Correlation of Proximal Femoral Bone Geometry from Plain Radiographs and Dual Energy X-Ray Absorptiometry in Elderly Patients

Tanawat Vaseenon MD*, Chawapon Chaimuang MD*,
Areerak Phanphaisarn BSc*, Sirianong Namwongprom MD, PhD**,
Sirichai Luevitoonvechkij MD*, Sattaya Rojanasthien MD*

** Department of Orthopaedic Surgery, Chiang Mai University, Chiang Mai, Thailand*
*** Nuclear Medicine Unit, Department of Radiology, Chiang Mai University, Chiang Mai, Thailand*

Background: *Fracture prevention in osteoporotic patients is the primary treatment goal in assessing bone mineral density, identification of fracture risk, and determination of who should be treated. The literature shows that parameters of proximal femoral bone geometry such as hip axis length, femoral neck shaft angle (FNA), femoral neck width (FNW) and femoral neck cortical thickness (FNCT) can predict the risk of hip fracture. Those parameters are presented automatically with dual energy X-ray absorptiometry (DXA) scans, which are available in well-equipped hospitals.*
Objective: *To determine the correlation between proximal femoral bone geometry and the parameters from DXA scans and those from plain radiographs.*
Material and Method: *Forty-eight patients with no previous hip fractures or history of secondary osteoporosis underwent both a DXA scan of the hip area and a plain hip radiograph done in the same position, 25 degrees internal rotation. Bone geometries from both groups were measured to determine the correlation using Pearson correlation coefficient.*
Results: *Correlation between the parameters HAL, FNA, FNW and FNCT from the DXA scans and from the measurement of the plain radiograph was significant (p<0.01) and the level of correlation was moderate to high. The FNCT had least mean difference (0.04). In addition, the parameter FNCT, less than 0.29 mm in both DXA scans and plain radiographs, showed a significant correlation with osteoporosis (T-score <-2.5).*
Conclusion: *The bone geometry parameters from either DXA scans or plain radiographs may be used to predict osteoporotic hip fracture with a moderate to high correlation. Plain radiographs are very helpful when DXA scan results are not available. The FNCT parameter has a strong correlation with osteoporosis.*

Keywords: *Bone geometry, Hip fracture, DXA, Plain X-ray, Osteoporosis, BMD*

J Med Assoc Thai 2015; 98 (1): 39-44
Full text. e-Journal: *http://www.jmatonline.com*

At present, osteoporosis is a major problem for national public health systems in all countries. The risk of osteoporotic related fractures may not only reduce the quality of life of patients but also causes an increase in morbidity, mortality and financial burden. The patients who have osteoporotic hip fractures may have many complications associated with osteoporosis such as an increased risk of disability, loss of the ability to live independently as well as an increased risk of death[1]. Hip fractures occur more frequently now and are increasing by 1-3% per year in most countries of the world[2]. The estimated incidence of hip fractures is about 151.2 per 100,000[3]. The mortality rate after an osteoporotic hip fracture at one year following the fracture is 18%[4]. Fracture prevention is the primary treatment goal for patients with osteoporosis by assessment of bone mass, identification of fracture risk and a determination of who should be treated[5].

The World Health Organization (WHO) defines osteoporosis as bone mineral density 2.5 standard deviations or more below the mean peak bone mass of a healthy 25-year-old (T-score). The American National Institute of Health Consensus Conference in 2000 defined osteoporosis as a skeletal disorder characterized by compromised bone strength, predisposing a person to the increased risk of fracture. Bone strength is determined by both bone density and bone quality. Bone density is the volume of mineral per area determined by peak bone mass and the amount of bone loss. Bone quality refers to architecture, turnover, damage accumulation and mineralization[5].

Correspondence to:
Vaseenon T, Department of Orthopaedic, Faculty of Medicine, Chiang Mai University, Chiang Mai 50200, Thailand.
Phone: 053-945-544, Fax: 053-946-442
E-mail: tvaseenon@yahoo.com

The gold standard measurement used to diagnose osteoporosis is based on an assessment of bone mineral density (BMD) by dual-energy X-ray absorptiometry (DXA)[6].

