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Clinical Study

Performance comparison between Hounsfield units and DXA in predicting lumbar cage subsidence in the degenerative population

Lindsay D. Orosz, MSPA-C[a,*], Kirsten A. Schuler, BS[a], Brandon J. Allen, BA[a], Wondwossen T. Lerebo, PhD[a], Tarek Yamout, MD[b], Rita T. Roy, MD[a], Thomas C. Schuler, MD[b], Christopher R. Good, MD[b], Colin M. Haines, MD[b], Ehsan Jazini, MD[b]

[a] *Department of Research, The National Spine Health Foundation, Reston, VA 20191, USA*
[b] *Department of Surgery, The Virginia Spine Institute, Reston, VA 20191, USA*

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Abstract

BACKGROUND CONTEXT: Bone mineral density assessment is essential for surgical planning for most spine surgeries, but gold standard dual-energy x-ray absorptiometry (DXA) is affected by degeneration often resulting in falsely elevated scores. Studies of the opportunistic measurement of computed tomography (CT) Hounsfield units (HU) suggest lower CTHU values predict interbody cage subsidence, yet cutoff values vary and lack standardization.

PURPOSE: This study aimed to determine if value CTHU<135 was associated with lumbar interbody cage subsidence and to compare the predictive performance of subsidence between CTHU and DXA.

STUDY DESIGN/SETTING: Single-center, multi-surgeon, retrospective cohort study

PATIENT SAMPLE: Adult, circumferential lumbar fusions ≤5 interbody levels with DXA, CTs, radiographs, and at least 1 year of follow up.

OUTCOME MEASURES: CTHU at L1, lowest DXA T-score, and postoperative change in disc space height (cage migration) on radiographs

METHODS: Lowest DXA T-scores overall and of the lumbar spine were recorded and categorized, and L1 CTHUs were measured. Interbody fusions were analyzed for subsidence ≥2 mm on radiographs by a validated, computer vision algorithmic approach. Analysis determined if an association existed between subsidence and CTHU<135 or DXA lowest T-score. Logistic regression analyzed the performance of predicting subsidence by each method.

RESULTS: The 127-patient cohort had 82.7% degenerative pathologies, 45.7% males, median age of 60 years, 2.4% osteoporosis on DXA, 44.1% CTHU<135, and 13.4% subsidence. CTHU<135 (p=.004) and age (p=.016) were significantly associated with subsidence, however DXA lowest T-score (p=.550) was not. The odds of subsidence were significant if CTHU<135 for crude and adjusted (OR=4.0, 95% CI 1.2−13.9, p=.029) comparisons. The odds of subsidence were not significant for DXA_{any} lowest T-score or DXA_{spine} lowest T-score (OR=1.8, 95% CI 0.6−4.9, p=.284 and OR=1.1, 95% CI 0.3−4.1, p=.920, respectively).

FDA device/drug status: Not applicable.

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*Corresponding author. Department of Research, National Spine Health Foundation, 11800 Sunrise Valley Drive, Suite 330, Reston, VA 20191, USA.

E-mail address: lorosz@spinehealth.org (L.D. Orosz).

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CONCLUSION: CTHU<135 was associated with subsidence while DXA lowest T-score was not in this study of patients with degenerative pathologies. The odds of subsidence were 4.0 times higher for CTHU<135 after controlling for known risks, supporting this cutoff value. This study suggests that CTHU is a more reliable predictor of subsidence than DXA in this primarily degenerative population and is a useful tool for assessing bone quality at the region of interest when planning lumbar surgery.

Keywords: Bone health; CTHU; DEXA; DXA; Hounsfield units; Lumbar surgery; Subsidence

Introduction

The importance of maximizing bone health to avoid devastating bone-related complications for spine surgery patients cannot be overstated. The delicate balance between the rate of bone modeling and remodeling becomes increasingly uneven throughout adulthood, with rapid remodeling leading to poor bone health and reduced strength [1]. Low bone mass and osteoporosis are characterized by progressive decreases in density and increases in porosity of bones, which affect millions of adults and an estimated 50% of patients undergoing arthroplasty or spinal fusions [2,3].

The 2005 US Surgeon General report on bone health estimated that more than 10 million people over the age of 50 years had osteoporosis and an additional 34 million were at risk in the US [4,5]. The National Bone Health Alliance (NBHA) provides a more recent estimate using updated diagnostic criteria, including bone mineral density (BMD), scores from the Fracture Risk Assessment Tool (FRAX), and low energy fractures irrespective of T-scores. The NBHA showed that an estimated 30% of women and 16% of men in the 50+ years category have osteoporosis [6]. The prevalence increased with age, with an estimated 77% of women and 46% of men in the 80+ years category having osteoporosis in the US. The trends in this report are supported by other prevalence studies [7].

The escalating prevalence of osteoporosis is fueled, in part, by the extended longevity of advanced-aged adults and the increasing incidence of common risk factors such as Vitamin D deficiency, dietary restrictions and nutritional deficits, chronic diseases, and the use of medications detrimental to bone health [8]. Yet, the presence of low bone mass and osteoporosis continue to be underdiagnosed and undertreated, resulting in the vast majority of patients undergoing spine surgery having a sub-optimal bone density to support the surgical plan [9]. As such, it has become essential to evaluate BMD prior to most spine surgeries to effectively plan for optimization and reduce the devastating risk of bone-related surgical complications [10,11].

