



The Effects of Primary Stent Implantation vs. Percutaneous Transluminal Angioplasty on the Femoro-popliteal Artery Deformations due to Leg Flexion

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Introduction



The long-term outcomes of endovascular therapy in the femoro-popliteal (FP) arterial tract has been adversely effected by high restenosis rates. The hypothesis has been that the poor clinical outcomes result from mechanical factors induced by the movement of the leg during routine activities, such as walking or stair-climbing. The healthy FP artery deformations have been the subject of numerous studies^{1,2}. However, these studies can only present limited information to improve current treatment methods and devices. To this end, it is crucial to analyze the deformations of arteries with Peripheral Arterial Disease (PAD) prior to and after endovascular treatment. Such studies would not only provide information on the arterial deformations of the target population, but also on the mechanical state of the artery resulting from different treatment modalities. Therefore, the aim of this study was to estimate the in-vivo deformations of 35 FP arteries with PAD prior to endovascular surgery and after primary stent implantation and Percutaneous Transluminal Angioplasty (PTA).

Patient Demographics & Image Acquisition

> 35 patients

Age (Mean ± SD)	69 ± 10	Region of the lesion	# of patients treated with PTA	17
Gender		- Common Femoral Artery to	- Non-coated balloons	15
- Male	20	Mid/Distal SFA	- Drug-coated balloons	2
- Female	15	- Proximal to Mid SFA	# of patients treated with stents	18
Fontaine stage	IIB	- Proximal to Distal SFA	- Pulsar-18	6
Calcification		- Mid SFA	- Everflex	9
- Moderate	23	- Mid to Distal SFA	- Zilver-PTX	5
- Severe	12	- Distal SFA	- Xpert	1
Lesion length (mm) (Mean ± SD)	69 ± 9	- Distal SFA to Popliteal Artery		
Total occlusions	18	- Popliteal Artery		

- > A lightweight calibration phantom was attached to the patients' thighs using a strap
- > A set of two angiographic images was acquired
 - Separated by a view angle of 45-60 degrees



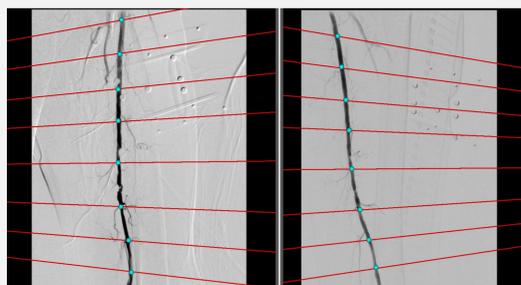
- With the leg **straight** & knee/hip flexion of 70°/20°

- > Acquisitions performed **before** treatment and **after** either stent implantation or PTA

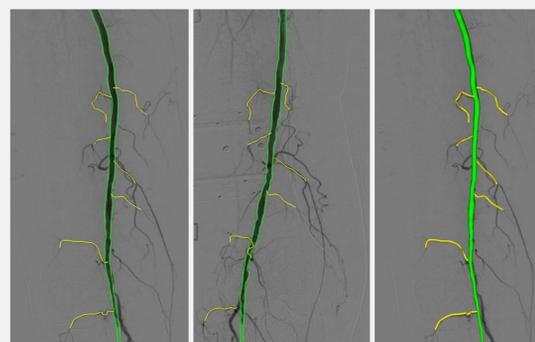
2D/3D Reconstruction & Quantification of Arterial Deformations

> 3D reconstruction of the arterial centerline

- Calibration of the two images via the the phantom
- Images related to each other by the epipolar constraint
- Segmentation of the artery by 2D contour extraction

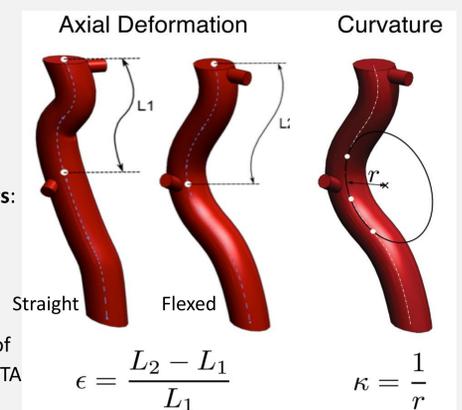


- Computation of the arterial centerpoints
- Triangulation of the 2D centerpoints to a 3D position



