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Augmenting the MIDRC Dataset using Deep Learning-Based Quantification of Abdominal Aortic Calcification: Proof-of-Concept for Population-Level Disease Screening

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Introduction

Large public imaging datasets like the MIDRC dataset of 20,000+ CT scans have facilitated rapid development of machine learning tools to fight diseases like COVID-19. However, these datasets seldom have disease labels beyond their primary use case (e.g., COVID-19 status for MIDRC), limiting their use for other prediction tasks. We evaluated the feasibility of deep learning-based quantification of abdominal aortic calcification to augment the MIDRC dataset with potential biomarkers for population-level cardiovascular risk assessment.

Hypothesis

Deep learning-based abdominal aortic calcium quantification will allow for augmentation of the MIDRC dataset with population-level assessments of cardiovascular disease risk.

Methods

We first validated the state-of-the-art TotalSegmentator deep learning multi-organ CT segmentation model on two datasets of CT scans of the abdomen/pelvis for segmentation of the abdominal aorta and imaged portions of the thoracic aorta using Dice scores: 1) subset of the MIDRC dataset (COVID-19-NY-SBU [N=1285]; primary dataset) and 2) AMOS dataset (N=250; secondary dataset). Aortic calcifications were segmented on the COVID-19-NY-SBU dataset using Hounsfield Unit voxel thresholding (>250 HU); automated calcium segmentations were validated using 100 manually segmented scans. The aortic calcifications were localized to thoracic vs. abdominal aorta using an automated bodypart regressor model. Agatston score for the abdominal aorta was calculated by multiplying area of calcium by a factor related to maximum plaque attenuation.

Results

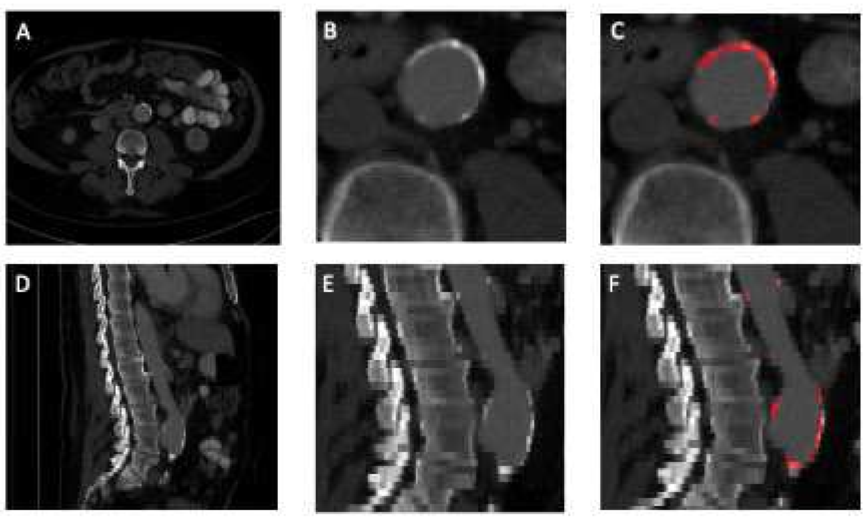
TotalSegmentator had high performance for aortic segmentation on both datasets with mean Dice scores of 0.88 and 0.91 on the MIDRC and AMOS datasets, respectively (Figure 1). Automated aortic calcification similarly had Dice score of 0.88 on our primary dataset (MIDRC) with high correlation with manual segmentations (R2 of 0.9575; Figure 2). In the MIDRC dataset, 75% of patients had aortic calcification; of these, 73% had abdominal aortic calcifications and 77% had thoracic aortic calcifications. For patients with calcifications [N=963], the mean Agatston score in the abdominal aorta was 15,235; 792 patients (62%) had scores >1000 (previously-validated cardiovascular disease risk threshold).

Conclusion

Deep learning-based quantification of abdominal aortic calcifications can augment large public datasets like MIDRC, allowing for population-level assessments of cardiovascular disease risk. Our proof-of-concept paves the way for augmenting other large datasets, including the remainder of the MIDRC dataset, which our group is actively working on next.

Statement of Impact

Augmentation of large imaging datasets for disease risk assessment with deep learning models paves the way for population-level screening for chronic conditions like cardiovascular disease.



Examples of deep learning-based aortic calcification segmentation in the abdominal aorta. Panels (A) and (D) show single axial and sagittal slices, respectively. Panels (C) and (G) demonstrate a portion of the aorta with calcium. Panels (D) and (H) highlight in red the aortic calcification automatically detected by the deep learning model. Note that our models segmented calcium in the entire 3D CT volume, from which the Agatston scores were calculated.

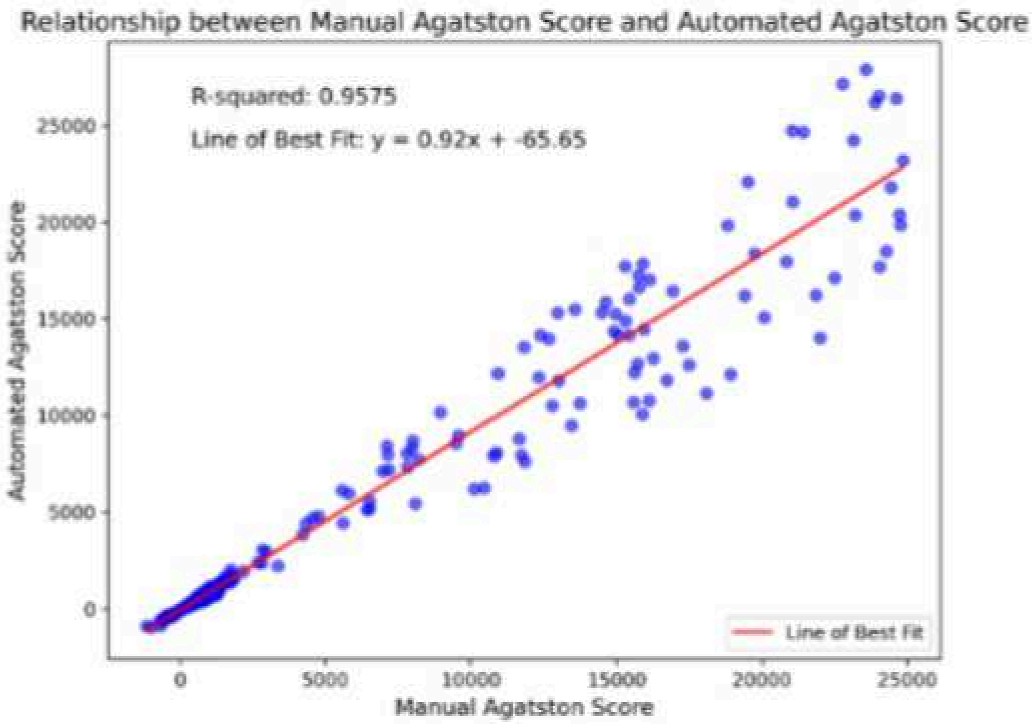


Figure 2: Deep learning-based aortic calcification segmentation and Agatston score calculation correlates well with manual segmentation and score calculations with correlation coefficient of 0.96.

Keywords
MIDRC; Datasets; Aortic Calcification; Opportunistic Screening; Deep Learning