Effect of Rotation on Myocardial Strain Determination Using Real-Time Three-Dimensional Echocardiography

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ABSTRACT

Background: A better understanding of the mechanics of the heart can be provided with the analyses of cardiac rotation and its effects on cardiac function. Previous studies have implied an impact of rotation on strain, but the relationship has not been reported. This study was designed to evaluate the effect of rotation on strain using the three-dimensional echocardiography (3DE).
Methods: Six porcine hearts were studied. A balloon was sutured into the left ventricle through the mitral annulus and connected with a pulsatile pump. The hearts were pumped at varying rotation degrees (0, 5, 10, 15, 20). A constant compaction of 10 mm and stroke volume of 50 mL were maintained throughout the experiment to simulate physiological cardiac motion. The heart model and a Toshiba PST-25SX Transducer were submerged in a torsion tank for imaging acquisition. At each rotation degree, two full-volume loops were acquired and then analyzed using the Toshiba UltraExtend Advanced Cardiology Package.
Results: With increasing rotation degrees, 3DE-derived global circumferential strain, radial strain and general 3D strain were increased ($P<0.05$). ANOVA analyses among varying degrees of rotation indicate a significant effect on circumferential, radial, and 3D strain ($P<0.05$).
Conclusions: 3DE is feasible to detect the effect of rotation on strain. Greater rotation degrees yielded greater strain values.

BACKGROUND

The dynamic function of the heart is a complex interaction of shortening, thickening and rotational motion. Although there is continuing debate about macroscopic myocardial architecture and its impact on dynamic function of heart, LV twisting motion is believed to be the consequence of oblique myocardial fiber orientation that induces rotation around the long axis during contraction. Since the magnitude of LV twist is determined by contractile force, it is suggested that measurement of LV twist could be implemented as a clinical index of contractility and may also serve as a potential marker of myocardial dysfunction in the diseased heart. This concept is partially supported by earlier experimental work, but none of the methods used in experimental work were either non-invasive , to allow this evaluation without disturbing structural integrity of myocardium, or had high enough temporal resolution to accurately evaluate myocardial motion. With the advent of digital tracking of acoustic tags in scan line echocardiographic image data, computation of rotation and strain (contraction) can be done simultaneously in short axis planes noninvasively using high resolution dynamic images and has been validated against more invasive and high resolution methods. We studied this strain rotation interaction in freshly harvested pig hearts driven at calibrated rotation and stroke volume.

METHODS

We studied six freshly harvested pig hearts. The major vessels and atria were removed. Each heart was attached to the pulsatile pump apparatus by plastic tubing and a latex balloon, which was secured into the LV at the mitral valve annulus. The apex of the heart was fixed on a base plate and attached to a torsion machine which was then submerged into water The 3D matrix transducer was held at the apex for image acquisition. The balloon and closed tubing system was filled with water and driven by the pump at a constant stroke volume of 50 ml at the rate of 60 beats per minute. The torsion machine was set to a constant compaction of 10 mm. Full Volume 3D image loops were acquired with Toshiba Artida ultrasound system (Toshiba Medical Systems, Tochigi, Japan) for varying degrees of rotation (0,5,10,15,20). Image loops were analyzed by 3D wall motion tracking(3D-WMT) program. Circumferential, Radial and 3D strain were computed at all rotation degrees.

Figure 1. Experimental Setup

RESULTS

At each rotation degree, two full-volume loops were acquired and then analyzed using the Toshiba UltraExtend Advanced Cardiology Package
Our results showed that with increasing cardiac rotation values, cardiac strain values were also increased. ANOVA Single-Variable Analysis revealed a statistically significant effect of rotation on derived strain values for CS , RS and 3DS (all $p< 0.01$).
The average values of CS, RS, and 3DS were plotted against different rotation degrees in increasing order (0,5,10,15,20), which showed that increased cardiac rotation values elevated cardiac strain values for all circumferential, radial, and 3D strain (Figure 3).

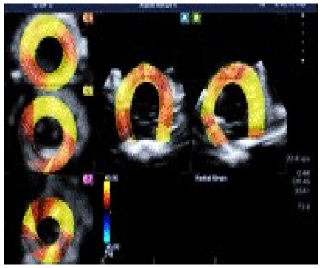

Figure 2. Deriving strain data for cardiac strain values using 3DWMT

CONCLUSION

This relationship between cardiac rotation and strain indicates that rotation has an impact on strain. Increased rotation degrees were found to result in statistically significant higher strain values in CS, RS, and 3DS.
Four D echocardiography is feasible to evaluate the impact of rotation on strain values.

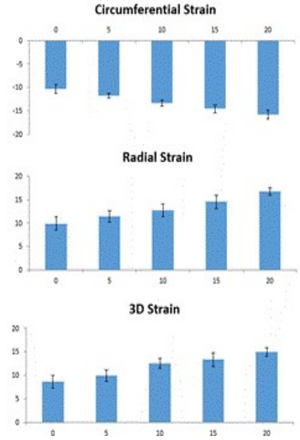

Figure 3. Average Cardiac Rotation Values plotted against CS, RS, and 3DS Values

DISCLOSURES

No relationships to disclose:

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