MRI of the Placenta

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SickKids®

MRI safety

MRI interacts with the body in a number of ways:

- main magnet exerts strong forces on ferromagnetic material
- RF fields cause heating of tissue (temperature change should be at most 1 degree C)
- rapid switching of gradient fields induces currents that can stimulate peripheral nerves
- MRI produces acoustic noise (as high as 120 dB)

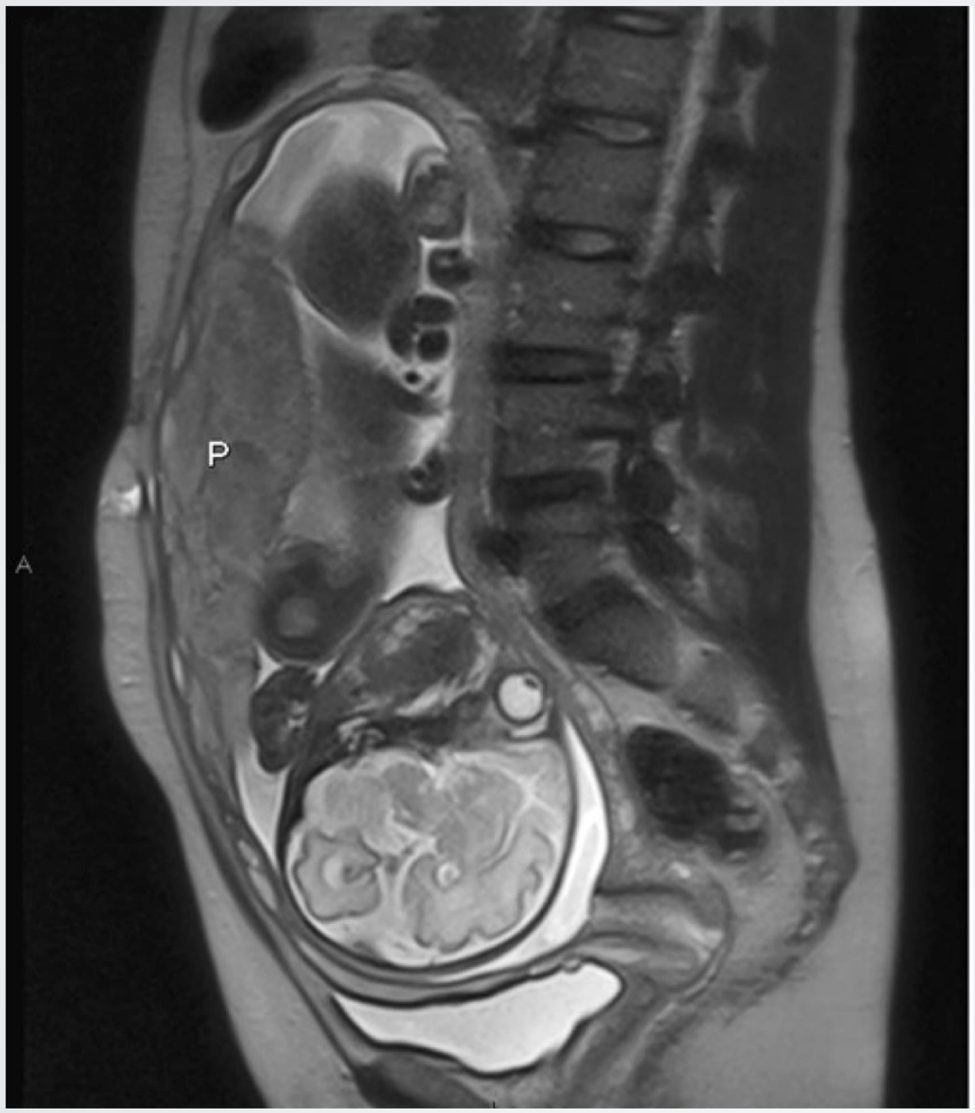
Extensive investigation has found no evidence of MRI being harmful during pregnancy.

