Geometry of Proximal Femur in the Prediction of Femoral Neck Fracture in the Elderly Female Thai Population

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A retrospective study of two groups of 157 patients with one-sided hip fracture and 157 aged matched control group was performed in Siriraj hospital. Geometric measurement of femoral neck was performed as hip axis length (HAL), femoral neck length (FNL), femoral neck width (FNW), femoral head diameter (FHD), acetabular bone width (ABW), and femoral neck–shaft angle (NSA).

*All geographic parameters are higher in length/width or degree in the femoral neck fracture group than in the normal control group. Among these parameters, ABW has the strongest association with femoral neck fracture (*p *0.000, odds ratio = 2.85), followed by FNW (*p *0.001, odds ratio = 2.51).*

According to the low sensitivity and specificity, and ROC curve, using this parameter as a screening tool for femoral neck fracture is still questionable. Further prospective study with a standard position, interval changing of femoral geometry, or combined with bone density or femoral architecture is suggested.

Keywords: *Acetabulum, Aged, Anthropometry, Body weights and measures Femoral neck fractures, Femur head, Hip fractures*

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Femoral neck fracture is one of the hip fractures which represent the most serious consequence of osteoporosis in terms of incidence, morbidity, mortality and financial cost(1). The incidence of hip fracture in the elderly increases with aging(2-4). In Thailand, the incidence of hip fracture (per 100,000) in four Asian countries is 114 in male and 289 in female(3). The mortality rate during hospitalization is 2.1%. The 3-, 6, and 12-month survival rates after hip fractures are 91%, 88% and 83%, respectively(5). The direct cost incurred from hip fracture in 1 year period is 30% of Thai National GDP per capita and cost effectiveness to save 1 hip fracture is equal to Thai National GDP per capital(6). Early detection of the high risk patient and primary prevention can reduce the incidence, morbidity, mortality and financial cost.

The major determinants of hip fractures are trauma, usually from minor falls(7,8) and bone strength of the upper end of the femur. The factors determining bone strength at the hip include bone density, bone architecture and bone geometry. In contrast to density, which is a measure of mineral content of bone, architecture and geometry are measures of skeletal structure(9).

In adults, architectural variables are considered to be those that can be modified by the remodeling processes in response to mechanical forces imposed on the skeleton, whereas geometric variables are more permanent and largely determined by the modeling processes active during growth(9).

Because of its cost effectiveness, wide availability of plain radiography which can offer sufficient spatial resolution and contrast to access macroscopic of the proximal femur, and new measurement method providing by PACS system which is not affected by magnification in radiographic images, femoral geometry is selected as investigative modality in this study.

The previous studies showed that geometry of the proximal femur could predict the femoral neck fracture in the elderly(9-18). To our knowledge, the correlation between the geometry of proximal femur

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and femoral neck fracture in elderly females has never been studied in Thai population.

The purpose of our study was to correlate proximal femoral geometry and the occurrence of femoral neck fracture by comparing the geometry of the contralateral normal hips in patient with femoral neck fracture, and that of control group without femoral neck fracture. The study was performed in the elderly, female, Thai population groups.

Material and Method

Patients

The retrospective study was performed in the 259 female Thai patients with 60 years of age and older who were diagnosed with femoral neck fracture by ICD 10 coding S72.0 at Siriraj Hospital from January 2005 to December 2006. Patients were excluded from this study if (1) antero-posterior plain radiograph of pelvis on PACS (Picture Archiving and Communications Systems) was not available for evaluation, (2) the patients had a history of developmental dysplasia of bones or systemic arthritis, (3) the non-fractured side had undergone any prosthesis, (4) tumor at the hip, or (5) fractures related to car or motorcycle accident.

Ninety patients with no available plain film on PACS and 12 patients with bilateral hip fractures or prosthesis on non-fractured side were excluded from this study. Finally, 157 patients were enrolled in this study with the mean age ± SD of 77.3 ± 7.9 years (range 60-99 years). All of these fractures were caused by falls on the same level from slipping, tripping and stumbling at home.

A group of 157 aged matched, elderly, Thai females without femoral neck fracture (with 60 years of age and older, and not exceeding 5 years difference from the fracture one) with available plain radiographs of pelvis on PACS on the same interval was selected as the control group. The patients with history of developmental dysplasia of bones or systemic arthritis, and prosthesis of both hips were excluded from this study. Their means age ± SD were 74.3 ± 8.2 years (range 60-98 years).

