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Vertebral fractures and spinopelvic parameters in patients with osteoporosis

Osteoporozlu hastalarda vertebral kırıklar ve spinopelvik parametreler

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Abstract

Aim: Bone mineral density (BMD) generally assesses fracture risk in the elderly but is not included in assessment of vertebral fracture status. In this study we aimed to investigate spinal alignment and pelvic orientation in patients with osteoporosis and identify indicators of vertebral fractures (VFs).

Methods: Seventy patients above 50 years of age with osteoporosis were included in this retrospective cohort study. Patients were allocated to two groups comprising 29 patients with and 41 patients without VFs. Demographic and clinical characteristics and back pain scores evaluated by Visual Analogue Scale were obtained by scanning patient files. Sagittal vertebral axis (SVA), spinal and pelvic parameters were evaluated with lateral radiography. All parameters and their effect of VFs were compared in both groups.

Results: Femoral neck BMD, sacral slope, lumbar lordosis, and pain scores were significantly different in patients with and without VFs (P=0.016, P=0.032, P=0.010, P<0.001, respectively). However, no significant difference was observed in terms of lumbar spine BMD, pelvic tilt, pelvic incidence, and thoracic kyphosis (P=0.394, P=0.313, P=0.258, P=0.341, respectively). Sacral slope and lumbar lordosis were positively correlated in patients with and without VFs (r=0.54, P=0.003 and r=0.50, P=0.001, respectively). SVA>50 mm and pain scores were predictors of VFs according to results of logistic regression.

Conclusion: The spinal deformity in patients with osteoporosis may be explained by the spinal parameters. In our study, we concluded that pain and sagittal imbalance in osteoporosis patients are important parameters for vertebral fractures.

Keywords: Osteoporosis, Sagittal balance, Spinopelvic parameters, Vertebral fracture

Öz

Amaç: Kemik mineral yoğunluğu (KMY) genellikle yaşlı bireylerin kırık riski değerlendirmesini gösterir ancak vertebral kırık durumunun değerlendirilmesini içermez. Biz bu çalışmada osteoporozlu hastalarda spinal sagital denge bozukluğu ve pelvik uyum bozukluklarını araştırmayı ve vertebral kırıkların (VK) tahmini göstergelerini tanımlamayı amaçladık.

Yöntemler: Bu retrospektif kohort çalışmada 50 yaş üzeri 70 osteoporoz hastası dahil edildi. Hastalar vertebral kırıkları olan; 29 VK(+) ve olmayan; 41 VK(-) olmak üzere iki gruba ayrıldı. Demografik ve klinik özellikler ile Görsel Analog Skala ile ölçülen sırt ağrısı skorları dosya taraması yolu ile elde edildi. Lateral radyolojik inceleme ile sagital vertebral aks (SVA), spinal ve pelvik parametreler değerlendirildi. Tüm parametreler her iki grupta da karşılaştırıldı ve bu parametrelerin VK üzerindeki etkisi analiz edildi.

Bulgular: Vertebral kırığı olan ve olmayan hastalarda femur boynu KMY, sakral eğim, lomber lordoz ve ağrı skorlarının anlamlı derecede farklı olduğu bulundu (sırasıyla P=0.016, P=0.032, P=0.010, P<0.001). Bununla birlikte, lomber omurga KMY, pelvik tilt, pelvik insidans ve torakal kifoz açısından anlamlı bir fark gözlenmedi (sırasıyla P=0.394, P=0.313, P=0.258, P=0.341). Sakral eğim ile lomber lordoz arasında pozitif anlamlı bir korelasyon bulunmuştur (sırasıyla r=0.54, P=0.03 ve r=0.50, P=0.001). Lojistik regresyon sonuçlarına göre SVA >50 mm ve ağrı skorları VK'ın belirleyicileriydi.

Sonuç: Osteoporozlu hastalarda omurga deformitesi omurga parametreleriyle açıklanabilir. Çalışmamızda osteoporoz hastalarında ağrı ve sagital dengesizliğin, vertebral kırıkların göstergeleri olduğu sonucuna varıldı.