Dual-energy x-ray absorptiometry (DXA) remains the gold standard method of evaluating BMD, yet some challenges do exist with this method that particularly affect many patients undergoing spine surgery [12,13]. This paper focuses on the falsely elevated T-scores that result from surrounding degenerative pathologies, most pronounced in the spine, such as bone spurs, facet hypertrophy, and degenerative spinal deformities that are often found in combination in those undergoing spine surgery [14−16].

Computed tomography (CT) scans are often obtained as part of preoperative planning for cases using instrumentation guidance systems, addressing spinal deformities, and implanting artificial discs. The Hounsfield Unit (HU) measurement, the standardized linear attenuation coefficient of tissue, is easy to adopt into practice by taking just seconds to measure using picture archiving and communication system (PACS) tools [17]. If a CT is readily available, this additional measure of BMD is advantageous to spine surgeons as it can be obtained at the region of interest (ROI) and is not affected by surrounding degenerative changes, perhaps providing a more reliable and accurate representation of the degenerative spine surgery patient's local bone quality [18,19].

Although the opportunistic measurement of Hounsfield Units on CT (CTHU) is gaining in popularity, cutoff values vary and lack standardization [20]. The primary purpose of this study was to determine if the cutoff value of CTHU<135 was associated with interbody cage subsidence in this sample population, and to compare the predictive performance of subsidence between CTHU and DXA methods. Secondarily, this study assessed the relationship between the lowest T-scores from the lumbar spine region with the lowest T-scores overall within the same DXA report.

Methods

Patient selection and classification

This is a retrospective cohort study of prospectively collected data at a multi-surgeon, single institution. The institution maintains a thoracolumbar registry of surgical cases involving the thoracic and/or lumbar spine regions. Cases include decompression, fusion, and arthroplasty procedures. For this study, all adult fusion cases were initially extracted from the registry between 2019 and 2021, then cases were excluded if the fusion was not circumferential (any anterior approach to interbody fusion with posterior fixation), as this was the most common lumbar fusion procedure performed at the institution with both DXA and CT scans. Additionally, cases were excluded if they extended above L1, if DXA, lumbar CT, or lumbar radiographs were missing, and if follow-up was less than 1 year (Fig. 1). This institution

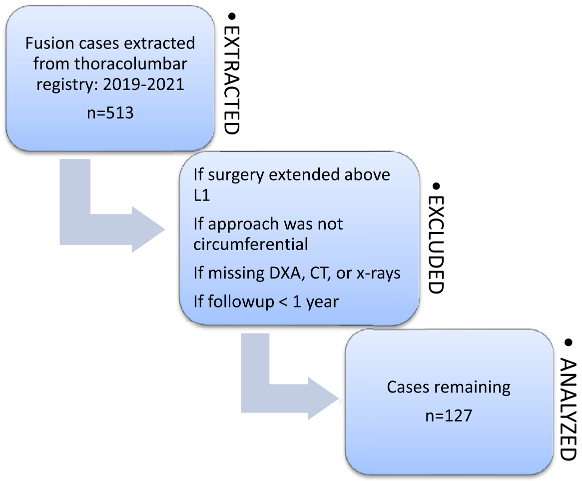

Fig. 1. Flow diagram depicting cohort development.

obtains DXA scans as part of the preoperative preparation routine for all lumbar fusions. Anterior approaches included anterior lumbar interbody fusion (ALIF), lateral lumbar interbody fusion (LLIF), a combination of ALIF and LLIF, or oblique lumbar interbody fusion (OLIF). Bone morphogenetic protein-2 (BMP-2) was used in combination with local autograft in all anterior cages. Implant selections were based on surgeon preference. Posterior fixation options included open or percutaneous approaches, pedicle or cortical screws, unilateral or bilateral fixation, and extension of fixation to the pelvis with S2AI screws.

Data collection

Demographic data, surgical data, DXA reports, and images were collected from the institution's spine registry database, electronic medical recording system, PACS, hospital records, and operative reports. From DXA reports, the lowest T-scores overall and of the lumbar spine region (L1−4) were recorded. T-scores were categorized as: normal $\geq -1.0 >$ osteopenia $> -2.5 \leq$ osteoporosis according to the World Health Organization (WHO) criteria.

Image analysis

Hounsfield units were measured using the standard PACS elliptical tool on lumbar CT scans at L1 using the method described by Anderson et al., Ran et al., and Lee et al. using the midsagittal view of the sagittal reconstruction images (Fig. 2) [21−23]. See Video 1 for a brief tutorial of the HU measurement method. The mean HU value reported by the tool was recorded, then categorized as HU≥135 or HU<135. The threshold of 135HU was initially selected based on established thresholds found in the literature as being associated with low bone mass and subsidence from populations sampled from similar geographical regions, then was compared to 100HU using ROC analysis based on the established HU value associated with osteoporosis [24−31].

