Khoroushi et al.
Egyptian Rheumatology and Rehabilitation (2024) 51:20
https://doi.org/10.1186/s43166-024-00253-w

Egyptian Rheumatology and Rehabilitation

RESEARCH

Open Access

Opportunistic screening for osteoporosis using computed tomography scans and its comparison with DXA findings: a two-center cross-sectional study

Farzaneh Khoroushi[1], Ehsan Keykhosravi[2], Mohammad Taghi Shakeri[3], Masoumeh Salari[4], Ehsan Hassan Nejad[5], Asma Payandeh[6] and Omid Salarzaei[1*]

Abstract

Background Osteoporosis is a prevalent condition leading to an increased risk of bone fractures. Osteoporosis poses a worldwide public health concern, impacting over 200 million individuals and resulting in a staggering 1.66 million hip fractures each year. Opportunistic osteoporosis screening can be employed during CT scans to assess bone mineral density (BMD) through Hounsfield units (HU) without the need for additional imaging, radiation exposure, or appointments. This study aimed to investigate a CT scan's diagnostic value in the opportunistic osteoporosis screening through L1 vertebra densitometry and compare it with dual-energy x-ray absorptiometry (DXA) findings.

Results One hundred forty-nine patients with an average age of 67.70 ± 10.94 years were included in the study. The age of osteoporotic patients was significantly higher than osteopenic ($p = 0.001$) and normal individuals ($p < 0.001$). The HU of osteoporotic patients was found to be significantly lower compared to both osteopenic ($p = 0.023$) and normal individuals ($p < 0.001$). According to the ROC curve for osteoporosis prediction using the HU (AUC = 0.793 and $p < 0.001$), with a cut-off of 103 HU, the CT scan had a sensitivity of 69% and a specificity of 74% for the diagnosis of osteoporosis.

Conclusion Individuals with osteoporosis exhibit a significantly lower average HU compared to both osteopenic and healthy individuals. A CT scan can serve as an effective predictor of osteoporosis in patients. The CT images obtained for reasons unrelated to osteoporosis diagnosis can be employed to discern patients with osteoporosis without incurring the added cost or radiation exposure.

Keywords Osteoporosis, Fracture, Bone density, CT scan, DXA

*Correspondence:
Omid Salarzaei
Salarzaee@yahoo.com
Full list of author information is available at the end of the article

Background

Osteoporosis is a prevalent condition that affects people worldwide. It is marked by decreased bone mass and changes in bone structure, leading to an increased risk of bone fragility and fractures [1]. Osteoporosis poses a worldwide public health concern, impacting over 200 million women all over the world and resulting in a staggering 1.66 million hip fractures each year [2]. Approximately 33% of women and 20% of men over the age of 50 will suffer from an osteoporotic fracture at some point in their lives [3]. Due to the aging population, there is an expected significant increase in the prevalence of osteoporosis in the future [4]. As age advances, the decrease in bone mineral density (BMD) becomes more apparent, leading to a significant rise in the proportion of patients diagnosed with osteoporosis [5].

The main description of [5] BMD revolves around its representation as a *T*-score, indicating the difference in standard deviations (SD) between an individual's BMD and the mean value of young, healthy individuals [4]. According to the report from the World Health Organization (WHO), BMD is categorized as normal when the *T*-score is within ± 1SD, osteopenia when the *T*-score ranges between − 1.0 and − 2.5 SD, and osteoporosis when the *T*-score falls below − 2.5 SD [6].

Generally, the recommended technique for assessing osteoporosis is through the utilization of dual-energy *x*-ray absorptiometry (DXA) scans, explicitly targeting the lumbar spine and hip to measure BMD of the central skeleton [7].

It is important to acknowledge that there are several limitations when using DXA to define osteoporosis. These limitations include the confounding effects on surrounding soft tissue, bone artifacts resulting from osteoarthritis, aortic calcification, and vertebral compression fractures. Additionally, DXA does not provide information on bone microstructure or quality, both of which are thought to play a role in fracture risk [8, 9]. It is worth mentioning that about half of patients with osteoporotic vertebral compression fractures had non-osteoporotic *T*-scores and displayed false-negative results on DXA scans [10]. DXA has limited applicability in individuals with spinal deformity or a history of spinal surgery [11].

