UPCOMING HIGHLIGHTS AND NEW APPLICATIONS

An insight into the new and developing approaches to further advance the field of fetal CMR.

In the coming year, we're expecting some exciting developments in fetal CMR. There are of course several topics that need to be addressed when thinking about the future. This includes improvements of *smart-sync*, important clinical findings how fetal CMR can impact treatment and care and of course new applications that are needed to bring fetal CMR to the next level. We as Northh Medical are continuously working on every front of this topic and are eager to contribute to the further development of fetal CMR.

Thinking about further improvement of *smart-sync* for the next year, we will release a new software update in 2024 that will improve the reliability of the gating signal especially in cases of an anterior placenta, high BMI patients and in cases where the fetal heart is very close to the transducer.

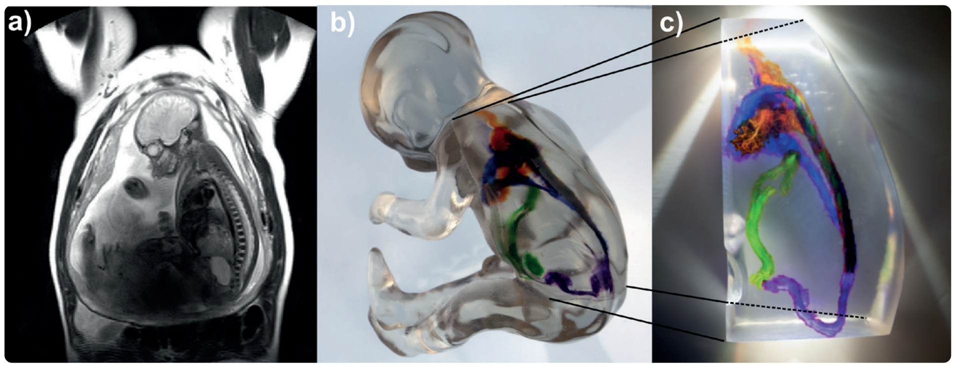

Figure 6: a) T2 weighted single shot fast spin echo localizers were used to obtain the fetal volume and b) 4D flow MRI was fused with the 3D volume. A 3D printed insert c) was created to minimize the optical distortion of the 4D flow MRI data.

In cooperation with the Childrens Hospital Colorado and Alexander Barker we are also working on increasing the acoustic window of the ultrasound transducer. This will enable a gating signal even in cases of larger fetal movement.

Until today, an amazing increase and presence of fetal CMR on conferences and publications has been observed. We anticipate this trend to continue in 2024 and we are more than curious on the results. With the increasing application of fetal CMR by the best specialists in the world we also anticipate advancements not solely in the realm of anatomical imaging, but also in the burgeoning area of fetal cardiac functional assessment. The refinement of imaging sequences, specifically tailored to meet the precise needs of paediatric radiologists and cardiologists, is expected. Moreover, enhancements in data acquisition acceleration and the improvements of techniques for motion artifact correction are anticipated. Additionally, advancements in flow imaging will facilitate a deeper understanding of specific complex CHD cases and possible outcome. This comprehensive understanding is an important objective in the context of ongoing progress in fetal cardiac diagnostics and therapeutic interventions.

One of the most important developments that is needed to establish fetal CMR in clinical care is to overcome fetal motion and to provide additional value to the already powerful fetal echocardiography. In this issue we are focusing on the development of 4D Flow and 3D postprocessing.

To provide an insight into the current state of fetal 4D flow imaging, a patient specific 3D print of a 33-week gestational age fetus combined with 4D flow MRI is shown in *Figure 6*. The greater vessels illustrate unique features of the fetal cardiovascular system and mixing patterns. For example, left heart flow is shown in orange (left atrium, left ventricle, aorta), right heart flow is shown in purple (right atrium, right ventricle, pulmonary artery, ductus arteriosus), and umbilical vein flow is shown in green. The data was acquired at the Children's Hospital Colorado and the University of Colorado Denver, Anshutz Medical Campus (postprocessing and 3D printing by Takashi Fujiwara, Conor Brady, and Nick Jacobson) where the group around Alex Barker is using 4D flow to calculate flow ratios between vessels in order to predict i.e. cases of aortic coarctation.

Building on this methodology, Dr. Pim van Ooij and his 4D Flow group at UMC Amsterdam have started their *FetalFlow* project end of 2023 in cooperation with

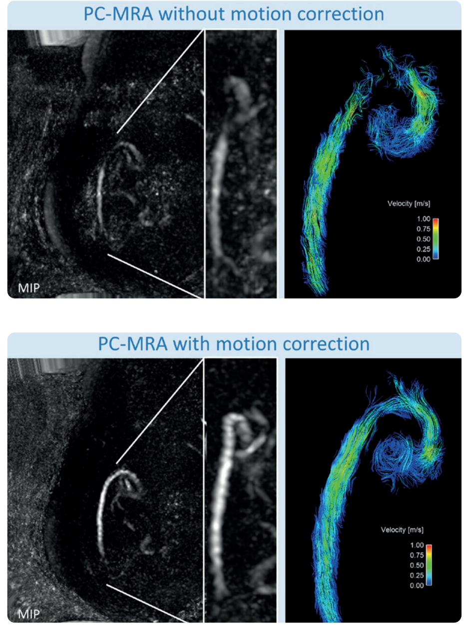

Figure 7: Fetal blood flow from the left heart to the descending aorta, shown in maximum intensity projections in the sagittal direction (left) and magnified inserts in the coronal direction (middle) of phase contrast magnetic resonance angiography (PC-MRA) images generated through 4D flow acquisition, with corresponding streamline visualizations (right). Motion compensated images have been corrected for maternal respiration and fetal bulk motion.