Each interbody fusion level was analyzed for subsidence, defined as ≥ 2mm of loss of disc space height or cage migration, at an outside Imaging Core Lab by a validated, automated, computer vision algorithmic approach (Fig. 3) [32]. The analysis compared the immediate postoperative standing lateral lumbar radiograph to each subsequent postoperative standing lateral radiograph up to those collected at the 1-year follow-up. Computer analysis results were cross-referenced with clinical notes from each visit to be sure the presence of subsidence was not missed. If subsidence was suspected on the first postoperative radiograph, comparison was made to intraoperative fluoroscopic images, and manual measurements were made by a fellowship-trained spine surgeon. The automated computerized method could not utilize fluoroscopic images for analysis.

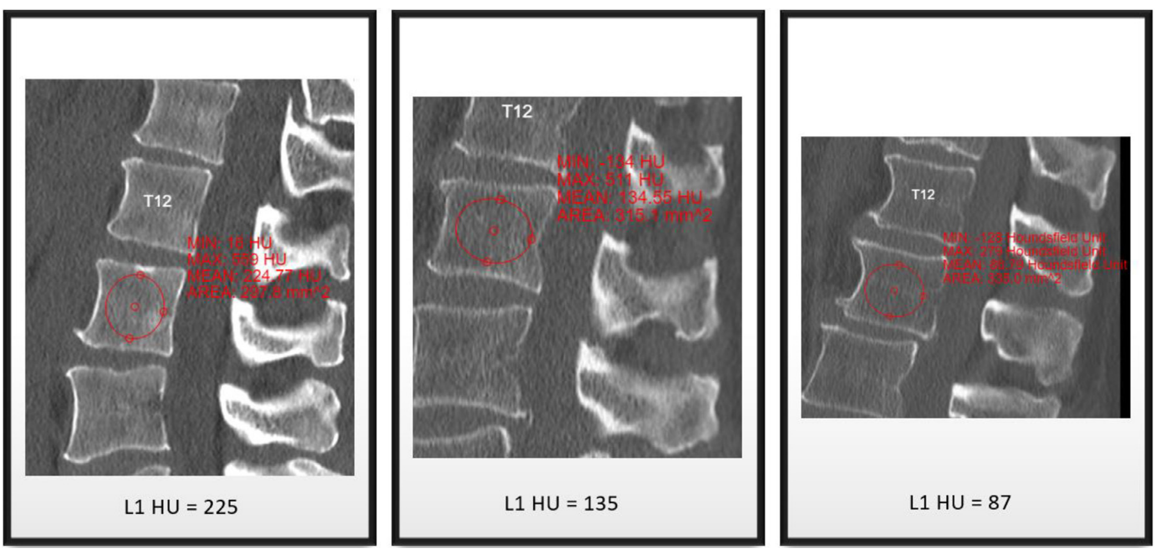

Fig. 2. Examples of CTHU measurement technique using midsagittal view at L1 vertebral body on 3 separate CT scans.

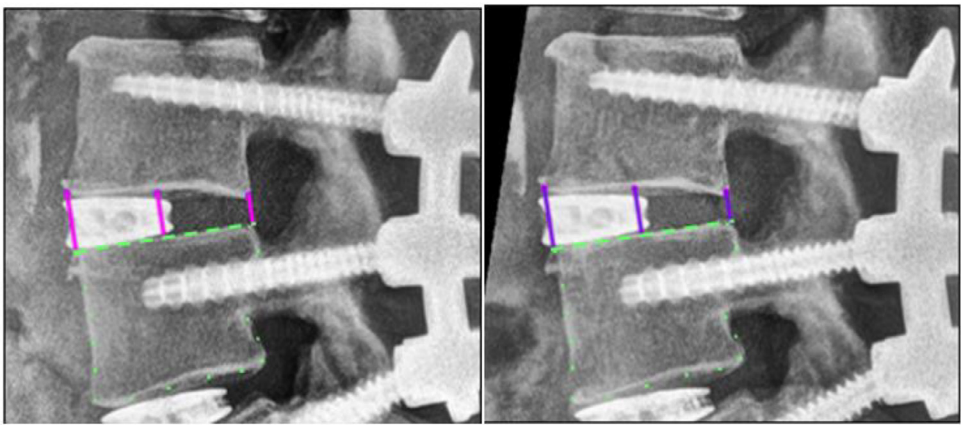

Fig. 3. Automated method for subsidence evaluation using Functional X-Ray Analysis (RAYLYTIC, GmbH, Leipzig, Germany). Example demonstrates disc space height comparison between 2-week postoperative lateral x-ray (left) and 6-month postoperative lateral x-ray (right). Numerical height in millimeters is determined by the software and differences are calculated automatically.

Statistical analysis

Data was analyzed using StataCorp. 2023. *Stata Statistical Software: Release 18*. College Station, TX: StataCorp LLC. Categorical data was summarized using frequencies and percentages, median and interquartile range (IQR) for nonparametric data and mean with standard deviation for parametric data. Pearson's chi-square test or Fisher's exact test was employed as appropriate to determine the association between subsidence and other predictor variables. Scatterplot was used to demonstrate the relationship between the lowest T-scores of the lumbar spine region compared to the lowest overall T-scores on the same DXA report. Receiver operating characteristic (ROC) analysis was conducted to compare the performance between established values of 135HU and 100HU in determining the HU cutoff threshold for this study. To compare the Area Under the Curve (AUC) of the 2 ROC curves, DeLong's test was employed.

