Isovolumic relaxation time measured by Cardiovascular Magnetic Resonance: a pilot study

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Background

Diastolic dysfunction (DD) is associated with many cardiovascular diseases, including atrial fibrillation[1]. Isovolumic relaxation time (IVRT) is a parameter which has been used to assess DD and estimate pressure[2], although it is only rarely used in current clinical practice. IVRT is the time period at the end of systole, between the aortic valve closure and mitral valve opening. During IVRT, left ventricular (LV) pressure rapidly decreases, while LV volume is maintained. A recent study links IVRT to the untwisting time for the LV[3]. Echocardiography is able to measure IVRT, using Doppler to monitor flow below the mitral valve in a 3-chamber view[4]. In healthy subjects, IVRT is less than 70ms, though it prolongs in impaired LV relaxation and exhibits pseudonormalization at very high filling pressures[4]. We hypothesized that IVRT could be estimated on cardiac MRI using the end-systolic quiescent period measured on mitral valve plane displacement curves[5] from feature tracking on 2- and 4-chamber cine sequences.

Methods

In this IRB approved study, 8 consecutive patients were included (age 46±16 years, 7 male) with diverse study indications. All subjects had information about left sided filling pressures within 6 months of MRI (pulmonary capillary wedge pressure, N=5; LV end diastolic pressure, N=3). Cine sequences were acquired with 2x2x8mm spatial resolution, 30ms temporal resolution, using b-SSFP cine acquisition (TR / TE / Θ = 3ms / 1.5ms / 50°). Using the 2- and 4-chamber cine, left atrial (LA) volumes, LA EF, and LA global longitudinal strain (GLS)[6] were measured. The parameter e' (peak mitral valve velocity during early filling) was estimated with feature tracking[5]. LA LGE was also acquired and quantified as described previously[6,7]. **IVRT Measurement**: Feature-tracking of the mitral valve plane[5] on 2- and 4-chamber cine sequences was performed to obtain time-resolved displacement curves, whose average was smoothed to eliminate discontinuities. During end-systole, the RR fraction where the displacement values are within 5% of its peak displacement (Fig. 1) was obtained and considered to be IVRT (% of RR).

Results

Fig. 2 shows that IVRT (% of RR) is highly correlated with lower LA GLS, higher LV filling pressure and greater LA fibrosis, in this small cohort. Table 1 shows the correlations to other measures of diastolic function and LA remodeling.

Conclusion

As with other diastolic filling measures, IVRT is rarely or never quantified using CMR. The relationship between IVRT, pressure and other correlates—atrial fibrosis, atrial strain and e'—associated with high filling pressures and atrial remodeling, is remarkable, though requires confirmation in larger cohorts. IVRT normalized by RR demonstrated a stronger correlation than IVRT alone to atrial structural and pressure abnormalities. The temporal resolution for cine MRI may be a limitation in accuracy of IVRT measurement and echocardiography comparison studies are highly warranted.

