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PREOPERATIVE MEASUREMENT OF ANEURYSMS AND STENOSIS AND STENT - SIMULATION FOR ENDOVASCULAR TREATMENT

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Introduction

Focused vessel diseases for stent simulation and measurement

- Aneurysm – dilation of a blood vessel.
- Stenosis – narrowing of a blood vessel.

Two Treatment Alternatives (before rupture or obliteration occurs) [1, 2]

- Endovascular treatment (done by deploying a stent graft with a catheter, Fig. 1).
- Open surgery (stressful on the patient and not eligible for everyone, e.g. risk patients).

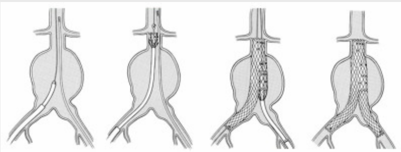

Fig. 1. Minimally invasive treatment of an abdominal aortic aneurysm (AAA).

Methods

Preprocessing

- Affected artery is segmented with a region growing method from user-defined seed points.
- Skeletonization algorithm determines the vessel centerlines [3, 4].

Simulation

- The stents are deformed by using an active contours (ACM) method [5].
- The ACM method minimizes the following energy functional and bases on [6]:

$$E = \int_{t=0}^{1}\int_{s=0}^{1} E_{int}(v(s,t)) + E_{ext}(v(s,t))\,ds\,dt$$

Measurement

- Local ACM adaptation (six contours positioned automatically into the CT-data, Fig. 2, 3).
- Global ACM adaptation (setting the internal forces almost to zero, Fig. 2 right).

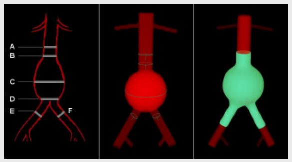

Fig. 2. For choosing an AAA stent six relevant sizes are needed (left). Phantom measured with several single ACM contours (middle). Phantom measured with one closed ACM contour (right).

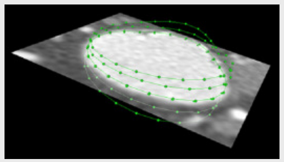

Fig. 3. MPR CT-slice with an ACM modeling 5 consecutive contours.

Results

- The methods were implemented in C++ within the MeVisLab environment.
- Results are demonstrated for CTA with variations in anatomy and location of the pathology.

- The deviations between the different measuring methods and the ground truth are about one millimeter (approx. 5 %).

	GT	M1	M2	D1	D2
A, B	24.0 mm	25.1 mm	23.8 mm	4.4 %	0.8 %
C	69.5 mm	70.5 mm	67.9 mm	1.4 %	2.4 %
D	39.0 mm	41.8 mm	40.5 mm	6.7 %	3.7 %
E, F	15.4 mm	16.1 mm	14.7 mm	4.4 %	4.8 %

Tab. 1. Measuring results of an AAA-phantom (GT=ground truth, M1=closed ACM, M2=6 single ACMs, D1=deviations between GT and M1, D2=deviations between GT and M2).

Fig. 4. Tube-Stent (Carotid stenosis)

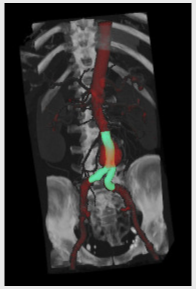

Fig. 5. Y-Stent Graft (AAA)

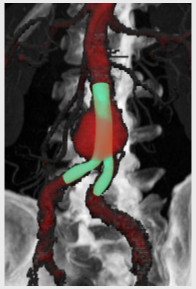

Fig. 6. Y-Stent Graft (AAA)

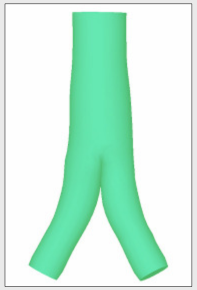

Fig. 7. Y-Stent Graft Model (closed surface)

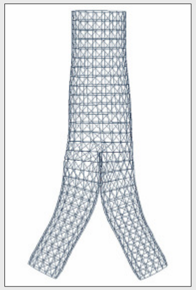

Fig. 8. Y-Stent Graft Model (wireframe)

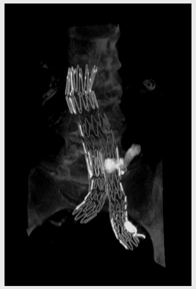

Fig. 9. Y-Stent Graft (postoperative CT scan)

Conclusion

We present two methods to measure aneurysms and stenosis and one comprehensive method which can simulate and visualize stents in preoperative CT-data. The stents can be simulated in aneurysm as well as stenosis cases.

The proposed methods are based on the numerical technique of active contours. In comparison to [7], where information of individual two-dimensional CT-slices is used, we get a more precise measurement by exploiting three-dimensional ACMs. In this way, the physician is supported in both measuring an affected artery and in choosing a stent before the deployment operation is taking place.

Our method is a contribution to support the planning of endovascular therapy for different types of stenosis and aneurysms with tube-stents. The complex process of stent planning for abdominal aortic aneurysms with Y-stents is also supported. In the long term, we hope to contribute to reducing the mortality rate by a more precise planning of the endovascular surgery based on precise preoperative vessel measuring and stent simulation.

References

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