Cardiac magnetic resonance (CMR) diffusion tensor imaging (DTI) is a promising technique capable of probing the myocardial microstructure by assessing the myofiber orientation. New technical developments in CMR DTI in recent years have allowed the clinical application of this powerful imaging technique. CMR DTI has been used to study myocardial infarction and hypertrophic cardiomyopathy in patients, revealing their adverse effects on myocardial microstructure. The article in this issue of *Circulation: Cardiovascular Imaging* by von Deuster et al describes a new clinical application of CMR DTI.

In this single-center study, von Deuster et al studied patients with dilated cardiomyopathy (DCM) using CMR DTI and assessed the change in the myocardial fiber orientation by imaging at 2 separate time points in the cardiac cycle. DCM is a major cause of heart failure that causes ventricular chamber enlargement, wall thinning, and systolic dysfunction. The authors hypothesized that a combination of CMR DTI, myocardial tagging, and biomechanical modeling will shed new insight into the alterations of myocardial microstructure and functional performance (strain) in patients with DCM when compared with healthy controls. They measured helix angle transmurality (HAT) and found it was steeper in patients DCM when compared with age-matched controls. Conversely, it was impaired during cardiac contraction in patients with DCM, compared with controls. Their developed biomechanical modeling could not explain the steeper HAT in patients with DCM, but could support the impaired dynamic reorientation of fibers.

This study displays the superb and important teamwork between clinicians and scientists that allows this cutting-edge imaging technology into clinical evaluation of cardiovascular diseases, such as DCM. Their biomechanical modeling did not support the steeper helix angulation, but it is a natural extension to collect functional and microstructural CMR data. In addition, the recruitment and scanning of patients with DCM are a major accomplishment, as many DCM patients may have implantable MR incompatible hardware such as ICD, LVAD, or pacemakers.

Although we greatly appreciate the enormous technical challenges that were overcome in completing the study, the choice of CMR DTI technique raises concerns about its accuracy in patients with DCM. For example, the dual-phase stimulated echo (STEAM) diffusion CMR technique requires breath-holds to achieve a clinically acceptable scan time since prospective navigator gating has low scan time efficiency. Consequently, each patient underwent 22 breath-holds to achieve the necessary signal-to-noise ratio to robustly map myocardial fiber orientations at a single short-axis slice. This is in comparison with the typical 16 to 20 breath-holds needed for full LV coverage of functional and late gadolinium enhancement imaging in a routine clinical CMR examination. Furthermore, the STEAM technique is susceptible to arrhythmia when scanning outside of systole because STEAM diffusion encoding is achieved over 2 heart beats.

Therefore, STEAM DTI requires neighboring heartbeats to be encoded in the exact same position to avoid irreversible motion-induced signal loss. Alternative techniques to address patient comfort and arrhythmia would be motion compensated spin echo diffusion CMR techniques that diffusion encode in a single heart beat allowing for free breathing and more robustness to arrhythmia. Future improvements to the STEAM DTI CMR technique are needed to reduce the burden of patients.

Another technical concern is the estimation of HAT, defined as the slope of the transmural helix angle course, in patients with DCM. Patients with DCM exhibit thinning of the left ventricular wall, making it challenging for diffusion CMR to accurately quantify the HAT with the spatial resolution (2.5×2.5×8 mm³) used in the study. The reported wall thickness for patients with DCM used in the study was 9±1 mm, and only the inner 80% of the wall was used to calculate the HAT yielding a total of 2 to 3 pixels at each radial spoke. Further studies are needed to validate if 2 to 3 pixels is sufficient to yield an accurate estimate of HAT.

A final and perhaps the most vital consideration is their conclusion that there is a steeper diastolic helix angulation in patients with DCM than in normal subjects. This finding is not only inconsistent with the biomechanical model used in...
the study (Figure 7) but, most importantly, it is inconsistent in studies of ex vivo human hearts,\textsuperscript{17,18} where there is a flattening of the helix angulation. Their own strain data support this, as the longitudinal strain is reduced. This diminution of shortening during torsion occurs because the fibers have a more horizontal orientation, as described by Sallin.\textsuperscript{19} We wonder how this fundamental difference between structure and function can be resolved because the steeper helical angulation would enhance, rather than diminish cardiac performance. We look forward to their further studies to provide clarification.

In summary, we commend the authors for adding to the ever growing clinical use of diffusion CMR. Interfacing myocardial microstructure and its dynamics offers a new exciting perspective to our knowledge and may extend far beyond studying DCM. Technically, CMR DTI will need to be further improved to reduce the burden of patients. The future holds great promise for using CMR DTI to accurately quantify HAT. A concert of experimental studies is needed in order for this potential to be explored and further validated. We believe that CMR DTI will become a powerful tool to facilitate our understanding of the relationship between myocardial structure and functional performance of the heart and potentially improve diagnosis and treatment of cardiovascular disease.

Disclosures

None.

References


Key Words: Editorials • diffusion tensor imaging • dilated cardiomyopathy • heart failure • human • systole
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