To Evaluate the Diagnostic Performance of Hounsfield Unit Histogram Analysis on the Precontrast Abdominal-Pelvic CT to Predict Osteoporosis of the Femur

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Introduction (1)

- Osteoporosis is a major public health concern
- Up to 50% of women & 20% of men are at risk of developing an osteoporosis-related fracture during their life
- Among the osteoporosis related-fractures, proximal femur fracture
 - → most common complications
 - & higher mortality and morbidity



Introduction (2)

- Osteoporosis diagnosis based on central DXA in postmenopausal women and men aged ≥ 50 years if the *T*-score of the lumbar spine or hip is -2.5 or less
- Limitations of DXA
 - 1) Not measure volumetric bone mineral density
 - 2) Not measure bone geometry
 - 3) Not distinguish btw cortical and trabecular bone
- DXA is underused, thus, growing appreciation of the need for broader screening efforts



Introduction (3)

- In the U.S.A, more than 25 million abdominal-pelvic CT scans are performed in adults each year
- Even if a small number of these patients undergo opportunistic osteoporosis screening, the impact could be substantial
- Several studies have shown optimistic results using CT for opportunistic screening of osteoporosis
- The average CT HU value for multiple or even a single vertebra is correlated with the DXA *T*-score and could be used for opportunistic screening of osteoporosis



Introduction (4)

- Femoral neck consists mainly of dense trabecular bones and Ward's triangle, which are closely related to osteoporosis
- Focal osteoporosis defects play an important role in hip fracture
- Bone mineral density (BMD) of the femur is a strong predictor of hip fracture
- HU histogram presents the distribution of variable HU values from fat tissue to hard cortical bone

→ Changes in the microstructure of trabecular bone represented as a decrease in the HU value on CT



Introduction (5)

• Average HU value

➔ a single value representative of certain ROI but it is a summation of the HU histogram

• HU Histogram value

➔ Possible HU range analysis to assess BMD changes during osteoporosis



Purpose

 To evaluate the diagnostic performance of CT HU histogram analysis on an precontrast abdomenpelvic CT scan to predict osteoporosis in adults > 30 years old using the DXA *T*-score as a reference standard.



<u>Patient Enrollment</u>

- Retrospective study approved by our institutional review board
- Between March and July of 2017
- Time interval btw DXA and APCT: mean 5.3 days, range 0–25 days
- 207 patients (68.2 yrs, range 36–96 yrs) were finally included
- M:F =42:165





Material & Method (2)



- DXA performed using the standard technique according to the International Society for Clinical Densitometry guidelines
- Machine: GE Healthcare Lunar Prodigy densitometers (Madison, WI, USA).
- The lowest DXA *T*-score of the femoral neck was used as the reference standard
- The WHO definition
 - Osteoporosis: T-score ≤ -2.5
 - Osteopenia: *T*-score of –1.0 to –2.4
 - Normal: *T*-score > -1.0



<u>CT Imaging</u>

- Three MDCT (SOMATOM SENSATION 64, SOMATOM Definition Edge, SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany)
- Standard single-energy CT mode
- On automatic tube voltage or current selection protocols
- Scanning parameters of SOMATOM SENSATION 64 CT (n=19):

detector collimations of 64 x 0.625mm; pitch of 1.4; gantry rotation time of 0.5 second; tube currents of 210 mAs; tube voltage of 120 kVp; and filter back projection (B40f)

 Scanning parameters of SOMATOM Definition Edge or Definition Flash CT scanners (n=188):

detector collimations of 128 x 0.6mm; pitch of 0.6; gantry rotation time of 0.5 second; tube currents of 200 or 289 mAs; tube voltage of 100 or 120 kVp; and iterative reconstruction (Sinogram-affirmed iterative reconstruction, S1, I40f).



