New quantitative ultrasound techniques for bone analysis at the distal radius in hip fracture cases: differences between femoral neck and trochanteric fractures

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Summary

***Background*. Ample evidence on etiological and pathological differences between femoral neck and trochanteric fracture cases suggests the possibility of individualized treatment. There are many issues related to areal bone mineral density and other quantitative computed tomography parameters of the proximal femur. Although osteoporosis is a systemic problem, little has been reported regarding differences in bone structural parameters, including bone mineral density, between them in regions other than the proximal femur.**
***Methods*. Participants were consecutive female patients >50 years of age admitted to the Saiseikai Suita Hospital (Osaka prefecture, Japan) for their first hip fracture between January 2012 and September 2014.**
Cortical thickness (CoTh, mm), volumetric trabecular bone mineral density (TBD, mg/cm^3), and elastic modulus of trabecular bone (EMTb, GPa) were obtained as the new QUS parameters using the LD-100 system (Oyo Electric, Kyoto, Japan).The mean values of these parameters were compared between femoral neck and trochanteric fracture cases. In addition, correlations between age and each QUS parameter were investigated for each fracture type. A receiver operating characteristic (ROC) curve analysis was performed to examine the degree of effect each parameter on the fracture types. The area under the curve (AUC) for each parameter was compared to the AUC for age.
***Results*. There were 63 cases of femoral neck fracture (mean age, 78.2 years) and 37 cases of trochanteric fracture (mean age, 85.9 years). Mean TBD and EMTb were significantly higher for femoral neck fractures. There were significant negative correlations between QUS parameters and age for femoral neck fractures ($P < 0.005$). The regression lines for femoral neck fractures were above those for trochanteric fractures for TBD and EMTb. AUCs were 0.72 for age, and 0.61, 0.65, and 0.65 for CoTh, TBD, and EMTb, respectively.**
***Conclusions*. The new QUS parameters indicated that TR fracture cases were more osteoporotic than were FN fracture cases, even at the distal radius. There might be systemic differences between them, in addition to localized factors at the proximal femur.**

KEY WORDS: hip fracture; femoral neck fracture; trochanteric fracture; quantitative ultrasound; distal radius; osteoporosis.

Background

Hip fracture, one of the primary osteoporotic fractures, has a profound influence not only on decreasing healthy life expectancy but also the length of the lifespan overall. Although the recent decline of its incidence has been suggested even in Japan, the number of new patients continues to increase tremendously due to the rapid increase in the elderly population (1). Fracture prevention is a major health and socioeconomic concern in many countries.
There are two types of hip fracture, namely femoral neck fracture (FN fracture) and trochanteric fracture (TR fracture). There is a lot of evidence to indicate etiological and pathological differences between them, suggesting the possibility of individualized treatment to improve prevention of hip fractures (2, 3). Among these differences, there are many issues related to areal bone mineral density (areal BMD) as measured by dual energy X-ray absorptiometry (DXA) and other quantitative computed tomography (QCT) parameters on the proximal femur (4-6). Apart from these radiation methods, quantitative ultrasound (QUS) is easily utilized for health examination purposes, even outside of medical institutions, because it does not involve exposure to ionizing radiation. Recently, a new ultrasound method to assess bone densitometry at the distal radius based on two longitudinal waves (new QUS) was developed (LD-100 system, Oyo Electric, Kyoto, Japan), and it was proven to show significant corrections with peripheral QCT (pQCT) measurement values (7).Al-

though osteoporosis is a systemic problem, little has been reported about differences in bone structural parameters, including bone mineral density (BMD), between FN and TR fractures in regions other than the proximal femur.
The aim of this study was to investigate the differences between FN and TR fractures using the new QUS parameters obtained at the distal radius.

Participants and methods

Participants

The participants were consecutive female patients >50 years of age admitted to the Saiseikai Suita Hospital (Osaka prefecture, Japan) for first hip fracture between January 2012 and September 2014. Patients with a history of systemic administration of corticosteroid were not included. Women with hip fractures secondary to tumors were also excluded.