Hence, incorporating alternative techniques, such as computed tomography (CT), is required to improve the detection of osteoporosis. One benefit associated with a CT scan is its distinctive capacity to measure the trabecular and cortical bone density within the vertebral body independently. The metabolic activity of the trabecular part of the vertebral body is approximately eight times greater than that of its cortical part. Therefore, when it comes to evaluating bone changes linked to age or osteoporosis treatment, CT scans outperform DXA [12]. Additionally, the bone density values derived from the CT scan method are not influenced by bone or body size [13]. One distinct benefit of CT in comparison to DXA BMD screening lies in its capability to detect unsuspected osteoporotic compression fractures precisely. This enables the diagnosis of osteoporosis regardless of the patient's DXA *T*-score [10, 14].

Despite the aforementioned advantages of the CT scan, the great radiation dose relative to the DXA scan limits its use routinely in osteoporosis screening. However, opportunistic osteoporosis screening can be employed during CT scans to assess BMD through Hounsfield units (HU) without the need for additional imaging, radiation exposure, or appointments [15, 16].

Radiologists employ HU as a relative quantitative measurement of radio density when interpreting CT images. The computation of the Hounsfield unit necessitates a linear transformation of the baseline linear attenuation coefficient of the X-ray beam. Distilled water is defined as having a Hounsfield unit value of zero, in contrast to air which is assigned − 1000 HU [17].

This study aimed to investigate the diagnostic value of a CT scan in opportunistic osteoporosis screening through L1 vertebra densitometry and compare it with DXA findings.

Methods

The present cross-sectional study was conducted on eligible patients admitted to Ghaem and Emdad Hospitals, academic hospitals of the Mashhad University of Medical Sciences, Mashhad, Iran. In the present study, individuals who underwent densitometry using the DXA method between 2021 and 2022 and subsequently received CT scans within a 90-day window before or after were identified and had their radiology records reviewed.

Individuals were categorized into three groups based on the *T*-score obtained through the DXA method: [6]

- Normal: *T*-score ≥ − 1
- Osteopenia: *T*-score less than − 1 and more than − 2.5
- Osteoporosis: *T*-score equal to or less than − 2.5

Patients included in the study underwent a CT scan of the chest or abdomen using a 16-slice multi-detector CT machine at a fixed peak voltage of 120 kV. The average density of the L1 vertebra was measured in the CT scan images of the patients. This measurement was taken on the images along the body's midline, two adjacent cuts on the left side, and two adjacent cuts on the right side. Two blinded expert radiologists conducted the measurements. Finally, the average of these five values was recorded as the density of the vertebra.

A circular area with a diameter of about 2 cm in the anterior two-thirds of the trabecular part of the vertebral bodies was designated as the region of interest (ROI), excluding bone lesions, sclerosis of the vertebral endplate, and venous network (Fig. 1). Hounsfield's number was evaluated in a CT scan, with the *T*-score obtained from the DXA method being considered the gold standard. The receiver operating characteristic (ROC) curve was employed for this specific purpose. The area under the curve (AUC) was calculated using SPSS 25.0 as the software, with the determination of sensitivity and specificity conducted for different cut points. The ANOVA test was implemented in situations of normal distribution, whereas the Kruskal-Wallis test was conducted for non-normal distributions. Pearson's test was implemented to analyze the correlation between variables in instances of normal distribution, while the Spearman correlation test was utilized for non-normally distributed data. A p-value < 0.05 was considered statistically significant.

Results

One hundred forty-nine patients with an average age of 67.70 ± 10.94 years were included in the study, of which 129 (86.6%) were female. Ninety-one patients (61.1%) had osteoporosis, and 33 patients (22.1%) had osteopenia.

Figure 2 illustrates the comparison of gender distribution among normal individuals, individuals with osteopenia, and individuals with osteoporosis. The results demonstrate a significant difference in the occurrence of osteoporosis between the genders. In detail, 66.7% of female patients were found to have osteoporosis, while the prevalence among male patients was 40% ($p = 0.033$).

