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The comparison of computed tomography densitometry and DEXA for diagnosis of osteoporosis

Comparison Of DEXA and Computed Tomography Densitometry

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Abstract
Aim: In this study, we aimed to compare DEXA and CT densitometry in the diagnosis of osteoporosis and to evaluate the contribution of Hounsfield Unit calculation to the diagnosis of osteoporosis. Also, we examined the bone mineral loss in osteoporosis by CT volumetry on lumbar vertebrae and femur neck. Materials and Methods: A total of 102 patients (51 females, 51 males) who underwent DEXA and CT densitometry on the same day were evaluated according to their measurements of lumbar vertebrae and femur neck. The DEXA T-scores and BMD values of L1-L2-L3-L4 vertebra bodies and femur neck were compared with CT densitometry HU values which were measured as the same regions. Also, CT volumetric measurements of vertebral bodies and femur neck were compared with DEXA results of the same regions. Results: A statistically significant correlation between DEXA results and CT HU values of lumbar vertebrae and femur neck was found as DEXA T-score and BMD value increase, CT HU value increased. CT HU values of patients which were classified according to WHO classification (osteoporosis, osteopenia, and normal density groups) were found to be statistically significantly different. We observed that an L1 vertebra corpus HU value < 161 and a femur neck HU value <96 suggest an increased risk of osteoporosis. As age increases, CT HU value statistically decreased. Also, we detected that DEXA T-score and BMD values of lumbar vertebrae and femur neck were correlated with CT volumetric measurements of these regions. Discussion: CT densitometry of lumbar vertebrae and femur neck may be an alternative method to DEXA for the diagnosis of osteoporosis. We suggest that a CT densitometry technique with a low-dose scan of an ideal region may be a promising modality for the diagnosis of osteoporosis.

Keywords
DEXA; CT Densitometry; Hounsfield Unit; CT Volumetry; Osteoporosis

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Introduction

Osteoporosis is a systemic bone mineralization disorder which occurs secondary to a reduction in bone density and microarchitectural bone tissue changes leading to the increase in bone fragility [1].

Dual-energy X-ray absorpti¬ometry (DEXA) is currently the gold standard method for evaluating bone mineral density in modern medical practice while recent studies reported that Hounsfield Unit values calculated on Computed Tomography (CT) scans may be useful for estimating the bone mineral density [2,3].

In this study, we aimed to evaluate the correlation of results of DEXA and Hounsfield Unit values calculated on CT scans and also to compare the diagnostic value of DEXA results and the volumetric measurements which were obtained by CT scans for osteoporosis.

Material and Methods

Patients

Medical records of all patients who underwent a DEXA and a non-enhanced abdominal CT at the same day with various complaints in a tertiary university hospital between 2013 January and 2015 May were retrospectively screened. Patients who had previous hip or femur or spine surgery history, operation material (prosthesis, spinal instrumentation, etc) in lumbar or hip region, systemic metabolic or malignant disorders which involving skeletal system, acute or chronic infectious conditions and also congenital malformations were excluded from the study. A total of 102 patients (51 male and 51 female) were included in this study. The study was approved by a Local Ethics Committee in 18/06/2015 with a number of 09.

DEXA Examination

All the DEXA examinations were performed by a Hologic 2000 Dexa system (Waltham MA, USA). Bone mineral density (BMD), area and T-Z scores were obtained on both the first through fourth lumbar vertebrae and also femur neck. According to WHO osteoporosis classification, a T score of >-1 was defined as normal density, between -1 and -2,5 was defined as osteopeny and <-2,5 was defined as osteoporosis [4].

CT Densitometry

CT images was obtained by a 16 detector multislice CT system (Somatom Emotion 16-slice;CT2012E - Siemens AG Berlin and München-Germany).

Region of interest (ROI) values were calculated on axial images at three seperate locations: immedi¬ately inferior to the superior end plate, in the middle of the ver¬tebral body, and superior to the inferior end plate of each L1, L2, L3, L4 vertebra bodies. Also three values of ROI was obtained on axial images at three seperate locations for femur neck. An average value of these three ROI values were calculated for each bones. The largest possible elliptical region of inter¬est was drawn by excluding the cortical margins (Figure 1).

