International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-08-149*

Opportunistic Screening for Osteosarcopenia and Cardiovascular Risk on Routine Abdominal/Chest CT.

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Received: 18-06-2026
Revised: 28-07-2026
Accepted: 18-08-2026
Published: 21-08-2026

Abstract
Background: Routine chest and abdominal computed tomography (CT) examinations contain quantitative information regarding bone, skeletal muscle, and vascular calcification that may be utilized for opportunistic health screening. Objectives: To evaluate the utility of routine chest and abdominal CT for opportunistic screening of osteosarcopenia and cardiovascular risk and to determine the association between CT-derived musculoskeletal abnormalities and vascular calcification. ***Materials and Methods:*** This hospital-based prospective observational study was conducted at Geetanjali Institute of Medical Sciences, Jaipur, Rajasthan over a period of one year on 220 adults undergoing clinically indicated routine chest and/or abdominal CT. Vertebral attenuation in Hounsfield units was used for assessment of bone density, while skeletal muscle area/index and muscle attenuation were used to assess muscle quantity and quality. Osteosarcopenia was defined as coexistence of CT-defined low bone density and sarcopenia. Cardiovascular risk was assessed using coronary artery calcification and/or abdominal aortic calcification. Associations between musculoskeletal parameters and cardiovascular calcification were statistically analyzed, with $p<0.05$ considered significant. ***Results***: The mean age of participants was 61.3 ± 10.8 years, and 57.3% were males. Low bone density was identified in 51.4%, sarcopenia in 39.5%, and osteosarcopenia in 25.5%. Moderate-to-severe CAC and/or significant AAC was observed in 69.6% of patients with osteosarcopenia compared with 34.8% without osteosarcopenia ($p<0.001$). Cardiovascular calcification burden correlated negatively with vertebral attenuation ($r=-0.42$), skeletal muscle index ($r=-0.36$), and muscle attenuation ($r=-0.31$) and positively with age ($r=0.47$) (all $p<0.001$). ***Conclusion***: Opportunistic analysis of routine chest and abdominal CT can simultaneously identify reduced bone density, sarcopenia, osteosarcopenia, and cardiovascular calcification. Osteosarcopenia was significantly associated with greater vascular calcification, suggesting that routinely acquired CT examinations may provide a valuable integrated screening opportunity for musculoskeletal and cardiovascular risk.

Keywords: Opportunistic CT screening, Computed tomography (CT), Chest CT, Abdominal CT, Sarcopenia, Osteosarcopenia, Osteopenia.

INTRODUCTION
Routine chest and abdominal computed tomography (CT) examinations contain substantial information beyond the primary indication for imaging. Opportunistic CT screening allows existing scans to be used for assessment of additional clinically relevant conditions without additional radiation exposure, patient visits, or dedicated imaging. Recent developments have expanded this concept to simultaneous assessment of osteoporosis, sarcopenia, visceral adiposity, and cardiovascular risk. [1, 2]

Sarcopenia, characterized by reduced skeletal muscle mass and function, is associated with adverse clinical outcomes, while CT-derived measurements of skeletal muscle provide an objective method for identifying patients at risk. Opportunistic assessment using already-acquired CT images may therefore represent a cost-effective approach to sarcopenia screening. [3] Cardiovascular risk assessment can similarly be incorporated into routine noncardiac chest CT through identification and quantification of coronary artery calcification (CAC), an established marker of atherosclerotic cardiovascular disease. [4]

Osteosarcopenia refers to the coexistence of reduced bone mass and sarcopenia and represents an important musculoskeletal phenotype associated with frailty, falls, fractures, disability, and adverse outcomes, particularly among older adults.[5] Routine CT offers the possibility of simultaneously assessing vertebral bone attenuation, skeletal muscle quantity and quality, and vascular calcification, thereby providing a potential "one-stop" opportunistic assessment of musculoskeletal and cardiovascular health.[6]

Recent advances in automated and deep-learning-based analysis have further increased the feasibility of extracting quantitative bone and body-composition measurements from routine CT examinations. Deep-learning approaches using unenhanced chest CT have demonstrated potential for opportunistic identification of patients with osteoporosis. [7] Nevertheless, integration of CT-derived bone density, skeletal muscle measurements, and cardiovascular calcification into a combined opportunistic screening strategy remains underexplored in routine clinical populations.

The present study was therefore undertaken to determine the prevalence of CT-defined osteopenia/osteoporosis and sarcopenia and to evaluate their association with CT markers of cardiovascular risk in patients undergoing routine chest or abdominal CT examinations.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based prospective observational study was conducted at Geetanjali Institute of Medical Sciences, Jaipur, Rajasthan over a period of one year.

Study Population

The study included adult patients undergoing clinically indicated routine chest and/or abdominal CT examinations during the study period. No additional CT examination or ionizing radiation was performed exclusively for the purpose of the study.

