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Opportunistic Screening for Osteoporosis Using Routine Chest CT in the Elderly

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Abstract: *Osteoporosis is a major public health concern, particularly in the elderly population, due to its association with high fracture risk and mortality. This study aimed to evaluate the diagnostic value of T12 Hounsfield unit (HU) values from chest CT scans for identifying osteoporosis and to explore their correlation with bone mineral density (BMD) T-scores. A total of 109 patients aged 60 and above who underwent both DXA and chest CT were included. The results showed that T12 HU values significantly correlated with BMD T-scores ($r = 0.606$, $P < 0.001$). Three models were evaluated: Model A (T12 HU only), Model B (Age + Gender + BMI), and Model C (T12 HU + Age + Gender + BMI). Model C demonstrated the highest diagnostic performance (AUC = 0.872), outperforming the other models. Using a T12 HU threshold of 155.8, the sensitivity was 80.6%, specificity was 70.3%, and the positive and negative predictive values were 75.9% and 81.3%, respectively. These findings suggest that T12 HU values, derived from routine chest CT, can serve as an effective tool for osteoporosis screening, particularly when combined with demographic factors such as age, gender, and BMI.*

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

1. Introduction

Among older adults worldwide, osteoporosis affects about 35.3% of women and 12.5% of men. In China, the prevalence among individuals aged 50 years and older is 16.96%, with women disproportionately affected [1]. Evidence also shows that individuals with osteoporosis face a significantly higher risk of all-cause mortality compared with those without the condition [2]. These findings highlight the pressing public health importance of early identification and timely intervention for osteoporosis.

Bone mineral density (BMD) is a central indicator of bone health and fracture risk, and remains one of the primary diagnostic criteria for osteoporosis [3]. The International Society for Clinical Densitometry (ISCD) currently recommends dual-energy X-ray absorptiometry (DXA) of the lumbar spine and hip as the preferred method for BMD assessment [4]. DXA offers precise measurements, allows fracture risk prediction, and provides excellent stability and reproducibility [5]. However, its reliance on specialized equipment and the lack of consistent osteoporosis management policies in some regions have contributed to persistently low screening rates among eligible populations [6]. More recently, computed tomography (CT)–derived Hounsfield unit (HU) values, which reflect tissue attenuation, have been shown to predict osteoporosis risk, especially in settings where conventional BMD testing is not feasible [7]. Unlike DXA, this approach requires no additional examination, thereby reducing healthcare costs and avoiding extra radiation exposure.

Chest CT is widely used for lung cancer screening and follow-up of pulmonary nodules, but it also captures structural information of the thoracic spine [8]. Among these vertebrae, the 12th thoracic vertebra (T12) is a clinically common site of osteoporotic fractures, and such fractures are closely linked to BMD [9]. By reconstructing chest CT data to obtain sagittal views of the thoracic spine, previous studies have demonstrated the utility of this approach for evaluating vertebral morphology and identifying individuals at high risk of low BMD [10]. Establishing a reliable correlation between T12 HU values on chest CT and BMD would therefore provide an economical and practical means of assessing bone quality without the need for additional imaging. This strategy could improve early detection of osteoporosis while adding clinical value through the secondary use of routine chest CT scans.

The aim of this study is to examine the relationship between T12 HU values obtained from chest CT

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reconstructions and BMD, and to assess the diagnostic performance of T12 HU values for identifying osteoporosis in older adults.

2. Materials and methods

2.1 Study population

This retrospective study analyzed clinical and imaging data from 421 patients who underwent DXA at our hospital between July 2024 and January 2025. Eligible participants were aged 60 years or older and had completed a chest CT scan within 30 days of their DXA examination. Patients were excluded if they met any of the following criteria: (1) incomplete imaging data, including chest CT scans not covering all 12 thoracic vertebrae or incomplete DXA results; (2) vertebral fractures or severe spinal deformities involving T11, T12, or the left hip; or (3) prior surgical intervention on T11, T12, or the left hip.

After applying these criteria, 109 patients were included in the final analysis. The study protocol was reviewed and approved by the institutional ethics committee (ZB-KYIRB-AF/SC-08/02.0). Owing to its retrospective design, informed consent was waived.

Baseline characteristics were extracted from electronic medical records and included gender, age, body mass index (BMI), history of diabetes, and history of hyperlipidemia.

