Inverted Left Ventricular Apical Rotation in Patients eligible for Cardiac Resynchronization Therapy assessed by Tagged MRI Predicts acute Response to Biventricular Pacing

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Introduction: Left ventricular (LV) torsion is essential for normal cardiac functioning. The torsional deformation is caused by the obliquely oriented myofibers in the cardiac wall (1). Since torsion is directly related to myofiber structure, cardiomyopathies are expected to express via torsion (2). In this study, torsion is analyzed using high temporal resolution MRI tagging in heart failure patients eligible for cardiac resynchronization therapy (CRT) and the predictive value of disorders in torsion for the acute response to biventricular pacing is evaluated.

Methods: In 23 patients eligible for CRT (65±10yrs, 13 male) undergoing a temporary pacing protocol and 12 controls (43±11yrs, 7 male), MRI myocardial tagging (CSPAMM) was performed using a SFFP sequence with a multiple brief expiration breath-hold scheme (3). The imaging parameters were as follows: FoV: 300x300mm^2, flip angle: 20º, TR: 3.6ms, TE: 1.8ms, BW: 850Hz/pixel, matrix size: 256x78, slice thickness: 6mm, temporal resolution: 15ms, tag-line distance: 7mm. Basal and apical short axis images were acquired. Additionally, a 3-chamber cine with the same temporal resolution was made to determine the timing of the valves. After drawing myocardial contours on the short-axis images, the motion of the myocardium was tracked using extended HARP-tracking (4). The rotation of the tracked points around the moving center of mass of the LV was calculated. Counterclockwise rotation as seen from the apex was considered positive. Disorders in torsion were analyzed by determining the correlation between basal and apical rotation until the moment of mitral valve opening (mvo), where positive correlation reveals a large torsion disorder and negative correlation indicates a normal torsion. This number, ranging from –1 to +1, was called the 'torcor'.

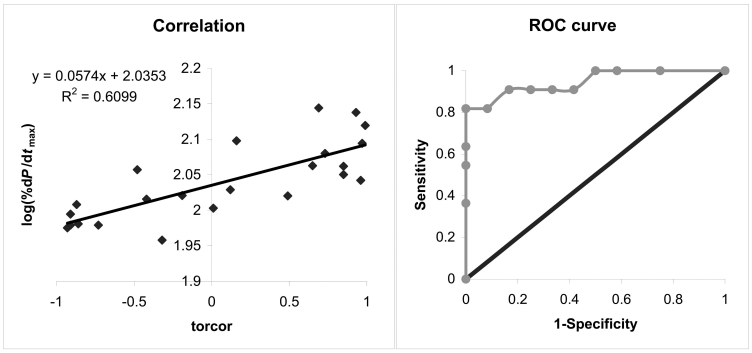

Figure 1. Correlation and ROC curves.

Acute response to temporary biventricular pacing was defined by the maximum relative increase in d*P*/d*t* (%d*P*/dt_{max}) with respect to baseline from different pacing combinations in the patients, where a value >10% indicated response. To achieve this, a sensing lead was placed in the right atrium for atrial-sensed ventricular stimulation. Pacing leads were placed in the following locations: RV outflow tract, RV apex, LV anterolateral wall, LV inferolateral wall, and a catheter-tip manometer was inserted in the LV to record LV pressure.

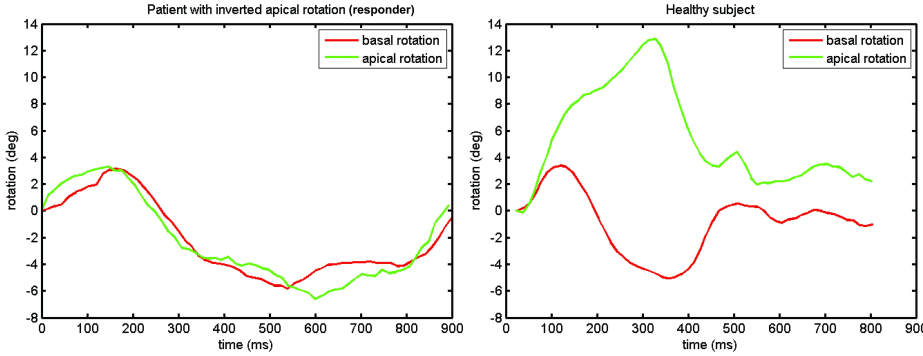

Figure 2. Rotation curves of a patient and a healthy subject.

