ARAŞTIRMA MAKALESİ / *RESEARCH ARTICLE*

Determination of Osteopenic and Osteoporotic Spine with Hounsfield Unit in Spinal Fusion Surgery

Spinal Füzyon Cerrahisinde Hounsfield Unit ile Osteopenik ve Osteoporotik Omurganın Belirlenmesi

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ABSTRACT

Aim: *Bone mineral density (BMD) is vital in spinal fusion surgery. Dual X-ray absorptiometry (DEXA) is the gold standard for evaluating BMD. In this study, we aim to assess the bone density of the patients using Hounsfield units (HU) who underwent spinal surgery with instrumentation.*

Material and Method: *Computed tomography (CT) and DEXA results of 99 cases of 40 years of age or older who had posterolateral fusion operation between 2014 and 2017 were evaluated retrospectively. The HU values of the vertebral body obtained from the lumbar CT, which is routinely used in surgical planning, were measured with the image archiving and communication system (PACS; Maroview, Infinitt Healthcare). Three measurements were taken from each vertebra. Hounsfield unit values were determined according to age groups. These results were compared with the L1–4 DEXA results acquired before the operation and/ or within six months.*

Results: *HU values of patients obtained from CT were classified between four age groups. Hounsfield unit values of each vertebral level were compared with the T score obtained with DEXA. The correlations of the HU value with the T score were significant (p <0.001). The mean HU values of the compared levels decreased consistently over the ten years. The differences were statistically significant. There was no significant difference between HU values in age groups.*

Conclusion: *Estimating the osteopenic/ osteoporotic spine by measuring the HU values from CT is a simple, cost-effective method that helps surgical planning at instrumentation.*

Key words: *Hounsfield unit; lumbar vertebrae; instrumentation; posterolateral fusion; osteoporosis; spine*

ÖZET

Amaç: *Kemik mineral yoğunluğu (KMY), spinal füzyon cerrahisinde önemli bir faktördür. BMD'yi değerlendirmek için Dual X-ray absorpsiyometri (DEXA) altın standarttır. Bu çalışmada, enstrümantasyon ile spinal cerrahi uygulanan Hounsfield üniteleri (HU) kullanan hastaların kemik yoğunluğunu araştırmayı amaçladık.*

Materyal ve Metot: *2014–2017 yılları arasında posterior transpediküler vida-rod sistemleri ile posterolateral füzyon operasyonu geçiren 40 yaş ve üzeri 99 olgunun BDT ve DEXA sonuçları retrospektif olarak değerlendirildi. Cerrahi planlamada rutin olarak kullanılan lomber BT'den elde edilen vertebra gövdesinin HU değerleri PACS sistemi ile ölçüldü. Her bir omurdan üç ölçüm alındı. Hounsfield ünitesi değerleri yaş gruplarına göre belirlendi. Bu sonuçlar operasyon öncesi ve/veya altı ay içinde alınan L1–4 DEXA sonuçları ile karşılaştırıldı.*

Bulgular: *Bilgisayarlı tomografiden elde edilen hastaların HU değerleri dört yaş grubu arasında sınıflandırıldı. Her bir vertebral seviye için HU değerleri, DEXA ile elde edilen T skoru ile karşılaştırıldı. HU değeri ile T skoru arasındaki korelasyonlar anlamlıydı (p <0,001). Ortalama HU değerleri, dekatlar boyunca karşılaştırılan vertebra seviyelerinde tutarlı bir şekilde azaldı. Farklar istatistiksel olarak anlamlıydı. Yaş gruplarında HU değerleri arasında anlamlı bir fark yoktu.*

Sonuç: *Bilgisayarlı tomografiden HU değerlerini ölçerek osteopenik/osteoporotik omurgayı tahmin etmek, enstrümantasyonda cerrahi planlamaya yardımcı olan basit, uygun maliyetli bir yöntemdir.*

Anahtar kelimeler: *Hounsfield birimi; lomber vertebra; enstrümantasyon; posterolateral füzyon; osteoporoz; omurga*

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Introduction

Success in spinal instrumentation operations is multifactorial. Many factors have an impact on surgical success. The quality of bone is an important prognostic factor for fusion. Severe osteoporosis is an important cause of failure, such as loosening and pulling out of the pedicle screw after spinal fusion surgery[1–4]. Therefore, bone mineral density (BMD) is essential in surgical planning.