After BMD at the hip area is investigated using a DXA scan, hip geometry such as hip axis length, femoral neck shaft angle, femoral neck width, femoral neck cortical thickness and others can be assessed accurately. The bony architecture or bony geometry is one factor determining bone strength as described in the previous paragraph. Many studies suggest that these hip bony geometry calculations can predict the risk of hip fractures[6-14]. However, DXA facilities are not available at every medical center in all countries, but plain radiographs are widely available. The present study was conducted to evaluate the correlation of proximal femoral bone geometry from plain radiographs and dual energy X-ray absorptiometry (DXA). If the data from two methods are correlated, it would indicate that data from plain radiography can be used to predict the hip fracture risk accurately in the same way as data from a DXA scan.

Material and Method

Study design and patients

Prospective consecutive forty-eight patients were recruited at the Orthopedic Outpatient Department of Chiang Mai University between August 2012 and March 2013. The inclusion criteria were healthy patients over 50 years old with no concurrent hip fracture or injury. The exclusion criteria were a pathologic fracture, previous hip fracture and a history of secondary osteoporosis (e.g., chronic renal failure, thalassemia, chronic steroid use). The subjected included 4 males and 44 females with a mean age of 64 years, weight of 55 kg and height of 150.4 cm. Their mean body mass index was 24.37 kg/m^2. All of the patients underwent a DXA scan and a plain radiograph of both hips AP view. This study was begun after receiving approval from Chiang Mai University Hospital Institutional Review Board and informed consent was obtained from all patients.

DXA scan

A hip DXA scan was performed on all patients using the discovery A (S/N 82938) model scanner at Chiang Mai University. The patients were in supine position with internal rotation of both hips at 25 degrees (Fig. 1). The foot blocking system was used to promote the internal rotation position of both hips. The bone mineral density was measured and the hip bony geometry parameters such as hip axis length[15], femoral neck shaft angle (FNA), femoral neck width (FNW) and femoral neck cortical thickness (FNCT) were obtained automatically[15] (Fig. 2).

Plain radiograph

Following the DXA scan, a plain radiograph was performed on both hips of all patients in AP view[14]. The patients were in the supine position and internal rotation position of both hips with the foot blocking system was the same as for the DXA scan. The hip bony geometry parameters were measured on the same side of the hip as in the DXA scan. All of the radiographs were digitized using the picture archiving communication system (PACS) software at Chiang Mai University, and all the parameters and angles were measured using the calipers and goniometers provided by the software. Two investigators (TV and CC) measured twice (four measurement total) and then

Fig. 1 Patients were in supine position with 25 degrees hip internal rotation for both DXA scan and plain radiography.

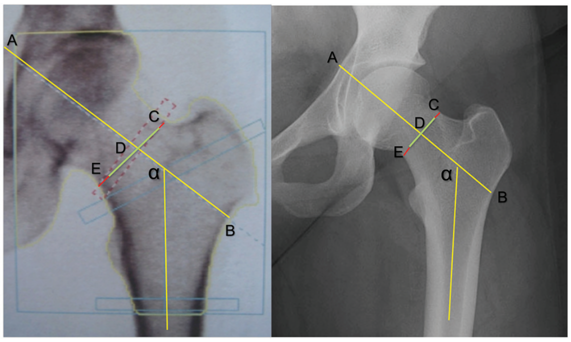

Fig. 2 Parameters measured from the hip anteroposterior on a DXA scan (left) and a plain radiograph (right). 1) The distance A to B is the hip axis length, 2) the alpha (α) angle is the femoral neck shaft angle, 3) the distance C + D + E is the femoral neck width, and 4) the distance C plus the distance E is the femoral neck cortical thickness[14,15].

calculated the average for each parameter. 1) Hip axis length[15]: Length along the femoral neck axis from below the lateral aspect of the greater trochanter through the femoral neck to the inner pelvic brim. 2) Femoral neck shaft angle (FNA): Angle formed between the femoral neck and the shaft of the femur. 3) Femoral neck width (FNW): Shortest distance within the femoral neck region of interest. 4) Femoral neck cortical thickness (FNCT): Femoral neck cortical thickness at the level of the width measurement at the femoral neck.

Statistical analysis

Statistical analysis was performed to determine the significance of the correlation between two methods using the Statistical Package for Social Sciences (SPSS) 16.0 (SPSS Inc., Chicago, IL, USA). The bivariate Pearson correlation test was used to determine correlation between the DXA scan parameters and parameters from the plain radiograph, including BMD (T-score). Mean difference was used to determine the error of parameters from two methods. Statistical significance was accepted for p-value <0.05.

