[] COMPARING APPLES TO ORANGES; MEASURED SKIN VIBRATIONS CORRELATE PHENOTYPICALLY WITH COMPUTED POST-STENOTIC FLOW INSTABILITIES. A PRAGMATIC BUT ROBUST TOOL FOR EARLY DETECTION OF CAROTID STENOSES?

Viviana Mancini[1], Aslak W. Bergersen[2], Kristian Valen-Sendstad[2], Patrick Segers[1]

[1]*Ghent University*
[2]*Simula Research Laboratory*

* Mancini and Bergersen contributed equally to this work.

Abstract: Early detection of asymptomatic carotid artery stenosis is crucial for prevention of ischemic stroke. We aim to investigate the ability of Laser Doppler Vibrometry (LDV) to infer asymptomatic stenosis from the intensity of stenosis-induced flow instabilities (IFI), transmitting their energy into mechanical vibrations detectable at the skin. We therefore combined *in-silico* and *in-vitro* experiments to understand how the common carotid artery flow rate (Q_{CCA}), internal/external carotid flow split (Q_{ICA}/Q_{CCA}), and degree of stenosis affected IFI. We used the 2nd order fluid-dynamical finite-elements solver Oasis [1] to *in-silico* simulate three cardiac cycles with stenosis severity of 56, 66, 76, 86, and 96%, in addition to a healthy-subject model. Geometries were obtained from patient-specific computer tomography angiography images [2,3] with an internal carotid artery (ICA) stenosis of 76%. Flow rates (Q_{CCA}: 145-529 ml/min) and flow splits (Q_{ICA}/Q_{CCA}: 11.9 to 70.8%) were varied for a physiologically plausible range, which led to a total of 19 simulations [4,5]. Mesh element and time step sizes were set based on previous spatial and temporal sensitivity studies [6]. We computed IFI from 20Hz high-pass-filtered pressure traces, obtained downstream the stenosis, and found $Re_{stenosis}$ to be the best predictor for the presence of instabilities (Figure 1-A). These results confirmed *in-vitro* experiments in a compliant replica of the 76% stenosis model where, similarly, $Re_{stenosis}$ was related to an increase in IFI derived from LDV displacement (Figure 1-B) recorded on the skin-mimicking foil surrounding the tissue-mimicking gel in which the model was embedded [7]. The overall correlation between experimental and computational data was $R^2 = 0.9956$. The absence of turbulence in a healthy-subject model allowed us to estimate that $Re_{stenosis}$ can predict moderate and severe stenosis with 77% sensitivity. However, the severe stenosis models did not harbor flow instabilities because of limited Q_{ICA}, and would hence remain undiagnosed using LDV. These findings are in agreement with clinical studies [8] on expertly operated carotid auscultation. We conclude that LDV has the potential to be used as diagnostic tool for asymptomatic carotid stenosis.

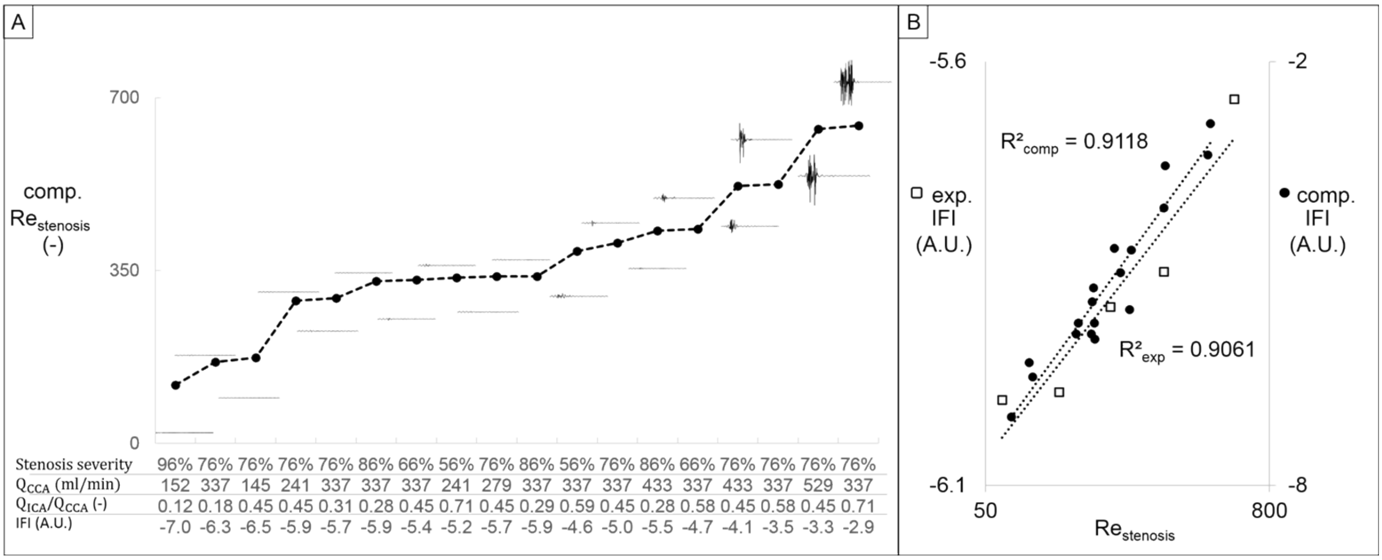

Figure 1: While being largely insensitive to expectedly relevant factors such as stenosis severity, inlet flow rate and flow split (A), the instabilities of high-pass filtered pressure traces from stenosis-induced flow instabilities increased together with $Re_{stenosis}$, both computationally and experimentally (B).

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References: [1] Mortensen et al., *Comput Phys Comm* 2015;188:177-188. [2] Bergersen et al., *JOSS* 2019 – submitted. [3] Iannaccone et al., *Int J Artif Organs* 2014;37:928-939. [4] Likittanasombut et al., *J Neuroimaging* 2006;16:34-38. [5] Groen et al., *J Biomech* 2010,43:2332-8. [6] Mancini et al., *Cardiovasc Eng Technol* 2019 – submitted. [7] Mancini et al., *PlosONE* 2019 – submitted. [8] Johansson et al., *BMC Neurology* 2008;8:1-8.