Left Ventricular Internal Flow in Patients with Dyssynchronous Heart Failure: Quantification by Cine MRI

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Background

The accurate diagnosis of left ventricular (LV) dyssynchrony appears crucial to identify candidates for cardiac resynchronization therapy (CRT)[1]. The duration of the QRS on surface electrocardiogram remains the only accepted clinical measure of LV dyssynchrony for identifying patients who need CRT, but it has low sensitivity[2] and specificity[3] (~50-60%). Thus, better methods to quantify LV dyssynchrony are needed.

Mechanical dyssynchrony creates abnormal displacement of blood *within* the LV, from early-activated regions to late-activated regions during systole[4]. This internal flow, or "sloshing," represents wasted energy due to dyssynchronous motion of the LV walls. Quantification of internal flow may represent a better method to diagnose the presence and physiologic severity of dyssynchrony. Furthermore, the mechanical activity producing sloshing may represent wasted myocardial work which can be alleviated by CRT.

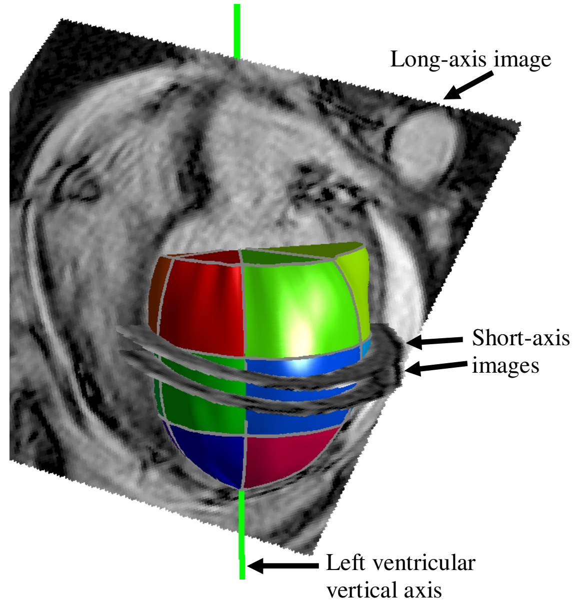

Figure 1. *Three-dimensional endocardial surface of the left ventricle of a patient with severe heart failure and prolonged QRS duration divided into 18 regional volumes.*

Hypothesis

Internal flow can be quantified using standard cine short-axis cardiac magnetic resonance (CMR) images and will be significantly increased in patients undergoing CRT compared to healthy, normal controls.

Methods

CMR images were obtained from 10 healthy volunteers and from 10 patients undergoing CRT with a high likelihood of dyssynchrony (class III/IV heart failure, LV ejection fraction <35%, and QRS >150ms). SSFP short-axis cine images were acquired during breath-holds with a 1.5T Philips Intera scanner using a 5-element phased array cardiac coil (slices 8-10mm thick with no gaps, 20 time points per cardiac cycle). Two-chamber and four-chamber SSFP long-axis cine images were also acquired.

The LV was divided into 18 regional volumes: 6 wedge-shaped 60^0 regional volumes at each of the 3 longitudinal levels (basal, mid-ventricular and apical) (Fig 1). Internal flow was defined as the sum of the regional volume changes minus the global volume change for each time frame in the cardiac cycle: $IF(t)=\sum|\Delta V(t)_{regional}| - |\Delta\sum V(t)_{regional}|$. Internal flow fraction (IFF) was defined as the amount of internal flow that occurred during systole ($IFF_{systole}$) or diastole ($IFF_{diastole}$) as a percentage of stroke volume.

Results

$IFF_{systole}$ was 21±10% in the patients and 2±2% in the normal controls ($p<0.001$). An $IFF_{systole}$ threshold of 6% discriminated patients from normal controls with 100% accuracy (Fig 2). $IFF_{diastole}$ was 24±9% in the patients and 8±2% in the normal controls ($p<0.001$). An $IFF_{diastole}$ threshold of 12% discriminated patients from normal controls with 100% accuracy. $IFF_{diastole}$ was greater than $IFF_{systole}$ in the normal controls ($p<0.001$) while the patients had similar IFF during systole and diastole ($p=0.44$).

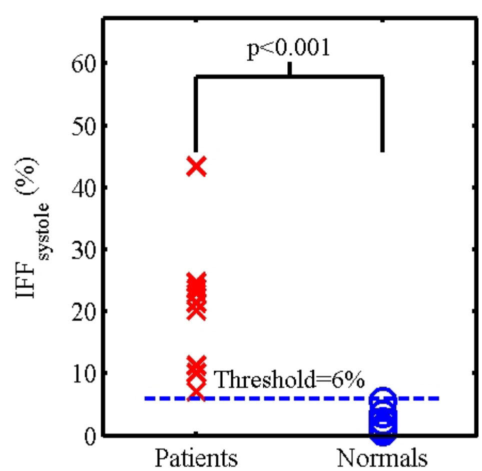

Figure 2. *Internal flow during systole as a fraction of stroke volume ($IFF_{systole}$) is significantly different in patients with severe heart failure and prolonged QRS duration compared to normal controls.*

Conclusions

Systolic internal flow expressed as a percentage of stroke volume discriminates between patients with dyssynchronous heart failure and normal controls with 100% accuracy. Quantification of internal flow from cardiac magnetic resonance images may be useful in identifying patients who need cardiac resynchronization therapy.

References

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