Osteoporosis is a systemic disease with increased bone fragility resulting in low bone density and microarchitecture bone tissue degradation. DEXA, used as a routine screening, is the gold standard for BMD measurement. In osteoporotic patients with aortic calcification, severe bone protrusion, sclerosis, and obesity, DEXA results may be normal[1–4].

Measurement of BMD using computed tomography (CT) was an old technique. However, it has not been routinely used. Recent studies have increased the probability of predicting BMD using diagnostic CT images[5–8]. A Hounsfield unit (HU) represents a normalized index of X-ray based on a scale of -1000 defined for air and 0 for water[9]. Hounsfield unit values can be used as a marker for bone mineral density. Lumbar CT is performed routinely to identify anatomical structures before spinal fusion surgery.

In this study, bone density of the spine was evaluated using vertebral HU values obtained from CT scanners routinely used for spinal instrumentation surgery. These results were compared with DEXA results. Standard HU values were tried to be determined to predict normal, osteopenic, and osteoporotic backbone.

Material and Method

This study was approved by the Medipol University Institutional Review Board (05/05/2020–354). Informed consents were obtained from every patient. Ninety-nine patients aged 40 years and older who underwent fusion operation with lumbar spinal instrumentation in our clinic were evaluated retrospectively. Patients with previous lumbar spinal instrumentation, those with secondary diseases that may affect BMD, such as a spinal fracture, spinal tumor, spondylopathy, and systemic disease, and patients under medical treatment for osteoporosis were excluded.

Hounsfield unit values of the vertebral body obtained from lumbar KBT, routinely used in surgical planning, were measured with the PACS system. Patients who had DEXA up to 6 months before the operation or who were considered to be osteopenic and/or osteoporotic in the operation planning were included in the study.

A 126-channel CT scanner (Somatom Perspective, Siemens) was used for CT scans in all patients. An image archiving and communication system (PACS; Maroview, Infinitt Healthcare) was used to calculate the average HU value of the vertebral body. Hounsfield unit measurement for each vertebra was obtained using a protocol described by Schreiber et al.[9]. The HU calculation was measured from L1 to L5 in three locations: inferior to the upper cortex, the middle of the vertebral body, and the top of the lower cortex (Fig. 1). For the

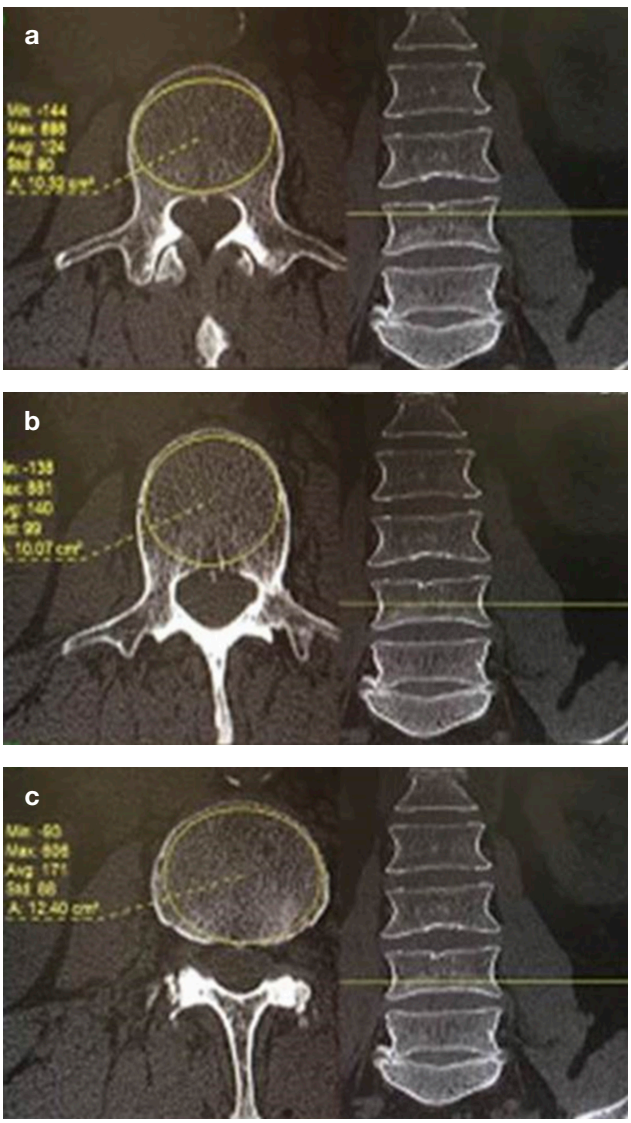

Figure 1 a-c. *Measuring HU with CT: inferior of the upper cortex (a), middle of the vertebral body (b), above the lower cortex (c). When the largest possible elliptical area, excluding cortical edges, is drawn with the PACS system, the system automatically calculates the HU value.*

