

Fetal cardiac MRI and left ventricular function assessment using a new gating strategy based on Doppler Ultrasound: Preliminary results

Jin Yamamura¹, Björn Schönnagel¹, Manuela Tavares de Sousa¹, Chressen Much¹, Friedrich Ueberle², Gerhard Adam¹, Fabian Kording¹, and Fabian Kording¹

¹Diagnostic and Interventional Radiology, University Medical Center Hamburg-Eppendorf, Hamburg, Hamburg, Germany, ²Biomedical Technology Fakultät Life Sciences / Medizintechnik, University of Applied Sciences Hamburg, Hamburg, Hamburg, Germany

Target Audience

Clinicians and scientists dealing with fetal magnetic resonance tomography (MRI), especially for audiences trying to perform cardiac MRI in fetus in utero.

Introduction/Purpose

The commonly used method to evaluate the fetal heart is echocardiography (ECG). However, the detection of congenital heart diseases by ECG varies from 45% to 74% and an alternative imaging modality would be desirable. Fetal cardiac magnetic resonance imaging (MRI) has the potential to visualize anatomy and to assess functional parameters of the fetal heart but was up to now not feasible due to a missing gating strategy. The purpose of this study was to perform fetal cardiac MRI using a newly developed Doppler ultrasound sensor (DUS) for external fetal cardiac gating in human fetus for the first time.

Material and Methods

Three pregnant volunteer (gestation week 32, 34, 34) were examined at 1.5 T MRI to evaluate the DUS gating method for fetal cine MRI. To obtain a gating signal from the fetal heart, an MRI compatible ultrasound transducer of a cardiotocogram was employed for cardiac triggering. The ultrasound transducer (HP 15245A) of a standard CTG (model HP 8040A, Hewlett Packard, Palo Alto, USA) was employed for cardiac MRI triggering instead of the routine 4-lead ECG. The transducer consists of a printed circuit with 7 piezoelectric crystals and passive electronic components. It emits 1024 kHz ultrasound pulses at a repetition frequency of 3.2 kHz and an ultrasound power of 1.5 mW/cm². DUS signals from the CTG were transferred to LabView with a data acquisition card. Trigger signals were processed based on a newly developed algorithm and transmitted to the physiologic unit of the MRI for cardiac gating.

Initially scout images were obtained in axial, coronal and sagittal orientations with half-Fourier acquisition single-shot turbo spin-echo (HASTE) sequences

(TR 1080 ms, TE 55 ms, Flip angle 150°, FoV 400 mm). Afterwards, retrospective cine cardiac MR imaging was performed by using a steady-state free precession (SSFP) sequences in two-, three-, and four-chamber long-axis orientations and in the short-axis orientation not only to assess the morphology but also to assess the left ventricular function. The typical scan parameters were: TR 34.91 ms; TE 1.34 ms; FoV 400 ms; Flip-angle 55°; slice thickness 3 mm. Left ventricular function parameters were assessed by cardiac cine MRI and compared to parameters obtained from consecutively performed standard ECG.

Statistical analysis:

Linear regression was performed to estimate any significant differences between DUS triggered fetal cardiac MRI and the echocardiography, which was used as gold standard.

Results

Cardiac gating signals from the fetus could be reliably detected. No artefacts and interferences were observed, resulting in very good image quality (Figure 1 & 2). The synchronous contraction of the ventricles was clearly visualized from the apex to the base with an average R-R interval of 464 ± 94 ms. The average end-systolic and end-diastolic volumes calculated from cine cardiac MRI and ECG were 0.58 ml / 0.62 ml and 3.17 ml / 3.22 ml, yielding stroke volumes of 2.60 ml / 2.59 ml with an ejection fraction of 80 % / 81 % and cardiac output of 334 ml/min / 335 ml/min, respectively. There was no significant difference between the DUS triggered cardiac MRI and the echo-cardiography.

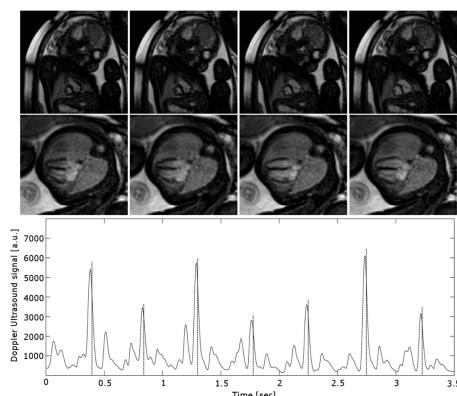


Figure 1: Short axis images of end- and mid-systole and diastole in the upper row and in the four chamber view below respectively. Shown at the bottom is the acquired Doppler ultrasound signal during MRI acquisition and the corresponding trigger signal outputs.

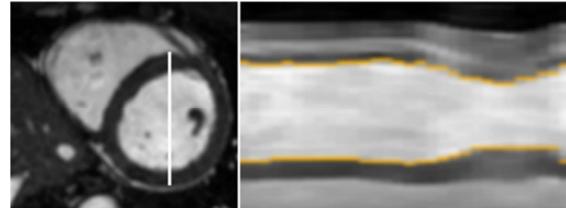


Figure 2: Short axis images of fetal heart in whole cardiac cycle, i.e. within the total R-R-Interval, using the DUS-triggering. One can recognize the whole contraction of the fetal heart with any significant artefacts.

Discussion/Conclusion

For the first time, cine cardiac MRI could be performed in a human fetus using a newly developed DUS device and dedicated software for fetal cardiac triggering. Fetal cardiac functional parameters revealed high agreement in comparison with standard fetal echocardiography. Fetal cardiac MRI has the high potential to detect cardiovascular malformations and to evaluate fetal cardiac function and, hence, may be important to overcome the limitations of echocardiography.

Key Words: fetal MRI, cardiac MRI, triggering method, ultrasound, Doppler, fetus