Evaluation of CEA techniques with a simulation tool

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Disclosure

Speaker name:

.....Reza Ghotbi.....

I have the following potential conflicts of interest to report:

Consulting

Employment in industry

Stockholder of a healthcare company

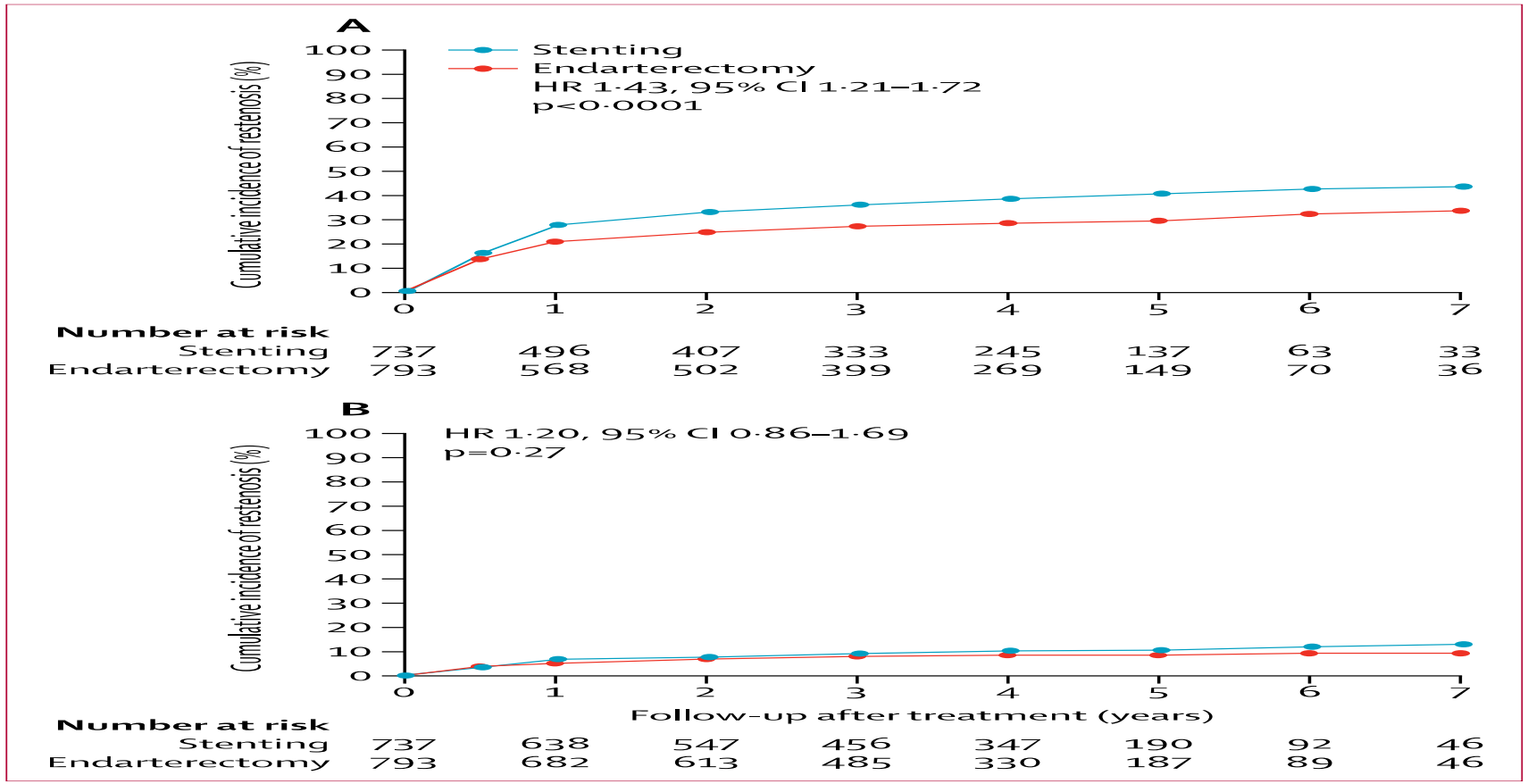
Owner of a healthcare company

Other(s)

X I do not have any potential conflict of interest

Restenosis and risk of stroke after CAS or CEA for symptomatic carotid stenosis in the International Carotid Stenting Study (ICSS) *Lancet Neurol* 2018; 17: 587–96

2001-2008, 1713 patients (855 CAS and 858 CEA), of whom 1530 were followed up with US (737 CAS and 793 CEA) for a median of 4 years



Restenosis and risk of stroke after CAS or CEA for symptomatic carotid stenosis in the International Carotid Stenting Study (ICSS) *Lancet Neurol* 2018; 17: 587–96

Interpretation:

Moderate (≥50%) restenosis occurred more frequently after stenting than after CEA

and

increased the risk for ipsilateral stroke in the overall population.