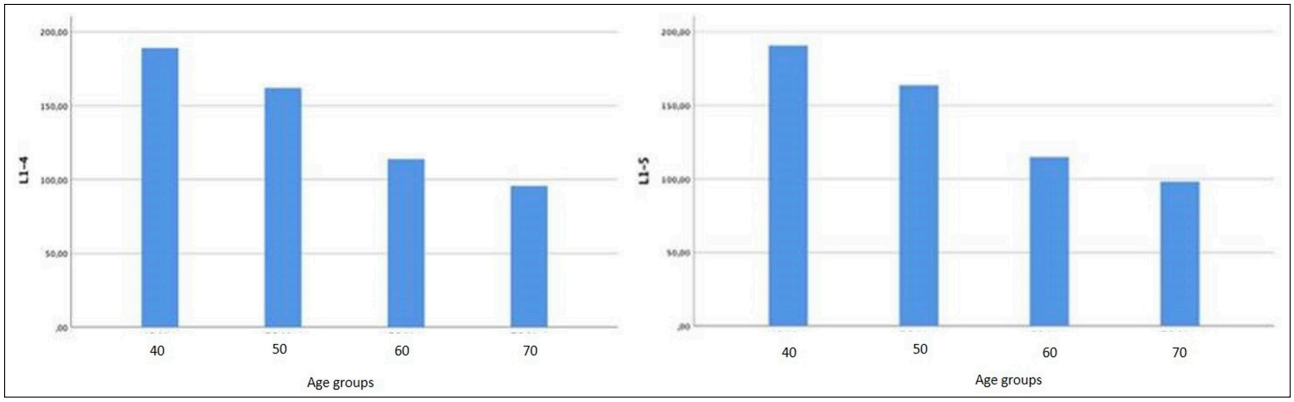

Figure 2. *Decrease of L1–4 and L1–5 HU values in proportion to age.*

averages to be standard for each measurement, the largest possible elliptical area was drawn, except for the cortical edges. By calculating the mathematical average of HU values in three axial slices, a HU value was calculated for each lumbar vertebra. In DEXA scans, results were given according to the L1–4 vertebrae. Hounsfield unit results compared with both L1-4 and L1-5 results.

Statistical Analysis

Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. The data was evaluated using descriptive statistical methods, and the Shapiro-Wilk Test was used to assess the distribution. A comparison of the three and above groups with a normal distribution of quantitative data was performed using the ANOVA test, and the Mann-Whitney U Test was used to compare the differences between the three and above groups. The cut-off value of quantitative data was determined with ROC analysis. Significance was evaluated at p <0.01 and p <0.05 levels.

Results

This study included 67 women and 32 men aged 40–79. The HU values of patients were classified into four groups. Average HU values decreased consistently over the ten years at the compared vertebral levels (Fig. 1). The differences were statistically significant (p <0.05). The subgroup analysis showed no significant difference between the vertebrae in the age groups (p>0.05). However, there were significant differences between the age groups (p <0.05) (Table 1). There was a considerable decrease in HU values between the 50 s age group and the 60 s age group (p <0.05). There was no significant difference in HU value between genders (p>0.05). There was no difference between the lumbar region vertebrae regarding HU values (p>0.05). When the values obtained from L1-4 and HU obtained from L1-5 were compared, the differences were insignificant (p>0.05). The HU values obtained from our study tended to decrease with age, and BMD decreased (Fig. 2).

