EMMS 2026

Surgeon-In-The-Loop

Virtual Reality for Real-Time Exploration of Patient-Specific Hemodynamic in Congenital Heart Surgery Planning

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ROMed2VR

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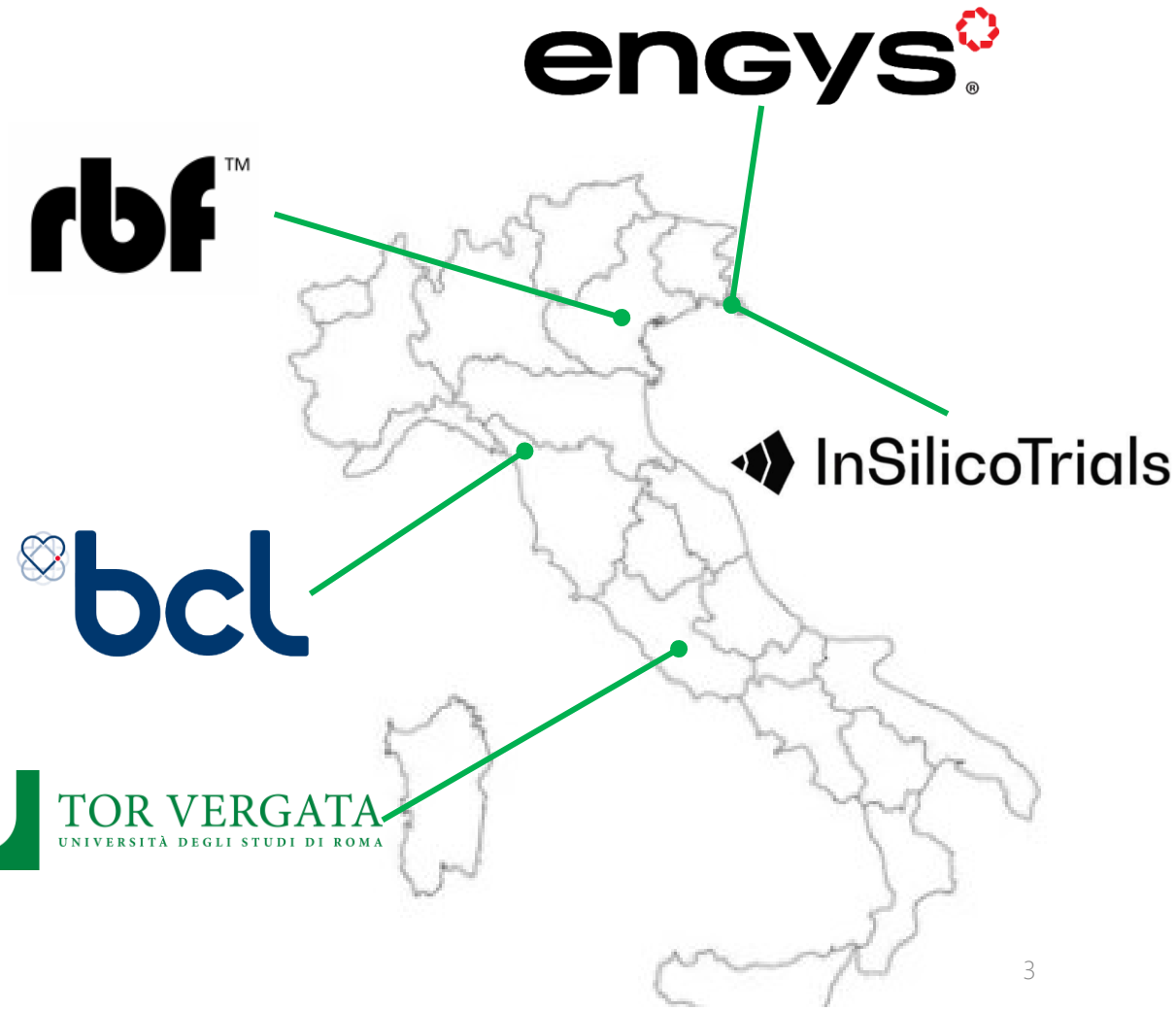
Agenda

