FETAL MRI POST-PROCESSING

Using slice-to-volume reconstruction for fetal MRI post-processing of the fetal brain, thorax and body

Fetal MRI plays a crucial role in clinical settings, offering valuable insights for diagnosing and supporting fetal health. While postprocessing of MR images is well-established across all patient groups, there remains a significant gap when it comes to fetal imaging – no dedicated software solution exists. To address this unmet need, we have developed a fetal MRI post-processing platform. Our vision is to make post-processing of fetal MR images as seamless and accessible as it is for pediatric and adult imaging. The platform already integrates a slice-to-volume reconstruction algorithm, developed by King's College London (auto-proc-SVRTK package)[14], to provide a single volumetric motion corrected dataset.

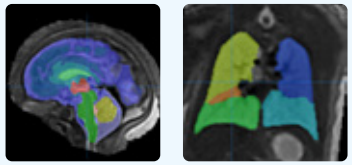
It is readily available for the brain[15,16], thorax[17] and body[14] for download and can be easily integrated into your preferred software for further analysis or annotation. Furthermore, we have incorporated the automated brain and lung volume segmentation algorithm developed by Uus et al.[18,19]. Development of the automated fetal weight estimation is underway in cooperation with Takashi Fujiwara and Alex Barker of the University of Colorado and we look forward to releasing it soon.

Fetal Motion Correction

BRAIN THORAX BODY

Turning 2D motion-corrupted images in a comprehensive motion-corrected 3D volume through slice-to-volume reconstruction.

Volume Segmentation



BRAIN THORAX

Automated segmentation and multi-regional parcellation with no manual work necessary.

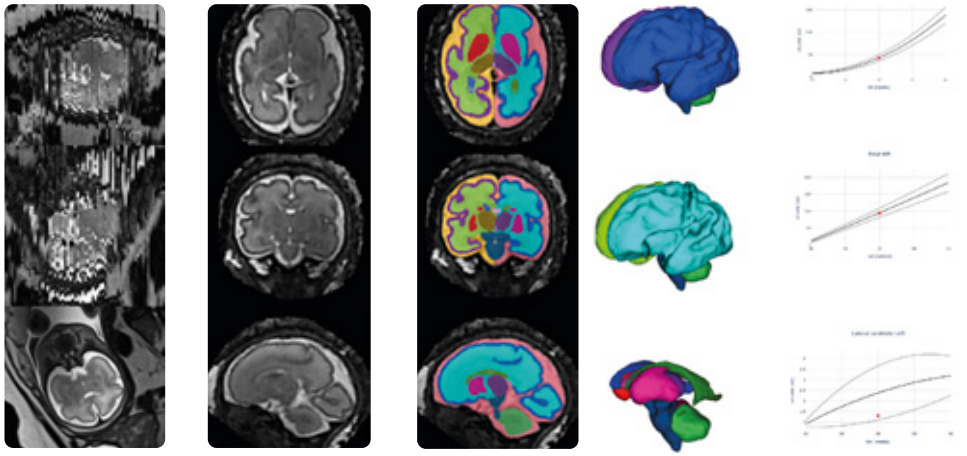
Disclaimer:
The fetal MRI Post-Processing Software is only for research purposes and is not yet CE or FDA approved.

REGION OF INTEREST: BRAIN

CHALLENGE: Image acquisition in specific planes can be complex and may require repeated scans for accurate results. Extensive training of MR personnel is necessary.

SOLUTION: A comprehensive brain volume offers re-orientation and accessibility in any imaging plane, significantly improving diagnostic capabilities. Additionally, automated brain segmentation and parcellation provide enhanced insights and efficiency.

INPUT DATA | **OUTPUT DATA** | **SEGMENTATION** | **REPORTING**



One motion-corrupted example image stack

Motion-corrected 3D volume

Automated multi-regional segmentation

Automated volumetry reporting for brain

AUTOMATIC BRAIN SEGMENTATION

For any reconstruction of the brain, a brain volumetry and brain segmentation with parcellation in different regions of interests is performed and can be viewed on the platform as well as downloaded.

The used algorithm was developed by Uus et al.[18] and incorporated a deep learning pipeline for the automated fetal brain segmentation.

The labeled region of interests include:

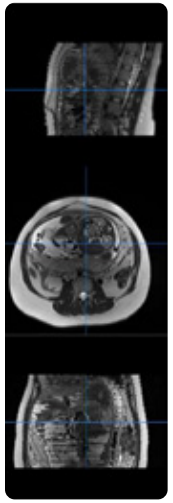
- Cortical grey matter
- White matter
- Cerebrospinal fluid
- Deep grey matter
- Ventricles
- Cavum
- Brainstem
- Cerebellum

REGION OF INTEREST: THORAX

CHALLENGE: Manual segmentation of the lungs in motion-corrupted 2D slices is both time-intensive and prone to errors due to motion artifacts, often resulting in incorrect volume assessments.