Table 1. *Comparison of HU values between age groups*

		N	mean ± standard deviation	%95 confidence interval	p
40–49 age group	L-1	22	185.86±15.6	178.94–192.78	0.319
	L-2	22	184.95±16.16	177.78–192.12	
	L-3	22	190.36±17.09	182.78–197.94	
	L-4	22	194.91±13.76	188.80–201.00	
	L-5	22	197.14±26.63	185.32–208.94	
	L-1–4	22	189.05±14.72	182.51–195.57	
	L-1–5	22	190.65±16.35	183.39–197.89	
50–59 age group	L-1	31	170.71±29.61	159.84–181.57	0.329
	L-2	31	166.19±36.55	152.78–179.60	
	L-3	31	152.06±30.75	140.78–163.34	
	L-4	31	159.19±30.44	148.02–170.36	
	L-5	31	170.52±38.19	156.50–184.52	
	L-1–4	31	162.07±29.84	151.12–173.01	
	L-1–5	31	163.74±28.51	153.27–174.19	
60–69 age group	L-1	30	117.13±24.19	108.10–126.16	0.544
	L-2	30	114.57±23.72	105.71–123.42	
	L-3	30	108.57±21.75	100.44–116.68	
	L-4	30	115.07±24.85	105.78–124.34	
	L-5	30	118.87±25.29	109.42–128.31	
	L-1–4	30	113.86±20.94	106.04–121.68	
	L-1–5	30	114.84±21.07	106.97–122.70	
70–79 age group	L-1	16	96.19±25.4	82.65–109.72	0.563
	L-2	16	89.94±30.28	73.80–106.07	
	L-3	16	92.13±30.82	75.70–108.54	
	L-4	16	104.56±37.2	84.73–124.38	
	L-5	16	108.06±31.97	91.02–125.09	
	L-1–4	16	95.69±25.72	81.98–109.39	
	L-1–5	16	98.18±25.83	84.4–111.93	
Kruskall-Wallis Test	*p<0.05		**p<0.01		

A significant difference was found between the L1–4 values according to the groups (p <0.001). The L1–4 value of the group with normal HU value was statistically significant compared to the group with osteopenic and osteoporosis (p <0.001). In addition, the L1–4 value of the osteopenic group was higher than that of the osteoporosis group (p <0.001).

A significant difference was found between the groups' HU values of L1–5 vertebrae (p=0.001; p <0.01). The L1–5 value of the group with normal HU values was higher than the group with osteopenic and osteoporosis statistically significant (p=0.001; p <0.01). The L1–5 value of the osteopenic group was higher than that of the osteoporosis group (p=0.001; p <0.01).

The optimal cut-off value was calculated with the ROC curve to estimate osteopenia and osteoporosis using the HU value.

When the cut-off point of the L1–4 measurement was taken as 127.55, the sensitivity was determined as 93.7%, and the specificity as 99% as the reliable cut-off value. When the cut-off point of the L1-4 measurement was 76.9, sensitivity was determined as 98.8%, and specificity as 99% as a reliable cut-off value. When the cut-off point of the L1-5 measurement was taken as 125.5, sensitivity was determined as 98.4% and specificity as 93.7% as a reliable cut-off value. When the cut-off point of the L1-5 measurement was taken as 78.7, sensitivity was determined as 99.8%, and specificity was defined as a reliable cut-off value as 99.7%.

When the DEXA results of the patients were examined, the average T scores of 99 patients ranged from -3.4 to +2.8. Correlations of HU value with T score were significant (p <0.001).

According to the guidelines of the World Health Organization, the lumbar vertebrae T-score of 99 patients was divided into three groups: normal (-1.0 or greater), osteopenic (less than -1.0 and greater than -2.5), and osteoporotic (–2.5 or less) (Table 2). Average HU values of patients in normal, osteopenic, and osteoporotic groups were 168.57±27.64, 101.98±11.16, and 61.78±12.39 HU according to L1-4. According to L1-5, it was 169.57±28.13 normal, 104.86±12.9 osteopenic, 61.8±12.3 osteoporotic HU (Table 3). The differences in mean HU values between the groups were significant (p <0.001).

A post-hoc power analysis was performed to calculate the power obtained using the current findings of the study. The mean L1-4 measurement was calculated as 168.57±27.64 in the patient group with normal HU, 101.98±11.16 in osteopenic patients, and 61.78±12.39 in osteoporotic patients. The corresponding effect size value was determined as f=2.45. Still, it was accepted as the upper limit of the effect size value. The value of f=0.40 was taken into account. Considering the relevant effect size value, the power value obtained from our study, where the type I error was accepted as 5%, was determined as 95%, with a total of n=99 units, and the analyses were analyzed by G*Power has been made[10].