Bivariate binary logistic regression analysis was carried out to select potential candidate predictors for the full model with a cutoff point p-value≤.20. Multivariable binary logistic regression analysis was used to estimate the independent effect of predictors on subsidence. The model was built and compared by stepwise backward elimination procedure. Interactions and confounders were checked by using change in beta coefficient with cutoff point beta change > 20%. Multicollinearity for variables in the final fitted model was checked using variance inflation factor (VIF) with cutoff point mean VIF > 5, and results showed much less than this (VIF=1.05). Classifying ability (predicting power) of variables in the final fitted model was checked by receiver operating characteristic (ROC) curve and overall goodness of fit was checked using Hosmer-Lemeshow chi-square test. Associations between predictors and odds of subsidence were summarized using adjusted odds ratio. Statistical significance was tested at p-value<.05.

Research ethics statement

This study was approved by a Commercial Institutional Review Board (IRB) and was conducted in accordance with the 1964 Helsinki Declaration, its amendments, and other equivalent ethical standards. All study participants or their legally authorized representative signed informed consent forms and Notice of Privacy Practices prior to study enrollment.

Results

Background and surgical characteristics

A total of 127 patients remained after exclusion criteria were applied and had a median follow-up of 17 (12−24) months. The median age was 60 (51−69) years, 45.7% were males, 32.3% were nicotine users, 87.4% were white, and 82.7% had a degenerative primary diagnosis. Only 2.4% met the WHO criteria for osteoporosis on DXA, 11.8% had established osteoporosis value of CTHU≤100, and 44.1% had CTHU<135 (Table 1).

The median number of interbody fusion levels per case was 2 (1−2) at 57.5% of cases, with the most common levels being at L4/5 (37.2%) and L5/S1 (34.4%). ALIF was the most common anterior approach to interbody fusion at 74.8%, with bilateral (74.0%) pedicle (86.6%) screw fixation using a percutaneous (57.5%) approach without extension (92.1%) to the pelvis (Table 2).

Hounsfield unit threshold

ROC analysis was conducted using values 135HU and 100HU. The observed area under the ROC curve (AUC) for 135HU was 0.69 and for 100HU was 0.64. Given better discriminatory performance, cutoff value 135HU was selected for use in this subsidence study. DeLong's test did not detect a statistically significant difference between the ROC curves (p=.432).

Table 1
Patient characteristics

Characteristic *N*=127	Value N (%)
Male Sex	58 (45.7)
Age (years, median (IQR))	60 (51−69)
Age categories (years)	
≤ 59	60 (47.2)
60−69	37 (29.1)
≤ 70	30 (23.6)
CCI	
< 2	107 (84.2)
≥ 2	20 (15.8)
Nicotine users (current or recent)	41 (32.3)
Race	
White	111 (87.4)
Black	12 (9.4)
Hispanic	2 (1.6)
Asian	2 (1.6)
BMI categories (kg/m^2)	
18.5−24.9	24 (18.9)
25−29.9	40 (31.5)
30−34.9	36 (28.3)
> 35	27 (21.3)
Follow-up length (months, median (IQR))	17 (12−24)
DXA lowest T-score (any region)	
Normal (≥−1.0)	72 (57.6)
Osteopenia (< −1.0, >−2.5)	50 (40.0)
Osteoporosis (≤ −2.5)	3 (2.4)
Hounsfield units (L1 CTHU)	
≥135	71 (55.9)
<135	56 (44.1)
Subsidence	
No	110 (86.6)
Yes	17 (13.4)

Values represent the number of patients (%) unless otherwise specified.
IQR, interquartile range; *CCI,* Charlson Comorbidity Index; *BMI,* body mass index; *DXA,* dual- energy x-ray absorptiometry; *CTHU,* computed tomography Hounsfield units.

Table 2
Surgical details

Characteristic *N*=127	Value N (%)
Primary diagnosis	
Degenerative	105 (82.7)
Deformity	18 (14.2)
Revision	4 (3.2)
Interbody fusion levels (median (IQR))	2 (1−2)
1-level	33 (26.0)
2-levels	73 (57.5)
≥ 3-levels	21 (16.5)
Interbody fusion by level (*N*=247 levels)	
L1/2	7 (2.8)
L2/3	19 (7.7)
L3/4	44 (17.8)
L4/5	92 (37.2)
L5/S1	85 (34.4)
Anterior surgical approach	
ALIF	95 (74.8)
LLIF	21 (16.5)
ALIF/LLIF	6 (4.7)
OLIF	5 (3.9)
Posterior fixation approach	
Open	54 (42.5)
Percutaneous	73 (57.5)
Posterior fixation type	
Pedicle	110 (86.6)
Cortical	17 (13.4)
Posterior fixation laterality	
Unilateral	33 (26.0)
Bilateral	94 (74.0)
Pelvic fixation	
No	117 (92.1)
Yes	10 (7.9)

Values represent the number of patients (%) unless otherwise specified.
IQR, interquartile range; *ALIF,* anterior lumbar interbody fusion; *LLIF,* lateral lumbar interbody fusion; *OLIF,* oblique lumbar interbody fusion.

Primary outcomes

Of 127 patients, 13.4% had subsidence, defined as ≥ 2mm of loss of disc space height or cage migration. A significant association was found between the predictor variable CTHU<135 and subsidence compared to CTHU≥135 (23.2% CTHU<135 vs. 5.6% CTHU≥135 with subsidence, p=.004). Age category was the only other predictor associated with subsidence, while sex, nicotine status, CCI, BMI, surgical details, and DXA lowest T-score were not (Table 3).

