# UNDERSTANDING THE ROLE OF HIGH-FREQUENCY VASCULAR VIBRATIONS IN ARTERIOVENOUS FISTULA FAILURE

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## Introduction

Native arteriovenous fistula (AVF) is the preferred vascular access for hemodialysis, yet 40% of them fail within 1 year after surgery [1] mainly due to stenosis. We have recently shown that transitional flow induces vibrations in the AVF vein wall at frequencies exceeding hundreds of Hz, and suggested that the associated mechanical stresses may directly impact the mechanobiology of smooth muscles cells [2]. The aim of this fluid-structure interaction (FSI) longitudinal study is to explore the relation between high-frequency vascular vibrations and adverse AVF wall remodeling.

## Methods

Contrast-free magnetic resonance imaging and Doppler Ultrasounds measurements were performed at multiple timepoints (up to 1 year) in six patients with a native radio-cephalic AVF. Two patients underwent successful maturation and long-term patency, whereas the others experienced complications, characterized by either stenosis or excessive dilatation. AVF geometries were reconstructed from medical images and meshes of about 200,000 tetrahedral elements were generated. Fully coupled 2$^{nd}$ order accurate space/time centred high-fidelity FSI simulations were conducted using turtleFSI [3] with a time discretization of 0.1 ms. Patient-specific inflow and pressure were incorporated, and the distinct properties of artery and vein were modeled with a 3-term Mooney-Rivlin model. The simulations also accounted for the stiffening and thickening of the vein during maturation. The perivascular tissue was modeled with Robin boundary conditions. The computed vascular displacement was high-pass filtered using a frequency threshold of 25 Hz to isolate the vibrations from the inflation due to pressure pulsation. Wall displacement spectrograms were generated to illustrate the evolution of high-frequency content over the cardiac cycle [4].

## Results

Patients with AVF complications exhibit significantly higher vibration amplitudes with respect to those experiencing good patency (median [IQR] = 11.5 μm [5.8−23.7 μm] vs. 2.7 μm [1.8−6.9 μm], $p < 0.05$), along with a visibly enhanced spectral content up to 500 Hz. *Figure 1* represents the outcomes for two representative patients, P1 exhibiting vein stenosis at 1 year, and P2 with successful long-term patency.

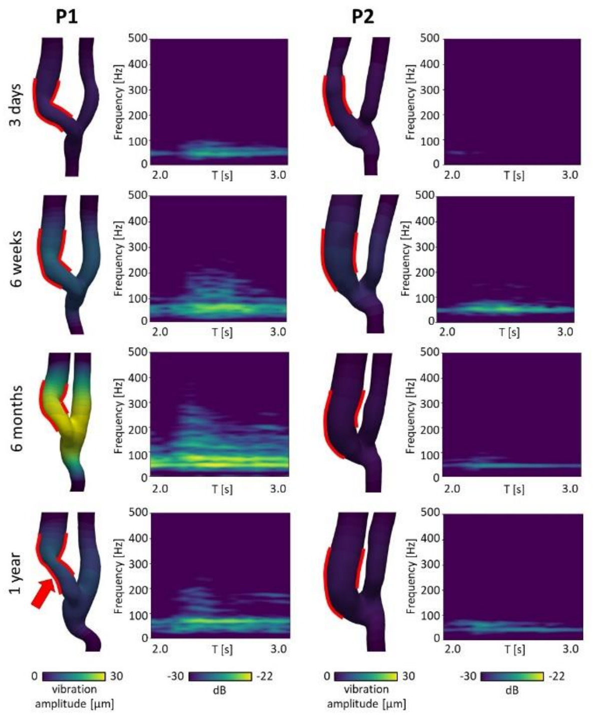


*Figure 1: Time-averaged vibration amplitude maps and wall displacement spectrograms extracted in the juxta-anastomotic vein (region between the red lines) for two representative patients at four timepoints.*

## Discussion

Results indicate the presence of significantly higher vibration amplitudes in patients who experienced AVF complications compared to those with successful maturation and long-term patency. Our findings indicate distinct vibration responses associated to different clinical outcomes, suggesting a potential association between high-frequency vascular vibrations and adverse AVF remodeling. If validated in a larger cohort, this finding could hold significant implications for clinical management. The possibility of identifying AVFs at risk of failure through vibration monitoring could enable surgeons to timely intervene, thereby enhancing AVF clinical outcomes.

## References

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