Motion and fast imaging

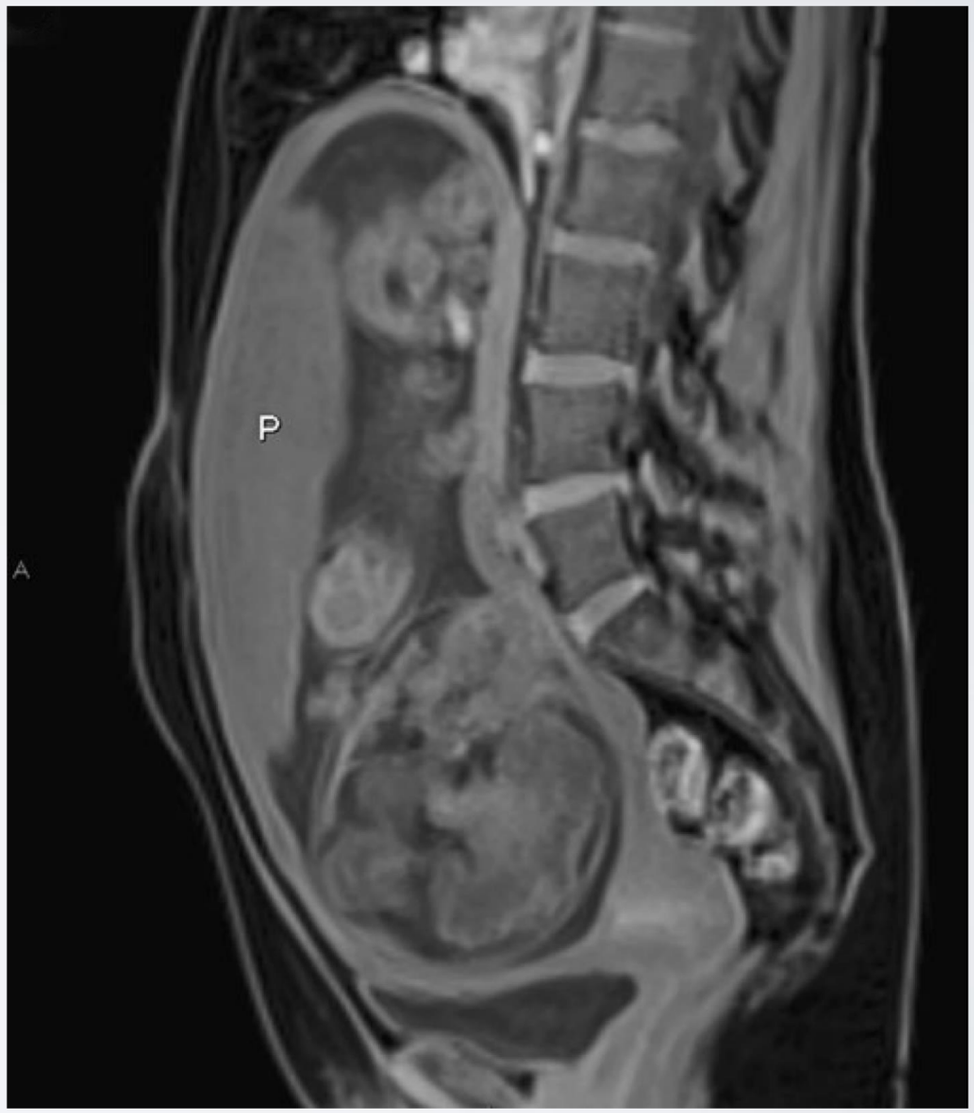
- MRI acquires an image from a whole 3D volume or 2D slice at once
- this region needs to be free of motion for the duration of acquisition
- sources of motion include respriatory motion and fetal motion, particularly early in gestation
- MRI images are typically acquired as quickly as possible in a single breath-hold to reduce motion

Contrast mechanisms: T1 and T2

- T2 weighting emphasizes fluid spaces, edema
- T1 weighting emphasizes tissue rigidity
- placental T1 and T2 drop with gestation



