Development of Deep Learning Artificial Intelligence to Detect Osteoporosis

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Introduction

- Osteoporosis is a significant health and economic issue, with over 54 million diagnosed Americans and costs reaching six trillion USD across the USA, Canada, and Europe.
- Early diagnosis is crucial to reduce fractures and hospital stays by enabling efficient, preventative treatments.
- Dual-energy X-ray absorptiometry (DEXA) is the current gold standard for assessing bone density.
- Despite being the gold standard for osteoporosis screening, DEXA scans are frequently overlooked or under prescribed by clinicians.
- Conversely, noncontrast cardiac computed tomography (CT) for coronary calcium scoring is gaining traction as a method for risk stratification of future atherosclerotic events.
- Noncontrast cardiac CT may also offer opportunistic assessment of bone density, adding value to the procedure.
- The aim of this study was to develop an Artificial Intelligence (AI) algorithm to predict bone density at the trabecular spine using DEXA as standard of reference in the Dallas Heart Study 2 (DHS2) cohort.

Materials and Methods

T-spine Trabecular Bone Segmentation on CT (N = 100) → Train AI Segmentation model and apply to 2797 unseen CTs → Collect T-Spine bone density values obtained in the same patients during DHS2 → Train a regression model using the CT images & segmentations to predict the bone density

Figure 1. Flowchart of plan to develop bone density AI.

- A random sample of 100 individuals from DHS2 were selected to develop the segmentation mode.
- Two medical students used 3D Slicer (slicer.org) to manually segment the spinal trabecular bone included in the field of view of the CT, which were reviewed and edited as necessary by a radiologist with more than 10 year of experience. An ensemble segmentation model was developed using MONAI (monai.io).
- Segmentations were generated in 2797 unseen CTs. This cohort was randomly split into training (n = 1679), validation (n = 559), and testing (n = 559) sets. CT images and segmentations were used as input for training another regression model based on DenseNet architecture to predict bone density as defined by DEXA scan obtained in the same patients

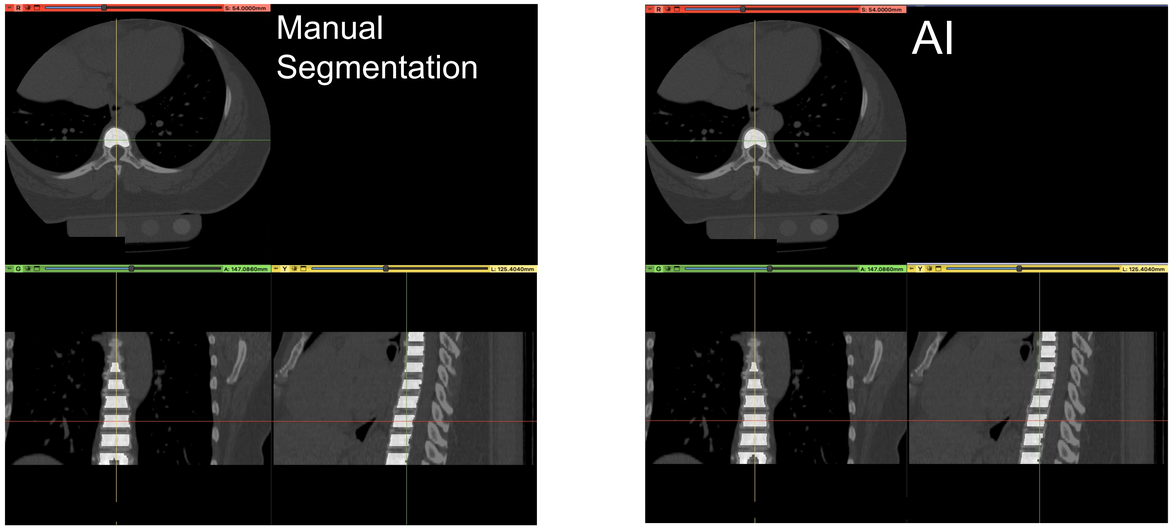

Figure 2. Manual segmentation (left) of trabecular bone versus AI segmentation (right) on the same patient.

