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Predicting Osteoporosis Using Thoracic Spine HU Values from Chest CT: Validation Across Multiple CT Scanner Vendors

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Abstract: *Osteoporosis is a common metabolic bone disease, and early bone mineral density (BMD) assessment is essential for timely intervention. Although dual-energy X-ray absorptiometry (DXA) is the diagnostic gold standard, its accuracy may be affected by spinal degenerative changes. Hounsfield unit (HU) measurements from thoracic CT scans offer a potential alternative for opportunistic screening, yet the consistency across different CT manufacturers remains unclear.This retrospective study included 207 patients who underwent thoracic CT and DXA within 60 days. Patients were grouped by CT manufacturer: Toshiba (n = 120), United Imaging (n = 57), and Siemens Healthineers (n = 30). HU values at T10 were measured, excluding cases with metabolic bone disease or image artifacts. One-way ANOVA compared HU values among groups, and Pearson correlation evaluated associations with the lowest DXA T-score.Mean HU values were: Toshiba 191.8 ± 60.55, United Imaging 172.8 ± 58.62, Siemens 172.2 ± 63.77 (P = 0.081). HU values correlated significantly with T-scores (r = 0.6213–0.6588), with no significant intergroup differences (P = 0.940).Thoracic HU values are consistent across CT devices and correlate well with BMD, supporting their use as a reliable, cost-effective tool for opportunistic osteoporosis screening.*

Keywords: *Osteoporosis, Bone Mineral Density (BMD), Hounsfield Unit (HU), Thoracic CT*

1. Introduction

Osteoporosis is a metabolic bone disease with a high global prevalence, mainly characterized by microstructural destruction of bone tissue, a progressive decrease in bone mass, and a marked increase in bone fragility [1]. Epidemiological studies have shown that the disease burden of osteoporotic fractures in China is rapidly increasing, with the number of new cases expected to exceed 5.9 million by 2050, and the associated healthcare expenditures projected to surpass $20 billion[2-3]. As an important biomarker for the diagnosis and prognosis of osteoporosis, the quantitative assessment of bone mineral density (BMD) is crucial for disease screening. Early intervention based on accurate identification of individuals with abnormal BMD can effectively reduce the risk of fragility fractures and improve patient outcomes.

In clinical screening for osteoporosis, dual-energy X-ray absorptiometry (DXA) plays a valuable role in fracture risk assessment and is regarded as the gold standard for bone density testing [4]. However, recent evidence-based studies suggest that approximately 6.3% of low-trauma fracture cases occur in individuals whose BMD levels do not meet the diagnostic criteria for osteoporosis (T-score > -2.5) [5]. The pathophysiology of this clinical phenomenon is closely associated with the technical limitations of DXA: ectopic calcifications,such as degenerative vertebral osteophytes, structural changes in the spine, and vascular calcification,can lead to abnormally elevated photon absorption values, thereby compromising the accuracy of BMD measurements at specific anatomical sites, particularly the lumbar spine [6-7].This suggests that relying solely on DXA-based T-score assessments may fail to fully capture regional alterations in the biomechanical properties of bone tissue.

Opportunistic screening for osteoporosis can be achieved through quantitative Hounsfield unit (HU) analysis based on existing imaging data obtained during routine computed tomography (CT) examinations. This technique significantly enhances the efficiency of detecting abnormal bone metabolism without the need for additional imaging procedures, ionizing radiation exposure, or extra appointment scheduling [8].Romme et al. measured mean HU values at the 4th, 7th, and 10th thoracic

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vertebrae on routine chest CT scans in patients with chronic obstructive pulmonary disease (COPD), and compared them with bone mineral density (BMD) measurements obtained from dual-energy X-ray absorptiometry (DXA) of the hips and lumbar spine (L1 to L4). Their findings confirmed that HU values derived from thoracic CT scans can serve as a reliable indicator for detecting reduced BMD [9].However, little research has been conducted on whether variations in scanning equipment affect the accuracy of HU-based screening.

In this study, we will conduct a retrospective cohort analysis to compare the predictive performance of Hounsfield unit (HU) values measured at the 10th thoracic vertebra on chest CT images acquired using different CT scanners for detecting bone loss. This study aims to determine whether the HU-based method is a reliable tool for screening bone abnormalities.