Anahtar kelimeler: Osteoporoz, Sagital denge, Spinopelvik parametreler, Vertebral kırık

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Introduction

Osteoporosis leading to an increased risk of fracture and poor posture is a global health problem involving more than 200 million people, the incidence of which is predicted to considerably increase by the year 2050 [1]. Impaired spinal biomechanics and spinal imbalance are important causes of vertebral fractures (VFs) and morbidity in patients with osteoporosis [2]. Studies have shown that when a vertebral fracture develops, the fracture risk increases more with the number of previous vertebral fractures, especially within the first year [3,4]. The increased fracture risk may not always be explained by low bone mineral density (BMD) [5]. Spinal curvature and load-bearing capacity of the spine are also thought to contribute to VFs [6]. On the other hand, thoracic kyphosis is another risk factor for a new vertebral fracture independent of BMD [7,8].

Various postural changes, such as increase in lumbar lordosis, posterior tilt or rotation of the pelvis, extension of the hip, flexion of knees and dorsiflexion of ankles, may occur due to an increase in thoracic kyphosis [9-14]. Additionally, patients with sagittal malalignment often present with pain, poor balance, and gait disturbance [15]. Numerous studies on spinopelvic parameters have shown that these measurements may change with age, gender, weight, and pelvic morphology [16,17].

Sagittal imbalance causes displacement of the sacrum and pelvis in case of loss of normal lumbar lordosis, or an increase in thoracic kyphosis, or both [18]. Many studies on spinal sagittal imbalance and radiographic spinopelvic parameters have investigated older populations but there are few studies on the effect of these parameters on VFs in osteoporotic patients.

In our study, we aimed to determine the importance of sagittal balance, lumbar lordosis, and thoracic kyphosis in patients with osteoporosis and whether these parameters in the osteoporotic spine are predictive factors in the development of spontaneous VFs.

Materials and methods

Patients who were referred to SANKO University, Sani Konukoğlu Research and Practice Hospital, Physical Medicine and Rehabilitation outpatient clinic between May-October 2018 were included in this retrospective cohort study. A total of 70 (67 females; 3 males) patients underwent BMD measurement and digital x-rays radiographs. Back pain scores, previously evaluated by visual analogue score (VAS) (0-10 cm) [19], were recorded from patient files. All subjects were diagnosed with osteoporosis based on BMD diagnostic criteria [20]. Radiographic investigation of the anteroposterior and lateral whole spine, including hip joints, were investigated to assess VFs. Demographic and anthropometric measurements consisting of age, gender, height, and weight were obtained from the patient files. Body mass index values (BMI) [21] were calculated from measured BMD scans. The patients were divided into two groups as those with and without at least one vertebral asymptomatic collapse fracture (VFs (+) group and VFs (-) group, respectively). We excluded patients with a history of VFs secondary to trauma or an accident, who underwent instrumented fusion surgery, immobile patients, those with concomitant medical conditions such as metastatic disease or hyperparathyroidism, chronic alcohol users, smokers and those using corticosteroids for more than 3 months. Patients with documented VFs within the last 6 months were also excluded to avoid biased results in pain scores.

Bone mineral density measurement

Lumbar spinal bone mineral density (LSBMD) and femoral neck bone mineral density (FNBMD) of the non-dominant proximal femur were measured by dual-energy X-ray absorptiometry (DEXA) (GE-Lunar DPX). BMD measurements (g/cm^2) at the lumbar spine and hip were used to diagnose osteoporosis [22]. T-score of at least -2.5 standard deviations or below were considered as the presence of osteoporosis.

Spinal and pelvic parameters

Lumbar lordosis, thoracic kyphosis, pelvic tilt, pelvic incidence, and sacral slope were measured using a picture achieving computer system (Angora Viewer Version 2.1.11, Data-med).

Lumbar lordosis is defined as the angle between superior endplate of L1 and the superior endplate of S1, and thoracic kyphosis is measured from the superior endplate of T4 to the inferior endplate of T12 using Cobb's method [23].

The three pelvic parameters measured in this study included pelvic tilt, pelvic incidence, and sacral slope. Pelvic tilt (PT) is a positional pelvic parameter represented by the angle between the line joining the bicoxofemoral axis with the midpoint of the S1 endplate. Pelvic incidence (PI) is a morphologic parameter to define lumbar alignment. PI angle indicates the ability of posterior pelvic rotation, which is determined by the angle between the line joining hip axis, center of the S1 endplate and the line orthogonal to the S1 endplate. The pelvic retroversion of patients with small PI has a small compensatory mechanism to achieve sagittal balance. Sacral slope is a positional parameter, as well as the PT. SS is measured by the angle between the sacral endplate and the horizontal plane (Figure 1) [24].