Results

The intraclass correlation coefficient indicated excellent measurement agreement for both inter-observer reliability (r = 0.93) and intra-observer reliability (r = 0.97) in the comparison of bone geometry from the DXA scans and the plain radiographs.

The mean parameters for HAL, FNA, FNW and FNCT were 100 mm, 129 degrees, 3.05 mm and 0.28 mm with DXA scan and 110 mm, 128 degrees, 3.26 mm and 0.33 mm with the plain radiograph, respectively. The proximal femoral bone geometry from the DXA scan correlated significantly with the proximal femoral geometry from the plain radiograph including HAL r = 0.769 (p<0.01), FNA r = 0.477 (p<0.01), FNW r = 0.624 (p<0.01) and FNCT r = 0.391 (p<0.01), respectively. Mean differences for HAL, FNA, FNW and FNCT were 13.86, 0.22, 0.25 and 0.04, respectively. The parameter of HAL was overestimated from plain radiograph measurement (Table 1).

Comparison of bone mineral density (T-score) and bone geometry from DXA scan

The mean parameters for HAL, FNA, FNW and FNCT were 99.8 mm, 128 degrees, 3.08 mm and 0.21 mm with the osteoporotic group (T-score equal or less than -2.5) and 100 mm, 130 degrees, 3.05 mm and 0.29 mm with the non-osteoporotic group (T-score greater than -2.5), respectively. Only the FNCT from the DXA scan showed a significant correlation with osteoporosis, r = 0.720 (p<0.01).

Comparison of bone mineral density (T-score) and bone geometry from plain radiographs

The mean parameters for HAL, FNA, FNW and FNCT were 107 mm, 128 degrees, 3.23 mm and 0.29 mm with the osteoporotic group and 110 mm, 129 degrees, 3.27 mm and 0.34 mm with the non-osteoporotic group, respectively. The FNCT from the plain radiograph showed a significant correlation with osteoporosis, r = 0.325 (p = 0.024). There were no significant relationships between T-score and HAL, FNA, or FNW (Table 2).

Discussion

The present study explored the correlation of simultaneous bone geometry measurements between DXA scanning and plain radiography for the first time. Use of plain radiograph measurement by general practice physicians and nurses is an appropriate alternative in areas where there are no facilities for DXA scanning.

Table 1. Showing the mean of hip axis length, femoral neck shaft angle, femoral neck width and femoral neck cortical thickness from plain radiograph and DXA scan combination with their correlation coefficient, p-value and mean difference

Bone geometry	Mean		Correlation (r)	p-value	Mean difference
	Plain radiograph	DXA scan			
Hip axis length (mm)	110	100	0.769	<0.01	13.86
Femoral neck shaft angle (degree)	128	129	0.477	<0.01	0.22
Femoral neck width (mm)	3.26	3.05	0.624	<0.01	0.25
Femoral neck cortical thickness (mm)	0.33	0.28	0.391	<0.01	0.04

DXA = dual energy X-ray absorptiometry

Table 2. Showing the mean of hip axis length, femoral neck shaft angle, femoral neck width and femoral neck cortical thickness from plain radiograph and DXA scan in osteoporotic group (BMD <-2.5) combination with the correlation coefficient and *p*-value

Bone geometry	Plain radiograph			DXA scan		
	Mean	Correlation (r)	*p*-value	Mean	Correlation (r)	*p*-value
Hip axis length (mm)	107.0	0.131	0.374	99.8	0.039	0.790
Femoral neck shaft angle (degree)	128	0.017	0.909	128	0.136	0.357
Femoral neck width (mm)	3.230	0.064	0.663	3.08	0.295	0.042
Femoral neck cortical thickness (mm)	0.294	0.325	0.024*	0.21	0.720	<0.01*

BMD = bone mineral density

Previous studies have presented bone geometry from both DXA scans and plain radiographs including reporting correlations with hip fracture, low bone mineral density and fracture rate[5]. However, the position of the hip on the DXA scans and plain radiographs have not been the same in any of those studies[6,8]. In addition, the measurements differed in rotational position of the hip as well as cortical thickness and neck width[9]. The present study used a consistent hip rotation of 25 degrees internal rotation in both the DXA scans and the radiographs. Having the position on the different images the same increases accuracy of parameter measurement and interpretation.

