Correcting Aortic Diameter Measurement Errors from Severe Angulations

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Abstract

Surgical decisions often hinge on the maximum aortic diameter—but current automated measurement methods fail in anatomies with severe angulations. We show that sharp bends in the aortic centerline distort the vessel in orthogonal planes, leading to unreliable readings. Our model, *CorrectNet*, learns to segment around these distortions, restoring measurement reliability and strengthening surgical planning.

Keywords: Computed Tomography Angiography, Maximum aortic diameter, Aneurysm, Aortic dissection, Deep Learning

1. Introduction

A few millimeters' difference in the maximum diameter measurement — the largest transverse diameter of the aorta at a given point — can overturn the decision to proceed with aortic surgery.

The American Heart Association considers the maximum aortic diameter the most essential component of CT and MRI reports (Isselbacher et al., 2022). Guidelines define its absolute value (≥55mm) and its growth rate (≥5mm/year) as the primary and secondary criteria, respectively, for aneurysm surgical repair (Borger et al., 2018; Hiratzka et al., 2010; Svensson et al., 2013). It also stratifies risk in aortic dissection and guides TEVAR decisions (MacGillivray et al., 2022).

But measurements found in official reports diverge significantly from remeasured values (Perry et al., 2022). These discrepancies directly affect patient outcomes. To standardize the procedure, researchers advocated measuring diameters in planes orthogonal to the centerline, mitigating errors due to tortuosity. They also developed automated methods to reduce inter-observer variability and processing (which includes segmentation) time (Perry et al., 2022; Adam et al., 2021), although Adam et al. acknowledge that these sometimes produce measurement errors far beyond the variability range of human annotators.

In this work, we explain why such outliers necessarily arise for certain profiles of aortas, where the centerline path follows severe angulations. We also propose a correction method to restore measurement reliability in those cases.

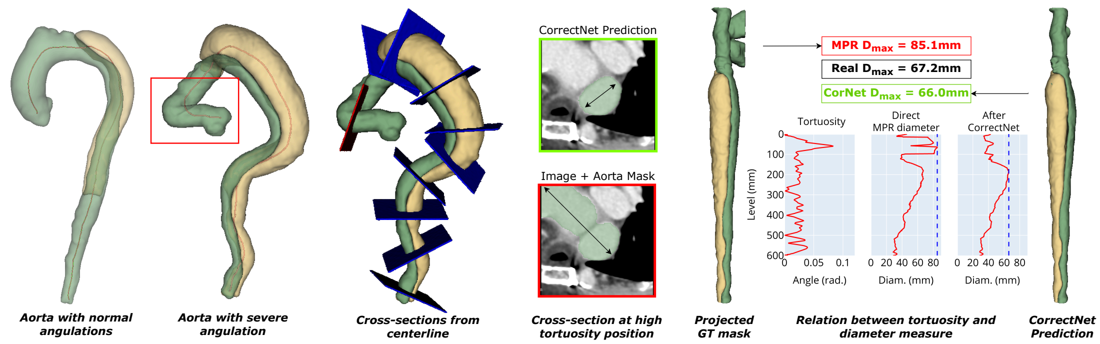

Figure 1: Reliable maximum diameter measurement in aortas with severe angulations. MPR: multi-planar reformation; D$_{max}$: maximum diameter; GT: ground truth. Level: position on the centerline.

2. Method

When orthogonal planes intersect areas where the aortic centerline exhibits extreme angulations, an undesirable phenomenon occurs: the cross-sections may capture portions of the vessel that extend beyond the angulation, leading to erroneous maximum diameter measurements with automatic methods (Fig.1). These techniques consider the segmented aorta, as it appears in the given orthogonal plane, and measure the diameter of the smallest circle circumscribing that mask. Since the cross-section at severe angulations catches an additional part of the vessel, the resulting automatic measure explodes (Fig.1).

