Correlation and Visualization of Left Atrial Scar due to Pulmonary Vein Ablation with Recorded Ablation Sites

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Introduction: Radio frequency (RF) pulmonary vein (PV) ablation is an increasingly popular therapy for atrial fibrillation (AF). One endpoint of RF ablation is complete electrical block between the left atrium (LA) and the pulmonary veins. The success rate in eliminating AF with this procedure is 60 to 85%. The CARTO system (Biosense, Webster) can be used to create electroanatomic mapping (EAM) data of the surface of the LA and PVs during the procedure, and the CARTOMERGE software package registers this data to previously acquired CT or MRI images for use as a guide during the ablation procedure. After the procedure, the scar generated by RF ablation[1] can be imaged using high spatial resolution late gadolinium enhancement (LGE) cardiovascular MR (CMR)[2]. In order to understand the relationship between the sites of RF application and the scar pattern that results, we sought to develop a technique to fuse and visualize the EAM data with the scar data from the LGE scan.

Methods: MR angiograms and LGE images of the LA, obtained 30-60 days post ablation on a 1.5 T Philips Achieva scanner, were registered with EAM data in 8 subjects with atrial fibrillation. Scarred regions in the LGE images were identified and segmented with a visually determined threshold. Single high intensity pixels were removed by dilation and erosion filters, and a rigid landmark transform was performed to register the segmented LGE images to the angiogram.[3] The angiograms are then manually segmented to remove the aorta and the pulmonary arteries using MIPAV[4], since these structures obscure the visualization of the scar on the surface of the left atrium, and also reduce the quality of the registration of the angiogram to the EAM (CARTO) surface. We have developed a software tool using Kitware's Visual Toolkit (VTK 5.0.3) and Insight Segmentation and Registration Toolkit (ITK 3.4.0) to register and display the data. Surfaces are extracted from the segmented LGE and MR angiogram using an implementation of the marching cubes algorithm in VTK.[5] The recorded sites of RF application and LA surface points were fused with the MR angiogram surface using a landmark rigid registration followed by the iterative closest point algorithm, as previously described.[6]

Results: Qualitative comparisons of this software tool to the commercially available CARTOMERGE suggest that the registration is reasonable, showing similar placement of recorded ablation locations around the pulmonary veins, and on the LA wall [Figure 1]. When the EAM data is applied to a surface with rendered LGE scar, there is also a qualitatively reasonable agreement between the scar and intended ablation sites [Figure 2].

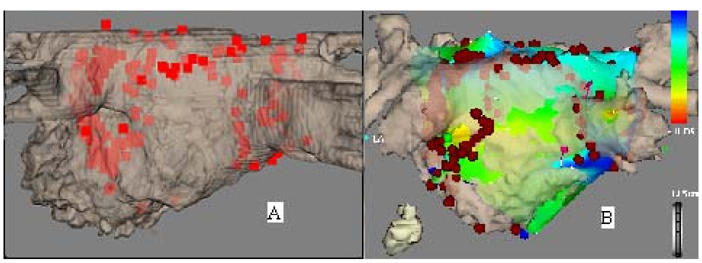

Figure 1: (A) Software tool developed with VTK/ITK, with RF application site EAM data displayed in red.
(B) Commercially available CARTOMERGE for same patient. Surface created from EAM data (as indicated in scale to the top right) not represented in (A)

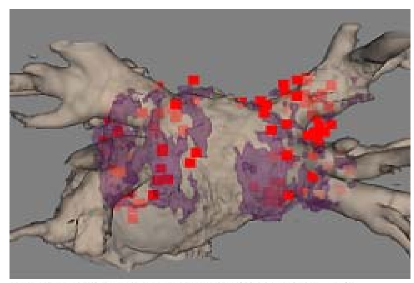

Figure 2: RF application site EAM data registered with the post RF ablation scar and MR angiogram surfaces

Discussions and Conclusions: The fusion between EAM and MRA achieved by our software tool is visually reasonable when compared to the vendor provided CARTOMERGE software. In fusing LGE data with the MR angiogram and rendering both with the EAM data, we create a tool to visualize the correspondence between each scarred region as measured by MR, and the sites of RF application as recorded by CARTO. This tool can be used help to understand why some cases experience recurrent AF, and why a repeat ablation procedure is sometimes required for success. Future work will focus on providing quantitative values for agreement between the EAM data and MRA and LGE scar data, and relate clinical success of the ablation procedure to the extent of agreement between scarred locations and CARTO ablation locations.

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