2. Materials and methods

2.1 Patients' population

We reviewed the medical and radiologic records of all patients who underwent dual-energy X-ray examinations at our institution between October and December 2024.Inclusion criteria: (1) Participants aged 18 years or older; (2) availability of chest CT data within 60 days of the dual-energy X-ray examination.

Exclusion criteria: (1) incomplete imaging data (e.g., chest CT did not include the 10th thoracic vertebra); (2) presence of diseases affecting bone metabolism (e.g., hyperthyroidism) or use of medications known to affect bone metabolism (e.g., glucocorticosteroids); (3) history of surgery involving the 10th thoracic vertebra or the left hip; and (4) severe spinal deformities.Patients were categorized into three groups based on the scanning equipment used. There were no significant differences in age, sex, or BMI among the groups. In total, data from 207 patients met the study's inclusion criteria.This study was approved by the Ethics Committee (ZB-KYIRB-AF/SC-08/02.0). Informed consent was waived due to the retrospective nature of the study.

2.2 DEXA data acquisition

Spine (L1–L4) and hip BMD T-scores were measured using a Horizon-Wi DXA scanner (Hologic, Inc., Waltham, MA). The lower of the two T-scores was selected as the reference standard. One of the bone densitometry devices was calibrated daily according to standard protocols prior to use.

2.3 Measurement of vertebral HU

According to previous studies and following the method described by Zhang et al. [10], images were retrieved from the PACS server. The measurement site was identified using the localization phase of the scan. The region of interest (ROI) was then manually outlined on the sagittal reconstruction of the corresponding vertebral trabeculae. The ROI was required to be as large as possible while excluding the vertebral cortical bone, surrounding venous plexus, and other adjacent structures.All chest CT scans were performed using the following parameters: tube voltage, 120 kV; tube current, automatic; slice thickness, 1.0 mm.

3. Statistical analysis

Data analysis was performed using R version 4.4.2 (R Core Team, 2024) within the RStudio IDE (version 2024.12.1+563; RStudio Team, 2024). Categorical variables are presented as proportions or ratios, while continuous variables are expressed as means and standard deviations. The Kolmogorov-Smirnov test was used to assess whether continuous variables followed a normal distribution. For normally distributed data, between-group comparisons were conducted using the Student's t-test; for non-normally distributed data, the Mann-Whitney U test was applied. When comparing more than two groups, one-way analysis of variance (ANOVA) was used.The correlation between DXA T-scores and Hounsfield Unit (HU) values was illustrated using scatter plots and quantitatively assessed using Pearson correlation coefficients. Differences between correlation coefficients were evaluated using Fisher's Z transformation.

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4. Results

Table 1: Sample size, mean CT values and one-way ANOVA results for different CT manufacturers.

CT system	Sample size (n)	HU value	*P*
Toshiba	120(58.0%)	191.8 ± 60.55	0.081
United Imaging Healthcare	57(27.6%)	172.8 ± 58.62	
Siemens Healthineers	30(14.4%)	172.2 ± 63.77	

A total of 207 patients were included in this study. The data were categorized into three groups based on the chest CT scanning devices used. Of these, 120 patients were scanned with Toshiba devices, yielding a mean HU value of 191.8±60.55; 57 patients were scanned with United Imaging Healthcare devices, with a mean HU value of 172.8±58.62; and 30 patients were scanned with Siemens Healthineers devices, with a mean HU value of 172.2±63.77.There was no statistically significant difference in HU values among the three device groups (Table 1, P = 0.081). Pairwise comparisons between the three groups also showed no significant differences in HU values (Figure 1).

