Enhancement of aortic dissections in CT Angiography: Are common filters robust enough?

SPIE. MEDICAL IMAGING

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INTRODUCTION

This work analyses filters for vessel enhancement considering aortic dissection (AD), scenario generally not considered by previous works. AD (Fig.1) is an aortic disease that is thought to originate from a tear of the intimal wall, followed by a radial crack. This crack subsequently creates another lumen through which blood may flow. This lumen is called false lumen (FL), in opposition to the main or true lumen (TL). The knowledge of several features is fundamental: the extent of FL, the location of primary intimal tears and exit tears, the orientation of the dissection, its caliber, and volume, to name a few. The need for these features shows that the segmentation of the AD can have an immediate clinical utility and can be also useful to obtain a 3D geometry.

AD is a rare disease and it is therefore difficult to obtain large datasets to train deep neural networks. Here, we evaluate an algorithmic approach to segment AD without involving a learning step. We start with the extraction of the centerlines using a thinning algorithm following an initial vessel enhancement step, which is first required. The aim of vessel enhancement algorithms is to improve the quality of the vessel perception, increasing the vessel contrast against the background and other structures. The particularity is that AD is characterized by at least two parallel tubular structures with a high degree of deformation. We here compare and evaluate three different vessel enhancement filters on images of AD. In chronological order: Sato [1], Frangi [2], and Jerman [3]. We evaluate these filters from different points of view.

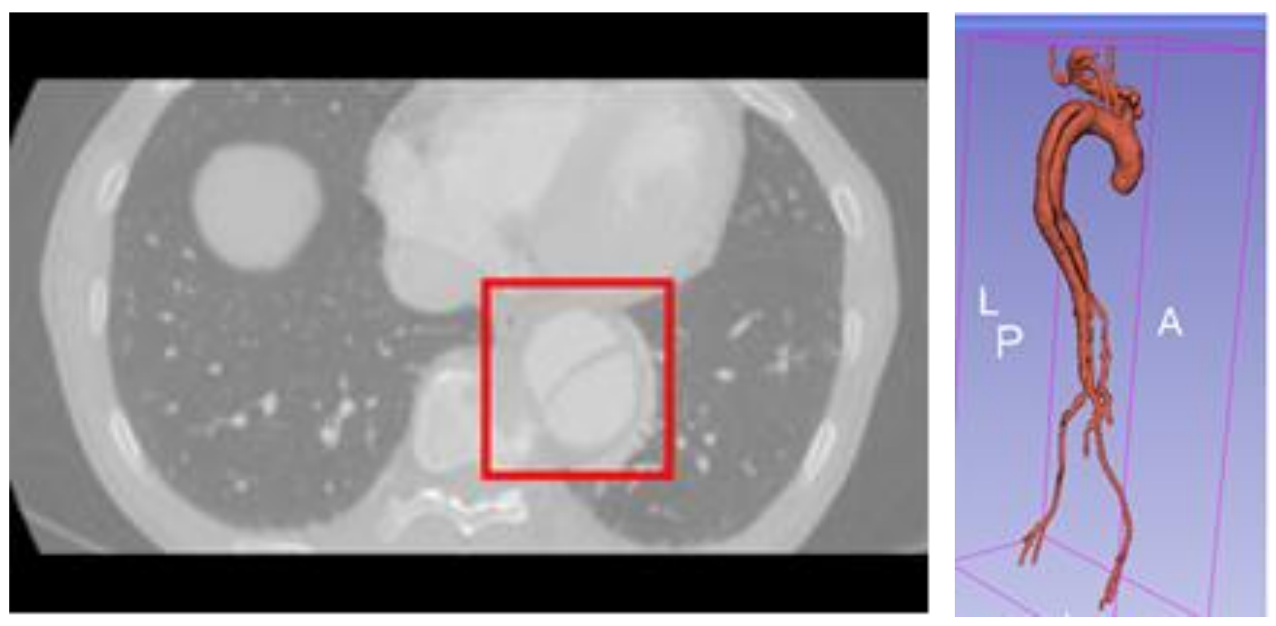

Fig. 1 On the left: Example of AD (limited in red) in a CTA scan, the flap is clearly visible. On the right: example of an obtained segmentation.

METHODS

The dataset consists of five CTA images of different patients with AD [4, 5]. All images were resampled to an image spacing of [1,1,1] mm. Afterwards, noise reduction using curvature anisotropic diffusion and, then, images were windowed to a range of [950,1770] HU.

On this obtained image, the Sato filter, the Frangi filter, and the Jerman filter are applied separately. Different values of sigma are used, this is related to the fact that without changing the value, the aorta becomes enhanced, but the flap is not visible because it is enhanced too, or in other cases, the aorta and its dissection are not clearly enhanced. To extract the centerline, a skeletonization algorithm is applied. The purpose of this step is to obtain both the centerline of the TL and FL and to have the segmentation of the two lumens already separated by the flap. The thinning algorithm requires a binary image as input, so on the enhanced images, a thresholding operation is applied. For having the segmentation, the geodesic active contour method is applied, it requires two input images. The first one is the centerline – points that belong to it are considered as seeds that will guide the development of the segmentation. The second image input is the edge potential map, this image is obtained from the original image subject to a sigmoid filter. Some segmented areas require a little post-processing to eliminate small extra parts.

