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Comparison of quantitative computed tomography and dual-energy X-ray absorptiometry in elderly patients with vertebral and nonvertebral fractures: Preliminary results

Vertebral ve vertebra dışı fraktürü olan yaşlı olgularda dual–enerji X-ışını absorbsiyometri ve kantitatif bilgisayarlı tomografi karşılaştırması: Preliminar sonuçlar

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Abstract

Aim: Dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography (QCT) are methods used today to evaluate bone mass and structure and determine the risk of fractures. In this study, spinal and femoral bone density results measured by DXA and QCT in elderly patients with vertebral and non-vertebral fractures were compared to identify the most effective method in determining the risk of osteoporosis and fractures.

Methods: In this retrospective cohort study, 45 elderly patients aged 65–84 years were analyzed. Group 1 included 11 patients with atraumatic vertebral fractures, Group 2 included 11 patients with non-vertebral fractures and Group 3 included 23 patients without fractures. T-scores and bone mineral density (BMD) values of spinal (lumbar 1-4) and femoral (neck) regions measured by both DXA and QCT were evaluated.

Results: Spinal and femoral T-scores and BMD values measured by DXA and QCT were similar between the groups ($P>0.05$ for all). In Group 1, lumbar BMD value, lumbar and femoral neck T-scores measured by QCT were significantly lower than DXA ($P<0.001$, $P=0.004$ and $P=0.037$, respectively). In Group 2, lumbar BMD value and T-score measured by QCT were significantly lower than DXA ($P<0.001$ and $P<0.001$). In Group 3, lumbar T-score, lumbar and femoral neck BMD values measured by QCT were significantly lower than DXA ($P<0.001$, $P<0.001$ and $P=0.004$, respectively).

Conclusion: QCT is an effective method that can be used in elderly patients with fractures and arthrosis where DXA may yield false-positive results.

Keywords: Geriatrics, Ostoeporosis, Vertebral fracture, Bone density, DXA, QCT

Öz

Amaç: Günümüzde Dual-enerji X-ışını absorbsiyometrisi (DXA) ve kantitatif bilgisayarlı tomografi (KBT) kemik kütle ve yapısını değerlendirmek, kırık riskini belirlemek için kullanılan yöntemlerdir. Bu çalışmada vertebral ve vertebral bölge dışında kırığı olan yaşlı hastalarda, DXA ve KBT ile ölçülen spinal ve femoral bölge dansitometri sonuçlarını karşılaştırarak, osteoporoz ve kırık riskini belirlemede en etkin yöntemi araştırmayı amaçladık.

Yöntemler: Bu retrospektif kohort çalışmasında 65- 84 yaş aralığında 45 yaşlı hasta analiz edildi. Grup 1'e atravmatik vertebral kırığı olan 11 hasta, Grup 2' ye spinal bölgenin dışında kırığı olan 11 hasta, Grup 3'e ise kırığı olmayan 23 hasta dahil edildi. Spinal (lumbar 1-4) ve femoral (boyun) bölgelerden ölçülen, DXA ve KBT ile yapılan kemik mineral yoğunluğu (BMD) ölçümleri ve T skorları değerlendirildi.

Bulgular: Gruplar arası değerlendirmede, DXA ve KBT ile ölçülen, lumbar ve femoral boyun BMD değerlerinde ve T skorlarında üç grup arasında istatistiksel olarak anlamlı bir farklılık bulunmadı (tümü $P>0,05$). Grup 1'de KBT ile ölçülen lumbar BMD değeri, lumbar ve femoral boyun T skor değerleri, DXA ölçümlerinden istatistiksel olarak anlamlı düşük bulundu (sırasıyla, $P<0,001$, $P=0,004$ ve $P=0,037$). Grup 2'de KBT ile ölçülen lumbar bölge BMD ve lumbar bölge T skor değerleri, DXA ölçümlerinden istatistiksel olarak anlamlı derecede düşük bulundu ($P<0,001$ ve $P<0,001$). Grup 3'de KBT lumbar bölge T skoru, lumbar ve femoral boyun BMD değerleri, DXA ölçümlerinden istatistiksel olarak anlamlı derecede düşük dulundu (sırasıyla, $P<0,001$, $P<0,001$ ve $P=0,004$).