Table 2. *Normal, osteopenic, and osteoporotic values according to HU values*

T score	mean ± standart deviation	95 confidence interval	p
L1–4			
Normal (≥ -1.0)	168.57±27.64	161.60–175.52	0.001
Osteopenic (<-1.0 or > -2.5)	101.98±11.16	97.95–105.99	0.001
Osteoporotic (≤ -2.5)	61.78±12.39	42.05–81.49	0.001
L1–5			
Normal (≥ -1.0)	169.57±28.13	134.34–151.10	0.001
Osteopenic (<-1.0 or > -2.5)	104.86±12.9	100.21–109.51	0.001
Osteoporotic (≤ -2.5)	61.8±12.3	42.22–81.37	0.001

Table 3. *Comparison of normal, osteopenic, and osteoporotic HU values*

	Normal	Osteopenic	Osteoporotic
Bredow et al.[23]	120.80±41.80	78.80±23.00	54.70±25.20
Choi et al.[10]	167.90±47.20	109.70±28.90	80.40±38.70
Schreiber et al.[9]	133.00±37.60	100.80±24.50	78.50±32.40
Current study	168.57±27.64	101.98±11.16	61.78±12.39

Discussion

In surgical procedures where fusion is aimed by spinal instrumentation, osteoporosis is one of the leading causes of surgical failure[11,12]. Identifying the osteoporosis before fusion surgery is very important.

Dual X-ray absorptiometry is the gold standard for evaluating BMD[2,12–14]. However, patients with severe degeneration, aortic calcification, and obesity may have false normal BMD values[12,15–17].

Bone mineral density can also be measured using CT. Patients of various age groups, regardless of gender, can be evaluated at no additional cost. Quantitative CT only provides true volumetric Bone Mineral Density measurement (mg/ cm^3). Unlike DEXA, cortical and trabecular bone can be analyzed separately. Computed tomography is more sensitive than DEXA in predicting vertebral fractures and monitoring bone loss. The main advantage of DEXA is that it excludes the measurement of structures that do not contribute to the mechanical resistance of the spine and selectively measures the trabecular bone. It is not affected by extra-bone calcifications. Computed tomography is useful for monitoring BMD changes in patients with structural abnormalities that prevent the use of DEXA in their spine (scoliosis, etc.). However, CT cannot be used in WHO diagnostic classification criteria. Computed tomography has several limitations, such as the high cost and the risk of high radiation exposure. Therefore, CT is not widely used in clinical practice in estimating osteoporosis, but it is routinely used in surgical planning[12,18,19].

The National Osteoporosis Foundation recommends that the lowest T-score for the L1-L4 lumbar vertebra, total proximal femur, or femoral neck should be evaluated for the diagnosis of osteoporosis[1,20]. In our study, we used the HU values obtained from L1–4 and L1-L5 and found a correlation with the DEXA values of the patients. We found 98.8% sensitivity and 99% specificity in CT. The cut-off value of this study shows that HU values are sensitive and specific for screening osteopenia and osteoporosis.

Patients with lumbar spinal instrumentation and those with secondary diseases such as spinal fracture, spinal tumor, spondylopathy, and systemic disease that may affect BMD may also give false results.

In spinal fusion surgery, trabecular bone density is significant in the success of instrumentation. Dual X-ray absorptiometry evaluates trabecular and cortical bone, but only trabecular bone density is calculated. At the same time, HU values are obtained from CT. Planning the spinal fusion operation according to HU values will increase success.

Türkyilmaz et al. used HU values for implant surgery in dentistry to detect the regional oral BMD[21]. Metal torques are highly correlated with insertion torque and stability of metal implants[22]. Hounsfield unit value can be an important prognostic factor in implant stability for any bone region in dentistry. Measuring the value of HU in the planned screw trajectory can be used to estimate the strength of the bone-screw interface. We think the measurement of HU can be useful in predicting fusion success before spine fusion surgery.

Zou et al. investigated the relation between screw loosening and HU in patients with pedicular screws. They demonstrated that the HU values measured on CT are an independent determinant for loosening the pedicle screw and that the low HU value is significantly correlated with the higher risk of loosening[23]. Bredow and Schwaiger also achieved similar results in their studies[24,25]. Some researchers reported that the fusion rate was considerably higher in patients with high HU values, and low HU values paved the way for developing pseudoarthrosis[23–26].

In our study, there was a maximum time gap of 6 months between CT and DEXA that can affect the study results. However, we exclude those who have medical treatment for osteoporosis and those with an endocrine disease that affects BMD, so this may be a low probability.

The significant limitations of this study are its retrospective nature and the relatively small number of patients in this series.

Conclusion

Hounsfield unit values obtained from lumbar CT significantly correlates with BMD based on DEXA scanning. This study obtained valid HU values for diagnosing healthy individuals, osteopenia, and osteoporosis.

Conflict of Interest

The authors declare no conflict of interest.

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