age and other confounding factors, longer FNL and larger NSA were found in patients with femoral neck fractures. After ROC analysis, NSA was deemed as the most reliable geometrical parameters for identifying types of hip fractures.

Influence of FNL on femoral neck fracture risk had been extensively explored [20, 22-23]. Duboeuf et al[20] studied 42 patients with cervical fractures and 24 women with intertrochanteric fractures within the EPIDOS prospective cohort. The results revealed that hip axis length was specifically associated with femoral neck fractures and not with other osteoporotic fractures. Gnudi et al[22] performed a cross-sectional study and reported that patients with femoral neck fractures had a longer hip axis length than those with intertrochanteric fractures. The hip axis length was approximately regarded as the femoral moment arm. The longer the moment arm, the less force was required to produce a fracture. In consistent with previous studies, the present study showed that longer FNL was independent predictor for the occurrence of femoral neck fracture (OR=1.089, P<0.001). However, the ROC analysis showed that FNL had a poor AUC value (0.606), which indicated that FNL might not be the best geometrical parameters for identifying femoral neck fractures and intertrochanteric fractures.

In this study, we found that a larger NSA was independent risk factor for the occurrence of femoral neck fractures (OR=1.171, P<0.001). With the AUC value of 0.721, the NSA was deemed as the best predictive factor for femoral neck fractures compared with other morphological parameters in this study. Various studies had noted that larger NSA was associated with femoral neck fractures [11, 22, 24]. Yamauchi et al[11] reported that NSA might be independent predictors for determining the proximal femur fracture types. Another study revealed that a smaller NSA was found in patients with intertrochanteric fractures compared with patients with femoral neck fractures[24]. Pulkkinen et al[25] demonstrated that patients with cervical fractures had substantially larger NSA than patients with trochanteric fractures, indicating that NSA was the best factor to predict the type of hip fracture. Another study reported that a larger NSA was associated with lower cortical thickness in the inferior than in the superior part of the femoral neck[19]. Owing to the weakness of the inferior part of the femoral neck, the femoral neck fractures might be more likely to occur in patients with a larger NSA. On the other hand, the greater load might focus on the intertrochanteric area than femoral neck with similar bending stress in patients with lower NSA[19]. Moreover, the angle rotation of the leg might actually have a profound effect on the type of hip fracture at the moment of contact with the floor. The rotation leg might compensate the effect of high NSA during the falling accident and the intertrochanteric fracture might occur[26].

It had been extensively studied that age was associated with the occurrence of different fracture types [11, 27]. The possible reason might be that the increasing of age will influence the distribution of BMD. The BMD decreased with the increasing age in patients aged >50 years, which might cause the thinning of the proximal femur cortex and the increasing of the medullary cavity[28]. Several studies reported that patients with intertrochanteric had lower BMD in both the superior and inferior femoral neck, while only the superior femoral neck had a lower BMD in patients with femoral neck fractures [9, 29]. In present study, older age was independent predictor for the occurrence of intertrochanteric fractures (OR=1.050, P=0.018). However, there was not statistical difference in total hip BMD between femoral neck fractures and intertrochanteric fractures. Furthermore, the BMD in the inferior or the superior part of the femoral neck was not measured. This was one of the limitations in this study.

The present study's strength was that the measurement was applied on the 3D reconstruction images, which will greatly improve the accuracy of measurement. However, this study had several limitations. Firstly, this was a retrospective study. Secondly, the sample was relatively small. Thirdly, the BMD of the proximal femur was not tested separately, which will influence the occurrence of fracture types. Therefore, a further study with larger sample size and prospective design was needed to confirm these findings.

Conclusions

The present study showed that age, FNL and NSA were independent predictors for identifying femoral neck fractures and intertrochanteric fractures. Moreover, a larger NSA was considered as the best predictor for the occurrence of femoral neck fractures after ROC analysis. Furthermore, geometrical measurements on three-dimensional images might be a useful method for identifying fracture types.

Conflict of interest: The authors declare that they have no conflict of interests.

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Figure Legends

Figure 1 Definition and measurements of geometric parameters of the proximal femur. a, The transverse slice at the level of 10mm distal to end of the lesser trochanter (T10). b, The transverse slice at the level of 30mm distal to end of the lesser trochanter (T30). c, T0, The transverse slice at the level of the apex of the lesser trochanter; F-G, femoral neck length; D-E, femoral neck width; A-L, femoral head height; J-K, femoral head diameter; A-I, offset; A-H-C, neck shaft angle.

Figure 2 ROC analysis for key parameters. A. Receiver operating characteristic curves for key parameters. B.Area under the curve values for each parameters.