TITLE: Redefining the Fiber Architecture: A Breakthrough in Atrial Digital Twin Modeling

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ABSTRACT:

A crucial aspect of developing atrial digital twins (ADT)—virtual models of patients' atria—is the precise assignment of myocardial fibers, which play a key role in tissue characterization. However, reconstructing atrial fibers from medical imaging remains challenging. As a result, mathematical models are commonly employed for fiber generation in ADT. Current methodologies rely on semi-automatic techniques, are designed for specific atrial morphologies, and lack thorough validation against imaging-derived fiber data. In this study, we present a novel atrial rule-based method that enables highly detailed myofiber orientation mapping and robust regional annotation across bi-atrial geometries of varying complexity. We evaluate the method on eight high-resolution bi-atrial geometries reconstructed from a sub-millimeter Diffusion-Tensor-Magnetic-Resonance Imaging (DTMRI) dataset of human atrial fibers. Validation is performed by quantitatively reproducing the fiber architectures observed in DTMRI, with a detailed comparison against ground truth data. Additionally, we analyze electrophysiology (EP) simulations using both rule-based and DTMRI fibers to assess differences in electrical behavior. Our results demonstrate that our method surpasses current state-of-the-art fiber modeling aprroach, highlighting its superior accuracy. This underscores the importance of incorporating highly detailed fiber orientations in EP simulations. This work represents a significant advancement in the development of physics-based atrial digital twins, setting a new standard for fiber prescription in ADT.

REFERENCE:

[1] R. Piersanti, R. Bradley, S.Y. Ali, A. Quarteroni, L. Dede' and N.A. Trayanova. Defining myocardial fiber bundle architecture in atrial digital twins, Computers in Biology and Medicine 188, 109774 (2025).