Plain radiographs

The antero-posterior plain radiographs of pelvis including both proximal femurs on PACS were used for analysis.

Image evaluation

The measurements were done by using PACS with agreement of two observers: a 10-year experienced with 10 years experiences musculoskeletal radiologist and a 3^{rd} year radiology resident.

The geometric parameters of proximal femur were defined as below (Fig. 1-2):

- Hip axis length (HAL) was defined as distance along femoral neck axis from femoral shaft axis to the inner pelvic brim (length form A to B)

- Femoral neck length (FNL) was defined as the distance from the femoral shaft axis to the center of the femoral head along the neck axis which was perpendicular to the femoral neck width axis (length form B to C)

- Femoral neck width (FNW) was defined as the shortest distance within the femoral neck (length form D to E)

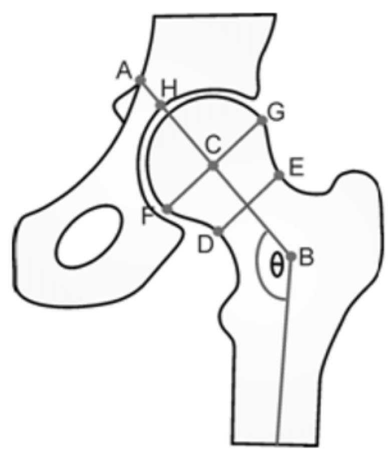


Fig. 1 Diagram of geometric parameter of proximal femur HAL = A-B, FNL = B-C, FNW = D-E, FHD = F-G, ABW = A-H, NSA = θ

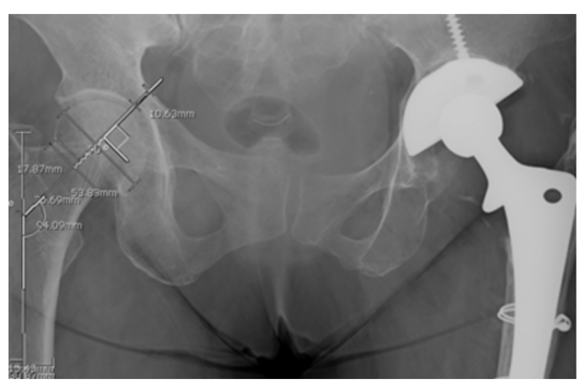


Fig. 2 The geometric parameter was performed at right femoral neck of 67 years old woman with history of left femoral neck fracture

- Femoral head diameter (FHD) was defined as the maximal diameter of femoral head measured parallel with the line of the femoral neck width measurement (length form F to G)

- Acetabular bone width (ABW) was defined as the width of the acetabulum along the extension of femoral neck axis (length form A to H)

- Femoral neck-shaft angle (NSA) was defined as the angle between the femoral neck axis and the femoral shaft axis

Length and width were measured to within one hundredth of cm and angles were measured in degree. In the femoral neck fracture group, the measurement was done on the non-fractured side. In the control group, one side of the hip was selected for measurement. Some studies stated that there was no differentiation of the hip geometry between both sides[17-19]. Reproducibility of the study was also performed by randomly selected 10 radiographs in each group and repeated measurement by at least 2- week interval by the same radiologist and resident.

Statistics

The mean and standard deviation of each parameter in both femoral fracture group and control group were calculated, using independent-samples t test. A p-value of less than 0.05 was considered statistically significant. The receiver operating characteristic (ROC) curve was used to establish the cut off level for the femoral geometry for the evaluation of the femoral neck fracture group compare to the normal control group. Then, the sensitivity and specificity of each parameter was calculated.

The reproducibility of the study was performed using intraclass correlation coefficients and the information was interpreted as followed; < 0.4 = poor agreement, 0.4-0.75 = fair-good agreement, > 0.75 = excellent agreement

Results

The reproducibility was done by measurement of 10 radiographs in each group. The study showed intraclass correlation coefficients of 0.85 (excellent agreement), 0.86 (excellent agreement), 0.95 (excellent agreement), 0.97 (excellent agreement), 0.66 (fair-good agreement), 0.66(fair-good agreement), for HAL, FNL, FNW, FHD, ABW, NSA, respectively.

