Magnetic Resonance Imaging of the fetus

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The Moonbeam Trust

Overview

- Practicalities and Sequences
- Clinical applications
    - Non Central Nervous System
    - Central Nervous System(CNS)

- Research and development: studies in IUGR pregnancies

Fetal MR imaging

- Relatively new technique
- Complimentary to ultrasound

- Main application for CNS
- Motion is a major problem
    Initially paralysed fetus (French studies)
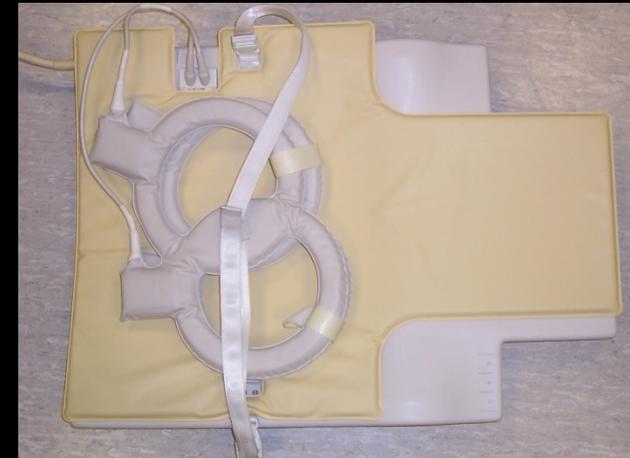   Sedation mother in some units (non UK)

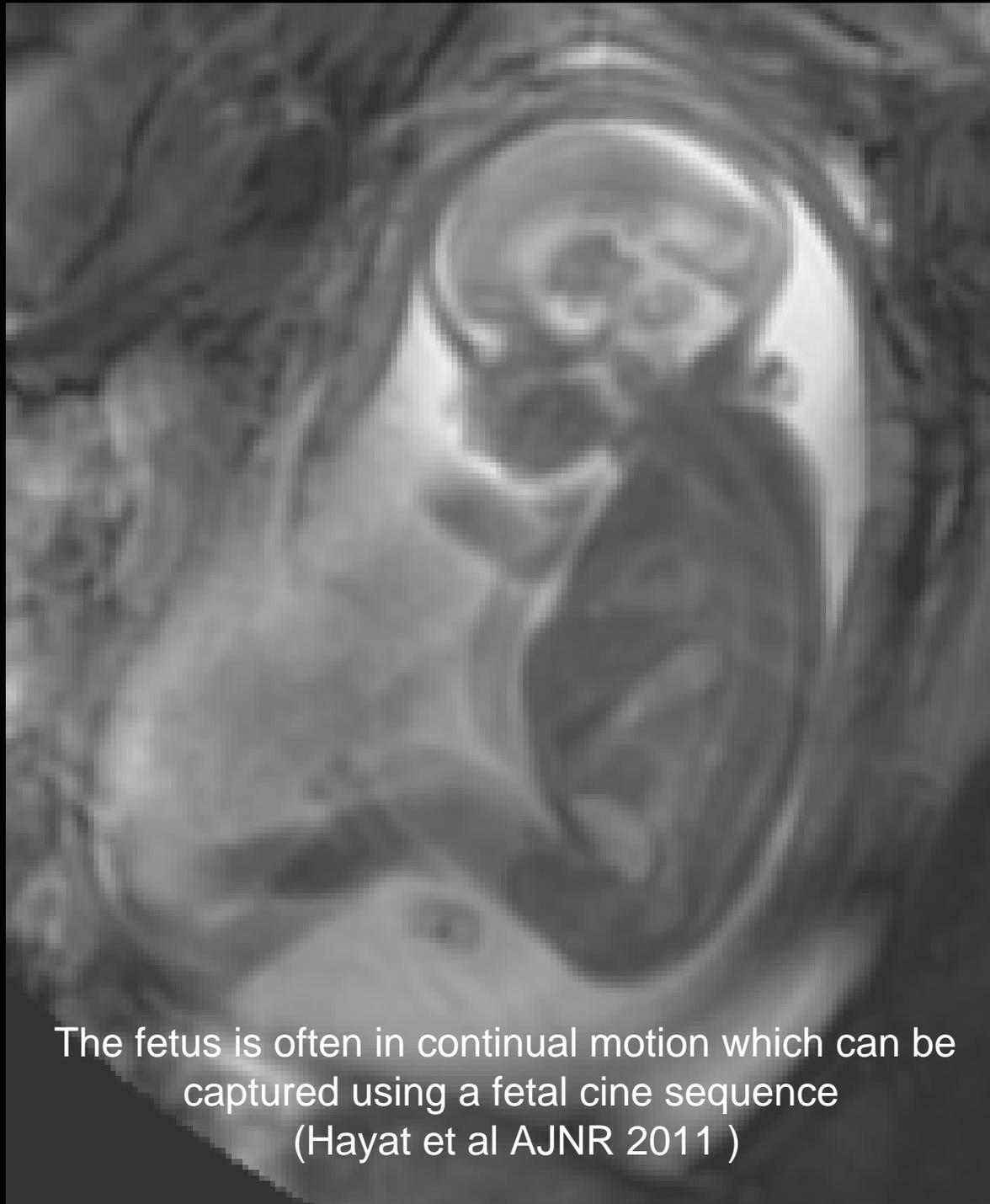Philips 1.5 Tesla magnet

Pregnant patient in left lateral tilt
Ear protection
Fan on to keep cool
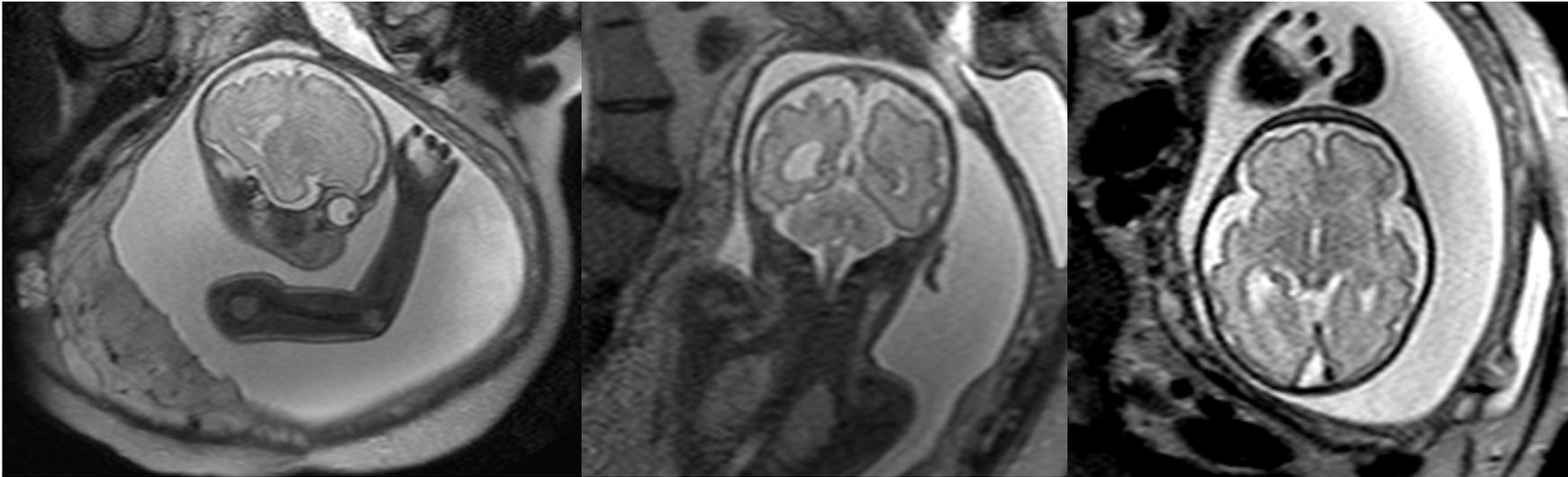

Cardiac coil- 5 channels
Around abdomen

We wow use a new cardiac coil with 32 channels.
Gives better coverage and higher signal to noise

The fetus is often in continual motion which can be
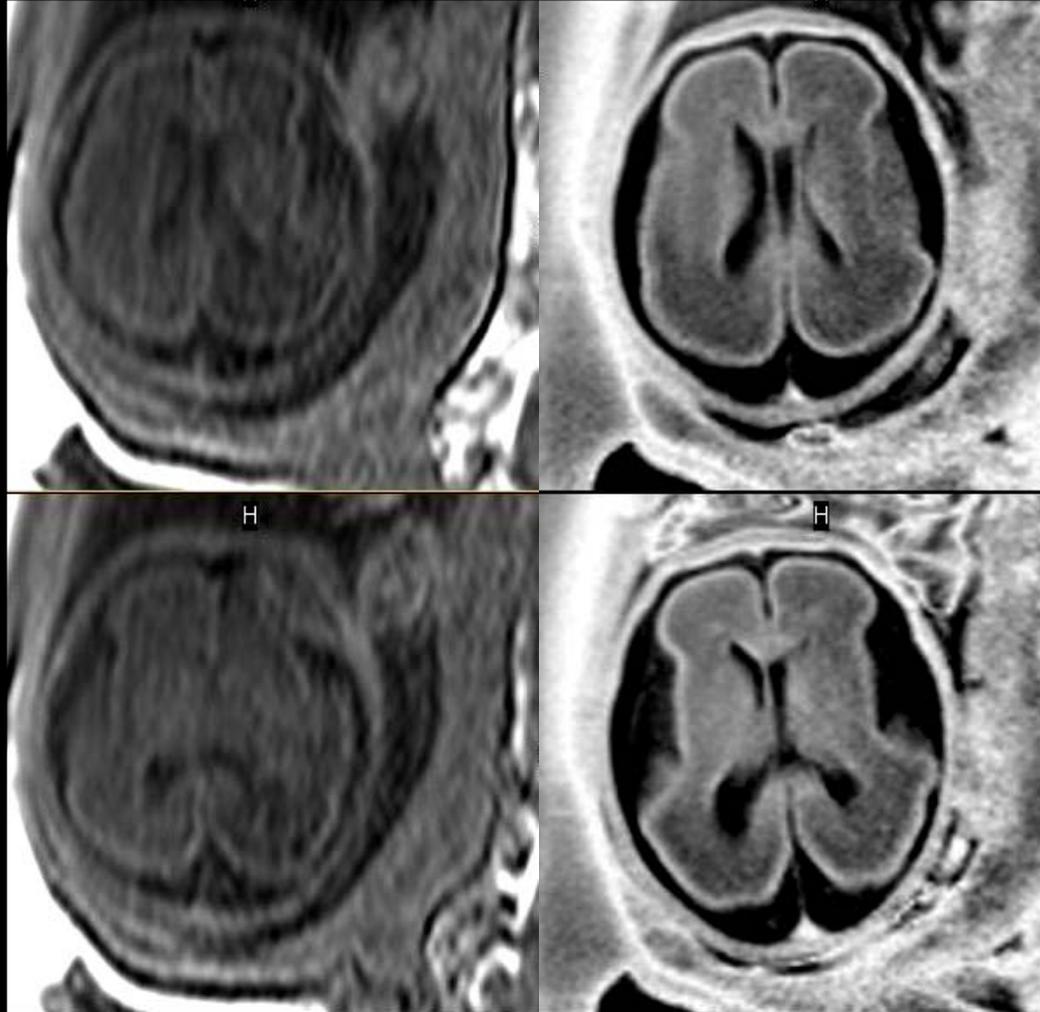captured using a fetal cine sequence
(Hayat et al AJNR 2011)

