Fully Automated Tissue Perfusion Estimation Using Ultrasound: Application in Human Placenta

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Introduction

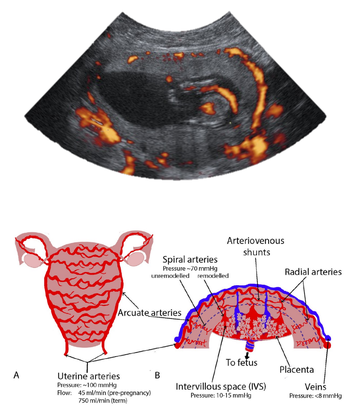
Background: power Doppler ultrasound (PD-US) is the ideal modality to assess tissue perfusion as it is cheap, patient-friendly and does not require ionizing radiation. However, meaningful inter-patient comparison only occurs if differences in tissue-attenuation are corrected for.

Objective: propose a fully automated method named **3D-svFMBV** (3D Signal Vessel Fractional Moving Blood Volume) to standardise the PD signals to correct the attenuation [1].

Clinical utility: evaluate 3D-svFMBV using 143 first-trimester placental ultrasound volumes. More biologically plausible perfusion estimates were obtained, showing improved prediction of pre-eclampsia compared with the results of the old technique FMBV [2].

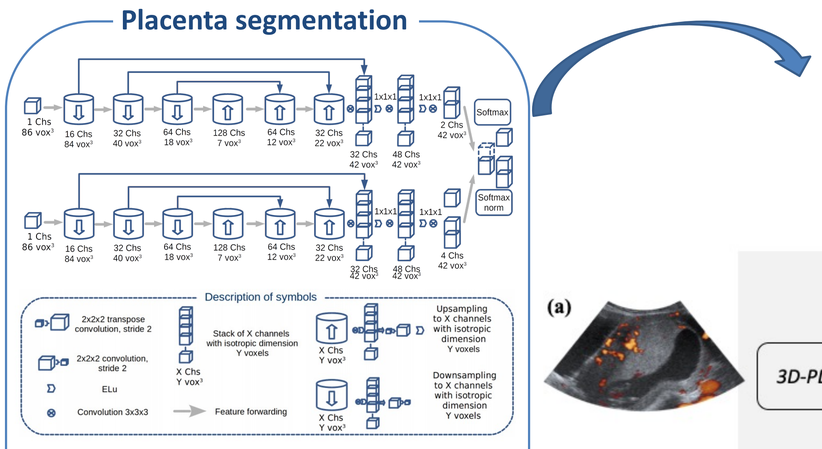
Ultrasound scans are carried out by a sonographer [3]

