

FROM RESEARCH TO CLINICAL APPLICATION

Experts in the field of fetal CMR share their experiences. Through their insights, we explore how fetal CMR has evolved from research-driven innovation to a vital tool in clinical practice.



Your general workflow at Lund University Hospital:

The patients are referred to the hospital after an ultrasound performed by a midwife has shown suspicion of a cardiovascular malformation. A fetal echocardiogram is then performed by the obstetrician and fetal cardiologist, whereafter fetal CMR is considered in cases where ultrasound seems insufficient. Clinical fetal CMR scans are planned during office hours, and all patients are invited to participate in research scans. Pure research scans including healthy volunteers are commonly executed during evenings and weekends. Two dedicated techs and one researcher are available to perform fetal CMR scans, with a senior available if needed. The formal reports are written by a paediatric radiologist and usually images are shown for the fetal cardiologist and discussed together with echocardiography findings.

Common patients you scan?

Tetralogy of Fallot (TOF), hypoplastic left and right heart syndrome (HLHS/HRHS), CoA, Ebstein anomaly, multiple malformations.

Common MRI protocol you use?

A standard clinical protocol is commonly used, with addition of research sequences as feasible. The basic protocol consists of overlapping anatomical tra/sag/cor SSFP



Erik Hedström,
Associate Professor at Pediatric Radiology at Lund University

stacks for anatomy, cine transversal and short-axis stacks together with the standard cine 4/3/2 chamber views for function. A 3D sequence is used for fetal weight determination, and T2-weighted images for nutmeg pattern assessment. 2D flows are performed at least in the umbilical vein and descending aorta, which may be repeated during ma-

ternal hyperoxygenation.

Any research? Or only clinic?

All clinically referred patients are also offered participation in research scans added to their clinical scans. Healthy volunteers are imaged for development and reference values.

Do you write reports? Who writes them and what to include?

A paediatric radiologist writes the report, which includes a dedicated cardiovascular report. As part of the report, there is also an overview assessment of the fetal, placental, and maternal anatomy. Other incidental findings have so far ranged between herniated discs, cysts including more severe multicystic disease, placental anomaly, to tumours.

VOICES FROM THE FIELD

“Fetal CMR is an amazing tool that has transformed the way we diagnose congenital heart diseases prenatally, and more importantly has helped us provide more clarity and understanding for expecting parents. It has helped us prepare for high-risk infants and allowed for lower risk infants to remain with their mothers with less intensive monitoring after birth, allowing for that important bonding.”

Richard Friesen, M.D.

Pediatric Cardiologist,
Children’s Hospital Colorado, USA

“Fetal CMR as a complement to fetal echocardiography can provide valuable diagnosis and prognosis-relevant information in cases of cardiac malformations or anomalies.”

Prof. Laurent Salomon,

Maternal Fetal Medicine,
Hospital University Paris Necker, France

“Fetal CMR has the potential to become an adjunct to echocardiography for comprehensive assessment of cardiovascular disease and recent technical developments support its integration into clinical practice.”

Prof. Julian Luetkens,

Interim Chair Radiology, University Hospital Bonn, Germany

“Fetal CMR is a great addition for us when things get tough, and ultrasound reaches its limits! It helps us prepare for the time after delivery of babies with the most complex cardiac and situs anomalies and we are learning more about the structure and function of the fetal myocardium.”

Prof. Brigitte Strizek,

Director of obstetrics and prenatal medicine,
University Hospital Bonn, Germany

“As a member of the team who first published on this topic, I see two groundbreaking futures in fetal CMR: From a clinical standpoint, a major improvement in our diagnostic and prognostic capabilities regarding congenital heart diseases when ultrasound examinations are limited, e.g. by maternal obesity. From a research standpoint, a paradigm shift on the way we understand the physiology and pathophysiology of both fetal and placental circulations.”

Prof. Guillaume Gorincour,

Pediatric Cardiologist, Foundation LUMIERE,
ELSAN Clinique Bouchard, France

Your general workflow in the Hospital:

Fetal CMR is mentioned at time of fetal diagnosis at the 20-week scan. Patients are then referred for fetal CMR, either at the 20-week scan or at the 28-week scan when they return for repeated monitoring. The fetal CMR then coincides with the last clinic visit around 32 to 34 weeks. We try to book the fetal CMR at the same time as the fetal cardiac echo and the clinician review.

Who is referring patients to the fetal CMR?

Our patients are referred by our fetal cardiologists after diagnosis.

Common patients you scan?

Our referrals include patients with single ventricular pathology, including hypoplastic left heart syndrome, but also other duct-dependent circulations that require ductal stenting in the postnatal period, suspicion of coarctation, transposition of the great arteries, severe tricuspid regurgitation, and other unusual cases.

Common MRI protocol you use?

We have a standard protocol that we slightly adapt according to clinical referral questions. We start with real-time CINE imaging for initial localisation of the heart. We then perform a quick 3D volume for fetal volumetrics



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followed by our cine imaging and flow imaging. At the end, we acquire the black blood HASTE for the slice-to-volume (SVR) reconstruction.

Any research? Or only clinic?

All our patients receive a clinical report and are also consented for research.

Do you write reports after your scan? Who writes them and what to include?

