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Numerical modelling of the electrical activity of the atria and the pulmonary veins.

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INTRODUCTION : NUMERICAL MODELLING FRAMEWORK

Pre-processing
Parameters setting

Numerical model

Post-processing
Medical or biological insight

Monodomain :

$$\underbrace{\alpha(C_m \partial_t V + I_{ion}(V))}_{\text{electrophy.}} + \underbrace{\text{div} D \nabla V}_{\text{coupling}} = \underbrace{I_{app}}_{\text{stim}}$$

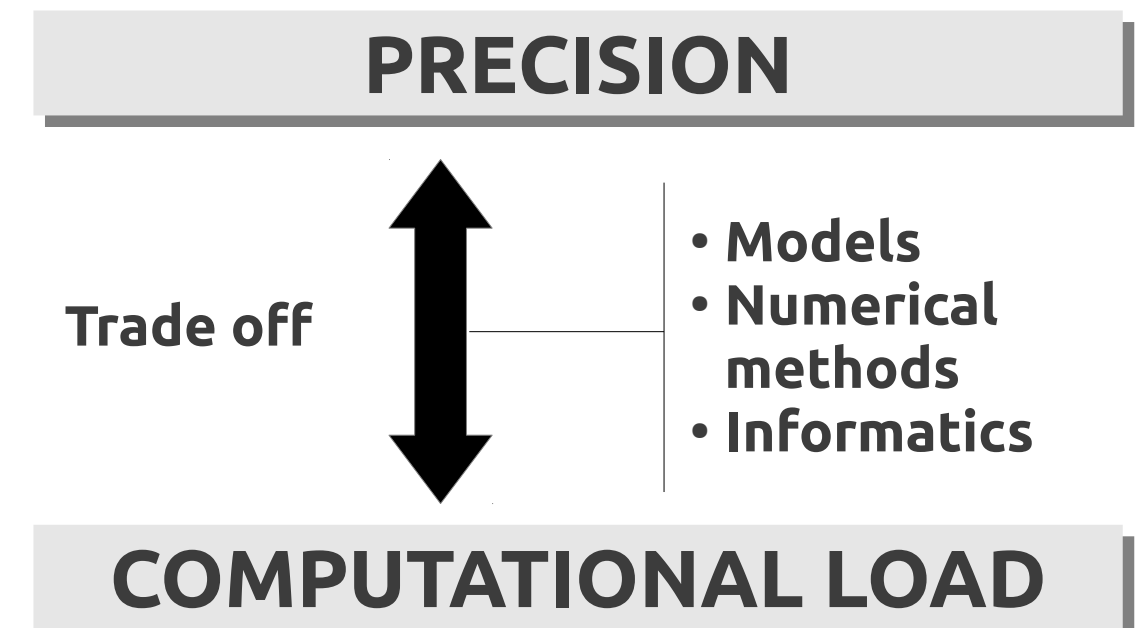
INPUTS

- Electrophysiology : ionic models
- Tissue anisotropy and coupling
- Anatomy : IRM, fibres.
- Stimulation : SAN, trigger, electrode...

OUTPUTS

- Potential maps : V_m, Φ_i, Φ_e .
- Electrophysiological insights : EGM / ECG PA, $\partial V / \partial t_{max}$ Ionic currents
- ...

