AAA-100: A Curated Dataset of 3D Watertight Abdominal Aortic Aneurysm Models

Patryk Rygiel*[1], Dieuwertje Alblas*[1], Christoph Brune[1], Stefan Smorenburg[2,3], Kak Khee Yeung[2,3], and Jelmer M. Wolterink[1]

[1] Department of Applied Mathematics, Technical Medical Centre, University of Twente, Enschede, The Netherlands
{p.t.rygiel,d.alblas,c.brune,j.m.wolterink}@utwente.nl
[2] Department of Surgery, Amsterdam UMC location Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
[3] Amsterdam Cardiovascular Sciences, Microcirculation, Amsterdam, The Netherlands

1 Introduction

An abdominal aortic aneurysm (AAA) is a local dilatation of the abdominal aorta exceeding 30 mm that might rupture, with fatal outcomes in 70-80% of cases [4]. Personalized 3D models of AAAs, including surrounding vasculature such as iliac and renal arteries play an important role in tailored clinical decision-making for AAA patients [6]. Models could be used for, e.g., AAA growth modeling [2], stent-graft sizing and positioning for endovascular aorta repair (EVAR) procedures, or 3D printing for surgical practice.

Extracting high-quality 3D arterial models from imaging modalities such as computed tomography angiography (CTA) is a time-consuming and challenging problem. For downstream applications such as computational fluid dynamics (CFD) or shape analysis, models should have sub-voxel accuracy, be watertight, and adhere to topological constraints. Public data sets containing vascular models in AAA patients are not widely available. The Vascular Model Repository provides 32 AAA models [8], while a recent public data set contains models of 19 patients [9]. The current document describes the *AAA-100* dataset, containing 100 detailed 3D AAA models with consistent anatomical boundaries acquired semi-automatically from pre-operative CTA scans. These models span a wide range of possible AAA pathology. Moreover, all models are carefully curated to be anatomically and topologically correct.

2 CTA scans

The models were obtained from pre-operative CT angiography (CTA) scans of 100 AAA patients treated with endovascular aorta repair (EVAR) at the Amsterdam UMC between January 2017 and December 2021. The local medical ethical committee approved the study protocol. Scans contained at least the thoracic region until the iliac bifurcation with in-plane resolutions and slice thicknesses ranging between 0.6-1.0 mm^2 and 0.5-2.0 mm, respectively. Volume sizes were 512 by 512 by 172-1897 voxels.

3 Model extraction

The 3D models of AAAs included in this dataset contain the lumen of the abdominal aorta, inferior to the T12 vertebra. Moreover, models include the proximal 5 cm of both iliac arteries and the proximal 3 cm of both renal arteries. The location and shape of the iliac and renal arteries play an important role in (CFD) simulations, clinical decision-making, and stent positioning.

Models were obtained using an automatic algorithm proposed in [7]. The method performs iterative scale-invariant, rotation equivariant segmentation of single branches by centerline tracking [3] and local contour regression, originating from a seed point. Obtained contours delineating the vessel lumen were combined by fitting an implicit neural representation of the signed distance function (SDF) of the vessel surface [1]. SDFs of individual vessels were blended into one SDF representing the entire vascular tree of interest and subsequently meshed using marching cubes at their zero level-set. For this dataset, meshes were extracted in a semi-automatic fashion: The seed points for all five included vessels were identified automatically and - if necessary - corrected manually.

* Equal contribution.