CT Volumetry

Volumetric evaluation was performed using automatic CT software (Siemens Syngo Multimodality Workplace; Version VE52A). L1 vertebra corpus superior margin and L4 vertebra corpus inferior margin were identified as reference levels for volumetric evaluation of lumbal vertebrae. Superior end point of femur head and inferior end point of trochanter minor were identified as reference levels for volumetric evaluation of femur neck. Abdominal CT scans were transferred to SSMMW volume programe. For to provide an optimal contour borders and to reduce the parsiel volume effect, the optimal axial slice was chosen and magnified which leds to a favorite evaluation of drawn VOI (Volume of interest) values in sagittal and coronal

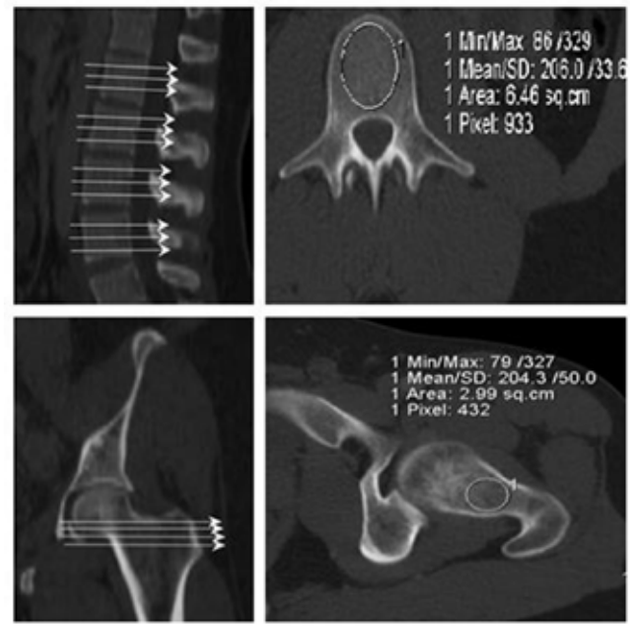

Figure 1. The ROI measurements were performed by largest possible elliptical region of inter¬est was drawn by excluding the cortical margins of lumbar vertebrae bodies and femur neck. An average value was obtained from three ROI values.

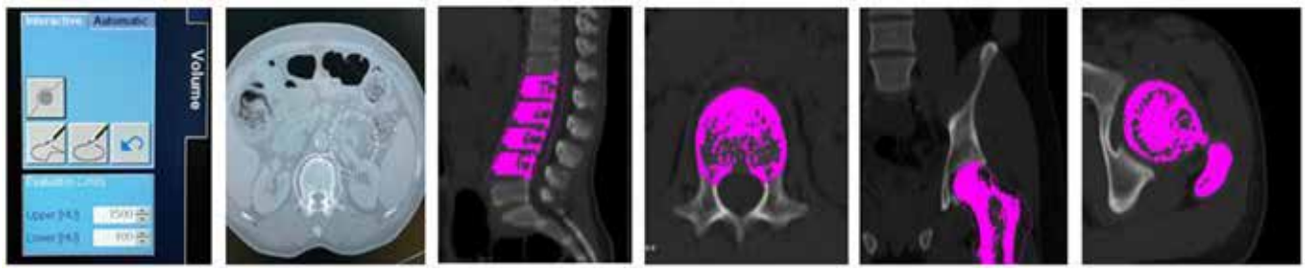

Figure 2. CT volumetric measurement technique for lumbar vertebrae and femur head-neck.

planes. Vertebrae body and femur neck borders was drawn on magnified axial CT slices and highest-lowest threshold values were identified by measuring the neighboring tissues such as vascular, muscular and adipose structures by Threshold-based CT volumetry technique. Because of the higher HU values of bone tissue, the highest threshold value was chosen as 1500 HU. For an optimal discrimination of a normal density bone and osteoporotic bone, 100 HU were selected as lowest threshold value.