Bivariate binary logistic regression analysis was conducted to select potential candidate predictors for the full model with cutoff point p-value≤.20. Of the remaining predictors, CTHU<135 had the only significant independent effect on subsidence, with a crude odds ratio (OR) of 5.1 (95% CI 1.5−16.6, p=.007), while lowest T-score, age ≥ 70 years, female sex, CCI ≥ 2, nicotine use, and number of treated levels did not. Remaining predictors in the multivariable model were CTHU<135, female sex, CCI≥2, and nicotine use. After controlling for those potentially confounding variables, the effect of CTHU<135 on subsidence remained significant. The odds of developing subsidence if CTHU<135 was 4.0 (95% CI 1.2−13.9, p=.029) for the adjusted OR (Table 4).

Secondary outcome

The scatterplot in Fig. 4 depicts differences between the lowest T-scores from the lumbar spine region compared to the lowest T-score overall from the same DXA report. Values where DXA_{spine}=DXA_{lowest} are seen along the red line, which occurred when T-scores were only reported from the lumbar spine region. Results show that all lowest T-scores from the lumbar spine region were elevated in comparison to the lowest T-scores of any other region. The highlighted example in the scatterplot shows black arrows pointing to the lowest lumbar spine region T>+2 corresponding to the lowest other region T<−2.

Case example

The results of this study led to the surgeons at this institution measuring HUs routinely, when a preoperative CT

Table 3
Bivariate analysis of characteristics by subsidence

Characteristic	Subsidence N(%)		p-value
	No	Yes	
Hounsfield Units (L1 CTHU)			.004
≥135	67 (94.4)	4 (5.6)	
<135	43 (76.8)	13 (23.2)	
DXA lowest T-score (any region)			.550
Normal (≥ −1.0)	64 (88.9)	8 (11.1)	
Osteopenia (< −1.0, >−2.5)	41 (82.0)	9 (18.0)	
Osteoporosis (≤ −2.5)	3 (100.0)	0 (0.0)	
Age categories (years)			.016
≤ 59	57 (95.0)	3 (5.0)	
60−69	28 (75.7)	9 (24.3)	
≥ 70	25 (83.3)	5 (16.7)	
Sex			.09
Male	47 (81.0)	11 (19.0)	
Female	63 (91.3)	6 (8.7)	
Nicotine status			.162
Never	77 (89.5)	9 (10.5)	
Current or recent use	33 (80.5)	8 (19.5)	
CCI			.097
< 2	95 (88.8)	12 (11.2)	
≥ 2	15 (75.0)	5 (25.0)	
BMI categories (kg/m^2)			.503
18.5−24.9	22 (91.7)	2 (8.3)	
25−29.9	34 (85.0)	6 (15.0)	
30−34.9	29 (80.6)	7 (19.4)	
> 35	25 (92.6)	2 (7.4)	
Fused Levels			.681
One level	30 (90.9)	3 (9.1)	
Two levels	62 (84.9)	11 (15.1)	
Three or more levels	18 (85.7)	3 (14.3)	
Anterior surgical approach			.234
ALIF	81 (85.3)	14 (14.7)	
LLIF	20 (95.2)	1 (4.8)	
ALIF/LLIF	4 (66.7)	2 (33.3)	
OLIF	5 (100.0)	0 (0.0)	
Posterior fixation approach			.144
Open	44 (81.5)	10 (18.5)	
Percutaneous	66 (90.4)	7 (9.6)	
Posterior fixation laterality			.729
Unilateral	28 (84.8)	5 (15.2)	
Bilateral	82 (87.2)	12 (12.8)	
Pelvic fixation			.623
No	102 (87.2)	15 (12.8)	
Yes	8 (80.0)	2 (20.0)	

Values represent the number of patients (%) unless otherwise specified.
ALIF, anterior lumbar interbody fusion; *LLIF,* lateral lumbar interbody fusion; *OLIF,* oblique lumbar interbody fusion.

was available. This case example (Fig. 5) represents unexpected differences found between DXA and CTHU after routine investigation begins and demonstrates how the results altered the surgical plan. This is a 58-year-old male with AP/lateral lumbar radiographs showing mild-moderate degenerative changes in the lumbar spine, including disc space collapse with vacuum changes at L5/S1, multilevel anterior spurring most notable at L4/5, degenerative spondylolisthesis with decreased disc space height and facet hypertrophy at L4/5, as well as mild aortic calcification (Fig. 5A). Remaining workup revealed significant stenosis at L4/5 and L5/S1, and 2 level fusion was planned.

Preoperative DXA reports the lowest T-score = −0.8 and calculates the FRAX scores as 4.8% major osteoporotic-related fracture probability and 0.3% hip fracture probability, all being normal results (Fig. 5A). CT was obtained just prior to surgery for robotic guidance planning. The L1 CTHU mean = 75.58, which was well below the 135HU cutoff value described in this study as having an increased risk of subsidence (Fig. 5A). The surgeon adjusted the operative plan to include more points of fixation, and this patient did not subside up to 1 year following the L4/5, L5/S1 ALIF with plate at L5/S1 and bilateral percutaneous pedicle screw instrumentation (Fig. 5B). Based on normal DXA results, the complex issue of medical treatment for low BMD is not discussed in this paper.

