

# Predictive Value of Native Computed Tomography in Low Energy Vertebra Fracture Risk Assessment

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## Abstract

**Background:** Computed tomography (CT) can be used to accurately determine bone density in Hounsfield units (HU), the use of CT as a predictive tool has not been conclusively demonstrated in relation to low energy vertebra compression fracture (VCF).

The aim of this study was to define the CT parameters that could be used to predict the risk of VCF.

**Materials and Methods:** One hundred consecutive patients undergoing CT scans were enrolled in this study. Bone density measurements were obtained at the T10-L5 levels from the cancellous portion of the vertebral body in the mid-sagittal, mid-coronal and axial planes. The presence of a single-level or multi-level VCF was identified by CT. Multi-level degenerative changes were characterized and recorded. Logistic regression was utilized to assess the relationship between the variables of bone density in HU, single- or multi-level VCF and the presence of degenerative changes.

**Results:** HU were found to have a strong correlation to the risk of VCF. HU of less than 101 were associated with a significant increase in the rate of VCF, whereas HU of less than 82 were associated with a significant increase in the rate of multi-level VCF. Hypertrophic degenerative changes were found to be associated with a decreased rate of VCF.

**Conclusion:** CT data can accurately define the risk of VCF and therefore presents a useful clinical tool to support the need for prophylactic medical therapies for osteoporosis or to provide information useful in counseling patients at risk for VCF.

**Keywords:** Computed tomography; Hounsfield units; Bone minimal density; Vertebral compression fracture

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## Introduction

Vertebral compression fractures (VCF) are a commonly encountered clinical condition in the older adult population and often require nonoperative and operative therapies. It has been estimated that 40% of women will experience this pathology within their lifetime [1-3]. Following an initial VCF, the odds of recurrent VCF within a decade is over 25% [4]. Although both genders are affected by VCF, the incidence is noticeably higher

in females [5-7]. VCF leads to a variety of secondary problems including progressive spinal deformity, decreased lung capacity, and reduced gastrointestinal function [8-10].

Dual emission x-ray absorptiometry (DEXA) is frequently used to assess bone mineral density of the lumbar spine, hip, wrist or calcaneus and has been used widely as a diagnostic tool in the surveillance of osteoporosis. Unfortunately, the sensitivity of DEXA in predicting fracture risk has been shown to be relatively

poor, leading some to suggest the need for additional diagnostic studies that more accurately predict fracture risk [11-13]. Computed tomography (CT) is a commonly employed diagnostic modality useful in the workup of a variety of spinal conditions. CT data is capable of accurately defining bone density using Hounsfield units (HU). The HU scale represents the relative radiodensity of a body tissue according to a calibrated gray-level scale, based on the values for air (-1000 HU) and water (0 HU); this scale is slightly non-linear [14]. The use of the HU scale has been utilized to measure the likelihood of success in dental implants, a procedure which relies on a stable bone-implant interface [15,16]. Some have suggested that CT measures could play a useful role in identifying patients at risk for low energy VCF [17,18]. It was clearly defined that both phantomless quantitative computed tomography and simple ROI attenuation measurements are effective for bone density screening, however the opportunity for VCF prediction was not investigated [19]. In this study, we hypothesized that a threshold of bone density in HU could be identified, below which the risk of VCF would be significantly increased.

## Materials and Methods

One hundred consecutive patients older than 40 years were enrolled in this study between August and December 2012. Patients were selected for study inclusion if they underwent a CT scan of the lumbar spine as a part of the medical work up for symptoms of axial back pain. Patients with a history of high energy trauma or oncologic lesions were excluded from study participation.

The CT scans were performed from the T10-L5 levels using a single CT scanner (Aquilion 32, Toshiba Corporation). The scans utilized a slice thickness was 0.5 mm, covering a scan area of 50 cm. The scan parameters included: tube voltage 120 kV, tube current 300 mA, auto mAs range 180-400; 1.0 sec/3.0 mm/0.5 × 32, helical-pitch 21.0. Integrated software was utilized for calculations of bone density (Vitrea Version 5.2.497.5523) incorporating a window width/window level ratio of 2000/500.