- ROMed2VR - Project Overview & Consortium
- Clinical Challenge – State of the Art
- Numerical workflow for patient specific DT
- VR Integration and Validation
- Conclusions

Project Overview & Consortium

- ROMed2VR was a collaborative research project involving:
  - **ENGYS** – CFD automation & project coordination
  - **RBF Morph** – ROM development & VR integration
  - **InSilicoTrials** – Validation, IP and digital platform
  - **Fondazione Toscana Gabriele Monasterio** – Clinical expertise
  - **University of Rome Tor Vergata** – Scientific supervision

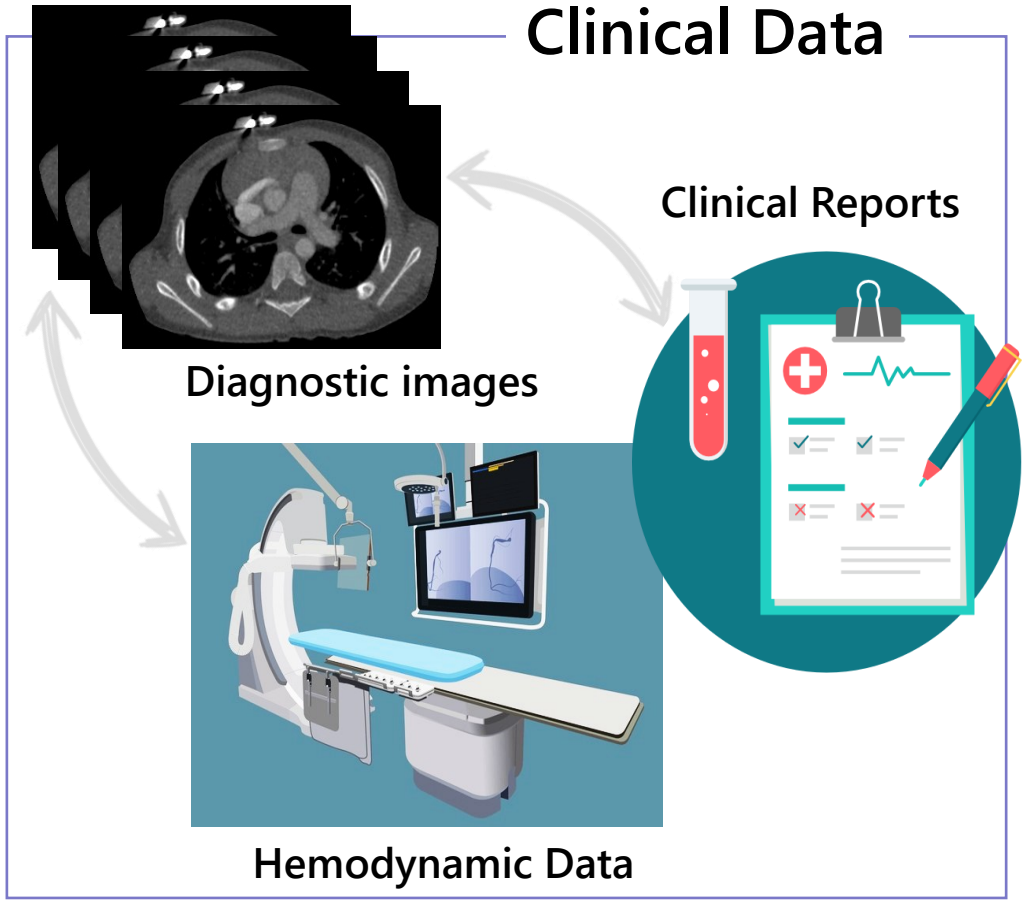


Clinical Challenge

- **Challenge**: Making the Medical Digital Twin available for neonatal cardiovascular surgery
- **Modified Blalock-Taussig shunt** (mBTS) is widely used in cyanotic congenital heart disease
- Associated with **significant morbidity** and mortality
- Complications include **hyper-perfusion** and shunt **thrombosis**
- Surgical planning relies on **fragmented clinical data**