> Arterial deformations

- Based on a method by Choi¹
- Calculations directly performed on reconstructed arterial centerlines
- Centerlines divided into **3 segments**:
 - Proximal to lesion/treated region
 - Lesion/treated region
 - Distal to lesion/treated region
- Paired t-tests to assess the effects of leg flexion & stent implantation and PTA on arterial deformations



Results

Reconstruction Accuracy

The average forward projection error: **1.18 ± 0.28 mm**
The average backward reconstruction error: **1.03 ± 0.15 mm**

Arterial Deformations

	Axial Deformation (%)	Curvature Change (cm ⁻¹)			Axial Deformation (%)	Curvature Change (cm ⁻¹)			Axial Deformation (%)	Curvature Change (cm ⁻¹)	
		Mean	Maximal			Mean	Maximal			Mean	Maximal
Pre-Angio			Post-Balloon			Post-Balloon					
Proximal to lesion	-5.4 ± 2.0	0.03 ± 0.04	0.10 ± 0.09	Proximal to lesion	-4.4 ± 3.6	0.01 ± 0.02	0.05 ± 0.05	Proximal to lesion	-8.7 ± 8.7	0.08 ± 0.10	0.18 ± 0.19
Lesion	-5.5 ± 3.2	0.04 ± 0.05	0.15 ± 0.12	Lesion	-7.4 ± 5.3	0.06 ± 0.06	0.19 ± 0.12	Lesion	-3.2 ± 2.9	0.03 ± 0.04	0.16 ± 0.14
Distal to lesion	-11.9 ± 4.0	0.10 ± 0.11	0.25 ± 0.20	Distal to lesion	-11.6 ± 4.3	0.15 ± 0.17	0.25 ± 0.21	Distal to lesion	-9.3 ± 6.7	0.09 ± 0.07	0.24 ± 0.18

- > **Prior to and following** endovascular therapy, leg flexion caused:

- Shortening of the artery
- Increase in the mean and maximal curvatures

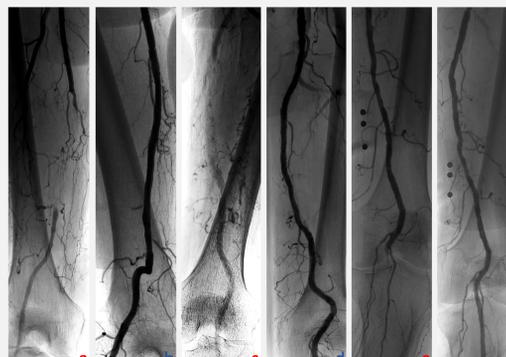
→ The **ballooned** arteries exhibited **increased shortening** compared to **their stented counterparts** within the lesion

→ Average curvature values in both straight and flexed positions were **similar before and after** treatment within/distal to the lesion

Discussion & Conclusion

- > The deformations of the FP arteries are primarily affected by leg flexion⁴
- > Arterial shortening differs between stent types
 - With Zilver-PTX, the artery shortened less compared to the Everflex and Pulsar-18 fitted arteries
- > The choice of the treatment method has a statistically significant effect on the post-interventional axial deformations
- > The choice of the treatment method does not influence the overall bending behavior of the FP arteries

> Arterial kinking



Angiographic images of the femoropopliteal (FP) arteries of 3 patients acquired **prior to PTA (a, c, e)** and **following primary stent implantation (b, d, f)** and with a hip/knee flexion of 20°/70°.

- > Depending on the anatomical position of the stents (e.g. Distal SFA & popliteal artery), the additional axial stiffening of the arteries may lead to **chronic kinking**
 - Within 6 months, 20% of the patients had restenosis, with 4 of them exhibiting arterial kinking
- > For peripheral arteries, a '**leave-nothing behind**' approach is recommended
 - PTA is not associated with kinking
 - If bail-out stenting is absolutely necessary, current stent designs should be improved to allow for additional shortening

References

- Choi et al. 2009. *Ann. Biomed. Eng.*
- Klein et al. 2009. *Catheter Cardiovasc. Interv.*
- Schumman et al. 2016. *J. Vasc. Interv. Rad.*
- Gokgol et al. 2016. *J. Endovasc. Ther.*