RESEARCH ARTICLE

Effects of Hip Geometry on Fracture Patterns of Proximal Femur

Seyyed Morteza Kazemi, MD; Mohamad Qoreishy, MD; Ali Keipourfard, MD; Mohammadreza Minator Sajjadi, MD; Shahram Shokraneh, MD

Research performed at Akhtar Hospital, Tehran, Iran

Received: 19 Auqust 2015 *Accepted: 23 January 2016*

Abstract

Background: Some studies have previously shown that geometry of proximal femur can affect the probability of fracture and type of fracture. It happens since the geometry of the proximal femur determines how a force is applied to its different parts. In this study, we have compared proximal femur's geometric characteristics in femoral neck (FNF), intertrochanteric (ITF) and Subtrochanteric (STF) fractures.

Methods: In this study, 60 patients who had hip fractures were studied as case studies. They were divided into FNF, ITF and STF groups based on their fracture types (20 patients in each group). Patients were studied with x-ray radiography and CT scans. Radiological parameters including femoral neck length from lateral cortex to center of femoral head (FNL), diameter of femoral head (FHD), diameter of femoral neck (FND), femoral head neck offset (FHNO), neck-shaft angle (alpha), femoral neck anteversion (beta) were measured and compared in all three groups.

Results: Amount of FNL was significantly higher in STF group compared to FNF (0.011) while ITF and STF as well as FNT and ITF did not show a significant different. Also, FND in FNF group was significantly lower than the other two groups, i.e. ITF and STF. In other cases there were no instances of significant statistical difference.

Conclusion: Hip geometry can be used to identify individuals who are at the risk of fracture with special pattern. Also, it is important to have more studies in different populations and more in men.

Keyword: Femur, Fracture, Geometry, Hip

Introduction

Hip osteoporosis is one of the most prevalent orthopedic problems among the elderly which accompanied by challenging treatments that may result in unsatisfactory outcomes (1-7). 93.6 out of 100,000 persons at the age of 50 and above suffer from hip fractures annually in Iran which is mainly related to fall down accidents (8).

Although recent developments have decreased the prevalence of hip fractures in many counties, including Iran, still 25% of patients who call for hospital admission are among elderly population (9).

Bone fracture is caused when an applied external force is greater than energy absorption capacity of the bone due to changes in elastic and plastic shapes (10). The force applied to proximal femur in physiological activities and traumas, is a mixture of bending, axial and compression forces. When ground reaction is applied to hip, tensile stress is caused in the upper tissue and compressive stress in lower parts. In fact, falling on greater trochanter causes reversal of these forces, (10-12). Once the intensity of these two stresses is greater than the ultimate yield strength in the hip, fractures occurs (13).

Many factors affect the intensity of stress generation in bone, as well as bone's resistance against the generated stresses. Mechanical strength of a bone is related to physical attributes of ingredients (volume of material and their type of special dispersion), geometry and conditions including direction and amount of the force

Corresponding Author: Mohamad Qoreishy, Akhtar Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran
Email: Qoreishy@gmail.com

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

applied (14).

In this study, we have used x-ray radiography and CT images to study and compare geometric parameters of proximal femur in different types of hip fracture including intertrochanteric, subtrochanteric, and femoral neck in order to assist with identifying geometric risk factors, in addition to bone mineral density (BMD). Recent investigations have revealed that prevalence of hip fractures and associated financial burden in Iran is significantly lower than the developed countries (5, 6). Such lower prevalence can be explained by the differences in the geometry of the proximal femur.. In addition, to the best of our knowledge, no similar studies have been carried out among Iranian populations while previous studies indicate that geometric parameters are different in different races (5).

Material and Methods

In this study, 60 patients, including 38 female and 22 males suffering from hip fracture caused by low energy trauma have been studied. The patients have been admitted to Akhtar Hospital's emergency department in 2013 with the age range of 60 to 75 years old. Patients suffering from pathological fractures, paralysis, rheumatic diseases, bone Paget´s disease, chronic kidney disease and liver or lung disease were excluded from this study. Likewise, individuals with a history of long-term immobilization (for 6 months or more), long-term medications (for 6 months or more) , using drugs with impacts on bone metabolism such as estrogen, anabolic steroids, calcitonin, bisphosphonates, and also patients under treatment with antiepileptic drugs or corticosteroids for more than 3 months were not included in the study. Patients were examined initially to make sure that they do not belong to the excluded patient populations. Then, goals and the methodology of the study were explained to volunteer patients or their companion/care provider. Once they agreed to get involved in the study, written consent forms were handed out to be signed.

