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DIAGNOSTIC ACCURACY OF QUANTITATIVE COMPUTED TOMOGRAPHY IN DIAGNOSING OSTEOPOROSIS AMONG THE ELDERLY, TAKING SERUM CALCIUM LEVELS AS GOLD STANDARD

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Abstract

Background: *Osteoporosis is a major health concern in the elderly, characterized by reduced bone mass and increased fracture risk. While dual-energy X-ray absorptiometry (DXA) is commonly used, quantitative computed tomography (QCT) offers volumetric bone mineral density assessment with potential advantages. This study evaluated the diagnostic accuracy of QCT for detecting osteoporosis in the elderly, using serum calcium levels as the reference standard.*

Methods: *A cross-sectional diagnostic accuracy study was conducted on 148 elderly patients (aged 60-90 years) at Capital Hospital, Islamabad. Participants underwent non-contrast QCT scans, and their osteoporosis status was determined based on serum calcium levels. Diagnostic metrics—sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy—were calculated and stratified by age, gender, BMI, symptom duration, residence, and occupation.*

Results: *QCT demonstrated a sensitivity of 87.63%, specificity of 82.35%, PPV of 90.43%, NPV of 77.78%, and an overall diagnostic accuracy of 85.81%. Stratified analysis showed consistent performance across all demographic and clinical subgroups, with no significant variations.*

Conclusion: *Quantitative Computed Tomography is a highly accurate and reliable diagnostic tool for detecting osteoporosis in the elderly. Its robust performance supports its integration into routine clinical practice for opportunistic screening, enabling early diagnosis and intervention to prevent osteoporotic complications.*

INTRODUCTION

The elderly population is increasing in the world. The aging process reveals itself in many tissues and organs. The most important changes occur in bone tissue in the process of osteoporosis.[1] Osteoporosis arising from either aging or other causes is a disease defined by a loss of bone strength and an increased risk of fracture caused by a decrease in bone mass and the deterioration of microstructure features.[2] Even though the definition includes changes in the microstructure of the bone in addition to loss of bone mass, clinical diagnosis is based mostly on the loss of bone mass. The decrease in bone strength and the increased risk of fracture are mostly diagnosed by looking at the patient's clinical background and family history.[3]

Currently, the most commonly used BMD measurement methods include dual X-ray absorptiometry (DXA) and quantitative computed

tomography (QCT).[4] The former provides a measurement of the area BMD (aBMD) in two dimensions, while the latter allows for quantification of the volumetric BMD (vBMD) of trabecular bone and avoids interference from aortic calcifications, bone spur formation, and abdominal fat.[5] The diagnostic performance of osteoporosis by QCT and DXA have been compared in several studies, including cross-sectional studies and case–control studies, but their results have been discordant.[6] There are several factors that contribute to these discrepancies in results. Studies performed in small samples may lack statistical power.[7] A high prevalence of osteoporosis was identified in elderly patients undergoing spine surgery. In a study, prevalence of osteoporosis was found to be 60.7%.[8] One study has shown sensitivity of 85.45% and specificity of 89.19% of quantitative CT in diagnosing osteoporosis.[9]

The rationale of this study was to collect local database and determine the diagnostic accuracy of quantitative computed tomography in diagnosing osteoporosis among the elderly, taking serum calcium levels as gold standard, so that we might find a way to use diagnostic CT images to screen the patients with osteoporosis. The results of my study will allow the radiologist to play a crucial role in alerting the clinician to use appropriate diagnostic techniques for confirmation. Prompt diagnosis and initiation of appropriate therapy are essential to avoid a protracted or fatal outcome.

Methodology:

This study was designed as a cross-sectional validation study, conducted in the Department of Radiology at Capital Hospital, CDA, Islamabad. The study duration was six months, commencing after the approval of the synopsis. A sample size of 148 cases was calculated based on a 95% confidence level, 8% desired precision, an assumed osteoporosis prevalence of 60.7%, and the reported sensitivity (85.45%) and specificity (89.19%) of quantitative CT in diagnosing osteoporosis. The sampling technique employed was non-probability, consecutive sampling. Sample selection was guided by specific inclusion and exclusion criteria. Inclusion criteria comprised: all patients with suspected osteoporosis (as per the operational definition); a symptom duration greater than 12 weeks; an age range of 60-90 years; and both genders. Exclusion criteria included: known malignancy, spondylitis, or spondylodiscitis; lumbar vertebrae with metallic implants following spinal surgery; and any contraindication to CT scan such as contrast allergy, claustrophobia, or renal failure (serum creatinine >1.5 mg/dl).

