FETAL CARDIAC MR (FCMR)

Author: **Damir Jaganjac**[1.]

[1.] Application Specialist at Berg for Canon CT/MRI, Bosnia and Herzegovina

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Magnetic resonance imaging is a non-invasive method that does not use ionizing radiation to produce images, which is its greatest advantage for visualizing fetal pathology. Fetal magnetic resonance imaging is used to visualize pathologies of the central nervous system, abdomen, thoracic organs, and heart, particularly when ultrasound examination is insufficient. FCMR allows detailed visualization of the fetal heart and surrounding structures during pregnancy. It is particularly useful in diagnosing congenital heart defects and assessing fetal circulation, especially when other methods such as ultrasound are inconclusive.

EQUIPMENT

The procedure can be performed on 1.5T and 3T magnetic resonance devices.

In addition to the MRI machine, the most important role belongs to the ECG machine.

This procedure requires a Doppler ultrasound system (Smart Sync) by Northh Medical.

Smart sync device is compatible with all leading MR device manufacturers such as: Canon, Siemens, General Electric, Philips, United Imaging.

Connection to MR systems is established via Wi-Fi or an additional connector box that is an integral part of the device, depending on the specific MRI system manufacturer.

The ECG of each device operates based on the heart's electrical potentials, and upon entering the magnetic field, distortions of the RR interval may occur. The larger the magnetic field, the more pronounced the distortions.

The Smart Sync device is based on ultrasound and therefore has no distortion.

The Smart Sync device measures myocardial motion and generates a trigger in real time at the beginning of systole and at the beginning of diastole.

Its application is simple and requires no skin preparation, no ECG electrodes, and it is not affected by patient movement. It is reliable and safe to use, with no interference with the MRI system in cases of low ECG voltage (large patients), postoperative scar tissue, or in patients with a pacemaker.

It is suitable for both retrospective and prospective imaging. Retrospective imaging are used for patients with arrhythmia or irregular heartbeats, and in the prospective mode, triggering is specifically set to occur in the diastole.

Systole:

The actual motion of the myocardium that we aim to freeze in time is measured. Depending on the beat-to-beat variation, the delay of the systolic trigger on the R-wave is between 100-130 ms

actual motion is always sorted into the right cardiac phase in retrospective CINE sequences. This is not possible with ECG, as the time between the R-wave and the actual motion varies from beat to beat within a range of 60–120 ms, leading to motion artifacts when using ECG triggering

the state of motion always starts in the same cardiac phase as measured (the trigger). This is independent of the RR interval length = non periodic beats. With ECG, the motion state is not measured and will be sorted into incorrect cardiac phases => Improved image quality in case of arrhythmia

Diastole:

It is activated at the time point when no motion occurs, at the beginning of diastasis (the resting period) Advantage: The diastolic trigger can be used as real-time information if acquisition (prospective) is intended to occur during the resting phase. There is no need for calculations. For prospective scans with longer preparation times, a systolic trigger can be used, and the time between systole and diastole is displayed on the Smart Sync monitor

SAFETY: as is known during the examination itself, the body warms up after the RF wave and therefore it is necessary to limit the time duration of the examination and avoid examinations in the first trimester when the fetus is most sensitive. The vast majority of today's data have failed to show that MRI exposure has adverse effects on the developing fetus. 3T MR examinations performed in normal mode for less than 30 minutes can be considered safe. Gadolinium-based contrast agents (GBCAs) should not be given1 Keep the duration of MRI exposure as short as possible and apply normal mode (SAR<2W/kg)3

PERFORMING THE PROCEDURE:

Indications for this procedure are congenital heart defects, functional assessment of the heart with assessment of the flow and volume of the heart chambers, planning of interventions soon after birth.

For engineers working with magnetic resonance imaging and cardiac magnetic resonance, there is no significant difference in the procedure. Standard sequences are used. The sequences used are as follows:

SSFP CINE: Commonly used to assess cardiac function and morphology

PC blood flow: 2D measurement of blood flow

4D flow: Evaluation of blood flow through the aorta and large blood vessels.