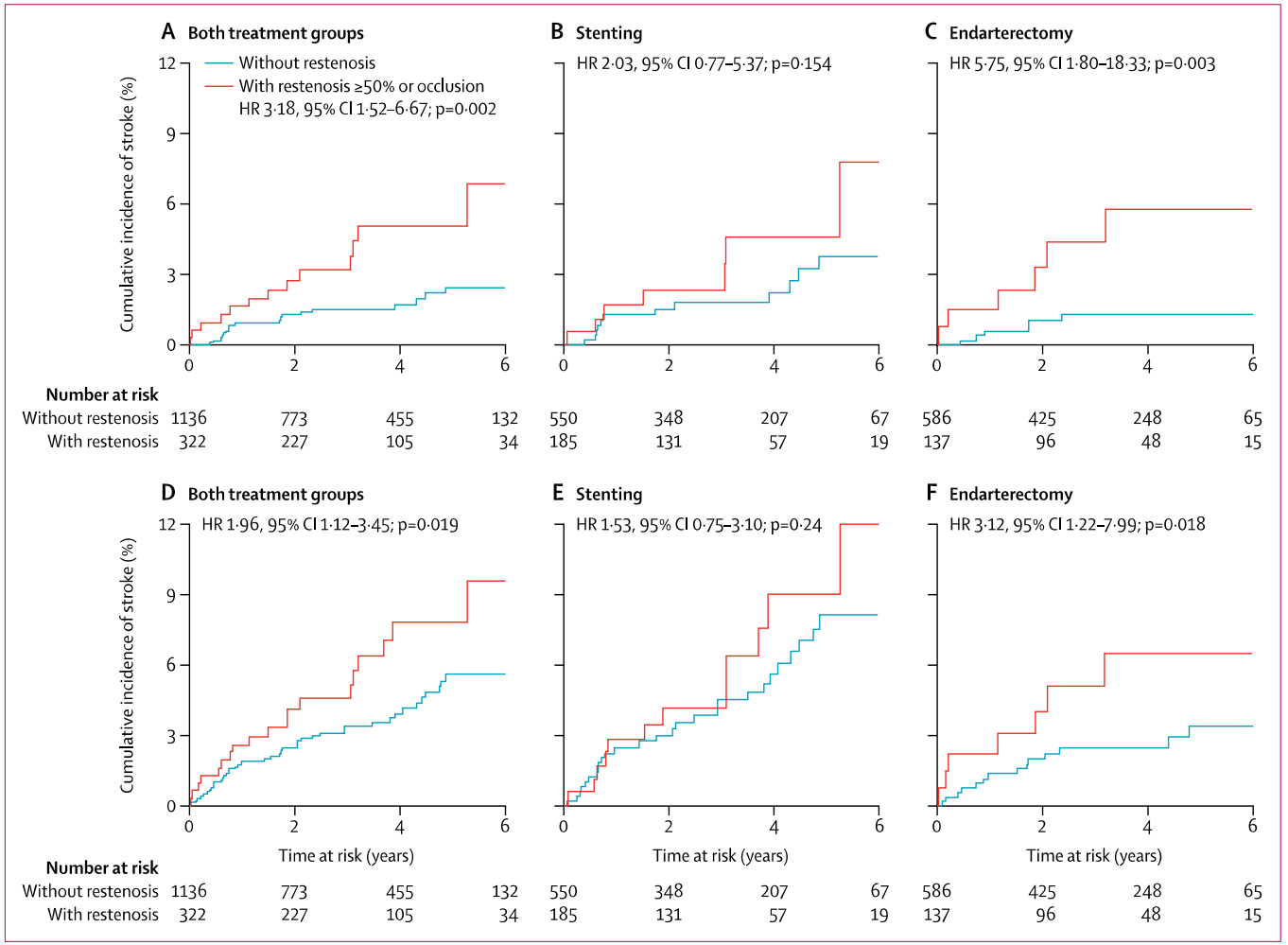


Figure 3: Kaplan-Meier curves of time to (A–C) ipsilateral stroke and (D–F) stroke in any territory with and without at least moderate (≥50%) carotid artery restenosis or occlusion

Geometric risk for artherosclerosis on carotid bifurcation

The relationship between pathophysiology of the vascular atherosclerosis and its vascular hemodynamic effects has been studied using various methods.

Results support that the geometric risk is linked to the different Wall Shear Stress (WSS) aspects.

Using comutational fluid dynamics (CFD) the changes in the volumetric hemodynamics of the carotid artery resulting from different methods of endarterectomy and in particullar unfavorable fluid dynamic condition, such as chaotic low WSS can be well described.

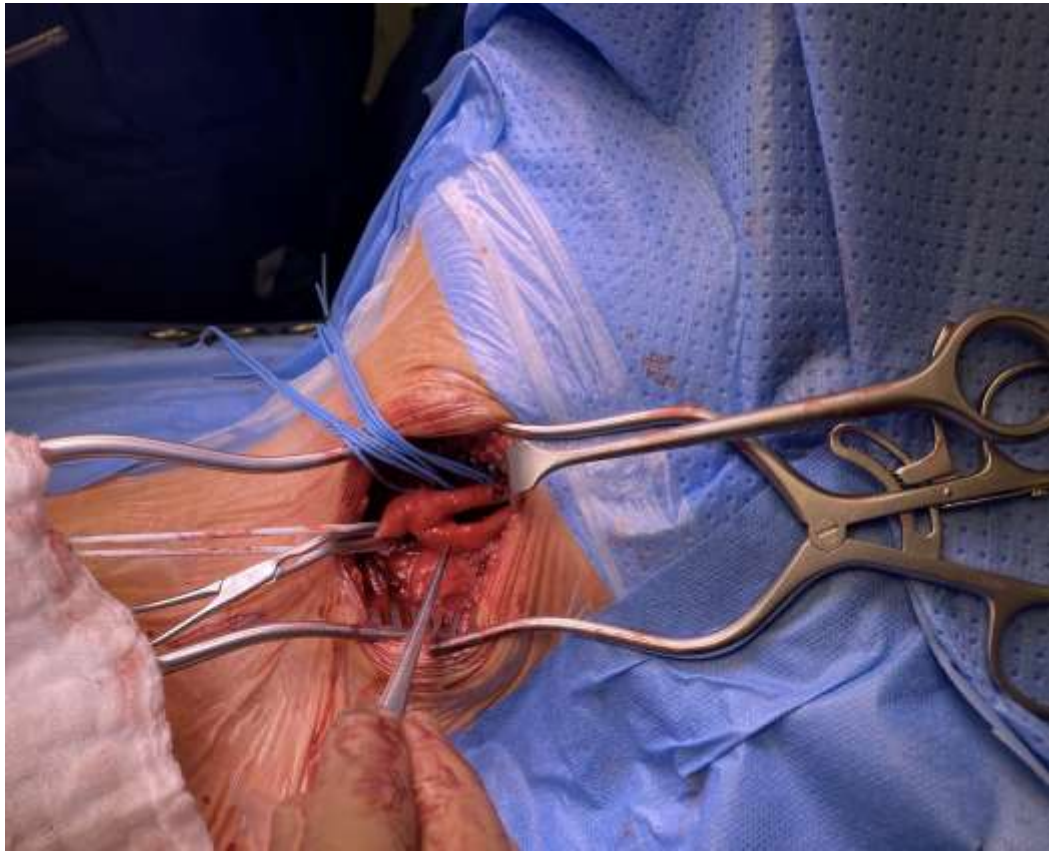
Harloff, A. et al. Determination of aortic stiffness using 4D flow cardiovascular magnetic resonance - a population-based study. J. Cardiov. Magn. Reson. 20, 43 (2018).