Sonuç: KBT, ileri yaş olgularda kırık ve artroz gibi DXA yönteminin yanlış pozitiflik verebileceği durumlarda kullanılabilecek etkin bir kemik mineral yoğunluğu ölçüm metodudur.

Anahtar kelimeler: Yaşlı, Osteoporoz, Spinal kırık, Kemik yoğunluğu, DXA, KBT

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Introduction

Osteoporosis is a systemic metabolic bone disease with an increasing prevalence among the geriatric population and causes decreased bone mineral density, deterioration of the microarchitecture, and increased risk of bone fractures [1]. Prevalence of osteoporosis increases with age and it is reported to be 15% in patients aged between 50–59 years and 70%–80% in patients aged ≥80 years [1-3]. The prevalence of osteoporotic fractures, which is the main complication of osteoporosis, also increases with age. Osteoporotic fractures, or fragility fractures, are classified into vertebral and non-vertebral fractures [2,3]. Fragility fractures are most commonly observed in the vertebra, whereas non-vertebral fracture locations include the forearms, hips, rarely the ribs, pelvis, and clavicle [3,4]. Vertebral fractures constitute 27% of all osteoporotic fractures among women and men. This rate is higher among the geriatric population and the prevalence increases to 50% in patients aged ≥80 years, which is very close to the prevalence of coronary artery disease in developed countries [5-8].

Although vertebral and non-vertebral osteoporotic fractures are preventable among the geriatric population, they constitute a public health concern that causes increased morbidity, mortality, and health expenditure. The presence of a single vertebral fracture increases the risk of a future vertebral fracture by 5-fold and other fractures by 2/3-fold [9]. History of vertebral fracture in patients older than 65 years increases the risk of a new vertebral fracture by 7 to 10-fold within 5 years [9,10]. Moreover, it increases the risk of a non-vertebral fracture by 2.8 to 4.5-fold [3]. Therefore, early diagnosis and treatment of osteoporosis are important for the geriatric population. Bone mineral density measurement in the diagnosis of osteoporosis is an important predictor of fracture risk. Dual-energy X-ray absorptiometry (DXA) is the standard modality of bone mineral density measurement. However, with the recent advancements in technology, quantitative computed tomography (QCT) is recommended as an alternative or complementary diagnostic method due to its ability to separately evaluate three dimensional volumetric trabecular and cortical bone mineral densities and to show correct volumetric bone mineral density without being influenced by factors that affect bone size and shape such as degeneration and hypertrophic changes [11-13].

There are a few studies comparing QCT and DXA modalities in patients with vertebral fractures in the geriatric population; however, there is only one study analyzing the relationship of these modalities with non-vertebral fractures conducted in older males [13,14]. In this study, in male and female elderly patients with vertebral and nonvertebral fractures, spinal and femoral bone mineral density results measured by DXA and QCT were compared to identify the most effective modality in determining the risk of osteoporosis and fractures.

Materials and methods

A total of 45 geriatric patients (age >65 years) who were referred to the Radiology Clinic for osteoporosis screening from the Physical Therapy and Rehabilitation outpatient clinic between December 2018 and June 2019 were included in this retrospective study. Informed consent was waived because of the retrospective nature of the study. This study was approved by the Ethics Committee of the Fatih Sultan Mehmet Training and Research Hospital (17073117-050.06 FSM EAH-KAEK 2020/12-26). Patients <65 years, those with metabolic or metastatic bone disease, those with a history of radiation therapy, and cortisone use were excluded. We included all cases that have performed both QCT and DXA and match our study criteria since the beginning of the QCT service in our hospital, until the date of scientific committee approval. Patients who had vertebral fractures occurring without trauma or with mild trauma and whose fractures were detected using direct radiography or advanced imaging methods were included in group 1 (n = 11). The vertebral compression fracture was in the lumbar region in 5 cases, the dorsal region in 5 cases, and both dorsal and lumbar regions in 1 case. Patients who had non-vertebral or peripheral fractures occurring without trauma or with mild trauma and whose fractures were detected with the medical history taken from the patient or with current imaging methods were included in group 2 (n = 11). Patients without fracture history, spinal pathology, and without a pathology that can cause secondary osteoporosis such as rheumatic disease and medication use were included in group 3 (n = 23).