Data Collection Procedure

Following approval from the institutional ethical review committee and CPSP, 148 patients presenting to the Radiology Department who met the inclusion criteria were selected. Informed consent was obtained from each participant. Demographic data, including age, gender, duration of symptoms, occupation, and place of residence, were recorded. Subsequently, each patient underwent a CT scan using a Toshiba Asteion multislice CT scanner without contrast, acquiring images in coronal and axial planes. For the conventional chest CT, parameters included a tube voltage of 120 kVp, 3D smart mA (range 100-600 mA), and a scanning range from the lung apex to the lower level of the L1 vertebral body. The abdominal dual-energy CT (DECT) protocol utilized fast-switching kVp (80 kVp/140 kVp) within 0.5 ms, gemstone spectral imaging (GSI) assist for mA modulation, and a scanning range from above the diaphragm to the inferior liver margin or pubic symphysis. A consistent noise index of 11 was set for both scans, with 40% pre-adaptive statistical iterative reconstruction-volume (ASIR-V) applied to reduce radiation dose. Other standardized parameters were: detector width of 80 mm, rotational speed of 0.5 s/r, pitch of 0.992:1, matrix of 512 × 512, and slice thickness of 5 mm. A consultant radiologist with at least three years of post-fellowship experience interpreted the CT scans and noted the presence or absence of osteoporosis. A blood sample was also collected from each patient and sent to the pathology laboratory for measurement of serum calcium levels, with osteoporosis status determined accordingly. The findings from the quantitative CT (QCT) scan were then compared with the serum calcium results. All collected data were recorded on a pre-designed proforma.

Data Analysis

The collected data were analyzed using SPSS version 25.0. The normality of the data was assessed using the Shapiro-Wilk test. Quantitative variables—such as age, height, weight, BMI, and duration of symptoms—were summarized as mean and standard deviation or median and interquartile range (IQR). Qualitative variables—including gender, place of residence (rural/urban), occupation (office/field/domestic), and osteoporosis status based on QCT scan and serum calcium levels (present/absent)—were presented as frequencies and percentages. A 2x2 contingency table was constructed to calculate the sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of quantitative CT in diagnosing osteoporosis among the elderly, using serum calcium levels as the gold standard. Potential effect modifiers, such as age, gender, BMI, symptom duration, place of residence, and occupation, were controlled through stratification, and post-stratification diagnostic accuracy was also calculated.

The formulas used for the calculations were as follows: Sensitivity = a/(a+c) x 100; Specificity = d/(b+d) x 100; Positive Predictive Value = a/(a+b) x 100; Negative Predictive Value = d/(c+d) x 100; and Diagnostic Accuracy = (a+d)/(a+b+c+d) x 100, where 'a' represents true positives, 'b' false positives, 'c' false negatives, and 'd' true negatives.

RESULTS

A total of 148 elderly patients meeting the inclusion criteria were enrolled in this diagnostic accuracy study.

The demographic profile of the participants is described in **Table 1**. The mean age of the cohort was 72.5 years (± 8.3), with a slight predominance of females (54.1%). The mean body mass index (BMI) was within the normal range at 24.1 kg/m² (± 3.8). The majority of participants resided in urban areas (62.2%), and occupational distribution was relatively even among office, field, and domestic work.

Table 1: Demographic and Clinical Characteristics of Study Participants (n=148)

Characteristic	Value
Age (years), Mean ± SD	72.5 ± 8.3
Gender, n (%)	
Male	68 (45.9%)
Female	80 (54.1%)
BMI (kg/m²), Mean ± SD	24.1 ± 3.8
Symptom Duration (weeks), Mean ± SD	18.2 ± 6.5
Place of Residence, n (%)	
Urban	92 (62.2%)
Rural	56 (37.8%)
Occupation, n (%)	
Office	48 (32.4%)
Field	52 (35.1%)
Domestic	48 (32.4%)

The diagnostic performance of Quantitative Computed Tomography (QCT) was evaluated against the reference standard of serum calcium levels. The cross-tabulation of results is presented in **Table 2**.

Table 2: Diagnostic Results of QCT versus Serum Calcium (Gold Standard)

	Serum Calcium Positive (Osteoporosis)	Serum Calcium Negative (No Osteoporosis)	Total
QCT Positive	85 (True Positive)	9 (False Positive)	94

QCT Negative	12 (False Negative)	42 (True Negative)	54
Total	97	51	148

Based on the contingency table, the diagnostic accuracy metrics for QCT were calculated and are summarized in **Table 3**.

Table 3: Diagnostic Accuracy of Quantitative CT in Detecting Osteoporosis

Metric	Value (%)	95% Confidence Interval
Sensitivity	87.63%	79.5% – 93.4%
Specificity	82.35%	69.1% – 91.6%
Positive Predictive Value (PPV)	90.43%	82.6% – 95.5%
Negative Predictive Value (NPV)	77.78%	64.4% – 87.7%
Diagnostic Accuracy	85.81%	79.2% – 91.0%

The results indicate that QCT demonstrated good sensitivity (87.63%) and specificity (82.35%) for diagnosing osteoporosis in the elderly. The overall diagnostic accuracy was 85.81%.

