Rapid automatic segmentation of enhanced tissue in LGE MRI of long-standing persistent atrial fibrillation

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Introduction: Atrial fibrillation (AF) is the most common heart rhythm disorder. In order for Late Gd enhancement magnetic resonance imaging (LGE MRI) to ameliorate the AF management, the ready availability of the accurate enhancement segmentation is required. However, the computer-aided segmentation of enhanced tissue in LGE MRI of AF is still an open question.[1] On top of this, the number of centres that have reported successful application of LGE MRI to guide clinical AF strategies remains low, while the debate on LGE MRI's diagnostic ability for AF still holds.[2]

Objective: This study seeks to propose a robust -though simple- automatic technique to consistently segment enhanced tissue within the left atrial (LA) wall of LGE MRI datasets from AF patients studied at our centre. A visual perception assessment of the proposed segmentation technique is provided. We juxtapose segmentation results against the unique endocardial bipolar voltage map that was available for one patient of this study. We test the hypothesis that our enhancement segmentation technique can recreate the (aimed) ablation lesions in a faithful way. We look into how our technique fares against other related approaches of the literature.

Methods: 13 patients presented to our centre with long-standing persistent (LSP) drug-refractory AF, and were treated with first-time ablation. MRI: Whole-heart navigator-gated 3D inversion-prepared segmented gradient echo imaging[3] (32–36 slices, 1.5x1.5x4mm, reconstructed to 64–72 slices, 0.7x0.7x2mm) was performed (both pre-procedurally and at 3 months post-ablation) on a Siemens 1.5T Avanto 15 mins after Gd administration. Data was acquired on every cardiac cycle with a nominal acquisition duration of 144–160 cardiac cycles (assuming 100% respiratory efficiency). The diagnostic quality of the images was confirmed by an expert in cardiac MRI. Ablation: Either thoracoscopic or percutaneous ablation was delivered. The latter was implemented in a stepwise lesion set fashion: 1) antral PV isolation; 2) linear ablation at the LA roof and mitral isthmus; and 3) ablation of the LA complex fractionated electrograms. Segmentation Method: Intensity I at each voxel i of the manually segmented LA wall was normalized as $NI(i)=[I(i)-\mu_{bp}]/\sigma_{bp}$ where μ_{bp} and σ_{bp} are the mean and standard deviation of the signal intensity distribution of the voxels that constitute the LA blood-pool (reference region). Cut-off levels of the normalized intensity were identified through experimentation and validation by experts. The selected thresholds were T_{PRE} = 1 1/4 for pre-ablation datasets and T_{POST} = 1 5/8 for datasets acquired at 3 months post-ablation.

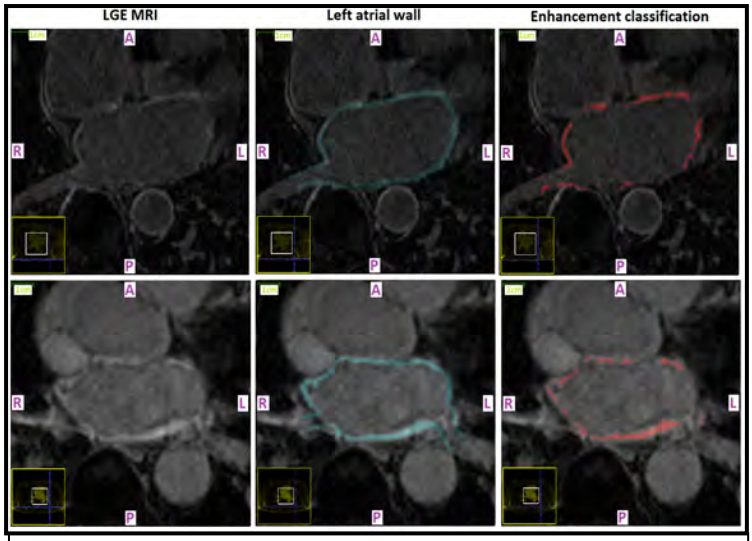

Fig.1 Baseline (top) and 3 months post-ablation (bottom) enhancement segmentation in two different random LSPAF patients. Left: Original data. Middle: LA walls. Right: Overlaid results.