References

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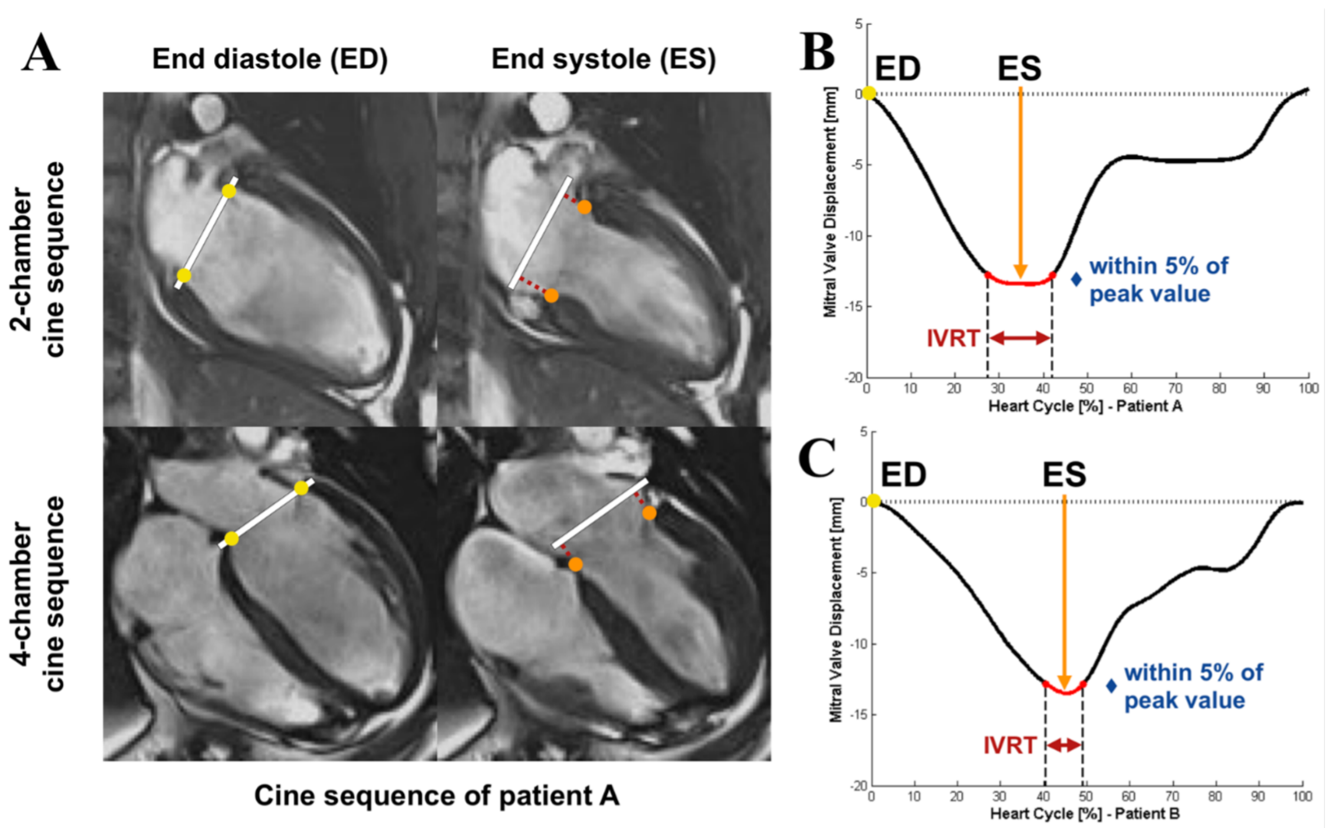

Figure 1. A) From 2- and 4- chamber cine sequences, the mitral annular points are marked in end-diastole (yellow points) and in end-systole (orange points) and in all remaining phases (not shown), the initial mitral valve plane (white line) is set in end-diastole in both views and the mitral valve displacement is obtained by the average of the perpendicular distance of the mitral annular points to the initial plane. IVRT is indicated by the dashed lines, and is calculated as the time at which the valve is within 5% of the peak valve displacement. The valve displacement curves and IVRTs are shown for two subjects: B) IVRT = 160ms (14.7% of RR). C) IVRT = 73ms (8.7% of RR).