New QUS measurements

The transducers of the LD-100 system were set at the distal radius of each participant with ultrasound gel. The non-dominant side was generally assessed, except in cases with a previous fracture at the corresponding site. Cortical thickness (CoTh, mm), volumetric trabecular BMD (TBD, mg/cm^3), and elastic modulus of the trabecular bone (EMTb, GPa) were obtained as the new QUS parameters and were calculated from the propagation speed (m/s) and the attenuation (dB) of both fast and slow waves (7). T-score results were also automatically provided.

Data analysis

T-scores were used for the data analysis. The mean values of these parameters were compared between FN and TR fracture cases. In addition, correlations between age and each QUS parameter were investigated for FN and TR fractures.
A receiver operating characteristic (ROC) curve analysis was performed to examine the degree of effect of each parameter on the fracture types. The area under the curve (AUC) for each parameter was compared to the AUC for age.
The Mann-Whitney U-test was used to compare parameters between FN and TR fracture cases. A P-value of <0.05 was regarded as significant. Statistical analyses were conducted with StatFlex Ver. 6.0 (Artech Co., Ltd., Osaka, Japan).

Results

A total of 100 fractures from 100 subjects was included. There were 63 cases of FN fracture and 37 cases of TR fracture. The mean age (SD) was 78.2 (10.1) years for FN fractures and 85.9 (6.9) years for TR fractures ($P < 0.005$). Body characteristics and complications requiring medication for each fracture type are shown in Table 1. There were no significant differences in height, weight, or body mass index (BMI). FN fracture cases had a greater number of complications, but the ratio was not significantly different.
Mean CoTh was numerically thinner for TR fractures than for FN fractures, but the difference was not significant (Figure 1a). Mean TBD and EMTb were significantly lower for TR fractures than for FN fractures (Figures 1b, 1c).
Distributions of each QUS parameter by age for both fracture types are shown in Figure 2. There were significant negative correlations between QUS parameters and age for FN fractures ($P < 0.005$). The correlations were not significant for TR fractures. For TBD and EMTb, the regression lines for FN fractures were above the lines for TR fractures.
Figure 3 shows the ROC curves for age and each QUS parameter. AUCs were highest for age (0.72). Each QUS parameter had an AUC of >0.61 (Table 1).

Discussion

TR fracture patients were reported to have a greater extent of osteoporosis than FN fracture cases (8). In addition to a lower BMD, a thinner cortex has also been recognized for TR fracture cases in the proximal femur (5, 9, 10).
Our results showed that TR fracture cases had a greater extent of osteoporosis, even in the distal radius. There were significant differences not only for TBD but also for EMTb, which is directly related to mechanical bone strength (7). Numerically, CoTh was thinner for TR fracture cases. Those results in the distal radius may indicate that the differences between these fracture cases are systemic.
Generally, older individuals are more susceptible to TR fractures than to FN fractures (11, 12). TR fracture patients had a significantly higher mean age than other fracture patients. The ROC analysis showed the highest AUC of 0.722 for age compared to those for the QUS parameters. These results suggest a strong correlation between age and fracture types. On the other hand, moderate correlations between TBD and EMTb related to the fracture types were indicated by the respective AUCs of 0.649 and 0.652, which were not significantly different when compared to the AUC for age. The regression lines for FN fractures were above those for TR fractures on the scatter plots for TBD and EMTb.
FN fractures occurred at a relatively younger age than did TR fractures. However, our results showed that this is not caused by an earlier systematic worsening of anatomical elements, because the new QUS parameters primarily reflect structural strength of bone, similar to the parameters for DXA and QCT.
Recently, the rate of increase was shown to be more remarkable for FN fractures than for TR fractures in Japan (13). A higher ratio of FN fractures than of TR fractures is observed in Western countries, in contrast to the ratios observed in Japan (14, 15). A higher incidence was also recognized among urban populations compared to that in rural populations (16, 17).
Previous studies suggest that patients who experience FN fractures have higher body fat percentages (18), higher body mass indices (BMIs), and are more likely to have undergone treatment for hypertension (19). Arakaki et al. reported the relation of regional trends in obesity and a high prevalence

Table 1 - Areas under the curve for age and each quantitative ultrasound parameter.