TRADE OFF

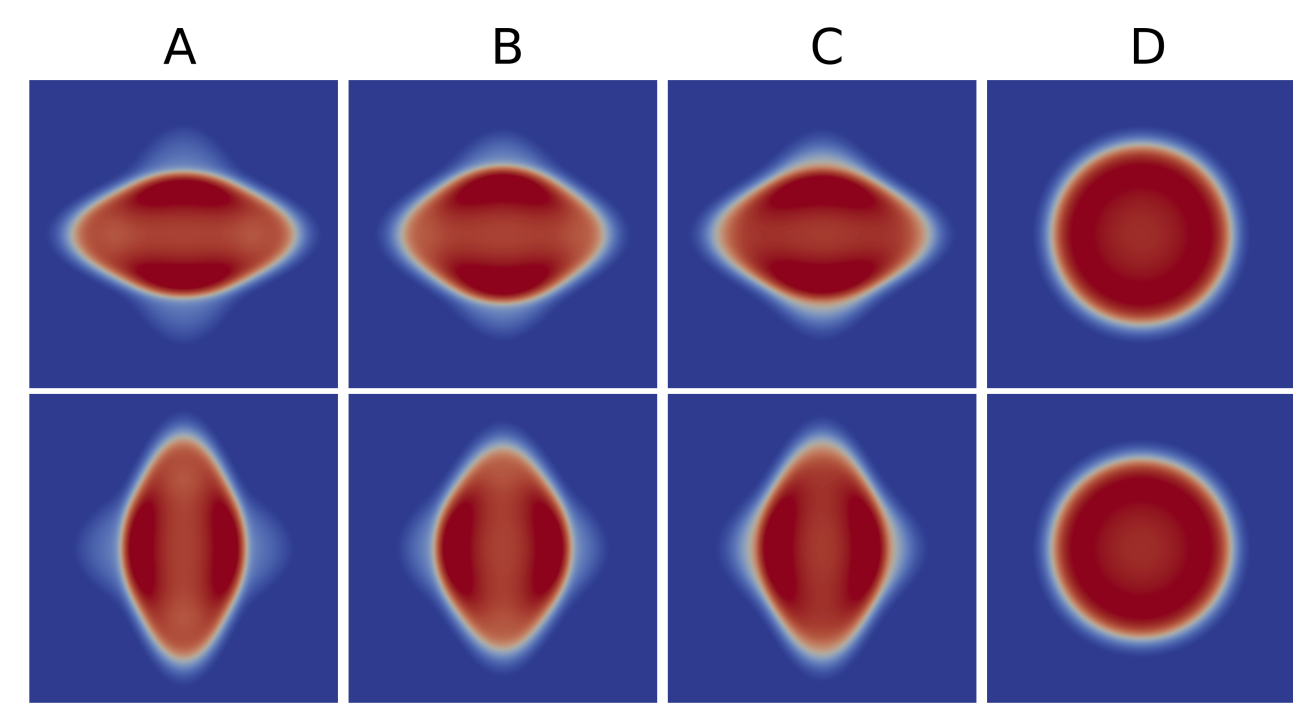
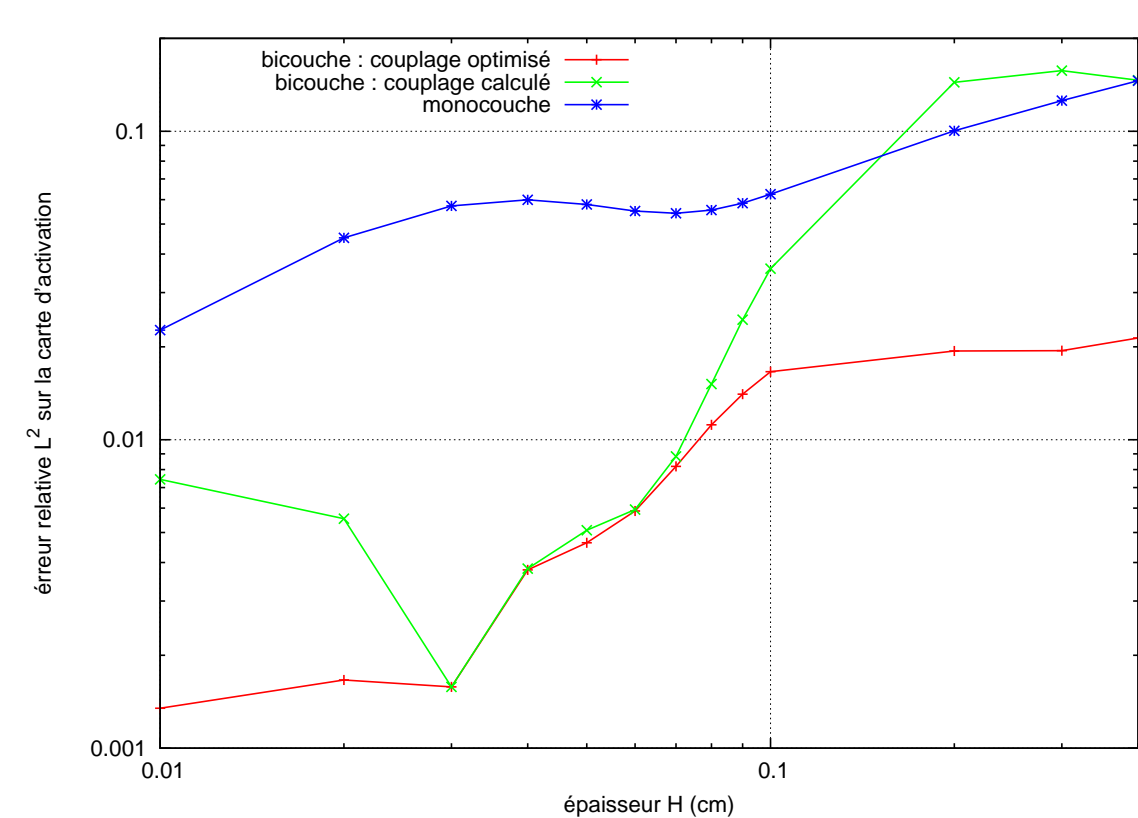