The fetal CMR reports are written by me, a pediatric cardiologist with level 3 EACVI accreditation in congenital CMR. We have reporting templates for the different common diagnoses. For example, see our CoA template on the next page: ●

REFERENCES FOR REPORTING TEMPLATE

- 8 Kacem et al., "Fetal Weight Estimation: Comparison of Two-dimensional US and MR Imaging Assessments", *Radiology*, 2013
- 9 Maskatia et al., "A Fetal Risk Stratification Pathway for Neonatal Aortic Coarctation Reduces Medical Exposure", *J Pediatr.*, 2021
- 10 Minocha et al., "Reference Values for Fetal Cardiac Dimensions, Volumes, Ventricular Function and Left Ventricular Longitudinal Strain Using Doppler Ultrasound Gated Cardiac Magnetic Resonance Imaging in Healthy Third Trimester Fetuses", *J Magn Reson Imaging*, 2024
- 11 Toole BJ et al., "Importance of relationship between ductus and isthmus in fetal diagnosis of coarctation of aorta", *Echocardiography*, 2016
- 12 Gómez-Montes et al., "Gestational age-specific scoring systems for the prediction of coarctation of the aorta", *Prenat Diagn.*, 2014
- 13 Lloyd et al., "Analysis of 3-Dimensional Arch Anatomy, Vascular Flow, and Ventricular Function in the Fetus with Coarctation of the Aorta", *Circulation: Cardiovascular Imaging*, 2021

REPORTING TEMPLATE: COARCTATION OF THE AORTA

HISTORY: Fetal suspicion of coarctation of the aorta

FETAL WEIGHT: Estimated fetal weight based on volumetrics today was **xx** kg⁸.

EXAM: A fetal CMR scan was performed. The scan was well tolerated. Static imaging, cine imaging, 4D Flow MRI, 2D Flow MRI, and static black blood with fetal USS ECG gating completed. Fetal HR was **xx** bpm. Standard images are available to view on **xx** platform, 3D reconstruction on **xx** platform. Key images are attached to the report below. Mother is aware that this is a cardiac scan only and not designed to assess any structures outside the heart.

CONCLUSION: Haemodynamic risk stratification tool suggests **xx** risk of coarctation, and anatomical risk stratification suggests a **xx** risk.

LEFT HEART: 4 pulmonary veins drain into the left atrium. The left ventricle *is/is not* apex forming (RV/LV length = **xx**). *Mildly slender/normal sized* mitral valve annulus. Visually good LV function. The ascending aorta arises from the LV. Normal sized ascending aorta. Left-sided arch with conventional branching pattern. The transverse arch is narrowed measuring **xx** mm (z-score **xx**) with a **xx** risk of coarctation⁹. On 4D Flow MRI imaging there is very *little/reduced/acceptable* mitral inflow seen (tricuspid/mitral inflow **xx:xx** %).

RIGHT HEART: Single right SVC and IVC drain into the RA. The tricuspid valve annulus is non-dilated. Normal RV function. The main pulmonary artery arises from the anterior RV. MPA is normal in size. Good sized branch pulmonary arteries.

VOLUMETRICS¹⁰:

LV:

LVEDV **xx** ml, **xx** ml/kg (N: 1.9-2.9 ml/kg)
LVESV **xx** ml, **xx** ml/kg (N: 0.8-1.6 ml/kg)
LVSV **xx** ml, **xx** ml/kg (N: 0.9-1.5 ml/kg)
LVEF **xx** % (N: 56-70%)

RV:

RVEDV **xx** ml, **xx** ml/kg (N: 2.5-3.7 ml/kg)
RVESV **xx** ml, **xx** ml/kg (N: 1.3-2.1 ml/kg)
RVSV **xx** ml, **xx** ml/kg (N: 1.1-1.7 ml/kg)
RVEF **xx** % (N: 46-59%)

MEASUREMENTS IN MM⁸:

- Mitral valve: **xx** (z-score **xx**)
- LV length: **xx** (z-score **xx**)
- Ascending aorta: **xx** (z-score **xx**)
- Distal transverse arch : **xx** (z-score **xx**)
- Isthmus (sag): **xx** (z-score **xx**)
- Isthmal displacement: **xx**
- Descending aorta : **xx** (z-score **xx**)
- Ductal arch : **xx** (z-score **xx**)
- Tricuspid valve: **xx** (z-score **xx**)
- RV length : **xx** (z-score **xx**)
- MPA: **xx** (z-score **xx**)

*Gestation specific z-score [xxx insert local reference for z-score]

FLOW VOLUMES PER CARDIAC CYCLE IN MLS (2D/4D FLOW MRI):

- Mitral valve: **xx**
- Tricuspid valve: **xx**

RISK STRATIFICATION SCORES:

ANATOMICAL:

- TV/MV = **xx** suggests *reduced/increased* risk of CoA (>1.48 increased risk for CoA^{11,12}).
- Aortic arch/Descending aorta ratio = **xx** suggests *reduced/increased* risk of CoA (<0.50 increased risk for CoA¹¹).
- Transverse aortic/Ductal arch ratio = **xx** suggests *reduced/increased* risk of CoA (<0.7 increased risk for CoA⁹)

HAEMODYNAMIC:

- 2D/4D Flow MRI imaging tricuspid/mitral inflow = **xx:xx** mls and **xx:xx** % (normal 50:50%; false positive 70:30%; true CoA 75:25%¹³).
- Cardiac MRI risk score is **xx** [**xx**%] (using Isthmal displacement/descending aorta ratio and left heart flow mls/kg/min¹³).