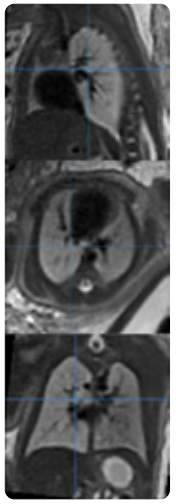
SOLUTION: A comprehensive 3D volume reconstruction facilitates tracking of anatomical structures. This is further enhanced by automated multi-regional lung segmentation and accurate volume calculation, streamlining the diagnostic process.

INPUT DATA



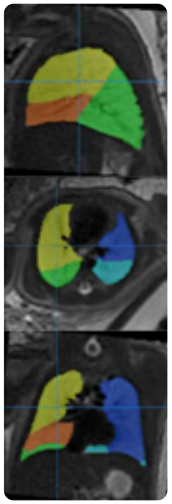
One motion-corrupted example image stack

OUTPUT DATA



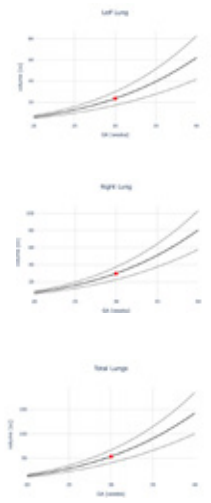
Motion-corrected 3D volume

SEGMENTATION



Automated multi-regional segmentation

REPORTING



Automated volumetry reporting for lungs

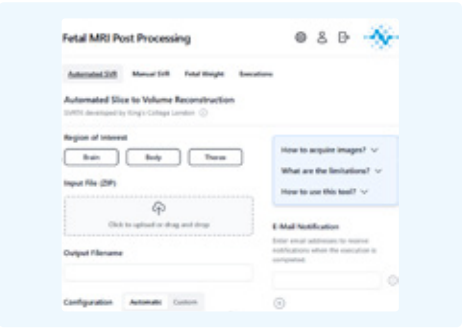
AUTOMATIC LUNG SEGMENTATION

Uus et al.[19] developed the automated lung segmentation pipeline and enabled the multiregional deep learning segmentation for both normal and abnormal congenital diaphragmatic hernia lung anatomy.

No more manual segmentation in corrupted individual slices is necessary. The parcellation is guided by location of bronchi and pulmonary vessel branches and regions with no pronounced vasculature, fetal lung histology studies and annotated adult CT lung lobe segmentation datasets.

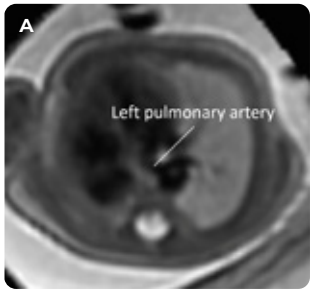
THE POST-PROCESSING PLATFORM

Register for FREE by simply scanning this code or visiting pp.northh.de and start the reconstruction of your fetal MR images!



EXAMPLE FOR PRACTICAL USE: ABSENT RIGHT LUNG AND SUSPICION OF COARCTATION OF THE AORTA

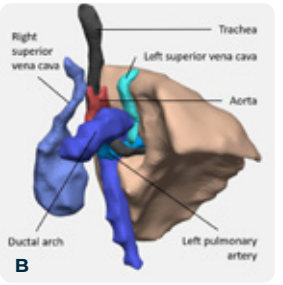
Clinical Case Report – Malenka Bissel & Lisa Ferrie (University of Leeds, Leeds teaching hospitals trust):



Fetal CMR was performed at gestational week 27 alongside body MRI to assess right lung tissue presence and investigate possible coarctation. Fetal echocardiography revealed no right pulmonary artery and raised suspicion of coarctation.

Serial ultrasounds, echocardiograms, and fetal body and heart MRIs were conducted in the same session. Due to early gestation, DUS *smart-sync* gating was not attempted, but the SVR platform with black blood imaging proved effective *(Figure 9)*.

In this case, the fetal CMR added very important additional information that was incredibly useful to understand the postnatally encountered difficulties with ventilation and oxygenation, as the baby was too unwell to undergo postnatal cross-sectional imaging.



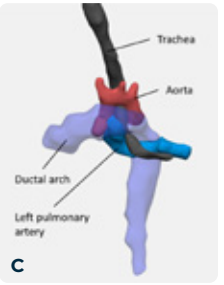


Figure 9: **(A)** SVR reconstruction from black blood HASTE stacks **(B)** 3D reconstruction from SVR data showing LPA sling **(C)** 3D reconstruction from SVR data showing all cardiac structures and lung volumes (right lung aplasia)

OUTLOOK: FETAL WEIGHT

CHALLENGE: Normalization of fetal anatomy and function using fetal weight. For example, blood flow measurements and the dimensions of the heart chambers are often described and analysed in relation to fetal weight[20].

