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VENTRICULAR PACING DEPTH LOCALIZATION BASED ON EPICARDIAL ACTIVATION MAPS

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Premature ventricular contractions (PVCs) are a heart rhythm abnormality that leads to poorly synchronized contraction and impaired blood flow. PVCs are commonly treated with radiofrequency ablation (RF) to heat and destroy the small regions of tissue causing the irregularity. There are two distinct approaches to access the heart for RF ablation. Approach one is used if the PVC is located towards the epicardium, or outer heart surface; a small incision is made in the chest wall, and a steerable catheter is inserted to direct an ablation catheter to the believed site of origination of the PVC. Approach two is used if the PVC is located towards the endocardium, or the inner wall of the heart; catheter access is simpler via the femoral vein to the heart chambers and the PVC site. The choice of approach can be ambiguous due to the limited accuracy of current clinical PVC localization techniques, particularly the depth within the ventricular wall. This ambiguity increases procedure time and patient risk, and limits the success of the treatment. The long term goal for this project is to improve non-invasive PVC localization by creating a metric based on body-surface ECGs that will determine the depth of a PVC, specifically epicardial versus endocardial. As a first step, in this study we created an algorithm and a candidate metric from measured epicardial potentials validated from known PVC sites.

Our novel localization metric is based on epicardial activation time maps, which measure the amount of time taken at each location to detect a propagating electrical wave. Depending on the location of a PVC's origination site, activation time maps have distinct, oriented patterns. The oriented patterns develop on a region of the epicardial surface immediately radial from the activation site. The localization algorithm estimates the depth of a PVC by calculating the orientation of the developed pattern. The first step is to determine which electrodes have been activated during the first 15% of the activation duration and project the selected electrodes onto a plane. Next, we fit a line to the activated electrodes and determine its angle relative to a local horizontal axis on the heart; we found that this angle predicts the depth of the PVC. To test the novel PVC localization technique, we stimulated PVCs in the left ventricular free wall of an open chest animal experiment. The sites of origin of the PVCs lay at nine known, regular intervals along an electrode array that is introduced in the heart. From each experimental recording, five representative beats were extracted and epicardial activation time maps were computed from epicardial potentials measured simultaneously using a 247-lead epicardial sock.

Our algorithm was able to calculate the angle of the orientated pattern for each stimulation site. Overall, the general trend was as follows; as the depth of a PVC becomes more superficial, the angle of the developed pattern rotates in a clockwise direction, mimicking the known rotation of underlying myocardial muscle fibers. By calibrating the depth of stimulation with activation orientation, we will be able to predict the unknown depth of a PVC from the epicardial surface. Future work will test the hypothesis that a similar pattern is detectable from the torso surface, thus resulting in a noninvasive approach to determine the location and depth of a PVC.