Use of Machine Learning to Predict Osteoporosis Status from Plain Hand Radiographs

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INTRODUCTION: Currently, osteoporosis is diagnosed based on DEXA (dual x-ray absorptiometry) scans, however, there is mounting evidence that other modalities may be equally accurate, if not superior, to DEXA in analyzing bone mineral density. Previous studies have demonstrated that the second metacarpal cortical percentage (2MCP) correlates with osteoporosis status. We hypothesize that a machine learning algorithm can predict osteoporosis status from plain hand radiographs. We propose a novel, end-to-end pipeline that takes raw hand radiographs, identifies and segments the second metacarpal, and uses its features, specifically the 2MCP, to predict osteoporosis status.

METHODS: A large, multi-institutional dataset of patients having undergone x-ray(s) of the hand within one year of a dual x-ray absorptiometry (DXA) scan was generated. A series of preprocessing steps removed extraneous information and a convolutional neural network was trained on 61488 AP hand x-rays (image augmentation from 427) to detect and automatically segment the second metacarpal. Images were augmented by rotation in increments of 5 degrees and flipping to make the classifier robust and independent of rotation. A total of 1660 hand x-rays were passed through the trained algorithm to extract the second metacarpal. Post-segmentation steps included edge detection, truncation, and visualization of the middle third on a line profile through the center of the metacarpal (Figure 1). A computer vision-based approach was implemented to automatically compute the average 2MCP and compared with measurements performed by two, independent measurers.

RESULTS:
Automatic second metacarpal detection accuracy was 100% in a testing set of 1660 radiographs that were used in the subsequent steps. The machine learning algorithm was able to perform independent of rotation of the presented image. The middle third of the metacarpal was then isolated. Interobserver reliability between two independent human experts was high, with a correlation coefficient of 0.67. The automated 2MCP measurement was in good agreement with manual measurements (correlation coefficient 0.74)(Figure 2).

DISCUSSION AND CONCLUSION: We present a novel, machine learning algorithm, trained on a large, multi-institutional dataset, that can accurately measure the 2MCP, a metric previously shown to predict osteoporosis status. The algorithm output will further be directly correlated with T-scores from DXA scans (ground truth) to refine osteoporosis prediction. With this large, multi-institutional dataset, we aim to generate a complete end-to-end pipeline that will produce consistent, generalizable results. Future iterations of this machine learning algorithm could serve as a serendipitous screening tool to diagnose osteoporosis earlier to prevent osteoporotic fractures.
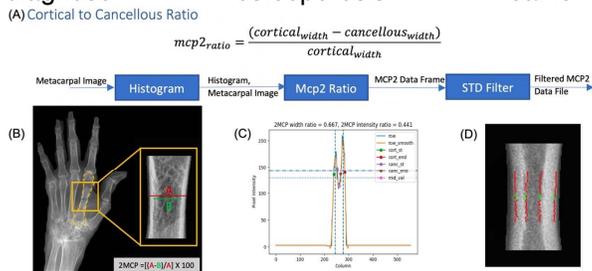

Figure 1. (A) Overview of machine learning workflow for osteoporosis prediction. (B) Identification of the middle third of the second metacarpal to calculate cortical and cancellous ratios for the 2MCP calculation. Blue line indicates location used for 1D intensity plot. (C) Visualization of the middle third of the second metacarpal on a line profile (1D intensity plot). (D) Example of automated algorithmic identification of cortical and cancellous borders, n=64 (red) and average (green).
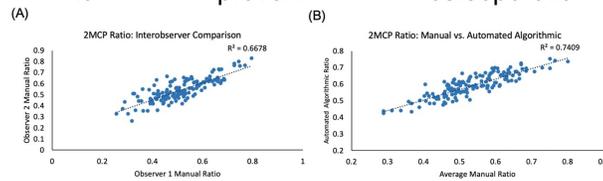

Figure 2. 2MCP training dataset. (A) Interobserver comparison between the manual 2MCP measurements by two independent experts. (B) Comparison between average manual 2MCP ratio and automated algorithmic 2MCP ratio. n = 145 hand radiographs.