FUTURE FOCUS: WHAT'S NEXT?

Key developments and expert insights on functional fetal CMR

Building on the content from our last webinar, we'll explore how fetal CMR is set to advance prenatal care and where this technology may take us in the future. Moderated by Dr. Malenka Bissell, the session featured leading experts who discussed key advancements and challenges in the field.

In this section, we share highlights from the session in an interview-style format, showcasing the most promising developments and future directions in fetal cardiac imaging.

RESEARCH TOPIC PRESENTED BY FOUR FETAL CMR EXPERTS

Julian Luetkens' presented research focuses on "Myocardial Strain Analysis in CHD." This technique tracks tissue motion and deformation of the fetal myocardium, specifically measuring longitudinal, radial, and circumferential strain. In a recent study involving 60 fetuses, Prof. Luetkens and his team found that strain patterns differ between healthy fetuses and those with CHD. They observed reduced left ventricular longitudinal strain, particularly in HLHS, and increased left ventricular longitudinal strain in fetuses with CoA. By using fetal CMR and optimized software for strain analysis, this method has shown high feasibility and reproducibility, possibly improving the understanding and differentiation of CHD.

Prof. Julian Luetkens,
Interim Chair Radiology, University Hospital Bonn

Can you explain what impact temporal resolution has on strain measurements, and whether it significantly affects the potential clinical use of this technique?

"For accurate strain estimation, high temporal resolution is essential. In our study, we had an average-temporal resolution of 17 milliseconds for reconstructed 25 images, which is much lower than what's used in adults when doing feature tracking strain with CMR. In echocardiography, however, the temporal resolution is even higher. Also, fetuses have much higher heart rates, the average in our cohort was 137 beats per minute. Although the temporal resolution of MRI cine acquisition is high, you still might miss the peak strain values. To use this as a clinical tool, it's crucial to accurately capture the peak strain. To determine if this is possible, we would need to conduct comparative studies, possibly with echo strain. However, we don't yet have clarity on this. Temporal resolution might be a limitation for fetal MRI strain assessment right now."

The second presentation by Alex Barker focused on efforts to establish normal values for fetal CMR in the third trimester, specifically regarding ventricular volumes, function, and strain. He and his team compared CMR to echocardiography and found that CMR-derived ventricular volumes were 50–100% higher due to geometric assumptions in echocardiography. However, when indexed by fetal weight, CMR values closely aligned with newborn studies. Alex also highlighted the importance of combining 4D flow MRI measurements with anatomical data to enhance the accuracy of diagnosing conditions like suspected CoA. The results showed promising predictive capabilities for adverse outcomes and high reliability in distinguishing true cardiac anomalies, paving the way for future multi-center studies and further advancements in fetal CMR.

Alex Barker, PhD,
Associate Professor Radiology at University of Colorado

We often encounter a lot of fetal motion throughout the stack. How do you handle this? Do you take multiple stacks? Do you have any tips for making the process more reliable?

"Sometimes we need to reacquire the stack or a specific slice of the stack due to motion. The more views you acquire, the higher the chance the baby will move, and for things to go wrong. In about 75% to 80% of our cases, we manage to get the short-axis stacks. We're also very careful with the timing of our acquisitions to avoid waking up the baby. However, once we start acquiring cine images with breath holds, we risk waking the baby up, which can be challenging and we need to reacquire. Since we're doing these as research studies for a reference value paper, we're fortunate to have the time to reacquire. But we need to consider what a realistic clinical workflow would look like. In a clinical setting, you can't keep trying to get that perfect stack – sometimes, you have to move on."

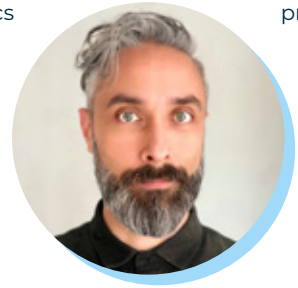
Eric Schrauben demonstrated the potential of 4D flow MRI for fetal cardiac imaging, emphasizing the importance of motion correction to improve its reliability. He presented cases where 4D flow provided valuable complementary information to echocardiography, such as in the diagnosis of transposition of the great arteries (TGA) and CoA. By introducing a motion correction pipeline consisting of a free-running (PROUD) acquisition and retrospective adjustments, he and his team significantly improved image quality, recovering smaller vessels and reducing mass conservation error from 14% to 5%. This advancement enhances the accuracy of both flow measurements and anatomical scans, supporting the clinical use of 4D flow MRI.

Eric Schrauben, PhD,
Scientist, MRI-Researcher, Amsterdam UMC, Netherlands

You're using a 3T scanner, but would prefer to use a 1.5T scanner. Why is that?

„I think the preference for a 1.5T scanner is because many other anatomical scans benefit from it. For 4D flow segmentations, it's often useful to have an imaging method that provides a more accurate representation of the anatomy, rather than just relying on a spoiled gradient echo image. That said, I understand your point—at 3T, we do get a stronger signal, especially in 4D flow acquisitions. So, it's definitely a trade-off."

