Use of Cardiac Magnetic Resonance Imaging and Cardiac Magnetic Resonance feature-tracking strain analysis to characterize and differentiate aortic annular strain patterns in aortic valve regurgitation versus normal aortic valves.

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Abstract

Understanding the aortic annulus is important for obtaining reproducible and durable aortic valve repair and allowing advances for TAVR treatment of aortic regurgitation. Significant limitations exist when using echocardiography and CT-based imaging with feature tracking at the aortic annulus. Cardiac Magnetic Resonance is used to obtain Regional Longitudinal Strain (RLS) and can be modified to obtain circumferential annular strain at the fibrous and muscular portions of the aortic valve annulus. Holst and colleagues use a novel method to characterize and prove that adverse annular deformation occurs at the muscular portion of the aortic valve annulus in patients with aortic regurgitation. The direction of muscular annular deformation in patients with aortic regurgitation is opposite to the direction of muscular annular deformation in patients with normal aortic valves.

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Running Title: Longitudinal Stain Analysis of Aortic Annulus

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Abstract

Understanding the aortic annulus is important for obtaining reproducible and durable aortic valve repair and allowing advances for TAVR treatment of aortic regurgitation. Significant limitations exist when using echocardiography and CT-based imaging with feature tracking at the aortic annulus. Cardiac Magnetic Resonance is used to obtain Regional Longitudinal Strain (RLS) and can be modified to obtain circumferential annular strain at the fibrous and muscular portions of the aortic valve annulus. Holst and colleagues use a novel method to characterize and prove that adverse annular deformation occurs at the muscular portion of the aortic valve annulus in patients with aortic regurgitation. The direction of muscular annular deformation in patients with aortic regurgitation is opposite to the direction of muscular annular deformation in patients with normal aortic valves.

Key Words

cardiac magnetic resonance imaging, feature tracking, aortic valve annulus, strain analysis

The aortic valve annulus has become a more prominent feature for analysis as more attention is paid to percutaneous aortic valve replacement, surgical aortic valve repair, and homograft aortic valve replacement. The aortic valve annulus has been studied[1] – especially where annular contribution to aortic insufficiency is now better understood and where aortic annuloplasty accompanying aortic valve repair is in greater use with growing evidence that it can improve aortic valve repair durability.[2,3,4,5]

Holst and colleagues[6] are to be congratulated for a timely pilot study of the aortic valve annulus. The aortic annulus consists of a muscular component and a fibrous component. The authors show that aortic annular dilation and adverse deformation occurs at the muscular component of the aortic annulus. In their study, CMR imaging and CMR feature-tracking strain analysis is used to characterize aortic annular regional longitudinal strain (RLS) in humans with regurgitant aortic valves (n=4) compared to humans with normal aortic valves (n=7). Previous CT-based studies of aortic annular deformation analysis have been published;[1,5] however, using CT-based imaging, it is not possible to obtain feature tracking at the muscular portion of the aortic annulus. The novel modality, as reported in this study, produces increased sensitivity for evaluation of aortic annular deformation. This is accomplished by modifying CMR imaging software – originally intended to be used to obtain LV global longitudinal strain – and obtaining regional longitudinal strain (RLS) data from the aortic valve annulus and computationally converting the data to arrive at circumferential aortic annular strain data.[7]

It is important to define abnormal aortic annular deformation and normal aortic annular deformation. Adverse systolic aortic annular deformation in patients with severe aortic insufficiency results in muscular annular dilation, (positive strain value); normal aortic annular deformation in patients with normal aortic valves results in muscular annular constriction, (negative strain values). Despite an exceedingly small patient sample size, the data obtained in the study are sufficiently robust to preliminarily support the hypotheses and conclusion. The hypotheses and evidence supporting the hypotheses are as follows:

In patients with severe aortic regurgitation, adverse aortic annular deformation is located at the muscular portion of the aortic annulus. The muscular portion of aortic annular RLS of patients with severe aortic regurgitation is significantly different compared to patients with normal aortic valves, (median RLS: 4.18% in patients with severe AR vs -10.41% in well-functioning AVs, p=0.024; at RLS muscular annulus; segments II-IV).

There is no contribution of adverse aortic annular deformation at the fibrous portion of the aortic annulus, (median RLS: -2.66% in aortic regurgitation patients vs -3.86% in healthy controls, p=0.788; at RLS fibrous annulus; segments I, V-VII).

(The authors use median (IQR) instead of mean (SD) because the sample size is too small to approximate a normal distribution.)

It is significant to observe that, in the muscular section of the aortic annulus, the direction of the median RLS in the aortic regurgitation group is opposite from the direction of the median RLS in the normal aortic valve group, (segments II-IV). The median RLS difference between groups achieves statistical significance because the RLS differences are in opposite directions. If this data holds up in a future study with a sufficient sample size, then this finding is of major physiological significance. The authors speculate on the implications regarding adverse annular remodeling; including right aortic leaflet prolapse in patients with adverse muscular annular deformation and dilation.

It is immensely helpful to pay attention to the one excellent figure in the manuscript. A CMR image of the aortic valve is used to correlate surrounding anatomic structures. The figure also shows anatomic annotated overlays of the CMR-strain generated imaging – correlated with longitudinal aortic valve annular strain (with anatomically associated segments I-VII), and with comparison of the muscular component to fibrous component. (The use of aortic annular segments I-VII appears to be a novel addition to the author's imaging analysis.)

A significant objective for aortic valve surgery is improvement of aortic valve repair reproducibility and durability.[3,4,5] The use of a variety if aortic valve annuloplasty techniques is undergoing a resurgence since first proposed in 1966.[9] Is there value in using CMR-based strain analysis to study bicuspid aortic valve pathology and bicuspid aortic valve repair? TAVR for treatment of aortic regurgitation is significantly underdeveloped. Certainly, there may be a place for CMR-based strain analysis to better understand and develop improved TAVR technology. This pilot study adds to a series of ongoing studies where we can track the valuable contributions of this group and other groups of scientists in their quest to obtain a better understanding of cardiac physiology using novel computational imaging and strain methods.

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