Power doppler ultrasound



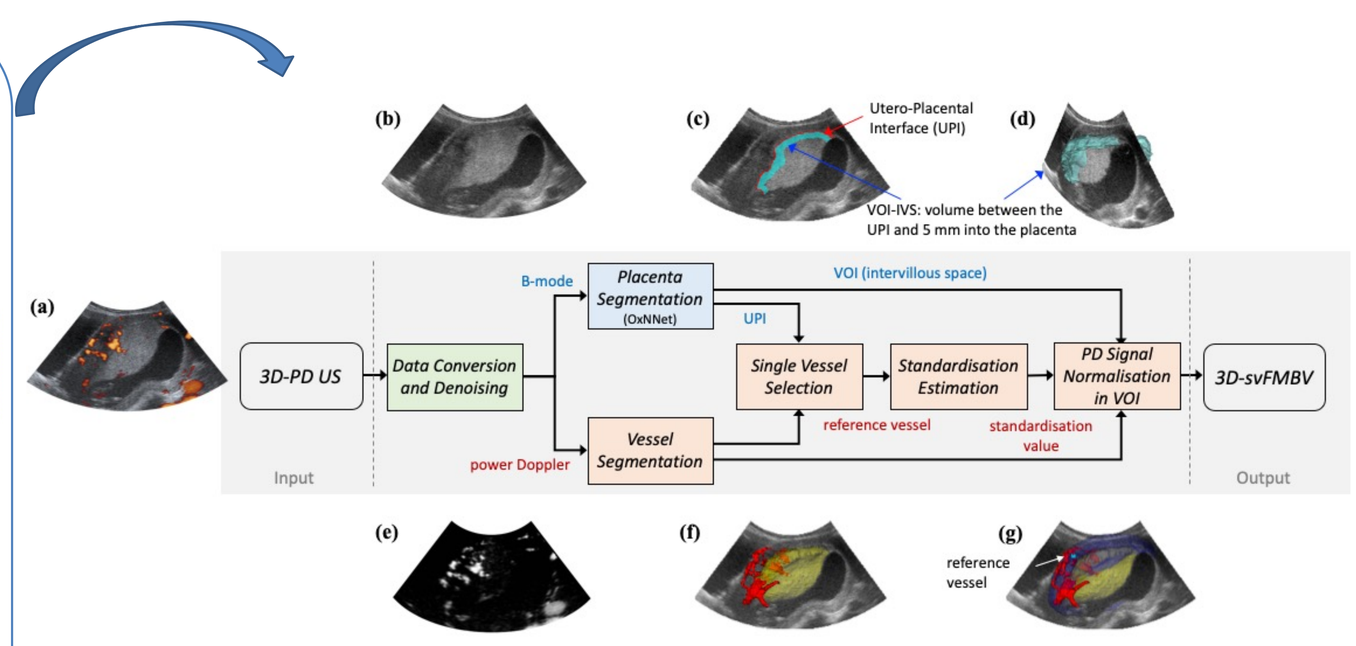
Uterine vasculature in pregnancy [4]

Method: 3D-svFMBV



A multi-class fCNN [5]

- Segment the **placenta, amniotic fluid and fetus** to localize **placental bed**
- Two pathway, hybrid Model using **Transfer Learning**
- Achieve the state-of-the-art performance, Dice similarity coefficient (**DSC**): 0.82 (0.08) for placenta, 0.93 (0.04) for amniotic fluid, 0.88 (0.04) for fetus



Scheme of 3D-svFMBV estimation: the processing pipeline shows the steps to estimate 3D-svFMBV values at placental bed.

3D-svFMBV estimation

Target tissue:

- Volume at the utero-placental interface (UPI).
- Contains the intervillous space (IVS), where the maternal blood from the spiral arteries bathe the fetal villi.

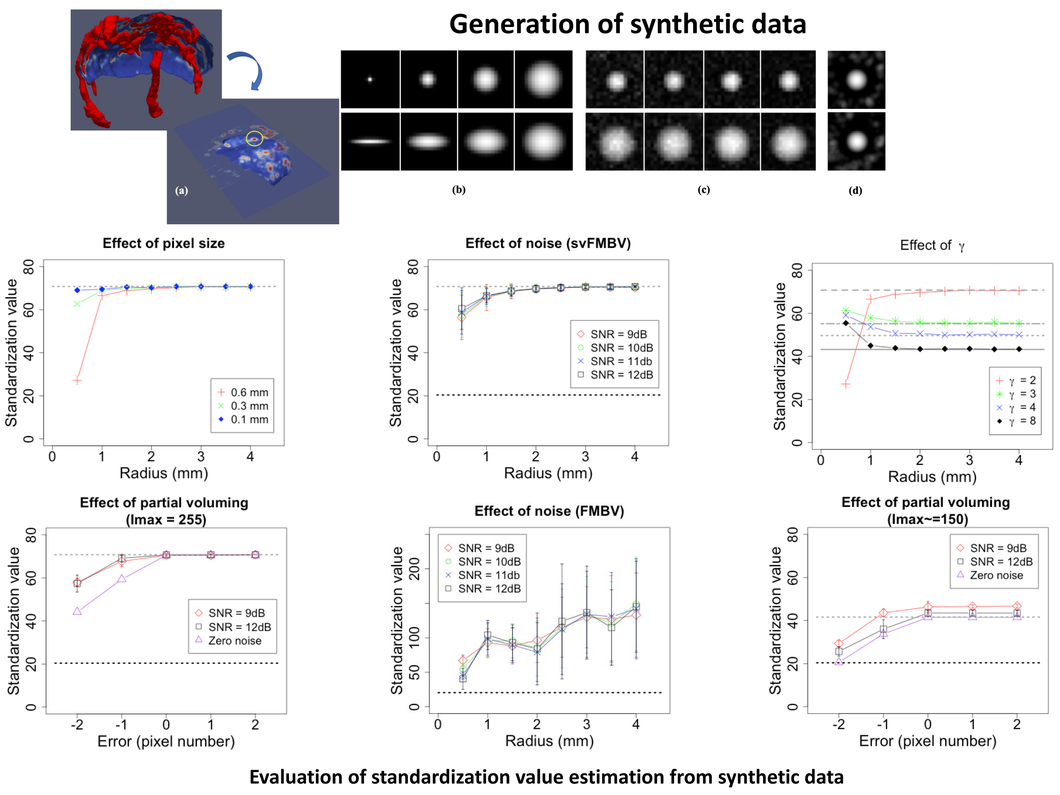
Standardisation value:

- A large single vessel located at a certain distance from the UPI into the uterus
- Record the maximum PD signal (**100% vascularity**)
- Experienced the same degree of attenuation as the target tissue
- **Standardisation value** (PD signal) calculated from this reference vessel

3D-svFMBV *

- Average PD signal values within the target tissue divided by the obtained **standardization value**.

Results

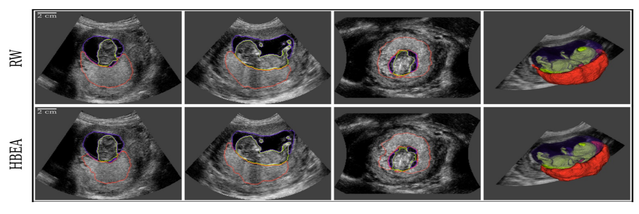


Evaluation of standardization value estimation from synthetic data

Clinical data:

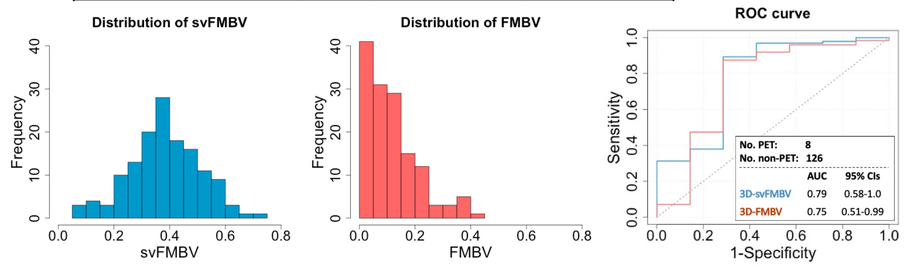
- A total of 143 women underwent scanning between 11+0 and 13+6 weeks' gestation. The pregnancy outcomes were collected from the hospital records
- 3D-US data were collected as part of a previous study with ethical approval for secondary analysis (REC ref: 08/H0604/163).
- Scans were acquired using a Voluson E8™ (GE Healthcare, Milwaukee, USA) scanner and a RAB4-8-D 3D/4D curved-array abdominal transducer.

Segmentation



DSCs: 0.85, 0.96, 0.94 for three components, respectively

Perfusion (3D-svFMBV)



Comparison between 3D-svFMBV and 3D-FMBV (Shapiro-Wilk test, p = 0.77 and p<0.001, respectively)

ROC curves for the prediction of pre-eclampsia

Conclusions

- The proposed 3D-svFMBV technique shows very promising results for automatically estimating perfusion in the first-trimester placenta.
- This has the potential to serve as a screening test for adverse pregnancy outcomes.
- The proposed perfusion estimation has the potential to be used for many different target organs e.g. ovary, kidney, and tumor perfusion.

References

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