Bone mineral density value (BMD) measurement with DXA was performed with the Lunar DPXL (GE-Lunar Prodigy, Madison, WI, USA, 2013) device from the lumbar (L1-4) spine and left femoral neck regions with the use of projections in anteroposterior (AP) direction. The position of the patients, measurement technique and analysis were adjusted according to the recommendations of the manufacturer. Daily calibration with a phantom was performed for device standardization. The precision error of the phantom was 0.3% and in vivo precision error was <1% in all measurement regions. Bone density measurement with QCT was performed with the 64-detector and 128-slice CT device (Optima CT660, GE Healthcare, Tokyo, Japan, 2014) from the L1-4 lumbar region and proximal femur region (kVp = 80/120/140, mAs = 160, slice thickness = 2–3 mm). The femoral neck and lumbar analyses were performed using QCT PRO with CliniQCT bone mineral density analysis software (Mindways, Austin, TX, USA). DoseWatch monitor of the CT device used in our hospital enabled the examination of the patients with the use of the lowest dose possible.

Statistical analysis

For evaluating the results, IBM SPSS Statistics 22 (IBM SPSS, Turkey) software was used for statistical analyses. In the evaluation of study data, compliance of parameters with normal distribution was evaluated using Shapiro–Wilk test. For evaluating study data, besides the descriptive statistical methods (Mean, Standard deviation, and frequency), one-way ANOVA was used in the intergroup comparison of the parameters showing normal distribution for comparing quantitative data and Tukey HDS test was used in identifying the group causing the difference. Paired sample t-test was used in the comparison of the DXA and QTC methods in terms of quantitative data showing normal distribution. McNemar's test was used in the evaluation of qualitative data. A *P*-value of <0.05 was considered statistically significant.

Results

Ages of the 45 patients included in the study varied between 65 and 84 years and the mean age was 72.84 (5.49) years. Demographics of the patients are presented in Table 1 and no statistically significant difference was observed except for BMI.

According to the intergroup comparison, there was no statistically significant difference between the three groups in terms of lumbar BMD, neck BMD, lumbar T, and neck T values in the DXA and QCT measurements (P>0.05) (Table 2). According to the intragroup comparison, QCT lumbar BMD (P<0.001.), QCT lumbar T (P=0.004), and QCT neck T (P=0.037) values were lower than DXA lumbar BMD, lumbar T, neck T values in group 1 (P<0.05). There was no statistically significant difference between DXA and QCT methods in terms of neck BMD values (P>0.05). In group 2, QCT lumbar BMD (P<0.001) and lumbar T (P<0.001) values were lower than DXA lumbar BMD and lumbar T values (P<0.05). There was no significant difference between DXA and QCT methods in terms of neck BMD and neck T values (P>0.05). In group 3, QCT lumbar BMD (P<0.001.), lumbar T (P<0.001), and neck BMD (P=0.004) values were lower than DXA lumbar BMD, lumbar T, and neck BMD values (P<0.05). There was no statistically significant difference between DXA and QCT methods in terms of neck T values (P>0.05) (Table 3).

Table 1: Demographic characteristics

		Group 1 Mean (SD) n=11	Group 2 Mean (SD) n=11	Group 3 Mean (SD) n=23	*P*-value
Age (years)		73.36 (6.52)	72.18 (6.27)	72.9 (4.76)	0.882
Height (cm)		157.09 (8.98)	154.64 (6.59)	158.3 (10.33)	0.561
BMI (kg/m²)		27.59 (3.82)	37.99 (7.41)	29.92 (3.83)	<0.001
Gender	Male	3 (27.3 %)	1 (9.1 %)	3 (13 %)	0.556
	Female	8 (72.7 %)	10 (90.9 %)	20 (87 %)	

SD: standard deviation

Table 2: Comparison of BMD values and T scores measured by QCT and DXA between the groups