Guerciotti, B. et al. Computational study of the fluid-dynamics in carotids before and after endarterectomy. J. Biomech. 49, 26–38 (2016).

Harrison, G. J. et al. Closure technique after carotid endarterectomy influences local hemodynamics. J. Vasc. Surg. 60, 418–427 (2014).

Modified Eversion Endatherectomy

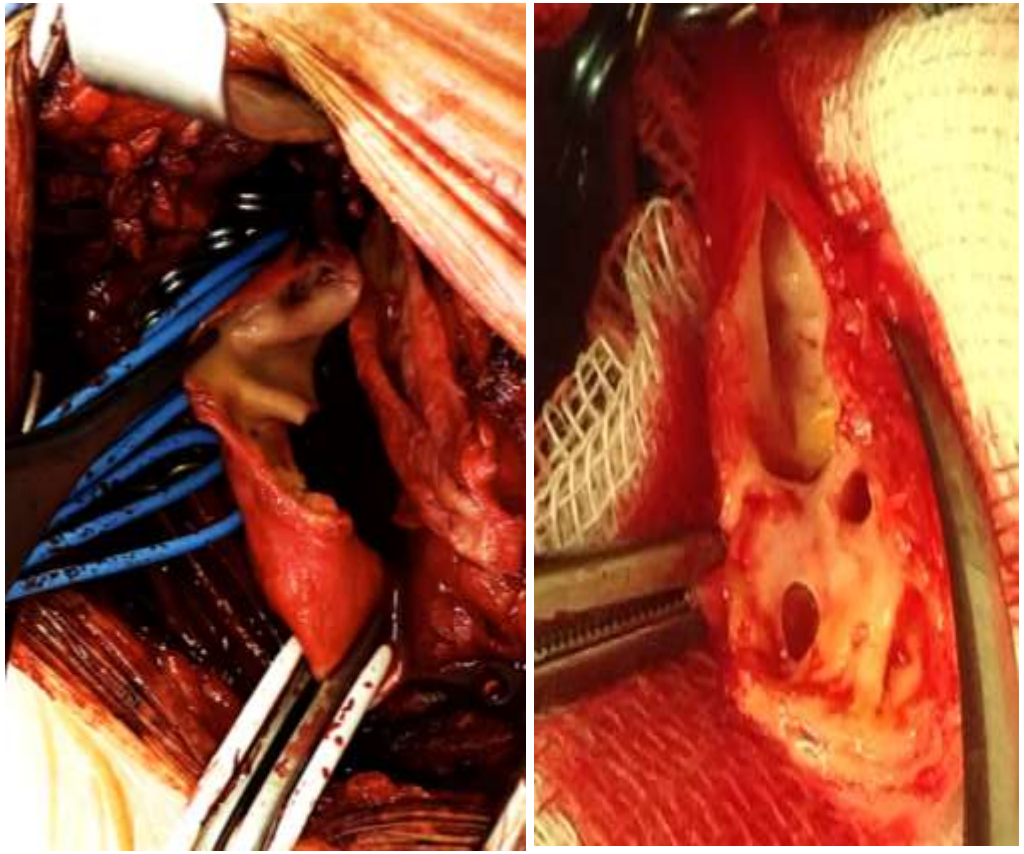
Retrojugular Approch in LA



Modified Eversion Endatherectomy

Retrojugular Approch in LA

Desobliteration CCA, CIA & CEA



Modified Eversion Endatherectomy

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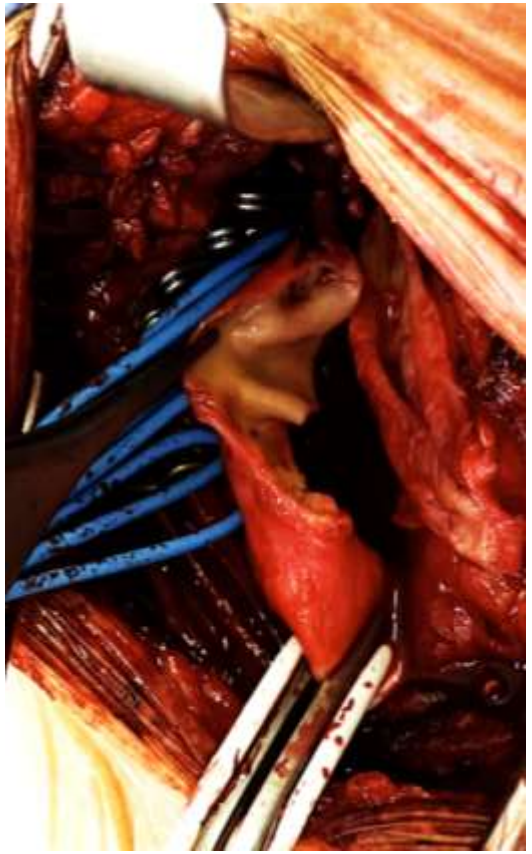
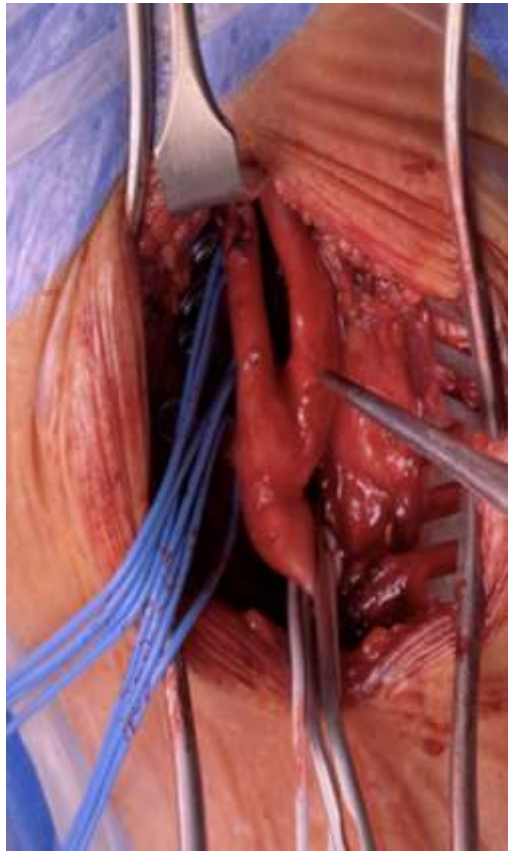


