Novel approaches and "similarity score" for the identification of active sites during patient-specific catheter ablation of atrial fibrillation

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Abstract. Atrial fibrillation (AF) is the most common cardiac arrhythmia and precursor to cardiac diseases. Catheter AF ablation is associated with limited success rates, and existing mapping systems fail to identify target sites for ablation. We evaluated the performance of frequency-, information-, and statistical-based approaches to identify the AF drivers using unipolar and bipolar electrograms (EGMs) obtained from numerical simulations under different clinical scenarios. We also developed a "similarity score" to more accurately identify the spatial location of active sites of arrhythmia in patients with AF. Results from numerical simulations demonstrate that all approaches are able to accurately identify AF drivers from EGMs for clinical catheters. "Similarity score" pinpoints the spatial sites with high values that were observed only in patients with unsuccessful AF termination, suggesting that these active AF sites were missed during the ablation procedure.

Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia and precursor to other cardiac diseases. Catheter ablation is associated with limited success rates in patients with persistent AF. Currently, existing mapping systems fail to identify critical target sites for ablation. Recently, we proposed and validated several individual techniques, such as dominant frequency (DF), multiscale frequency (MSF), kurtosis (Kt), and multiscale entropy (MSE), to identify active sites of arrhythmias using simulated intracardiac electrograms (iEGMs). However, the individual performances of these techniques to identify arrhythmogenic substrates are not reliable.

In this study, we aimed to develop a similarity score by combining the various iEGM analysis approaches based on an earth mover's distance (EMD) method. We further demonstrated that this similarity score can identify active spatial sites of AF in patients with unsuccessful AF termination, while no active sites of AF were present in patients with successful AF termination. Clinical bipolar iEGMs were obtained from patients with AF who underwent either successful (m = 4) or unsuccessful (m = 4) catheter ablation. A similarity score (0–3) was developed via the EMD approach based on a combination of DF, MSF, MSE, and Kt techniques.

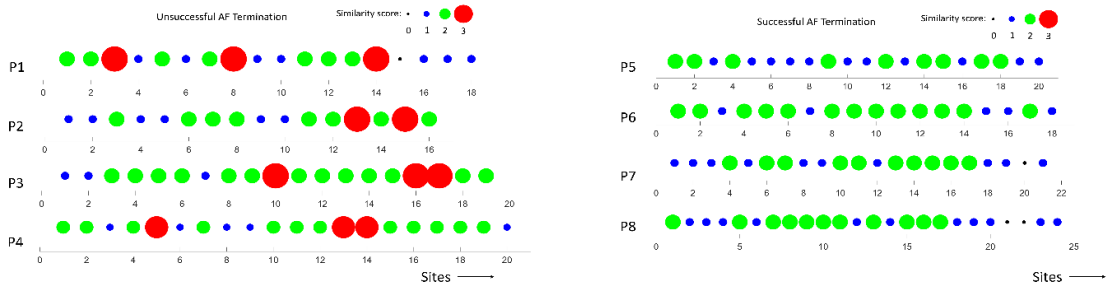

Figure 1: Similarity scores calculated at different spatial sites in patients with unsuccessful (**left**) and successful (**right**) AF termination. Note the presence potentially active AF sites with a high similarity score (3, red) in all patients with unsuccessful AF termination.

Results and Discussion

In this retrospective study, we investigated the performance of individual EGM analysis approaches (DF, MSF, Kt, and MSE) and newly developed similarity scores to identify potential, abnormal, electrically active sites in patients with previously unsuccessful AF termination. The major findings of this study are as follows: (1) individual approaches can discriminate between patients with successful and unsuccessful AF termination but fail to robustly identify spatial sites with active AF drivers, (2) a novel EMD-based similarity score was developed and validated to identify the active AF sites in patients with unsuccessful AF termination, and (3) there was no single common region in the atria associated with active AF sites in patients with unsuccessful AF termination, thus indicating the need for patient-specific mapping and ablation therapy.