Fetal MR sequences

- Fast single shot T2 weighted image acquisition
- Image slice in less than 1 second

T1 weighted imaging

Previous
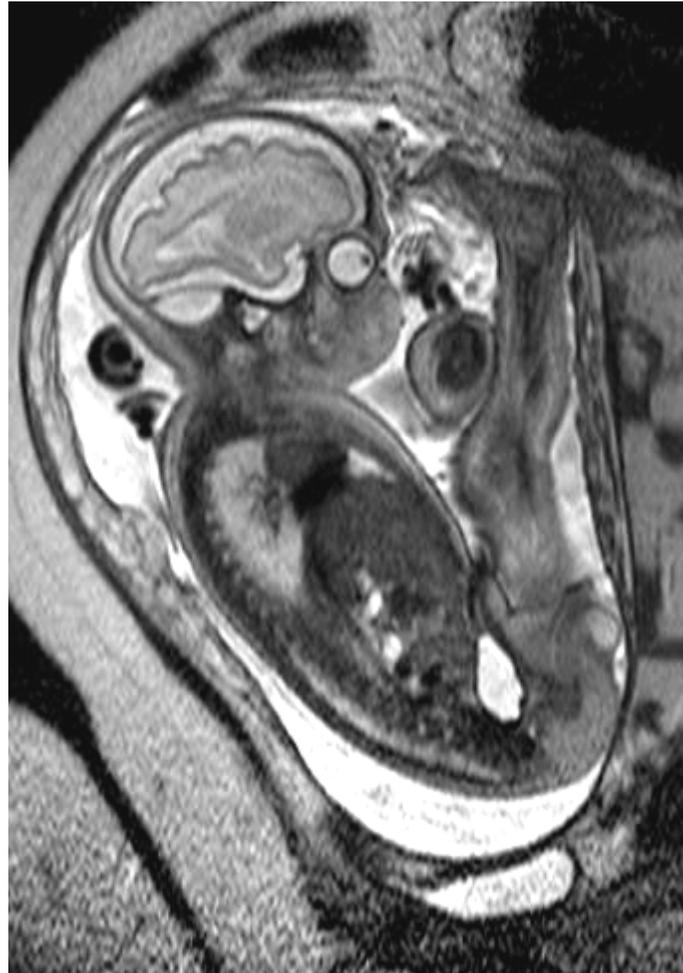T1W spin echo
acquired
with breathhold

Recently
developed

SNAPIR*

* Malamateniou et al Radiology 2011

Clinical non CNS imaging

- Chest
- Abdomen
    - Renal
    - Liver
- Skeletal
- Cardiac

T2 weighted single shot sequence

- Possible to image the entire fetus, even at late gestations
- Diagnosis: Diaphragmatic hernia (bowel in chest- arrow)

Diaphragmatic hernia

- Assess contents of chest
  - Stomach (arrowhead)
  - liver

- Assess lung signal intensity and volume
  - Visually (arrows)
  - Objectively

- Use to predict respiratory outcome

Fetal hydrops

- Pleural effusion

- Compressed lung

- Ascites

- Subcutaneous oedema

Abdominal Imaging

- Ultrasound: Renal pelvis dilatation (A)
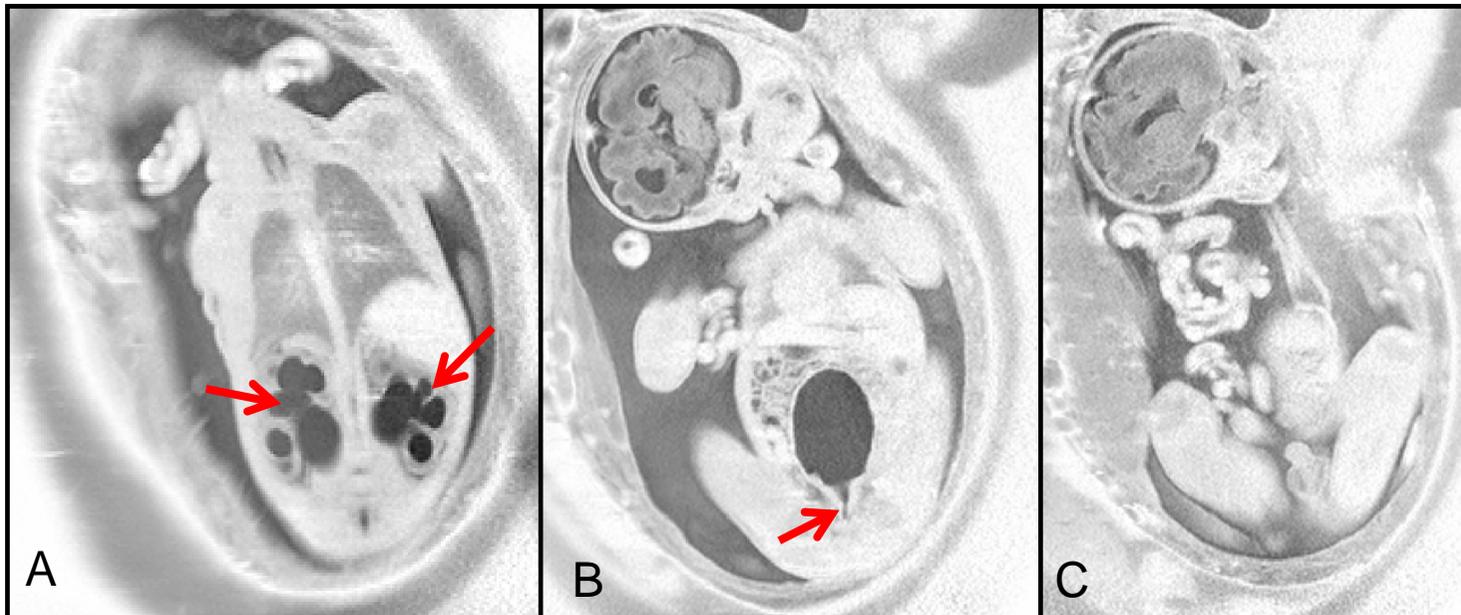
- Posterior urethral valves (B) in male fetus (C)

CNS imaging

Common indications

- Ventriculomegaly
- Agenesis of the corpus callosum
- Cerebellar anomalies
- Congenital infection

- Complications of twin pregnancies
- Acute hypoxic event

Ventriculomegaly

- Most common reason for MRI referral
- Detect any obvious cause for ventriculomegaly e.g. haemorrhage /obstruction
- Identify additional anomalies
- Predict outcome to counsel parents

Ventricular dilation with evidence of germinal matrix haemorrhage

Ventricular dilation with evidence of germinal matrix haemorrhage
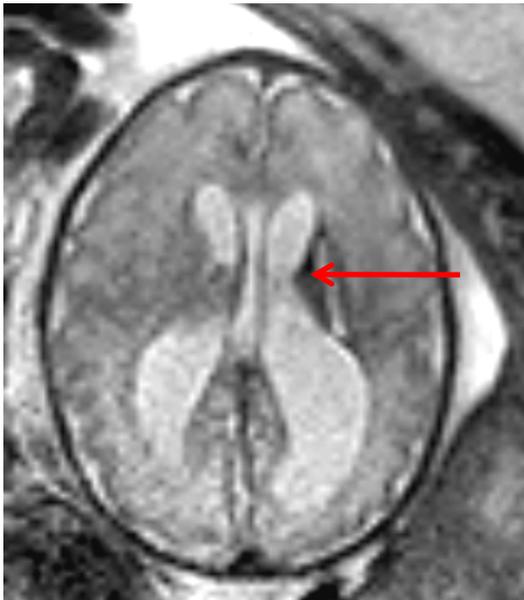
- Haemorrhage involves basal ganglia (arrow)

Ventricular dilation with evidence of germinal matrix haemorrhage
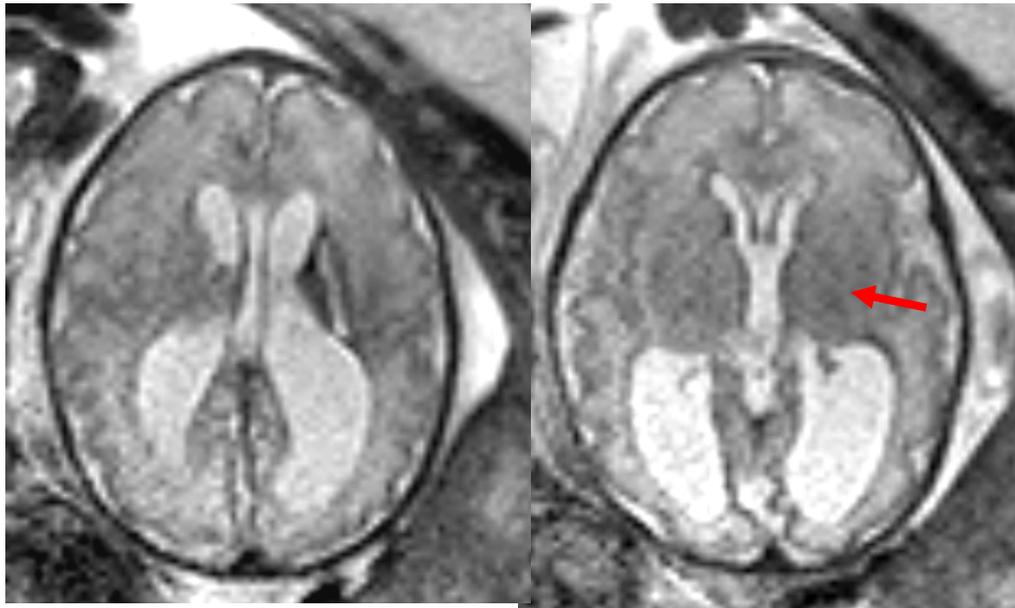
- Posterior limb of internal capsule (PLIC) may be spared (arrow)