	Group 1 Mean (SD) n=11	Group 2 Mean (SD) n=11	Group 3 Mean (SD) n=23	*P*-value
DXA lumbar BMD (g/cm²)	1.01 (0.14)	1.2 (0.29)	1.2 (0.23)	0.074
DXA femoral neck BMD (g/cm²)	0.71 (0.23)	0.82 (0.38)	0.81 (0.18)	0.490
DXA lumbar T score	0.98 (1.13)	-0.31 (1.92)	0.29 (1.83)	0.135
DXA femoral neck T score	-1.45 (0.92)	-1.25 (1.05)	-1.04 (0.77)	0.440
QCT lumbar BMD (g/cm³)	0.06 (0.03)	0.08 (0.02)	0.08 (0.03)	0.342
QCT femoral neck BMD (g/cm³)	0.57 (0.07)	0.65 (0.15)	0.63 (0.2)	0.473
QCT lumbar T score	-3.56 (2.32)	3.43 (0.83)	-3.53 (1.01)	0.974
QCT femoral neck T score	-2.07 (0.58)	-1.34 (1.36)	-1.48 (1.79)	0.465

QCT: Quantitative Computed Tomography DXA: Dual X-ray Absorptiometry, BMD: Bone Mineral Density

Table 3: Comparison of BMD values and T scores measured by QCT and DXA within the groups

		DXA (gm/cm²)	QCT (gm/cm³)	*P*-value
Group 1	Lumbar BMD	1.01 (0.14)	0.06 (0.03)	<0.001
Mean (SD)	Femoral neck BMD	0.71 (0.23)	0.57 (0.07)	0.088
n=11	Lumbar T score	-0.98 (1.13)	-3.56 (2.32)	0.004
	Femoral neck T score	-1.45 (0.92)	-2.07 (0.58)	0.037
Group 2	Lumbar BMD	1.2 (0.29)	0.08 (0.02)	<0.001
Mean (SD)	Femoral neck BMD	0.82 (0.38)	0.65 (0.15)	0.079
n=11	Lumbar T score	-0.31 (1.92)	-3.43 (0.83)	<0.001
	Femoral neck T score	-1.25 (1.05)	-1.34 (1.36)	0.795
Group 3	Lumbar BMD	1.2 (0.23)	0.08 (0.03)	<0.001
Mean (SD)	Femoral neck BMD	0.81 (0.18)	0.63 (0.2)	0.004
n=23	Lumbar T score	0.29 (1.83)	-3.53 (1.01)	<0.001
	Femoral neck T score	-1.04 (0.77)	-1.48 (1.79)	0.229

QCT: Quantitative Computed Tomography DXA: Dual X-ray Absorptiometry, BMD: Bone Mineral Density

Discussion

Although DXA is a frequently used method for measuring bone mass, diagnosing osteoporosis, and determining the risk of vertebral and non-vertebral fractures, many studies have shown that DXA has limitations in predicting and determining the risk of vertebral and non-vertebral fractures. The most important limitation is that DXA is affected by the bone size as well as osteophytes and hypertrophic changes of the vertebra that influence bone size. On the other hand, QCT performs three-dimensional measurements. It evaluates the density and geometry of the bone separately while determining the risk of fracture. Another important difference between the two measurement modalities is that QCT separately evaluates the cortical and trabecular bones [13-16] (Figure 1).

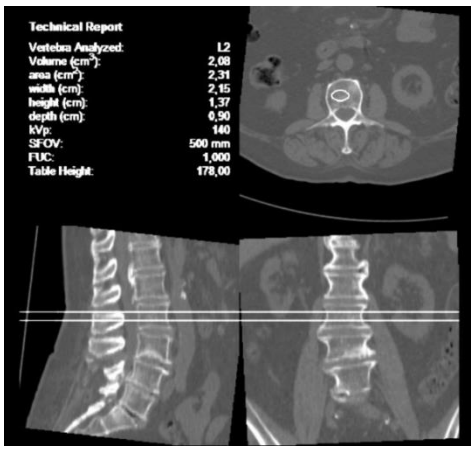

Figure 1: Three-dimensional QCT measurement technique of trabecular bone density of the L2 vertebra in a geriatric patient with lumbar spondylosis findings

Cortical and trabecular bones show different amounts of decreased density in different musculoskeletal regions, in relation to age and menopause [13,17-20]. It was shown that many types of fractures were associated with QCT volumetric BMD and DXA two-dimensional areal BMD measurements. In the volumetric BMD measurements, there was a stronger relationship with the trabecular bone compared to the cortical bone. However, this relationship varies according to the fracture type [14]. Considering all age groups, there are many studies emphasizing that QCT lumbar and total hip measurements are more effective than DXA in showing vertebral fractures [15,16,21]. The relationship with hip fractures and other non-vertebral fractures was evaluated in a limited number of studies [14,21].

