DOI: 10.14744/cm.2022.07742
Comprehensive Medicine 2023;15(1):58-62

RESEARCH ARTICLE

The Effect of Bone Density Measurement with Computed Tomography on Lumbosacral Fusion and Trajectory of Sacral Screw

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ABSTRACT

Objective: Sacral screw loosening is a common complication after lumbosacral fusion surgery. This study aims to determine the locations where screw loosening may be less with the help of computed tomography (CT)-derived bone density measurements in Hounsfield units (HU) in patients undergoing posterior lumbosacral fusion and to examine the effects of determining the trajectory of sacral screw placement on fusion success.

Materials and Methods: The files of patients who underwent lumbosacral posterior fusion for different indications in our clinic between September 2017 and November 2020 were retrospectively reviewed. The patients' admission complaints, neurological examination findings, diagnoses, pre-operative HU values, and intraoperative and post-operative complications were evaluated.

Results: The data of 50 patients were analyzed in this study. The study group predominantly consisted of patients with spinal stenosis (n=23). There were differences between the HU values of the right and left vertebral facets and the corpus vertebra ($p<0.001$). The subgroup analyses revealed higher HU values in the corpus vertebra (213.5) than in the right (82.5) and left (80.5) vertebral facets ($p<0.001$ and $p<0.001$, respectively), with no difference between the right and left HU measurements ($p>0.999$). The comparison between genders showed no significant difference ($p>0.05$). The mean follow-up duration of the patients was 29.3±14.12 (range, 10–48) months.

Conclusion: We are of the opinion that pre-operative CT-derived bone density in HU provides the prediction of normal, osteopenic, and osteoporotic sacral segments, thus preventing screw loosening, which paves the way for surgical failure.

Keywords: Hounsfield unit, lumbosacral stabilization, spinal stenosis

How to cite this article: Bulut G, Baykal D. The Effect of Bone Density Measurement with Computed Tomography on Lumbosacral Fusion and Trajectory of Sacral Screw. CM 2023;15(1):58-62

INTRODUCTION

The sacrum is a triangular bone at the base of the human spine that forms by the fusing of the five sacral vertebrae. This bone, which forms the basis of the entire spine, also plays a key role in spinal sagittal balance. This region is also important in the stabilization of the lower lumbar region.[1]

The lumbosacral junction is the transition region between the mobile spinal column and the stable pelvis and lower limbs. Surgeries performed in this region are challenging due to the high force applied to the weak osseous structure and the complex anatomical structure of the region. Moreover, this region is the most difficult region of the spine to fuse.[2] Complications such as instrument failure, screw breakage, and pseudoarthrosis are frequently encountered.

Sacral screw loosening resulting from lumbosacral fusion surgery is a common surgical problem.[3] It leads to postoperative morbidity, labor, and economic loss.

This study aims to determine the locations where screw loosening may be less with the help of computed tomography (CT)-derived bone density measurements in Hounsfield

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Received date: 30.06.2022
Revised date: 19.12.2022
Accepted date: 03.10.2022
Online date: 31.01.2023

Comprehensive Medicine published by Kare Publishing.

units (HU) in patients undergoing posterior lumbosacral fusion and to examine the effects of determining the trajectory of sacral screw on fusion success.

MATERIALS and METHODS

After obtaining approval for the study from the Non-Invasive Clinical Research Ethics Committee of Istanbul Medipol University Faculty of Medicine (dated 17.06.2021/679), the files of patients who underwent lumbosacral posterior fusion for different indications in the Department of Neurosurgery of Istanbul Medipol University Nisa Hospital between September 2017 and November 2020 were retrospectively reviewed. The patients' complaints, neurological examination findings, diagnoses, post-operative HU values, and intraoperative and post-operative complications were evaluated. Posterior stabilization and neuromonitoring were performed in all patients.

The HU values of the vertebral body obtained from lumbar CT, which is routinely used for surgical planning, were calculated using the picture archiving and communication system (PACS). For CT scans of all patients, a 126-channel CT scanner (Somatom Perspective model, Siemens) was used. A (PACS; Maroview, Infinitt Healthcare) operated in the Microsoft Windows environment was used to calculate the mean HU of the area of the vertebral body demarcated by the trabecular region. The HU measurement for each vertebra was obtained using the protocol described by Schreiber et al.[4] HU values were measured from two regions, medial and lateral to the S1 vertebra, and from three distinct locations of the vertebral body: just inferior to the superior cortex, mid-vertebral body, and superior to the inferior cortex. The largest possible elliptical area was drawn excluding the cortical edges so that the averages for each measurement were standardized (Fig. 1). A HU value was calculated for each lumbar vertebra by taking the mathematical average of HU values in three axial slices.

Patients who underwent lumbosacral fusion for various pathologies were included in this study. Pediatric patients, patients lost to follow-up, patients treated without posterior fusion, and patients with systemic diseases were excluded from the study.

Statistical Analysis

The Shapiro-Wilk test was used to check whether the variables follow a normal distribution. Continuous variables were expressed as mean±standard deviation and median (minimum-maximum) values. Categorical variables were expressed as n (%). Independent sample t-test or Mann–Whitney U-test was used for comparisons between gender groups according to the results of the normality test. SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) software was used for statistical analyses. $P<0.05$ was considered statistically significant.