- Motor outcome likely to be normal

Agenesis of the corpus callosum

- May be referred with ventriculomegaly
- Occasionally as a parenchymal cyst
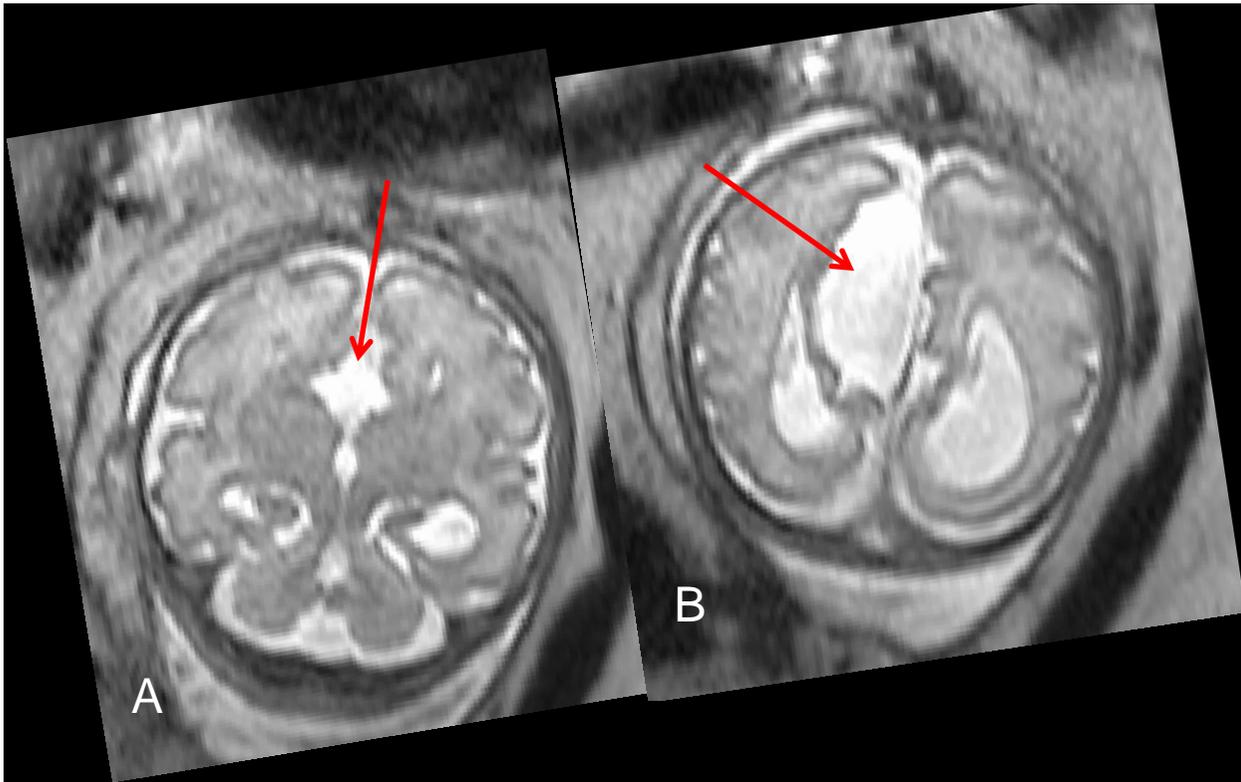
Agenesis corpus callosum (A) with interhemispheric cyst (B) (arrow)

Agenesis with interhemispheric cyst
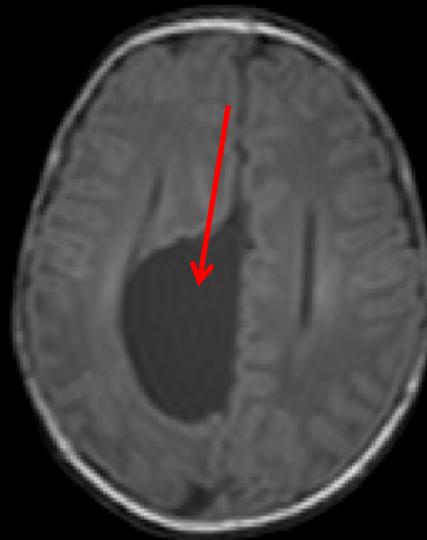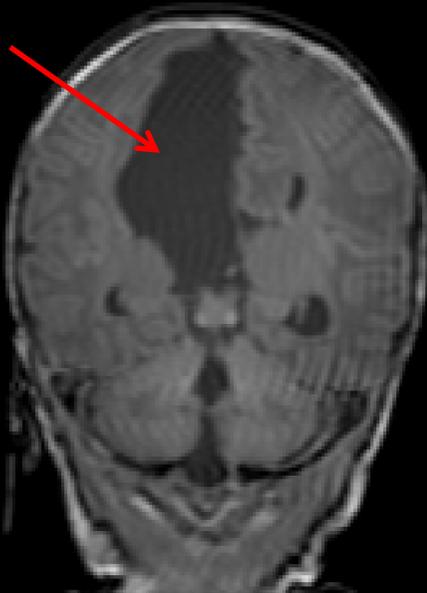
Postnatal imaging
T1 weighted
showing cyst (arrow)
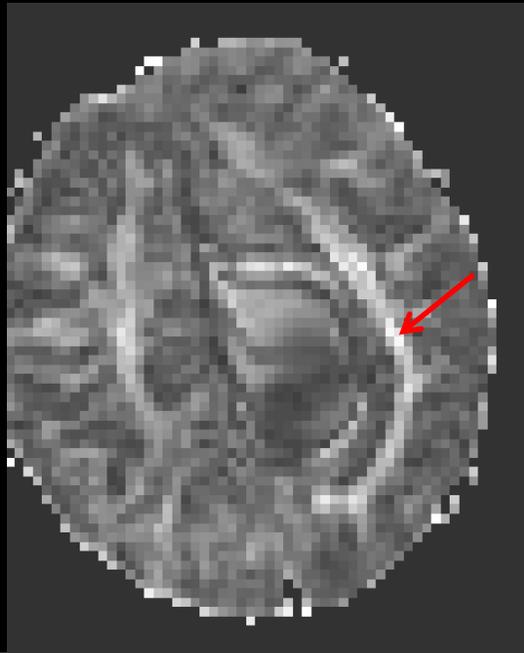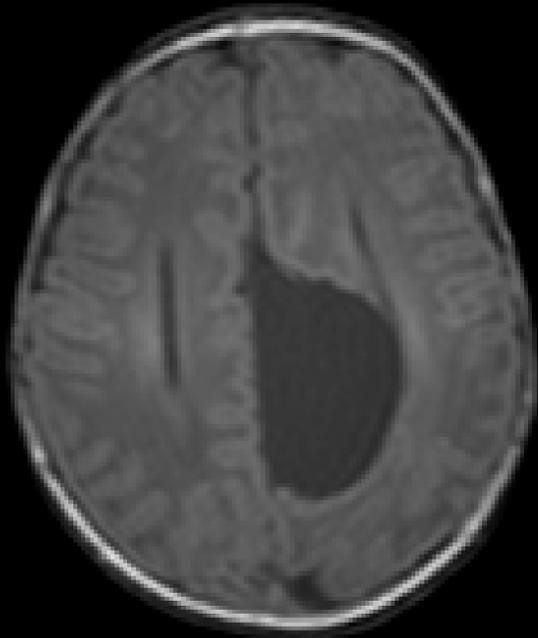
Postnatal diffusion tensor imaging (DTI) Showing white matter tracts circumventing cyst
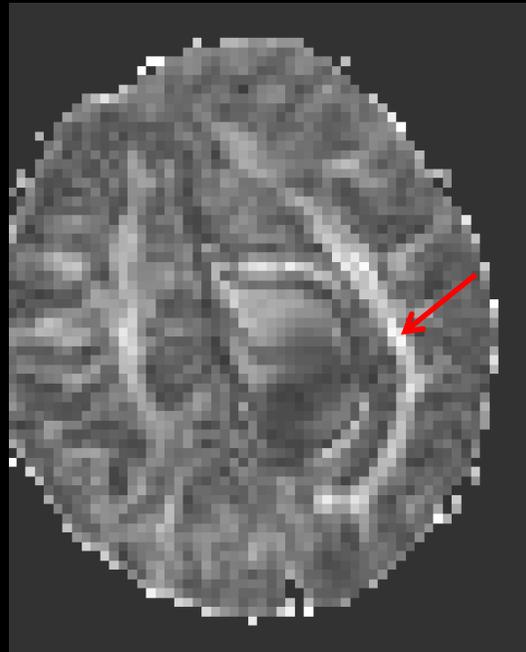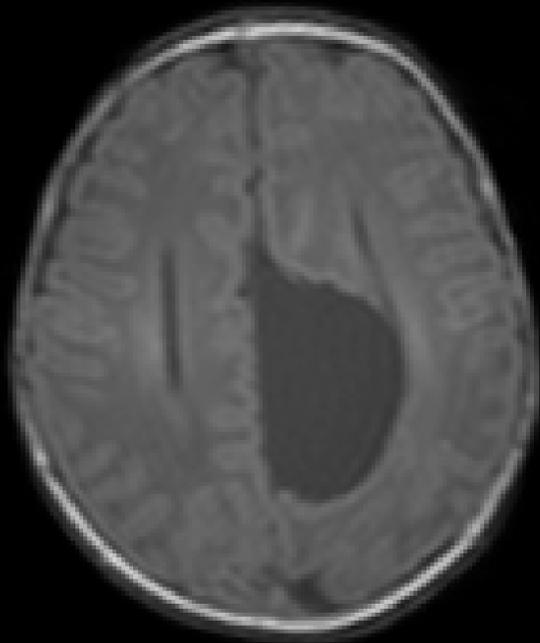
Postnatal diffusion tensor imaging (DTI) Showing white matter tracts circumventing cyst
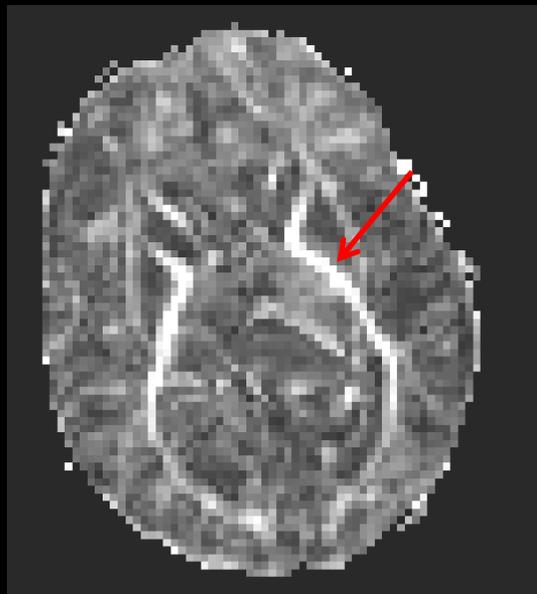
Normal PLIC may Predict normal gross motor function

Cerebellar anomalies

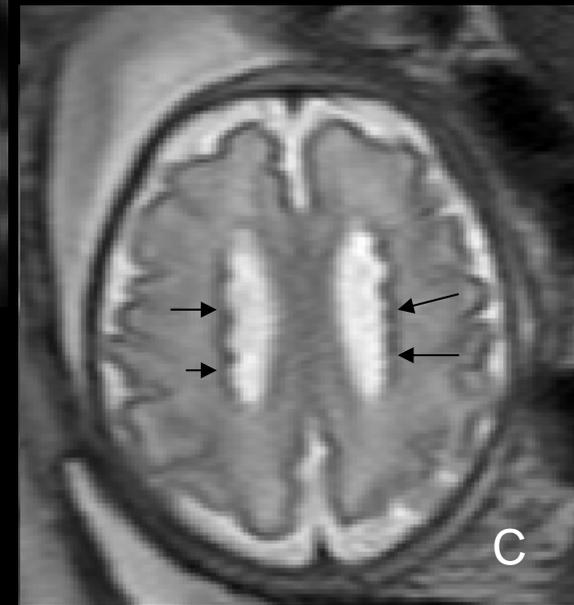- Large cisterna magna
- Cerebellar hypoplasia
- Cerebellar haemorrhage
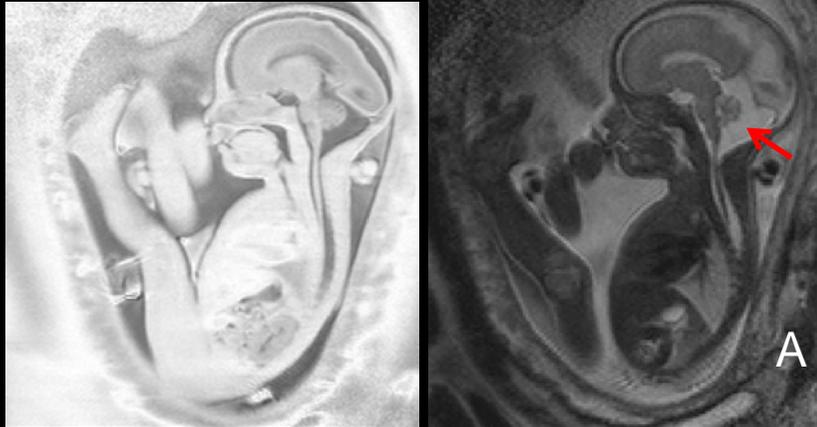
26^{+3} weeks . Large cisterna magna
➢10mm (A,B)