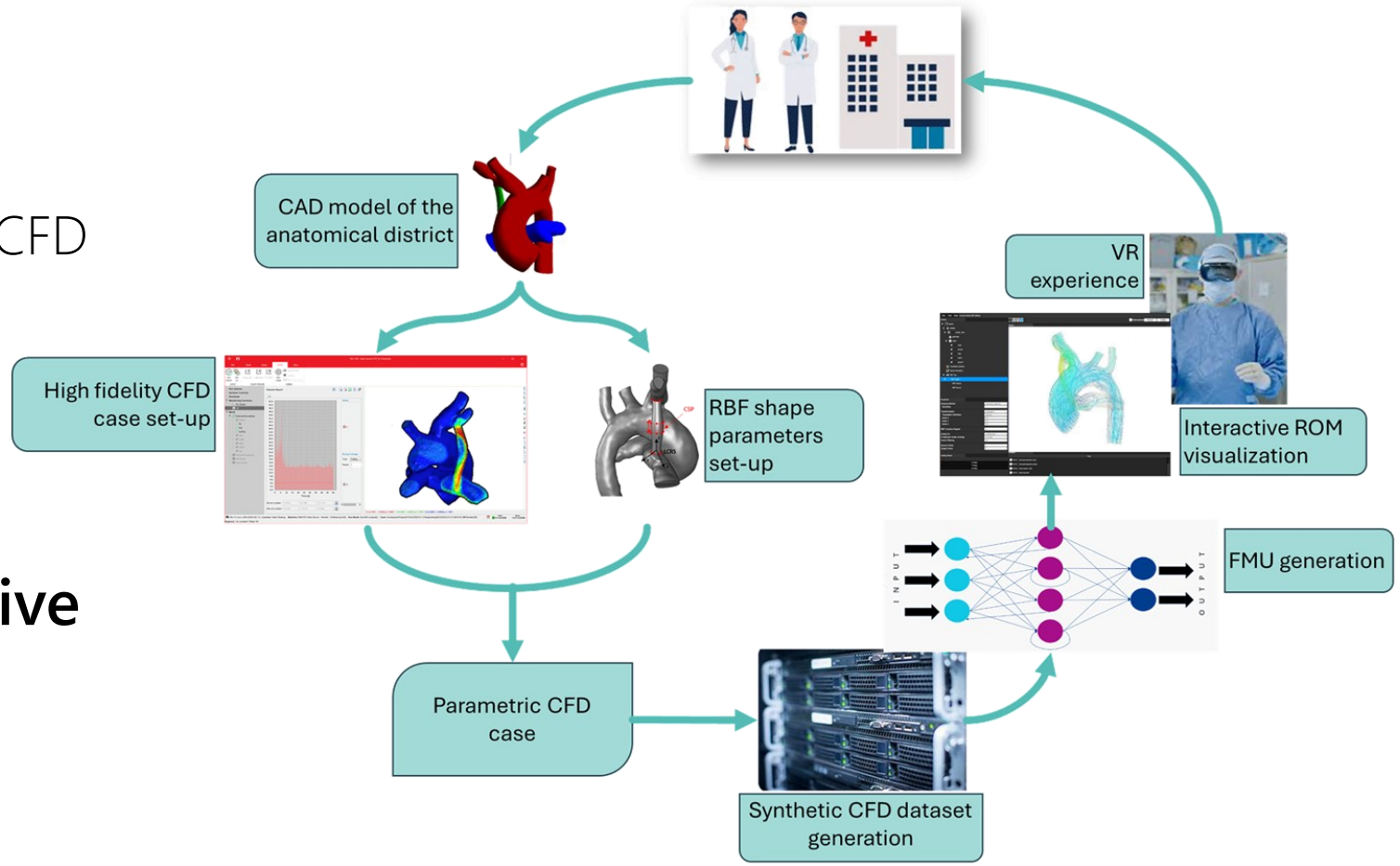
State of the Art

- Congenital heart defects are among the most **common birth anomalies**
- Physicians must interpret **heterogeneous and unstructured data**:
  - diagnostic imaging
  - hemodynamic parameters
  - clinical reports
- Lack of **integrated** decision-support **tools**
- **High-fidelity CFD** is promising but not clinically interactive.