The result of geometric measurement at the proximal femur is shown in Table 1. All geometric parameters were significantly correlated with femoral neck fracture ($p < 0.05$). All geographic parameters are higher in length/width or degree in the femoral

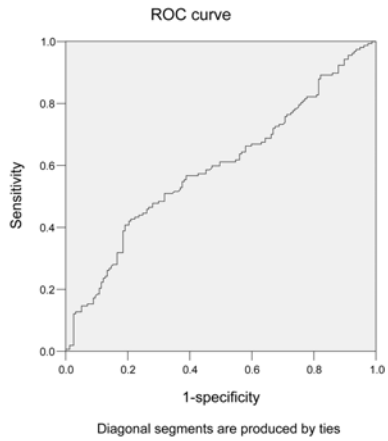
Table 1. Means and standard deviation of the geometric parameters of proximal femur in femoral neck fracture group and control group

Parameter	Femoral neck fracture (n = 157)	Control group (n = 157)	p-value	Mean difference	95% CI of mean difference
HAL (mm)	89.96 ± 10.03	86.92 ± 9.13	0.005	3.05	0.92-5.17
FNL (mm)	50.87 ± 8.48	48.82 ± 7.93	0.028	2.05	0.23-3.88
FNW (mm)	32.99 ± 2.49	31.97 ± 2.64	0.001	1.01	0.44-1.58
FHD (mm)	49.73 ± 3.11	48.89 ± 3.51	0.025	0.84	0.10-1.57
ABW (mm)	14.00 ± 3.18	12.24 ± 2.50	0.000	1.77	1.13-2.40
NSA (degree)	142 ± 8	140 ± 7	0.011	2.10	0.48-3.73

Table 2. Sensitivity and specificity of each parameter at the mean value of control group

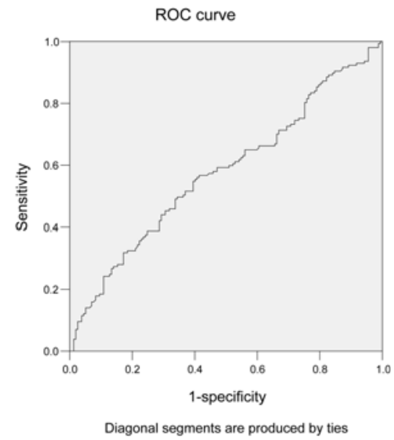
Parameter	Value	Sensitivity (%)	Specificity (%)	Odds ratio	95% CI of odds ratio
HAL (mm)	87	59.9	50.3	1.51	0.97-2.38
FNL (mm)	49	59.2	50.3	1.47	0.94-2.30
FNW (mm)	32	66.9	55.4	2.51	1.59-3.97
FHD (mm)	49	60.5	54.1	1.81	1.16-2.83
ABW (mm)	12	77.1	54.1	2.85	1.75-4.63
NSA (degree)	140	58.6	52.2	1.55	0.99-2.42