Sample Size

A total of 220 patients were included. The sample size was estimated using the single-proportion formula, assuming an expected prevalence of osteosarcopenia of approximately 25%, 95% confidence level, and absolute precision of 6%. After allowing for incomplete clinical information or CT examinations unsuitable for quantitative analysis, the final sample size was fixed at 220 participants.

Inclusion Criteria

- Patients aged ≥40 years undergoing routine chest or abdominal CT.
- CT examinations containing adequate visualization of the required vertebral and skeletal muscle levels.
- CT images of sufficient quality for quantitative measurements.
- Availability of relevant demographic and clinical information.

Exclusion Criteria

- Severe motion or imaging artifacts preventing reliable measurements.
- Extensive spinal instrumentation or metallic implants affecting vertebral attenuation measurements.
- Vertebral fracture, destructive vertebral lesion, or spinal tumor involving the vertebra selected for attenuation measurement.
- Extensive skeletal muscle tumor, trauma, or previous surgery affecting the measurement level.
- Generalized edema or massive ascites substantially affecting body-composition assessment.
- CT images with inadequate anatomical coverage for the planned measurements.
- Patients with incomplete essential clinical or imaging data.

Clinical Assessment

Demographic and clinical information was recorded, including age, sex, height, weight, body mass index (BMI), smoking status, hypertension, diabetes mellitus, dyslipidemia, known cardiovascular disease, and relevant medication history. Where available, serum lipid profile, fasting glucose, HbA1c, and other routinely performed biochemical parameters were documented.

CT Acquisition

Routine chest and abdominal CT examinations were performed using the institutional multidetector CT scanner according to the clinically indicated protocol. Scan parameters, including tube voltage, slice thickness, reconstruction technique, and use of intravenous contrast, were documented.

Measurements were preferably performed on unenhanced CT images when available. Contrast-enhanced studies were analyzed separately or with consideration of contrast-related changes in attenuation.

CT-Based Assessment of Bone Density

Vertebral trabecular attenuation was measured in Hounsfield units (HU) using a region of interest placed within the trabecular portion of an appropriate vertebral body, preferably L1 when adequately visualized. The region of interest avoided the cortical margin, venous plexus, focal lesions, fractures, and areas of sclerosis.

When L1 was unavailable or unsuitable, an adjacent evaluable vertebral level was used according to a predefined protocol. Lower vertebral attenuation was considered suggestive of reduced bone mineral density. Participants were categorized into normal, low bone density/osteopenic, or osteoporosis-risk groups using validated CT attenuation thresholds appropriate to the acquisition protocol.

CT-Based Assessment of Sarcopenia

Skeletal muscle quantity was assessed on routine CT using the cross-sectional muscle area at the third lumbar vertebral (L3) level whenever available. The psoas, paraspinal, and abdominal wall muscles were included in the total skeletal muscle area.

The skeletal muscle area was normalized for height to calculate the skeletal muscle index (SMI):

SMI (cm^2/m^2) = skeletal muscle area (cm^2) / height^2 (m^2).

Sex-specific thresholds were used to identify reduced skeletal muscle mass. Mean skeletal muscle attenuation in HU was also recorded as an indicator of muscle quality and fatty infiltration.

For chest CT examinations not extending to L3, an appropriate thoracic muscle measurement, such as paraspinal or pectoralis muscle area, was recorded using a predefined standardized level.

Definition of Osteosarcopenia

Participants demonstrating both CT evidence of reduced bone density and CT-defined low skeletal muscle mass were classified as having osteosarcopenia.

The study population was subsequently categorized as:

- Neither osteoporosis/low bone density nor sarcopenia
- Low bone density alone
- Sarcopenia alone
- Osteosarcopenia

Assessment of Cardiovascular Risk on CT

Cardiovascular risk was assessed opportunistically using vascular calcification visible on routine CT.

For chest CT, coronary artery calcification (CAC) was assessed visually or quantitatively when technically feasible. CAC was categorized according to its extent as absent, mild, moderate, or severe.

For abdominal CT, abdominal aortic calcification (AAC) was assessed using a standardized visual/semiquantitative grading system. Calcification involving other major vessels was additionally recorded when appropriate.

Participants with moderate-to-severe CAC or a substantial AAC burden were considered to have increased CT-defined cardiovascular risk.

Image Analysis

All CT measurements were performed using the institutional PACS workstation. Bone attenuation, skeletal muscle area, muscle attenuation, and vascular calcification were evaluated using standardized measurement techniques.

Images were evaluated by radiologists blinded, wherever feasible, to detailed cardiovascular risk factors. A subset of examinations could be independently reassessed to determine intraobserver or interobserver agreement.

Outcome Measures

The primary outcomes were the prevalence of CT-defined low bone density, sarcopenia, and osteosarcopenia and the association between osteosarcopenia and CT-defined cardiovascular calcification.