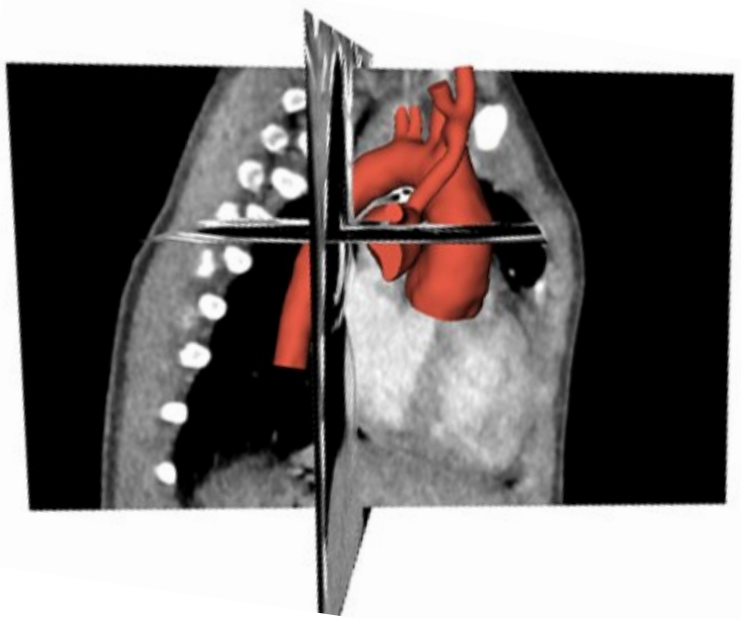
ROMed2VR Objectives

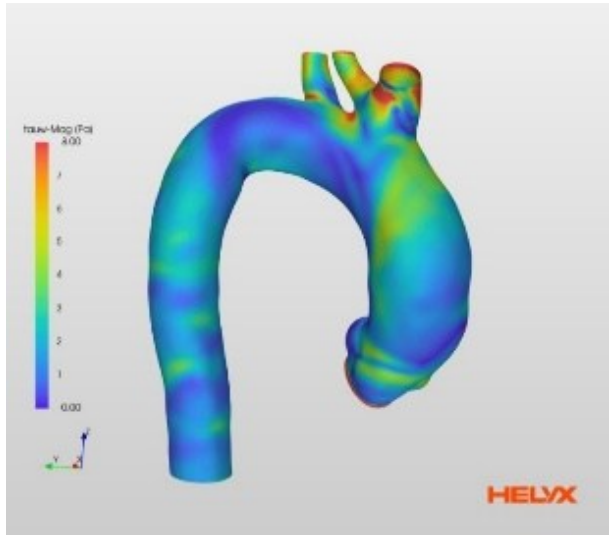
- Develop an **integrated numerical and VR framework** based on:
  - Patient-specific high fidelity CFD simulations
  - Reduced Order Modeling (ROM)
  - Real-time immersive visualization
- Goal: Support **pre-operative surgical decisions** and reduce patient risk.

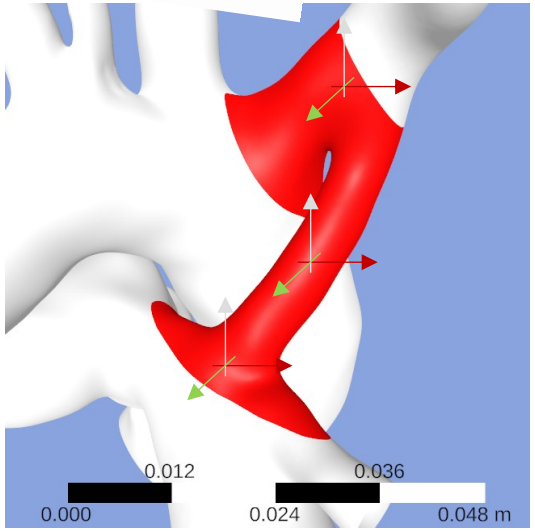


Patient-Specific Data & Parametrization

- **CT-based** geometry reconstruction
- Automated CFD setup (Python workflow)
- **Shape parameters** defined with clinical relevance:
  - shunt diameter
  - anastomosis location

