Beyond Transmembrane Potential: Why Volumetric Source Imaging Is Less Sensitive to Intracellular Uncertainty

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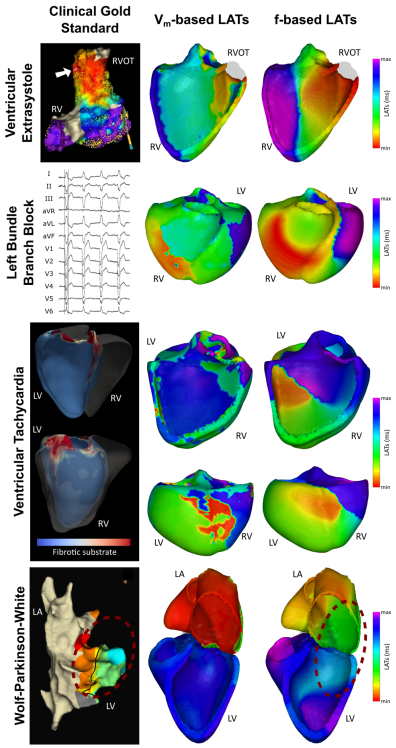
Introduction: Volumetric ECGI methods typically reconstruct transmembrane potential (V_m), whose governing equation is explicitly coupled to the intracellular conductivity tensor. This makes reconstruction accuracy dependent on precise knowledge of myocardial fiber orientation and intracellular conductivity, quantities that are highly uncertain in clinical practice.

Methodology: We propose Volumetric Source Imaging (VSI), which directly estimates cardiac sources, decoupling the inverse solution from intracellular anisotropy. Robustness was evaluated via a stress test on 10 simulated ventricular ectopic beats, systematically perturbing fiber angles (0°–90°) and intracellular conductivities (up to 100% noise). Clinical applicability was demonstrated in four patients with distinct arrhythmic conditions.

Results: Under increasing structural perturbations, V_m-based LAT accuracy degraded (CC from 0.66 ± 0.09 to 0.60 ± 0.07; MAE increase $\approx 1.5ms \pm 0.4ms$), whereas VSI maintained a flat, stable error profile (CC=0.86 ± 0.04; MAE=$0.24 \pm 0.08ms$). In clinical cases, VSI mitigated spatial smearing and artifactual conduction blocks, providing activation maps concordant with invasive references.

Conclusions: VSI provides robust volumetric cardiac mapping without requiring patient-specific intracellular data, offering a clinically viable alternative for pre-procedural planning and targeted ablation therapy.



Clinical translation in four distinct scenarios. For each case, 3D LAT maps obtained via Transmembrane Potential (V_m) and Cardiac Source (f) are compared against the clinical gold standard.