2.2 Radiographic data acquisition

DXA measurements were obtained using a Horizon-Wi scanner (Hologic, Waltham, MA) with daily calibration. Trained technologists acquired standardized scans of the lumbar spine (L1–L4) and left hip, defined regions of interest (ROIs), and generated automated outputs. Participants were classified into normal(T-score $\geq$ -1.0), osteopenia(-1.0 > T-score > -2.5), or osteoporosis(T-score $\leq$ -2.5) groups according to the lowest T-score.

Chest CT scans were performed primarily on an Aquilion PRIME TSX-303A system (Canon Medical Systems, Tochigi, Japan). Fixed parameters included 120 kVp tube voltage, automatic tube current modulation, and 1-mm reconstructions using a soft-tissue kernel. Scanners underwent daily calibration to ensure HU accuracy.

HU measurements were conducted on the Picture Archiving and Communication System (PACS). Using the ROI tool, operators placed ROIs on the mid-sagittal plane of the T12 vertebral body to extract HU values. ROIs were confined to trabecular bone and excluded cortical bone and focal lesions (e.g., hemangiomas, venous plexus, Schmorl's nodes). Each measurement was repeated one week later, and the mean of the two readings was used for analysis.

3. Statistical analysis

Statistical analysis and graph generation were performed using GraphPad Prism 10 (GraphPad Software, LLC, California, USA). Continuous variables are presented as means ± standard deviation, while categorical variables are reported as percentages. Demographic and radiographic data were categorized based on DXA results. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Intergroup differences were analyzed using chi-square tests (or Fisher's exact test) for categorical data and one-way analysis of variance (ANOVA) for continuous variables. Correlations between variables were assessed using Pearson's correlation coefficient. Multivariate logistic regression was used to calculate odds ratios. Receiver operating characteristic (ROC) curves were constructed to evaluate the diagnostic performance of T12 HU values for osteoporosis, determining the optimal cutoff point, area under the curve (AUC), as well as the negative predictive value (NPV) and positive predictive value (PPV).

4. Results

4.1 Participant characteristics and HU value

Baseline characteristics and radiographic data across groups (Table 1) showed that patients in the osteoporosis group were older, had a significantly higher proportion of females, and exhibited markedly

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lower BMI compared to the other groups ($P < 0.05$). No significant differences were found among the groups in terms of diabetes, hyperlipidemia, long-term glucocorticoid use, or alcohol consumption history ($P > 0.05$). Regarding radiographic indicators, the osteoporosis group had significantly lower minimum T-scores and T12 vertebral HU values compared to both the normal and osteopenia groups ($P < 0.001$).

Table 1: The baseline and radiographic data.

Baseline data	Non-osteoporosis(n=61)		Osteoporosis(n=48)	*P*
	Normal(n=37)	Osteopenia(n=24)		
Age (y)	69.1 ±6.9	66.8±6.0	73.8±10.2	0.009
Gender				<0.001
Male	23 (62.2%)	15 (62.5%)	7 (14.6%)	
Female	14 (37.8%)	9 (37.5%)	41 (85.4%)	
BMI(Kg/m^2)	25.0 ±3.0	24.4±2.6	22.2±2.2	<0.001
Diabetes	14 (37.8%)	14 (58.3%)	21 (43.8%)	0.283
Hyperlipidemia	14 (37.8%)	13 (54.2%)	23 (47.9%)	0.426
Long-term steroid use	5 (13.5%)	3 (12.5%)	8 (16.7%)	0.885
Alcohol abuse	3 (8.1%)	1 (4.2%)	1 (2.1%)	0.517
Radiographic data				
Min-T-score	-0.6 ±0.4	-1.7 ±0.4	-3.4 ±0.7	<0.001
T12 HU value	171.6 ±41.6	147.6 ±37.3	104.2 ±39.2	<0.001

4.2 Correlations between HU value and min-T-score

T12 HU values exhibited a significant positive correlation with minimum T-scores (r = 0.606, 95% CI: 0.471–0.713, $P < 0.001$). As T12 HU values increased, minimum T-scores also increased, suggesting that T12 HU is an effective indicator of bone density levels (Figure 1).