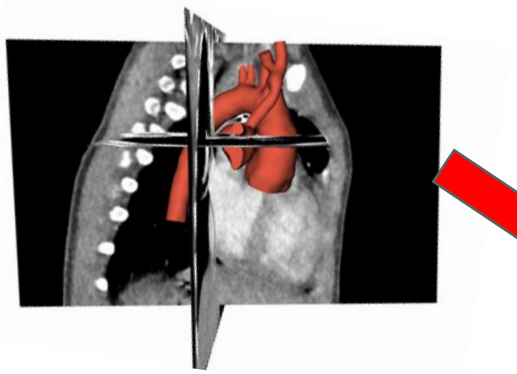




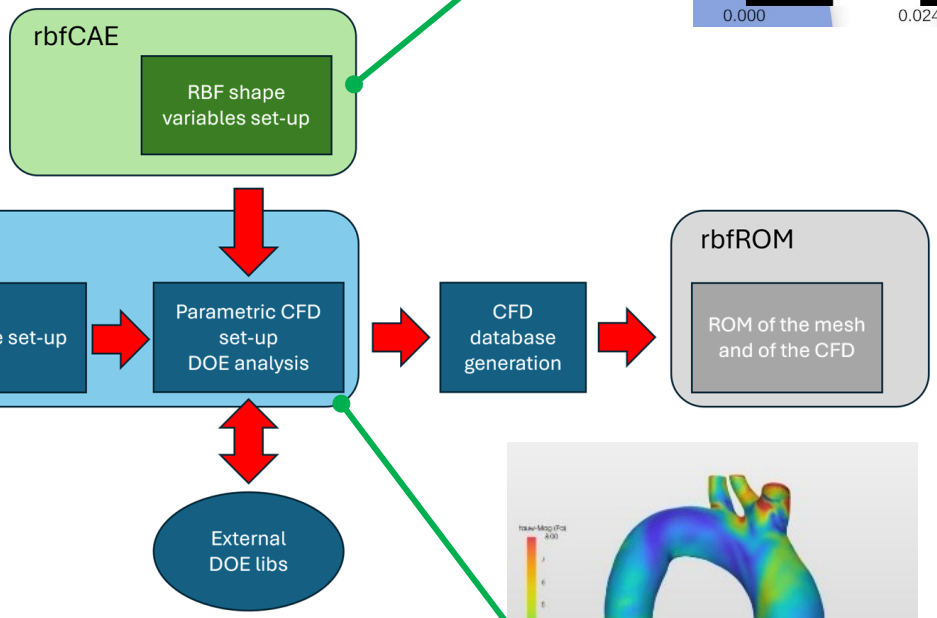


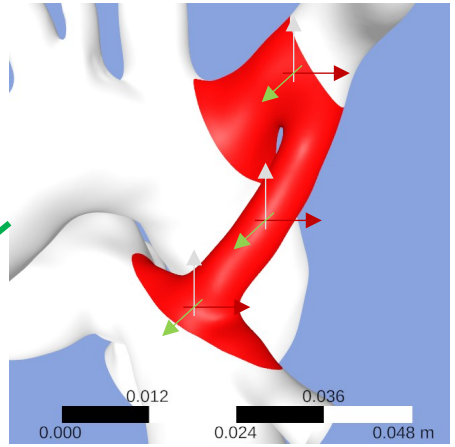
Numerical Workflow

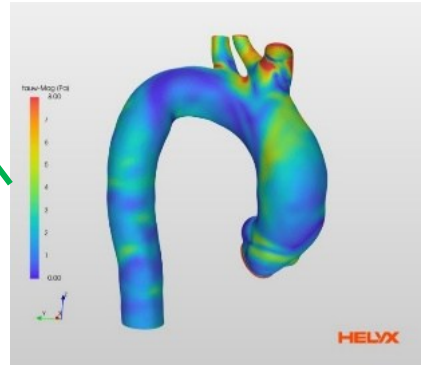
1. Baseline patient-specific mBTS case
2. Shape parametrization via RBF mesh morphing
3. CFD Design of Experiments
4. Snapshot database
5. POD-based reduced model
6. Real-time prediction

