Automating Linear Measurements of the Distal Ascending Aorta in CT Angiograms Using AI-based Heatmap Regression to Identify Oblique Planes

Andrew D. Missert, PhD, AI Scientist and Assistant Professor of Radiology, Mayo Clinic
Adam Dachowicz, PhD; Jason Klug, PhD; William Ryan; Gian Marco Conte, MD, PhD; Wolfgang Holler; MingDe Lin, PhD; Alex Bratt, MD

Introduction

Linear aorta measurements from CT angiograms are crucial indicators of cardiovascular disease. The current clinical standard involves manual annotations of doubly oblique multiplanar reformatted images, which can be challenging, time-consuming, and subject to substantial inter- and intra-reader variability. We propose automating this process through AI-based methods, applying them to the distal ascending aorta just proximal to the brachiocephalic trunk.

Hypothesis

An AI model optimized for heatmap regression can accurately identify the doubly oblique measurement plane. Combined with aortic semantic segmentation, this approach will enable automated linear measurements with accuracy in the range of inter-reader variability.

Methods

In this prospective study, 579 linear annotations of the distal ascending aorta were performed by 47 board-certified radiologists using a semantic annotation engine integrated into the clinical PACS workflow. We applied a 3D aorta segmentation model (nnU-Net) to each CTA volume and computed the centerline. A heatmap annotation was generated by convolving a Gaussian kernel (sigma=1.0) with the 2D surface defined by the intersection of the 3D aorta mask and the plane perpendicular to the centerline closest to the annotation. A regressive heatmap model was then trained using 148,224 3D image patches from the training set. Testing was performed on 29 reserved volumes. Automated measurements were obtained at the centerline location maximizing the heatmap and compared to manual annotations using Bland–Altman analysis.

Results

The automated measurements closely matched the manual results, with a mean difference of 1.35 mm ± 1.22 mm, which falls within reported inter-reader variability (4.7 mm).

Conclusion

Automated linear measurement of the distal ascending aorta just proximal to the brachiocephalic trunk is feasible using an AI-driven regressive heatmap approach, achieving accuracy on par with manual expert measurements.

Figure(s)

