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Correlation of proximal femur and lumbar spine hounsfield unit with risk of osteoporotic fracture

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***Abstract*---**Fracture is a major complication of osteoporosis, however screening is not routinely carried out. CT-scan provides an opportunistic opportunity for screening, therefore this study aims to analyze the correlation the bone density on CT-scan and the risk of osteoporotic fracture. This was a cross-sectional study on patients who underwent abdominal-pelvic CT scan. Bone density was assessed with Hounsfield Unit (HU) CT-scan of the proximal femur and 3rd lumbar spine. Proximal femoral HU values were measured at the trabecular and cortical bones of the head-neck junction (HNt, HNc), femoral neck (FNt, FNc), and inter-trochanteric (ITt, ITc). The proximal femoral HU values were measured at the superior endplate, mid vertebral body, and inferior endplate. The risk of osteoporotic fracture was assessed by FRAX. Negative correlations were found between the risk of major osteoporotic fractures and HU in HNt, HNc, mid vertebral body, inferior endplate and mean proximal femoral HU. Negative correlations were also found between the risk of hip fracture and HU in HNt, HNc, FNc, ITt, ITc, superior endplate, mid vertebral body, inferior endplate and mean proximal femoral HU. The correlation shown supports the use of HU assessment of the proximal femur and lumbar spine as an opportunistic screening tool.

***Keywords*---**hounsfield unit, risk factors, osteoporosis, CT-scan, fracture, FRAX.

Introduction

Osteoporosis is one of the major health problems that continues to increase in incidence worldwide . The main complication of osteoporosis is osteoporotic fracture which increases the risk of mortality and morbidity. Given the magnitude of the potential problem, it is important to determine the risk of future osteoporotic fractures as early as possible.

Bone Mineral Density (BMD) assessment of Dual X-ray Absorptiometry (DXA) is the gold standard for diagnosing osteoporosis and predicting fracture risk , but this modality is not routinely used for screening due to several constraints, including the presence of radiation, large tool size, expensive inspection costs, and limited equipment availability . On the other hand, CT scans are often performed for various indications that are not related to osteoporosis thus provides an opportunistic opportunity to screen for osteoporotic fracture risk . Various previous studies have discussed the use of the Hounsfield Unit (HU) value to estimate bone density in various body regions . The assessment can be easily calculated at no additional cost and with minimal effort but may provide valuable additional information about osteoporosis fracture risk that is very useful in reducing patient mortality and morbidity rates.

Comparison with other osteoporotic fracture risk estimation tools is necessary to support the benefits of HU assessment on CT-scan. FRAX is a questionnaire used to estimate the probability of major osteoporotic fractures and hip fractures over a 10-year period in untreated patients with osteopenia . The FRAX questionnaire was compiled based on data on various variables known to be associated with the risk of osteoporotic fracture. Information on BMD values can be included in the FRAX assessment but is not absolutely necessary and has no significant effect [6]. The output of the FRAX instrument is a percentage that describes the risk of major osteoporotic fractures and hip fractures; Treatment intervention is recommended if the percentage risk of major osteoporotic fracture is more than 20% and hip fracture is more than 3% .

This study aims to determine whether the density of the proximal femur and lumbar spine as assessed by HU is associated with the risk of osteoporotic fractures based on the FRAX score in the patient population undergoing abdominal-pelvic CT-scan in Surabaya. If proven to be associated, then the assessment of HU can be done routinely to screen for the risk of osteoporotic fracture in patients undergoing CT-scan examination.

Material and Methods

This cross-sectional study involved patients who underwent abdominal-pelvic CT scan at dr. Soetomo Surabaya in November 2021 – March 2022. The inclusion criteria November 2021 – March 2022, aged 40 – 90 years, and had a complete and accessible medical record. Patients were excluded if: they could not undergo a CT-scan, had fractures, had anatomical abnormalities, had infections and malignancies in the proximal femur and lumbar spine, and if they could not fill out the FRAX questionnaire.(Asomaning, K et al,2006)

Samples selected through stratified random sampling based on age group underwent a Hounsfield Unit (HU) CT-scan assessment of the proximal femur and lumbar spine as well as an osteoporotic fracture risk assessment using the FRAX instrument. Imaging of the proximal femur and 3rd lumbar vertebra was carried out using a CT-Scan brand Siemens type Somaris/5 16 slice in 2009 slice thickness 3 mm, inter slice distance 1 mm and CT-Scan brand Phillips type inguinity MRC 880 128 slice in 2017 ; slice thickness 3 mm, inter slice distance 1 mm, axial, coronal, and sagittal slices. Workstation AW Volume Share 5 and Horos software were used to determine HU values in the proximal femur and lumbar spine.