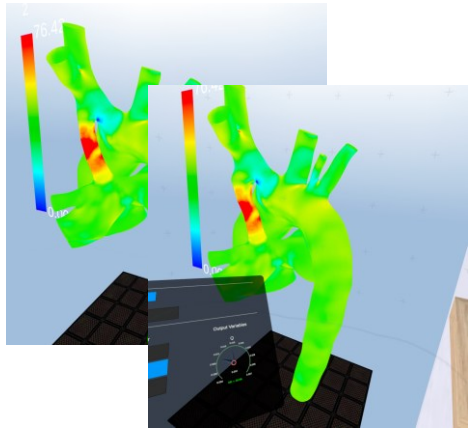


Patient-specific CT Data









Integration of mBTS CFD results into an immersive VR environment enabling real-time modification of the shunt geometry.

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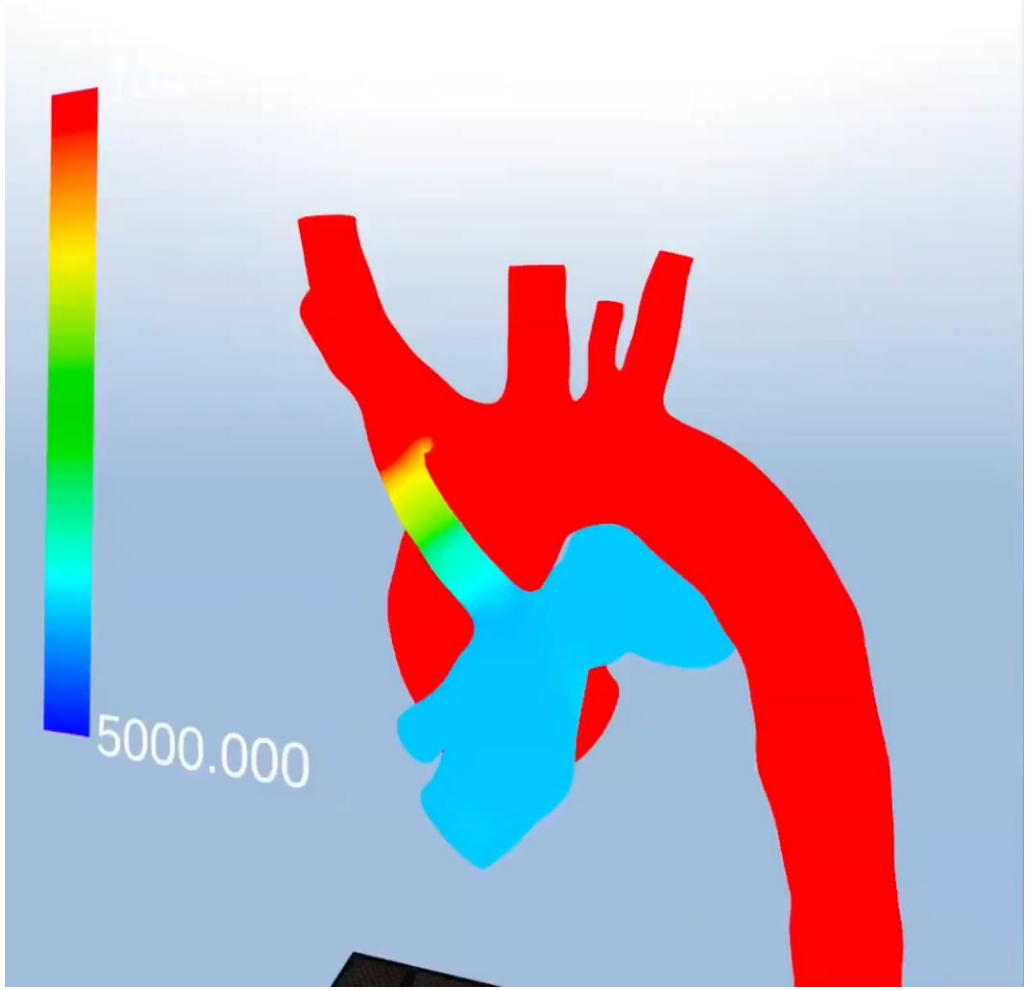
VR Integration: Surgeon-in-the-Loop

