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Canal to calcar ratio is associated with lumbar compression fractures

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ABSTRACT

Objective: Osteoporosis is one of the major public health problems. Singh (SI) and Genant indexes are the most well-known osteoporosis evaluation methods. Femoral cortical thickness index (CTI) and femoral canal to calcar ratio (CCR) values have been found to be more informative in the literature. This study aimed to investigate the relationship between SI, CTI, CCR, bone mineral density, and blood tests.

Patients and Methods: Hospital digital archives were searched and postmenauposal female patients who underwent bone scanning between 2018 and 2020 were included. Demographic data, blood laboratory and bone mineral densitometry (BMD) test results, and radiographic views were collected. The results were statistically analysed and expressed as mean ± standard deviation.

Results: The mean age was 66.14±6.82 years. There were 22 patients with lumbar compression according to Genant criteria. Also, 52 patients had osteoporosis and 35 patients had osteopenia according to the spine or hip BMD T scores. CCR was found to be significantly related to lumbar compression (p=0.04).

Conclusion: In this study, no correlation was found between CCR value and T score. However, CCR value was found to be associated with lumbar vertebral compression, which is helpful in the diagnosis of osteoporosis. It may be considered as a parameter that should be studied more in the diagnosis of osteoporosis.

Keywords: Osteoporosis, Canal to calcar ratio, Singh Index, Cortical Thickness Index, Lumbar compression

1. INTRODUCTION

Osteoporosis is one of the major public health problems. As the elderly population increases, osteoporosis-related fractures become more common [1]. The hip and spine are the most affected sites. Bone mineral densitometry (BMD) is the gold standard to identify this situation [2]. As osteoporosis is related to perioperative and postoperative technical complications, it is important to identify it for better surgical results [3, 4]. However, bone densitometry is more expensive than radiography, and x-ray devices are more common in healthcare centers. An easier and cheaper method to diagnose osteoporosis is needed and Singh index (SI) is a well-studied parameter that revealed different results about osteoporosis in literature. SI was published in 1970 and several studies have examined the reliability and validity of this method. Although, it is a cheap and easy method, there are controversial results about its reliability and validity in predicting osteoporosis compared to BMD in relevant literature and it was described as unreliable due to low rates in interobserver evaluations [5]. These controversial results lead investigators to find more reliable radiologic methods to compare with the current gold standard method, dual-energy x-ray absorptiometry (DEXA). Genant index (GI) is one of the most well-known and frequently used radiologic methods focusing on the spine, while SI focuses on the hip [6, 7]. Genant's index is based on vertebral body compression, which shows osteoporotic vertebral fractures [7]. Femoral cortical thickness index (CTI) and femoral canal to calcar ratio (CCR) were found to be more informative in the literature [8]. CCR and CTI are two radiologic methods first described by Dorr et al [9]. Although, these indices were primarily designed to select the correct prosthetic design for the hip (cemented or cementless femoral stem) preoperatively, they also reflect the osteoporotic morphological changes.

Lumbar compression fractures and their sequels are significant causes of back pain and disability in osteoporotic patients.

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This study investigated the association between osteoporotic lumbar compression fractures and osteoporotic, radiologic, and laboratory parameters and aimed to reveal the possible relationship between osteoporosis and radiological parameters.

Table I. *Description of Singh and Genant's Indices [6-7]*

	Singh Index
Grade	Description
1	Even the principal compressive trabeculae are markedly reduced in number and are no longer prominent
2	Only the principal compressive trabeculae stand out prominently, the others have been more or less completely resorbed.
3	There is a break in the continuity of the principal tensile trabeculae
4	Principal tensile trabeculae are markedly reduced in number but can still be traced from the lateral cortex to the upper part of the femoral neck
5	The structure of principal tensile and principal compressive trabeculae is accentuated. Ward's triangle appears prominent
6	All the normal trabecular groups are visible and the upper end of the femur seems completely occupied by cancellous bone.
	Description of Genant Index
Grade	Description
0	Normal
1	Mildly deformed (approximately 20-25% reduction in anterior, middle, and/or posterior height and a reduction of area 10-20%)
2	moderately deformed (approximately 25-40% reduction in any height and a reduction in area 20-40%)
3	severely deformed (approximately 40% reduction in any height and area)

2. PATIENTS and METHODS

The Study Population

Hospital digital archives were searched retrospectively between July 2018 and March 2020. The study was conducted in accordance with the Principles of the Declaration of Helsinki and was approved by the Kahramanmaras Sutcu Imam University Ethics Committee (date: 18.03.2020, approval number: 2020/06). Postmenauposal female patients with DEXA, lumbar, and pelvic x-rays, and comprehensive laboratory tests were included. The patients with missing data, acute lumbar and hip fractures for less than 6 months, rheumatologic diseases, and malignancies, were excluded. Patients with previous hip surgery, spine surgery, deformity of the proximal femur, and metabolic bone disease were excluded.