Table 1 presents a comparison of age and the Hounsfield unit among individuals categorized as normal, osteopenic, and osteoporotic. As seen, the age of osteoporotic patients was significantly higher than osteopenic patients ($p = 0.001$) and normal patients ($p < 0.001$). There was no significant difference between the age of osteopenic patients and normal people ($p = 0.140$). In addition, the Hounsfield unit of osteoporotic patients was found to be significantly lower compared to both osteopenic patients ($p = 0.023$) and normal individuals ($p < 0.001$). Furthermore, the Hounsfield unit of osteopenic patients was also significantly lower than that of normal individuals ($p < 0.001$).

In Fig. 3, the Hounsfield unit of patients is depicted according to their *T*-score, whereas Fig. 4 illustrates the ROC curve for osteoporosis prediction using the Hounsfield unit. According to AUC = 0.793 and $p < 0.001$, the Hounsfield unit can reliably predict the presence of osteoporosis in patients. In Table 2, the sensitivity and

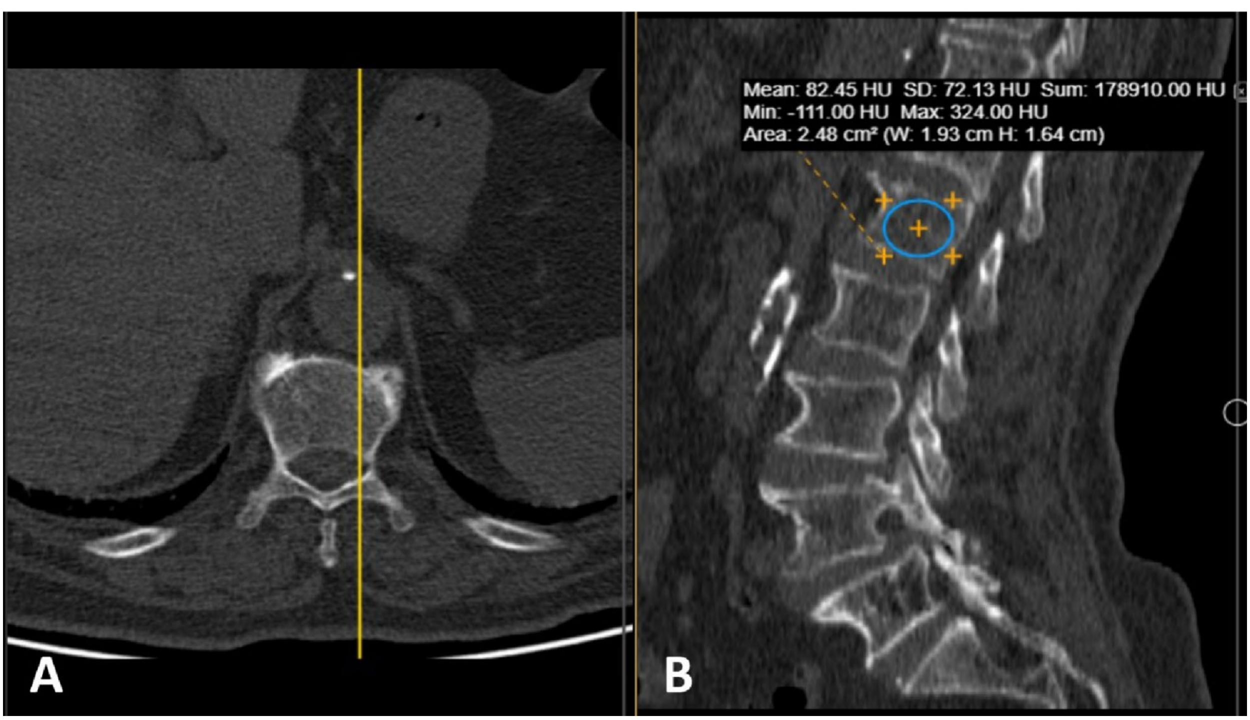

Fig. 1 Axial reconstruction of trabecular L1 vertebral body in the bone window (**A**) and sagittal reconstruction of the lumbar spine (**B**) used for the determination of attenuation of trabecular part of the vertebral body via ROI tool in the bone window, excluding bone lesions and sclerosis of the vertebral endplate