Discussion

The prevalence of osteoporosis among spine patients is being increasingly recognized, leading to contemporary scrutiny of DXA results and how they inform surgical planning. This study demonstrated that CTHU<135 was associated with postoperative interbody cage subsidence, defined as ≥ 2 mm, in this sample population of patients with 83% primary degenerative diagnoses, only 2.4% in the osteoporosis range, but 44.1% with CTHU<135. The odds of developing subsidence were 4.0 times higher if CTHU<135 compared to CTHU≥135 after adjusting for potential confounders. DXA lowest T-score was not associated with subsidence nor an independent predictor of subsidence. These findings support the cutoff value of 135HU as a predictor for subsidence, and CTHU outperformed DXA in predicting subsidence in this sample population with degenerative pathologies. Falsely elevated T-scores raise concern for the misrepresentation of actual bone mineral density at the surgical region of interest. Furthermore, scatterplot of the lowest T-scores from the spine region and from any other region on the same DXA report revealed that all spine values were substantially higher compared to any other region in this population of primarily degenerative patients.

A recent literature review was undertaken to determine a consensus on HU values predicting cage subsidence. After reviewing 37 studies, the ability of HU values to predict the risk of cage subsidence effectively following spine surgery was supported by the authors of the review. They suggested the HU method may be superior to DXA for predicting subsidence, but the lack of standardization of HU values across studies, reported as ranging from 60 to 135 HU, was noted as a hindrance. A partial explanation given for this range in HU values was race, gender, and age differences [20].

Varying HU values are found in the literature, with variations often correlating with the patient populations or geographical regions being studied [33−36]. Although race is often not reported in the available HU studies, generally studies from centers in North America and Europe use the

Table 4
Regression analysis with crude and adjusted odds ratio results predicting the subsidence outcome

Predictor	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
CTHU<135	5.1 (1.5−16.6)	.007	4.0 (1.2−13.9)	.020
Osteopenia	1.8 (0.6−4.9)	.284	-	-
Age ≥ 70 years	3.8 (0.8−17.1)	.082	-	-
Female sex	0.4 (0.1−1.2)	.098	0.6 (0.2−1.8)	.325
CCI≥2	2.6 (0.8−8.6)	.106	1.8 (0.5−6.6)	.370
Nicotine use (current/recent)	2.1 (0.7−5.8)	.168	1.6 (0.6−5.8)	.264
2-level fusion	1.8 (0.5−6.8)	.405	-	-
≥ 3-level fusion	1.7 (0.3−9.1)	.557	-	-

OR, odds ratio; *CI,* confidence interval; *CTHU,* computed tomography Hounsfield unit; *CCI,* Charlson Comorbidity Index.

cutoff value of 135 as borderline and 110 for osteoporosis, whereas studies from centers in East Asia use the cutoff value of 115 as borderline and 100 for osteoporosis [11,14−17,37−39]. Zheng et al. used data from the National Health and Nutrition Examination Survey (NHANES) database from 2005 to 2014 to understand how racial and ethnic differences in the USA affect bone mineral density [40]. They found that the prevalence of low BMD was 50.8% in non-Hispanic Whites, 23.7% in non-Hispanic Blacks, and 44.0% in Hispanics. However, advanced age, female sex, and fracture history were all associated with increased odds of low BMD in all 3 racial and ethnic groups. In our study, the majority of the patient population were white (87.4%), and the cutoff value associated with subsidence was CTHU<135, similar to Hayden et al.'s sample population reported as 97% white and borderline HU values ranging between 150 and 110 [15].

While DXA remains a useful screening tool for bone health assessment, spine surgery patients with degenerative pathologies may have artificially elevated results. In a recent imaging study assessing the discrepancy between DXA and CTHU methods of reporting BMD, Davidson et al. found that the disagreement rate for HU threshold of 135 vs. lumbar DXA was 53.8% and vs. overall DXA was 47.3% [14]. The disagreement rate for HU threshold of 110 vs. lumbar DXA was 40.0% and overall DXA was 33.3%. The overestimation rate of lumbar DXA for 135HU was 100.0% and for 110HU was 96.9%. The overestimation rate of overall DXA for 135HU was 88.6% and for 110HU was 74.2%. Both lumbar and overall DXA disagreed with both 135 and 110HU values, raising concern for inaccurately elevated DXA results irrespective of region evaluated. These results support the findings of this study that CTHU may be more accurate than DXA in degenerative lumbar spine patients. Furthermore, the scatterplot of this study depicted that DXA lowest T-scores of the spine region are consistently and substantially elevated in comparison to the lowest T-score of any other region.