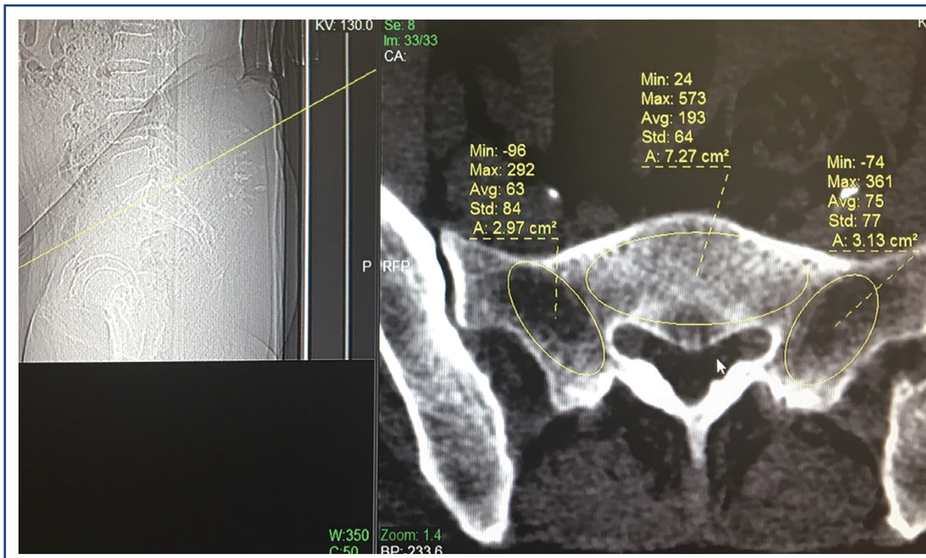

Figure 1. Hounsfield unit measurement with computed tomography. When the largest possible elliptical area excluding cortical edges is drawn using the Picture archiving and communication system system, the system automatically calculates the Hounsfield unit value

Table 1. Mean HU values

	n=50
Superior right	92.84±50.81
Superior corpus	224.92±67.53
Superior left	94.70±50.82
Middle right	77.60±47.95
Middle corpus	221.86±66.91
Middle left	79.68±45.52
Inferior corpus	79.04±56.49
Inferior corpus	219.14±72.61
Inferior left	74.60±46.75

Data are given as mean±standard deviation and median (minimum: maximum). HU: Hounsfield unit

Table 2. Comparisons between gender groups

	Gender		
	Female (n=37)	Male (n=13)	p
Age	61.46±9.20	56.38±13.43	0.137[a]
Superior right	86.03±44.60	112.23±63.43	0.110[a]
Superior corpus	218.27±70.84	243.85±55.17	0.215[b]
Superior left	88.95±45.41	111.08±62.98	0.179[a]
Middle right	72.08±43.93	93.31±56.89	0.172[a]
Middle corpus	218.16±70.48	232.38±56.73	0.515[a]
Middle left	75.00±46.43	93.00±41.65	0.224[a]
Inferior right	72.57±51.79	97.46±66.99	0.174[a]
Inferior corpus	215.41±75.07	229.77±66.74	0.545[a]
Inferior left	71.76±49.01	82.69±40.29	0.474[a]

Data are given as mean±standard deviation and median (minimum: maximum); [a]: Independent sample t-test; [b]: Mann–Whitney U-test

RESULTS

This study included a total of 50 patients, of whom 37 (74%) were female and 13 (26%) were male. The mean age of the patients included in the study was 60.14±10.55 years. The pre-operative lumbar CT-derived bone density values of the patients in HU are given in Table 1. The comparison between genders revealed no significant difference (p>0.05) (Table 2). The mean follow-up duration of the patients was 29.3±14.12 (range, 10–48) months.

There were differences between the HU values of the right and left vertebral facets and the corpus vertebra (p<0.001). The subgroup analyses revealed higher HU values in the corpus vertebra (213.5) than in the right (82.5) and left (80.5) vertebral facets (p<0.001 and p<0.001, respectively), with no difference between the right and left HU measurements (p>0.999) (Table 3).

Table 3. Comparisons between sacral HU values

	Right (n=150)	Corpus (n=150)	Left (n=150)
Measurement	82.50 (−39-235)	213.50 (72-394)	80.50 (−42-228)
	83.16±51.98	221.97±68.64	82.99±48.19
p			

Data are given as mean±standard deviation and median (minimum: maximum), cKruskal–Wallis test. HU: Hounsfield unit

Table 4. Diagnoses and levels of patients included in the study

Diagnosis	n
Spinal stenosis	23
Spinal stenosis+spondylolisthesis	13
Spinal stenosis+recurrent disk herniation	2
Spondylolisthesis	6
Recurrent disk herniation	2
Compression fracture	3
Level	
L2-L3-L4-L5-S1	10
L3-L4-L5-S1	13
L4-L5-S1	24
L5-S1	3

Twenty-three (46%) patients were operated for spinal stenosis. Fifteen patients had spondylolisthesis and recurrent disk herniation accompanying spinal stenosis. Posterior stabilization was performed in two (4%) patients due to recurrent disk herniation (Table 4).