No previous evidence was found showing that bone geometry parameters from DXA scans and plain radiographs could be used for the same purposes. The parameters from DXA scans may not be used by their measurements from the plain radiograph. To our knowledge, this study was the first that studied the correlation of measurements between DXA scans and plain radiographs. It was found that with this moderate to high degree of agreement, parameters from the plain radiograph could be used when DXA scanning is not available. However, the HAL parameter was not appropriate to use due to the overestimate measurement from plain radiograph; but the FNCT can be use for measurement because of the small mean difference.

The published literature indicates that bone geometry measured from DXA scans is the standard for predicting hip fracture and osteoporosis. The DXA scans interpret bone quality and bone geometry simultaneously. Bone geometry from DXA scans such as HAL and FNA have been used to predict both hip fracture and osteoporosis[7]. However, the present study found FNCT more reliable for predicting osteoporosis. A FNCT of less than 0.29 mm relates to a T-score of less than -2.5 with a *p*-value less than 0.05. Thus, this measurement can be very useful for general physicians to evaluate and help patients avoid osteoporotic hip fractures.

Studies conducted over the past 10 years have also reported that using bone geometry from plain radiographs could predict hip osteoporosis including hip fractures[6,10,14]. The measurement of HAL and FNA were the most reliable in predicting hip fracture, although no details were given regarding hip position during plain radiography[7]. The authors correlated bone geometry with Singh index and T-score. The present study found that FNCT was the only significant predictor for osteoporosis and that it was also very helpful for physicians in helping patients avoid hip fractures.

There were three main limitations of the present study. First is the limited number of cases. Increasing the number of individuals studied would increase reliability and reduce error. The second is that most of the samples were female, thus representing a group of osteoporosis types usually found in females. However, osteoporosis in men is increasing. Thus, the results of the present study may not be applicable to males. Lastly, different types of DXA scanners and different measurement programs may yield different numbers in bone geometry parameters.

Conclusion

Because of the moderate to high degree of correlation, the bone geometry parameters from either DXA scans or plain radiographs can be used to predict osteoporosis. Plain radiographs are very helpful when there are no DXA scan results available as is the case in some hospitals. The femoral neck cortical thickness parameter has a strong correlation with osteoporosis.

What is already known on this topic?

The bone geometry parameters from DXA scans can predict osteoporosis and hip fracture risk.

However, those parameters analyze from DXA scanners that present only in tertiary hospital. Those parameters that can measure from a standard plain radiograph may or may not used to predict osteoporosis or hip fracture due to difference investigation machines.

What this study adds?

This study adds new information that not all bone geometry parameter measurements from DXA scans can be relatively used on the plain radiograph measurements. A femoral cortical neck thickness is only one bone geometry parameter that can be used from the plain radiograph measurement as the osteoporosis prediction.

Acknowledgement

The authors wish to thank the radiologist teams and orthopedic residents for their help in the present study, and to G Lamar Robert PhD, for reviewing the manuscript.

Potential conflicts of interest

None.

References

1. Leboime A, Confavreux CB, Mehsen N, Paccou J, David C, Roux C. Osteoporosis and mortality. Joint Bone Spine 2010; 77 (Suppl 2): S107-12.
2. Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. Lancet 2002; 359: 1761-7.
3. Phadungkiat S, Chariyalertsak S, Rajatanavin R, Chiengthong K, Suriyawongpaisal P, Woratanarat P. Incidence of hip fracture in Chiang Mai. J Med Assoc Thai 2002; 85: 565-71.
4. Vaseenon T, Luevitoonvechkij S, Wongtriratanachai P, Rojanasthien S. Long-term mortality after osteoporotic hip fracture in Chiang Mai, Thailand. J Clin Densitom 2010; 13: 63-7.
5. Miller PD, McClung M. Prediction of fracture risk. I: Bone density. Am J Med Sci 1996; 312: 257-9.
6. Calis HT, Eryavuz M, Calis M. Comparison of femoral geometry among cases with and without hip fractures. Yonsei Med J 2004; 45: 901-7.
7. Brownbill RA, Ilich JZ. Hip geometry and its role in fracture: what do we know so far? Curr Osteoporos Rep 2003; 1: 25-31.
8. Pulkkinen P, Partanen J, Jalovaara P, Jamsa T. Combination of bone mineral density and upper femur geometry improves the prediction of hip fracture. Osteoporos Int 2004; 15: 274-80.
9. Michelotti J, Clark J. Femoral neck length and hip fracture risk. J Bone Miner Res 1999; 14: 1714-20.
10. Im GI, Lim MJ. Proximal hip geometry and hip fracture risk assessment in a Korean population. Osteoporos Int 2011; 22: 803-7.
11. 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: 69-73.
12. Leslie WD, Pahlavan PS, Tsang JF, Lix LM. Prediction of hip and other osteoporotic fractures from hip geometry in a large clinical cohort. Osteoporos Int 2009; 20: 1767-74.
13. Poole KE, Mayhew PM, Rose CM, Brown JK, Bearcroft PJ, Loveridge N, et al. Changing structure of the femoral neck across the adult female lifespan. J Bone Miner Res 2010; 25: 482-91.
14. Karabulut O, Tuncer MC, Karabulut Z, Aclkgoz A, Hatipoglu ES, Akkus Z. Relationship between radiographic features and bone mineral density in elderly men. Folia Morphol (Warsz) 2010; 69: 170-6.
15. Bergot C, Bousson V, Meunier A, Laval-Jeantet M, Laredo JD. Hip fracture risk and proximal femur geometry from DXA scans. Osteoporos Int 2002; 13: 542-50.