T2-weighted

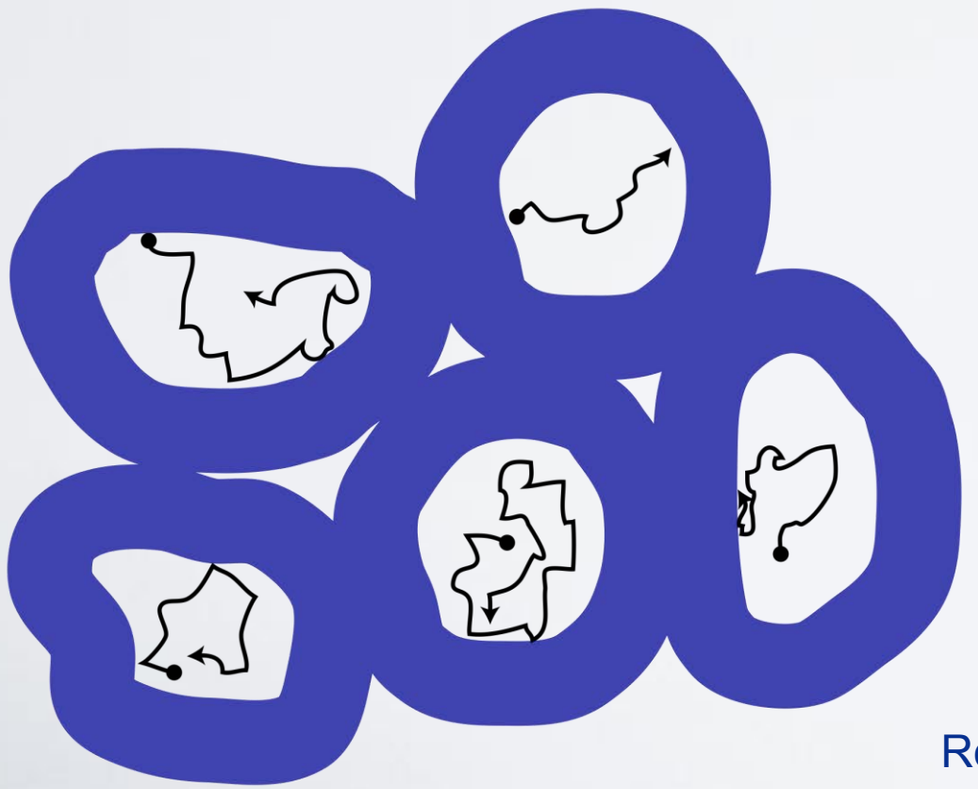


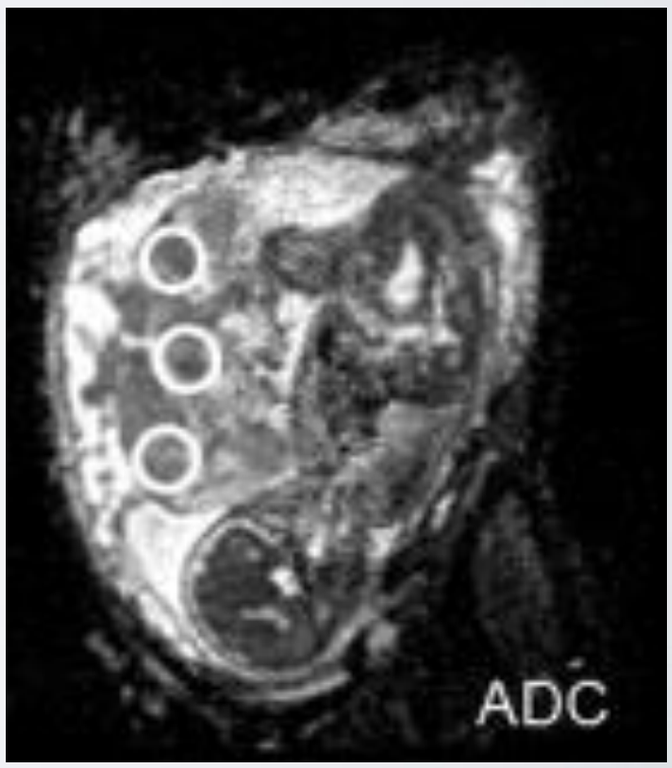
T1-weighted

Reproduced from Masselli et al. Abdom Imaging (2013) 38:573–587

Water diffusion

- MRI can be sensitized to random motion of water molecules
- cell membranes and structures that restrict motion lead to signal increase on a diffusion-weighted scan
- diffusion weighting creates contrast between the placenta and adjacent structures such as myometrium