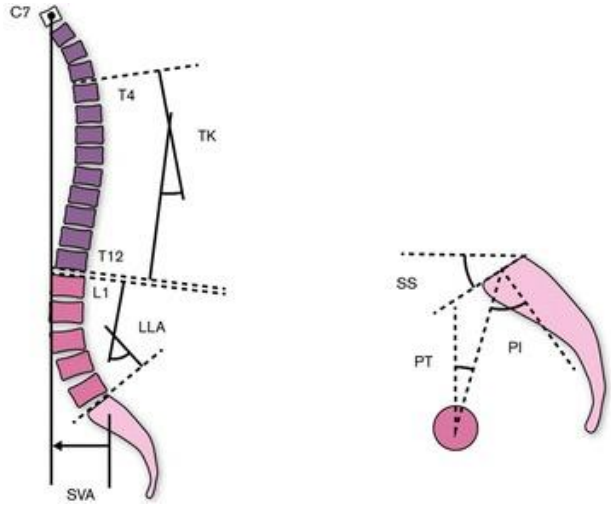

Figure 1: Sagittal curvatures of the spine and pelvic parameters: Lumbar lordosis angle (LLA) and thoracic kyphosis (TK), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), sagittal vertical axis (SVA) and C7 plumb line [24]

Sagittal global balance of the spine

Sagittal balance is most often assessed by determining the sagittal vertical axis (SVA) which corresponds to the horizontal distance between the C7 plumb line and the postero-superior S1 corner (Fig 1) [24]. Osteoporotic patients were

separated into the sagittal balance and sagittal imbalance group based on SVA (SVA≤50 mm, SVA>50 mm, respectively) [25]. Demographic and radiological measurements were compared between the groups.

Vertebral fractures

The thoracolumbar spine lateral view x-rays (T4 to L5) were interpreted by radiologists. Genant's method was used to quantify the VFs of the patients [26]. In this classification, vertebral fracture is based on the vertebral shape, with respect to vertebral height loss involving the anterior, posterior, and/or middle vertebral body.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 23. In univariate analysis, independent samples t-test and Mann-Whitney U tests were used for normally and non-normally distributed data, respectively. Descriptive statistics were expressed as median (minimum-maximum) values. Chi-square test with continuity correction was used for categorical variables. A multiple logistic regression was performed to identify indicators of VFs. After univariate analysis, variables with *P*-values <0.10 were included in the logistic model [27]. Forward conditional multiple logistic regression analysis was used to develop a determinative model. *P*-values <0.05 were considered statistically significant.

Results

The mean ages of all osteoporotic patients, as well as those with and without VFs were 69.9 (9.4), 72.24 (9.44) and 68.17 (9.17) years, respectively. There was no statistically significant difference between two groups with respect to age (*P*=0.075). Our radiologists identified 29 patients with grade 2-3 fractured vertebrae on whole spine lateral radiography. Twenty-seven (40.3%) of 67 female patients and 2 of 3 male patients had VFs, among which 15 had thoracic, 11 had lumbar and 3 had both thoracic and lumbar VFs (Table 1).

Mean height, weight, and BMI values of the 70 patients were 153.7 (6.7) cm, 69.3 (12.5) kg and 29.4 (5.6) kg/m^2, respectively. Median VAS back pain score was 7 (3-10) for all patients. Parameters of patients with and without VFs and comparisons of two groups are summarized in Table 2. Patients with and without fractures were found to be significantly different in terms of FNBMD, sacral slope, lumbar lordosis, and VAS scores (*P*=0.016, *P*=0.032, *P*=0.010, *P*<0.001, respectively). In addition, the two groups significantly differed with respect to SVA>50 mm and ≤50 mm (*P*<0.001).

Correlation coefficients between sacral slope and lumbar lordosis both in patients with and without VFs were r=0.54; *P*=0.003 and r=0.50; *P*=0.001, respectively. There were no correlations between VAS score and the other spinopelvic parameters in patients with VFs (Table 3).