Contours of vertebrae body and femur neck were drawn as all the bone tissues included in contours, rest tissues outside the contours were cleared by ROI nudge and this procedure were repeated for each 3 slices. Finally after the drawing process, vertebra and femur volumes were automatically calculated (Figure 2).

Statistical analysis

Descriptive statistics were presented as mean, standart deviation, minimum and maximum values. One-way ANOVA was used to compare the mean values of the groups. Pearson correlation coefficients were calculated to analysis the association of the features for each groups. A ROC curve analysis was performed to define a cut-off value for the discrimination of the groups regarding to T-scores. A p-value <0.01 was considered as statistically significant.

Results

A total of 102 patients (51 male,51 female F/M:1) between 10 and 84 years old were included in this study. Patients were classified to three groups according to their age. Group1 was constituted of 21 patients (20,6%) who are between 10 and 30 years old, group 2 was constituted of 52 patients (51%) between 31 and 60 years old while group 3 was constituted of 29 patients (28,4%) >60 years old.

DEXA examination of lumbal vertebrae showed normal results in 44 patients (24 male, 20 female, average 44 years old), osteopenia in 35 patients (19 male, 16 female, average 45 years old) and osteoporosis in 23 patients (8 male, 15 female, average 55 years old) according to DEXA WHO classification. For all of these 102 patients, the average T-scores of L1 vertebra was -1.27, L2 vertebra was -1.06, L3 vertebra was -1.25 and L4 vertebra was -1.32. Overall average T score of lumbar vertebrae was -1.24.

DEXA examination of femur showed normal results in 50 patients (30 male, 20 female, average 44 years old) , osteopenia in 41 patients (19 male, 22 female, average 50 years old) and osteoporosis in 11 patients (2 male, 9 female, average 52 years old) according to DEXA WHO classification. Overall average T score of femur neck was -0.83.

Three age groups were compared regarding to CT densitometry HU results of each L1-L2-L3-L4 vertebrae and femur neck in all three groups it is observed that HU values decrease statistically significantly as the age increase(p<0,01).(Table 1).

BMD values obtained by DEXA and HU values obtained by CT densitometry of lumbar vertebrae, were compared and a statistically significant correlation was found (p<0,01) since HU values increases as BMD increases for lumbar vertebrae.

BMD values obtained by DEXA and HU values obtained by CT densitometry of femur neck, were compared and a statistically significant correlation was found (p<0,01) since HU values increase as BMD increase for femur neck.

CT HU values of L1-L2-L3-L4 vertebrea and femur neck were compared to DEXA results of the same regions and we observed that HU values can be useful for the discrimination of normal density bone, osteopenia and osteoporosis (p<0,01). Table 7-8 details average HU values of normal density bone, osteoporosis and osteopenia according to WHO DEXA classification (Table 2).

An association of CT volume values measured at lumbar vertebrae bodies and femur neck with DEXA BMD values of the same regions were analysed and a statistically significant positive correlation between volume values and DEXA BMD values were found.(p<0,01).(Figure 3)

An association of HU values measured at lumbar vertebrae

Table 1. The distribution of CT HU values measured at lumbar vertebrae (L1-L2-L3-L4) and femur neck to the age groups.

CT HU values	Age Group	Number	Average HU Value	Standart dev.	Min.	Max.	P.
L1 vertebra	10-30	21	213,43	32,511	139	275	p<0,01
	31-60	52	186,17	35,636	104	277	
	>61	29	138,52	41,488	36	215	
	Total	102	178,24	45,504	36	277	
L2 vertebra	10-30	21	209,67	33,806	135	275	p<0,01
	31-60	52	182,90	36,221	107	269	
	>61	29	136,03	47,007	30	208	
	Total	102	175,09	47,110	30	275	
L3 vertebra	10-30	21	210,52	29,443	147	268	p<0,01
	31-60	52	176,42	36,827	107	273	
	>61	29	130,66	43,958	35	219	
	Total	102	170,43	46,895	35	273	
L4 vertebra	10-30	21	213,29	32,821	144	266	p<0,01
	31-60	52	178,31	38,334	86	276	
	>61	29	130,90	40,172	66	213	
	Total	102	172,03	47,568	66	276	
Average Femur neck	10-30	21	196,429	56,0469	95,0	298,0	p<0,01
	31-60	52	144,865	47,2930	26,0	253,0	
	>61	29	94,069	57,3086	11,0	222,0	
	Total	102	141,039	62,7759	11,0	298,0	

Table 2. The distribution of CT HU values measured on lumbar vertebrae and femur neck to the WHO classification identified by DEXA results.

