High resolution 3D imaging of post-mortem human fetal hearts

Eleftheria Pervolaraki[1], Steven Reynolds[2], Adriana Bucur[2], Alejandro Frangi[3], Richard Anderson[4], Martyn Paley[2], and Arun Holden[1]

[1]Faculty of Biological Sciences, University of Leeds, Leeds, Yorkshire, United Kingdom, [2]Academic Radiology, University of Sheffield, Sheffield, Yorkshire, United Kingdom, [3]Mechanical Engineering, University of Sheffield, Sheffield, Yorkshire, United Kingdom, [4]MRC Centre for Reproductive Health, Universityy of Edinburgh, Edinburgh, East Lothian, United Kingdom

Introduction

Cardiac function is closely related to myocardial structures, which have been known as myolaminae or sheets. The organisation of these structures is complex and it undergoes structural changes during development. High-resolution imaging can provide information on fibre orientation and organisation throughout the myocardium. Techniques such as diffusion tensor (DT) MRI and Fast Low Angle SHot (FLASH) have provided a better visualisation of the helical angles and the cleavage planes, respectively, of the human fetal heart.

Methods

The hearts were stored in Tyrode containing 0 mM CaCl2, 4% formaldehyde and 0.1%Gd-DTPA (Dimeglumine gadopentetate, Magnevist, Bayer Schering Pharma) and immersed in Fomblin® for MRI in a Bruker BioSpin (Ettlingen, Germany) 9.4T vertical MRI/S system. Cardiac geometry was imaged using a T1 weighted FLASH (Fast Low Angle SHot) sequence with 300 averages, TE = 5.3ms and TR = 15ms, for ~115h at a resolution of 58 x 58 x 58 µm, a matrix size of 256 x 256 x 360, a field of view of 14.8 x 14.8 x 20.8 mm with a flip angle of 30º [similar to 1]. DTMRI acquired cardiac geometry at 170µm with matrix size 128 x 128 x 128, TE = 15ms, TR = 500ms and a *b* value of 1000s/mm^2. The hearts were obtained from abortions performed under the UK 1990 Human Fertilization and Embryology Act. Storage of tissue, in premises, for imaging was licensed by the 2004 Human Tissues Act, all procedures were approved by NHS and University ethics committees, and informed maternal consent had been obtained for use of fetal material in research.

Results

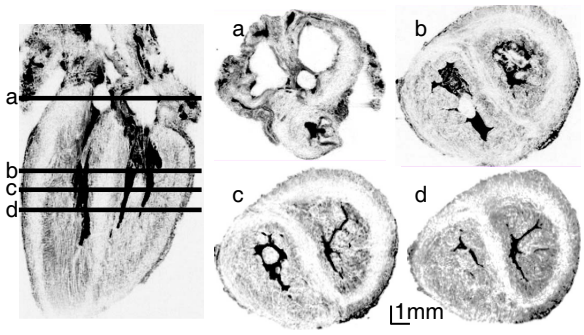

Figure 1. FLASH MRI determined organisation of a human fetal heart (139 DGA), resolution 58x58x58µm. The image is black/white inverted, with black Gd-DTPA signal. A long-axis slice is illustrated on the left with black lines (a, b, c, d) indicative of the positions of the short-axis slices represented on the right.

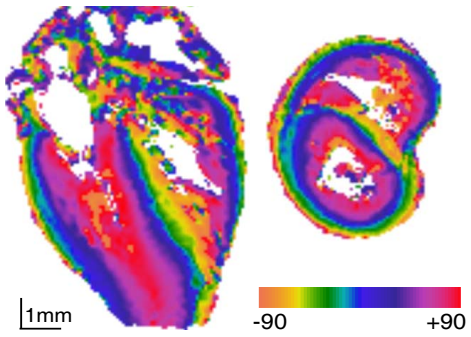

Figure 2. Architecture of human fetal heart (143DGA) from DT-MRI with 0.15mm isotropic voxels. Colour-coded representation of one long-axis slice and one mid-equatorial short-axis slice of the transmural helix angles of the heart.

Discussion

Mapping human fetal cardiac physiology is crucial for understanding normal development during gestation. MRI (DT and FLASH) offers high-quality spatial resolution images for the visualisation of cardiac structures such as cleavage planes, helix angles and fibre organisation during different developmental stages. FLASH MRI (Fig1) showed that the left and right ventricular free walls have similar thickness and that the sub-epicardial tissue appears more compact than the more interior sub-endocardial tissue. DT-MRI demonstrated a clear transmural helical organisation (Fig2) from –ve to +ve (something we did not observe in hearts with an age <116DGA; data not shown here).

Reference 1. Gilbert SH et al. Am J Physiol Heart Circ Physiol 302 H287-H298, 2012