3.1 ROC curve for HAL



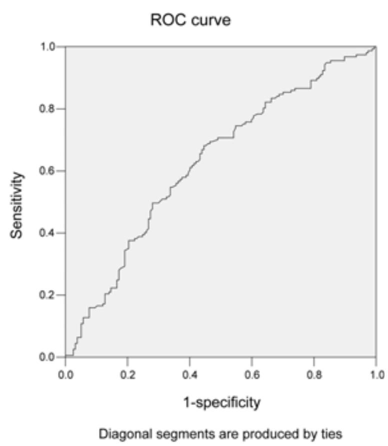
Area under curve = 0.592

3.2 ROC curve for FNL



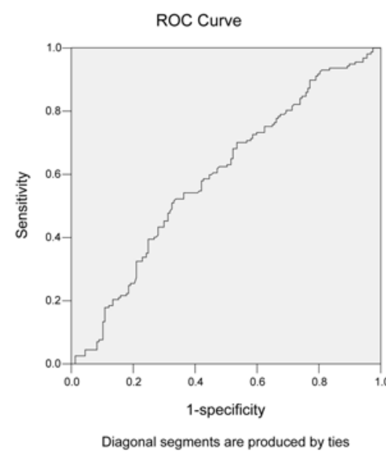
Area under curve = 0.577

3.3 ROC curve for FNW



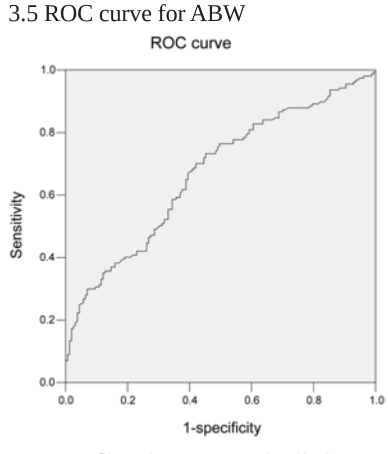
Area under curve = 0.627

3.4 ROC curve for FHD



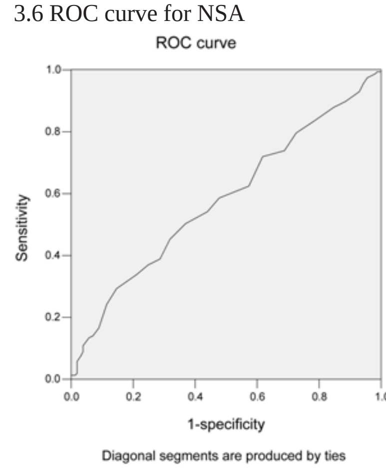
Area under curve = 0.592

3.5 ROC curve for ABW



Area under curve = 0.670

3.6 ROC curve for NSA



Area under curve = 0.579

Fig. 3 The receiver operating characteristic (ROC) curve of femoral geometry in diagnosing of femoral neck fracture neck fracture group than in the normal control group.

Then we used the mean of the control group for calculation of the sensitivity and specificity of each parameter, as shown in Table 2. The receiver-operating characteristic (ROC) curve for femoral geometry was near a diagonal, and the areas under the curve are 59.2%, 57.5%, 62.7%, 59.2%, 67.0% and 57.9% for HAL, FNL, FNW, FHD, ABW, NSA, respectively (Fig. 3).

Discussion

Hip fractures have high morbidity and mortality rate for the people as a complication for osteoporosis and are generally seen in old people. The femoral geographic measurements are important in the assessment of hip fracture risk(17). The recent studies have indicated that the geometry of the femoral neck is associated with the risk of hip fracture in the elderly(9-11,12-14,17-24) (Table 3, Fig. 4).

Mostly, these studies included Caucasian population. The different race plays an important role in the distribution of hip fracture and geometry of the proximal femur(22,23). Cummings et al(24) showed that the mean HAL of Asian and African women were significantly shorter than Caucasian women, and that might explain why they have a lower risk of hip fracture than the Caucasians.

The study focusing on the Chinese population conducted by Yang et al(12) which showed that only FNL was a significant geographic parameter for predicting femoral neck fracture ($p < 0.01$) after correction for age, body height, and body weight. However, the FNW, FHD, and NSA were not significant.

C-C et al(11) showed the relationship between HAL and fracture risk persisted even after adjustment for age, femoral neck density, height and weight. A longer HAL associated with an increased risk of both femoral neck and trochanteric fractures. This study also demonstrated the strong association of FHD and ABW with the femoral neck fracture. Nerveless, there was no significant association between FNW and NSA with the hip fracture.

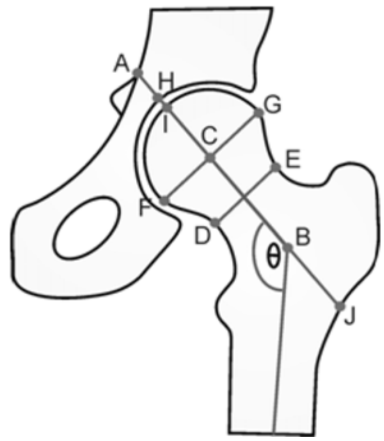


Fig. 4 Geometric parameters used in various published studies HAL = A-J, ABW = A-H, FAL = I-J, FNL = B-C, FNW = D-E, FHD = F-G, NSA = θ

In the study of Peacock et al(9), only HAL had significant association with the hip fracture with odds ratio of 3.52 which were higher than this study found out. However, the definition of HAL is different from this study. Some previous studies showed opposite results. In the study of Karlsson et al(13), shorter of HAL in the hip fracture group was found. Ferris et al(16) found that FNL was shorter in the fracture group than the osteoarthritis group and the NSA was smaller. These results could be due to different definitions of the parameters.