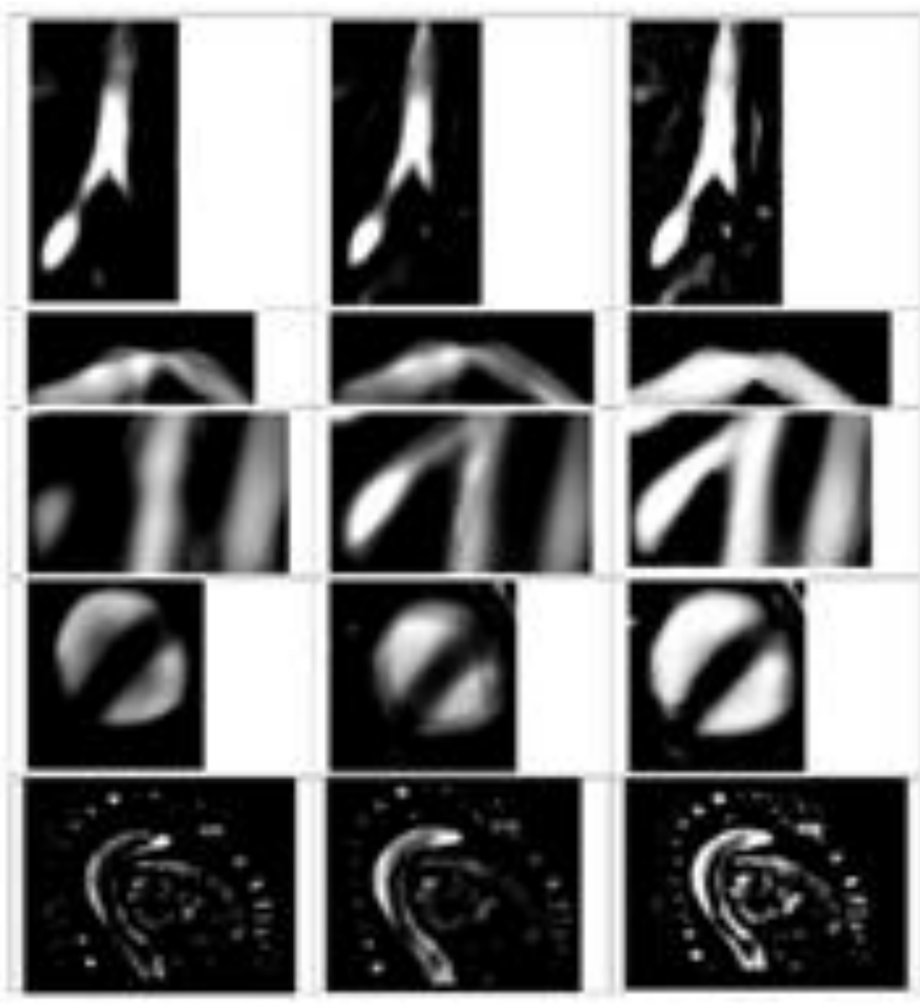

Fig. 2 In this order: outputs of Sato filter, Frangi filter, Jerman filter. Row 1: bifurcation, row 2: curved vessel, row 3: vessel of various diameters, row 4: axial section true and false lumen, row 5: sagittal section of image 4.

RESULTS

For the evaluation: first, the results of the enhancement filters are observed through a qualitative assessment, it is evident that the results of the Jerman filter produce a more uniform response (Fig. 2). In addition, we show a quantitative evaluation of the obtained segmentations with these different filters (Table 1). Results of this comparison are similar, due to the intermediate step between enhancement and active contour. Finally, another evaluation is made by thresholding the result and comparing it with the segmentation ground truth (Table 2).

	After Sato filter		After Frangi filter		After Jerman filter	
	HD	Dice	HD	Dice	HD	Dice
Image 1	64.78	0.81	26.04	0.85	21.19	0.86
Image 2	56.92	0.85	38.12	0.86	37.16	0.83
Image 3	44.73	0.77	39.53	0.77	77.81	0.77
Image 4	9.27	0.96	7.00	0.96	21.10*	0.96
Image 5	10.05	0.95	11.18	0.95	10.00	0.95

Table 1. The * is then recalculated without the first slice, that does not have a correct centerline, and the new value is 6.16 Voxel. (HD: Hausdorff distance)

	Image 1	Image 2	Image 3	Image 4	Image 5
After Sato filter	0.12±0.10	0.09±0.10	0.08±0.07	0.06±0.08	0.06±0.09
After Frangi filter	0.13±0.08	0.04±0.04	0.10±0.09	0.10±0.11	0.04±0.07
After Jerman filter	**0.19±0.03**	**0.16±0.03**	**0.14±0.03**	**0.20±0.02**	**0.15±0.06**

Table 2. Dice coefficient of enhanced structures. Best results are highlighted.

The most recent, Jerman filter, whose superior performance has been already demonstrated [3], remains strong also in cases of aortic dissections, with better outputs compared to Sato and Frangi filters. This is due to its ability to correctly enhance the aorta with its variation of morphology, that characterizes AD.

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