CT HU value	DEXA WHO osteoporosis results	No	Average HU value	Standart dev.	Minimum	Maximum	P.
L1 vertebra	Normal	44	200,70	42,760	93	277	p<0,01
	Osteopenia	35	173,17	30,870	110	255	
	Osteoporosis	23	142,96	45,912	36	232	
	Total	102	178,24	45,504	36	277	
L2 vertebra	Normal	44	197,57	43,516	74	275	p<0,01
	Osteopenia	35	169,43	32,481	95	251	
	Osteoporosis	23	140,70	50,584	30	232	
	Total	102	175,09	47,110	30	275	
L3 vertebra	Normal	44	193,14	44,590	70	273	p<0,01
	Osteopenia	35	163,63	32,973	96	251	
	Osteoporosis	23	137,35	47,758	35	227	
	Total	102	170,43	46,895	35	273	
L4 vertebra	Normal	44	192,86	47,783	84	276	p<0,01
	Osteopenia	35	166,51	34,635	96	257	
	Osteoporosis	23	140,57	46,043	66	232	
	Total	102	172,03	47,568	66	276	
Femur neck	Normal	50	178,68	50,228	69	298	p<0,01
	Osteopenia	41	116,93	47,552	36	226	
	Osteoporosis	11	59,82	40,875	11	123	
	Total	102	141,04	62,776	11	298	