The hip axis length can be measured along femoral neck axis from greater trochanter to inner

Table 3. Selected radiographic measurement from various published studies

Study	Peacock control	Peacock fracture	Yang control	Yang fracture	Karisson control	Karisson fracture	Michelotti control	Michelotti fracture	Carlis control	Carlis fracture
HAL	129.6	133.1							130.5	130.3
FAL	113.8	116.8			119.8	118.1	114.8	N/A	112.7	111.7
FNL			48.8	50.4			57.7	58.7		
FNW	32.3	32.5	33.7	33.4	38.9	39.6	36.5	37.5	35.8	37.3
FHD	54.7	55.7	49.4	49.5			52.0	55.2	53.3	53.3
ABW	15.8	16.8							17.8	18.2
NSA	122.91	123.82	132.1	131.0	127.2	129.1	127.1	128.0	128.9	132.8

pelvic rim[9,18], from femoral shaft axis to inner pelvic rim[15], or from greater trochanter to the edge of caput femoris[13], which was designed as FAL in other studies[9,13,17,18].

Joint space narrowing, stiff joint, and other anatomical features of osteoarthritis and hip dysplasia may affect the probable apparent of hip shape. These confounding factors are minimized by using the definition of HAL[13,17]. In order to avoid this effect, the ones with arthritis or hip dysplasia have been excluded from this study.

Our data (Table 1) show that all geometric parameters of proximal femur (HAL, FNL, FNW, FHD, ABW, NSA) have significant correlation ($p < 0.05$) with femoral neck fracture. The geographic parameters in the femoral neck fracture group are longer or wider than those in the normal control group.

Among these parameters, ABW has the strongest association with the femoral neck fracture (p 0.000, odds ratio = 2.85), followed by FNW (p 0.001, odds ratio = 2.51). The sensitivity and specificity of ABW and FNW are 77.1 and 54.1, and 66.9 and 55.4 respectively.

From the ROC curve, the areas under the curve are 59.2%, 57.5%, 62.7%, 59.2%, 67.0% and 57.9% for HAL, FNL, FNW, FHD, ABW, NSA, respectively. The curve near a diagonal line confirms that the femoral geometry has low diagnostic value for the femoral neck fracture.

The wide overlap of each parameter between the fracture group and the control group is also depicted. This finding corresponds with previous studies. Thus, using this parameter as a screening tool for predicting femoral neck fracture in clinical practice is still questionable due to the fact that sensitivity and specificity are not high.

Our study has some limitations because of retrospective nature of this study. Hip position cannot be properly controlled. The measurement may change greatly according to position of the legs which can minimize the accurate measurement of some of the dimensions.

Conclusion

Geometry of the proximal femur in the femoral neck fracture in the elderly, female, Thai population is different from the control group. In this study ABW and FNW have strong association with the femoral neck fracture. Because of the area under ROC curve and wide range with overlap of each parameter, using this parameter as a screening tool for the femoral neck fracture is still questionable. Further prospective studies with strict criteria for a standard position, interval changing of geometry of proximal femur in the same person for predicting the femoral neck fracture, or combining femoral geometry with bone density or bone architecture are suggested.

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การใช้ Femoral geometry เพื่อทำนายการมีโอกาสหักของคอกระดูกต้นขาในหญิงสูงอายุชาวไทย

นิตยา เล็กตระกูล, อรวีร์ รัตรสาร

ผู้วิจัยได้ทำการศึกษาย้อนหลังของการใช้ Femoral geometry ในผู้ป่วยหญิงสูงอายุชาวไทยที่มารับการรักษาในโรงพยาบาลศิริราช ด้วยอาการกระดูกต้นขาหัก 157 ราย เปรียบเทียบกับหญิงสูงอายุชาวไทยในช่วงอายุเดียวกันอีก 157 ราย Femoral geometry ที่ใช้ประกอบด้วย hip axis length (HAL), femoral neck length (FNL), femoral neck width (FNW), femoral head diameter (FHD), acetabular bone width (ABW) และ femoral neck-shaft angle (NSA) จากการศึกษาพบว่า parameter ทั้งหมด มีค่าเพิ่มขึ้นอย่างมีนัยสำคัญ ในกลุ่มผู้ป่วยกระดูกต้นขาหัก โดย ABW มีความเกี่ยวพันกับการหักของคอกระดูกต้นขามากที่สุด รองลงมาคือ FNW เนื่องจากความไว ความจำเพาะและพื้นที่ใต้เส้นโค้ง (ROC curve area) ยังมีค่าค่อนข้างต่ำ การใช้ Femoral geometry ในการทำนายการหักของคอกระดูกต้นขายังมีข้อจำกัด