- Bilateral irregular germinal matrix arrows (C)

Diagnosis: subependymal heterotopia female fetus
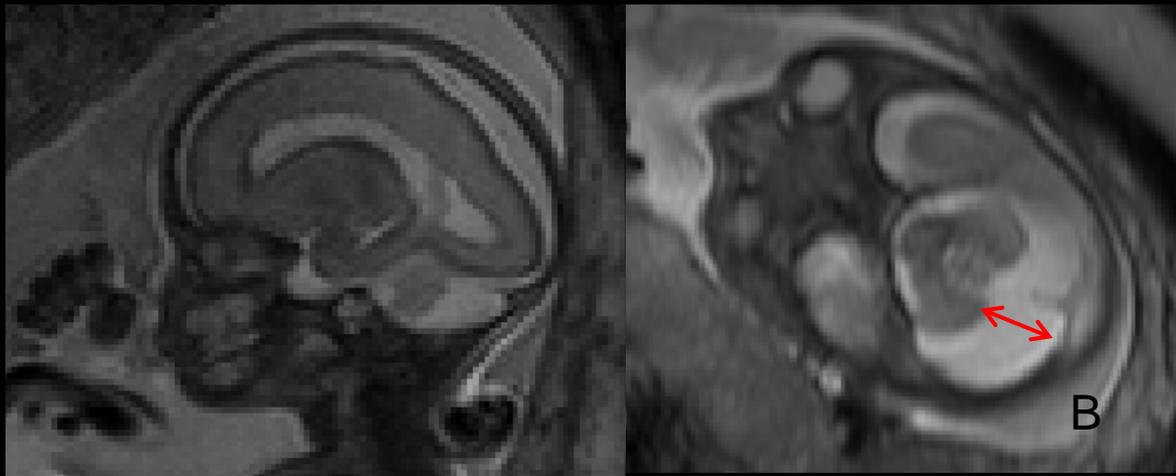
Repeat at 32 weeks GA

A

B

C

Not visible on sagittal or coronal images

Mother asymptomatic
Maternal grandmother epileptic

- Enlarged cisterna magna

Mother's images
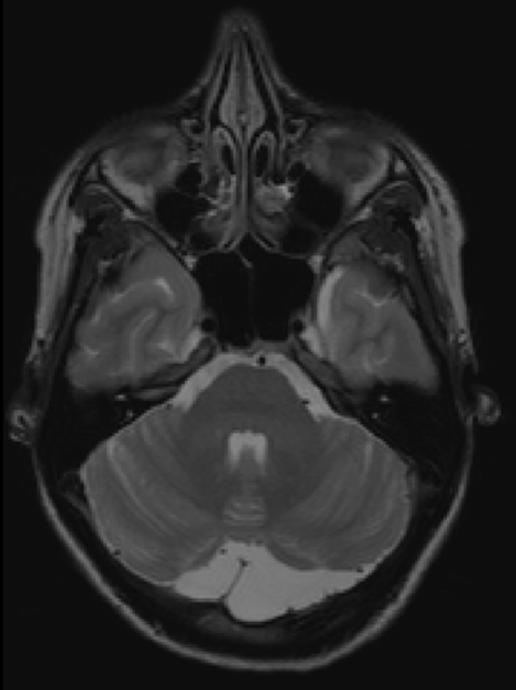
- Diagnosis:
  X linked subependymal heterotopia with enlarged cisterna magna

Research and development

- Improving image quality

Fetal motion

- Single slices fast acquisition - not artefacted

- But fetus moves in and out of plane during acquisition
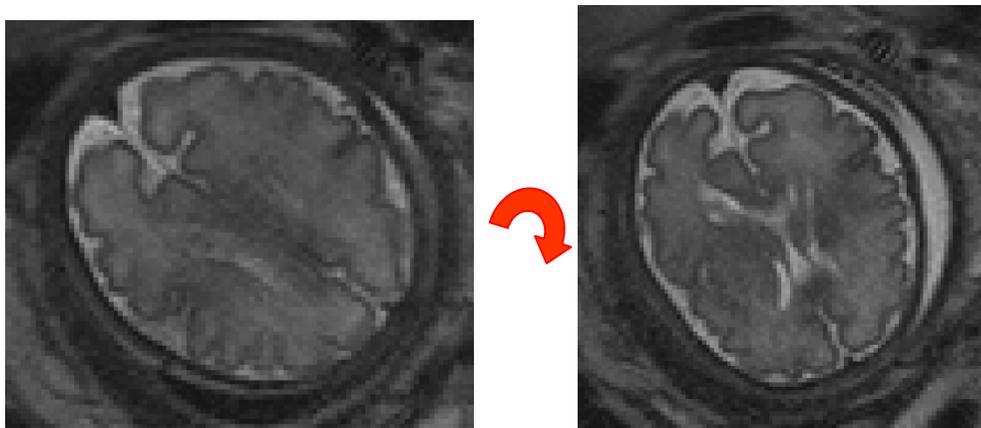
Rotation of fetal head between slices

Snapshot image acquisition with Volume reconstruction (SVR)*

Aim

- Provide high signal to noise, high resolution 3-Dimensional volumetric datasets of the brain in presence of fetal motion
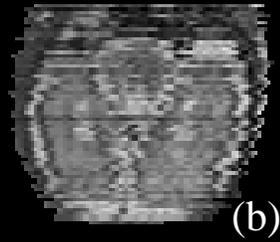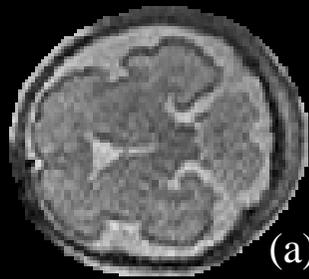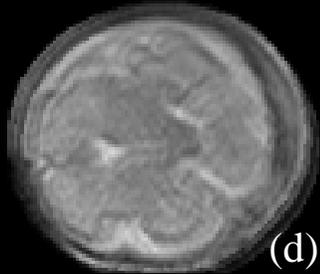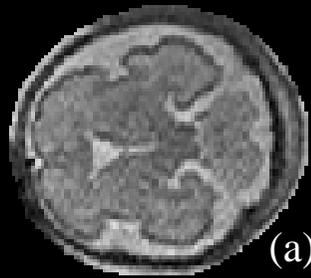
* Jiang et al 2007
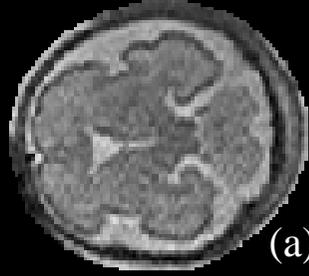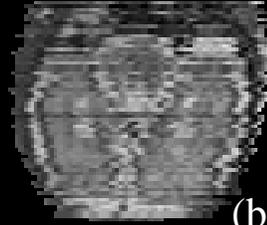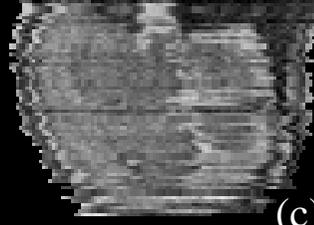
(a) (b) (c)

Dynamic scan
Single shot 1 loop
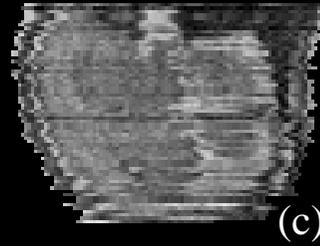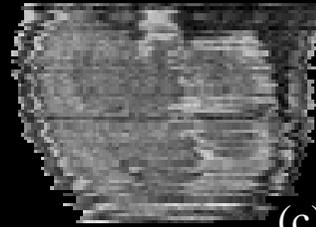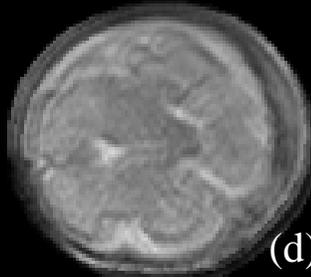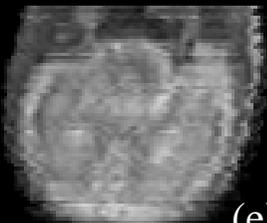
Dynamic scan
Single shot 1 loop
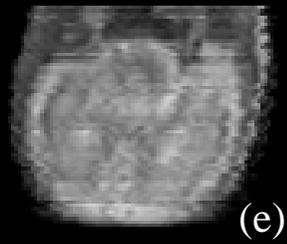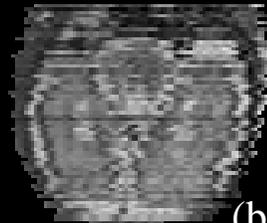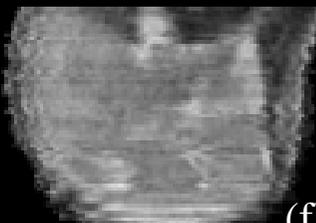
Combined loops
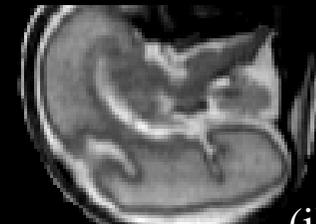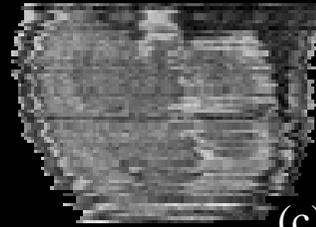
Dynamic scan
Single shot 1 loop
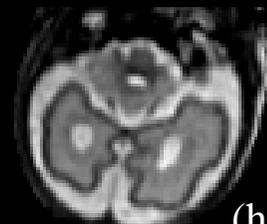
Combined loops
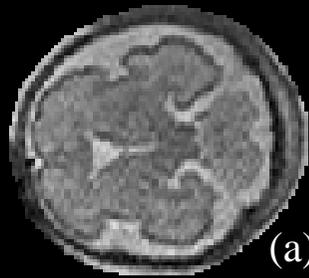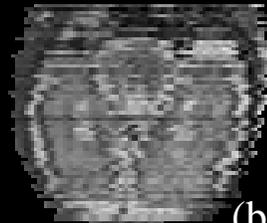
Registered
3D fetal data

