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Brief Report

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Echocardiographic MRI: an innovative fusion of functional and anatomic assessment strategy for CHD

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Abstract

We present a pilot case using an innovative fusion of echocardiogram and MRI achieved with a MATLAB-based imaging programme to explore the feasibility of this imaging strategy in the functional and anatomic assessment of a patient with repaired tetralogy of Fallot requiring pulmonary valve intervention. Echocardiogram and MRI neutralises the disadvantages and limitations of each individual imaging modality and yields important anatomic and haemodynamic information crucial to the treatment decision-making process. Future image fusion strategies can apply to three-dimensional images and image-directed therapy for CHD.

Introduction

Echocardiography and MRI are the mainstay imaging modalities used in the diagnosis and management of CHD from the pre-natal period to adulthood. MRI has been shown to be an effective non-invasive modality for visualisation of cardiovascular anatomy in CHD but this modality lacks the real-time haemodynamic profile delineated by echocardiography. Echocardiography with colour Doppler blood flow imaging and continuous-wave Doppler is ideal for non-invasive haemodynamic assessment of a myriad of CHD lesions; however, it is limited by the relatively poor resolution and field of view necessary for optimal anatomic definition of cardiac structures. Although cardiac catheterisation as an imaging and haemodynamic assessment methodology potentially possesses advantages of both echocardiograph and MRI, the invasive nature of cardiac catheterisation has more inherent risks.

Currently, a combined functional and anatomic assessment strategy with fusion of acquired data from two imaging modalities has been mainly performed for the following combinations: MRI–positron emission tomography, MRI–single photon emission CT, MRI–CT, and positron emission tomography–CT. Porter et al used three-dimensional ultrasound and MRI of the liver.[1] In addition, Rajpoot et al reported use of an automatic two-stage registration and fusion strategy to combine multiple single view of real-time three-dimensional echocardiographic images.[2] Lastly, Rasche et al reported fusion of volumetric ultrasound images with three-dimensional X-ray imaging data for cardiac structures.[3]

An innovative fusion of echocardiography with MRI, however, could neutralise the significant disadvantages of either imaging modality.[4] MATLAB, a matrix-based computer language, is well suited for processing digitalised images with matrices to undergo registration and segmentation. This dyadic "echocardiographic" MRI, or "E. MRI", has not been previously reported for CHD. We present a case that explores this fusion of echocardiography and MRI as a proof-of-concept in children and adults with CHD.

Case

We present the case of a 16-year-old male with a history of tetralogy of Fallot status post repair with residual pulmonary stenosis and insufficiency being followed for mild to moderate right ventricular dilatation that were demonstrated on cardiac MRI and chest magnetic resonance angiography. Imaging was obtained to assess for pulmonary valve replacement or implantation.

Materials and methods

Echocardiographic images were obtained by the Philips IE33 imaging system with pulsed- and continuous-wave Doppler imaging and in conventional planes. A parasternal short-access view of the atrioventricular and aortic valves was the most useful anatomic fiducial landmark for the programming platform. The MRI images were acquired from the Siemens 1.5 T Espree scanning system using TrueFISP™ sequence and a corresponding parasternal short-axis image was exported. Analysis revealed severe pulmonary insufficiency, and the right ventricle end-diastolic volume was calculated to be 186 mL/M2 and the end-systolic volume was calculated to be 96 mL/M2, both values showed increased volume.

Using MATLAB programming platform and image processing technology, a medical image fusion of the echocardiogram and MRI, called "E.MRI", was performed by the segmentation of the colour Doppler flow signal, registration at both location and cardiac cycle of colour Doppler and MRI, and fusion of both colour Doppler and MRI using geometric transformation. The image fusion extended the field of vision of the echocardiogram while retaining the insufficiency of the pulmonary valve.

Discussion

The fusion of echocardiographic and MRI images is appropriately suited for the evaluation of complex functional and anatomic CHD. These situations include atrioventricular valve regurgitation, semilunar valve regurgitation, and intracardiac shunting. Other less common situations, such as right ventricular conduit aneurysms or complex heterotaxy pre-Fontan operation, may also benefit from this fusion imaging modality. The advantages of fusion include simultaneous assessment of anatomy and function of essential cardiac structures, such as valvar stenosis and insufficiency; delineation of structures, such as aortopulmonary collaterals, outside the field of view of echocardiography with MRI imaging; and completion of anatomic information missing from one modality but replaceable with the other. Automation of classification of echocardiograms in the near future that uses machine learning can further facilitate the image fusion strategy.[5]

Advancements in artificial intelligence applications in radiology are extending the scope, utility, and analysis of advanced imaging studies in cardiology. The advent of multi-modal medical image fusion with accompanying algorithms that will incorporate feature extraction, more complete overlays, and artificial intelligence, such as neural networks, fuzzy logic, and classifiers like support vector machine, will herald a new era in medical imaging with more robust decision-making. Recent reports by Wang et al showed novel application of dependency model named explicit generalised Gaussian density dependency model as well as shift invariant shearlet transform domain methodology can lead to improved fusion results.[6,7]

Future work can involve "dynamic" fusion of echocardiogram and MRI images to provide even more realistic assessment of function and anatomy of CHD. Over a period of time, owing to continuous machine-learning algorithms, the dynamic segmentation and fusion of multi-modal images will be more seamless and have less error. This merged functional and anatomic non-invasive imaging dyad can potentially obviate the need for the more invasive imaging modalities such as angiography in high-risk patients with CHD. The images can even be presented in a three-dimensional format to fully capture the anatomic and functional aspects of the heart with congenital heart defects, essentially resulting in a non-invasive "super scan" of the heart, with both anatomic and hemodynamic evaluations, except for filling pressure. Finally, this image fusion technology can be applied to surgical navigation or even image-directed therapy, such as therapy used for certain valvuloplasty.[8]

Conclusion

The fusion of echocardiography and MRI for CHD can be achieved with MATLAB-based imaging programmes. The resultant echocardiographic MRI yields important anatomic and hemodynamic information to facilitate the decision-making process for the cardiologist and cardiac surgeon. Future applications of the image fusion strategy can include multimodal three-dimensional images with accompanying algorithms that will incorporate feature extraction, more precise overlays, and artificial intelligence to lead a new era in medical imaging with more robust decision-making.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S1047951118001749

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Ethical Standards. An expedited approval from the Children's Hospital of Orange County Internal Review Board was obtained for using echocardiographic and MRI data from the patient. This article does not contain any studies with human participants or animals performed by any of the authors.

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