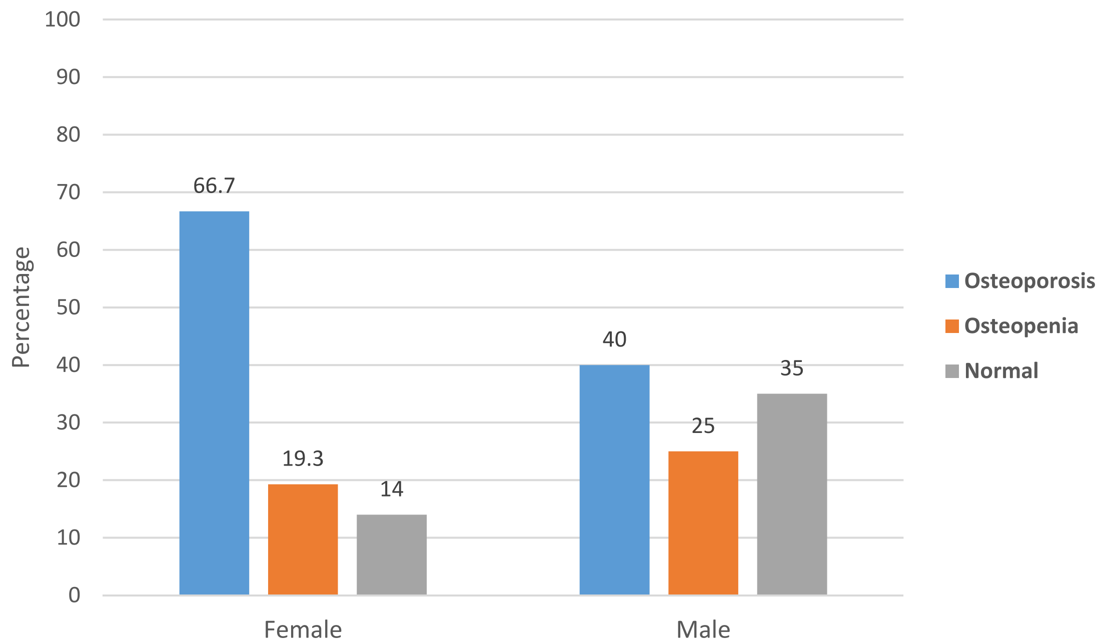

Fig. 2 Gender of patients with osteoporosis, osteopenia, and normal people

Table 1 Comparison of age and Hounsfield units of normal people, people with osteopenia, and people with osteoporosis

	Osteoporosis	Osteopenia	Normal	*P* value*	P1	P2	P3
Age	**71.32±9.51**	**63.83±10.02**	**58.76±10.67**	**0.001>**	**0.001**	**0.001>**	**0.140**
Hounsfield unit	**84.99±39.83**	**106.47±30.90**	**153.92±40.21**	**0.001>**	**0.023**	**0.001>**	**0.001>**

* ANOVA test

P1, comparison of osteoporosis with osteopenia, Tukey HSD test; *P2*, comparison of osteoporosis with the normal group, Tukey HSD test; *P3*, comparison of osteopenia with the normal group, Tukey HSD test