Results

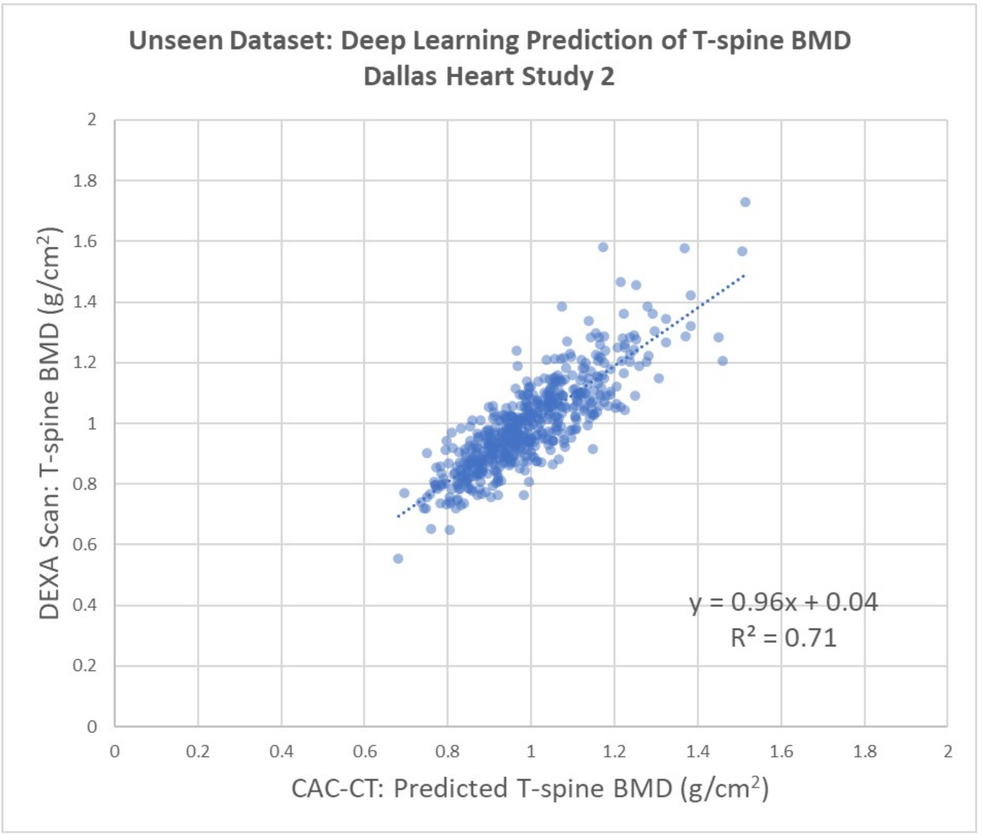

Figure 3. Plot of AI predicted thoracic spine bone mineral density (BMD) on the x-axis with actual DEXA T-spine BMD on the y-axis. The best model was trained for 102 epochs and the best training had a root mean square error (RMSE) of 0.0628 mg/cm^2 and validation RMSE of 0.0842 mg/cm^2. The linear regression equation was y=0.96x+0.04 with an R^2 value of 0.71.

- The segmentation model achieved a Dice similarity score of 0.97.
- Figure 3 represents the scatter plot of bone mineral density predictions from the AI model against the standard of reference in the unseen test set (n = 559).
- Bone density predictions were well correlated with their reference values, with an R^2 of 0.71.

Discussion

- This proof-of-concept study showed that AI can be used to automatically extract bone mineral density information from noncontrast cardiac CT obtained for calcium scoring purposes.
- Future iterations of the algorithm will focus on the improvement of the precision, leading to more accurate detection of osteopenia and osteoporosis.
- This advancement will help consolidate the use of opportunistic data from cardiac CT to detect osteoporosis, enhancing the value of the modality and providing earlier detection and better management of patients with low bone density.

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THE DALLAS HEART STUDY

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