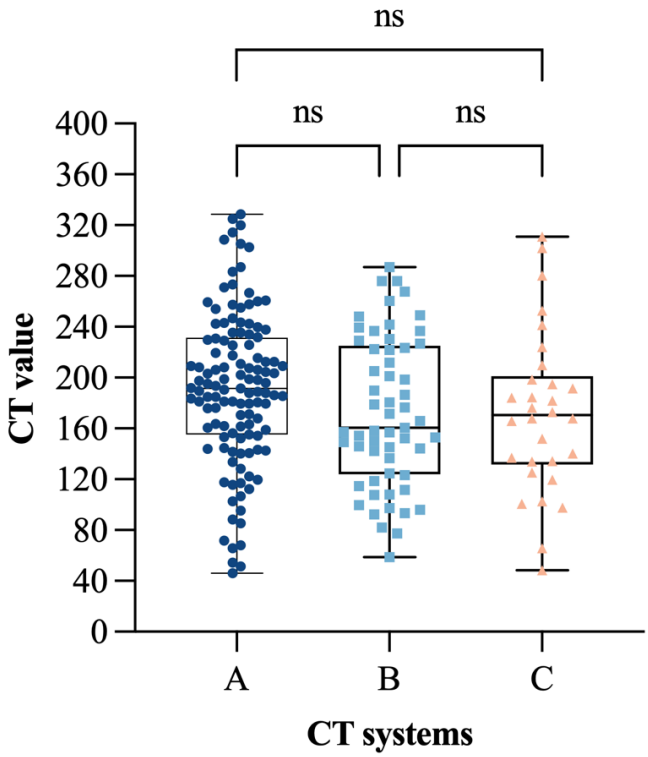

Figure 1: Distribution of CT values for samples from three different manufacturers' sources, analyzed by ANOVA in pairs.A: Toshiba, B: United Imaging Healthcare, C: Siemens Healthineers.

The HU values from all three devices were positively correlated with the minimum T-score (Figure 2). The strongest correlation was observed with the Siemens Healthineers device (r = 0.6588,P < 0.001),followed by the Toshiba device (r = 0.6528,P < 0.001), and the United Imaging Healthcare device (r = 0.6213,P < 0.001). After applying Fisher's Z transformation to compare the correlation coefficients, no significant differences were found among the three groups (Table 2, P = 0.940).

Table 2: Fisher's Z-transformations were performed on the Pearson correlation coefficients, r, of CT and T- score values from three different manufacturer sources, and the variability of the three data sets was analyzed using ANOVA.r1: Toshiba, r2: United Imaging Healthcare, and r3: Siemens. Healthineers.

Correlation coefficient	Fisher's Z	*P*
r1	0.777	0.940
r2	0.726	
r3	0.789	

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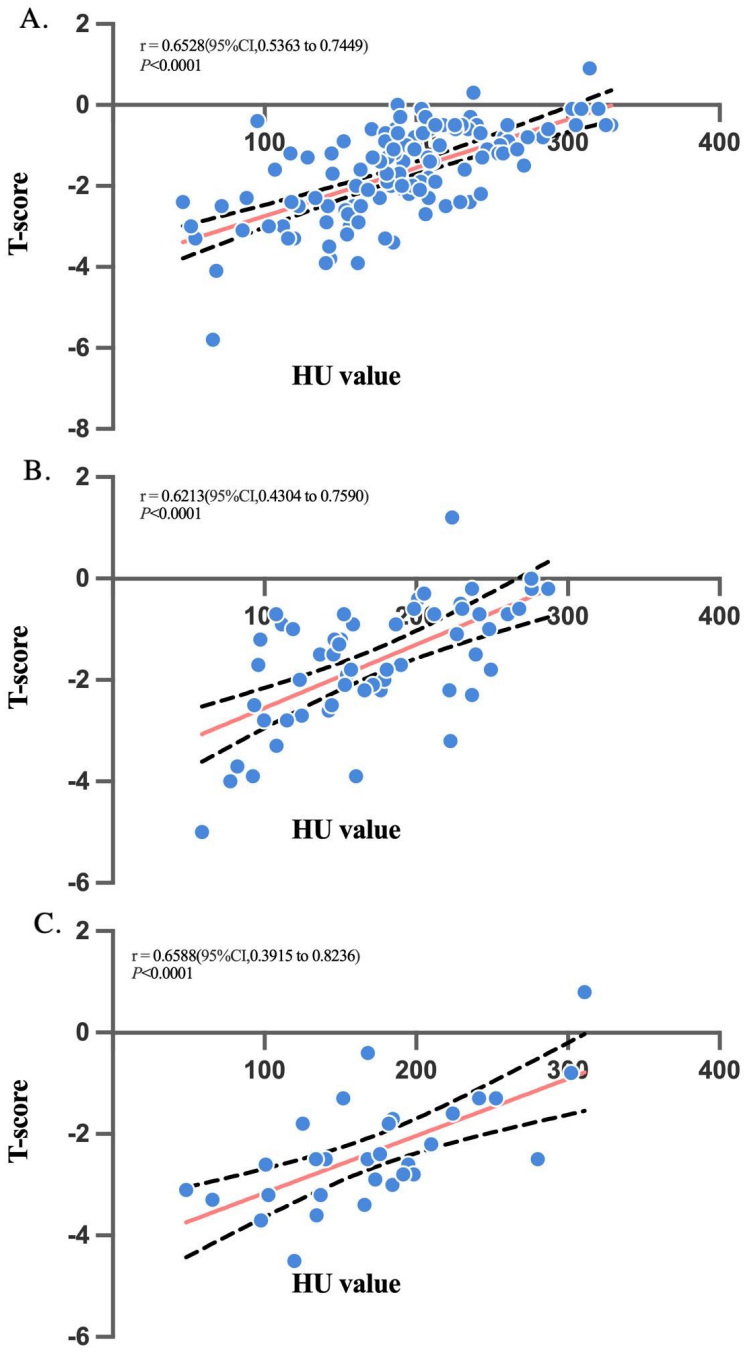