Data Source

Picture Archiving and Communication Systems (PACS) and hospital archive files were examined. Demographic data, blood test results, DEXA results, and radiographic views were collected. A total of 95 patients were included. BMD and T scores were measured by DEXA scan of the femoral neck and lumbar spine (Primus, Osteosys, Seoul, South Korea). Blood tests of blood calcium, phosphorus, and creatinine were collected. Direct radiographic views of the anteroposterior (AP) pelvis, AP, and lateral views of lumbar views were examined. CCR, CTI, and SI were calculated from the pelvis AP view as done previously in the literature (Figure 1) [6, 8]. SI and GI are described in Table I. GI was calculated from lumbar radiography as done previously in the literature [7]. GI of grade 1 and above is described as a lumbar compression fracture.

Table II. *Mean values, standard deviations, and p values of groups with or without lumbar compression*

	Patients with Lumbar Compression (N:22)	Patients without Lumbar Compression (N:73)	P Value
Singh Index	4.36±1.78	4.82±1.44	0.344
CCR	0.74±0.09	0.70±0.08	**0.04***
CTI	0.50±0.06	0.52±0.06	0.093
Age	68.14±5.71	65.57±7.04	0.135
Calcium (Mg/Dl)	9.49±0.52	9.59±0.45	0.292
Phosphorus (Mg/Dl)	3.27±0.51	3.46±0.58	0.216
Creatinin (Mg/Dl)	0.72±0.08	0.76±0.15	0.582
Lumbar BMD (gr/cm^2)	0.96 ± 0.12	0.99±0.18	0.158
Lumbar T Score	-1.61±1.60	-1.15±1.36	0.105
Femoral Neck BMD (gr/cm^2)	0.90±0.29	0.90±0.25	0.608
Femoral Neck T Score	-2.29±1.70	-2.36±0.97	0.555
BMI(Kg/M^2)	33.04±6.52	32.33±5.44	0.757
Weight (Kg)	77.50±15.51	76.28±13.57	0.569

*Data shown as mean ± standard deviation or n (%). *(p<0.05). CCR: Canal to Calcar Ratio, CTI: Cortical Thickness Index, BMD: Bone Mineral Density, BMI: Body Mess Index*

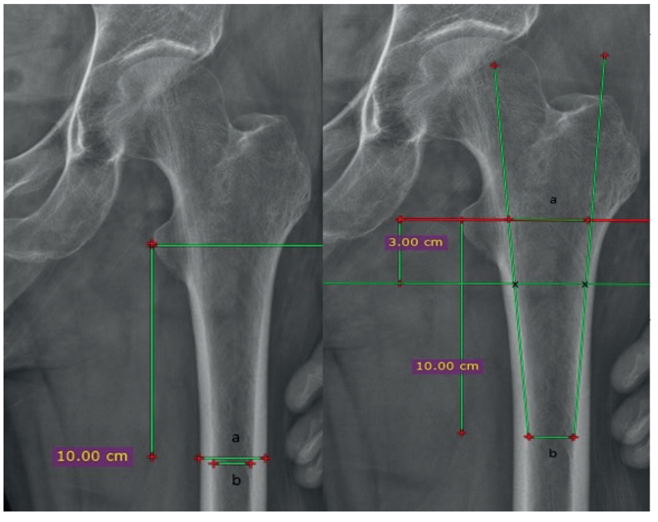

Figure 1. *Cortical Thickness index (CTI): (a-b)/a on the left, Canal to Calcar Ratio (CCR): b/a on the right*

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Statistical Analysis

Radiographic measurements, demographic data, and laboratory results were evaluated statistically, and the results were expressed as mean ± standard deviation (SD). The suitability of the quantitative data to the normal distribution was analyzed with the Single Sample Kolmogorov-Smirnov test. Either Student's t-test or Mann Whitney-U test was used according to distribution. The Chi-square test was used to compare categorical data between groups. Either Spearman correlation coefficient (rs) or Pearson's correlation coefficient was used to evaluate the relationship between variables depending on the distribution of variables. Finally, ROC curve analysis was performed to determine each radiographic measurement method's threshold values, sensitivity, and specificity. SPSS 22.0 software was used for analysis. P-value <0.05 was considered statistically significant.