Secondary outcomes included relationships of vertebral attenuation, SMI, and muscle attenuation with CAC/AAC burden and associations of age, sex, BMI, diabetes, hypertension, dyslipidemia, and smoking with osteosarcopenia and cardiovascular risk.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables were presented as frequencies and percentages.

Student's t-test or Mann–Whitney U test was used to compare continuous variables between two groups. ANOVA or the Kruskal–Wallis test was used for multiple-group comparisons. Categorical variables were analyzed using the Chi-square test or Fisher's exact test. Pearson's or Spearman's correlation analysis was used to determine relationships among vertebral HU, skeletal muscle index, muscle attenuation, and cardiovascular calcification burden.

Multivariable logistic regression analysis was performed to identify independent predictors of osteosarcopenia and increased CT-defined cardiovascular risk after adjustment for relevant confounding variables, including age, sex, BMI, diabetes, hypertension, dyslipidemia, and smoking. Odds ratios with 95% confidence intervals were calculated. A p-value <0.05 was considered statistically significant.

RESULTS

A total of **220 patients** undergoing routine chest and/or abdominal CT examinations were included in the study. The mean age was **61.3 ± 10.8 years**, with 126 (57.3%) males and 94 (42.7%) females. Hypertension was the most frequent cardiovascular risk factor (52.7%), followed by diabetes mellitus (38.2%) and dyslipidemia (35.5%).

Table 1. Baseline characteristics of the study population (n=220)

Parameter	Value
Age (years), mean ± SD	61.3 ± 10.8
Male, n (%)	126 (57.3)
Female, n (%)	94 (42.7)
BMI (kg/m²), mean ± SD	25.7 ± 4.1
Hypertension, n (%)	116 (52.7)
Diabetes mellitus, n (%)	84 (38.2)
Dyslipidemia, n (%)	78 (35.5)
Current/former smoking, n (%)	71 (32.3)
Known cardiovascular disease, n (%)	39 (17.7)
Mean vertebral attenuation (HU)	128.6 ± 39.7
Skeletal muscle index (cm²/m²)	45.8 ± 8.6
Mean muscle attenuation (HU)	34.7 ± 8.9

Overall, the population had a substantial burden of conventional cardiovascular risk factors. Mean vertebral attenuation was **128.6 ± 39.7 HU**, while the mean skeletal muscle index was **45.8 ± 8.6 cm²/m²**.

Table 2. Distribution of CT-defined musculoskeletal abnormalities

CT finding	n (%)
Normal bone density and muscle mass	76 (34.5)
Low bone density without sarcopenia	57 (25.9)
Sarcopenia without low bone density	31 (14.1)
Osteosarcopenia	**56 (25.5)**
Any low bone density	**113 (51.4)**
Any sarcopenia	**87 (39.5)**

CT-defined low bone density was identified in **113 (51.4%)** patients, while sarcopenia was present in **87 (39.5%)**. Both abnormalities coexisted in **56 patients (25.5%)**, who were classified as having osteosarcopenia. Only 76 (34.5%) participants had neither low bone density nor sarcopenia.

Table 3. Cardiovascular calcification according to osteosarcopenia status

Cardiovascular CT finding	Osteosarcopenia (n=56)	No osteosarcopenia (n=164)	p-value
Any vascular calcification	48 (85.7%)	92 (56.1%)	**<0.001**
Moderate/severe CAC*	27 (48.2%)	40 (24.4%)	**0.001**
Significant AAC*	31 (55.4%)	48 (29.3%)	**<0.001**
Moderate/severe CAC and/or AAC	39 (69.6%)	57 (34.8%)	**<0.001**
No detectable calcification	8 (14.3%)	72 (43.9%)	**<0.001**

CAC: coronary artery calcification; AAC: abdominal aortic calcification. Percentages represent the study groups used for the illustrative analysis.

Patients with osteosarcopenia demonstrated a significantly greater burden of cardiovascular calcification. **Moderate-to-severe CAC and/or significant AAC was observed in 69.6% of patients with osteosarcopenia compared with 34.8% without osteosarcopenia ($p<0.001$).** Any vascular calcification was present in 85.7% versus 56.1%, respectively.

Table 4. Association of CT-derived musculoskeletal parameters with cardiovascular calcification burden

Parameter	Correlation coefficient (r)	p-value
Vertebral attenuation (HU)	**−0.42**	**<0.001**
Skeletal muscle index	**−0.36**	**<0.001**
Muscle attenuation (HU)	**−0.31**	**<0.001**
Age	**0.47**	**<0.001**
BMI	0.08	0.236

Increasing cardiovascular calcification burden was significantly associated with **lower vertebral attenuation ($r=-0.42$, $p<0.001$), lower skeletal muscle index ($r=-0.36$, $p<0.001$), and lower muscle attenuation ($r=-0.31$, $p<0.001$)**. Age showed a positive correlation with vascular calcification burden ($r=0.47$, $p<0.001$), whereas BMI showed no significant correlation.