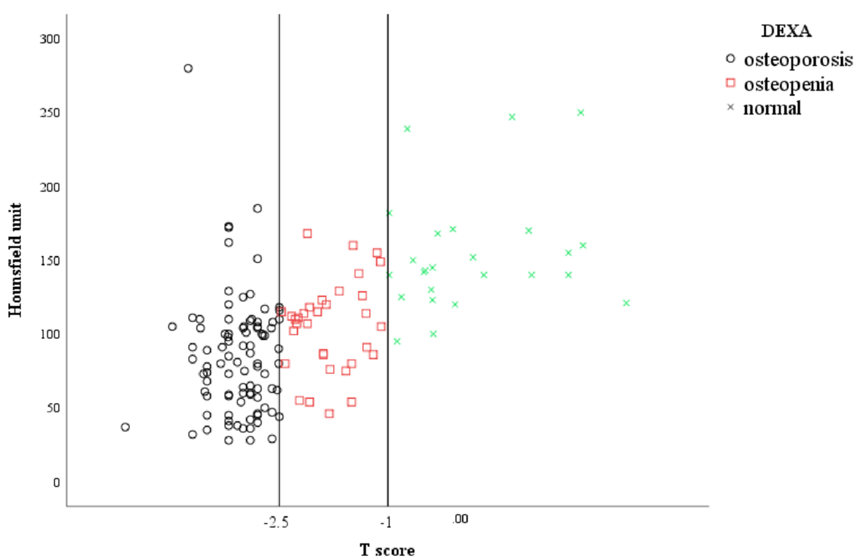

Fig. 3 Scatterplot plot showing the Hounsfield unit of patients with different *T*-scores

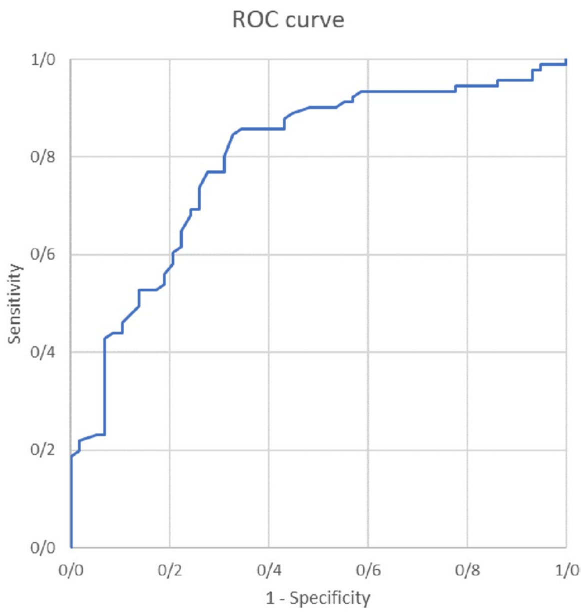

Fig. 4 ROC curve for predicting osteoporosis using Hounsfield units

specificity of different cut-offs of the Hounsfield unit for the diagnosis of osteoporosis are given.

The patients were divided into two groups to investigate the relationship between age and the concordance between CT scans and DXA results. Patients in the first group were 65 or younger (68 patients), whereas the second group consisted of patients older than 65 (81 patients). The results showed that in the first group, the AUC was equal to 0.825 (p < 0.001), and in the second group, it was equal to 0.700 (p = 0.014). According to the results, there has been a higher level of concordance between CT scan and DXA results in younger individuals compared to older individuals.

Discussion

The application of CT data obtained from imaging procedures performed for other purposes has been designated opportunistic use and does not demand additional radiation. The approach we employed necessitates minimal training and time, making it feasible for prospective implementation by an interpreting radiologist or retrospective usage by a radiologist or even a non-radiologist. Moreover, it incurs no additional expenses, patient time, equipment, or radiation exposure. CT calculates x-ray attenuation coefficients, which are normalized to the Hounsfield unit values. These coefficients can be utilized to estimate bone status and permit the measurement of bone mineral density through the application of techniques. Although BMD has traditionally been evaluated and defined through DXA, CT scans provide a more advanced method of assessment. CT scanning allows for a comprehensive spine analysis, enabling the placement of an ROI marker that accurately portrays the overall bone quality [18, 19].

The current study aimed to investigate the role of CT scans in diagnosing osteoporosis through L1 vertebra densitometry. This study sought to measure the density of the L1 vertebra, which is easily identifiable as the first non-rib-bearing vertebra and is consistently present in all routine abdominal and chest CT scans. As a result, its potential for achieving a higher overall screening yield is significantly increased. In our study, 61% of patients had osteoporosis based on DXA results, and nearly 22% had osteopenia. Predictably, the prevalence of osteoporosis was markedly higher in female patients compared to male patients, with 67% of females and 40% of males exhibiting the condition. Additionally, the age of patients with osteoporosis surpassed that of individuals with osteopenia and those with normal bone density. This matter is also anticipated as the likelihood of developing osteoporosis rises with advancing age [20].