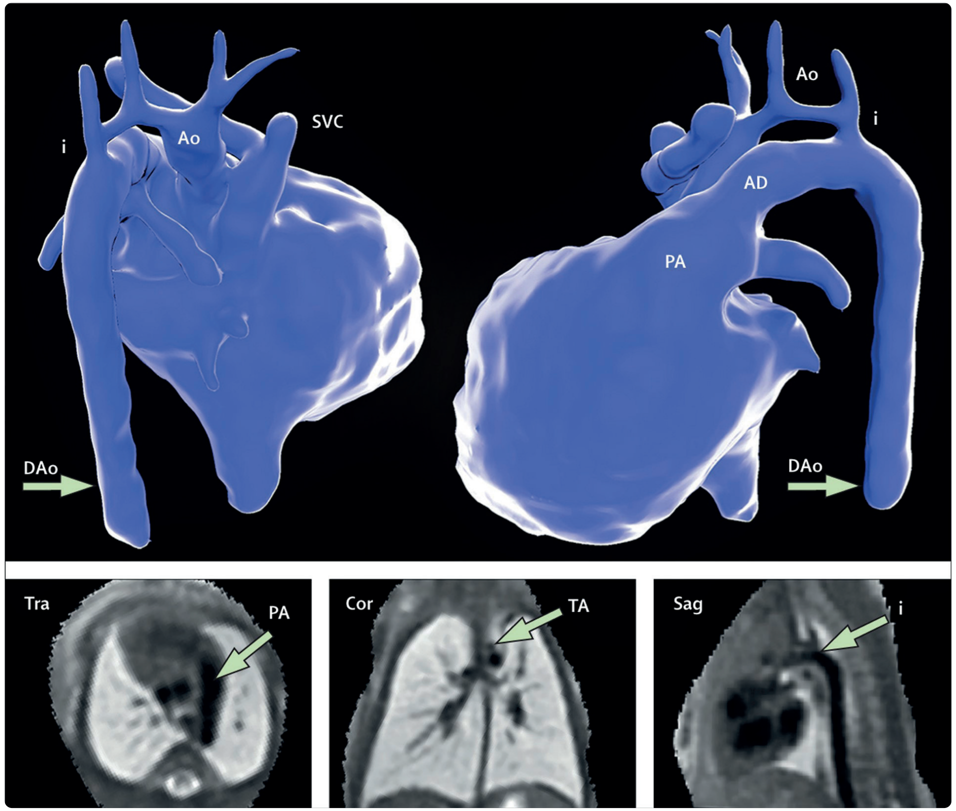

Figure 8: Segmentation of motion-corrected MRI data of a fetus with suspected coarctation of the aorta at 33 weeks' gestation. Posterior projection (top left) and left lateral projection (top right) are shown. The aorta (Ao), arterial duct (AD),descending aorta (DAo), aortic isthmus (i), and superior vena cava (SVC) are labelled. Coarctation was confirmed after birth and treated surgically. The bottom panel shows planes from the reconstructed 3D dataset in a transverse (Tra), coronal (Cor), and sagittal (Sag) orientation. See video 2 for more detail. TA=transverse arch. PA=pulmonary artery. Figure from Lloyd et al.[11]

Northh Medical. Their main objective is to employ advanced techniques such as 4D-Flow phase contrast, 3D Cine, and black blood imaging, enabling a detailed view of fetal cardiac flow dynamics and anatomy. Novel imaging technology will be developed to overcome motion artifacts caused by maternal respiration and fetal movements, compare *Figure 7*. Utilizing the *smart-sync* device to assess fetal cardiac motion, they aim to synchronize imaging sequences for precise motion compensation. To help with that, Northh Medical has developed a data logging function that allows the acquisition of fetal movement in real time. *FetalFlow* aims to redefine fetal health assessments through cutting-edge imaging innovations.

The use of *smart-sync* allows acquisition of intracardiac information and cardiac function, but it does not allow motion compensation or a 3D visualisation of the extracardiac vessels. However, extracardiac vessels are often necessary to visualize, especially in 3D, for a full understanding of the pathology. As the best possible prenatal diagnosis is the driver for the work of Northh Medical, we have decided to develop a post-processing tool based on the method developed at Kings College London and published by David Lyod et al. in the Lancet[11]. This method is based on a "slice to volume" reconstruction were several 2D single shot black blood images are used together with a motion compensation algorithm to calculate an isotropic high resolution 3D data set of the fetal heart. This data set can then be used to visualize the extracardiac vessels in 3D. One example is shown in *Figure 8* that illustrates the use of this post-processing tool.

We are happy to share the news that we already have developed a first beta version of this software and are currently testing it. We have simplified the workflow whereas the software only uses DICOM images as input. After a processing time of 10-20min the user will get an email notification that the motion compensated 3D dataset is ready to be downloaded. If you are interested to use this tool, please reach out to Dr. Fabian Kording at ***fk@northh.de.***

REFERENCE

11. Lloyd et al., „Three-Dimensional Visualisation of the Fetal Heart Using Prenatal MRI with Motion-Corrected Slice-Volume Registration".