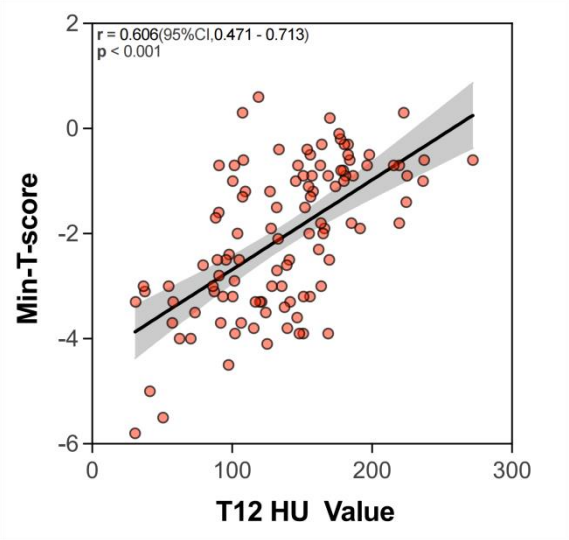

Figure 1: Scatter plot. Correlation between the minimum T score and T12 HU value.

4.3 Multivariate Logistic Regression Analysis

The regression results and diagnostic performance of the three models (Table 2) indicated that in Model A (T12 HU only), T12 HU was significantly associated with osteoporosis (OR = 0.970, 95% CI: 0.956–0.982, P < 0.001), with an AUC of 0.818. In Model B (Age + Gender + BMI), female gender (OR = 0.321, P = 0.011) and BMI (OR = 0.786, P = 0.005) were significant factors, yielding an AUC of 0.748, lower than that of Model A. In Model C (T12 HU + Age + Gender + BMI), T12 HU (OR = 0.967, P < 0.001) and BMI (OR = 0.758, P < 0.001) remained independent predictors, while age and gender were not significant. Model C achieved the highest AUC of 0.872 (95% CI: 0.809–0.935), outperforming Models A and B (P = 0.008 compared to Model B).

T12 HU alone demonstrated strong discriminatory ability, while the clinical variable model (age,

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gender, BMI) showed weaker discrimination. Model C, which combined T12 HU with clinical characteristics, exhibited the best diagnostic performance.

Table 2: Performance of models in distinguishing osteoporosis and non-osteoporosis.(Model A: T12 HU ; Model B: Age + Gender + BMI; Model C: T11 HU + Age + Gender + BMI).

Characteristic	Model A			Model B			Model C		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
T12 HU value	0.970	0.956 - 0.982	<0.001	—	—	—	0.967	0.950 - 0.981	<0.001
Age	—	—	—	1.016	0.964 - 1.075	0.555	0.942	0.874 - 1.01	0.098
Gender(Female)	—	—	—	0.321	0.131 - 0.767	0.011	0.508	0.179 - 1.443	0.200
BMI	—	—	—	0.786	0.656 - 0.922	0.005	0.758	0.608 - 0.92	<0.001
AUC(95% CI)	0.818 (0.733–0.902)			0.748 (0.649 – 0.848)			0.872 (0.809 – 0.935)		
P(ref. Model A)	—			0.304			0.078		
P(ref. Model B)	—			—			0.008		

4.4 ROC curve analysis

Model A (T12 HU) achieved an AUC of 0.818, Model B (Age + Gender + BMI) achieved an AUC of 0.748, and Model C (T12 HU + Age + Gender + BMI) demonstrated the highest AUC of 0.872 (Figure 2). Overall, Model C exhibited superior discriminatory ability compared to Models A and B, reinforcing the role of T12 HU values as a central diagnostic factor. Combining these with demographic characteristics further improved diagnostic accuracy.

With a diagnostic threshold of 155.8 for T12 HU, the sensitivity for identifying osteoporosis was 0.806 (95% CI: 0.700–0.881), and the specificity was 0.703 (95% CI: 0.542–0.825). The positive predictive value (PPV) was 75.9%, and the negative predictive value (NPV) was 81.3%. These results suggest that T12 HU values are a reliable and effective reference for diagnosing osteoporosis in clinical settings (Table 3).

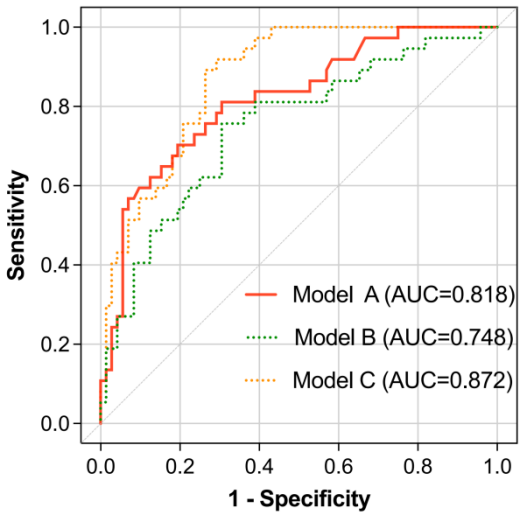

Figure 2: Multiple ROC curve analysis was performed to assess osteoporosis and non-osteoporosis.