	AUC	SE
Age	0.72	0.05
CoTh	0.61	0.06
TBD	0.65	0.06
EMTb	0.65	0.06

AUC, area under the curve; CoTH, cortical thickness; EMTb, elastic modulus of trabecular bone; SE, standard error, TBD, volumetric trabecular bone mineral density.

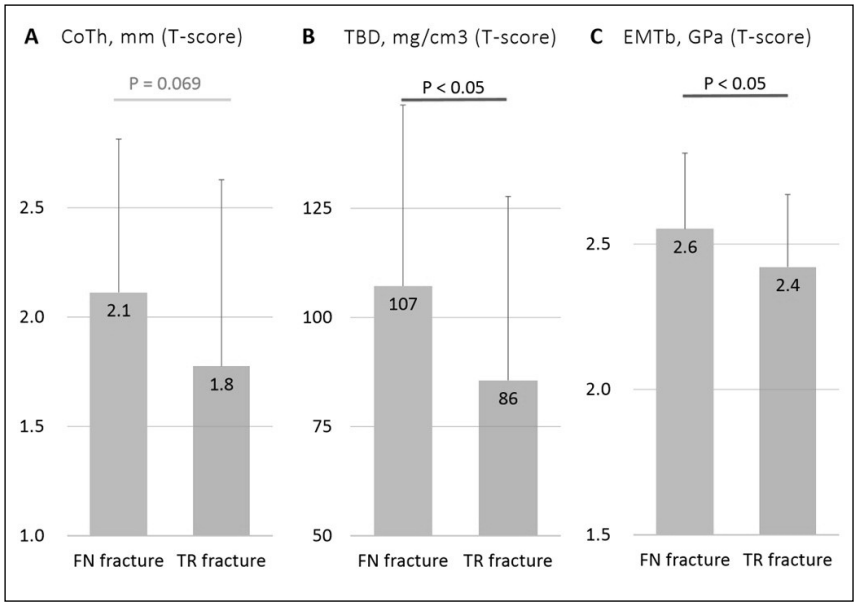

Figure 1 - Comparison of mean values for each new quantitative ultrasound (QUS) parameter between femoral neck fracture and trochanteric fracture cases. T-scores are also shown in parentheses: a) cortical thickness (CoTh), b) volumetric trabecular bone mineral density (TBD), c) elastic modulus of trabecular bone (EMTb).