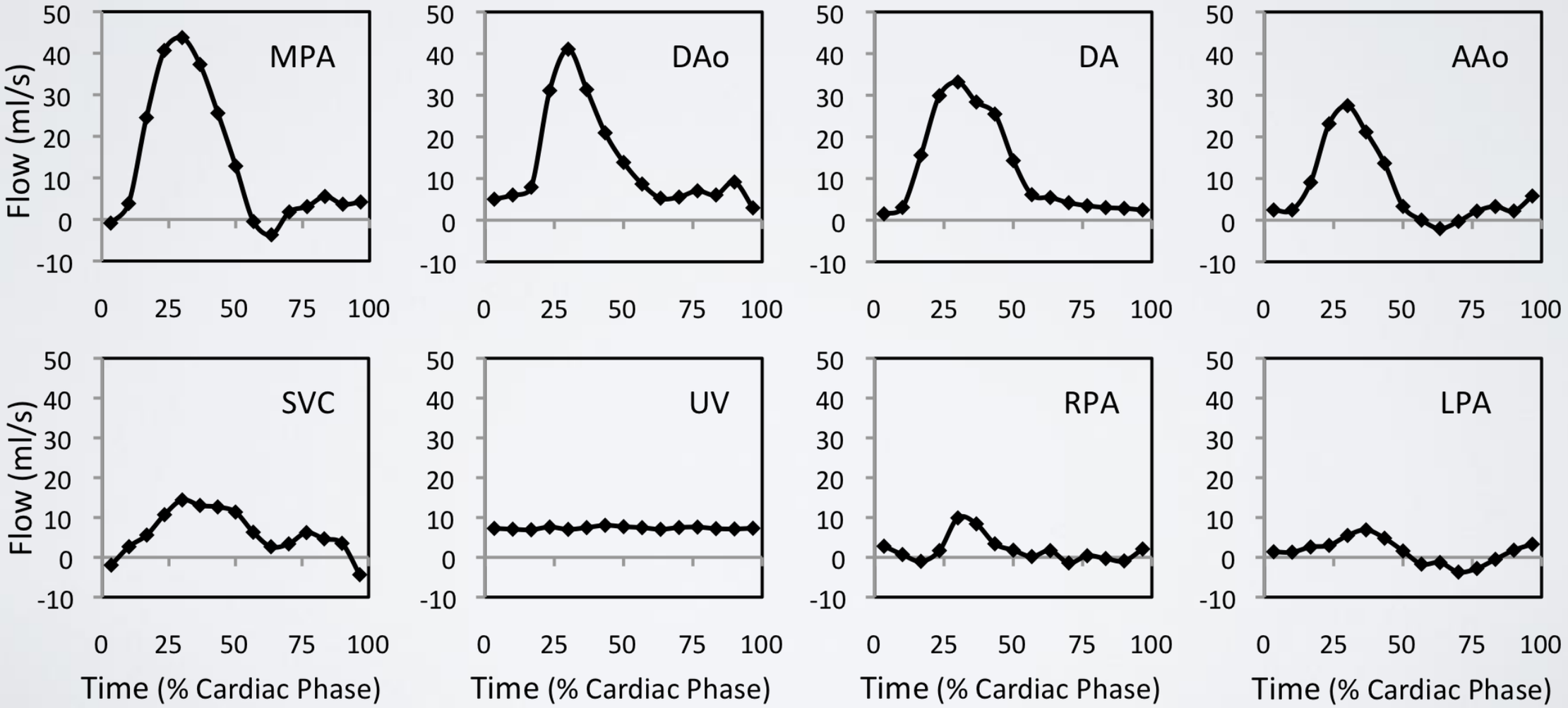


26 weeks GA

Reproduced from Manganro et al. Prenatal Diag. 30:1178-1184, 2010

Blood flow in a normal fetus

- phase contrast measurements of blood flow typically require fetal ECG
- metric optimized gating is a retrospective gating technique that eliminates the need for ECG (Jansz et al., MRM 2010)



normal fetus ~36 weeks GA

Courtesy of Drs. Macgowan and Seed

Placental blood volume: IVIM

- complex blood movement within a voxel, blood flow can be modelled as random motion

- Intra-Voxel Incoherent Motion or IVIM models the diffusion-weighted MRI signal as a sum of water diffusion and blood flow