We propose a simple solution: **CorrectNet**, a 3D nnUNet trained to segment the aorta in orthogonal planes while excluding any regions affected by overflow. During training, we manually removed these portions from the segmentation masks to serve as ground truth.

CorrectNet is integrated into a larger pipeline that performs automatic diameter and volumetric analysis of dissected aortas from CT angiography. We developed this pipeline for a study, currently under review, which demonstrated the predictive value of local false-lumen volume near the maximum diameter for outcomes in residual type-A dissection across two independent centers.

3. Experiment

Dataset Our private dataset includes 150 CT angiographies (CTA) from patients with residual type-A aortic dissection, split into 120 cases for training and 30 for testing. A radiologist manually segmented the aorta from the aortic valve to the aorto-iliac bifurcation. A second observer segmented the test set. Both observers corrected any overflow in the MPR segmentations before measuring the maximum diameters.

The overflow phenomenon occurred in 25 dissected aortas of the training set, regardless of the centerline extraction method. It has been demonstrated that high aortic angulations are more prevalent in dissected aortas(Cao et al., 2020).

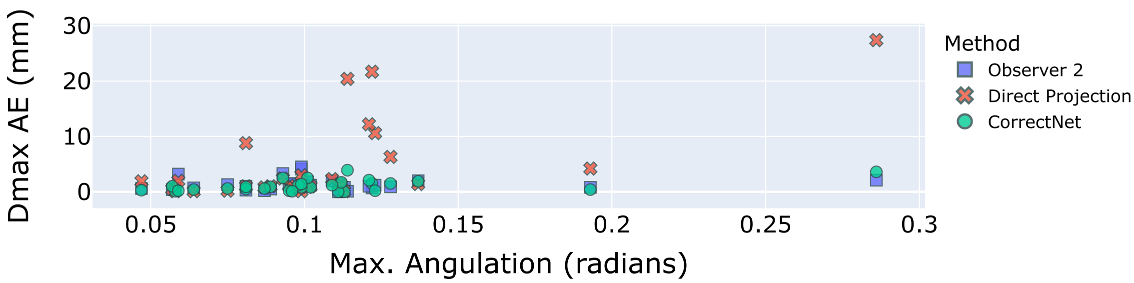

Figure 2: Absolute errors as a function of maximum aortic angulation for the different measurement approaches.

Angulation	Normal (n=23)	Severe (n=7)	All (n=30)
Direct Projection	*2.2 ± 4.2*	*12.0 ± 8.8*	*4.5 ± 6.9*
CorrectNet	**0.9 ± 0.9**	**1.6 ± 1.0**	**1.1 ± 1.0**
Observer 2	1.3 ± 1.2	1.2 ± 0.5	1.3 ± 1.1

Table 1: Mean absolute errors in maximum diameter measurement.

Measurements The maximum diameters were measured both with CorrectNet and with direct MPR projection of an automatic aorta masking, the classical approach. We categorized an angulation as severe if it exceeded 0.115 radians (99.5% percentile of all dataset angles) along consecutive centerline vectors. Additionally, to account for small variations in centerline sampling density, each angle was normalized by multiplying it by the ratio of the number of points on the current centerline to the average number of centerline points across the dataset (320 points ±25).

Results Figure 2 shows the measurement errors as a function of the maximum aortic angulation. Table 1 compares the mean absolute error (MAE) between the first observer's measurements, the classic approach, CorrectNet, and the second observer. The correlation between aortic angulation and large direct projection errors is clearly evident: MAE increased from 2.2 mm (Normal) to 12.0 mm (Severe). CorrectNet, with an MAE of 1.6 mm in the Severe group, almost eliminates the influence of angulation on the measurements. Moreover, it achieves this without compromising performance on normal profiles, actually improving them (0.9 mm MAE).

4. Conclusion

We identified severe aortic angulations as a major source of outliers in automatic maximum aortic diameter measurements and proposed an efficient solution to correct these inaccuracies. Left unaddressed, errors in aortic diameter measurement could result in unnecessary surgeries or delay crucial interventions.

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