VASCULAR WALL VIBRATIONS IN THE ARTERIOVENOUS FISTULA: A NOVEL MECHANOBIOLOGICAL STIMULUS?

Michela Bozzetto (1), **Luca Soliveri** (1), **Andrea Remuzzi** (2), **Kristian Valen-Sendstad** (3)

1. Istituto di Ricerche Farmacologiche Mario Negri IRCCS, Bergamo, Italy;
2. University of Bergamo, Dalmine, Italy; 3. Simula Research Laboratory, Oslo, Norway.

Background

Native arteriovenous fistula (AVF) is the preferred vascular access for haemodialysis, but it still has high failure rates due to stenosis formation [1]. We recently demonstrated that AVFs harbor transitional flows [2] and the goal of the present study was to investigate whether these hemodynamic conditions could promote aberrant mechanical stresses within the vascular wall.

Materials and Methods

We generated a 3D patient-specific model starting from non-contrast enhanced fast spin echo magnetic resonance images acquired at 3 days after radio-cephalic AVF surgery in a 72-year patient. An external layer with constant thickness of 0.3 mm was added to the AVF to include the vascular wall, that was modeled using three-term compressible Mooney-Rivlin. Robin boundary condition were used to represent the viscoelastic behavior of the surrounding tissues. We imposed pulsatile blood flow waveforms derived from US examination at the proximal and distal artery (*Figure 1*).

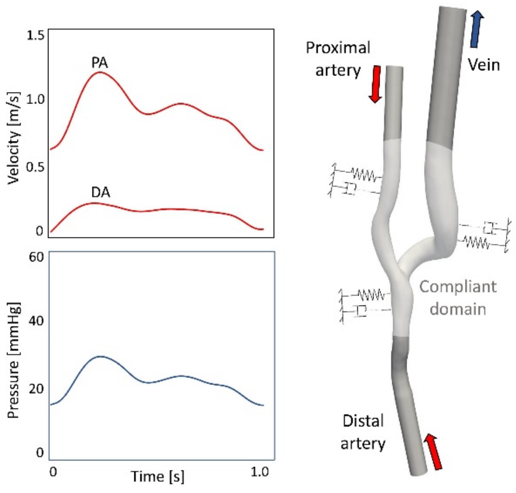

Figure 1: Patient-specific AVF model and velocity and pressure boundary conditions.

A validated and formally 2^{nd} order accurate fluid structure interaction solver [3] developed upon FEniCS Finite Element Model library was used to solve for wall deformation and flow field.

Results

High-fidelity fluid structure interaction simulations revealed the presence of wall vibrations up to 150 Hz and with amplitude of about 10 microns (Figure 2).

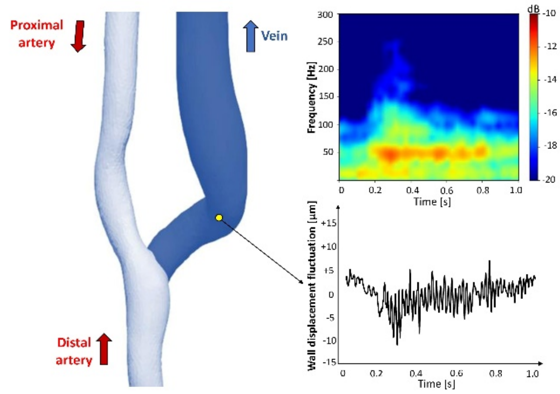

Figure 2: Spectrogram of the wall displacement in the vein (blue colored) and wall displacement fluctuation of a single point on the vein.

Interestingly, the vibrations were predominant at the anastomosis floor and on the inner venous side, locations that correlate with regions where stenosis typically develops (*Figure 3*).

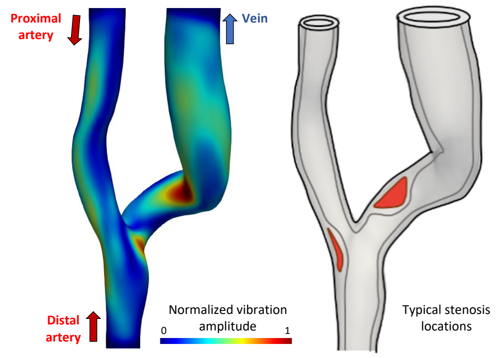

Figure 3: High amplitude vibrations phenotypically collocate with typical stenosis locations.

Conclusion

The same location of vascular wall vibrations and stenosis may suggest an unknown mechanobiological process linking high-frequency mechanical stresses within the vascular wall and adverse vascular remodellingremodeling.

References

1. Caroli et al, Kidney Int, 84: 1237–1245, 2013.
2. Bozzetto et al, ABME, 44(8): 2388–2401, 2016.
3. Bergensen et al, JOSS, 5(50): 2089, 2015.

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