The selection of the HU assessment area in the proximal femur followed the procedure described by Kim et al·In this study, HU values were measured in 3 parts: 1.) the femoral head-heck junction (HN); 2.) the middle area of the femoral neck (femoral heck/FN); and 3.) femoral intertrochanteric (IT) area. In each sectional imaging, HU values were measured in 2 regions to be studied, namely cortical bone and trabecular bone Kim et al··While in the lumbar spine following the procedure described by Schreiber et al.In this study, the HU value of the lumbar spine was measured in 3 sections: 1.) superior endplate; 2.) corpus mid; and 3.) inferior endplate.(Briot et al,2019)

The FRAX examination was carried out through interviews and examinations. Variables assessed on FRAX included age, gender, weight, height, history of fracture, history of femoral fracture from parents, smoking habits, glucocorticoid consumption, history of rheumatoid arthritis, secondary osteoporosis, alcohol consumption.(Burge et al,2007). Assessment of HU and FRAX were done by two examiners and cohen's kappa test was measured between the examiners to ensure inter-rater reability.

The data obtained were analyzed using SPSS 22. Descriptive analysis was carried out on the characteristics of the research subjects. Correlation test was conducted to analyze the correlation between HU scores and FRAX scores. The value of the correlation coefficient $r > 0.6$ is considered to be strongly correlated and the p value < 0.05 is considered significant.

Result and Discussion

Participant characteristics

Participants characteristics are shown in table 1. The total participants in this study were 50 people consisting of 19 men (38%) and 31 women (62%).

Table 1
Participant characteristics

	Male	Female	Total
Age (years old)	54.74 ± 11.71	54.03 ± 10.39	54.30 ± 10.80
BMI (kg/m^2)	20.93 ± 2.63	19.38 ± 3.40	19.97 ± 3.20

Note: the value indicates the mean ± standard deviation

Result of HU assessments are shown in table 2 and table 3 for proximal femur and lumbar vertebre respectively. In general, the HU values are greater in male and female in all point of assessment.

Table 2
HU assessment in the proximal femur

	Male	Female	Total
HNt	306.84 ± 69.05	282.77 ± 69.99	291.92 ± 69.93
HNc	279.74 ± 51.88	261.87 ± 70.72	268.66 ± 64.25
FNt	227.21 ± 118.43	209.26 ± 113.30	216.08 ± 114.10
FNc	199.05 ± 96.04	185.61 ± 106.77	190.72 ±102.36
ITt	184.84 ± 58.61	181.74 ± 70.33	182.92 ± 65.52
ITc	165.11 ± 61.17	162.06 ± 62.78	163.22 ± 61.56

Note: the value indicates the mean ± standard deviation

Table 3
HU assessment in the lumbar spine

	Male	Female	Total
Endplate Superior	190.26 ± 50.38	168.35 ± 64.84	176.68 ± 60.18
Corpus Mid Vertebral	187.00 ± 61.42	168.45 ± 66.58	175.50 ± 64.67
Endplate Inferior	200.89 ± 68.53	186.03 ± 74.51	191.68 ± 71.96
Average			181.24 ± 62.48

Note: the value indicates the mean ± standard deviation

Result of FRAX assessments are shown in table 4. In general, the FRAX score are greater in female and male for both risk of major osteoporotic fracture and risk of hip fracture.

Table 4
FRAX assessment results

	Male	Female	Total
Risk of major osteoporosis fracture (%)	2.76 ± 1.68	3.59 ± 2.76	3.28 ± 2.42
Risk of hip fracture (%)	0.75 ± 0.72	1.03 ± 0.96	0.92 ± 0.88

Note: the value indicates the mean ± standard deviation

Relationship between Proximal Femur Hounsfield Unit and FRAX score

Result of correlation test of the proximal femoral HU and FRAX are shown in table 5. Correlations was found between the proximal femur HU and FRAX score for both risk of major osteoporotic fractures and hip fractures.

Table 5
Correlation test of the proximal femoral HU and FRAX

	Major osteoporotic fracture risk		Hip fracture risk	
	r	p	r	p
HNt	-0.338*	0.016	-0.417*	0.003
HNc	-0.405*	0.004	-0.463*	0.001
FNt	-0.150	0.298	-0.270	0.058
FNc	-0.261	0.067	-0.406*	0.003
ITt	-0.234	0.102	-0.405*	0.004
ITc	-0.205	0.154	-0.423*	0.002

Note: the correlation coefficient value shows the Pearson correlation, the correlation is weak if r < 0.4, moderate if r = 0.4 - 0.59, strong if r > 0.6; p value indicates significance, there is significance if p < 0.05; *P value < 0.05.