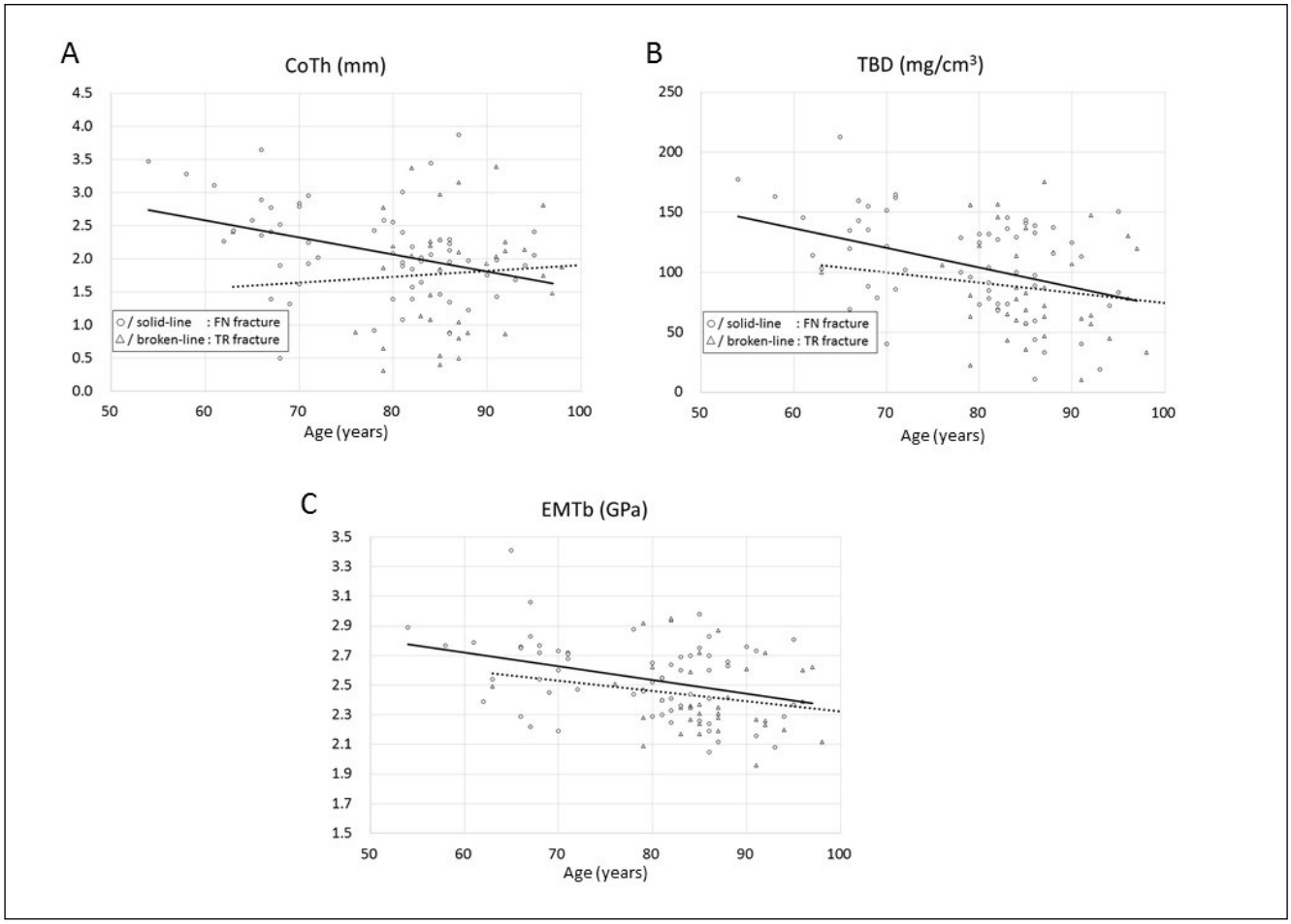

Figure 2 - Scatter plots of each new quantitative ultrasound (QUS) parameter by age. Regression lines are also depicted for both fracture types on the graph: a) cortical thickness (CoTh), b) volumetric trabecular bone mineral density (TBD), c) elastic modulus of trabecular bone (EMTb).

of FN fracture (20). Worsening collagen crosslinking is a major candidate related to bone fragility other than BMD, which is strongly affected by metabolic syndrome, such as diabetes (21).

Among our cases, there were no differences in height, weight, or BMI between fracture types. With respect to complications, a greater number of FN fracture patients had taken medication for diabetes (Table 2).

