An advanced simulator to investigate hemodynamic effects on vascular remodeling in arteriovenous fistula

A. S. Bolandrina (1) | E. Pederzani (1) | L. Soliveri (2) | S.Poloni (2) | I. Moscara (1) | L. Faustinelli (1)
E. Carrara (3) | C. E. Campiglio (2) | M. Bozzetto (3) | A. Remuzzi (2) | G. B. Fiore (1) | M. Soncini (1)

1 Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, IT
2 Department of Management, Information and Production Engineering, University of Bergamo, Bergamo, IT
3 Department of Biomedical Engineering, Istituto di Ricerche Farmacologiche Mario Negri-IRCCS, Bergamo, IT

INTRODUCTION

Arteriovenous fistulas (AVFs) represent the **gold standard** for hemodialysis, yet they still exhibit **high failure rates** due to maladaptive remodeling [1]. Although **local hemodynamics** plays a central role, current models show limited clinical translatability of their findings, reducing the understanding of disease progression [2]. Reproducing realistic hemodynamics in controlled environment is therefore essential to uncover the mechanisms leading to AVF failure.

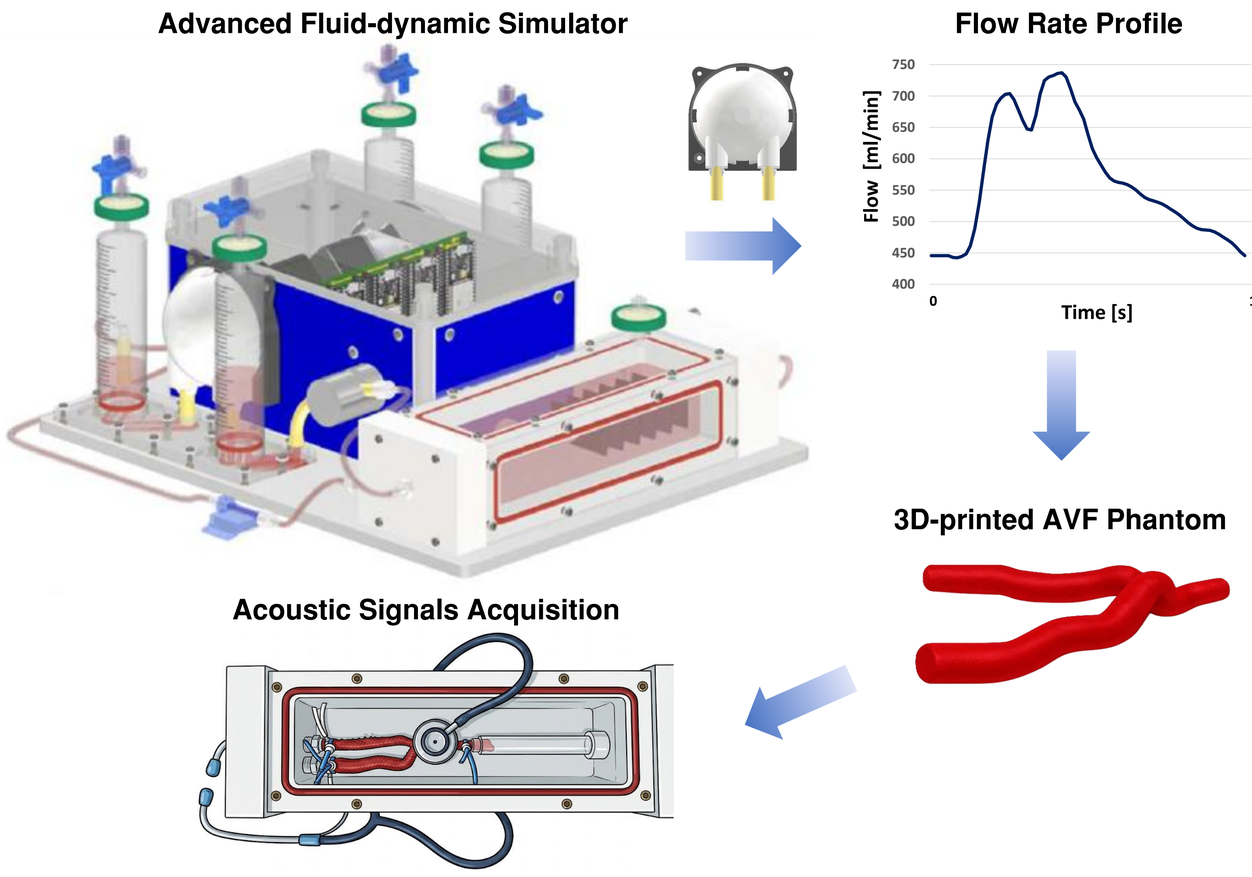
AIM of the STUDY

To develop a versatile in vitro vascular simulator capable of reproducing **patient-specific fluid-dynamics** in realistic geometries, enabling controlled investigation of flow disturbances in **AVF failure** through flow-induced vibrations and their acoustic signatures.

SYSTEM DESIGN and EXPERIMENTAL SETUP

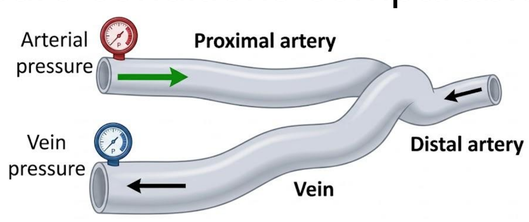
SYSTEM DESIGN: An advanced fluid-dynamic simulator was developed to host vascular models and apply **customizable flow conditions**. The system delivers physio-pathological flow-induced stimuli with high reproducibility, integrating **closed-loop control** of both flow and pressure.
Its modular architecture ensures adaptability to different vascular geometries, making it a versatile platform for different experimental applications.