ความสัมพันธ์ของโครงสร้างกระดูกต้นขาจากภาพถ่ายทางรังสีและเครื่องเด็กซ่าสแกนในผู้สูงอายุ

ธนวัฒน์ วะสีนนท์, ชวพล ชัยเมือง, อารีรักษ์ พันธ์ไพศาล, ศิริอนงค์ นามวงศ์พรหม, ศิริชัย ลือวิฑูรเวชกิจ, สัตยา โรจนเสถียร

ภูมิหลัง: *การป้องกันกระดูกสะโพกหักเป็นเป้าหมายสำคัญในการรักษาโรคกระดูกพรุนทำโดยการประเมินความหนาแน่นกระดูก วัดความเสี่ยงการเกิดกระดูกหักเพื่อประเมินการให้การรักษาโครงสร้างกระดูกต้นขา hip axis length, femoral neck shaft angle (FNA), femoral neck width (FNW) and femoral neck cortical thickness (FNCT) ใช้ทำนายการหักของกระดูกสะโพก ซึ่งค่าต่าง ๆ เหล่านี้ได้จากเครื่องเด็กซ่าสแกนที่มีในโรงพยาบาลขนาดใหญ่เท่านั้น*

วัตถุประสงค์: *การศึกษานี้เป็นการหาความสัมพันธ์ของค่าโครงสร้างกระดูกต้นขาจากภาพถ่ายทางรังสี และเครื่องเด็กซ่าสแกนว่ามีความสัมพันธ์กันหรือไม่*

วัสดุและวิธีการ: *ผู้ป่วยสี่สิบแปดรายที่ไม่มีประวัติกระดูกสะโพกหักหรือโรคกระดูกพรุนที่มีสาเหตุจากโรคอื่นได้รับการตรวจเด็กซ่าสแกนและภาพถ่ายทางรังสีของกระดูกสะโพกในท่าเดียวกัน คือ สะโพกหมุนเข้าในยี่สิบห้าองศา วัดค่าโครงสร้างกระดูกต้นขา และวิเคราะห์โดยใช้สถิติ Pearson correlation*

ผลการศึกษา: *พบว่าค่าโครงสร้างกระดูกต้นขาจากภาพถ่ายทางรังสีและเครื่องเด็กซ่าสแกนมีความสัมพันธ์สูงถึงปานกลางอย่างมีนัยสำคัญทางสถิติ ค่า femoral neck cortical thickness (FNCT) มีค่าเฉลี่ยความผิดพลาดที่น้อยที่สุดที่ 0.04 และ ค่า FNCT ที่น้อยกว่า 0.29 มิลลิเมตร จากทั้งภาพถ่ายทางรังสีและเครื่องเด็กซ่าสแกนมีความสัมพันธ์กับภาวะกระดูกพรุน*

สรุป: *ค่าโครงสร้างกระดูกต้นขาจากภาพถ่ายทางรังสีและเครื่องเด็กซ่าสแกนใช้ทำนายความเสี่ยงในการเกิดโรคกระดูกหักจากโรคกระดูกพรุน ภาพถ่ายทางรังสีมีประโยชน์ในกรณีที่ไม่มีเครื่องเด็กซ่าสแกนในโรงพยาบาล*