Measurements of bone density of the cancellous portions of the vertebral bodies without presence of VCF were obtained in HU at the level of L2 or L3 in the sagittal, axial and coronal planes. Measurements in the axial plane were taken at the level of the middle of the pedicles. Measurements in the sagittal and coronal

planes were taken along the geometric center of vertebra body. Oval-shape trabecular bone samples were selected using the maximal achievable diameters without traversing into cortical bone to calculate bone density in each plane. All cases with VCF were inspected by two certified radiologists using Genant visual semi-quantitative method [20] and were categorized as single-level or multi-level (greater than one level of VCF). Patients with degenerative changes in the spinal segments defined as loss of more than 50% of the disc height and associated endplate sclerosis were identified.

## Statistical Analysis

A power analysis was performed using a data subset to estimate sample size by the Monte-Carlo method with 2000 simulations. The interaction of bone density in HU, the presence of single-level or multi-level VCF and the presence of degenerative changes were assessed using logistic regression analysis.

## Results

The study included 63 females (63%) and 37 males (37%) with a mean age of 58 years (42-89 years). The age and bone density measurements are shown in Table 1.

The mean bone density was calculated from the axial, sagittal and coronal measurements of each vertebral segment and was used in the logistic regression analysis.

The frequency of VCF and degenerative changes is shown in Table 2.

The logistic regression analysis demonstrated a strong positive correlation between the rate of single level VCF and decreasing bone density. The parameters of the logistic regression model were  $B_0=2.6254$ ,  $p=0.0013$ ;  $B_1=-0.0387$ ,  $p<0.0001$ . Goodness of fit: Chi-square=37.1180;  $p<0.0001$ , percent of correctly predicted 81% (Figure 1).

The estimated logistic function:  $y=e^{2.6254-0.3872*x}/(1+e^{2.6254-0.3872*x})$

No fractures were observed in cases where the bone density was above 150 HU. The logistic regression model demonstrated a critical point of 101.78 HU associated with the significant increase in rate of single-level VCF (critical point associated with VCF probability growth acceleration was detected using derivatives of

**Table 1** Age and bone density measurements for the study cohort.

n=100	Mean (mean ± Standard error of mean)	Standard deviation	Maximum	Minimum
Patient age	58.18 ± 0.95	9.53	89	42
Bone density axial HU	102.01 ± 4.87	48.75	225	-28
Bone density sagittal HU	113.50 ± 5.03	50.39	227	-20
Bone density coronal HU	109.59 ± 5.17	51.70	212	-22
Mean bone density HU	108.37 ± 4.95	49.56	212	-17

**Table 2** VCFs and degenerative changes.

n=100	Detected VCF	Multi-level VCF	Degenerative changes
N of patients	27	18	52

logistic regression function). The estimated logistic regression for this value was  $B_0=0$ ,  $p=1$  (not significant);  $B_1=2.024382$ ,  $p=0.00014$ ; odds ratio(OR)=7.57; 95% confidence interval (CI) [2.74; 20.90]; goodness of fit: Chi-square=17.97233;  $p<0.0001$ .

The incidence of multi-level VCF was found to have a strong inversely relationship to bone density. The parameters of the logistic regression models were:  $B_0=1.5934$ ,  $p=-0.0338$ ;  $B_1=0.0355$ ,  $p=0.00013$ . Goodness of fit: Chi-square=27.21870;  $p<0.0001$ , percent of correctly predicted 86% (Figure 2).

The logistic regression model demonstrated a critical inflection point of 82.0 HU associated with a significant increase in rate of multi-level VCF (critical point associated with multi-level VCF probability growth acceleration was detected using derivatives of logistic regression function). The estimated logistic regression for this value was  $B_0=0.5261$   $p=0.1358$  (not significant);  $B_1=1.9588$ ,  $p=0.000$ , 0.011; Odds ratio(OR)=7.09; 95% confidence interval (CI) [2.23; 22.51]; goodness of fit: Chi-square=12.84427;  $p=0.0003$ .

Degenerative changes were found to correlate with a decreased likelihood of VCF. The parameters of the logistic regression model were Chi-square=8.976428  $p=0.0027$ ;  $B_0=0.3514$ ,  $p=0.2434$  (not significant);  $B_1=1.3978$ ,  $p=0.0050$  OR=4.04 [1.54;10.62]. Table 3 shows the breakdown of degenerative changes seen in this study.