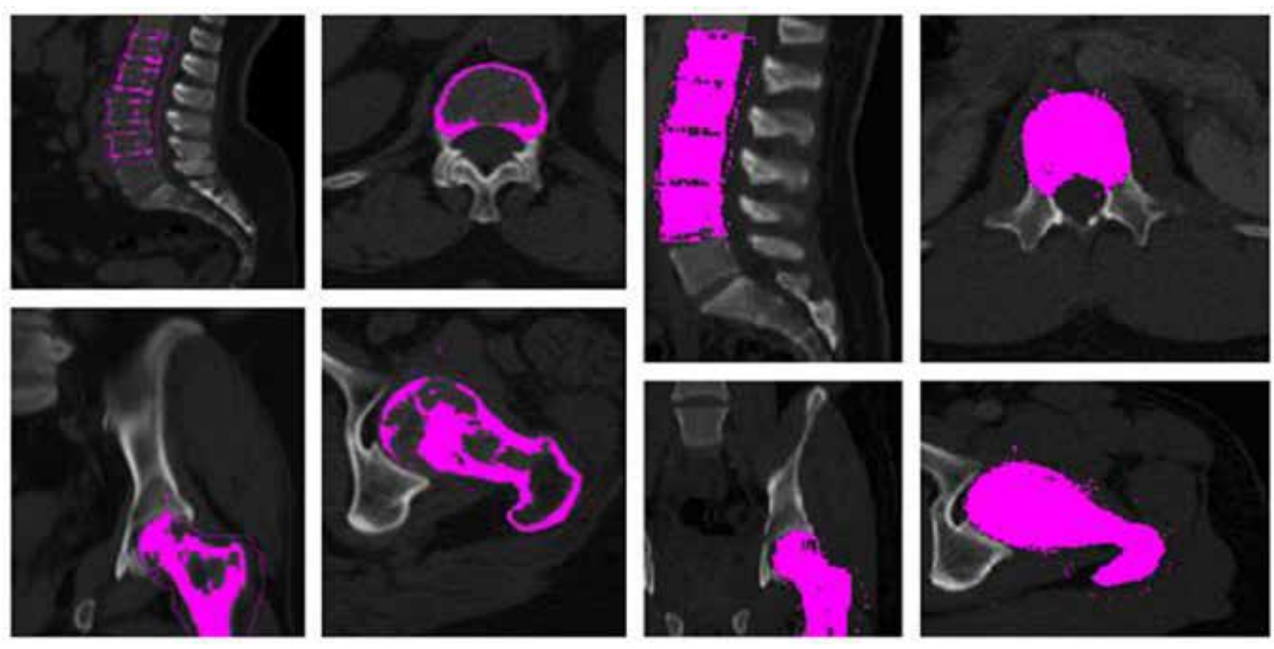

Figure 3. CT volumetric measurement of a patients with osteoporosis (A) according to WHO classification shows thinned cortex of bone and decreased enhancement of medullary bone. Volumetric measurement of a patients with normal density (B) according to WHO classification shows full homogenous and strong enhancement of bone tissue.

bodies and femur neck with DEXA T-score values of the same regions were analysed and a statistically significant positive corelation between HU values and DEXA T-score values was found(p<0,01).

A ROC (Receiver Operating Characteristic) analysis was performed to identify a cut-off value of HU values meaured at each lumbal vertebraes (L1,L2,L3,L4) and femur neck by corelating T-scores which were obtained at the same regions. When corelating HU values of lumbar vertebrae and T-scores at the same regions, area under a ROC curve was found to be 68%. For the optimal discrimination, a cut off value of 161 HU was found for L1 vertebra body. So we found that a value<161 HU at the L1 vertebra have potentiel risk of osteoporosis.

When correlating HU values of femur neck and T-scores at the same regions, area under a ROC curve was found to be 83 % .A cut off value of 96 HU was found for femur neck. So we found that a value < 96 HU at the femur neck have potentiel risk of osteoporosis.

Discussion

Osteoporosis is a systemic skeletal disorder which is characterised by decreased bone density and impaired microarchitecture of bone tissue leading to tendency of fracture. For this reason making an early and accurate diagnosis of osteoporosis is essential. A DEXA T-score <-2,5 suggests osteoporosis and requires treatment. A T-score>-1 is accepted as normal while the levels between -1 and -2,5 is associated with osteopeny [4].

Sungioon et al. studied 128 female patients over 40 years who underwent a Computed Tomography imaging because of a complaint of backache.70 of these 128 patients had also DEXA examination. They classified their patients to five groups according to their ages and reported a decrease of the HU levels as the age increases. They compared the HU values and the DEXA scores of each vertebraes and found a strong positive correlation between these two results while T-score increase as HU values increase. Also they compared HU values and BMD measurements of each vertebraes and found a strong positive correlation between these two results while BMD measuements increase as HU values increase, too. They reported an average value of 120 HU for normal density, 78 HU for osteopenic and 54 HU for osteoporotic patients. Finally it was concluded that especially a value <60 HU is associated with high risk of osteoporosis and also CT can differentiate osteoporotic and normal density patients [1].

Bansal et al. compared HU and T-scores and BMD values obtained from only lumbal vertebrae of 165 individuals (128 females and 37 males, mean age 48,2 years).When compared with female and male patients HU values and T-scores were found to be higher in female group. They suggested that as the age increases, HU value decreases and as T-score increases, HU value increases. They concluded that CT can dicriminate normal and osteoporotic patients even CT is more effective than DEXA for this discrimination [5].

Donalt von Borstel et al. compared DEXA T-scores –BMD values and CT HU levels of 79 female patients over 40 years measured at bilaterally femur necks. They observed proportional increase of BMD and T-scores as HU values increase [6].

Schreiber et al. compared age, BMD, T-score, and CT HU values of 25 patients (average age:71 years) which were measured at lumbal vertabrae. They reported that BMD and T-score is positively correlated with CT HU values. They concluded that CT HU measurement can be useful for differentiation of osteoporosis and normal density bone and also can contribute to WHO osteoporosis classification. They detected a decrease in HU values as age of the patients increases. They suggest that HU values are important for early diagnosis of osteoporosis and for detecting the risk of fracture which can be provided by present CT scans without any additional costs or time [7].

