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To cite this version:
Oumayma Bouhamama, Mark Potse, Rémi Dubois, Laura Bear, Lisl Weynants. A Patchwork Inverse Method in Combination with the Activation Time Gradient to Detect Regions of Slow Conduction in Sinus Rhythm. CinC 2020 - Computing in Cardiology, Sep 2020, Rimini / Virtual, Italy. hal-02945604

HAL Id: hal-02945604
https://hal.archives-ouvertes.fr/hal-02945604
Submitted on 22 Sep 2020

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A Patchwork Inverse Method in Combination with the Activation Time Gradient to Detect Regions of Slow Conduction in Sinus Rhythm

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Context
▶ Introduction: Noninvasive electrocardiographic imaging (ECGI) reconstructs epicardial electrical activity from potential measurements on the torso surface.
▶ Issue
▷ ECGI methods are known to produce artificial lines of block in healthy tissue
▷ Unclear if ECGI can detect regions of slow conduction in damaged hearts
▶ Purpose
▷ Develop a method to locate the regions of slowed conduction with ECGI
▷ Use this method to evaluate the ability of both classic ECGI methods and a new Patchwork Method, to detect these areas

Patchwork Method
Automatic selection of the optimal solution among several methods (FEM, MFS, BEM) to solve:

\[ Au^h = u^T, \]

A: the transfer matrix, \( u^h \): unknown cardiac sources and \( u^T \) the torso measurements.

Algorithm:
▶ For each time step \( n \):
▷ Compute the approximate solutions \( u^h_{n,F} \) and \( u^h_{n,M} \) with the FEM and the MFS,
▷ Use these solutions to compute the forward solution and the associated residuals \( R_B(\mathbf{u}_{n,F}^h) \) and \( R_B(\mathbf{u}_{n,M}^h) \) on the torso surface using the BEM formulation,
▷ For each epicardial point, select the method whose residual is the smallest on the nearest torso point
▷ Define \( \alpha_n = 0 \) if the MFS has the smallest residual, and 1 otherwise,
▶ For each time step \( n \), compute the new approximate solution as:

\[ u^h_n = \alpha_n u^h_{n,F} + (1 - \alpha_n) u^h_{n,M}. \]

Activation Time Gradient
▶ An activation time gradient was used to locate regions of tissue damage, with large gradient values corresponding to slow conduction zones
▶ Compute the absolute difference in activation time between the current node \( i \) and the nearest neighboring nodes.
▶ Five different methods were evaluated to define a single gradient value: maximum, minimum, mean, nearest neighbor and random.

Data
A set of 8 simulations was used, including 7 with tissue damage.

Results
Figure 1: Recorded activation time (a) and gradient maps (b–f) calculated with different methods in a case with no tissue damage

Figure 2: Recorded activation time and gradient maps calculated with different methods in one case with a damaged zone indicated by a black circle

Figure 3: Reconstructed (MFS, FEM and PM) gradient maps calculated with the max and mean methods in the case of no tissue damage

Figure 4: Reconstructed (MFS, FEM and PM) gradient maps calculated with the max and mean methods in a case of tissue damage in the zone indicated by the black circles zone indicated by a black circle

Conclusion
▶ PM method succeeded in locating 5 of the 6 slow conduction zones recorded,
▶ MFS and FEM reconstructions did not locate any damaged zones.
▶ PM overcomes some of the restrictions of current numerical methods, demonstrating its abilities in detecting slowed conduction zones.

References