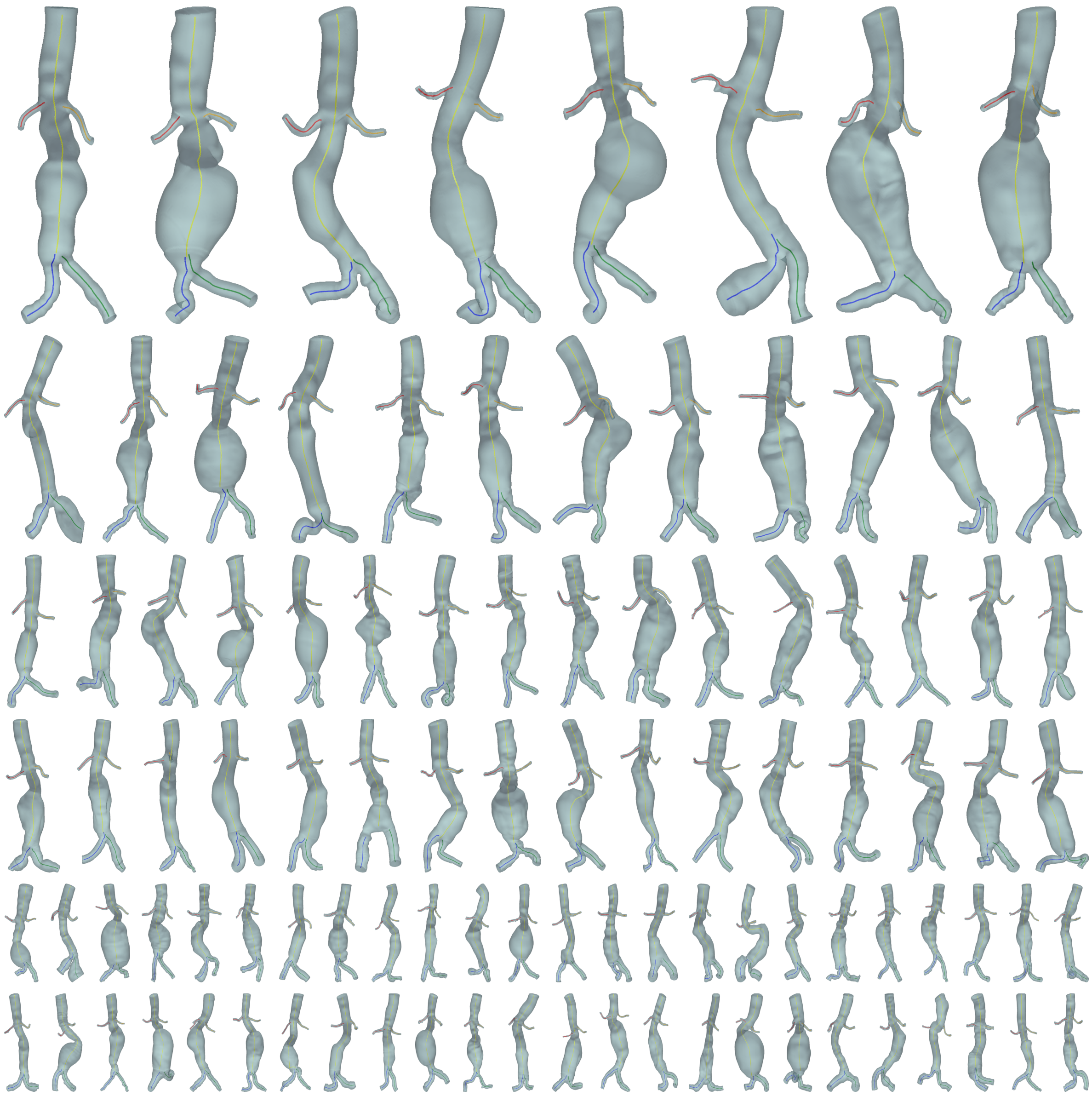

Fig. 1. Renderings of all 3D models included in the AAA-100 data set. Centerlines for the aorta (yellow), left/right iliac artery (green/blue), and left/right renal artery (orange/red) are shown.

4 Model quality

All included models were visually validated by three expert observers. Moreover, we quantitatively assessed the topological validity of the obtained models through Betti numbers. The topological correctness of the models can be expressed with the following Betti numbers: $b_0 = 1$, $b_1 = 0$, $b_2 = 1$; i.e. one connected component, zero non-surface holes, and a single void or cavity. This topological characterization leads to an Euler characteristic of 2, to which all the included msehs adhere.

5 Dataset structure

Fig. 1 visualizes all models contained in the *AAA-100* set. The 3D models are provided as triangular meshes in separate `.stl` files where each sample shape has a designated unique ID from 1 to 100 e.g. `AAA001`. Moreover, centerlines of the aorta and left/right renals and iliacs are provided as separate `.vtp` files. Both the centerlines and the vascular models are provided in the world coordinates (in mm) of the CTA scans from which they were extracted.

6 Discussion and Conclusion

We foresee that this data set can be used to derive novel insights into the pathophysiology of AAAs, and can serve as a basis for, e.g., advanced shape analysis, generative modeling, and simulations based on CFD or other finite element methods.

The current data set has limitations that we aim to address in future iterations. First, we only provide the vessel lumen, while it has been suggested that intraluminal thrombus also plays an important role in AAA growth [5]. Second, in contrast to other - smaller - AAA datasets [8, 9], we do at this point not provide the corresponding image data. Third, all included subjects were eligible for endovascular aorta repair (EVAR). Hence, these cases might contain larger aneurysms than those found in a typical cross-section of the AAA patient population, which may lead to bias in downstream analyses.

In conclusion, the *AAA-100* dataset provides 100 freely available, curated 3D vascular models of AAAs and abdominal vasculature.

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