SOLUTION: Fetal weight estimation using a deep learning network using a quick (< 10s) 3D acquisition (algorithm developed by Takashi Fujiwara and Alex Barker from the Children's Hospital Colorado in Denver).

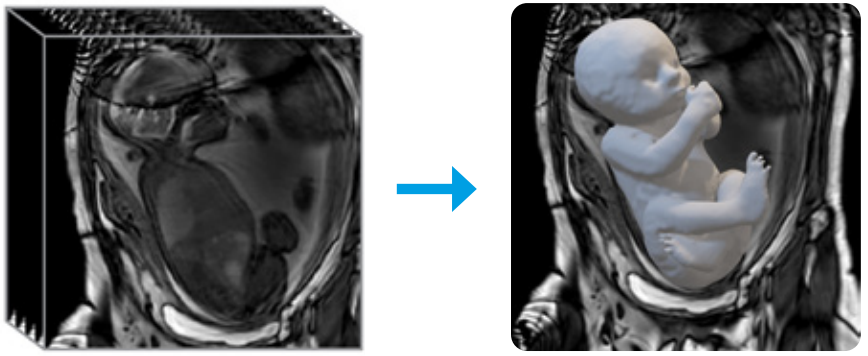
"We have extremely promising results but we're still in a multi-vendor validation phase and the release will be dependent on peer-reviewed publication of the results."

Alex Barker, University of Colorado

FETAL WEIGHT CALCULATION

On the segmented fetal body, the fetal weight is calculated using a conversion factor of 1.04 g/cm³ according to Kacem et al.[8].

Weight = Volume • 1.04 g/cm³



9-second breath-hold 3D FFE

Fetal weight estimate obtained in < 2 minutes

REFERENCES

14 Uus et al., "Deformable Slice-to-Volume Registration for Motion Correction in Fetal Body MRI and Placenta", IEEE Transactions on Medical Imaging, 2020

15 Uus et al., "Scanner-based real-time 3D brain+body slice-to-volume reconstruction for T2-weighted 0.55T low field fetal MRI", medRxiv, 2024

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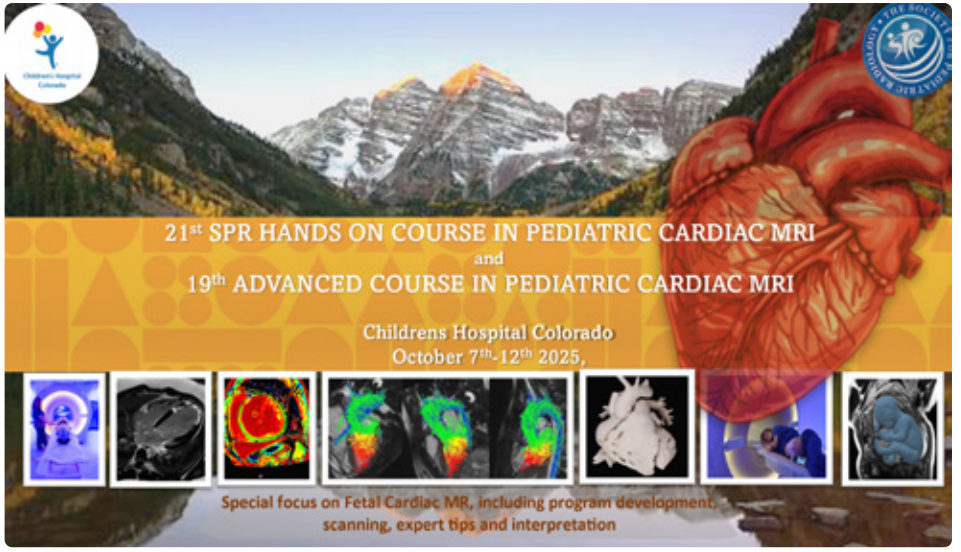
19 Uus et al., "Towards automated multi-regional lung parcellation for 0.55-3T 3D T2w fetal MRI", PIPPI MICCAI Workshop, 2024.

20 Ryd et al., "Automatic Segmentation of the Fetus in 3D Magnetic Resonance Images Using Deep Learning: Accurate and Fast Fetal Volume Quantification for Clinical Use", Pediatr Cardiol, 2023



WE'D LOVE TO HEAR YOUR OPINION ON FETAL MRI POST-PROCESSING!

Scan the code to participate in a short survey.

UNITED STATES UNIQUE CPT CODE FOR FETAL CARDIAC MRI

As fetal CMR becomes more widely used and accessible, the billing structure will need to keep pace. In the US, this would involve creation of a unique CPT code for fetal CMR. This code would recognize fetal CMR as a distinct procedure which utilizes unique acquisition methods (DUS gating) and unique expertise (fetal cardiology). US Groups wishing to assist with this effort can contact Dr. Schuchardt at ***ESchuchardt@health.ucsd.edu***