

Quantifying left atrial extracellular volume fraction: a pilot study

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Background

Left atrial (LA) fibrosis, conventionally quantified by LA late gadolinium enhancement (LGE), is a measure of atrial remodeling associated with atrial fibrillation (AF), higher LA volumes and lower LA ejection fraction (LAEF)¹. LA LGE is elevated in subjects with increased LA pressure measured invasively², suggesting potential relationship between LA LGE and diastolic function. However, it is challenging to quantify LA fibrosis by LA LGE, because the optimal threshold for its detection is unknown. In this work, we employed a T1 mapping method³ to characterize LA fibrosis, by deriving 3D LA extracellular volume (ECV) fraction maps. Using these ECV maps, we sought to characterize the relationship between LGE contrast-to-noise-ratio (CNR) and ECV in LA LGE images. Furthermore, we hypothesized that LA ECV would correlate more strongly with LA structural and functional correlates of diastolic dysfunction compared to conventional LA LGE quantification of % fibrosis.

Methods

In an IRB approved study 16 AF patients (age 54 ± 16 years) were imaged on a Siemens 1.5T scanner after providing informed consent. 3 patients were excluded due to previous AF ablation. 3D LA LGE was performed 20mins post gadolinium contrast injection (.2 mmol/kg), accompanied by a ShMOLLI in a 4-chamber view (acquired within 8.8 ± 3.7 mins of 3D LGE). T1-RefBlochi³ was used to transform the 3D LGE into 3D T1 maps. Using each patient's hematocrit (HCT) obtained within 42.4 ± 31.1 days of MRI, and assumed pre-contrast T1 for the myocardium and blood⁴, ECV maps were generated. The LA LGE was segmented to delineate the enhanced pixels and obtain the % fibrosis and average ECV of enhanced pixels (ECVave). A new metric was generated called LA ECV Scar Burden (ECV-SBi = $ECVave \cdot [LGE \text{ enhanced vol.}] / BSA$). Next, the ECVs of the enhanced pixels were compared to CNR and the image intensity ratio (IIR)⁵ for each subject. With feature tracking, time-resolved global longitudinal strain (GLS) and LA indexed volumes¹ were measured on 2- and 4-chamber cines, whose derivatives yielded peak flow rates (PFR)—LA E and A PFR—analogue to E and A. Further, they were used to measure CMR-derived e' and a' ⁶. LV myocardial ECV was estimated based on the post-contrast T1 mapping and HCT.

Results

The T1-RefBlochi method matched well to the ShMOLLI results as shown in Fig. 1. CNR and IIR of the enhanced pixels on LA LGE strongly correlated to the LA ECV as shown in Fig. 2, suggesting the commonly used value for LA LGE segmentations 2-4 SDs above blood pool correspond to an ECV of .66 to .81; and an IIR of 1.5, an ECV of .74. The new metric ECV-SBi had stronger correlations to LA functional parameters and e'/a' than LA LGE (Table 1).

Conclusion

We improved assessment of LA fibrosis by not only quantifying the amount of LA fibrosis but also characterizing it with LA ECV. The proposed relationship between CNR and IIR with LA ECV will help to threshold scar on LGE.

References

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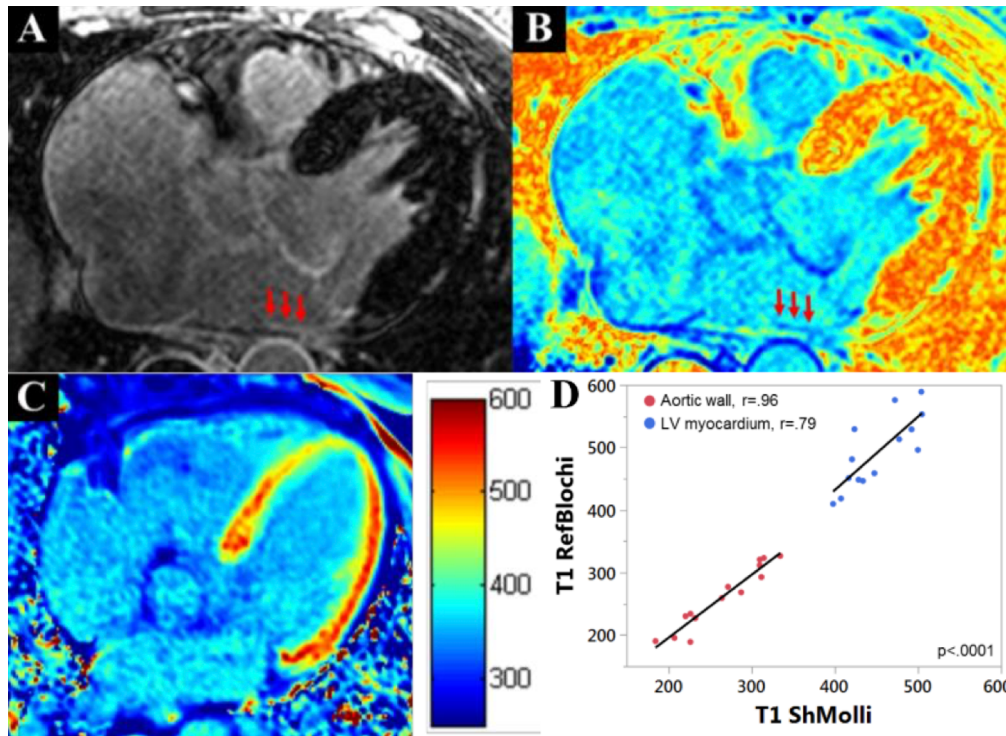