Dynamic scan
Single shot 1 loop
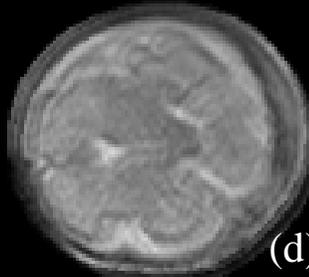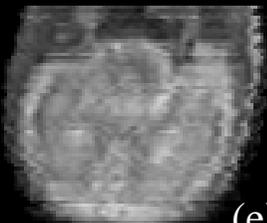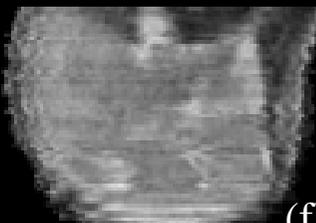
Combined loops
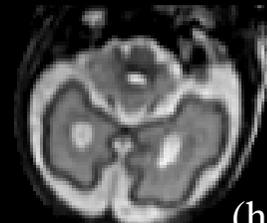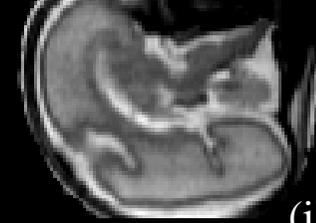
Registered
3D fetal data
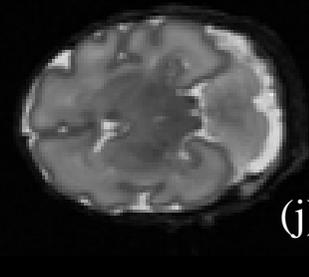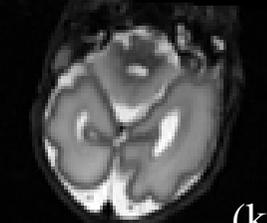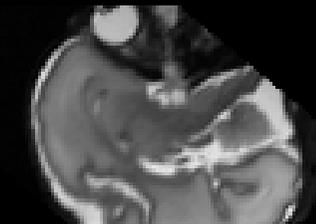
Ex utero data
3 Tesla
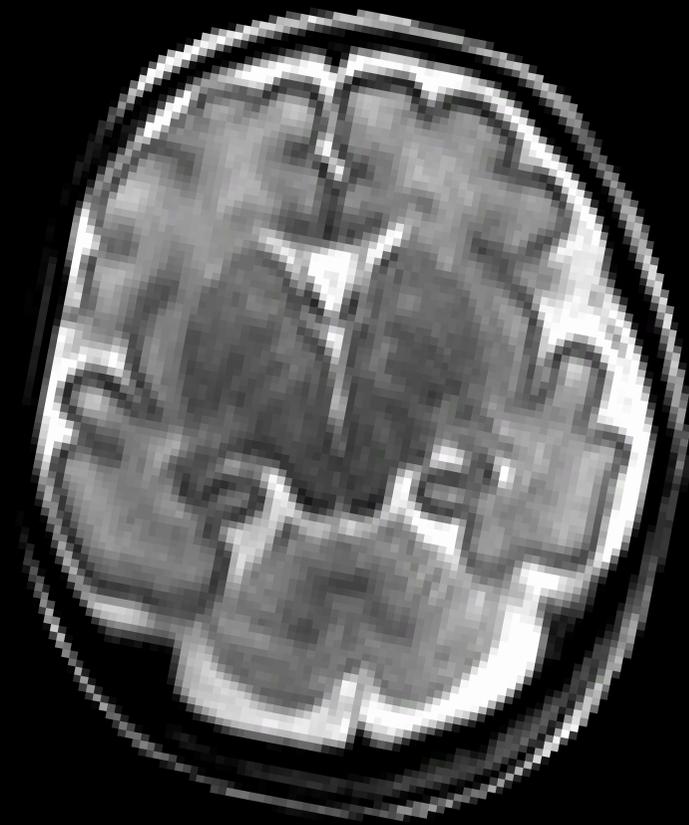
30 week fetus 1.5 Tesla
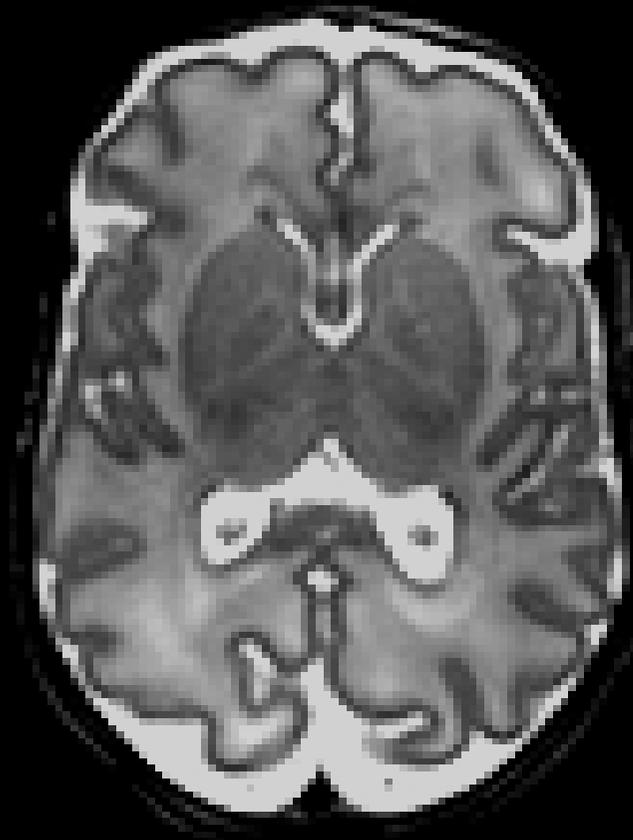
30 week preterm 3 Tesla

Quantifying normal brain development
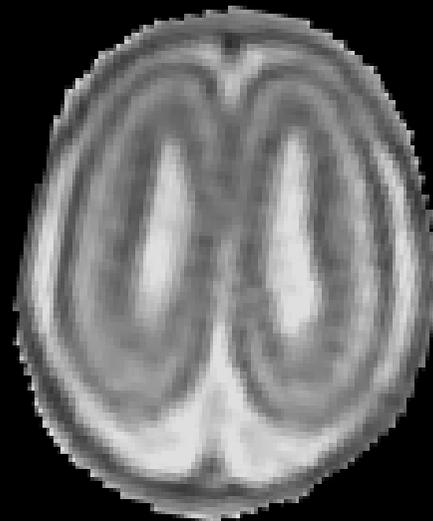
20 weeks

32 weeks

Manual Segmentation of normal fetal brain n=18

Hayat 2007
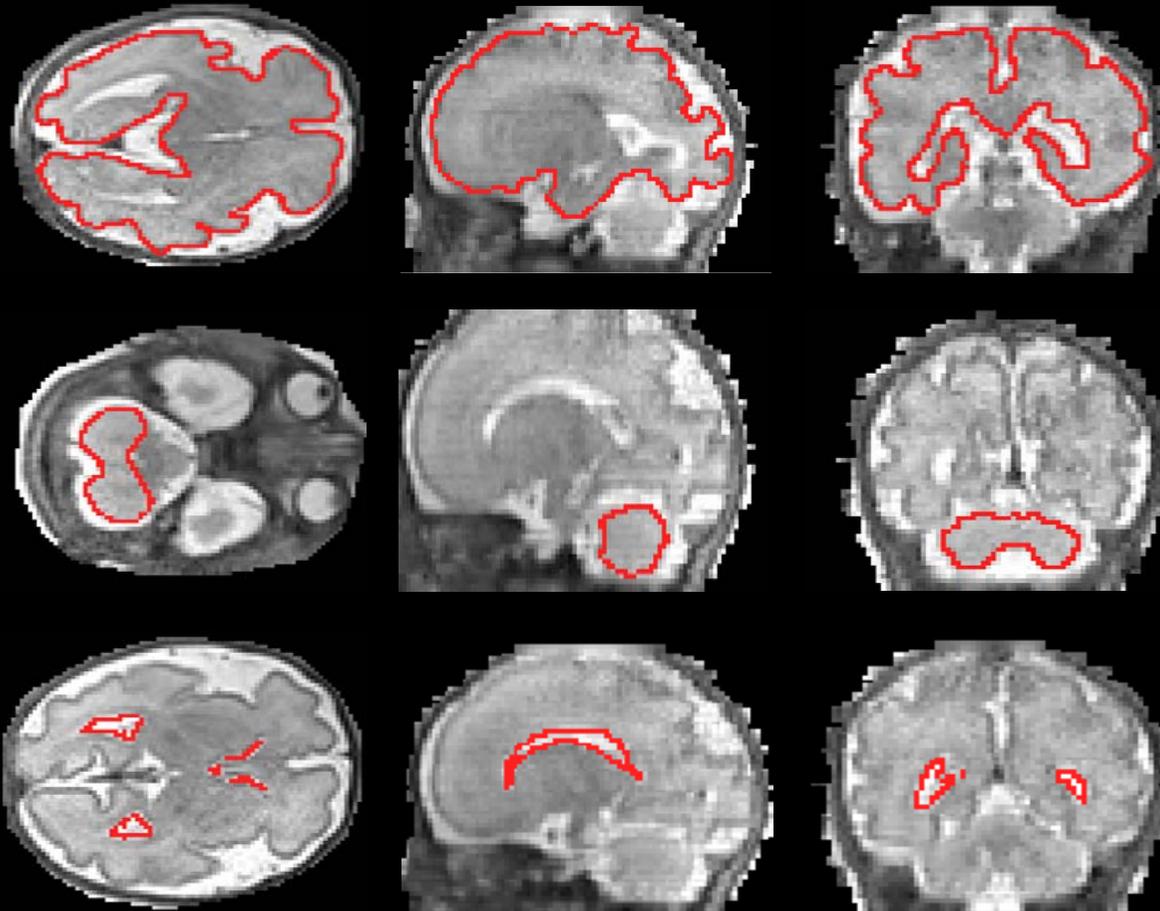
Cerebral Parenchyma Volume and Log Volume against gestational age

volume
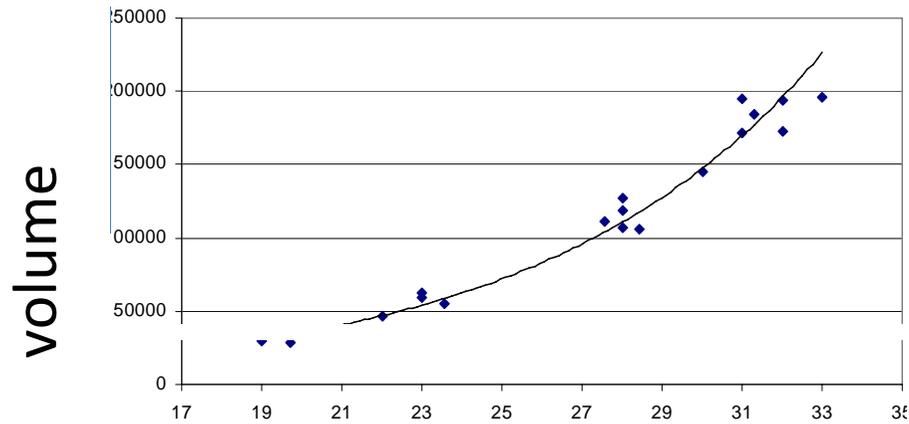
Gestational Age (weeks)

r = 0.99 *p* < 0.05

Gestational Age (weeks)

r = 0.99 *p* < 0.05

Hayat 2007
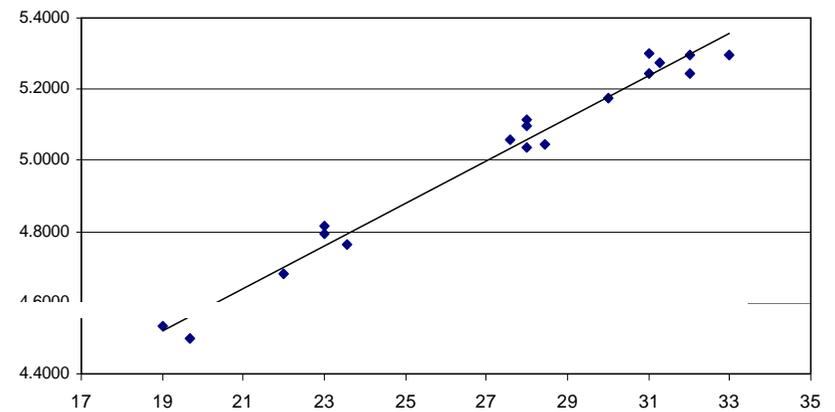
The fetus with intrauterine growth restriction (IUGR)

- Brain images may look normal

- High risk of mortality and short term morbidity

- Longer term
  - neurodevelopmental impairments
  - adult onset hypertension, diabetes.