This study aimed to determine the diagnostic significance of CT scans in osteoporosis. By examining the Hounsfield unit of CT scans obtained from the L1 vertebra of patients, it was observed that individuals with osteoporosis exhibited a significantly lower average Hounsfield unit compared to both osteopenic patients and healthy individuals. In addition, the Hounsfield unit in osteopenic patients was markedly lower compared to individuals with normal bone density. According to the ROC curve analysis, a CT scan has the potential to serve as an effective predictor of osteoporosis in patients.

Table 2 Diagnostic value of CT scan for the detection of osteoporosis

Hounsfield unit	Sensitivity (percentage)	Specificity (percentage)	Positive predictive value (percentage)	Negative predictive value (percentage)
Under 79	**46**	**90**	**87.8**	**51.6**
Under 93.5	**60**	**79**	**81.7**	**55.8**
Under 103	**69**	**74**	**80.6**	**60.4**
Under 113	**86**	**64**	**78.9**	**74.5**
Under 119	**89**	**55**	**75.6**	**76.1**
Under 128	**92**	**43**	**71.6**	**77.5**

When the Hounsfield unit cut-off of 103 is considered, a CT scan can exhibit a sensitivity of 69% and a specificity of 74% in diagnosing osteoporosis.

The examination of CT scans for bone strength measurement and fracture prediction has been the subject of a recent study. Studies have demonstrated that in addition to its role in diagnosing osteoporosis by measuring BMD, a CT scan possesses a distinct capability to offer anatomical morphology information and acquire numerous quantitative parameters related to bone health, all without inducing discomfort caused by movement, particularly in older individuals. Additionally, it is imperative to determine the particulars of vertebral fractures [21, 22].

DXA and CT scans are the primary clinical modalities employed to measure BMD. The possibility of opportunistically diagnosing osteoporosis during routine CT examinations conducted for other indications has been examined and compared with DXA [16, 19, 23, 24].

A study by Xiao-ming Xu et al. [25] found that discrepancies may exist between CT scans and DXA in diagnosing osteoporosis. This is attributed to factors such as spinal degeneration, aortic calcification, and fractures, which can create diagnostic ambiguity in spinal BMD measurement via DXA. According to their study, the CT scan proved to be a more sensitive technique for measuring BMD in older Chinese men. In this study, BMD was determined using both CT scan and DXA. In our study, given that DXA was regarded as the gold standard and BMD calculation was not conducted via CT scan, the sensitivity of DXA cannot be compared to that of a CT scan. Nevertheless, our study's findings indicate no complete concordance between the results of the CT scan and DXA, just like in the study conducted by Xiao-ming Xu. Furthermore, the discordance rate between CT scans and DXA exhibits an upward trend with increasing age.

Pickhardt's study [10] examined patients who underwent an abdominal CT scan and DXA 6 months apart. The results revealed a significant difference in the average Hounsfield unit between individuals with osteoporosis (based on DXA) and others. Also, by determining the cut-off of 135 for the Hounsfield unit in the L1 vertebra, the CT scan had a sensitivity of 75.5% and a specificity of 75.4% for the diagnosis of osteoporosis. Similar to Pickhardt's study, our study showed that CT scans can reliably detect osteoporosis in patients. Nevertheless, our study observed a different accuracy for the CT scan, with a sensitivity of 70% and specificity of 74% at the Hounsfield unit cut-off of 103. The precise cause for the disparity in the findings of the two studies remains undetermined. Scanner-to-scanner attenuation differences, differences in sample size, and demographic characteristics may have influenced the variation in the results. Additionally, variations in the age and gender of the subjects examined in different studies can be considered confounding variables due to the established correlation between bone marrow fat, which tends to increase with age, and the precision of BMD measurement [16].

Osteoporosis is a disease that is typically asymptomatic and often goes undetected until a complication, such as a fracture, arises. The broad application of abdominal or chest CT exams in clinical practice presents a unique opportunity to detect osteoporosis in patients who may lack awareness of their condition. Furthermore, the implementation of opportunistic CT can be employed to identify patients who might be susceptible to osteoporosis and necessitate additional assessment using DXA. Retrospective application of densitometry measurement is possible due to the indefinite storage of CT scans in electronic medical records. The simplicity of this approach is another key benefit, as it eliminates the need for dedicated software or intricate calculations. The application of opportunistic CT is applicable in preoperative planning for patients with poor bone status, allowing for treatment prior to surgery. It is strongly recommended that all adult patients who undergo abdomen or chest CT scans be screened for osteoporosis and have HU measurements taken at L1. The radiologists responsible for interpreting abdominal or chest CT scans should accurately report the presence of osteoporosis, according to the latest research findings. This will help raise attention among physicians and patients, leading to early treatment and prevention of fractures and associated difficulties.