A stratified analysis was conducted to control for potential effect modifiers, including age, gender, BMI, symptom duration, residence, and occupation. The diagnostic accuracy measures across these subgroups are presented in **Table 4**. The performance of QCT remained consistently high and stable across all stratified groups, with no subgroup showing markedly inferior sensitivity, specificity, or accuracy.

Table 4: Stratified Analysis of QCT Diagnostic Performance

Stratification	Category	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Age	60 – 75 years	88.2	84.6	90.9	80.0	86.8
	> 75 years	86.7	80.0	89.5	75.0	84.2
Gender	Male	85.3	81.8	87.9	78.3	83.8
	Female	89.5	82.9	92.1	78.6	87.5
BMI (kg/m²)	< 25	86.8	83.3	89.2	80.0	85.4
	≥ 25	88.5	81.0	91.7	75.0	86.2
Symptom Duration	≤ 12 weeks	87.0	85.7	90.9	80.0	86.7
	> 12 weeks	88.1	80.0	90.0	76.9	85.0
Residence	Urban	88.9	83.3	91.4	78.9	87.0
	Rural	85.7	81.3	88.9	76.5	83.9
Occupation	Office	86.4	85.7	90.5	80.0	86.1
	Field	88.5	80.0	89.2	78.6	85.2
	Domestic	87.5	81.8	91.3	75.0	85.4

In summary, this study found that Quantitative Computed Tomography (QCT) is a diagnostically accurate tool for detecting osteoporosis in the elderly population, with an overall accuracy of 85.81% compared to serum calcium levels. Its performance was robust and consistent across various demographic and clinical subgroups.

Discussion

Based on the present findings, this study demonstrates that quantitative computed tomography (QCT) is a reliable and accurate diagnostic modality for the detection of osteoporosis in the elderly population. When evaluated against serum calcium as the reference standard, QCT showed high sensitivity (87.63%) and specificity (82.35%), with an overall diagnostic accuracy of 85.81%. Importantly, this level of diagnostic performance remained consistent across different demographic subgroups, underscoring the robustness and reproducibility of QCT measurements. These results support the growing role of QCT as an effective imaging-based screening tool in routine clinical practice, enabling radiologists to identify individuals at increased osteoporotic risk and facilitate early intervention to prevent disease progression and related complications.

Our findings are partially consistent with the study cited in reference [10]. Both studies highlight the superior diagnostic capability of QCT compared with dual-energy X-ray absorptiometry (DXA). However, while the referenced study primarily focused on fracture prediction and reported limited predictive value of DXA, our study evaluated the diagnostic accuracy of QCT using a biochemical reference standard rather than fracture outcomes. This distinction suggests that QCT may be particularly valuable for early osteoporosis detection, even before structural failure or fracture occurs, thereby complementing outcome-based assessments reported in prior literature.[10]

In accordance with our results further reinforce the diagnostic reliability of QCT. The cited study reported strong correlations between CT-derived attenuation values and bone mineral density (BMD), with area-under-the-curve (AUC) values ranging from 0.68 to 0.88. Similarly, our study demonstrated a high overall accuracy of 85.81%, along with good sensitivity and specificity, confirming that QCT provides dependable quantitative information for osteoporosis detection and aligns well with previously reported diagnostic and predictive performance. [11]

Additionally, our findings are consistent with the observations where QCT showed superior sensitivity and effectiveness in identifying osteoporotic changes compared with conventional methods such as DXA. The higher sensitivity of QCT supports its utility in detecting early trabecular bone loss, which may be underestimated by areal BMD measurements obtained from DXA, particularly in elderly patients with degenerative spinal changes. [12]

Finally further strengthens the evidence base supporting CT-based quantitative techniques. Both studies demonstrate that CT-derived measurements exhibit good to excellent diagnostic performance for osteoporosis-related outcomes, emphasizing the clinical value of leveraging routinely acquired CT data for opportunistic osteoporosis screening. Collectively, these findings support the integration of QCT into clinical workflows as a reliable and accurate tool for osteoporosis assessment, particularly in populations at high risk for underdiagnosis using traditional techniques. [13]

Conclusion:

Based on the findings of this study, Quantitative Computed Tomography (QCT) **is a** highly accurate and reliable diagnostic tool **for** detecting osteoporosis in the elderly population, with **an** overall diagnostic accuracy of 85.81% when compared to serum calcium levels as the gold standard. QCT demonstrated good sensitivity (87.63%) and specificity (82.35%)**,** and its performance remained consistent across various demographic and clinical subgroups**,** including age, gender, BMI, and occupation.

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