The fetus with IUGR

- Cohort of IUGR fetuses = 40
    - Estimated fetal weight < 5th centile.

    - Graded by Doppler studies
        - Umbilical artery (UA) pulsatility index >95th C
        - As above with PI <5th centile in middle cerebral artery
        - Absent end diastolic flow (EDF) in UA
        - Reversed EDF in UA
        - Absent or reversed "a" wave in ductus venosus and/or pulsatilility in the umbilical vein

Damodaram (in prep.)

Growth parameters(ultrasound) in IUGR
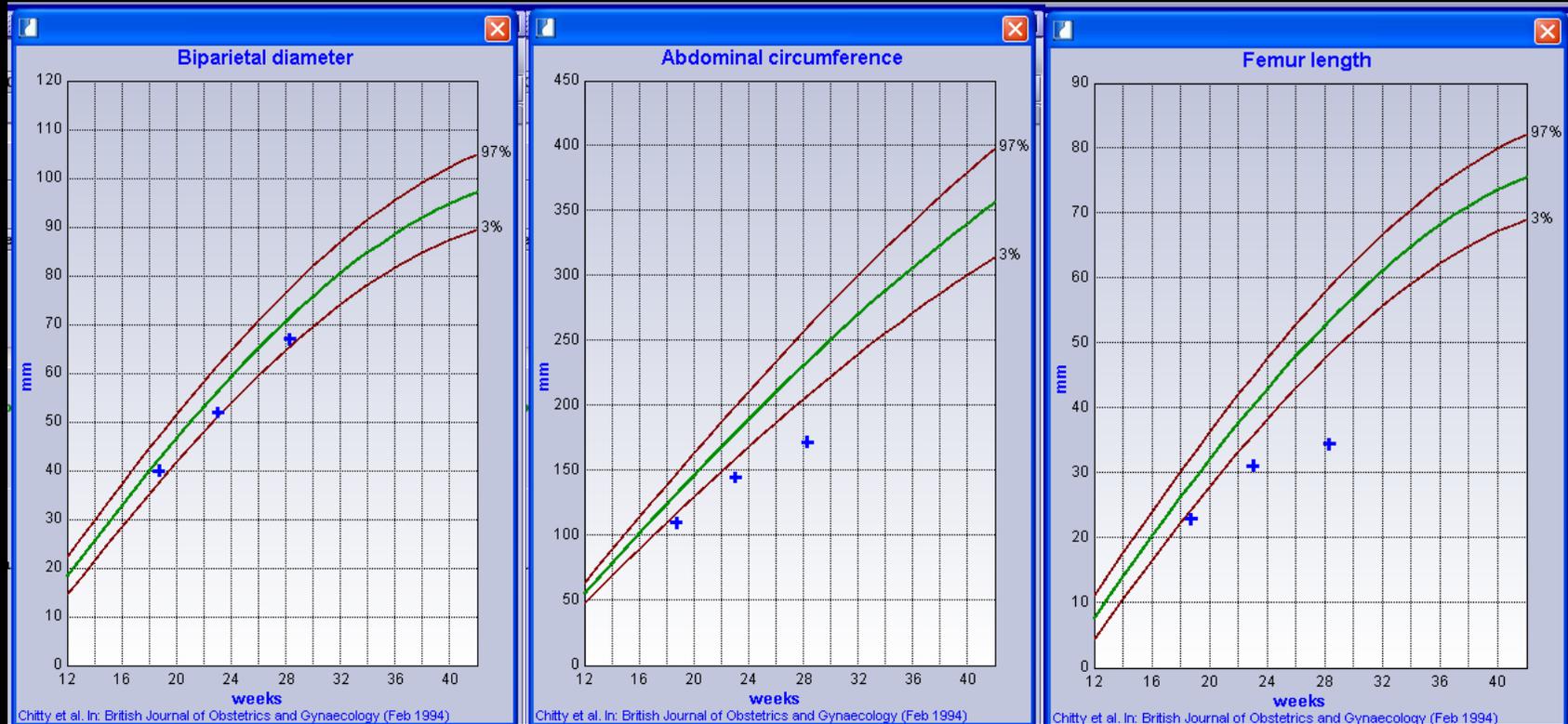
Umbilical Artery Doppler
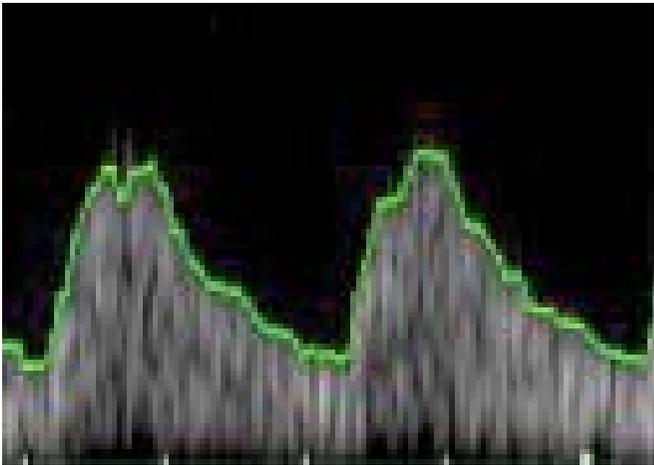
positive end diastolic flow
(normal pregnancy)
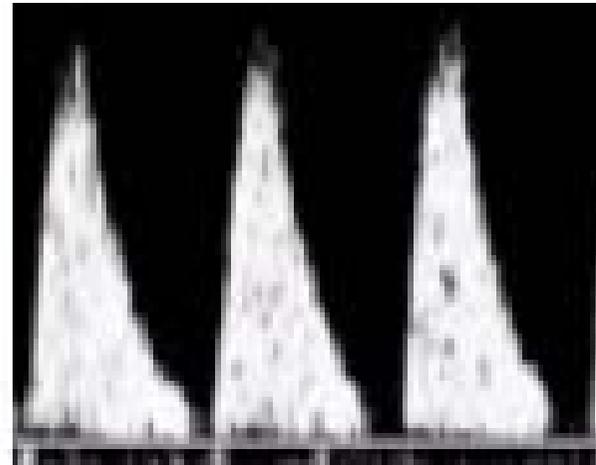
absent end diastolic flow
(growth restricted pregnancy)

The Placenta in IUGR

Reduced volume in IUGR

Placental volume and fetal weight

Damodaram et al 2012
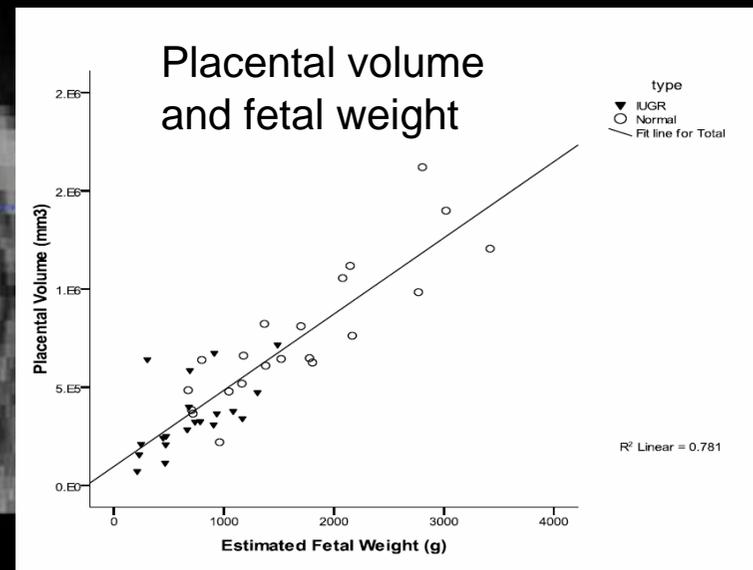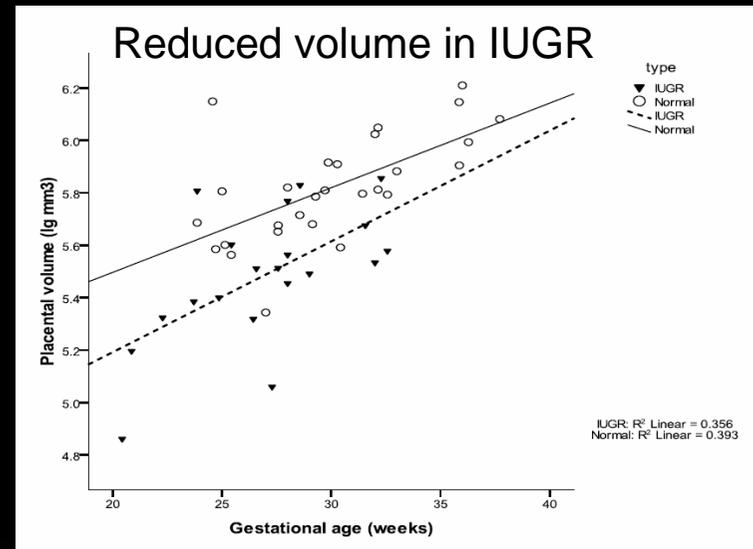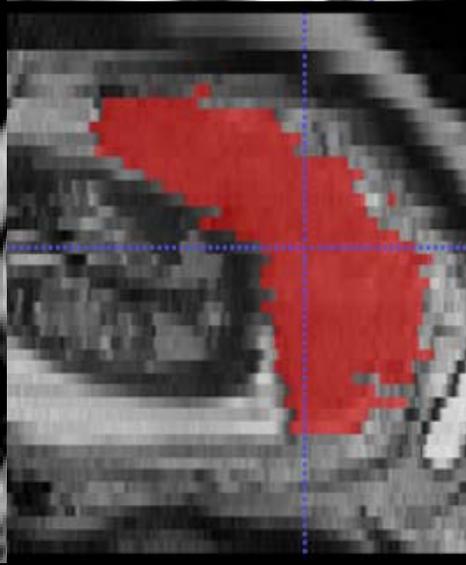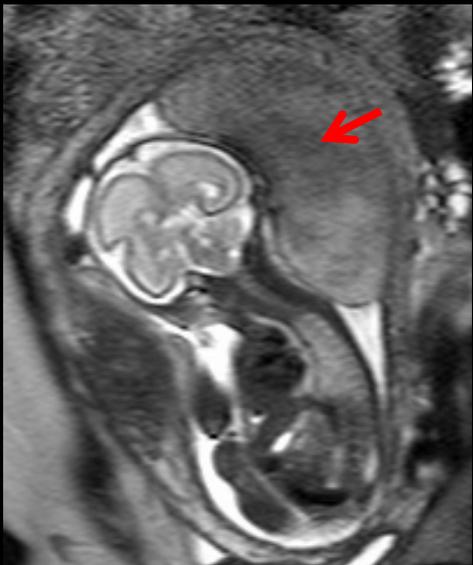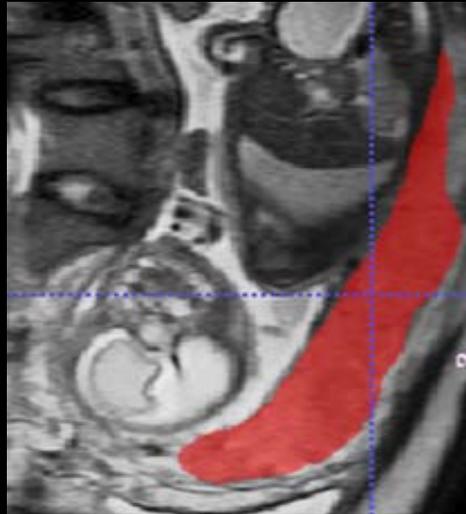
Body volume in IUGR