Our research has both strengths and limitations. The present study was limited by the requirement to explore the frequency of osteoporotic vertebral fractures in patients to compare the precision of CT scans and DXA in predicting such fractures. Additionally, our study exhibited strengths, notably its innovative exploration and implementation of CT scans as a trustworthy means of diagnosing osteoporosis among Iranians. In the future, further investigations should be conducted to diagnose osteoporosis using CT scans exclusively, thereby eliminating the need for DXA and the associated costs and radiation exposure in patients who have already undergone CT scans for other purposes. Given the relative availability of CT scans of the pelvis; identifying HU thresholds for osteoporosis in the hip of postmenopausal women is valuable to validate the opportunistic use of this technique. Future research focusing on correlating the CT bone attenuation data with fracture risk assessment (FRAX) is needed. Additionally, prospective studies evaluating the ability of the BMD measurement from CT scans to predict fracture risk are valuable to fully understand its potential role as a diagnostic tool.

In conclusion, the abdominal or chest CT images obtained for reasons unrelated to osteoporosis diagnosis can be employed to discern patients with osteoporosis without incurring the added cost or radiation exposure. Although direct HU measurement from a CT scan offers the potential for osteoporosis screening, it is not yet suitable for clinical usage. More research is needed to address machine variability and standardize measurements and cutoff values for diagnosis.

Abbreviations

AUC	Area under the curve
BMD	Bone mineral density
CT	Computed tomography
DXA	Dual-energy X-ray absorptiometry
HU	Hounsfield unit
ROC	Receiver operating characteristic
ROI	Region of interest
SD	Standard deviations
WHO	World Health Organization

Acknowledgements
Not applicable.

Authors' contributions
Conceptualization: F.K., E.K., and O.S. Project administration: F.K. and O.S. Data curation: F.K., O.S., M.S., E.H., and A.S. Methodology: M.TS., F.K., E.K., O.S., A.S., and E.H. Writing—review and editing: F.K., O.S., E.H., and A.S.

Funding
There was no funding for this study.

Availability of data and materials
The datasets created during the current study are available at the corresponding author in case of reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the medical ethics committee of Mashhad University of Medical Sciences (MUMS). The review board at MUMS has waived informed consent for the research based on its observational nature (Ethics code: IR.MUMS.MEDICAL.REC.1400.630).

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Radiology, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran. [2]Department of Neurosurgery, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran. [3]Department of Biostatistics, School of Public Health, Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran. [4]Department of Internal Medicine, School of Medicine, Ghaem Hospital, Mashhad University of Medical Sciences, Mashhad, Iran. [5]Department of Radiology, School of Medicine, Birjand University of Medical Sciences, Birjand, Iran. [6]Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.

Received: 12 January 2024 Accepted: 22 March 2024
Published online: 04 April 2024