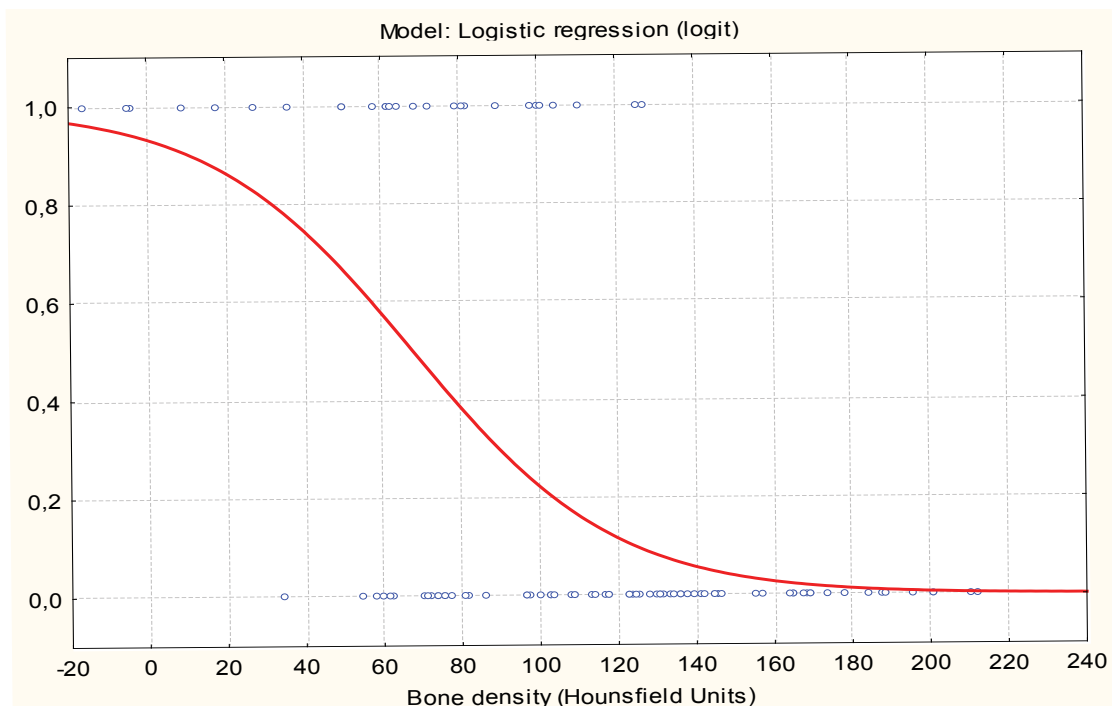
## Discussion

Although there are many reports demonstrating the correlation between reduced bone mineral density as measured by DEXA and low energy VCF [21-25], no clear cutoff for fracture risk has been identified. Furthermore, changes in bone mineral density as measured by DEXA have not always had a strong correlation to changes in fracture risk assessment [26]. Bone mineral density as measured by DEXA has a low predictive value for predicting the risk of future fractures [27,28]. For these reasons, some have recommended that DEXA values be combined with other clinical factors or diagnostic studies when estimating the risk of VCF [29-33]. In distinction, the detection of even a minimal VCF, is highly predictive of future fracture risk [33-36]. It would however but more clinically useful to establish the risk of a fracture before it occurs so that prophylactic treatment could be instituted to prevent fracture [37].