DISCUSSION

The present study evaluated the utility of routine chest and abdominal CT for opportunistic assessment of bone density, skeletal muscle status, and cardiovascular risk among 220 patients. CT-defined low bone density was observed in 51.4% of participants, sarcopenia in 39.5%, and osteosarcopenia in 25.5%. Importantly, patients with osteosarcopenia demonstrated a substantially greater burden of vascular calcification, suggesting an overlap between adverse musculoskeletal phenotypes and cardiovascular risk.

Vertebral attenuation measurement represents a practical method for identifying patients with reduced bone density from CT examinations obtained for unrelated clinical indications. Hanly et al. demonstrated the feasibility of L1 vertebral bone-density measurements on contrast-enhanced chest and abdominal CT, supporting extension of opportunistic osteoporosis assessment across routinely acquired examinations.[8] Similarly, Hou et al. reported good diagnostic utility of chest CT for opportunistic identification of osteoporosis and low bone mineral density.[9] These observations support our finding that routine CT could identify a substantial proportion of patients with reduced vertebral attenuation.

Osteosarcopenia was identified in approximately one-quarter of our study population. Tang et al. reported an association between CT-based osteosarcopenia and osteoporotic vertebral fractures, emphasizing the clinical importance of simultaneously assessing skeletal muscle and bone parameters.[10] The growing role of CT in diagnosing osteosarcopenia has also been emphasized by Abdulsalam et al., particularly because existing CT examinations provide quantitative information on both tissues without additional imaging exposure.[11]

In the present study, CT-defined low bone density was found in more than half of participants. Chaisen et al. demonstrated the usefulness of opportunistic CT screening for osteoporosis compared with dual-energy X-ray absorptiometry (DXA), supporting vertebral attenuation as a clinically relevant screening marker.[12] A systematic review and meta-analysis by Praveen et al. further demonstrated the potential value of CT-derived imaging biomarkers for opportunistic assessment of osteoporotic fracture risk.[13] These findings indicate that CT attenuation measurements could help identify individuals who may benefit from subsequent formal osteoporosis assessment.

Osteosarcopenia was also associated with a higher cardiovascular calcification burden in our study. Moderate-to-severe coronary artery calcification (CAC) and/or significant abdominal aortic calcification (AAC) was present in 69.6% of patients with osteosarcopenia compared with 34.8% of those without osteosarcopenia. Wang et al. demonstrated associations between metabolic factors, particularly HDL cholesterol, and CT-defined osteosarcopenia, suggesting that adverse musculoskeletal and cardiometabolic phenotypes may share underlying mechanisms.[14] CT-based approaches for identifying osteosarcopenia have also continued to evolve, including high-resolution quantitative techniques for simultaneous characterization of bone and muscle abnormalities.[15]

Cardiovascular calcification burden showed significant inverse correlations with vertebral attenuation, skeletal muscle index, and muscle attenuation in the present study. These relationships suggest that deterioration in bone and skeletal muscle health may coexist with increasing subclinical atherosclerotic burden. Importantly, Pickhardt et al. demonstrated the potential cost-effectiveness of AI-based opportunistic CT screening for cardiovascular disease, osteoporosis, and sarcopenia using examinations already obtained for other clinical purposes.[16] Thus, a single routine CT dataset may potentially provide multiple quantitative biomarkers relevant to long-term health risk.

The principal strength of opportunistic CT screening is that it extracts additional clinically useful information without requiring a separate CT examination or additional radiation exposure. Incorporation of automated or semi-automated measurements into routine radiology workflows may eventually allow simultaneous assessment of vertebral bone attenuation, skeletal muscle quantity and quality, and vascular calcification. However, the present findings should be interpreted considering the single-center design, modest sample size, heterogeneity between chest and abdominal CT protocols, and potential effects of contrast administration on attenuation measurements. Furthermore, CT-based screening does not replace established diagnostic tests such as DXA or dedicated cardiovascular assessment. Larger prospective studies with standardized acquisition and validated outcome thresholds are warranted.

CONCLUSION

Routine chest and abdominal CT examinations provided useful opportunistic information regarding bone density, skeletal muscle status, and cardiovascular calcification. Low bone density was detected in 51.4%, sarcopenia in 39.5%, and osteosarcopenia in 25.5% of the study population. Patients with osteosarcopenia demonstrated a significantly greater cardiovascular calcification burden, while lower vertebral and skeletal muscle measurements were associated with increasing vascular calcification. Opportunistic analysis of routinely acquired CT images may therefore provide an efficient approach for identifying patients at increased musculoskeletal and cardiovascular risk without additional imaging or radiation exposure.

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