Table III. *Mean values, standard deviations, and p-values of groups with or without osteoporosis and osteopenia*

	Patients with osteoporosis (N:52)	Patients with osteopenia (N:35)	Patients without osteoporosis or osteopenia (N:8)	P value
Singh Index	4.44±1.66	4.91±1.40	5.63±0.51	0.144
CCR	0.71±0.09	0.70±0.08	0.70±0.12	0.989
CTI	0.51±0.06	0.53±0.06	0.52±0.05	0.576
Age	66.78±6.50	66.82±6.28	59.12±7.93	0.038
Calcium (Mg/Dl)	9.59±0.54	9.46±0.33	9.92±0.30	0.009
Phosphorus (Mg/Dl)	3.48±0.55	3.29±0.54	3.57±0.78	0.308
Creatinin (Mg/Dl)	0.74±0.12	0.78±0.16	0.70±0.04	0.192
Lumbar BMD (gr/cm^2)	0.917 (0.18)*	0.994 (0.10)*	1.150 (0.21)*	0.0007**
Lumbar T Score	-1.75±1.37	-0.85±1.32	0.05±0.84	0.001***
Femoral Neck BMD (gr/cm^2)	0.603 (0.01)*	0.774 (0.01)*	0.873 (0.01)*	< 0.0001**
Femoral Neck T Score	-2.99±0.96	-1.82±0.57	-0.52±1.35	<0.001***
BMI(Kg/M^2)	33.04±6.52	32.33±5.44	36.47±4.69	0.007***
Weight (Kg)	72.02±13.20	80.80±13.28	87.50±10.74	0.002***

*Data shown as mean ± standard deviation or n (%). * Median (interquartile range) ** Mann-Whitney u test (p<0.05). ***Student's T test (p<0.05). CCR: Canal to Calcar Ratio, CTI: Cortical Thickness Index, BMD: Bone Mineral Density, BMI: Body Mess Index*

3. RESULTS

The power of the study was calculated as 61% by considering the 5% error rate of the post hoc power analysis method based on the averages of CCR of the groups containing a total of 95 subjects. The mean age was 66.14±6.82. There were 22 patients with lumbar compression according to the Genant criteria. Also, 52 patients had osteoporosis and 35 patients had osteopenia according to the spine or hip BMD T scores. Mean T scores for hip and spine were – 2.3 ± 1.17 and – 1.2 ± 1.43 respectively.

Patients were divided into two groups considering the presence of lumbar compression. SI, CTI, CCR, age, Ca, P, Creatinin, Lumbar T score and BMD, Femoral neck T score and BMD, body mass index (BMI), and weight values of both groups are presented in Table II.

Patients were divided into three groups due to the T score value of either the lumbar or femoral neck area. Patients with T score values below – 2.5 were defined as patients with osteoporosis, whereas patients with T score values between – 2.5 and – 1 were defined as osteopenia. SI, CTI, CCR, Age, Ca, P, Creatinin, Lumbar T score, and BMD, Femoral neck T score and BMD, BMI, and weight values of all groups are presented in Table III.

Correlation analysis released a significant correlation of vertebral compression with calcar to canal ratio (r: 0.212,p: 0.039). ROC analysis revealed that a CTI value less than 0.51 does not significantly indicate the presence of lumbar compression with 63.6% sensitivity, and 63% specificity but a CCR value of more than 0.71 indicates the presence of lumbar compression with 59.1% sensitivity, 57.3% specificity (Table IV).