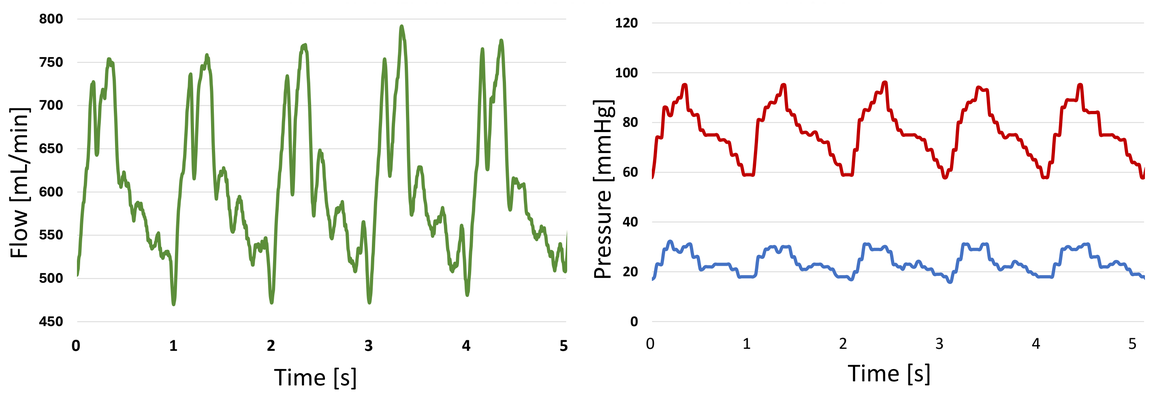
AVF PHANTOM and FLUID-DYNAMIC STIMULATION: **Patient-specific 3D-printed AVF phantoms** are integrated into the system to reproduce realistic geometries and perfused with a fluid with blood-like viscosity under physio-pathological flow conditions. **Acoustic signals** are acquired using an electronic stethoscope and analyzed spectrally for direct comparison with clinical data.



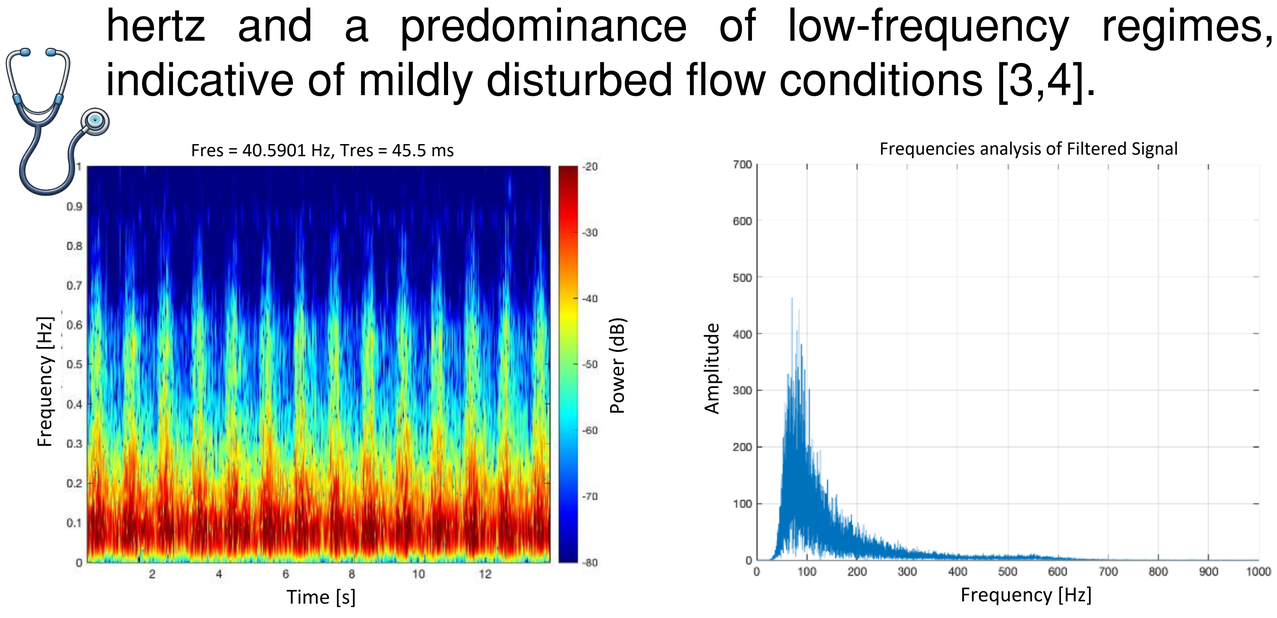
RESULTS

The system effectively reproduces physio-pathological flow and pressure conditions comparable to clinical data.





Acoustic signals are consistent with clinical observations, showing frequency components up to several hundred hertz and a predominance of low-frequency regimes, indicative of mildly disturbed flow conditions [3,4].



CONCLUSION

This platform is a versatile fluid-dynamic simulator for vascular models, capable of applying controlled fluid-dynamic conditions. It enables **patient-specific stimulation** and **acoustic analysis** in AVFs, offering an innovative approach to investigate the role of flow dynamics in AVF remodeling, with sound as a potential indicator of failure.

alessiasofia.bolandrina@polimi.it

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