IUGR =20
Normal =19

Damodaram (2012)
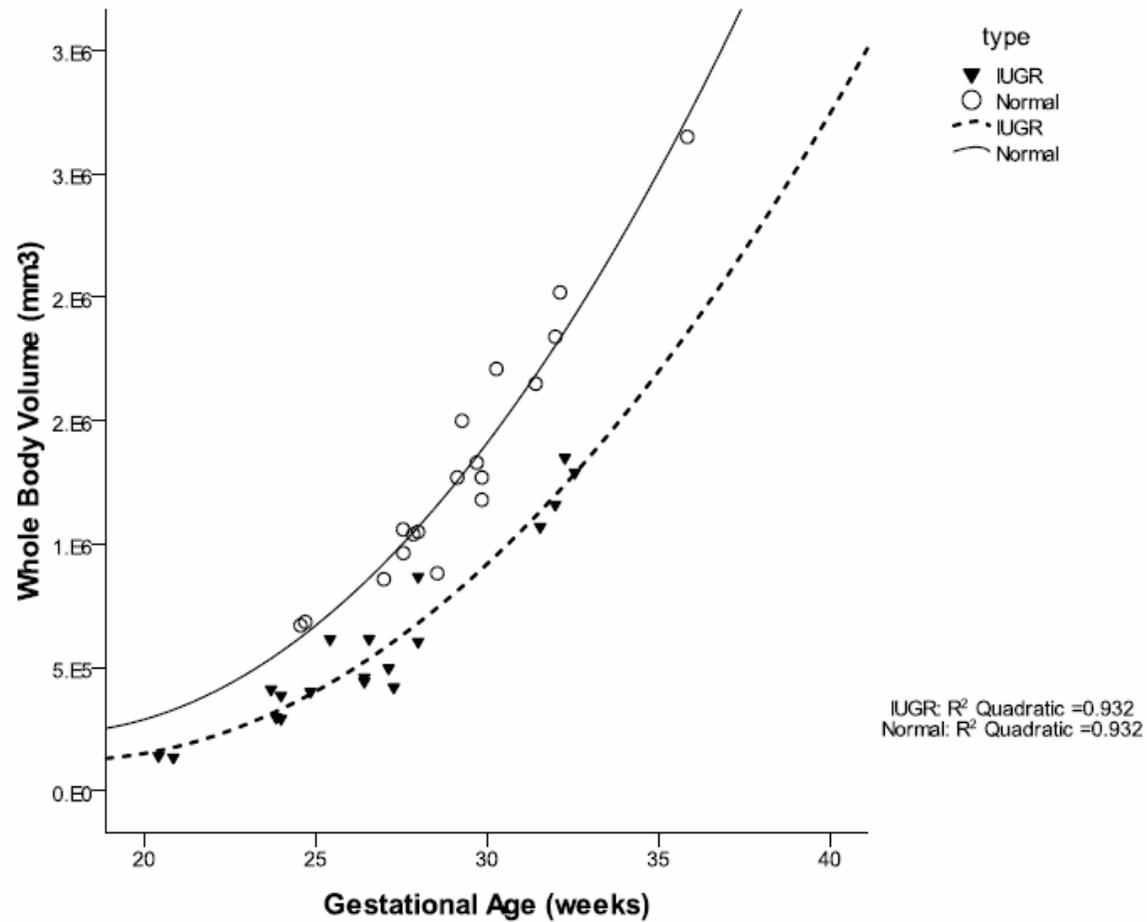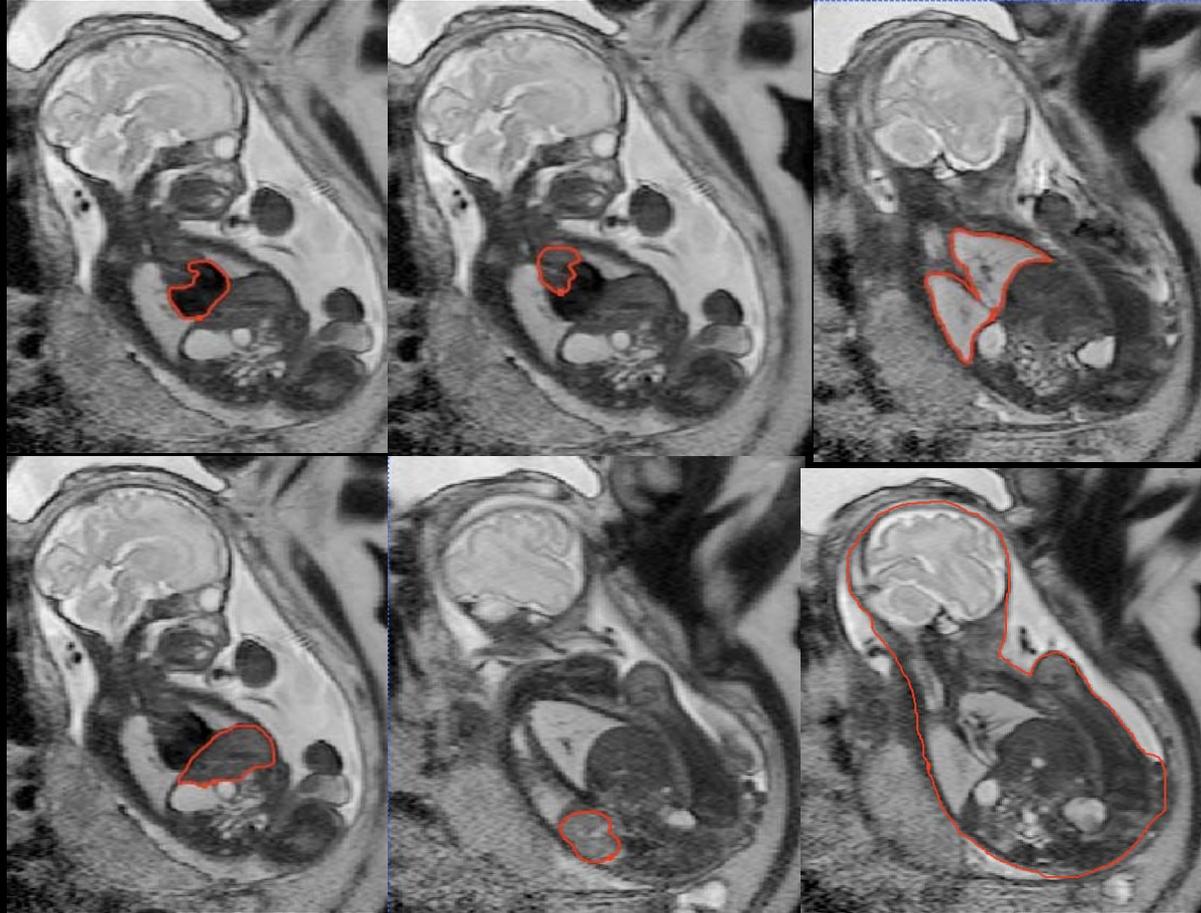
The fetus with IUGR

Is there any evidence of organ "sparing" ?

The fetus with IUGR: liver volume

p <0.001
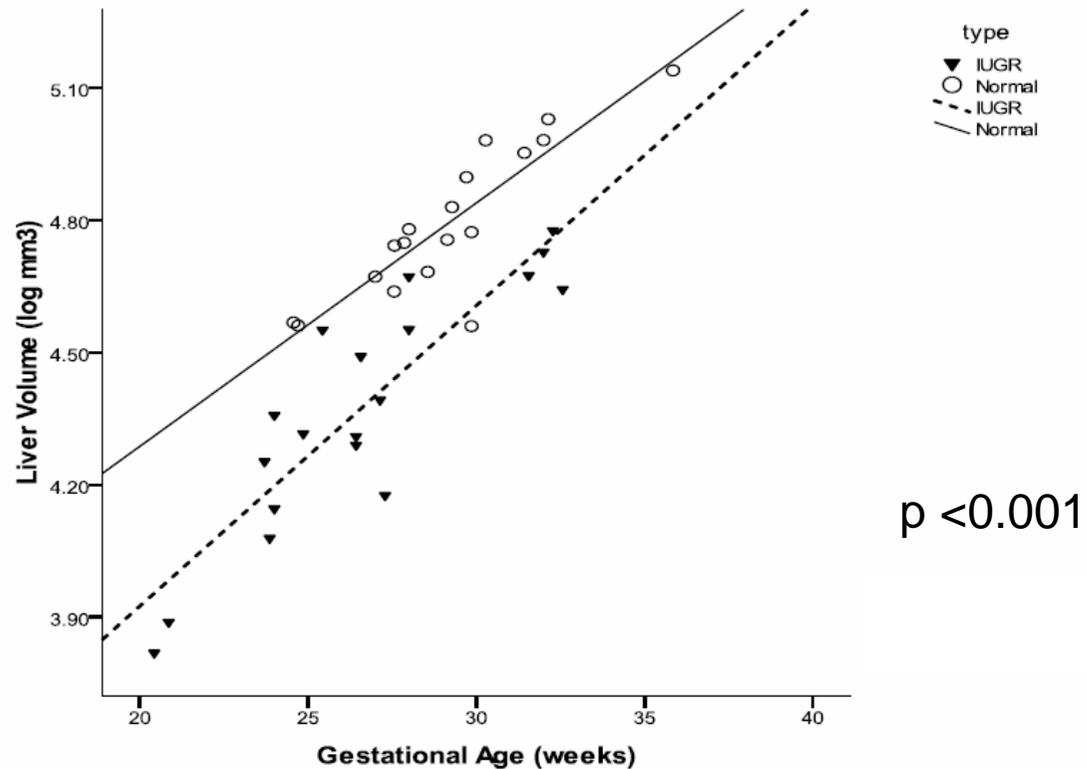
- Decreased glucose transfer and hepatic storage
- Decreased IGF-1 production
- Link to later adult disease ; type 2 diabetes

Damodaram (2012.)