Relationship between Lumbar Spine Hounsfield Unit and FRAX score

Result of correlation test of the lumbar spine HU and FRAX are shown in table 6. Correlations was found between the lumbar spine HU and FRAX score for both risk of major osteoporotic fractures and hip fractures.

Table 6
Correlation test of the lumbar spine HU and FRAX

	Major osteoporotic fracture risk		Hip fracture risk	
	r	p	r	p
Endplate Superior	-0.258	0.070	-0.412*	0.003
Corpus Mid Vertebral	-0.283*	0.046	-0.411*	0.003
Endplate Inferior	-0.288*	0.043	-0.518*	<0.001
Average	-0.291*	0.004	-0.473*	0.001

Note: the correlation coefficient value shows the Pearson correlation, the correlation is weak if r < 0.4, moderate if r = 0.4 - 0.59, strong if r > 0.6; p value indicates significance, there is significance if p < 0.05; *P value < 0.05.

Discussion

Participant characteristics

Characteristics of age and BMI showed that on average the participants belonged to the adult age group with a normal BMI which was known to have a lower fracture risk. This is in line with the results of the answers and the average FRAX score which showed that participants had low risk of major osteoporotic fractures and low risk of hip fracture.

The mean value of proximal femur HU did not lead to osteoporosis. This is based on previous studies where the trabecular inter-trochanteric (ITt) HU value > 210 was considered to indicate the absence of osteoporosis, while an ITt value < 170 was considered to indicate the presence of osteoporosis [12].On the other hand, the

mean value of the participant's lumbar vertebral HU also did not lead to osteoporosis. This is based on a previous study [20].who found that the lumbar spine HU threshold value 160 had a sensitivity of 90% and the lumbar spine HU threshold value 110 had 90% specificity in differentiating osteopenia from osteoporosis. (Gadam R.Ket al,2013)

Relationship between Proximal Femur Hounsfield Unit and FRAX score

It was found that the risk of major osteoporotic fracture was inversely related to the HU value of the trabecular bone and cortical head-neck junction, whereas the risk of hip fracture was inversely related to the HU value of the trabecular bone and cortical head-neck junction, the cortical femoral neck, and the intertrochanteric trabecular bone. The proximal femur is frequently involved in serious osteoporotic fractures which represent high morbidity and mortality in elderly patients. The results of this study are in line with previous studies where there is a significant correlation between HU and proximal femoral bone density as described by the BMD results [11,12,13]found a significant correlation between BMD as determined by DXA and HU values measured using a pelvic CT scan, in that study BMD values correlated with HU in the inter-trochanteric trabecular bone (ITt) [11,12]. According to Kim, an ITt value of 170 m less than 170 indicates osteoporosis with a positive predictive value of 96.9% and an ITt value of more than 210 indicates the absence of osteoporosis with a negative predictive value of 84.6%. Trabecular bone is a part of bone that has a high rate of bone turnover and is more prone to osteoporosis than cortical bone [11,18]. So the assessment of HU in this area better describes the condition of bone density. However, bone density is not the only determinant of fracture risk; there are still various other risk factors that can also have an effect.(Jang,S et al,2019)

Relationship between Lumbar Spine Hounsfield Unit and FRAX score

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This study has several limitations, firstly no comparison was made with DXA as the gold standard for assessing bone density and diagnosing osteoporosis. The HU value also cannot be converted to mg/dl units to describe bone density, as is the result of a quantitative CT-Scan (QCT) assessment (Schreiber, J. J,2014). However, the main aim of this study was to estimate the risk of osteoporosis-related fractures, therefore the use FRAX is considered appropriate as it was based on various risk factors. Previous studies showed that the absence of BMD value has no significant effect on the results of the FRAX . Other limitations include no comparison with the CT-scan result of other leg and no stratification was carried out during sampling, so there is a possibility that the samples have significant demographic characteristics and therefore the results need to interpreted carefully.(Pickhardt, P. J et al,2020)

Conclusion

The correlation between HU values of the proximal femur and lumbar spine and risk of osteoporotic fracture supports the use of HU assessment of the proximal femur and lumbar spine as an opportunistic screening tool. Further research is needed by comparing the value of HU with DXA as the gold standard in establishing the diagnosis of osteoporosis and by grouping participants by age group and diagnosis to get a more specific picture of the risk of osteoporosis and osteoporotic fractures.

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Conflict of interest

There is no conflict of interest

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