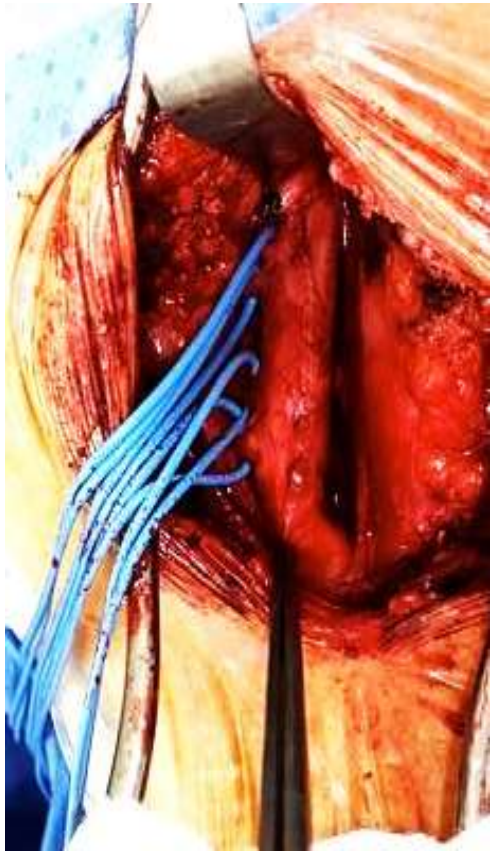
Modified Eversion Endatherectomy

Retrojugular Approch in LA

Desobliteration CCA, CIA & CEA

Geometric correction and Reanastomosis results in an higher Bifurcation and involves further carotid external side branches in the desobliterated area.

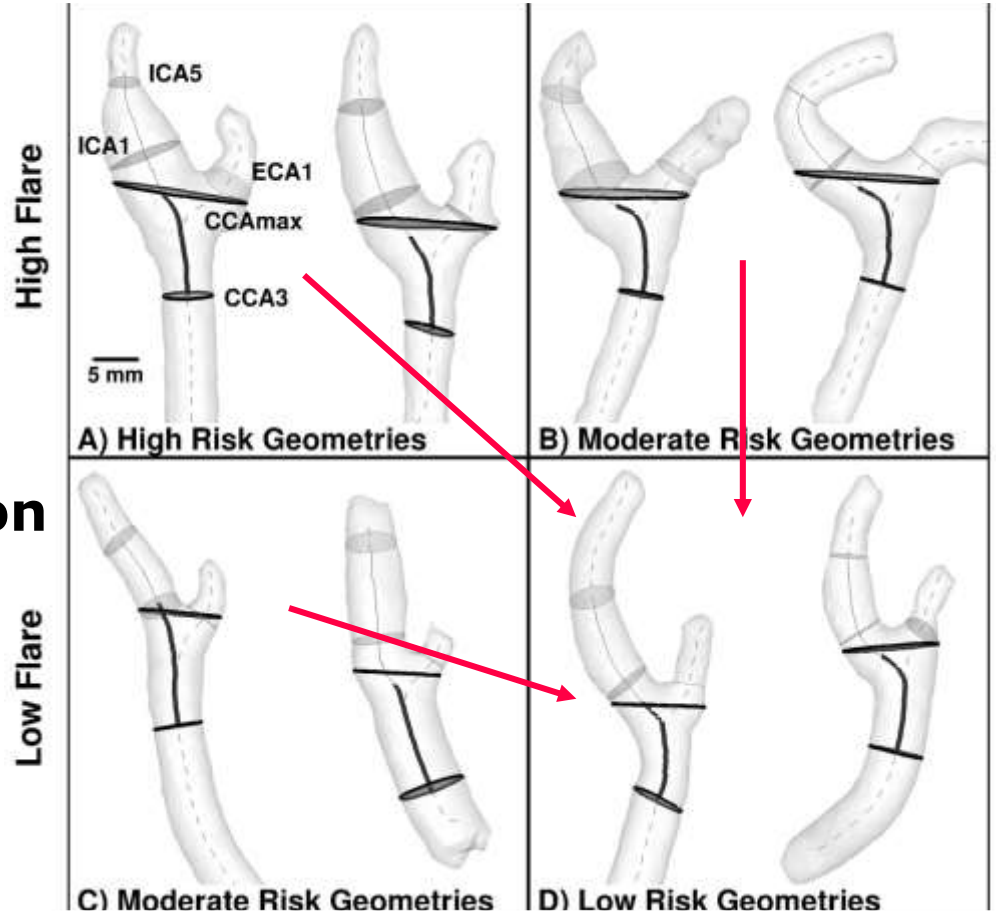




Why modified Endatherectomy?

The geometric risk hypothesis of atherosclerosis, which is predicted on the link between low and Oscillatory WSS at the carotid bulb.

The geometric risk should be reduced by complete TEA and geometric correction of carotid bifurcation.



Geometric risk for artherosclerosis on carotid bifurcation

The study explored hemodynamic disturbances and geometric features and the potential to predict the geometric risk after CEA.