- Immersive visualization of **pressure, velocity and WSS**
- Real-time modification of **surgical parameters**
- Immediate field update
- The surgeon becomes an **active explorer** of the hemodynamic solution space

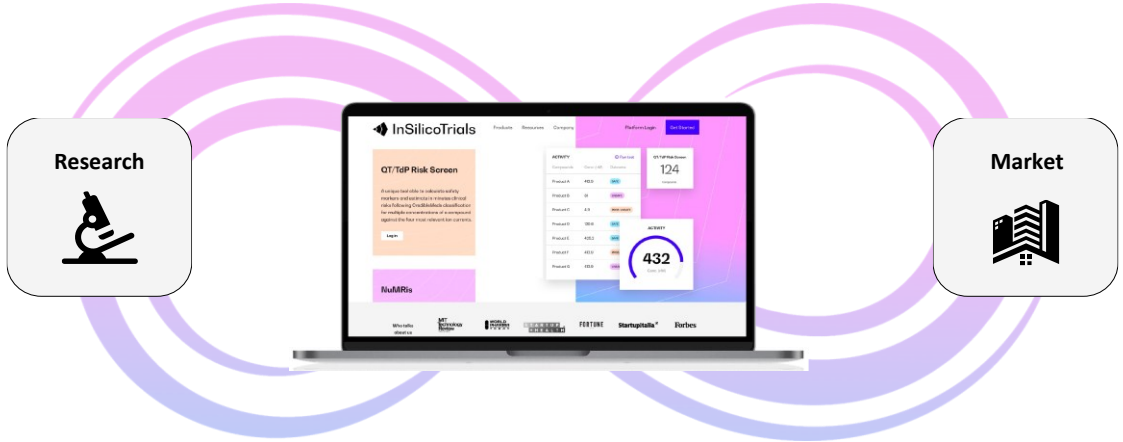


Clinical & Technical Evaluation

- Evaluation performed by:
  - 3 congenital heart **surgeons**
  - Technical **experts**
- Assessed via Technology Acceptance Model
- Results:
  - Clear and understandable interface
  - High usability
  - Considered promising for pre-operative planning

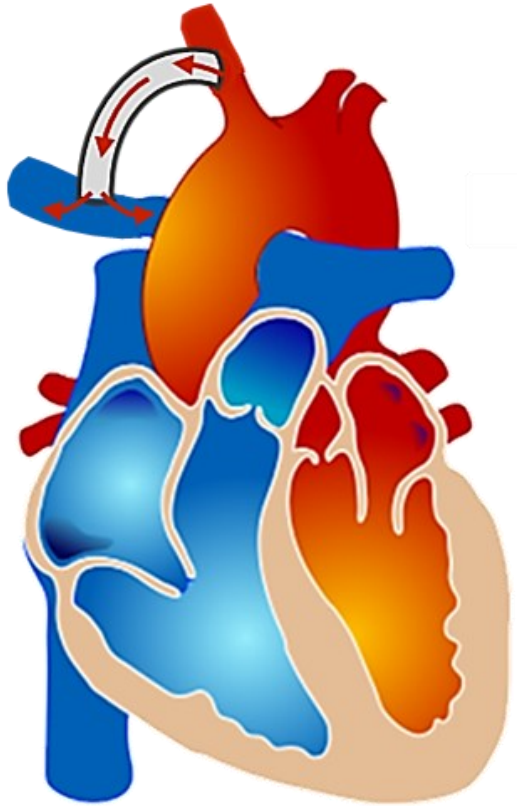
Impacts & Vision

- Scientific and technological advancement
- Clinical and social benefit
- Transition from research to clinical reality
- Cloud deployment potential
- Regulatory path as Software-as-Medical-Device
- Toward scalable cardiovascular digital twins.



Conclusions

- ROMed2VR integrates **patient-specific CFD**, reduced-order modeling and immersive VR into a unified workflow.
- The framework enables **real-time exploration** of surgical configurations in congenital heart disease.
- The **surgeon** becomes an **active decision-maker** within a simulation-driven environment.
- Initial **clinical feedback** confirms usability and **strong potential** for pre-operative planning.
- The approach represents a concrete step toward **scalable cardiovascular digital twins**.



Many thanks for your attention!

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