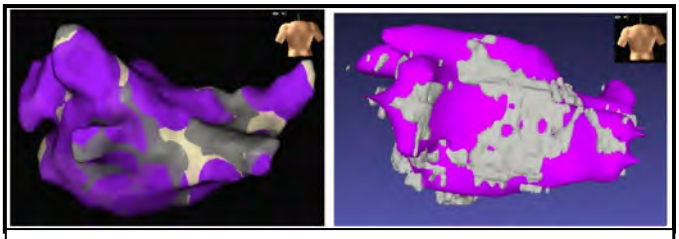

Fig.2 3D back view of LA wall tissue classified as "pre-existent fibrosis" (right –in gray, obtained from a baseline MRI) and the registered endocardial bipolar voltage map (left –measured with a NavX system: low voltage is showing in gray, healthy LA wall tissue is in purple).

Results: Proposed thresholds resulted in segmentations that are in good concordance with visual perception for both baseline and 3 months post-ablation datasets (Fig.1). Our technique produced accurate enhancement estimates regardless mean enhancement intensity, image contrast and background noise of each dataset. Mean measured relative extent of native fibrosis was 26.07 ± 9.03 %, which falls within the expected range for the studied arrhythmia phenotype.[4] MRI map compares well with the corresponding voltage map (Fig.2). The suggested method's capacity for reflecting ablation lesion patterns was typically revealed (Fig.3). Threshold levels proposed in other related studies[5,6] (that relied on the same reference region) led to gross underestimations of enhancement in our datasets (Fig.4).

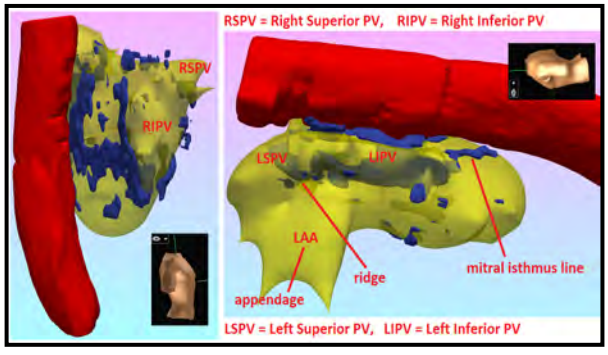

Fig.3 Classified enhancement distribution (in blue –obtained from a 3 months post-ablation dataset) comprised encirclement of each ipsilateral pair of PVs at their antra, as well as a mitral isthmus linear pattern, as expected by the respective ablation

Conclusions: We proposed a rapid, self-regulated and robust technique to consistently classify enhanced tissue in LGE MRI datasets from LSPAF patients studied at our centre. The technique's potential for successful employment in the AF management was demonstrated. Thresholds proposed by other institutions may not be usable for clinical studies performed in our centre. Inter-centre differences in the MRI acquisition protocol inevitably impede the selection of a universally optimal algorithm for segmentation of enhancement in AF studies.

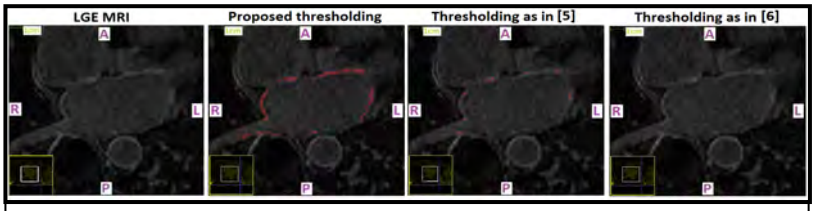

Fig.4 Comparison of enhancement segmentation techniques on a baseline dataset. Our technique conspicuously outperformed the methods proposed in studies [5] and [6] (which employed T_{PRE} = 3 and T_{PRE} = 4, respectively).

References: [1] Karim et al. *JCMR* 2013;**15**:105. [2] Hunter et al. *J Cardiovasc Electrophysiol* 2013;**24**:396. [3] Keegan et al. *MRM* 2014;**71**:1064. [4] Oakes et al. *Circ* 2009;**119**:1758. [5] Malcolme-Lawes et al. *Heart Rhythm* 2013;**10**:1184. [6] Ravanelli et al. *IEEE Trans Med Imaging* 2014;**33**:566.