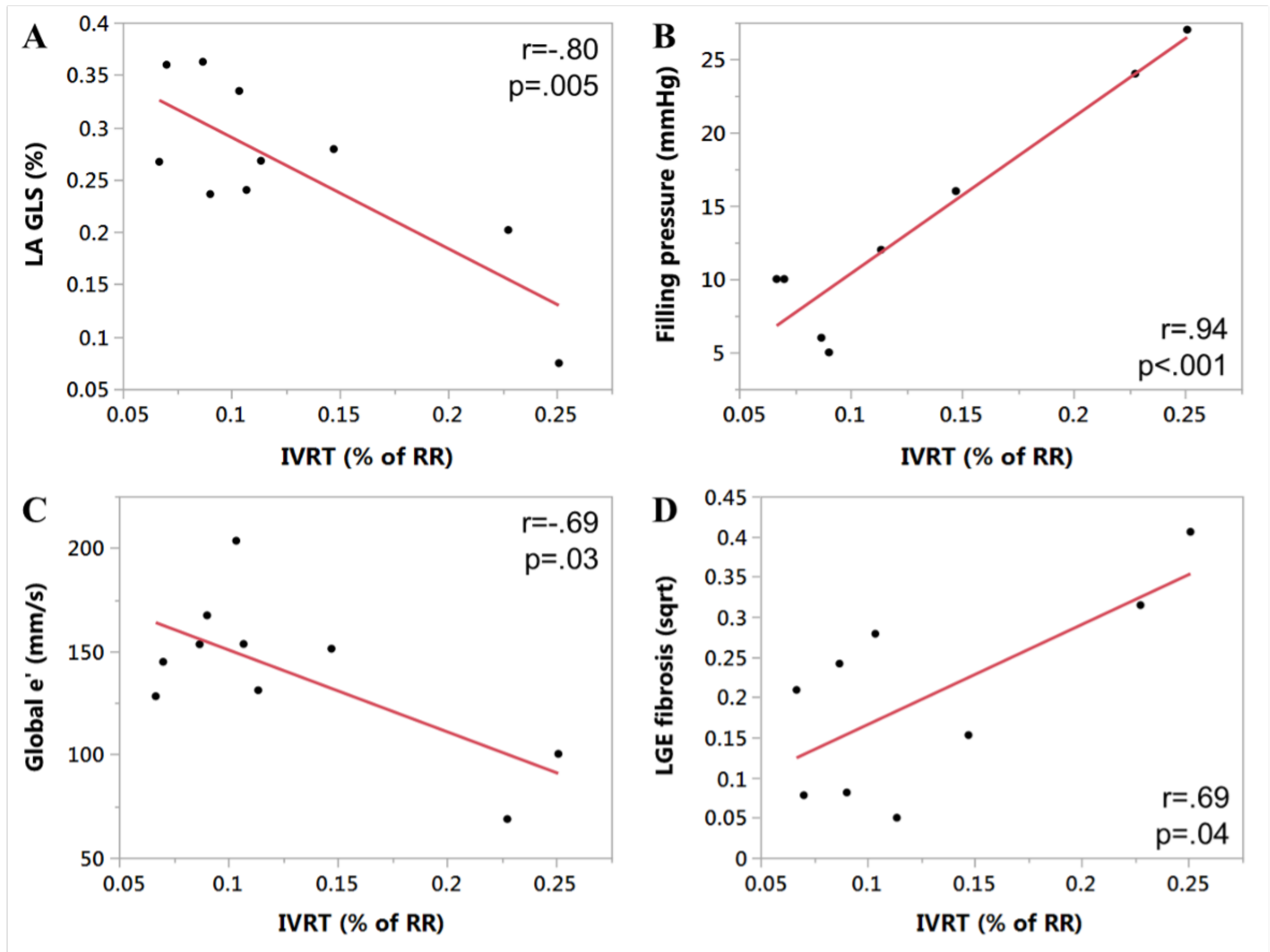

Figure 2. Correlations between IVRT (% of RR) and A) LA GLS. B) LV filling pressure. C) Global e' measured by CMR, from averaging septal and lateral e' from 2- and 4-chamber cine sequences. D) LA LGE % fibrosis. These indices of atrial remodeling and diastolic dysfunction all strongly correlate with IVRT (% of RR).

Table 1. IVRT assessment. LGE, late gadolinium enhancement; MRI, magnetic resonance imaging; LA EDVi, left atrial end-diastolic volume index; Peak LA GLS, peak left atrial global longitudinal strain; LA EF, left atrial ejection fraction.

	IVRT (ms)		IVRT (% of RR)	
	r	p	r	p
RR interval (ms)	.17	NS	.62	.05
Age (years)	-.04	NS	-.07	NS
TTE E (m/s)	.08	NS	.17	NS
TTE E/e'	.40	NS	.51	NS
Filling pressure (mmHg)*	**.81**	**.013**	**.94**	**<.001**
LA LGE fibrosis ($\sqrt{\%}$)*	.34	NS	**.69**	**.038**
CMR e' global (mm/s)*	**.66**	**.04**	**.69**	**.027**
LA EDVi (ml/m^2)*	.45	NS	**.78**	**.008**
Peak LA GLS (%)*	-.59	NS	**-.80**	**.005**
LA EF (%)*	**.67**	**.03**	**.90**	**.003**

* significant correlations