Table IV. *ROC analysis results of CCR and CTI*

Variable	Cutoff value	The area under the curve (95% confidence interval)	Sensitivity (%)	Specificity (%)	P value
CCR	0.71	0.645 (0.516-0.774)	59.1	57.3	0.040
CTI	0.51	0.619 (0.482-0.755)	63.6	63.0	0.093

CCR: Canal to Calcar Ratio, CTI: Cortical Thickness Index

4. DISCUSSION

In this study, the SI and laboratory parameters were found to be unrelated to osteoporosis as reported in previous studies [10, 11]. Although, SI scores were lower in the osteopenic and osteoporotic patient groups, they did not show a significant difference. On the other hand, CCR was found to be significantly higher in patients with lumbar compression (p=0.04) and significantly correlated with lumbar compression. Although, the CCR index was primarily described for proximal femoral morphology, it did not reveal any significant difference with osteoporosis and any correlation with femoral T neck scores in this study. Also, it was shown that CCR more than the cut-off value of 0.71, significantly indicated lumbar compression with 59.1% sensitivity and 57.3% specificity. Lumbar compression occurs as a result of osteoporosis and is known to significantly increase the lumbar spine bone density [12]. Therefore, it may be told that osteoporosis of the spine can give correct results with a T-score only at the period before compression happens, which

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we believe will explain this contradictive result. However, a prospective study with more patient data will give more accurate results. The cortical thickness index (CTI) did not reveal any significant difference with any osteoporotic parameter in this study. However, there are different results in the literature. Köse et al., found a significant relationship between osteoporosis with CCR and CTI [8]. Sah et al., found CCR not to be related to the T score, but CTI showed a significant relation [11]. Yun et al., and Yeung et al., found CTI to be significantly related to the DEXA score [13, 14]. The threshold values of CCR in this study for predicting vertebral compression were 0.71 with 59.1% sensitivity and 57.3% specificity. Although, this cut-off value was significant, these values need to be proved by further studies, especially by prospective randomized trials. Since, vertebral compression is one of the signs of osteoporosis and CCR significantly predicts lumbar vertebral compression in this study, CCR may be used to predict osteoporotic lumbar vertebral compression fracture risk.

Osteoporosis is considered a metabolic bone disease in which the balance between bone formation and resorption is disrupted. For diagnosis and treatment, it is necessary to investigate bone metabolism and the affecting factors. Certain laboratory tests are required to diagnose and monitor each patient's treatment. Routine laboratory findings in patients with primary osteoporosis are usually within normal limits [15]. Serum calcium exists in three different fractions protein-bound form, ionized form, and phosphate, sulfate, and bicarbonate complexes. Total Ca is ordinarily used in clinical evaluation. In this study, it is found that blood calcium results were significantly lower in osteoporotic and osteopenic patients; however, all results were at normal levels.

This study found that BMI and weight were significantly higher in a group of patients without osteoporosis or osteopenia. Nevertheless, the mean BMI values of all groups were obese (>30). Increased fat mass is thought to have negative effects on bone mineral density [16]. Decreased physical activity is often associated with obesity and that could contribute to a decrease in bone mass. Although, body mass has a positive effect on bone formation, it remains controversial whether mass obesity is beneficial to the bone. The underlying pathophysiological relationship between obesity and bone is complex; this result could be an example.

There were some limitations of this study. A small number of patients was included in this study. Moreover, low thoracic vertebra fractures which are common in patients with osteoporosis were not investigated in this study. The fact that all patients were postmenopausal women, that gender discrimination was made, and that premenopausal patients were omitted prevents the generalization of the population. The study design was retrospective and, therefore prone to bias. The omission of FRAX in our analysis is another limitation. The FRAX score integrates multiple clinical risk factors and BMD measurements to provide a comprehensive fracture risk assessment [17]. Including a comparison with FRAX would have enriched our study by offering a broader perspective on the predictive value of CCR in the context of established fracture risk assessment tools. Although, this study was from a secondary healthcare center with a more homogenous patient group, a prospective study with a large number of patients and including both genders is needed for more accurate results.

Conclusions

CCR was found to be associated with lumbar vertebral compression fractures. It can be considered a helpful tool in diagnosing lumbar osteoporosis. Although, the CCR value was not found to be associated with the lumbar or femoral neck T score in this study, it can be seen as a parameter that needs to be studied more in the diagnosis of osteoporosis, since, significant results were obtained in previous studies showing this relationship.

Compliance with Ethical Standards

Ethics committee approval: This study was pproved by Kahramanmaras Sutcu Imam University Ethics Committee (date: 18.03.2020, approval number: 2020/06). The study was conducted in accordance with the Declaration of Helsinki. Both oral and written informed consent was obtained from the patients.

Conflict of interest: No conflict of interest was declared by the authors.

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Authors contributions: EI: Idea/Hypothesis, EI: Design, EI: Data collection/Data processing, EI and EI: Data Analysis, EI and EI: Preparation of the article. Both authors approved the final version.

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