CEA were performed with classic Eversion technique (ET) in 20 cases and modified eversion technique (mET) in further 20 cases.

Results are compared with 20 healthy cases.

Vector flow Ultrasound acquisitions within one month after CEA were used for hemodynamic and geometric characterization.

Personalized computational hemodynamic simulations quantified the exposure to low and oscillatory wall shear stress (WSS). Geometry was characterized in terms of flare (the expansion at the bulb) and tortuosity.

Preliminary feasibility study (July 2018)
Objective: WSS quantification

Chair for Computer Aided Medical Procedures

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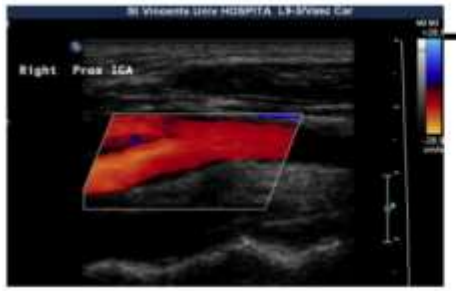
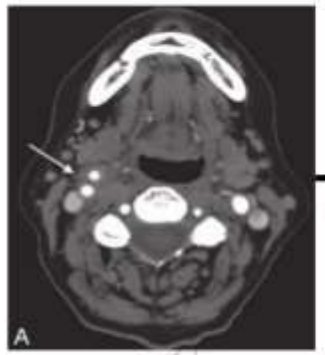
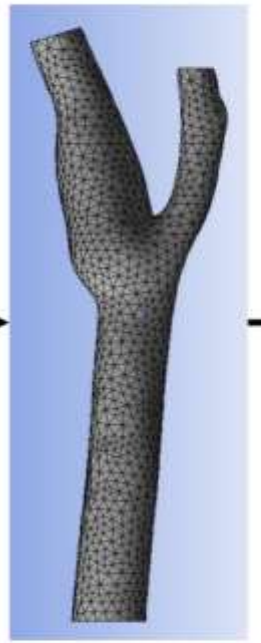
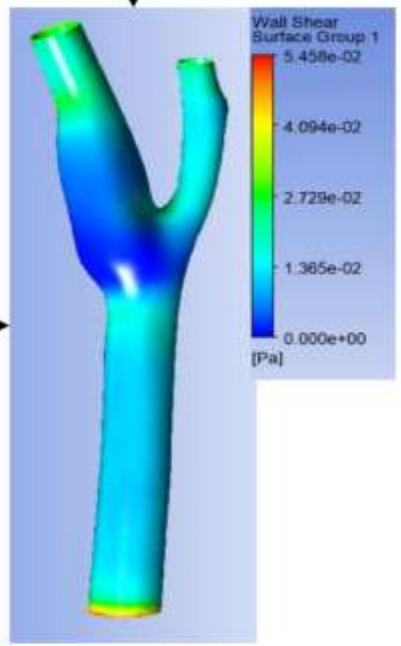
CAMP









3DSlicer

AUTODESK MESHMIXER

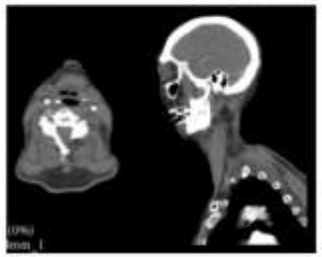
ANSYS

http://www.svuhradiology.ie/diagnostic-imaging/ultrasound/
https://www.researchgate.net/figure/A-Axial-CTA-neck-demonstrates-soft-tissue-attenuation-surrounding-the-right-carotid_fig1_5496929

3D with Vector flow US+Optical Tracking

1) Patient-specific pre-op → **2) Patient-specific post-op** → **3) WSS computation**

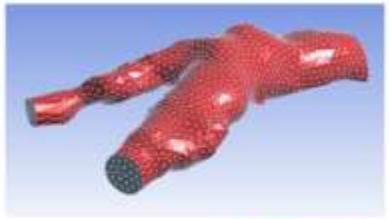
- CTA --> pre-op 3D geometry
- US



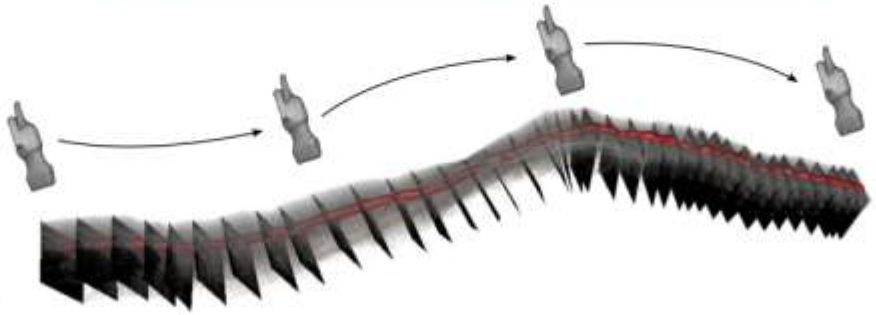
- CTA NOT AVAILABLE
- US WITH OPTICAL TRACKING

--> post-op 3D geometry using ultrasound!

[1]



WSS



[2]

[1] Fang, C. Ultrasound Navigation for Transcatheter Aortic Stent Deployment Using Global and Local Information. Appl. Sci. 6(12):391, 2016