All patients underwent anteroposterior (AP) and lateral x-ray radiography to identify the type of hip fracture. AP view was also done in internal rotation to measure the most realistic femoral neck length. Patients were classified under FNF, ITF or STF groups based on their type of fracture. Patients were then referred for CT scan on both sides. In AP internal rotation x-ray radiography, as shown in Figure 1, the following parameters were measured and statistically analyzed:

FNL: Length between lateral cortex in proximal femur and center of femoral head along femoral neck axis;

FHD: Femoral head diameter drawn from center of femoral head;

FND: Longest femoral neck diameter;

FHNO: Femoral head neck offset: the ratio of femoral head to femoral neck;

Alpha angle: neck-shaft angle: the angle between femoral shaft axis and femoral neck axis

Beta angle: femur Anteversion measured in CT scan.

To compare quantitative data collected from the three groups, ANOVA test including post hoc test in SPSS Ver.15 was performed. For qualitative analysis of the collected data, Chai Dou test was conducted. In this study, *P*<0.05 was considered as a significance threshold.

Results

Differences in age, gender, and BMI were not significant among the three groups. The amount of measurements for the three groups have been demonstrated and compared in Table 1. Amount of FNL in FNF was

Table 1. Comparison of Average Parameters Studied in All Three Groups

Group	FNF (n=20)	ITF (n=20)	STF (n=20)	*P*-Value
FNL (cm) *	9.6 ± 0.49 (8.9 – 10.5)	9.87 ± 0.49 (9.2 – 10.9)	10.04 ± 0.39 (9.3 – 10.6)	0.032
FHD (cm)	4.7 ± 0.45 (4.1 – 5.9)	4.83 ± 0.4 (4 – 5.9)	5.05 ± 0.43 (4.4 – 5.9)	n.s.
FND (cm) *	3.2 ± 0.29 (2.8 – 3.9)	3.64 ± 0.4 (3 – 4.1)	3.8 ± 0.29 (3.3 – 4.5)	0.045
FHNO *	1.48 ± 0.14 (1.27 – 1.87)	1.33 ± 0.14 (1.05 – 1.6)	1.33 ± 0.12 (1.17 – 1.58)	0.015
α (degree)	123.2 ± 7.1 (110 – 136)	124 ± 6.4 (110 – 132)	124.5 ± 5.5 (115 – 133)	n.s.
β (degree)	14.6±4.5	12.7±3.5	16.1±5	<0.001

*Instances with significant statistical difference
FNL: length of femoral neck from lateral cortex to center of femoral head;
FHD: diameter of femoral head;
FND: diameter of femoral neck;
FHNO: c/d ration;
α: neck-shaft angle;
β: femoral anteversion

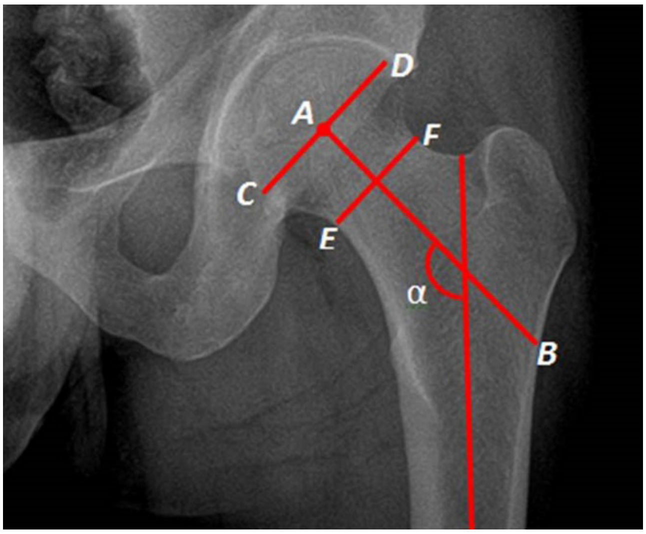

Figure 1. The method of measurement of radiographic parameters. femoral neck length: Length between lateral cortex in proximal femur (B) and center of femoral head along femoral neck axis (A); Femoral head diameter: Femoral head diameter drawn from center of femoral head (Line C-D); Femoral neck diameter: Longest femoral neck diameter (Line E-F); Femoral head neck offset: the ratio of femoral head to femoral neck; Neck-shaft angle (α): the angle between femoral shaft axis and femoral neck axis.

significantly lower than STF (0.011) while ITF and STF as well as FNF and ITF did not show a significant difference. Additionally, femoral neck diameter (FND) in FNF was significantly lower than ITF and STF (P=0.045). In other cases, no significant statistical difference.