Based on univariate analysis, a multiple logistic regression was performed for age, FNBMD, sacral slope, lumbar lordosis, VAS and SVA>50mm, which showed that SVA>50 mm (*P*=0.003) and VAS (*P*=0.001) were predictors of vertebral fracture in osteoporotic patients (Table 4). The risk of VFs in patients with SVA>50 mm was approximately 10 times higher than for those with SVA≤50 mm. In patients with higher VAS scores, the risk was 2 times higher than in patients with lower VAS scores. Sacral slope was also statistically significant with an odds ratio of 1, which is why it may be considered ineffective on VFs.

Table 1: Distribution of levels in patients with vertebral fractures

Levels of vertebrae fractures	n (%)
T9	3 (5)
T10	10 (16)
T11	14 (22)
T12	10 (16)
L1	8 (13)
L2	5 (8)
L3	2 (3)
L4	9 (14)
L5	2 (3)

T: Thoracic vertebrae, L: Lumbar vertebrae, n: number (%)

Table 2: Characteristics of patients

	Vertebral fractures (+) (n=29)	Vertebral fractures (-) (n=41)	*P*-value
Age	72.24 (9.44)	68.17 (9.17)	0.075[a]
Height (cm)	153.59 (8.85)	153.76 (4.87)	0.926[a]
Weight (kg)	68.69 (12.82)	69.66 (12.41)	0.752[a]
BMI (kg/m²)	29.35 (6.23)	29.49 (5.23)	0.923[a]
Lumbar spine BMD	-2.7 (-4.4; 0)	-2.8 (-4.2; -1.5)	0.394[b]
Femoral neck BMD	-2.5 (-3.7; -0.3)	-1.6 (-4.0; 0.1)	0.016[b]
Sacral slope	38.31 (8.75)	43.63 (10.82)	0.032[a]
Pelvic tilt	18 (6; 36)	15 (7; 34)	0.313[b]
Pelvic incidence	58.07 (11.80)	61.29 (11.54)	0.258[a]
Thoracic kyphosis	40.34 (10.57)	37.83 (10.96)	0.341[a]
Lumbar lordosis	36.38 (12.68)	44.56 (12.81)	0.010[a]
SVA>50 mm	24 (82.8%)	14 (34.1%)	<0.001[c]
VAS Score	8 (4; 10)	5 (3; 10)	<0.001[b]

Mean (Standard Deviation, Median (Min; Max)), n: number (%), [a] Independent samples t-test, [b] Mann-Whitney U test, [c] Chi-square test with continuity correction, SVA: Sagittal vertebral axis

Table 3: Correlations between VAS and spinopelvic parameters in patients with vertebral fractures

		Sacral slope	Pelvic tilt	Pelvic incidence	Thoracic kyphosis	Lumbar lordosis	SVA (mm)
VAS	r	0.229	-0.151	0.058	0.022	-0.200	0.300
	p	0.232	0.435	0.765	0.909	0.918	0.114

SVA: Sagittal vertebral axis, VAS: Visual analogue score

Table 4: Results of logistic regression

Variables	Coefficient	Odds Ratio	95% Confidence Interval	*P*-value
Sacral slope	-0.101	0.904	0.842-0.970	0.005
SVA>50 mm	2.334	10.317	2.159-49.307	0.003
VAS	0.757	2.132	1.361-3.339	0.001
Constant	-2.677	2.034		0.154

SVA: Sagittal vertebral axis, VAS: Visual analogue score

Discussion

This study assessed VFs with or without sagittal balance and compared spine curvatures and pelvic parameters in osteoporotic patients over 50 years of age. We found that VFs significantly varied in patients with sagittal imbalance, FNBMD and pain. Lumbar lordosis and sacral slope were also found to differ significantly associated with VFs of the spine in osteoporotic patients.

Osteoporosis reduces trabecular thickness and connectivity in bone mass and microarchitecture leading to increased vertebral fragility and fracture risk [28]. Loss of physiological curves in the thoracic and/or lumbar spine causes an increase in the risk of vertebral fracture more than eight times in patients after the age of 50 years old [8].

It is not clear whether thoracic kyphosis is a potent determining factor for potential osteoporotic VFs [29]. In our study, it was found that there was no significant thoracic kyphosis in patients with VFs (+) compared to VFs (-) group.