L4-L5-S1 posterior stabilization was the most frequently performed surgery in all patients (48%). Ten (20%) patients underwent five-level stabilization and 3 (6%) patients underwent two-level stabilization. The S1 segment was included in stabilization in all patients. Superficial wound infection was observed in three (6%) patients, who were subsequently initiated on antibiotic therapy. None of the patients developed neurological deficits. Revision surgery was performed in one (2%) patient due to post-operative radicular pain and the L5 pedicle screw was revised.

DISCUSSION

In spinal surgery, stabilization/fusion is an effective treatment option preferred by surgeons in many cases. Knowledge of anatomy and osseous structure of the lower lumbar and sacral region is the most important factor that increases the success of surgery.[5]

Due to the spongy osseous structure of the sacrum, the placement of the stabilization system and providing the fusion pose challenges. The pelvic structures are divided into three regions according to the strength of their osseous structure: Region 1, the strongest area containing the vertebral bodies of S1; region 2, the ilium; and region 3, the lower sacral region, the least strong area.[6] There are potential trajectories through which the screw can be angulated for stabilization, including anterolateral into the ala, anterior into the junction of the vertebral body and the ala, and anteromedial into the sacral promontory. Among these, the anteromedial trajectory represents the strongest biomechanical basis for spinopelvic structures.[7] This region has the strongest bone support. In our study, the HU values measured from this region were also higher. Like Katsuura et al.,[7] we believe that the medial trajectory of the screw will increase the success of surgery.

In cases where it is necessary to place a sacral screw, knowing the sacral HU values before surgery is very important for estimating the trajectory of the screw and preparing the equipment accordingly (cemented surgery, cannulated screw, dynamic stabilization system, bone cutter, etc.).[8–10] Trajectory of the screw toward the lateral part with a lower HU value to avoid neurologic deficits will lead to screw loosening problems in follow-ups.[11,12] Pre-operative examination of the sacral HU values on CT and positioning the screw accordingly during surgery may prevent screw loosening that may occur in the long term.[12,13] In all of the patients in this series, the trajectory of S1 screws was medial. No screw loosening was observed in the follow-up of the patients.

In their study, Schreiber et al.[4] found the normal bone density of the lumbar region as 133.0 in HU measured with CT, with a mean lumbar HU value of 78.5 in the osteoporotic patients. Our study group had values close to the normal range reported in this study.

Although DEXA is the gold standard for determining bone density today, it has limitations. Reference standards may not be applied to all populations or patients and bone size is not taken into account.[14]

During our study period, the female and male patient groups were not homogeneously distributed, with the number of female patients being higher. This may be attributed to the more frequent screening of degenerative processes in women. In our series, this is believed to be due to the presence of fewer trauma cases and the higher incidence of degenerative pathologies.

The major limitations of our study are the relatively low number of patients, non-homogeneous distribution of female and male patients, short mean follow-up period, and the lack of sacral region values of DEXA, which is used to detect osteopenia and osteoporosis.

Obtaining the HU value from a region of interest on a CT scan is easy and can be done accurately and reliably with minimal time or educational requirements. It does not specifically require spinal CT as it can be performed on CT scans for chest, abdomen, or pelvis examinations.[2]

The HU value obtained from CT can warn the physician against metabolic bone diseases such as osteoporosis. Pre-operative HU evaluation may alter the content of clinical or surgical practice. It can provide a more accurate prognostic risk assessment profile to the surgeon and the patient.[2] Furthermore, it can enable the use of instruments with different features in bones with low right or left HU and the correct planning of the surgery in such a way that these spaces are not included in the instrumentation.

An advantage of using the HU value instead of DEXA is that it can be easily used in the cervical, thoracic and sacral spine, for which there are no DEXA standards. It can provide valuable information in fusion surgeries that require instrumentation of these regions. As in our study, dividing the vertebra into several regions and selecting the trajectory of the instrumentation according to the local HU values may increase the success of surgery. It can help us take additional measures (such as cemented screwing) by detecting the low bone density in the area where the instrumentation will be performed.

CONCLUSION

HU obtained from CT yielded results that allowed us to predict normal, osteopenic, and osteoporotic sacral segments. In this way, screw loosening, which leads to surgical failure, can be prevented. However, this issue needs to be investigated with retrospective double-blind studies.

Disclosures

Ethics Committee Approval: The study was approved by the Istanbul Medipol University Faculty of Medicine Non-Invasive Clinical Research Ethics Committee (No: 679, Date: 17/06/2021).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer reviewed.

Authorship Contributions: Concept: G.B.; Design: G.B.; Supervision: D.B.; Funding: None; Materials: G.B.; Data Collection or

Processing: G.B.; Analysis or Interpretation: D.B.; Literature Search: G.B., D.B.; Writing: D.B., G.B.; Critical review: G.B., D.B.

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

Financial Disclosure: The authors declared that this study received no financial support.

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