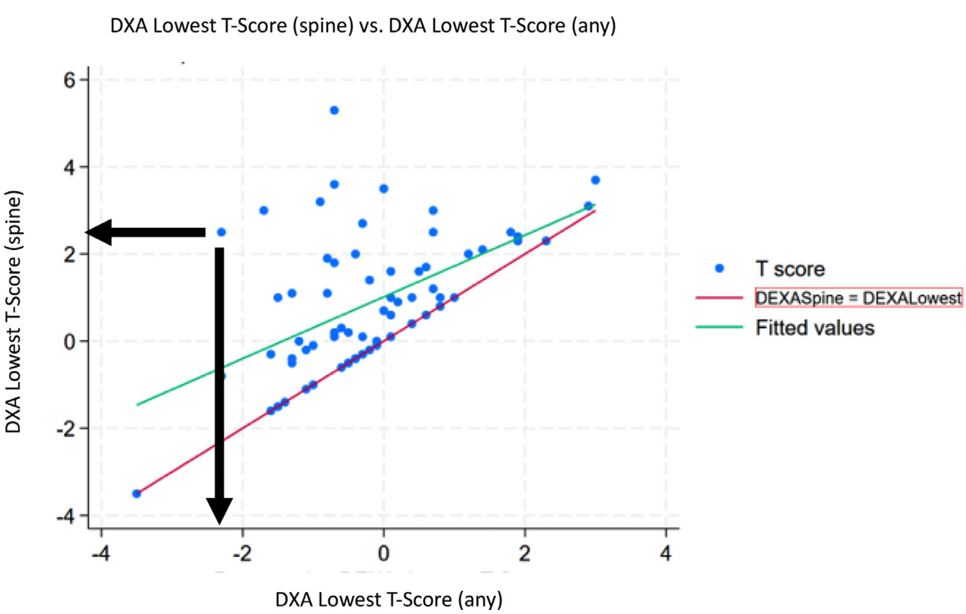

Fig. 4. Scatterplot depicting the degree of elevation of lumbar spine T-scores compared to T-scores from any other region on the same DXA report. Black arrow example: lowest spine T-score > +2, lowest any T-score < −2.

