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Digital twins in cardiology : Toward personalized simulation of cardiovascular physiology and intervention

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Statement of the Problem: Despite significant advancements in cardiovascular imaging, modeling, and intervention, current clinical approaches still fall short in delivering truly individualized care. A growing body of evidence suggests that personalized simulation environments—known as digital twins—can bridge this gap by providing patient-specific insights into cardiovascular physiology, risk stratification, and procedural outcomes. However, the full translational potential of digital twins remains underexplored in cardiology.

Methodology & Theoretical Orientation : This review synthesizes current literature on the core technologies, applications, and implementation challenges of digital twins in cardiovascular medicine. The discussion is structured around physics-based computational modeling, AI-driven data assimilation from biosensors and EHRs, and current clinical programs exploring digital twin paradigms. Regulatory and ethical dimensions are also addressed through the lens of emerging guidance from the FDA and EMA .

Findings : Digital twins have shown early promise in multiple domains: procedural planning for transcatheter valve implantation, non-invasive coronary physiology modeling (e.g., FFR-CT), simulation of ablation strategies in arrhythmia management, and individualized device programming for heart failure . Yet, their adoption is hindered by model calibration limitations, lack of validation frameworks, and the absence of interoperable platforms capable of real-time simulation. Ethical concerns regarding digital identity and algorithmic opacity also remain key barriers to clinical integration.

Conclusion & Significance: Digital twins represent a paradigm shift toward computationally enabled precision cardiology. By replicating the patient's physiological profile in silico, clinicians may gain unprecedented predictive power and therapeutic foresight. As interdisciplinary collaborations and regulatory frameworks mature, digital twins could become central to future cardiovascular care pathways, especially in structural interventions and device-based therapies .

Biography

Mehdi Ayoub Laaroussi, 25, is a cardiology resident at CHU Ibn Sina in Rabat. His academic focus includes ischemic heart disease, coronary microcirculation, and post-infarction remodeling. He is actively engaged in clinical research on microvascular injury after STEMI and aims to bridge translational cardiology with daily practice.

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