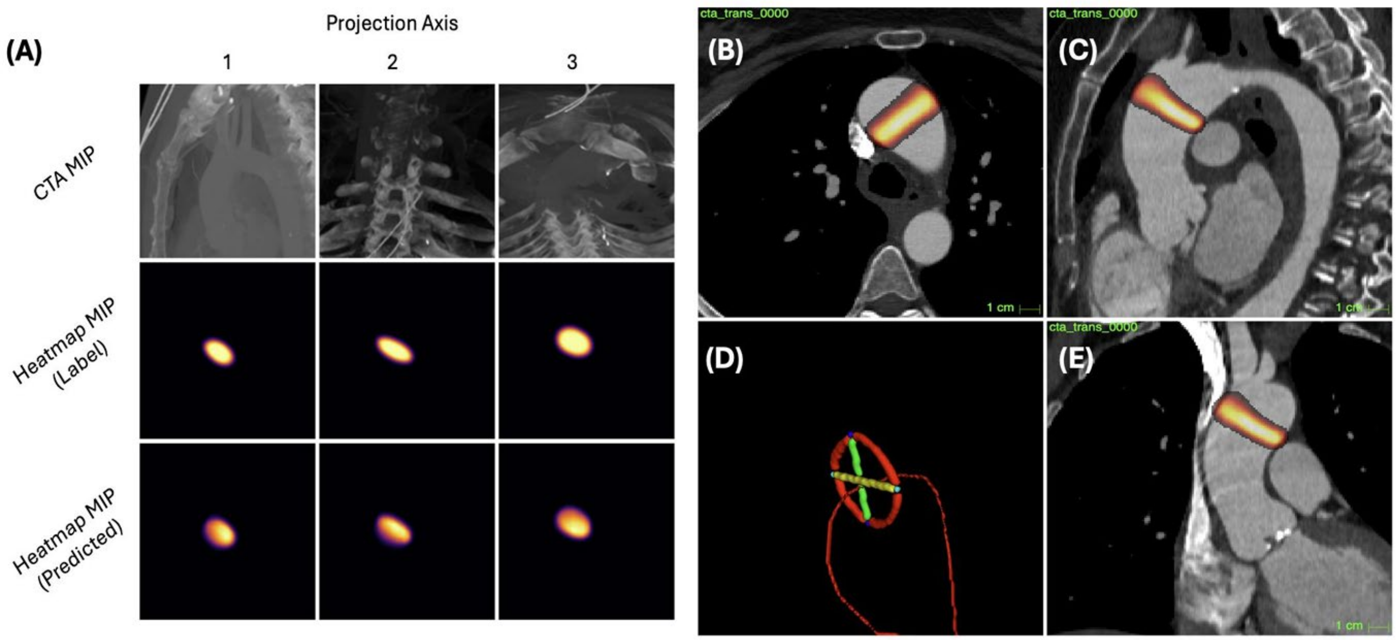

Figure 1. Panel (A) shows an example from the heatmap model training process. The model inputs, outputs, and labels were 3D image patches with dimensions of (160, 160, 160) pixels, normalized to a 1 mm spacing. The top row displays the maximum intensity projection (MIP) of the input CT image, the middle row shows the MIP of the heatmap label derived from radiologist annotations, and the bottom row presents the MIP of the AI heatmap regression model's prediction. Panels (B) through (E) depict a model inference example from the reserved test dataset. During testing, the model inputs consisted of the full-size CT volume. The AI heatmap prediction for the measurement plane is shown as an overlay in the axial, sagittal, and coronal views in (A), (B), and (E). Panel (D) visualizes the automated linear measurement at the point along the centerline (red line) that maximizes the heatmap prediction. The maximum diameter (green line) and minor axis (yellow line) are determined by intersecting the measurement plane with the aorta segmentation mask (red circle).

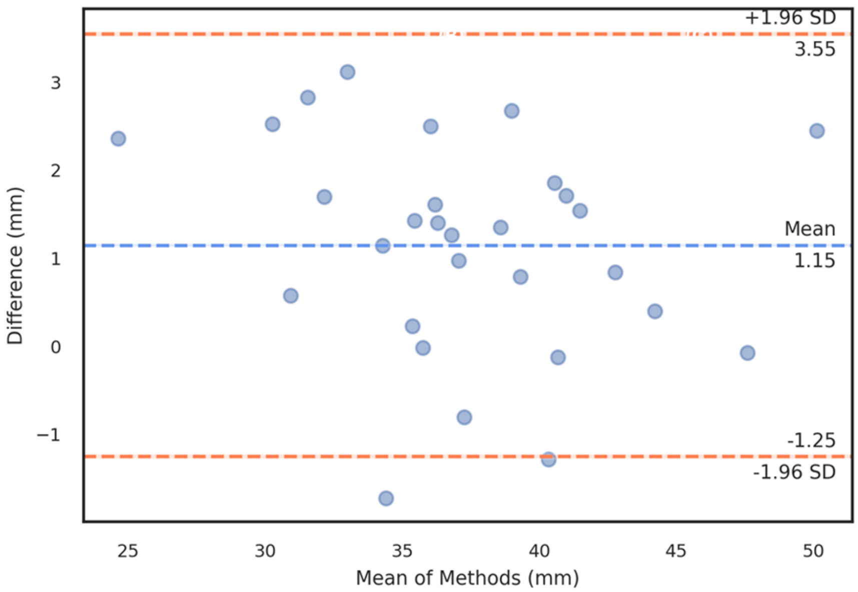

Figure 2. Figure 2: Bland-Altman plot comparing the automated AI measurement of the maximal distal ascending aorta diameter with manual annotations by board-certified cardiovascular radiologists. The AI measurements show a slight bias toward larger diameters (mean difference: 1.15 mm). The variability (1.96 SD of the difference) was 2.40 mm, which is below the previously reported intra-reader (3.2 mm) and inter-reader (4.7 mm) variability for aortic measurements (K. Singh et al., Eur J Vasc Endovasc Surg 25, 399–407 (2003)).

Keywords

Artificial Intelligence/Machine Learning; Imaging Research