Accuracy of Phantomless Calibration of Routine Computed Tomography Scans for Opportunistic Osteoporosis Screening in the Spine Clinic

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INTRODUCTION:

Osteoporosis is associated with an increased risk of complications after surgical treatment of the spinal disorders. Patient-specific phantomless calibration of computed tomography (CT) scans have been proposed as an alternative technique to overcome the limitations of Dual-energy X-ray absorptiometry (DXA). This technique uses the patient's own tissues as reference.

The objective of this study is to establish a simple method of phantomless bone mineral density (BMD) measurement by using available preoperative lumbar CT scans, and compare the accuracy of different combinations of reference tissues to diagnose low BMD against uncalibrated Hounsfield units (HU).

METHODS:

This is a retrospective diagnostic accuracy study. Institutional database was reviewed between 2015-2023. Patients (1) ≥18 years of age who were planned to undergo lumbar surgery, (2) with a preoperative lumbar CT scan, (2) and a DXA scan were included. Patients with (1) CT scans not dedicated to the lumbar spine, and (2) without hip or lumbar DXA scans were excluded.

Four different tissues were selected for internal calibration: subcutaneous adipose (A), erector spinae muscle (ES), psoas muscle (P) and aortic blood (AB), as shown on Figure 1. HU values of the tissues were linearly regressed against the standardized ground truth values from the National Institute of Standards and Technology database, which were 50 mg/cm^3 for muscle, 60 mg/cm^3 for blood and -50 mg/cm^3 for adipose. The equations for each internal calibration tissue were:

(1) $-50 \text{ mg / cm}^3 = a\,(HU_{fat}) + b$

(2) $-50 \text{ mg / cm}^3 = a\,(HU_{muscle}) + b$

(3) $-60 \text{ mg / cm3} = a\,(HU_{blood}) + b$

For simple in-office applicability, two equations are used for each calibration, and *a*
(slope) and *b* (intercept) are found by solving two equations. Calibrations were performed by using A+ES, A+P and A+AB. ES+AB and P+AB were not performed because of the high inaccuracy. Then by using a last equation, volumetric BMD (vBMD) can be calculated:

(4) $BMD = a\,(HU_{trabecularbone}) + b$

vBMDs derived from internally calibrated CT scans were analyzed for correlations with DXA T-scores, and by using a Receiver Operating Characteristics (ROC) analysis new thresholds for detecting low bone mineral density were designated. Areas under the curve (AUC) were calculated with 95% confidence intervals (CI).

RESULTS:

45 patients were included (M/F =10/35) with a mean age of 63.3 and mean BMI of 31.4. Mean total hip T-score was -0.5 (±1.2), worst hip T-score was -1.2 (±1.2), total lumbar T-score was -0.1 (±2.1) and worst lumbar T-score was –0.5 (±2). Mean overall vBMD by A+ES was 141.4 (±46.4), A+P was 131.3 (±52.3), and A+AB was 142.7 (±49.4). HU measurements and calibrated vBMDs were correlated against DXA T-scores as shown on Figure 2. Calibrated vBMDs achieved better correlation coefficients for almost every level when compared with uncalibrated HUs.

Previously proposed vBMD thresholds for osteoporosis (<80 mg/cm^3) and osteopenia (<120 mg/cm^3) were shown to have low sensitivities with the current method. ROC analysis was performed on detection of low bone density (T Score<-1), and the resulting thresholds were 162 mg/cm^3 (AUC=0.671, 95% CI=0.497-0.845) for A+ES, 115 mg/cm^3 (AUC=0.795, 95%CI=0.658-0.933) for A+P and 129 mg/cm^3 (AUC=0.797, 95% CI=0.658-0.937) for A+AB. The sensitivity and specificities of the new thresholds for low bone density can be seen on Figure 3. Calibration with Adipose and ES Muscle has the highest sensitivity, and is therefore considered the best candidate for screening purposes.

DISCUSSION AND CONCLUSION:

The results of this retrospective study demonstrate that in-office simple internal calibration of lumbar CT scans can be used to calculate vBMDs, which are better correlated with standard DXA scan T-scores when compared with uncalibrated HU measurements. Previously recommended vBMD thresholds have low diagnostic performances in this setting, and we suggest using adipose and erector spinae muscle for calibration, and a threshold of 162 mg/cm^3 for low bone density screening as it shows the highest sensitivity (>90%). With the proposed new thresholds, phantomless calibration of lumbar CT scans can provide an opportunity for screening in patients planned to undergo spinal surgery, allowing for the avoidance of logistical difficulties associated with conventional quantitative CTs and with higher correlations when compared with uncalibrated HU measurements. Expanding the clinical usefulness of this simple calibration method will require further studies.

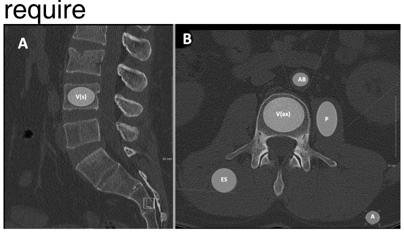

Figure 2. Correlations table.

		Total Hip T-Score	Femoral Neck T-Score	Total Lumbar T-Score
L1	**HU (Axial)**	.466*	.411*	.487*
	HU (Sagittal)	.522*	.514*	.523*
	vBMD by A+ES	.485*	.382*	.671*
	vBMD by A+P	.375*	.316	.527*
	vBMD by A+AB	.507*	.418*	.492*
L2	**HU (Axial)**	.584*	.530*	.574*
	HU (Sagittal)	.604*	.541*	.614*
	vBMD by A+ES	.553*	.475*	.711*
	vBMD by A+P	.640*	.601*	.691*
	vBMD by A+AB	.745*	.681*	.690*
L3	**HU (Axial)**	.524*	.447*	.473*
	HU (Sagittal)	.681*	.620*	.613*
	vBMD by A+ES	.505*	.339	.576*
	vBMD by A+P	.586*	.505*	.579*
	vBMD by A+AB	.667*	.585*	.585*
L4	**HU (Axial)**	.317	.306	.378
	HU (Sagittal)	.370	.346	.393
	vBMD by A+ES	.314	.298	.458*
	vBMD by A+P	.391*	.365	.487*
	vBMD by A+AB	.710*	.669*	.648*
Overall	**vBMD by A+ES**	.551*	.454*	.750*
	vBMD by A+P	.592*	.530*	.677*
	vBMD by A+AB	.713*	.635*	.656*

- Statistically significant correlations are represented with an asterisk (*).
-Correlation coefficients greater than 0.6 are presented with a gray background color.
-Abbreviations: vBMD, volumetric bone mineral density; HU, Hounsfield unit; A, adipose tissue; ES, erector spinae muscle; P, psoas muscle; AB, aortic blood.

vBMDs		**DXA Results**		
		Normal (T Score≥-1) n=13 (29%)	**Low (T Score<-1)** n=32 (71%)	
A+ES	**Normal** n=10 (22%)	6	4	**Sensitivity=0.907 Specificity=0.462**
	Low n=35 (78%)	7	28	
A+P	**Normal** n=28 (62%)	13	15	**Sensitivity=0.607 Specificity=1**
	Low n=17 (38%)	0	17	
A+AB	**Normal** n=28 (62%)	12	16	**Sensitivity=0.600 Specificity=0.923**
	Low n=17 (38%)	1	16	