Registration 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 important therapy for atrial fibrillation (AF). The success rate in eliminating AF with this procedure is 60 to 85%, which although higher than medical therapy, is still too low. 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. The most important electrophysiological (EP) endpoint of RF ablation is complete electrical block between the left atrium (LA) and the pulmonary veins. However, the EP clinicians also rely on CARTO to display the anatomic completeness of the ablations around each vein. After the procedure, the scar generated by RF ablation[1] can be imaged using high spatial resolution late gadolinium enhancement (LGE) [2] cardiovascular MR (CMR). Our group and others[3,4] have shown that these scar patterns have meaning, because their location and extent are correlated with recurrence. A further question is whether there are preferential sites of intended RF application where no scar can be observed, thereby providing an inaccurate portrayal of the ablation pattern. In order to understand the relationship between the sites of RF application and the scar pattern that results, we have developed a technique to fuse and visualize the EAM data with the scar data from the LGE scan.[3] Here we report on an extension of this work to a larger patient study with quantitative methods.

Methods: MR angiograms and LGE images of the LA scar, obtained 30-60 days post ablation on a 1.5 T Philips Achieva scanner, were registered with EAM data in 19 subjects (20 data sets counting one repeat) with AF. LGE scar was displayed in 3D, overlaid on the registered MR angiogram to provide anatomical context, as previously described[3,5]. 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.[4] The software tool used Kitware's Visual Toolkit (VTK 5.0.3) and Insight Segmentation and Registration Toolkit (ITK 3.4.0) to register and display the data, and measure several distance metrics. The distance metrics include the mean integration error between the CARTO surface and the MRA surface (to describe the registration), the distance between CARTO ablation points and the LGE scar surface (to describe the effectiveness of the ablation attempts), the distance between the LGE scar and the MRA surface (to describe the registration between the scar and the MRA), and the distance between each point on the LGE surface and the nearest ablation point (somewhat descriptive of scar lesion size).

Results: Table 1 lists the average distance ± standard deviation for each of the metrics, comparing patients with and without recurrent AF.

	CARTO surface to MRA (mm)	CARTO to LGE (mm)	LGE to MRA (mm)	LGE to CARTO (mm)
Average (N=20)	2.65±0.46	3.86±1.26	3.25±1.13	7.82±3.58
Average, N=11 (no Recurrent AF)	2.51±0.38	3.56±0.99	3.17±1.25	8.48±4.62
Average, N=9 (Recurrent AF)	2.83±0.50	4.22±1.51	3.35±1.02	7.02±1.59

Table 1: Table of measured distance metrics; Mean Integration Error (MIE) between CARTO surface points and the MRA surface, CARTO Ablation points to the nearest LGE scar surface point, the MIE between the LGE scar to the MRA surface, and the average distance between each point on the surface of the LGE scar to the nearest CARTO ablation point. Data presented in terms of mm ± standard deviation, for success, failure, and all cases.
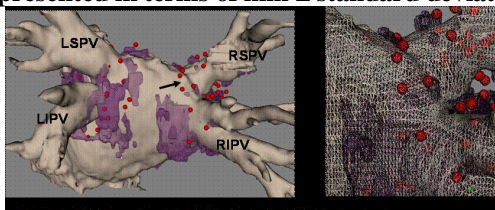

Figure 1 displays the registration, demonstrating a region of CARTO/LGE mismatch.

Discussions and Conclusions: Our registration provides a mean integration error of 2.65 mm, with patients with and without recurrent AF exhibiting similar registration accuracies. The distance from CARTO ablation points to LGE scar is larger in studies of patients with recurrent AF, vs. non-recurrent AF. The distance from LGE scar to nearest CARTO ablation, which is a measure of average lesion size, is smaller in studies of patients with recurrent AF vs. non-recurrent AF. A smaller lesion size could indicate possible poorer contact during ablation. None of the differences were statistically significant.

[1] Peters DC, et al. Radiology 2007;243(3):690-695

[2] Kim RJ, et al. Circulation 1999;100(19):1992-2002

[3] Taclas JE et al., ISMRM 2008 2100.

[4] Malchano ZJ et al. J Cardiovasc Electrophysiol 2006;17(11):1221-1229.