Figure 1. A) 3D LGE (axial slice) of the LA shows some posterior wall enhancement. B) T1 map by T1-refBlochi shows fibrosis with T1 shorter than blood (dark blue signal adjacent to arrows). C) Long-axis ShMOLLI T1 map acquired as reference. D) Comparison of T1 values for T1-RefBlochi and ShMOLLI show a good correspondence, especially for shorter T1s.

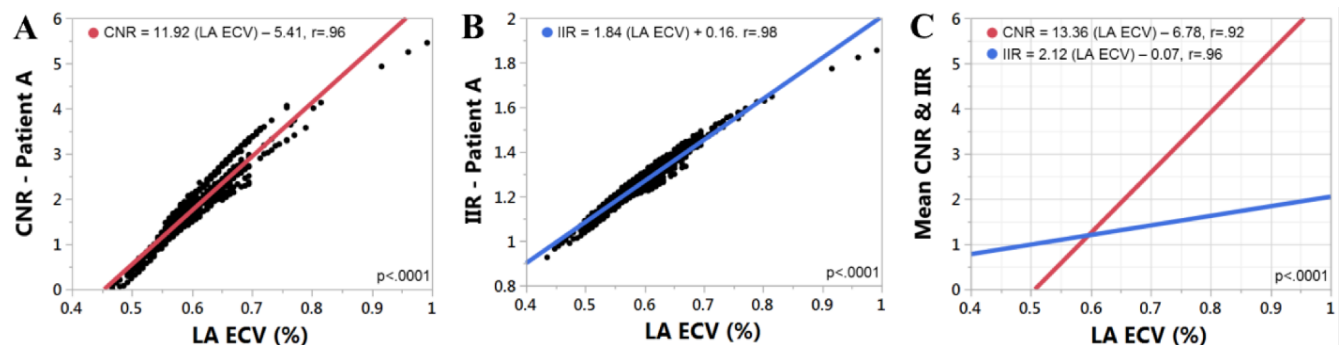


Figure 2. Relationship between contrast-to-noise-ratio (CNR) (A) and image intensity ratio (IIR) (B) against left atrial (LA) extracellular volume (ECV) in a representative patient. C) Resultant mean equations: $CNR = 13.86 (LA\ ECV) - 6.78$, $IIR = 2.12 (LA\ ECV) - 0.07$ ($N=9483$ scar pixels), averaged over all subjects.

Table 1. Left atrial (LA) assessment. Peak LA GLS, peak LA global longitudinal strain; LA EF, LA ejection fraction; MRI, magnetic resonance imaging; PFR, peak flow rates; ECV, extracellular volume.

	LA ECV-SBi (ml/m ²)		LA LGE ($\sqrt{\%}$)	
	r	p	r	p
Peak LA GLS (%)*	-.59	.034	-.50	.029
LA EF (%)*	-.59	.032	-.47	.044
LA min indexed vol. (ml/m²)*	.60	.031	.21	.380
LA max indexed vol. (ml/m ²)	.52	.071	.00	.990
CMR e' (mm/s)	-.18	.559	-.41	.082
CMR a' (mm/s)	-.52	.071	-.33	.169
CMR e'/a'*	.63	.020	.36	.134
LA E-PFR (ml/m ² /s)	.20	.507	.25	.310
LA A-PFR (ml/m ² /s)	.41	.159	.30	.220
LA E-PFR / LA A-PFR*	.66	.014	.31	.216
LA E-PFR / CMR e'*	-.63	.021	-.04	.862
LV myocardial ECV (%)	.35	.236	.44	.136

* significant correlations