Pseudo ECG-gating in fetal cardiac MRI
Preliminary results of a new method to evaluate congenital heart disease (CHD) in the fetus, with echocardiography correlation

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Purpose
Accurate preoperative diagnosis of CHD is paramount for birth management, surgical decisions and survival.
Fetal echo is the standard prenatal imaging modality but may be limited by acoustic window.
The purpose of this study is to investigate feasibility of pseudo ECG-gating and real time MR fluoro to improve temporal resolution and allow qualitative & quantitative analysis of fetal cardiac MRI (fetal CMR).

Materials & Methods
Fetal CMR was performed following IRB approval

19 fetuses (GA 28-36 weeks)
14 structurally normal hearts
5 known/suspected CHD

Fetal cardiac MRI (FCMR)
Fast T2 sequences were performed to evaluate fetal cardiac anatomy, to localize the fetal heart & to establish short & long axis imaging planes.

Steady-state free precession (SSFP)
Real time MR fluoro cine
short and long axis views to evaluate cardiac anatomy & function

Materials & Methods
The fetal heart rate (HR) was determined at the time of fetal echo.

pseudo ECG-gating
ECG simulator (Fluke Biomedical, Everett, WA) was used, to create an ECG trace – to replicate the fetal HR during the MR examination.
Continuous ECG recording during SSFP MRI acquisition was achieved using a wireless ECG system (Philips, Best, The Netherlands).

Materials & Methods
Quantification of LV function
Using 4 chamber [horizontal long axis] and/or 2 chamber [vertical long axis] views of the LV, an area length ejection fraction measurement was performed on FCMR images and qualitative function was visually assessed and graded as decreased, normal or increased
Echo – LV and RV ejection fraction was visually assessed and graded as decreased, normal or increased
**Materials & Methods**

Quantification of LV function

Using 4 chamber (horizontal long axis) and/or 2 chamber (vertical long axis) views of the LV, an area length ejection fraction measurement was performed on FCMR images and qualitative function was visually assessed and graded as decreased, normal or increased.

**Normal fetal heart**

End systole

End diastole

**Tetralogy of Fallot**

Posteriorly positioned twin.

Fetal echo shows a VSD (↑) & overriding aorta (AO).

Sagittal oblique SST2 view shows PA atresia (↓) and branch pulmonary arteries (↑) arising from the ductus arteriosus.

**TOF & esophageal atresia**

Fetal echo shows RV hypertrophy in this patient with TOF (↑).

FCMR shows MPA stenosis (↑), uplifted cardiac apex (↑), & aorta overriding a VSD (↑).

Inset image – dilated proximal esophagus due to atresia & TEF.

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**TAPVC**

FCMR shows a bridging liver and markedly hypoplastic pulmonary veins & (black↑) & AVSD (white ↑).

Pulmonary venous drainage suspected to be abnormal, below the diaphragm, on echo was confirmed on MR (white ↑).
Materials & Methods

LV & RV end diastolic (EDV) & systolic volumes (ESV) and ejection fraction (EF) were estimated using cardiac analysis software available on an Extended Workspace (Philips, Best, The Netherlands) and/or by multiplying the thickness of the slice by the sum of all the areas in the data set.

Qualitative, quantitative, & anatomic findings were compared to fetal echo; correlation was made by 2 experienced readers.

Fetal cardiac mass

Fetal echo showed a hyperechoic LV mass (↑), confirmed on FCMR as hyperintensity (↑), consistent with rhabdomyoma, but renal and neuro findings of tuberous sclerosis were not found on fetal MR.

Double outlet right ventricle

Fetal echo shows the main pulmonary artery (P) and the aorta (A) arising from the right ventricle (RV).

Findings of normally related great vessels and double outlet right ventricle are confirmed on axial FCMR (A) and (P). Ductal arch (black ↑).

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TAPVC

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Pulmonary venous drainage suspected to be abnormal, below the diaphragm, on echo was confirmed on MR (white ↑).
Preliminary results show pseudo ECG-gating FCMR and real time fluoro MR are feasible and qualitative functional analysis correlates well with fetal echo.

FCMR is essential for identifying or confirming normal & abnormal cardiothoracic anatomy, including definition of:
- pulmonary atresia
- anomalous pulmonary venous drainage
- hypoplastic ventricles
- atrioventriculoseptal defect
- tetralogy of Fallot
- probable rhabdomyoma
- normal cardiac structures

Results

Pseudo ECG-gated SSFP & real time MR fluoro cine for fetal CMR is feasible and functional analysis correlates with fetal echo.

Fetal CMR can be used to identify or confirm normal and abnormal fetal cardiac anatomy and is especially helpful when acoustic window limits sonographic examination.

Conclusion

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Clinical relevance

Fetal CMR is a valuable tool in evaluation of CHD. Direct fetal HR monitoring is not feasible in MR. Pseudo ECG-gating is a user friendly method for improving temporal resolution of fetal CMR images.

Artifacts

Pulsation (arrows) from the maternal aorta (small arrow) can result in ‘zebra’ stripe ghosting artifact (dotted ellipses) which obscure the fetal heart during systole.

Although the artifact persists in diastole, maternal aortic pulsation is reduced in diastole.

By changing the phase and frequency direction from R-L to foot-head, the artifact is resolved and cardiac structures are seen clearly.

Limitations

Small size of the fetal heart in relation to the size of the voxel and slice thickness potentially makes qualitative functional measurement inaccurate.

Small sample size.