Discussion

Solid evidence clearly suggests that low BMD is an important risk factor in hip fracture; however, nowadays hip's geometry and its role in bone strength as an important factor in instances of bone fracture has received a lot of attention (15, 16). Difference in hip geometry could change fracture pattern. Bowey et al. showed that patient sustaining an intracapsular fracture is more likely to have a longer femoral neck compared with intertrochanteric fractures. Also, intracapsular fractures occur in patients with narrower femoral neck (17). In addition, Faulkner et al. found that risk of hip fracture for hip axis length was nearly twice the mean value for each standard deviation (9).

Hip geometry determination could assist early detection of high risk individuals (5,15,18). Many studies suggested that hip fracture risk prediction requires simultaneous study of BMD and hip geometry (19-21). Some studies have used various measuring techniques to show that hip axis length, neck shaft angle or width of femoral neck have influences on hip fracture; while others have shown different or contradictory results (22). For instance, Keyak et al. showed that amount of length between lateral cortex of proximal femur is significantly higher in subtrochantric fracture compared to femoral neck fracture (11). This is an indicative of how opinions differ in terms of geometric attributes influencing risk of fracture and that researchers are yet to reach a consensus on the matter (23). The varying results mentioned above may caused by using different measuring and imaging methods, different studies (retrospective vs. prospective studies), limitations in sample volume and studies carried out in different populations.

Another important factor is that most of these studies have not differentiated various types of hip fracture (femoral neck fracture, subtrochanteric or intetrochanteric) (8). While different types of hip fracture in clinical or epidemiological affairs are considered as homogenous pathologies, there are fundamental difference in terms of anatomy, surgical treatments, BMD, etiology, risk factors, patients' characteristics, consequences and also morphological parameters (9, 24).

It is also important to study the role of these parameters in the increase of fracture risk factor in different populations because there is a difference between realistic role of these parameters in fracture patterns in Iran compared with other studies conducted in other countries (12, 24).

The limitations of our study include its retrospective single center nature. We did not estimate future fracture pattern by using the parameters. In addition, we did not not use 3D CT scan of fractures to measuring the parameters but it seems to be useful to determine some other parameters to find the special relationships between them and the pattern of fractures.

BMD measurement of femoral head found not to be a fracture predicting factor, especially in non-osteoporotic range. This study determined that geometry of proximal femur could affect the probability and type of fracture by changing that how force is applied in different parts of the bone. In addition, we found lower femoral neck diameter is a prominent risk factor in femoral neck fractures in compared with intertrochanteric or subtrochanteric fractures.

Evidence from our experience also suggest that a longer hip femoral neck length, longer femoral neck diameter and greater femoral head neck offset increase the risk of fracture; however, longer femoral neck diameter may decrease the risk of femoral neck fracture compared with trochanteric fractures. We hope that this study provides an impetus for further prospective multicenter researches focusing on these parameters in making special fracture patterns to determine special risk factors for fractures.

Seyyed Morteza Kazemi MD
Shahram Shokraneh MD
Ali Keipourfard MD
Mohamad Qoreishy MD
Akhtar Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Mohammadreza Minator Sajjadi MD
Taleghani Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran