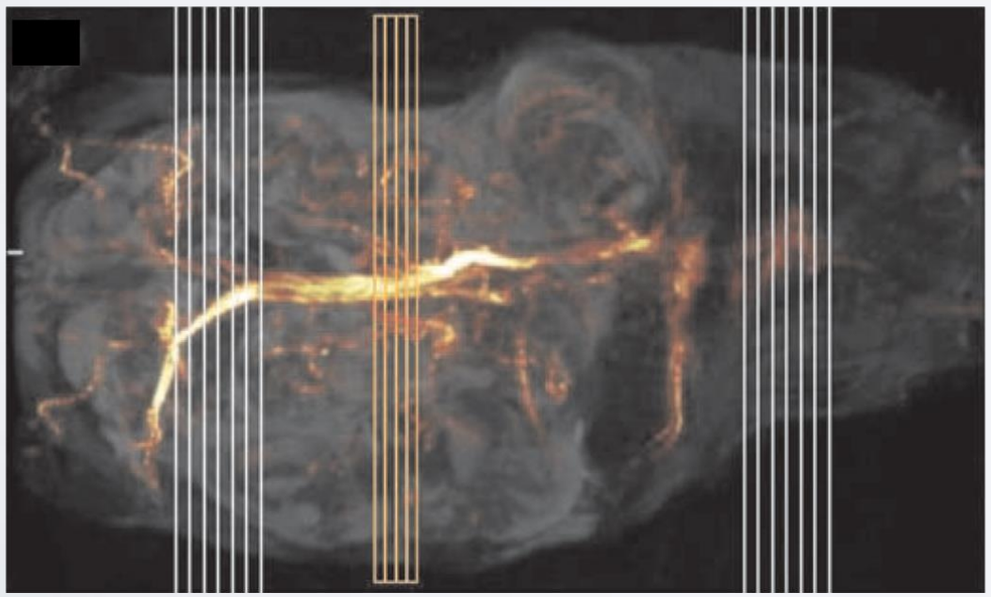
- IVIM has been used to estimate combined maternal / fetal blood volume fraction in the placenta to assess preeclampsia (Moore et al. NMRB, 2008)

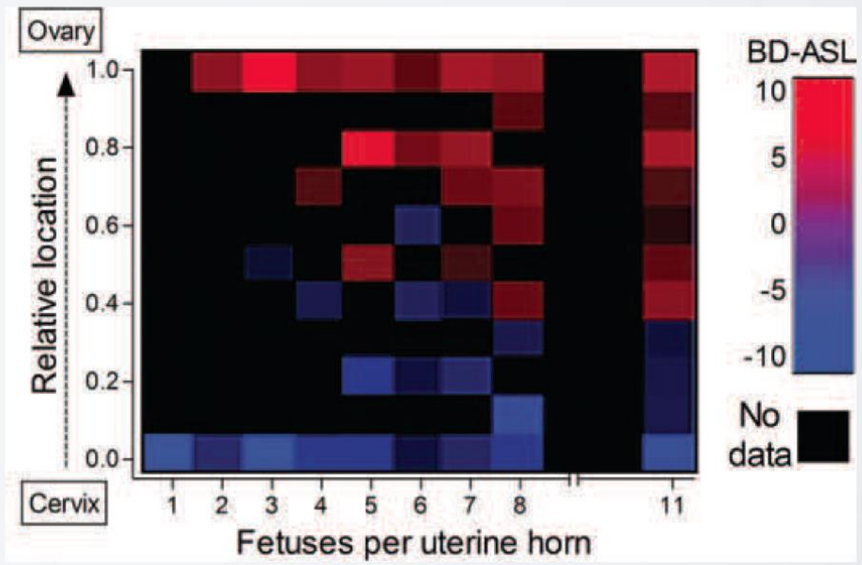
Placental perfusion

- tracer kinetics can be used to estimate utero-placental perfusion and blood volume
- Gadolinium chelates are a standard clinical agent for this purpose
  - safety during pregnancy is uncertain
  - accumulates in amniotic fluid
  - crossing into fetal circulation allow for membrane permeability estimation
- small paramagnetic iron oxide (SPIO) particles are an alternative
  - used in animal studies
  - stays in maternal circulation

Placental perfusion: ASL

- blood can be used as endogenous tracer in a technique called Arterial Spin Labelling (ASL)
- blood passing through a labelling plane is magnetically labeled for approximately 1-2s during which its concentration in the microcirculation and tissue can be measured
- an interesting application is to compare contribution from the two ends of the uterine horn in rodents