DERIVATION OF MATHEMATICAL MODELS

BILAYER SURFACE MODEL

- Three-dimensional behaviours for 2D computational load.
- Asymptotic analysis \Rightarrow Second order convergence.

$$\underbrace{\alpha(C_m \partial_t V_k + I_{ion}(V_k))}_{\text{electrophy.}} - \underbrace{\text{div} D \nabla V_k}_{\text{coupling}} + \underbrace{(-1)^k \tilde{\sigma} \frac{V_2 - V_1}{h^2}}_{\text{coupling}} = \underbrace{I_{app}}_{\text{stim}}$$



HOMOGENIZATION WITH GAP JUNCTIONS NON LINEAR DYNAMICS

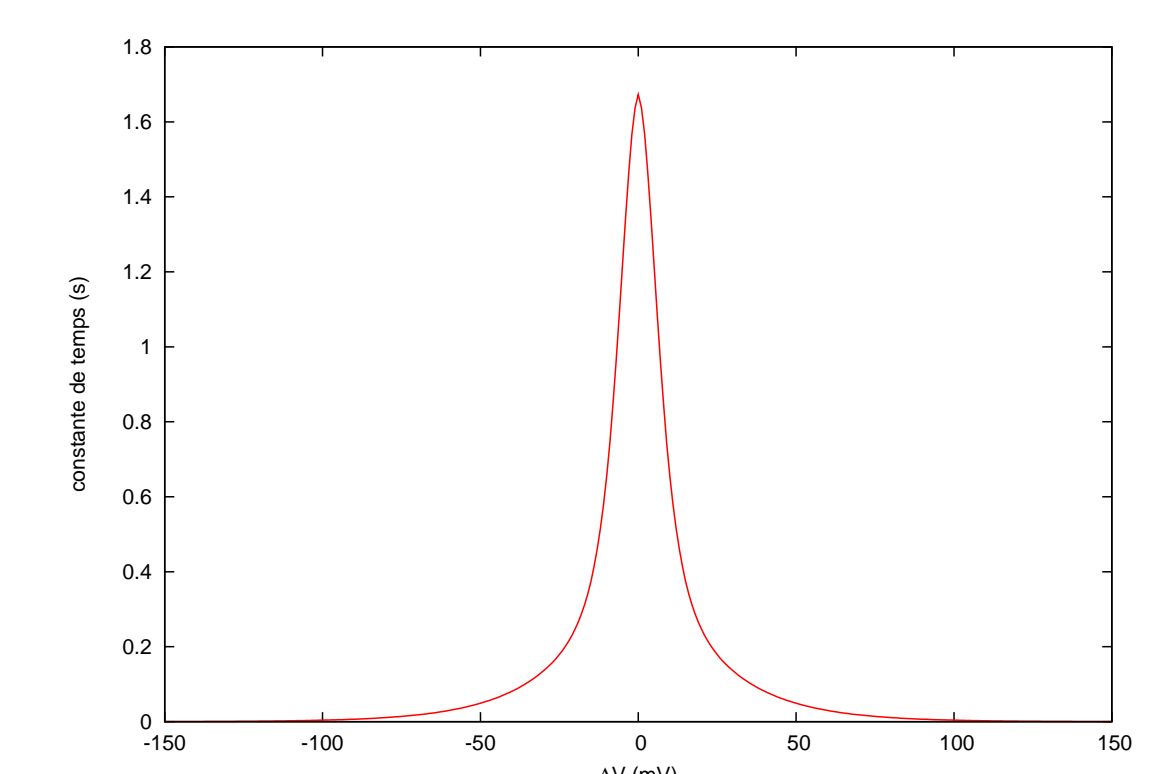
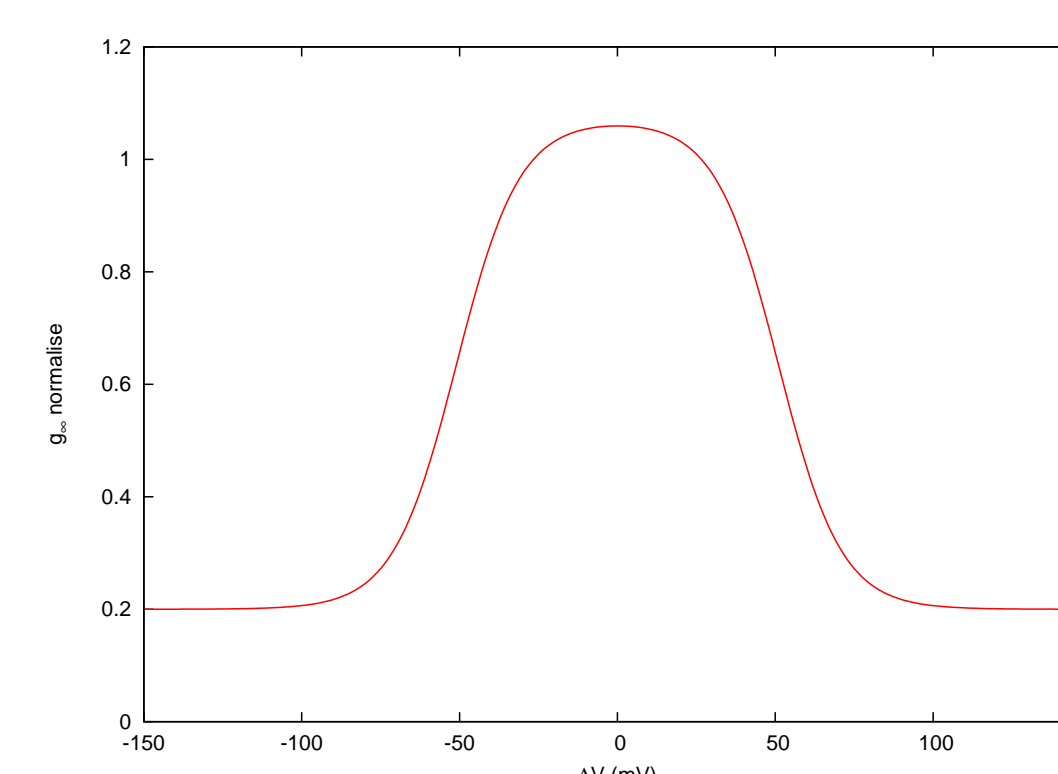
- GJ conductance:

$$G_{GJ} = G_{max} w_0$$

$$\partial_t w_0 = \frac{w_\infty(V) - w_0}{\tau(V)}$$

$$\beta(C_m \partial_t \phi_0 + I_{ion}(\phi_0)) - \partial_x(\tilde{\sigma}(w_0) \partial_x \phi_0) = 0$$

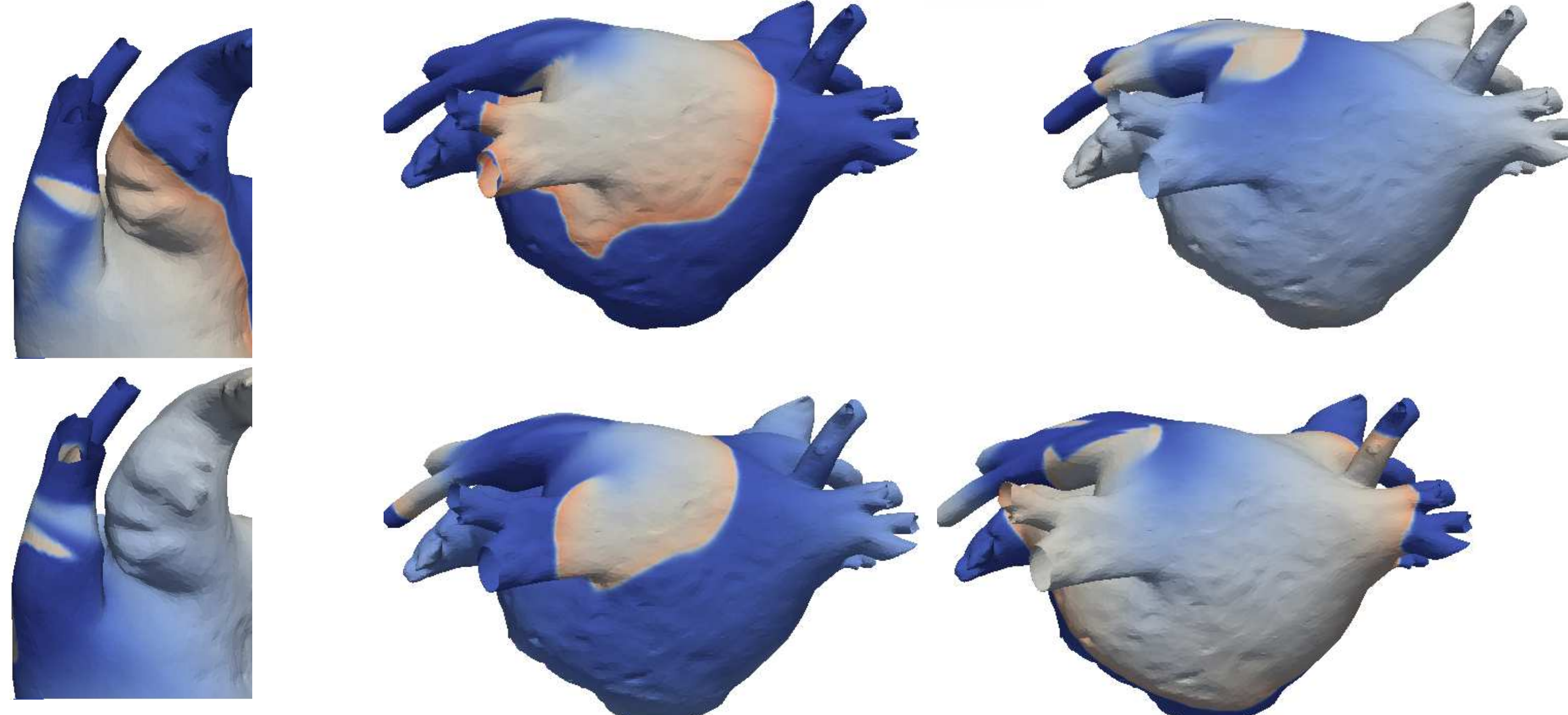
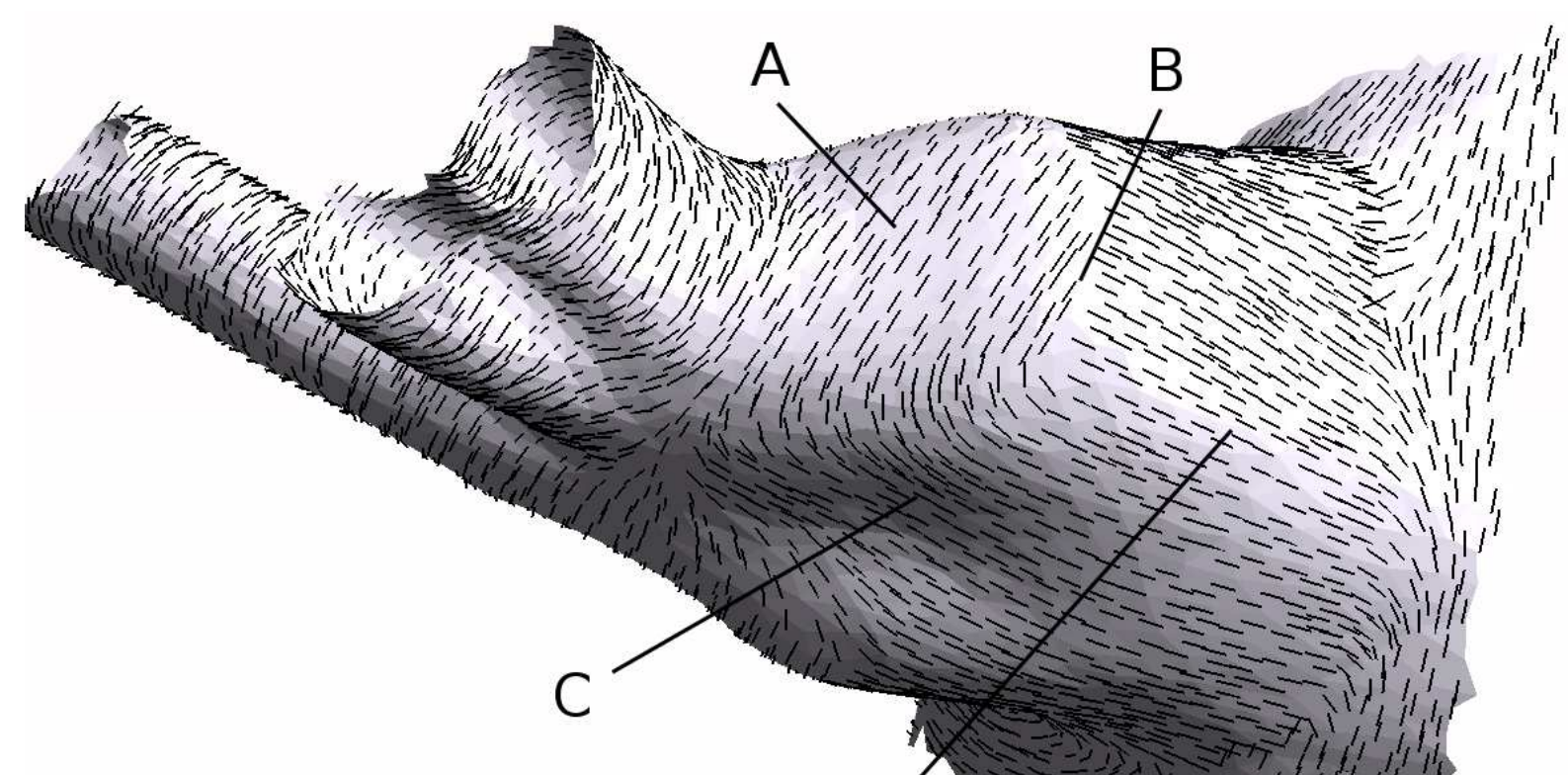
$$\partial_t w_0 + H(\mu(1 - \tilde{\sigma}(w_0)) \partial_x \phi_0, w_0) = 0$$