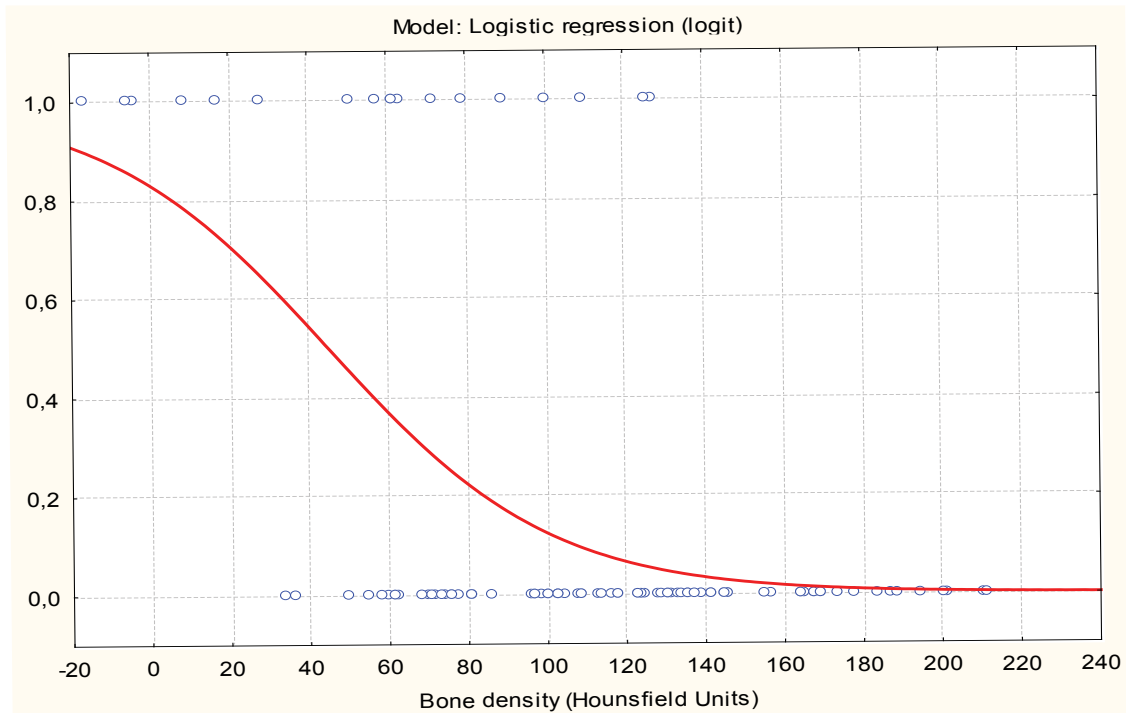
One explanation for the observed discrepancy in the predictive value of DEXA is the fact that DEXA provides an areal estimate of the integral BMD of the entire vertebra including both cortical and trabecular bony structures [17-38]. Additionally, the values provided by DEXA can be highly affected by bone size, spinal deformity or the presence of degenerative changes [17-39]. In distinction, CT provides a true volumetric bone density independent of bone size and allows the trabecular bone to be sampled independent from the endplates and posterior elements

**Table 3** Classification of cases based on presence of degenerative changes.

	Patients	Fractures
Subgroup without degenerative changes	46	19 (41%)
Subgroup with degenerative changes	54	8 (15%)



**Figure 1** The logistic regression function graph for single-level VCF probability.



**Figure 2** The logistic regression function graph for multi-level VCF probability.

[18-44]. It also allows the examiner to identify the presence of degenerative changes which have a prognostic impact on fracture risk as shown in the present analysis. For these reasons, quantitative CT has clear advantages in terms of predicting low energy fracture risk compared to DEXA [17,18].

The present study confirms that CT measurements have a strong relationship with VCF risk. A clinically useful finding of this study is significant correlation with increased VCF risk for patients with a bone density of less than 101 HU. Additionally, the risk of multi-level VCF is significantly increased when the bone density falls below 82 HU. Additionally, this study has confirmed what could be clinically suspected that patients with degenerative changes are less likely to suffer a VCF. This effect is likely due to the increased mechanical strength of the sclerotic endplates which stress shield the vertebral body in erect posture [45].

Although highly predictive, routine use of CT as a screening tool for osteoporosis is unsuitable due to the associated radiation exposure and cost of the study compared to DEXA. However, when CT scans are obtained for other clinical indications, they afford the clinician a unique opportunity to easily obtain useful

data that can be used to direct treatment and counsel patients with regards to fracture risk. In this capacity, CT provides excellent insights into bone density and an opportunity to make prognostic inferences is obtained.

Thus study has certain limitations which must be acknowledged. Only patients with axial pain requiring CT scanning for workup were included in this study. It is plausible that the asymptomatic population would have a different distribution of findings. In addition, the number of participants in this study is relatively small, however the power analysis confirmed that the sample size was sufficient to support the conclusions reached.

## Conclusion

In conclusion, the results of our study show that bone density measured by CT can be used to predict the risk of low energy VCF. Bone density above 150 HU is highly unlikely to be associated with low energy VCF. In contrast, bone density of 101 HU or less is associated with an increased risk of VCF, and bone density of less than 82 HU is associated with an increased risk of multi-level VCF. Clinicians can recommend preventive therapies and provide counseling for high risk cases to reduce the chances of future VCF.

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