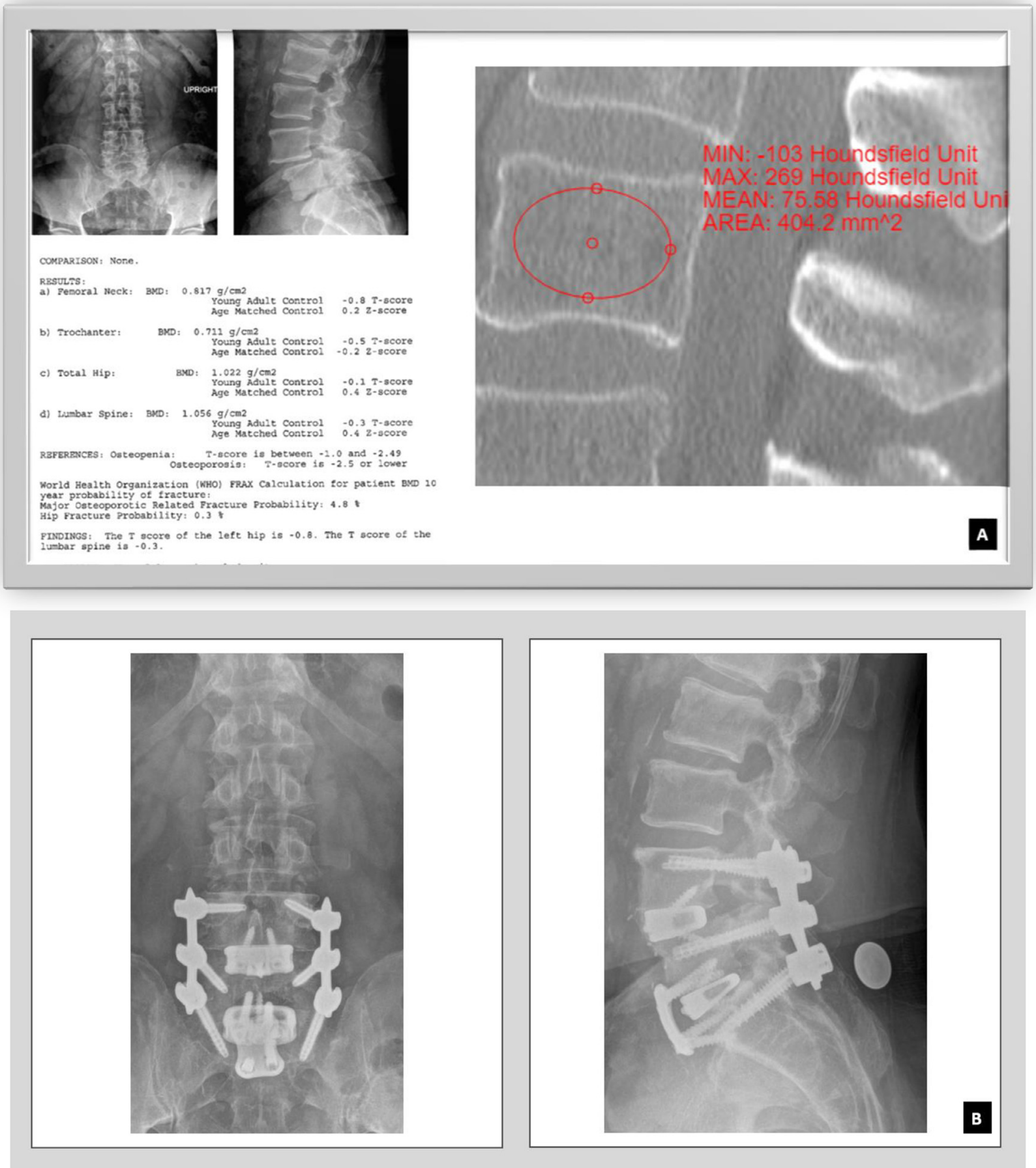

Fig. 5. Case example of disagreement between DXA and HU. (A) demonstrates preoperative AP and lateral X-rays with multilevel degenerative changes and mild aortic calcification anteriorly, DXA report showing normal bone mineral density (hips and lumbar spine), and midsagittal measurement of Hounsfield Units on CT (76 HUs). (B) demonstrates AP and lateral X-rays at 1 year postoperatively showing anterior interbody fusions at L4/5, L5/S1, anterior plate at L5/S1, and pedicle screws L4-S1. Subsidence did not occur in this case.

In a small retrospective study of patients undergoing single-level LLIF/PIF, lower HU values were found to be associated with cage subsidence severity, and the value of 135HU was suggested as the most appropriate HU threshold between mild and severe subsidence (sensitivity 60%, specificity 92%) [37]. In addition, the authors determined that HU value was an independent risk factor for severe subsidence and that the odds of subsidence if HU<135 was 15.7 (95% CI 1.6−152.0, p=.017). Similarly, in a retrospective study of patients undergoing transforaminal lumbar interbody fusion (TLIF), the authors found L1 HU and cage to suprajacent disc height difference to be independent predictors of subsidence when controlling for confounders [38]. They additionally found that L1 HU values were significantly higher in the group that did not develop subsidence compared to those that did (167.8HU vs. 137.7HU, respectively, p=.002). The findings of these studies agree with the current study and those of other approaches to spinal fusion, despite differences in surgical details which can also influence subsidence risk [23,39,41−43].

According to the 2023 Adult Official Positions of the International Society for Clinical Densitometry (ICSCD), bone health assessment should be considered in patients prior to elective spine surgery and opportunistic CTHU can be used to estimate the likelihood of osteoporosis (L1 HU < 100) and normal (L1 HU > 150) bone density to support bone health assessment decision-making [44]. This information can be useful to clinicians who consider adopting the HU method of assessing BMD preoperatively and for consideration in surgical planning [45].

Limitations

The inherent limitations of a retrospective review at a single institution exist, including unknown biases. A third-party Imaging Core Laboratory was used to analyze radiographs for subsidence to eliminate the potential for surgeon measurement bias. Although the sample size (n=127) in this study was larger than most subsidence studies to date, a larger and more diverse patient population (87.4% white in this study) would provide more generalizable findings. This study was not well represented by patients with osteoporosis (2.4%) as defined by DXA. The authors find it important to point out that this study of a relatively young and healthy patient population might be overlooked as having low BMD, particularly when DXA is encouraging, yet 13.4% had subsidence, 44.1% had CTHU<135, and 11.8% had CTHU≤100. This highlights the importance of the findings, which demonstrate the critical nature of making HU measurements for an additional data point when CT scans are available, as highlighted in the case example. Future studies of a more racially diverse patient cohort could be useful in comparing HU cutoff values associated with subsidence. This radiographic study does not include patient reported outcomes and therefore consequences of subsidence cannot be discussed. Furthermore, this study does not address medical treatment for osteoporosis, which is an important but entirely separate point of assessing BMD given that current treatment algorithms are based on DXA results and not HU values.

Conclusion

Among this cohort of patients undergoing circumferential lumbar fusion for degenerative pathologies, CTHU<135 was associated with interbody subsidence while DXA lowest T-score was not. The odds of developing subsidence were 4.0 times higher for CTHU<135 after controlling for other subsidence risk factors, supporting this cutoff value. This study demonstrates that CTHU is a reliable predictor of interbody subsidence and outperformed DXA, suggesting that in the degenerative lumbar population, DXA may not accurately represent lumbar spine bone quality. Spine surgeons should consider adding L1 CTHU measurements into their preoperative routine when CT scans are available.

Video 1: This video demonstrates the basic steps taken to measure Hounsfield Units (HUs) using the midsagittal view on CT in PACS.

Declaration of competing interest

One or more of the authors declare financial or professional relationships on ICMJE-TSJ disclosure forms.

CRediT authorship contribution statement

Lindsay D. Orosz: Writing − review & editing, Writing − original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kirsten A. Schuler:** Writing − review & editing, Writing − original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Data curation. **Brandon J. Allen:** Writing − review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Data curation, Conceptualization. **Wondwossen T. Lerebo:** Writing − review & editing, Validation, Supervision, Software, Resources, Methodology, Formal analysis, Data curation. **Tarek Yamout:** Writing − review & editing, Supervision, Software, Resources, Methodology, Investigation, Data curation, Conceptualization. **Rita T. Roy:** Writing − review & editing, Visualization, Supervision, Software, Resources, Project administration, Conceptualization. **Thomas C. Schuler:** Writing − review & editing, Visualization, Supervision, Resources, Methodology, Investigation, Data curation, Conceptualization. **Christopher R. Good:** Writing − review & editing, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Colin M. Haines:** Writing − review & editing, Visualization, Supervision, Resources, Methodology, Investigation, Data curation, Conceptualization. **Ehsan Jazini:** Writing − review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization.

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Supplementary materials

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