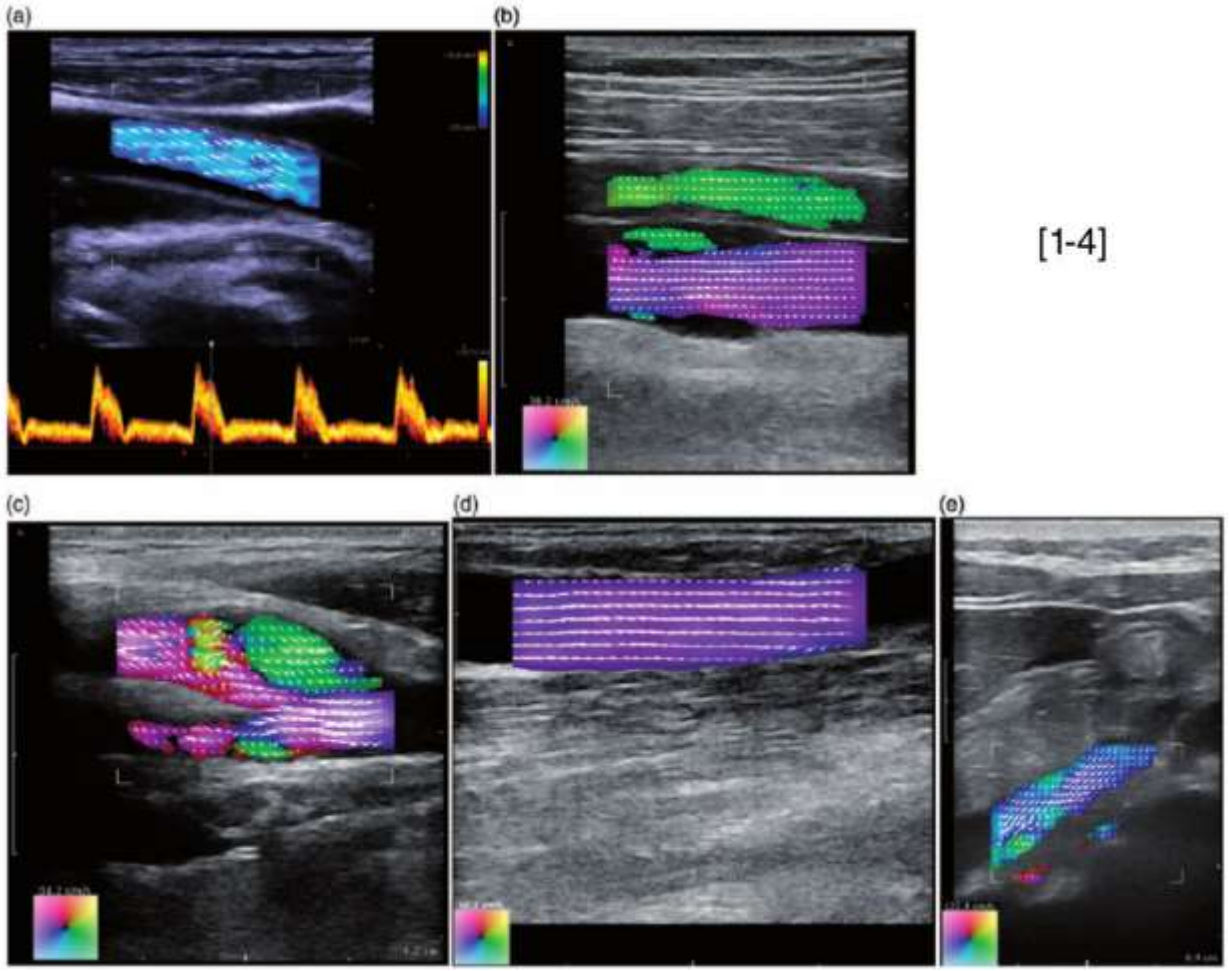
[2] Prevost, R. 3D Freehand Ultrasound Without External Tracking Using Deep Learning. Medical Image Analysis, 48:187-202, 2018

Vector Flow Imaging

This technique makes it possible to observe and quantify flow magnitude and direction.

Turbulences and vortexes can be analyzed, WSS can be approached.

It requires a specific ultrasound scanner supporting this technology.



[1-4]

[1] Jensen, Jørgen . "Ultrasound vector flow imaging—Part I: Sequential systems." *IEEE* 63.11 (2016): 1704-1721.

[2] Jensen, Jørgen . "Ultrasound vector flow imaging—Part II: Parallel systems." *IEEEl* 63.11 (2016): 1722-1732.

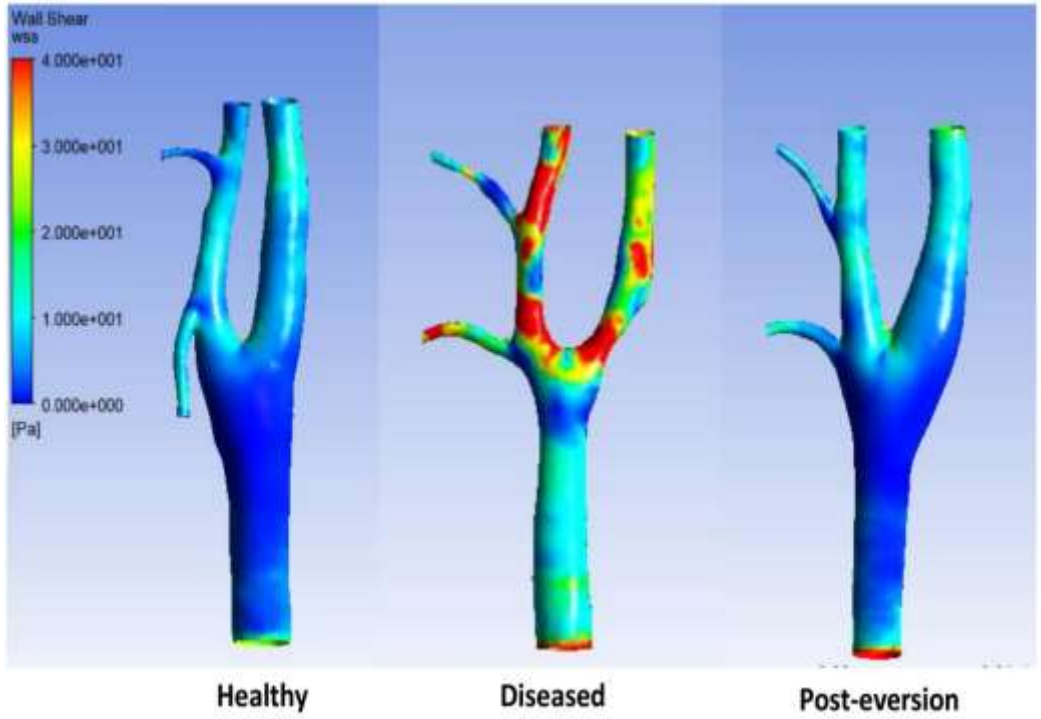
[3] Goddi, Alfredo. "High-frame rate vector flow imaging of the carotid bifurcation." Insights into imaging 8.3 (2017): 319-328.