Final insights into future topics were given by Joshua van Amerom on the 'Assessment of Cardiovascular Physiology'. He presented advancements in fetal CMR using 2D phase-contrast imaging to measure blood flow, offering key insights into fetal cardiovascular physiology. Furthermore, he highlighted the combination of T1 and T2 mapping for reliable blood oxygenation measurements and demonstrated how golden-angle radial acquisition improves motion correction compared to traditional Cartesian methods, enhancing image quality. Through clinical examples, including HLHS, Ebstein's anomaly, and TGA, he showcased the utility of fetal CMR for diagnosing CHD, guiding interventions, and informing delivery planning. The improved image quality and precise measurements provide critical insights for the diagnosis and management of CHD.



Joshua van Amerom, PhD,
Research Associate, Imaging Science & Biomedical Engineering, Sick Kids Toronto, Canada

Sometimes we don't try to identify each vessel right away; instead, we focus on capturing all the vessels and sort them out later. How do you approach this to ensure you've captured everything accurately?

"We have an excellent team here who are skilled and experienced at creating these prescriptions. It seems to be somewhat of an art, and that may limit wider adoption. But one way to learn would be to visit and see how it's done. There are also reference guides that include cross-sectional planes that show how to plan these scans."

CONCLUDING COMMENTS ON FUTURE DIRECTIONS

Are we really moving towards 2D flow as the future, or will we ultimately transition to 4D flow, eliminating the need to pinpoint individual vessels?

Joshua: I think low prescription complexity and redundant motion robust acquisition is the way to go. That's, I mean, just from based on my own background, being non-clinical, but also just what I've seen work quite well in the fetal brain, for example.

This involves densely covering the region of interest with numerous images and then assembling the data afterward. Similarly, with radial phase contrast acquisitions, we can extract the motion that occurred, perform data rejection, and process the results accordingly. For flow measurements, [...] a direct 4D flow acquisition is really appealing, especially if it is motion robust. We have done some work on this data, and I believe Eric was involved as well. At one point, we explored using 2D phase contrast measurements and reconstructing them using a slice-to-volume framework.

This approach remains appealing because it potentially combines the best of both worlds. However, it comes with extremely high computational complexity, making it a significant trade-off.

Eric: I don't think we'll be moving away from 2D flow anytime soon. However, as Josh suggests, it might be feasible to acquire multiple images or slice locations within a single stack. For example, the group in Denver is already doing this—they set up a prescription and then capture the next slice up from there. The idea is that, between the two slices, at least one will be usable, given the likelihood of motion.

That said, I agree it's a challenging task. Ultimately, the best approach moving forward will likely involve placing a box around the heart, developing an effective way to detect motion, and correcting for it. Measurements could then be performed retrospectively. However, while retrospective analysis is effective, it isn't always fast enough to meet clinical needs.

Alex: Building on what Eric and Josh have discussed, we often can't reliably capture some of the pulmonary flows, but we can almost always measure the descending aorta and the umbilical vein. In short, we try to get the 2D flows, but we don't spend too much time if the results aren't coming through. In those cases, we move on to 4D flow instead.

CONCLUSION

Fetal CMR is rapidly developing into a valuable diagnostic tool that connects research with clinical practice. Advances in functional imaging, motion correction, and data standardization are paving the way for more comprehensive fetal cardiac assessments, with the potential to significantly improve postnatal outcomes. However, there remains a strong need for further research in this area. Multi-center studies are essential to validate current findings and establish standardized protocols.

WANT TO WATCH THE RECORDING?
https://www.northh.de/recording

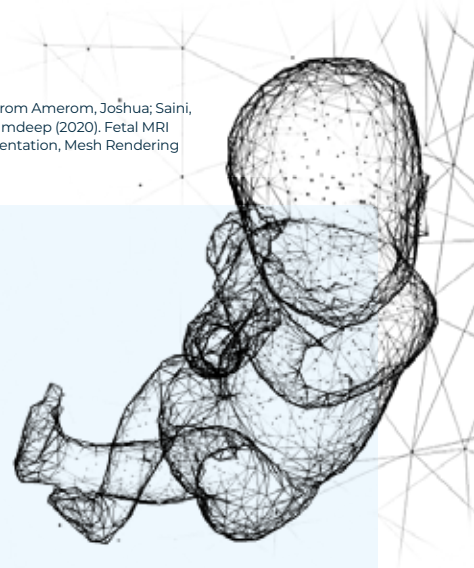


Figure from Amerom, Joshua; Saini, Brahmdeep (2020). Fetal MRI Segmentation, Mesh Rendering

KEY TAKEAWAYS

Promising research projects by using fetal CMR are ongoing:

- **Myocardial strain analysis:** Provides insights into fetal cardiac function, offering a complement to traditional echocardiography for enhancing the understanding and differentiation of CHD.
- **Normative Data:** Establishing MRI-specific benchmarks in healthy fetuses are vital for accurate diagnoses, especially in combination with 4D flow measurements.
- **Motion Correction in 4D flow:** Techniques to mitigate motion artifacts and therefore increase robustness are critical for advancing the clinical utility of fetal CMR due to better accuracy.
- **2D phase-contrast imaging:** Combining flow and oxygen saturation measurements by using 2D phase-contrast imaging helps plan delivery and improve neonatal outcomes.

Main Challenges remain:

- **High fetal heart rates** and **motion** are challenging. Temporal spatial resolutions must improve to ensure accurate diagnostic markers.
- Workflows and expertise for integrating these technologies with fetal CMR into **routine clinical** care need further refinement to improve efficiency and reduce manual adjustments.