

High Resolution MR Imaging of the Fetal Heart with Cardiac Triggering: a Feasibility Study in the Sheep Fetus

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Introduction

One of the greatest challenges in the fetal MR imaging is the evaluation of the fetal heart. Usually the cardiac imagings in adults are ECG triggered and is made with breathhold of the patient. Since the fetal heart lies within the uterus, a direct triggering of the heart frequency of the fetus is not possible. Until now, the echocardiography is the gold standard to visualize both the anomalies of the heart and of the great vessels. The aim of this study was to assess the feasibility of the cardiac triggered MRI of the fetal heart in sheep model.

Material and Methods

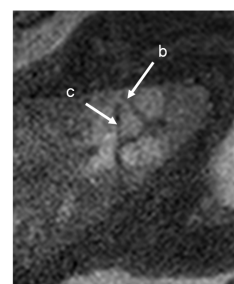
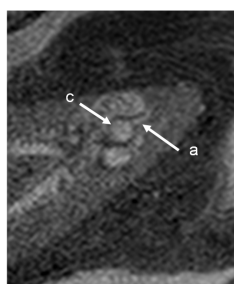
Images of the heart were performed on 6 pregnant ewes on a 1.5 T scanner (Philips Medical Systems, Best, Netherlands). The fetuses were chronically instrumented with a carotid catheter to measure the fetal heart frequency for the cardiac triggering. An initial T2-weighted turbo-spin-echo (T2 TSE) sequence was used for general anatomical orientation (TE 90 msec; TR around 4 seconds - the exact value depended on the number of slices needed to cover the area of interest). With this sequence, both a pseudo two chamber and a pseudo four chamber view of the fetal heart were performed to have the first idea of the morphology and the localization of the organ. Then a sensitivity encoding (SENSE) Cine- MRI sequences (FOV 380; TE 1.5ms; TR 3.0ms; TFE-Factor 12; Flip angle 60°; THK6.0/-1.2) with a total scan time of 54 s with breathhold of the maternal sheep and ECG triggering from the carotid catheter of the fetus in short axis of the fetal heart were performed. The voxel sizes were 1.98mm in cranio-caudal and 1.8mm in anterior-posterior orientation and the slice thicknesses were 6 mm each. Saturation bands were used to minimize fold-over artifacts in the phase-encode direction. The images were triggered by maternal ventilation. With the same parameter described above, the four, two and three chamber view was performed.

Results

The fetal heart frequencies ranged between 130 and 160 bpm. The mitral, the tricuspid, aortic and the pulmonary valves could be clearly observed. The foramen ovale could be visualized interatrially. The contraction was shown in cine sequences. The average blood volume at the end systole was 3.4ml (SD±0.2). The average volume at the end diastole was 5.2ml (±0.2); thus the stroke volumes of the left ventricle in the systole were between 1.7ml and 1.9ml with ejection fractions of 38.6%, respectively 39%.



Four chamber view in Cine-MRI:
Systole: a. left ventricle, contracted in systole; b. foramen ovale closed; c. aortic valve opened; d. right ventricle
Diastole: a. mitral valve opened; b. foramen ovale opened with a small jet; c. aortic valve closed; d. tricuspid valve opened



High resolution Cine-MRI of the fetal heart in short axis view: a. in diastole, the aortic valve is closed; b. in systole, the aortic valve is opened.

Discussion

In this present study, it was possible to perform a cardiac triggered MRI of the fetal heart for the first time ever. Herewith the feasibility and the possibility of the fetal cardiac MRI could be shown. The main limitation of this study was the invasiveness for the cardiac triggering. Cardiac triggering was only possible in a fetal sheep that was chronically instrumented with a carotid catheter. Therefore this approach was limited to experimental animal studies. Due to the invasiveness of this method, it is surely not practicable in human. Nevertheless, our results are of clinical interest. Although this study was invasive, it clearly demonstrated that the use of ECG triggering in fetal cardiac imaging is of great importance for enhancing the quality and thus the applicability of MR imaging. Using the ECG triggering, the fetal heart was visualized anatomically as well as functionally with the MRI technique. In the future it is necessary to develop a non-invasive approach of the fetal ECG triggering.

Conclusion

The ECG triggered cardiac MRI of the fetal heart allowed a meticulous evaluation of anatomical structures and functional information. This feasibility study demonstrates the applicability of MRI for future evaluations of fetuses with complex congenital heart defects, once a non-invasive method has been developed to perform fetal cardiac triggering.