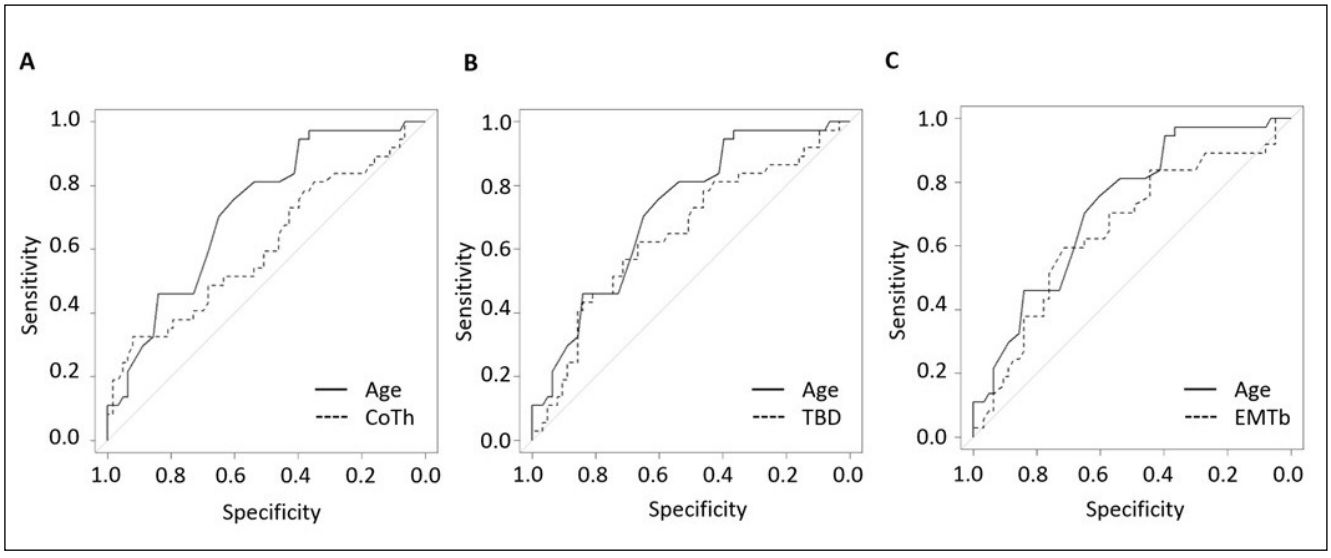

Figure 3 - Receiver operating characteristic curves by age for each new quantitative ultrasound (QUS) parameter.

TR fractures may be best prevented by increasing bone density (2). For FN fractures, the risk profile is considerably more complex than that for TR fractures (3). Because of the variety and complexity of osteoporotic fractures, the precise determination of risk factors for each osteoporotic fracture might be virtually impossible (22).

However, research specifically focusing on FN fractures could facilitate more effective individualized preventive measures. Our results indicate that systemic factors should be taken into consideration in future research, in addition to local factors.

This study has some limitations. First, there was no comparison with femoral neck BMD, which is recommended by WHO for the diagnosis of osteoporosis (23). Second, information about medication usage for osteoporosis was not available, though many of the cases were estimated to have been left untreated. Third, there was no control population, such as one without fractures. Our data do not indicate any candidate criteria to target to prevent hip fracture. Fourth, data were analyzed only from female patients because of the small amount of cases.

Conclusions

The new QUS parameters indicated that TR fracture cases were more osteoporotic than were FN fracture cases, even at the distal radius. There might be systemic differences between them, in addition to localized factors at the proximal femur.

Abbreviations

AUC: area under the curve
BMD: bone mineral density
BMI: body mass index
CoTh: cortical thickness
DXA: dual energy X-ray absorptiometry
EMTb: elastic modulus of trabecular bone
FN fracture: femoral neck fracture
pQCT: peripheral quantitative computed tomography
QCT: quantitative computed tomography
QUS: quantitative ultrasound

Table 2 - Body characteristics and complications.

Body characteristics	Femoral neck fracture	Trochanteric fracture
Height, cm, mean ± SD	149.8 ± 7.5	148.2 ± 6.1
Weight, kg, mean ± SD	48.4 ± 7.6	47.3 ± 9.5
BMI, kg/m^2, mean ± SD	21.7 ± 3.3	21.5 ± 4.0
Complications		
Diabetes, n (%)	16 (25.4%)	5 (13.5%)
Hypertension, n (%)	38 (60.3%)	22 (59.5%)
Rheumatic arthritis, n (%)	2 (3.2%)	0 (0%)
Vertebral fracture*, n (%)	4 (6.3%)	0 (0%
	Dialysis, n (%)	1 (1.6%) 0 (0%)

** Prevalent fractures. BMI, body mass index; SD, standard deviation.*

ROC: receiver operating characteristic
TBD: volumetric trabecular bone mineral density
TR fracture: trochanteric fracture

Declarations

Ethic approval and consent to participate

Ethical approval was obtained from the ethics committee of Kyoto Prefectural University of Medicine, and written informed consent was obtained from all patients prior to inclusion.

Consent for publication

Not applicable.

Availability of data and materials

The dataset supporting the conclusions of this article is available upon readers request - please contact corresponding Author (horii@koto.kpu-m.ac.jp).

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Competing interests

The Authors declare that they have no competing interests.

Author's contributions

MH, HF, NK, and TK contributed to the conception and design of the study. RS and MK participated in the data collection. MH, KS, NK, and EO performed the statistical analysis. MH, YM, and ST drafted the manuscript. All Authors read and approved the final manuscript.

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