In a study comparing DXA and QCT among patients with a vertebral fracture in the geriatric population, Lang et al. found that lumbar and femoral measurement values were significant in evaluating the risk of vertebral fracture in both measurement methods, that there was no difference between the two measurement methods and that the most relevant measurement value was lumbar spinal integral BMD in both measurement methods. However, they did not evaluate the relationship with non-vertebral fractures among the geriatric population [13]. Chalhoub et al. [14] performed a 9.7-year follow-up in a geriatric male population using both methods and underlined that lumbar and femoral BMD measurements could detect the risk of vertebral and non-vertebral fractures. However, they also stated that while QCT exhibited significant differences in detecting spinal and hip fractures, there was no difference between DXA and QCT in other peripheral fractures. In our study, in compliance with these two studies conducted with the geriatric population, there was no significant difference according to the intergroup comparison, whereas intragroup comparisons showed that QCT lumbar spinal and femoral measurement values were lower than DXA measurements in all

three groups. However, in our study, lumbar QCT measurement values were also found to be significantly lower than DXA measurements in the intragroup comparison of the patients with non-vertebral fractures. Chalhoub et al. found QCT is effective only in showing hip fracture as a peripheral fracture. Differently, we found it to be more sensitive in the patient group with hip and different peripheral fracture types. On the other hand, we did not classify peripheral fractures among themselves. As our study was conducted with the geriatric population, which exhibits senile osteoporosis that affects both the cortical and trabecular bones, we believe that QCT measurement values can be guiding in predicting both vertebral and non-vertebral fractures. However, due to the lack of difference between the groups, we believe that instead of the recently speculated opinion of replacing DXA with QCT in the geriatric population, QCT can be additionally used, when necessary.

International Society for Clinical Densitometry Official Positions emphasized that QCT was more sensitive than DXA and that it showed the characteristics and structural changes of the bone via a complex imaging technique [22]. However, high radiation dose and high costs are the disadvantages of QCT [23]. There are studies in the literature reporting that DXA and QCT lumbar and femoral measurements were correlated in premenopausal women without fractures [23,24]. Amstrup et al. [25] emphasized that there was a correlation between DXA and QCT in femoral and lumbar measurements in their correlation study conducted with postmenopausal women. They suggested that this correlation was weak in lumbar measurements and increased up to moderate-strong in the hip region. QCT measurements were also lower than DXA measurements in our geriatric patient group without fractures. We believe that degenerative changes which are prevalent among the geriatric population can cause a false increase in the DXA measurements of the lumbar region. In the group with vertebral fractures, the fact that compression fractures in the lumbar region could not be excluded in the DXA method, which can only be measured on AP images, may have caused a false elevation in density values. However, in QCT, after the lumbar vertebrae are scanned cross-sectionally, the vertebra with compression fracture can be excluded and the measurement can be taken from the appropriate location. At the same time, aortic calcifications, which are likely to be seen in the geriatric age group, can be included in the measurement field in DXA and causes an increase in density measurements. This obscures osteopenia /osteoporosis and leads to delay in diagnosis.

Limitations

This study had some limitations. One of the limitations was the low number of patients. Another limitation was that the patient population in our study was heterogeneous and normal, osteopenic and osteoporotic patient groups were not separated. There is a need for further studies conducted with a higher number of patients and homogenous patient groups in order to clarify the indications of both bone density measurement methods.

Conclusion

We believe that QCT can be a more sensitive method as it provided lower values in all three groups compared to DXA, but due to the lack of difference between groups in terms of fracture risk assessment, it may be beneficial to use QCT when indicated, rather than the view that QCT should replace DXA in the geriatric population. It seems more reasonable to prefer QCT in patient groups where DXA is not sufficient, such as marked degenerative changes or situations that require early diagnosis of osteoporosis.

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