<u>HUHA & average CT HU measurement</u>

- Measurements performed on a precontrast reformatted-coronal image (5 mm slice thickness)
- Using commercial three-dimensional (3D) analysis software (Aquarius iNtuition v4.4.12; TeraRecon Inc., Foster City, USA)
- All measurements performed by one radiologist (10 years of experience interpreting body images)
- Inter-rater agreement assessed by two radiologists (10 years of experience interpreting body images & 4 years of experience interpreting musculoskeletal images)



<u>HUHA & average CT HU measurement</u>

- No specific interactive training session to learn the measurement techniques
- Observers selected the image that contained the greatest amount of Ward's triangle and the principal compressive trabecula on the coronal reformatted image
- Drew the largest ROI over the femoral neck & intertrochanteric area adjacent to the outer cortex
- HUHA expressed as a percentage of the ROI area
- HUHA classified into arbitrarily seven categories from A to G
- area of each HU range, automatically calculated as a percentage of the entire area using the 3D analysis software
- The average HU value, simultaneously calculated using the same reformatted coronal image for same ROIs





<u>Statistical analysis</u>

- Independent *t*-test
 - to determine difference btw two groups: Demographic variables, HUHA categories, and average CT HU values
- Correlation analysis
 - to determine the HUHA categories and average CT HU values that best reflect the femur *T*-score qualitatively
- ROC curve analysis
 - diagnostic performance of HUHA & the average CT HU value in predicting osteoporosis with respect to the femur *T*-score reference standard
- Intra-observer agreement: a two-way mixed intra-class correlation coefficient (ICC) with absolute agreement
- Inter-observer agreement: kappa statistics
- A *p*-value < 0.05, considered significant difference





Patient Descriptions

	Osteoporosis	Non-osteoporosis	P-value
Number	67	140	
Sex (M:F)	9:58	32:108	
Age	80.9 ± 9.8	62.2 ± 12.7	< 0.001
T-Score	-3.3 ± 0.7	-0.8 ± 1.1	< 0.001
BMD (g/cm²)	0.538 ± 0.089	0.854 ± 0.186	< 0.001
Interval btw DXA and APCT	4.7 ± 4.6	3.8 ± 6.8	0.313
Average CT HU	59.4 ± 51.2	245.2 ± 91.9	< 0.001
HUHA (% of ROI area)			
A (-1024 to 0 HU)	44.2 ± 11.6	14.9 ± 23.1	< 0.001
B (1-24 HU)	8.1 ± 2.0	6.0 ± 3.8	< 0.001
C (25-49 HU)	7.4 ± 2.4	6.8 ± 3.8	0.208
D (50-74 HU)	6.4 ± 2.2	7.2 ± 3.6	0.005
E (75-99 HU)	5.5 ± 1.8	7.9 ± 2.9	< 0.001
F (100-129 HU)	5.9 ± 6.9	9.6 ± 3.3	0.001
G (130 HU ~)	23.2 ± 8.6	56.3 ± 19.2	< 0.001

Comparison of patient demographics and DXA, average CT HU, and HUHA values

between the osteoporosis and non-osteoporosis groups.

APCT = abdominal-pelvic CT; BMD = bone material density; DXA = dual-energy X-ray absorptiometry; HUHA = Hounsfield unit histogram analysis





Correlation & Simple Linear Regression Equation



Scatter plot and fitted linear regression line showing the relation between femur T-score and HUHA-A, including the range for the estimated 95% prediction limit (dashed lines).



<u>Results (3)</u>

Multiple comparison graphs of the HUHA-A, HUHA-G, and average CT HU distribution between osteoporosis and non-osteoporosis groups







Diagnostic Accuracy of HUHA-A, HUHA-G, & Average CT HU for Osteoporosis



⁺Youden index obtained from the ROC curve; SEN, sensitivity; SPE, specificity; AUC, area under curve; PPV, positive predictive value; NPV, negative predictive value



Conclusion

HUHA measurements in the femoral neck

- Closely related to BMD
- Can be used to predict osteoporosis as defined by the DXA *T*-score
- HUHA-A cutoff value of ≥ 27.5% showed the best diagnostic performance in predicting osteoporosis, with 97.1% sensitivity and 84.3% specificity