Cortet et al. [30,31] examined the relationship between lordosis and osteoporosis, and found no difference in lumbar lordosis in patients with and without VFs. However, our results showed that lumbar lordosis has a strong impact on VFs: The VFs (+) group had a higher degree of lumbar lordosis than the VFs (-) group. This result suggests that hyperlordotic posture is a crucial factor which increases the risk of VFs. Besides, VF (-)

group had high sacral slope without high pelvic tilt compared to VF (+) group. This could be due to several reasons: First, sagittal alignment in the VFs (-) group is characterized by a compensatory mechanism. An imbalance in thoracic hyperkyphosis patients with VFs can be concealed by changes such as lumbar spine flattening and pelvic orientation to maintain postural harmony.

It is known that sacral slope angle is strongly correlated with lumbar lordosis [32]. Spinopelvic harmony has the capability to compensate for sagittal imbalance of the spine through pelvic retroversion with change in sacral slope. We showed that lumbar lordosis was proportional to sacral slope angle.

Pelvic incidence (PI) is an important link between pelvic and spinal alignment parameters determining the capability of rotation of the pelvis around the femoral head's axis, which is the optimal way of compensation of sagittal alignment [33]. However, there was no statistically significant difference in the compensatory ability of pelvis retroversion between the two groups in our study.

The optimal value of the SVA varies widely among populations. The International Spine Study Group defines the radiographic criterion for spinal imbalance as SVA≥50 mm [25]. As in many studies [33-35], we also considered SVA>50 mm as the threshold for predicting sagittal imbalance. This indicates that spinal imbalance can be evaluated from the SVA on a standing lateral radiograph of the whole spine to estimate VF development in osteoporotic patients.

It is shown that BMI>25 is related to a higher likelihood of developing VFs among post-menopausal women with osteoporosis [36]. In contrast, our data showed that being overweight (BMI>25) and VFs were not associated in any of the groups. As shown in Table 1, the mean BMI was 29.35 (6.23) in the VFs (+) group and similarly, 29.49 (5.23) in the VFs (-) group.

In the present study, SVA was a worse identifier of patients with VFs. In other words, sagittal imbalance was higher in the osteoporotic patients with VFs than in the osteoporotic patients with no VFs. Previous studies showed that spinal sagittal balance is closely related with osteoporosis [37], akin to our findings. To a certain degree, a decrease of lumbar lordosis can be obviated by a coinciding decrease in sacral slope to obtain the spinal curvature and congruent posture [38].

In patients with VFs secondary to osteoporosis, impairments in physical function, health, quality of life, and survival correlate with spinal deformity [39]. Glassman et al. [40,41] observed that sagittal balance is associated with pain and mechanical stress on the vertebrae. However, in our study, there was no significant correlation between VAS and spinopelvic parameters in patients with VFs.

Our multiple logistic regression analysis including FNBMD, sacral angle, lumbar lordosis, increasing age, SVA and VAS score showed that VAS and SVA>50 mm were important predictive factors of VFs in osteoporotic patients. However, in our study, the statistical significance of FNBMD in the univariate analysis revealed that it should be considered in evaluation of the risk of VFs, even if LSBMD is normal or close to normal.

In the literature, a significant relationship between age and spinal sagittal vertical axis has been reported; however, we found no such result [42]. In our study, the mean ages of patients with and without vertebral fractures were similar. Presumably, this is due to the fact that sagittal alignment is characterized by decrease in spinal mobility and compensatory mechanisms with aging.

Limitations

This study has some limitations regarding compensation of sagittal balance, spinal curvature and impact of osteoporotic VFs. First, we did not examine total countervailing changes like knee flexion and ankle extension. Second, since the spinal vertebral axis changes during walking, conventional radiography in standing position alone was not adequate for assessment of balance in patients. In addition, we carried out this study with a relatively small number of patients with osteoporosis. Therefore, further studies in larger populations are necessary to validate these findings.

Conclusions

This article shows that spinal imbalance and VAS are determining predictive parameters for VFs in patients with osteoporosis. The results suggest that clinicians should pay attention to sagittal imbalance, pain and FNBMD in osteoporotic patients even if they have normal LSBMD.

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