Table 3: Diagnostic value of HU thresholds in differentiating between osteoporosis and non-osteoporosis.

Characteristic	Distinguishing osteoporosis from non-osteoporosis				
	Cutoff	Sensitivity (95% CI)	Specificity (95% CI)	PPV %	NPV %
T12 HU value	155.8	0.806 (0.700 – 0.881)	0.703 (0.542 – 0.825)	75.9	81.3

5. Discussion

This study focused on the T12 vertebra in chest CT scans. By delineating ROIs on chest CT images and controlling for potential confounding factors, we evaluated the role of thoracic vertebral HU values

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in diagnosing osteoporosis in the elderly population.

Osteoporosis is often asymptomatic, and many individuals only become aware of their condition after experiencing an osteoporotic fracture [11]. The standard method for diagnosing osteoporosis is BMD measurement. While the World Health Organization (WHO) recognizes DXA as the gold standard for BMD assessment, screening rates among eligible patients remain below 27% [12]. In Europe, there is no unified approach for identifying patients at high risk of fractures [13]. To enhance osteoporosis diagnosis and reduce fracture risk, the WHO has recommended the exploration of alternative technologies [14].

Recent studies have shown that HU values offer a simple and effective method for assessing bone quality [15]. Romme et al. [16] measured the average HU values of the 4th, 7th, and 10th thoracic vertebrae in routine chest CT scans of patients with chronic obstructive pulmonary disease (COPD) and compared them with the lowest T-scores obtained from DXA scans of the hip and lumbar spine (L1 to L4). Their findings confirmed a correlation between reduced HU values in the thoracic spine and decreased BMD. However, despite T12 being the most commonly affected by osteoporotic fractures, there is a limited body of research evaluating its BMD. Therefore, this study focuses on analyzing the relationship between T12 HU values and the minimum T-score from DXA, and assessing their respective predictive capabilities for osteoporosis.

In our analysis of differences and correlations, we observed that BMI, age, and gender could confound the results. Yang et al. [17] also confirmed a correlation between age and HU values. Similarly, Pan et al. [18] explored the impact of age and gender on the screening efficacy of thoracolumbar HU values from low-dose chest CT (LDCT) for low BMD and osteoporosis. In our multivariate logistic regression model, BMI was also identified as a significant factor. The ROC curve analysis showed that the model incorporating BMI, age, and gender achieved the highest AUC. This suggests that when using HU values to assess bone mass, it is crucial to account for the patient's BMI, age, and gender.

The findings of this study suggest that T12 HU values are highly effective in diagnosing osteoporosis. However, it is important to note that optimal diagnostic thresholds can vary across studies. Xue et al. [19] reported a T12 HU threshold of approximately 85.7 HU to distinguish bone reduction from osteoporosis, while Pan et al. [18] recommended ≤125 HU as the threshold for differentiating osteoporosis from non-osteoporosis. Other studies have suggested that the optimal threshold may lie within the range of 90–110 HU [20]. These discrepancies can primarily be attributed to differences in baseline characteristics, such as age distribution and BMI proportions, across study populations. Additionally, variations in ROI measurement techniques, BMD reference standards (e.g., DXA or QCT), and ethnic diversity within study cohorts may also influence the results [21][22].

This study has several limitations. First, the small sample size and single-center design may introduce selection bias, which could affect the generalizability and robustness of our conclusions. Second, only one vertebral measurement (T12) was selected, and the screening capability across multiple vertebrae remains to be validated. Future research should consider multi-center, large-sample, and prospective designs, incorporating additional vertebral segments and diverse imaging scanners to enhance the study and confirm its generalizability. Despite these limitations, our study demonstrates the feasibility of using HU values from reconstructed thoracic CT images to predict bone mass loss. We also hope that this research provides clinicians with an additional reference tool for assessing osteoporosis in middle-aged and elderly populations.

6. Conclusion

This study demonstrates that T12 HU values are highly effective in diagnosing osteoporosis. Using a threshold of 155.8, the sensitivity was 80.6%, specificity was 70.3%. These findings suggest that T12 HU can serve as a reliable reference for osteoporosis screening.

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