References

1. Karlsson KM, Sernbo I, Obrant KJ, Redlund-Johnell I, Johnell O. Femoral neck geometry and radiographic signs of osteoporosis as predictors of hip fracture. Bone. 1996; 18(4):327-30.
2. Chappard C, Bousson V, Bergot C, Mitton D, Marchadier A, Moser T, et al. Prediction of femoral fracture load: cross-sectional study of texture analysis and geometric measurements on plain radiographs versus bone mineral density. Radiology. 2010; 255(2):536-43.
3. Pulkkinen P, Jamsa T, Lochmuller EM, Kuhn V, Nieminen MT, Eckstein F. Experimental hip fracture load can be predicted from plain radiography by combined analysis of trabecular bone structure and bone geometry. Osteoporos Int. 2008; 19(4):547-58.
4. Thevenot J, Pulkkinen P, Kuhn V, Eckstein F, Jamsa T. Structural asymmetry between the hips and its relation to experimental fracture type. Calcif Tissue Int. 2010; 87(3):203-10.
5. Gnudi S, Ripamonti C, Lisi L, Fini M, Giardino R, Giavaresi G. Proximal femur geometry to detect and distinguish femoral neck fractures from trochanteric fractures in postmenopausal women. Osteoporos Int. 2002; 13(1):69-73.
6. Crabtree N, Lunt M, Holt G, Kroger H, Burger H, Grazio S, et al. Hip geometry, bone mineral distribution, and bone strength in European men and women: the EPOS study. Bone. 2000; 27(1):151-9.
7. Hassankhani EG, Omidi-Kashani F, Hajitaghi H, Hassankhani GG. How to Treat the Complex Unstable Intertrochanteric Fractures in Elderly Patients? DHS or Arthroplasty. Archives of Bone and Joint Surgery. 2014 Sep;2(3):174-9. PubMed PMID: 25386578. eng.
8. Beck TJ, Looker AC, Ruff CB, Sievanen H, Wahner HW. Structural trends in the aging femoral neck and proximal shaft: analysis of the third national health and nutrition examination survey dual-energy X-ray absorptiometry data. J Bone Miner Res. 2000; 15(12):2297-304.
9. Faulkner KG, Cummings SR, Black D, Palermo L, Gluer CC, Genant HK. Simple measurement of femoral geometry predicts hip fracture: the study of osteoporotic fractures. J Bone Miner Res. 1993; 8(10):1211-7.
10. Gregory JS, Testi D, Stewart A, Undrill PE, Reid DM, Aspden RM. A method for assessment of the shape of the proximal femur and its relationship to osteoporotic hip fracture. Osteoporos Int. 2004; 15(1):5-11.
11. Keyak JH, Rossi SA, Jones KA, Les CM, Skinner HB. Prediction of fracture location in the proximal femur using finite element models. Med Eng phys. 2001; 23(9):657-64.
12. Gregory JS, Testi D, Stewart A, Undrill PE, Reid DM, Aspden RM. A method for assessment of the shape of the proximal femur and its relationship to osteoporotic hip fracture. Osteoporos Int. 2003; 15(1):5-11.
13. Pulkkinen P, Eckstein F, Lochmuller EM, Kuhn V, Jamsa T. Association of geometric factors and failure load level with the distribution of cervical vs. Trochanteric hip fractures. J Bone Miner Res. 2006; 21(6):895-901.
14. Bouxsein ML, Szulc P, Munoz F, Thrall E, Sornay-Rendu E, Delmas PD. Contribution of trochanteric soft tissues to fall force estimates, the factor of risk, and prediction of hip fracture risk. J Bone Miner Res. 2007; 22(6):825-31.
15. Rudman KE, Aspden RM, Meakin JR. Compression or tension? The stress distribution in the proximal femur. Biomed Eng online. 2006; 5(1):12-9.
16. Flicker L, Faulkner KG, Hopper JL, Green RM, Kaymacki B, Nowson CA, et al. Determinants of hip axis length in women aged 10-89 years: a twin study. Bone. 1996; 18(1):41-5.
17. Bowey A, Andrew B. Proximal femoral geometry and hip fracture patterns. A multi-centre comparative radiological study from southern Australia and western Scotland. J Bone Joint Surg. 2010; 92(SUPP II):271-2.
18. Karasik D, Dupuis J, Cupples LA, Beck TJ, Mahaney MC, Havill LM, et al. Bivariate linkage study of proximal hip geometry and body size indices: the framingham study. Calcif Tissue Int. 2007; 81(3):162-73.
19. Martens M, van Audekercke R, de Meester P, Mulier JC. The mechanical characteristics of the long bones of the lower extremity in torsional loading. J Biomech. 1980; 13(8):667-76.
20. Alonso CG, Curiel MD, Carranza FH, Cano RP, Perez AD. Femoral bone mineral density, neck-shaft angle and mean femoral neck width as predictors of hip fracture in men and women. Multicenter Project for Research in osteoporosis. Osteoporos Int. 2000; 11(8):714-20.
21. Woodhead HJ, Kemp AF, Blimkie CJR, Briody JN, Duncan CS, Thompson M, et al. Measurement of midfemoral shaft geometry: repeatability and accuracy using magnetic resonance imaging and

dual-energy X-ray absorptiometry. J Bone Miner Res. 2001; 16(12):2251-9.
22. Nakamura T, Turner CH, Yoshikawa T, Slemenda CW, Peacock M, Burr DB, et al. Do variations in hip geometry explain differences in hip fracture risk between Japanese and white Americans. J Bone Miner Res. 1994; 9(7):1071-6.
23. Greendale GA, Young JT, Huang MH, Bucur A, Wang Y, Seeman T. Hip axis length in mid-life Japanese and Caucasian U.S. residents: no evidence for an ethnic difference. Osteoporos Int. 2003; 14(4):320-5.
24. Partanen J, Jamsa T, Jalovaara P. Influence of the upper femur and pelvic geometry on the risk and type of hip fractures. J Bone Miner Res. 2001; 16(8):1540-6.