T1/T2 mapping: - Cardiac tissue characterization

Examinations can be performed during the second and third trimesters of pregnancy, with fewer artifacts observed in the later stages of pregnancy when the fetus is larger (≥32 weeks of gestation)

For this procedure, the patient can lie on her back or on her left side. The supine position has proven to be superior to the lateral position, as the fetus remains calmer and motion artifacts are reduced.

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CINE sequence parameters:

	Parameters	Comment
FOV	270	Depending on anatomical dimensions and oversampling
No Wrap/Oversampling	70/70 %	Individual setting
Layer thickness (mm)	5-6	
#of layers	3	Individual setting with GAP-2
In-plane pixel acquisition	1.65 × 1.45	165 (freq) × 185 (phase)
Reconstruction pixel	1.05 x 1.05	Not relevant
Flip angle (FA)	70 (1.5T)/60 (3T)	
TR / TE	3.5/1.65 4.2/2.1	
Temporal resolution	26.5ms	
Acquisition phases	17.4	automatic adjustment depending on heart rate
Acquisition phases of cardiac cycle (%)	67	Adjust to temporal resolution
Reconstruction of cardiac phases	26	Changes may be caused by scanning time
NAQ/NEX/Acquisition	1	
Acceleration factor	1.8	SENSE, SPEEDER
Scan time	28	Depends on the number of layers, temporal resolution and spatial resolution
Sequences with BH	YES	Fewer artifacts than movement
Duration (cover / concatenation)	8-12 s	
RF shim	Adaptive	Adapt shim to the patient
B0	Volume	Adapt shim to the patient

Table1: Recommended CINE sequence parameters

FLOW sequence parameters:

Parameters	Values
TR	4.6 ms
TE	2.9 ms
FOV	280x230 mm
Layer thickness	5 mm
Flip angle (FA)	10
Acquisition voxel	2.5x2.5x5
Reconstructive voxel	1.17x1.14x5mm
Cardiac phases	35
VENC factor	120 cm/s
NAQ/NEX/Acquisition	1
Temporal resolution	12-13 ms
Sequence Duration	12s

Table 2: Recommended parameters for Flow sequence

RESEARCH

The study in Bosnia and Herzegovina was conducted in collaboration with gynecologists, cardiologists, and radiologists with the aim of evaluating image quality.

In Bosnia and Herzegovina, 7/1000 babies have heart problems in the fetal period.

For this study, 10 female volunteer patients were included with the aim of optimizing magnetic resonance parameters and the Smart Sync ECG system.

The research was conducted on Canon MRI machines of 1.5T and 3T.

CINE sequences and Flow sequences were used for the review.

Of the 10 fetuses, 9 had normal findings, while one fetus was diagnosed with ASD, confirming the validity of this method, as the abnormality had not been detected by ultrasound.

The advantages include: high-resolution imaging for visualization of small structures, a non-invasive method that does not use ionizing radiation, tissue characterization, and flow dynamics analysis.

The use of parallel imaging has greatly improved image quality and accelerated acquisition, while the use of artificial intelligence for denoising has eliminated noise and significantly enhanced image quality.

The limitations include fetal motion and limited availability, as the procedure requires specialized equipment and expertise; however, it is now available in Bosnia and Herzegovina.

The patients who underwent the examination are between 25 and 35 weeks pregnant.

CONCLUSION

FCMR is a non-invasive method that does not use ionizing radiation.

It is used as a complement to ultrasound examinations, particularly when ultrasound findings are inconclusive, such as in later stages of pregnancy or in cases of placenta previa.

In addition to cardiac structures, it enables visualization of all surrounding structures and possible anatomical abnormalities.

It allows for surgical planning before delivery so that the planned procedure can be performed as soon as possible after birth, avoiding delays associated with postnatal diagnostic planning and thereby saving valuable time for treatment.

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