References

1. Akkawi I, Zmerly H (2018) Osteoporosis: current concepts. Joints. 6(02):122–7
2. Cooper C, Campion G, Melton Lr (1992) Hip fractures in the elderly: a world-wide projection. OsteoporosInt 2:285–9
3. Reginster J-Y, Burlet N (2006) Osteoporosis: a still increasing prevalence. Bone. 38(2):4–9
4. Hernlund E, Svedbom A, Ivergård M, Compston J, Cooper C, Stenmark J et al (2013) Osteoporosis in the European Union: medical management, epidemiology and economic burden: a report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). Arch Osteoporos 8:1–115
5. Kanis J, Johnell O, Oden A, Jonsson B, De Laet C, Dawson A (2000) Risk of hip fracture according to the World Health Organization criteria for osteopenia and osteoporosis. Bone. 27(5):585–90
6. Cosman F, de Beur SJ, LeBoff M, Lewiecki E, Tanner B, Randall S et al (2014) Clinician's guide to prevention and treatment of osteoporosis. Osteoporos Int 25:2359–81
7. Blake GM, Fogelman I (2007) The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. Postgrad Med J 83(982):509–17
8. Lorentzon M, Cummings SR (2015) Osteoporosis: the evolution of a diagnosis. J Int Med 277(6):650–61
9. Bonnick SL (1998) Bone densitometry in clinical practice. Springer
10. Pickhardt PJ, Pooler BD, Lauder T, del Rio AM, Bruce RJ, Binkley N (2013) Opportunistic screening for osteoporosis using abdominal computed tomography scans obtained for other indications. Ann Intern Med 158(8):588–95
11. Watts NB (2004) Fundamentals and pitfalls of bone densitometry using dual-energy X-ray absorptiometry (DXA). Osteoporos Int 15:847–54
12. Engelke K, Adams JE, Armbrecht G, Augat P, Bogado CE, Bouxsein ML et al (2008) Clinical use of quantitative computed tomography and peripheral quantitative computed tomography in the management of osteoporosis in adults: the 2007 ISCD Official Positions. J Clin Densitom 11(1):123–62
13. Jergas M, Breitenseher M, Glüer CC, Yu W, Genant HK (1995) Estimates of volumetric bone density from projectional measurements improve the discriminatory capability of dual X-ray absorptiometry. J Bone Miner Res 10(7):1101–10
14. Cunningham GF (2005) Screening for osteoporosis. N Engl J Med 353(18):1975 (author reply -; author reply)
15. Summers RM, Baecher N, Yao J, Liu J, Pickhardt PJ, Choi JR et al (2011) Feasibility of simultaneous CT colonography and fully-automated bone mineral densitometry in a single examination. J Comput Assist Tomogr 35(2):212
16. Alacreu E, Moratal D, Arana E (2017) Opportunistic screening for osteoporosis by routine CT in Southern Europe. Osteoporos Int 28:983–90
17. DenOtter TD, Schubert J (2003) Hounsfield Unit. StatPearls Publishing, Treasure Island (FL)
18. Anderson PA, Polly DW, Binkley NC, Pickhardt PJ (2018) Clinical use of opportunistic computed tomography screening for osteoporosis. JBJS. 100(23):2073–81
19. Li Y-L, Wong K-H, Law MW-M, Fang BX-H, Lau VW-H, Vardhanabuti VV et al (2018) Opportunistic screening for osteoporosis in abdominal computed tomography for Chinese population. Arch Osteoporos 13:1–7
20. Pietschmann P, Rauner M, Sipos W, Kerschan-Schindl K (2009) Osteoporosis: an age-related and gender-specific disease–a mini-review. Gerontology. 55(1):3–12
21. Wáng YXJ, Santiago FR, Deng M, Nogueira-Barbosa MH (2017) Identifying osteoporotic vertebral endplate and cortex fractures. Quant Imaging Med Surg 7(5):555
22. Xiaoguang C, Ling W, Qianqian W, Yimin M, Yongbin S, Kai L (2014) Validation of quantitative computed tomography-derived areal bone mineral density with dual energy X-ray absorptiometry in an elderly Chinese population. Chin Med J (Engl) 127(8):1445–9
23. Graffy PM, Lee SJ, Ziemlewicz TJ, Pickhardt PJ (2017) Prevalence of vertebral compression fractures on routine CT scans according to L1 trabecular attenuation: determining relevant thresholds for opportunistic osteoporosis screening. AJR Am J Roentgenol 209(3):491–6

24. Lee S, Binkley N, Lubner M, Bruce R, Ziemlewicz T, Pickhardt P (2016) Opportunistic screening for osteoporosis using the sagittal reconstruction from routine abdominal CT for combined assessment of vertebral fractures and density. Osteoporos Int 27:1131–6
25. Xu X-m, Li N, Li K, Li X-Y, Zhang P, Xuan Y-j et al (2019) Discordance in diagnosis of osteoporosis by quantitative computed tomography and dual-energy X-ray absorptiometry in Chinese elderly men. J Orthop Translat 18:59–64

Publisher's Note