Values were compared between patients and controls. Since a negative or low torcor is expected to show similar low acute response, an exponential relationship is expected between torcor and %d*P*/dt_{max}. Therefore, the linear correlation between torcor and the logarithm of %d*P*/dt_{max} was calculated, where a p-value below 0.05 was considered as significant. Furhermore, ROC-analysis was performed to determine the predictive value of torcor for acute response to biventricular pacing.

Results: The average torcor in the patients was 0.08±0.73, while the average acute response was 10.4±14.0%. The average time to mvo was 480±92ms. In the control subjects, the average torcor was –0.68±0.22. All healthy subjects showed counterclockwise apical rotation and clockwise basal rotation. Their average time to mvo was 480±40ms. Torcor was significantly different between the patients and controls (p<0.01), but the time to mvo was not significantly different (p>0.99).

The correlation between torcor and log(%d*P*/dt_{max}) was high (r=0.78, p<<0.0001, Fig. 1). After visual inspection of the rotation curves, 9 of the patients showed inverted apical rotation with respect to control subjects (Fig. 2), while the direction of basal rotation was normal (average torcor: 0.85±0.13). They all had good acute response to biventricular pacing. In the remaining 14 patients, the average torcor was –0.42±0.48. Only 2 of these patients had good acute response. In the responders, torcor was 0.66±0.45, which was significantly different (p<<0.0001) from non-responders (torcor=-0.46±0.48) and controls. Torcor was not significantly different between the non-responders and the controls (p=0.10, Fig. 3).

Roc-analysis resulted in an area under the roc-curve of 0.94 (Fig. 1). The cut-off value with maximum Youden's index of 0.82 was torcor=0.5, corresponding to visually observed inverted apical rotation in the rotation curves. At this cut-off value, sensitivity was 0.82, specificity was 1, the positive predictive value was 1 and the negative predictive value was 0.86.

Discussion and Conclusion: Normal, counterclockwise apical rotation is caused by oppositely contracting myofiber layers in the cardiac wall. Inverted apical rotation could be the result of malfunctioning of a myofiber layer. Probably, the occurrence of inverted apical rotation in patients eligible for CRT suggests an activation disorder in one of the myocardial fiber layers, which might be restored by pacing. The high sensitivity, specificity and predictive value of this disorder in torsion indicated that high resolution MRI torsion analysis in this patient group would be very useful for discrimination of responders and non-responders. However, a larger group is needed to show the true validity of these results. Furthermore, it should be studied to what extent the acute response predicts the long-term response in these patients.

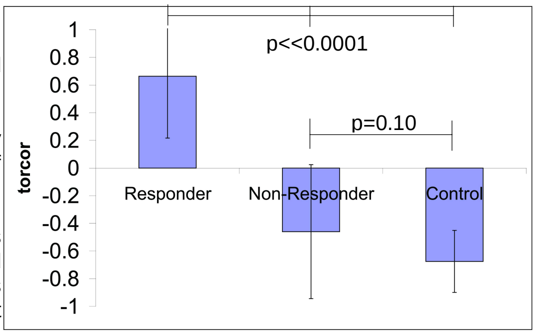

Figure 3. Average torcor in responders (n=11), non-responders (n=12) and controls (n=12).

References: 1. Ann Biomed Eng 7:299-318;1979. 2. J Am Coll Cardiol 48:2002-2011;2006. 3. Magn Res Med 49:722-730;2003. 4. J Magn Res Im 23:682-690;2006.