[4] Hansen, Kristoffer "Vector flow imaging compared with conventional Doppler ultrasound and thermodilution for estimation of blood flow in the ascending aorta." Ultrasonic imaging 39.1 (2017): 3-18.

Methodic:

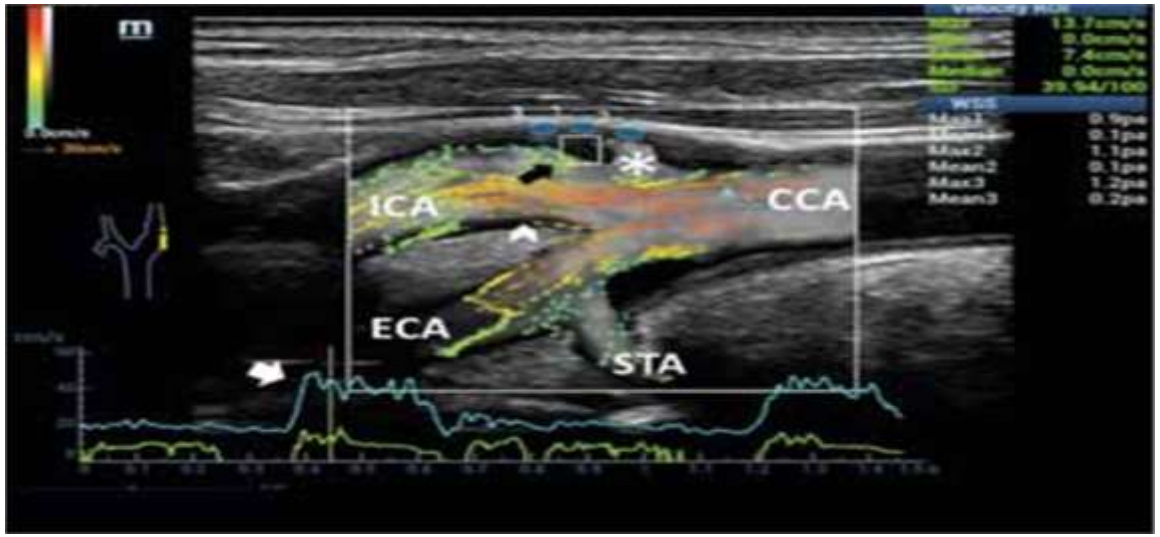
The framework is composed of three main steps.

1. Geometry construction:
A small set of (n=39) of carotid bifurcation volumes, preliminary Feasibility Study (2018), Based on these initial 3D examples, a larger collection of patient geometries (n=60) were manually constructed using the tool MESHMIXER to generate a three-fold collection of healthy, post-Eversion, and post- modified eversion geometries (n=20 each).

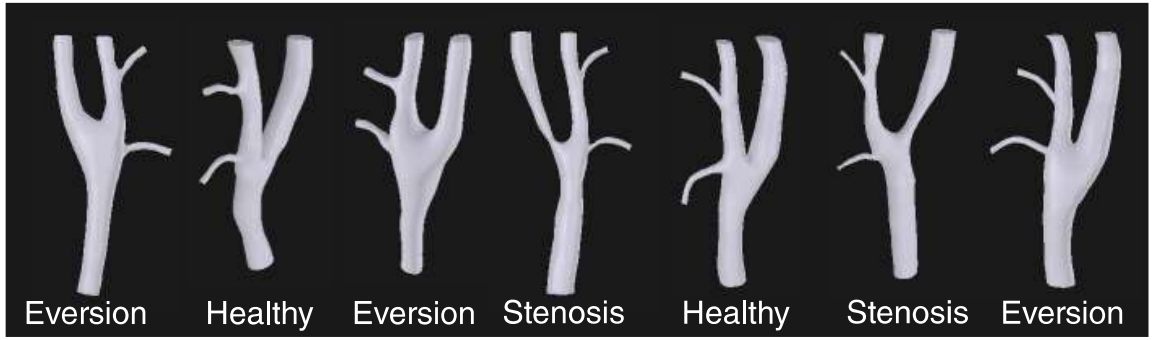


Methodic:

2) Dynamic parameters specification: for each simulated geometry, a total of 3 parameters settings was randomly applied. Parameters were peak systolic velocity (either 0.8 or 1.2 m/s), internal diameter (either 5.0 or 7.0 mm), and systolic blood pressure (either 120 or 150 mmHg), **thus leading to a collection of 180 models.**



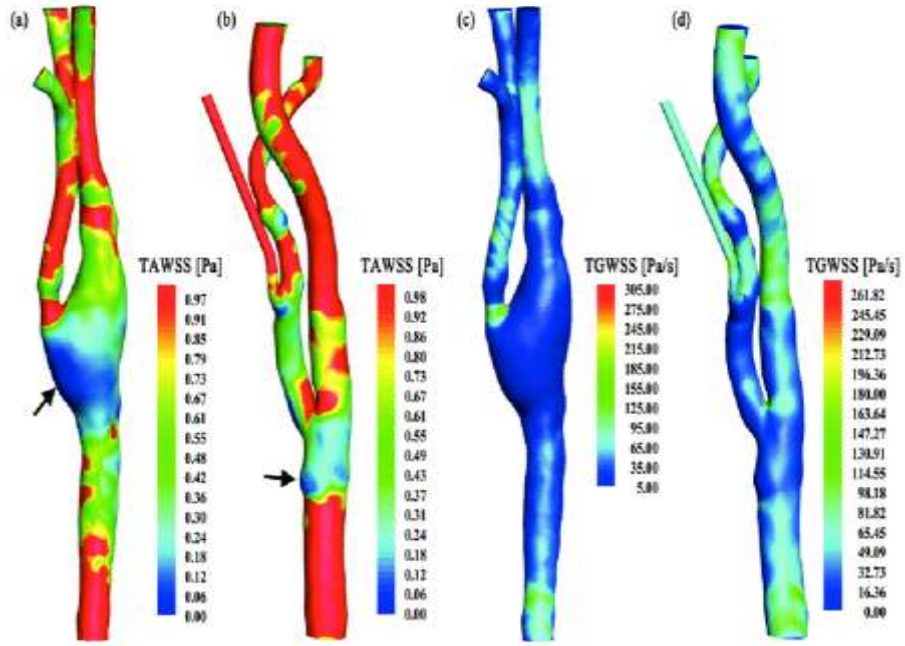
3) Wall Shear Stress (WSS) computation: WSS was adopted as an established surrogate marker of vascular health. The simulation platform ANSYS was used to compute WSS values for each models over a cardiac cycle.