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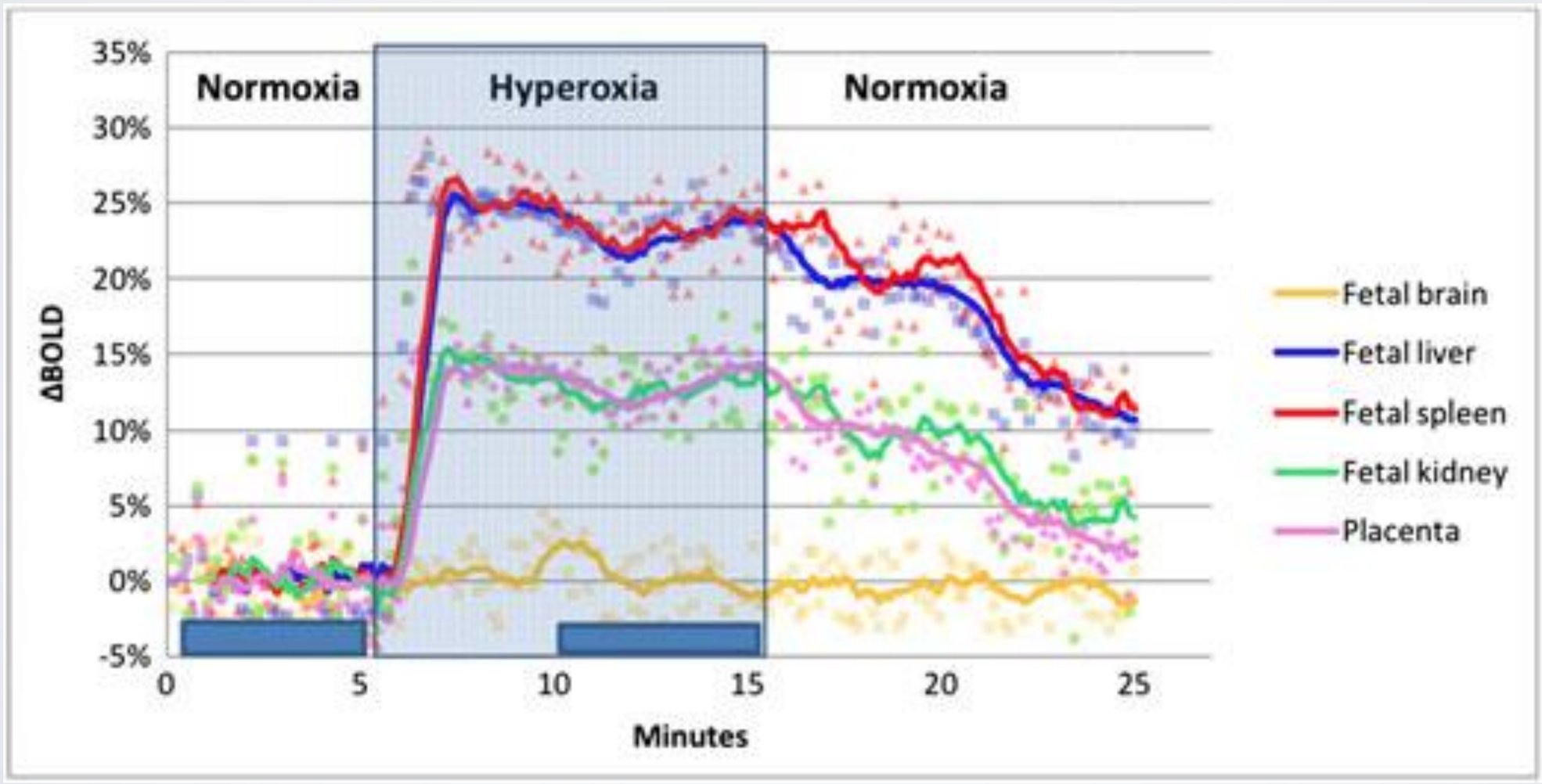
Blood oxygenation

- oxygen saturation in blood can be estimated from MRI measurements of T2
  - combined with phase contrast, small vessels can be isolated on the basis of their blood velocity and spatial location (Wernik et al. ISMRM 2011)
  - umbilical vein saturation in late gestation human fetus 85% ±4%

Blood oxygenation

- blood oxygenation changes tissue contrast by its effect on T2 and T2*
- BOLD signal can be used to assess relative tissue oxygenation



Reproduced from Sorenson et al. Prenatal Diagnosis 2013, 33, 141–145

Conclusions

- recent developments in faster scanning techniques for MRI have enabled a variety methods for studying the placenta
- a diverse range of contrast mechanisms allows for measurements of morphology, tissue structure, perfusion, blood volume, permeability, and blood oxygenation
- technology for placental / fetal exams is rapidly developing