ARRHYTHMIA TRIGGERS IN THE PV

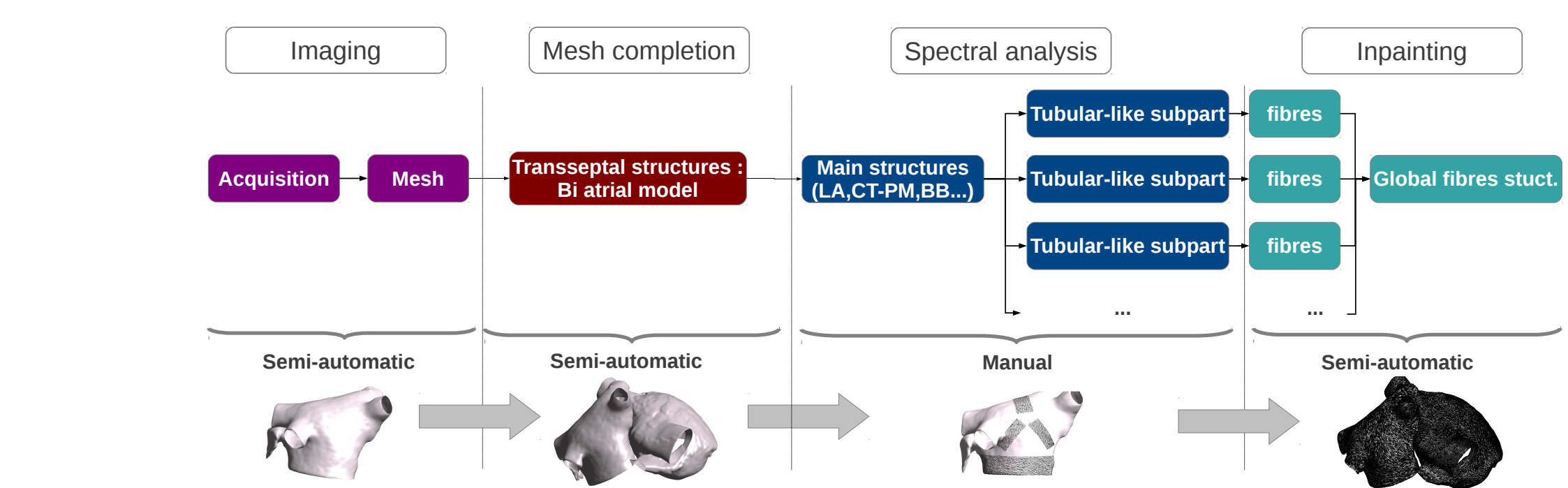
FIBRES DISCONTINUITY

- Bloc in LSPV
- Micro reentry in LSPV \Rightarrow Macro reentry in LA.