Initial Results:

Three Parameters indices were derived from the 3D and t WSS values:

- **Time-Averaged Wall Shear Stress (TAWSS)**
- **Osillatory Stress Index (OSI)**
- **Relative Residence time (RRT)**



The Analysis (Wilcoxon rank sum test) showed:

- **a statistically significant difference between healthy and the standard Eversiongeometries for all 3 Parameter in particullar local elevations in RRT in specific regions of vasculature that could described a aneurysmogenic phenotype.**

- ***<u>But not between healthy and modified Eversiongeometry</u>***

Conclusions

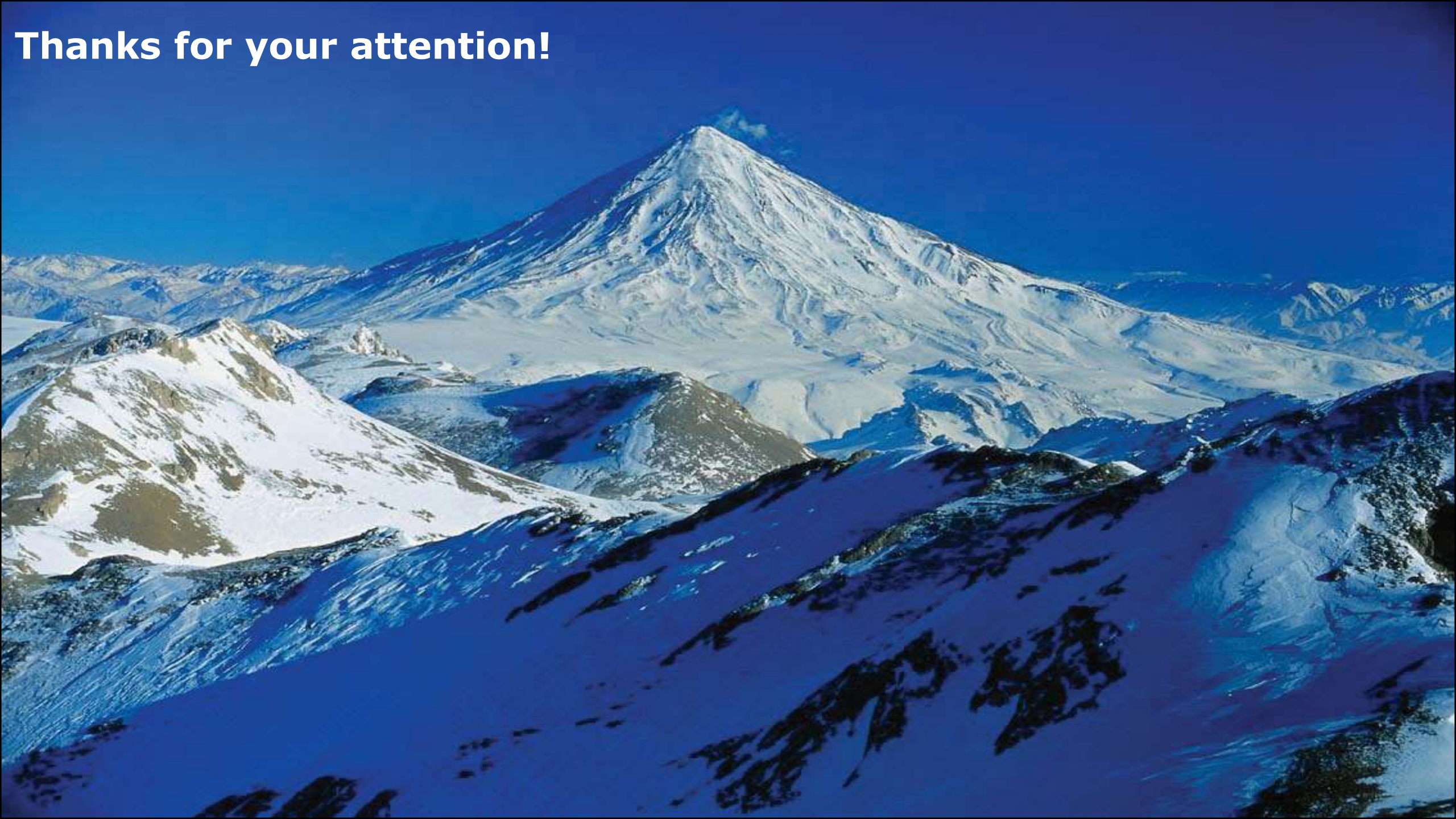
Our initial findings suggest that the modified eversion technique results in normalizing the hemodynamics in the early postoperative time.

mET reduces the flow disturbation, probably avoid a large widening of the carotid bulb (RRT), which is linked to restenosis.

WSS Measurement, Hemodynamics and geometry-based analyses hold potential for preoperative planning, guiding the technical decision, and probably stratifying long-term restenosis risk after CEA.

As changes occur post CEA in delayed manner, we try to collect data for further two years.

Thanks for your attention!



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