Na Li et al. found a strong correlation between BT HU values and DEXA T-score –BMD values. They concluded that CT HU measurement is superior to DEXA especially in the patients with aortic calcifications, focal sclerosis, fracture, osteophytis and degenerative changes in bone tissue. They also reported that CT may be used for the diagnosis of osteoporosis [7].

In a study of Ziemlewicz et al. a strong positive correlation between CT densitometry and DEXA BMD- T-scores. A few disparities between these two methods were attributed to features of the systems, calibration and scanning protocols. They concluded that CT HU measurement can useful to detect osteoporosis and the risk of fracture and also can be used in clinic practise [8].

In this study we examined the patients who underwent an abdominal CT scan and DEXA examination at the same day. HU measurements were performed at femur neck and vertebrae bodies on the CT scans by placement of ROI. These values were compared with DEXA results of the same patient. The HU values of L1-L2-L3-L4 vertebrae bodies and femur neck were analysed according to DEXA T-score-BMD, WHO classification, age groups and gender.

We observed a strong correlation between age groups (group 1: patients between 10-30 years old, group 2: patients between 31-60 years old, group 3: patients >61 years old) where HU values significantly decrease as age increases. The HU values we detected on vertebrae bodies and femur neck were found to be compatible with T-scores and groups according to WHO classification (osteoporosis, osteopeny and normal density) of these regions. We detected a significant increase in HU values as T-scores increase. In literature, most reports studied only postmenapausal women and a few studies were compared age and sex groups.

We also used a ROC analysis for CT HU values and DEXA T-scores to define a cut-off value for diagnosis of osteoprososis. All the values measured for each vertebraes and femur were detailed in graphics. We detected 162 HU for lumbal vertebrae and 96 HU for femur neck as a cut-off value for osteoporosis since the values lower than these levels have high risk for osteoporosis.

Schreiber et al. found an average 133 HU for normal density patients, 100 HU for osteopenic ones and 78 HU for osteoporotic ones at lumbal region (6). In a study of Sungjoon et. al, reported average 120 HU for normal density patients, 78 HU for osteopenic ones and 54 HU for osteoporotic ones at lumbal region(1). In our study the average HU value of normal density patients was 195, osteopenic ones was 166 and osteoporotic ones was 140 at lumbal region. The difference of HU values between normal density group, osteopenic group and osteoporot-

ic group at lumbal region was statistically significant. Average HU value of normal density patients was 178, osteopenic ones was 116 and osteoporotic ones was 59 at femur neck. The difference of HU values between normal density group, osteopenic group and osteoporotic group at femur neck was also statistically significant. Reported different HU values in literature is a challange for standardisation. These differences may be due to various systems used for examination, calibration, technique and the ethnics features of the patient population.

This is also the first study about correlation of volumetric measurement of lumbal vertebrae-femur neck and DEXA results. We aimed to show the decrease of volume of bone tissue, compatible with decrease in bone density. Our results confirmed that as DEXA T-scores decrease, the volume of bone tissue decreases, thinning of bone cortex and also reducement of medullary density occurs. Also the strong correlation between volume measurement and DEXA BMD and T-scores suggests that CT volumetry may be useful for the diagnosis of osteoporosis.

Volumetric results vary for either lumbal vertebraes and femur neck according to gender. When compared with female, males have statistically significant higher volume values. We think that biological conditions and hormones can role a play for this differences.

CT densitometry of lumbal vertebrae and femur neck may be an alternative method to DEXA for the diagnosis of osteoporosis. Artefacts of DEXA due to various conditions such as aortic calsifications, vertebral sclerosis, etc can alter the results and DEXA is a relatively non-common examination method which is not available in rural areas. Because CT is more common modality which is present in either small centers and is less sensitive to artefacts, a CT densitometry technique with low-dose scan of ideal focal region may be a promising modality for the diagnosis of osteoporosis.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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