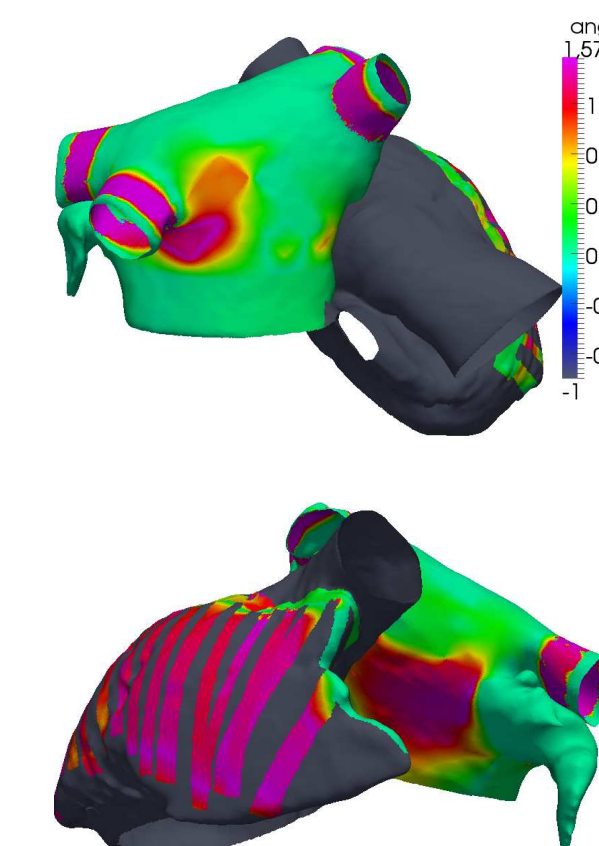


ARRHYTHMIA PERPETUATION IN THE ATRIA

BIATRIAL BILAYER MODEL OF HUMAN ATRIA



Angle differences

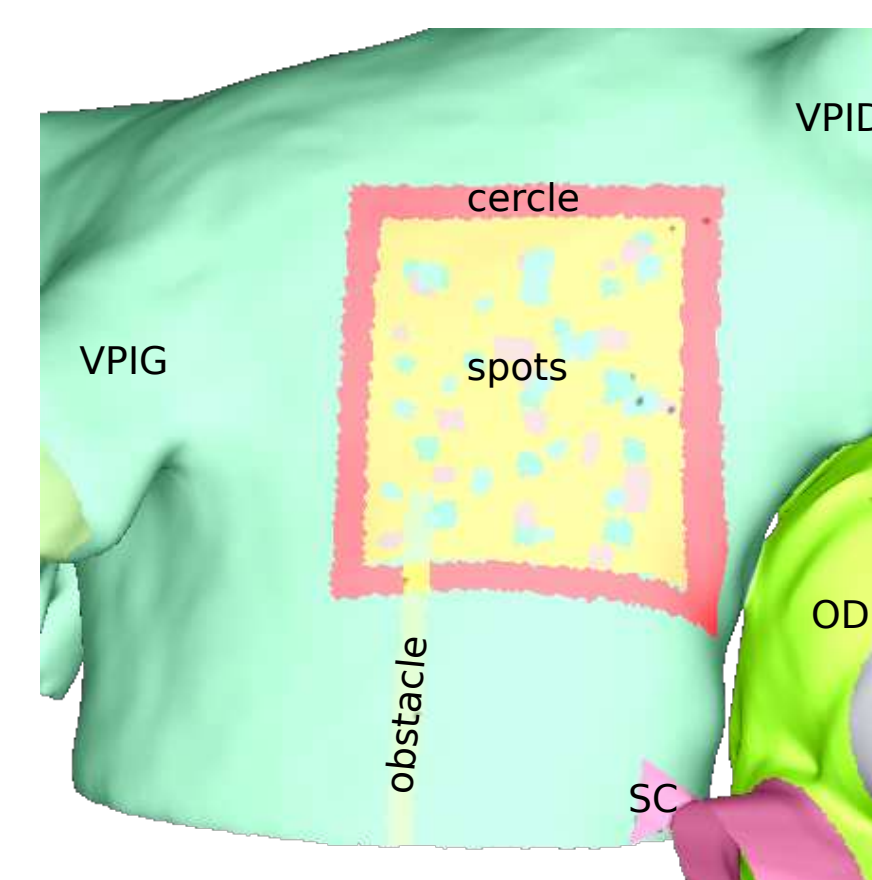


Activation times differences



Mono. vs. bilayer Endo vs epi

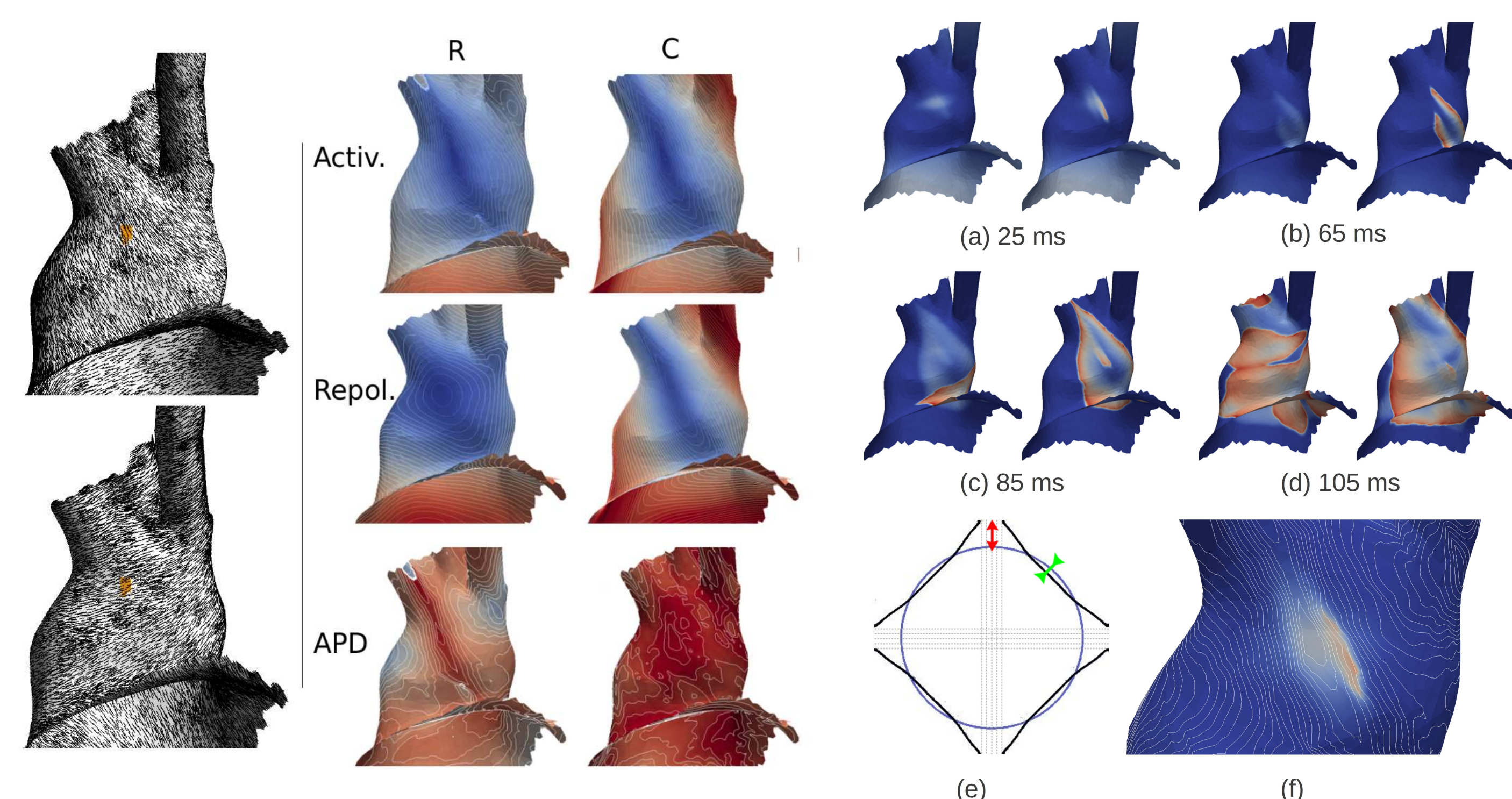
EFFECT OF TRANSMURAL FIBROSIS AND ABLATION.



- Transmurular fibrosis \Rightarrow Stabilization effect on a macro-reentry.
- Ablation protocol. Most efficient: surrounding line or line bloc to the closest natural obstacle. Less efficient: ablation spots.
- Non transmurular ablation are still efficient.

TRANSMURAL FIBRES DISCONTINUITY

Different dynamics during depolarization and repolarization \Rightarrow APD gradient \Rightarrow functional substrate of arrhythmia.



PERSONALIZATION