Figure 2: Scatterplot of correlation between HU values and T- scores for samples from three different vendor sources.A: Toshiba, B: United Imaging Healthcare, C: Siemens Healthineers.

5. Discussion

We compared the HU values of chest CT images from three different CT device manufacturers with the minimum T-score for bone mineral density. A one-way ANOVA was conducted to evaluate differences in mean HU values among the three device groups, and the results showed no statistically significant differences. Additionally, the HU values from all three manufacturers demonstrated a similar degree of correlation with the minimum T-score.

On the one hand, although the prevalence of osteoporosis is rising, only 27 percent of suspected cases undergo DXA examination [11]. On the other hand, for patients requiring instrumented spinal fusion, although many surgeons recommend obtaining DXA results preoperatively, a survey of practicing spine surgeons revealed that fewer than half routinely do so in clinical practice [12]. DXA

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remains the gold standard for the diagnosis and treatment of osteoporosis, as defined by the WHO. However, its accuracy can be compromised by factors such as vascular calcification, synovial hyperplasia, and degenerative osteophytes, potentially leading to false-negative results [13].Quantitative CT (QCT) is another diagnostic tool for osteoporosis that enables early detection. However, its widespread use in clinical settings is limited due to high equipment costs, complex post-processing requirements, and concerns about radiation exposure. In contrast, an increasing number of studies support the opportunistic use of conventional CT as a screening method for identifying patients at high risk for osteoporosis when DXA is unavailable [14-16].

Chest CT is a commonly used imaging modality, primarily for lung cancer screening, and the population undergoing chest CT overlaps significantly in age with those at risk for osteoporosis. Moreover, chest CT is frequently performed in hospitalized patients, making it a practical and cost-effective resource for opportunistic osteoporosis screening [17-18]. Recent studies have demonstrated the feasibility of using thoracic spine images from chest CT to predict osteoporosis [19-20]. The findings of our study further confirm that HU values obtained opportunistically from thoracic CT are not significantly affected by differences in CT scanner models and that this approach offers good generalizability for detecting bone abnormalities.

Nonetheless, this study has several limitations. First, although the study was retrospective in nature, the inclusion of cases was prospectively restricted to high-quality data to control for confounding variables such as sex and body weight, which may have introduced selection bias. Second, the sample size was limited by the number of available CT devices, and the study was conducted at a single center, necessitating larger multi-center studies to validate the findings. Lastly, HU values were obtained from only a single vertebral level in this study; future research should extend the analysis to multiple vertebral levels to evaluate the consistency and reliability of this method across different anatomical sites.

6. Conclusion

Measurement of thoracic spine HU values on chest CT provides a device-independent and cost-effective method for opportunistic osteoporosis screening.

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