The fetus with IUGR: liver volume

- An increase in the brain:liver ratio predicted perinatal mortality with an AUC of 0.89 (p =0.001, 95 CI = 0.78 – 1.0)

- A brain:liver ratio above 3.0 was associated with a 3.3 fold increase in relative risk of perinatal mortality (95% CI = 1.68 – 6.47).

The fetus with IUGR: renal volume

p <0.001
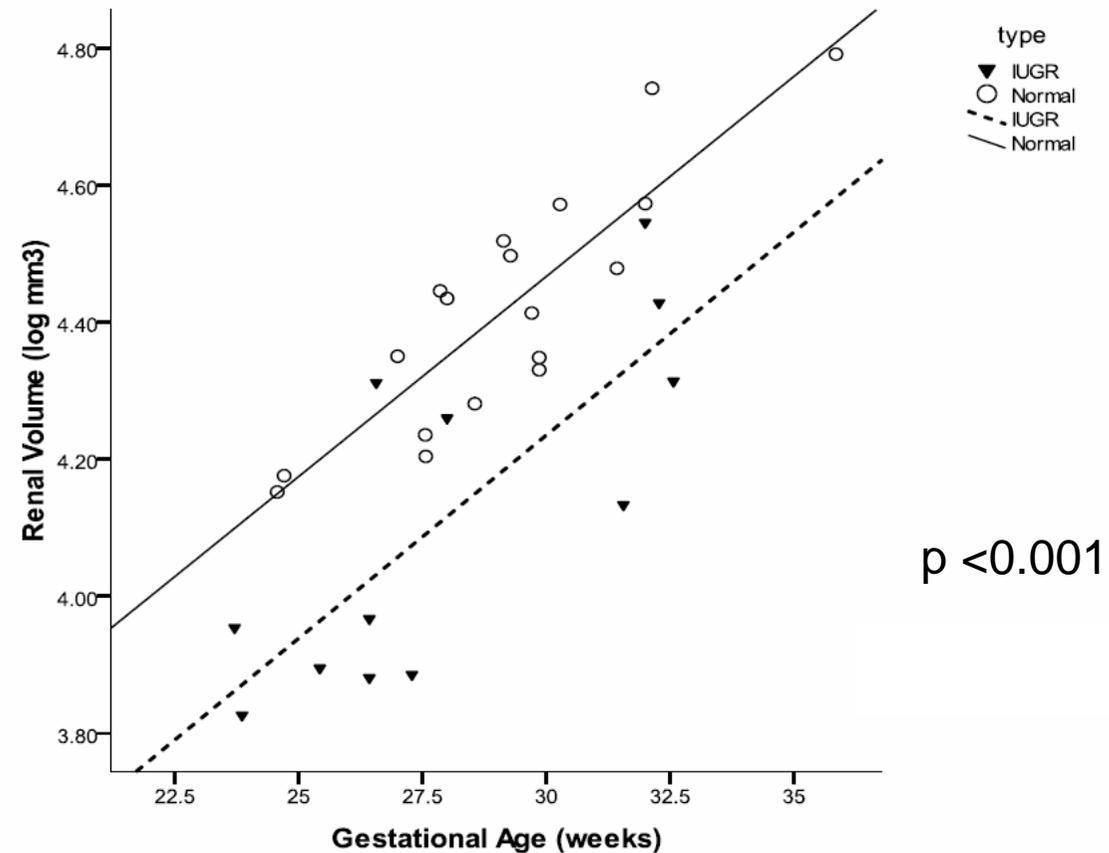
- Decreased nephron number
- Inappropriate activation of renin-angiotensin
- Adult onset hypertension

Damodaram (2012

The fetus with IUGR: lung volume

p <0.01
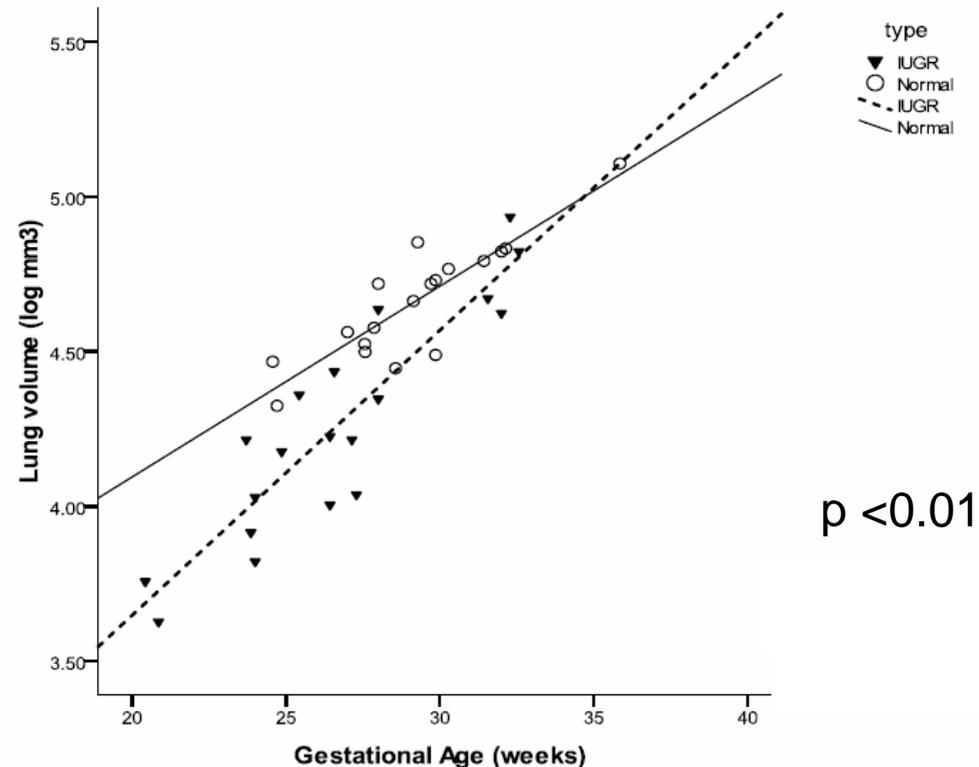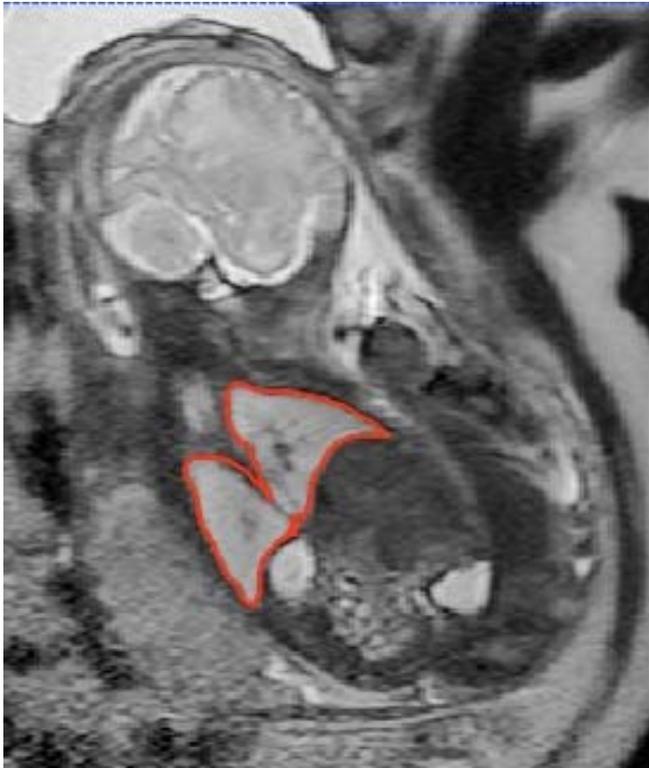
- Lung volume predicted need for CPAP (p=0.03)

- IUGR fetal sheep decreased alveoli and increased septal thickness
- Lung function relates to birthweight
- Additional problems from prematurity

Damodaram (2012

The fetus with IUGR: cardiac volume

p <0.01
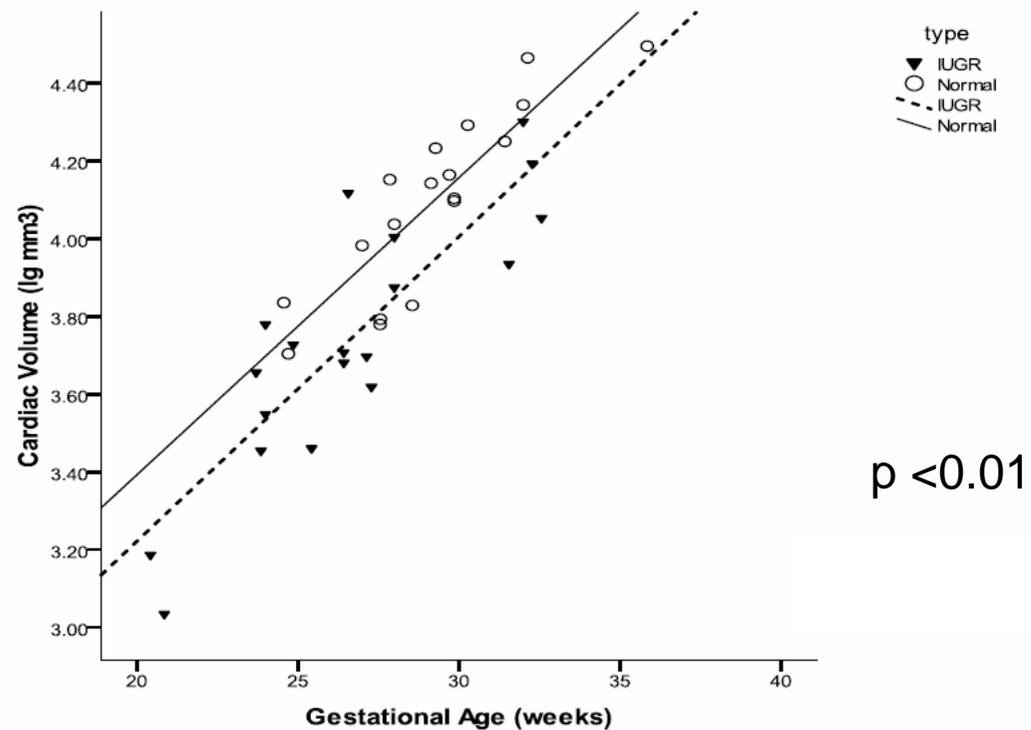
- Doppler studies show impaired cardiac function in human fetal IUGR
- Rat model shows incresaed apoptosis and decreased cardiomyocytes

- ? Predisposition to cardiac ischaemia in adult life

Damodaram (2012)

The fetus with IUGR: thymus volume

p <0.01
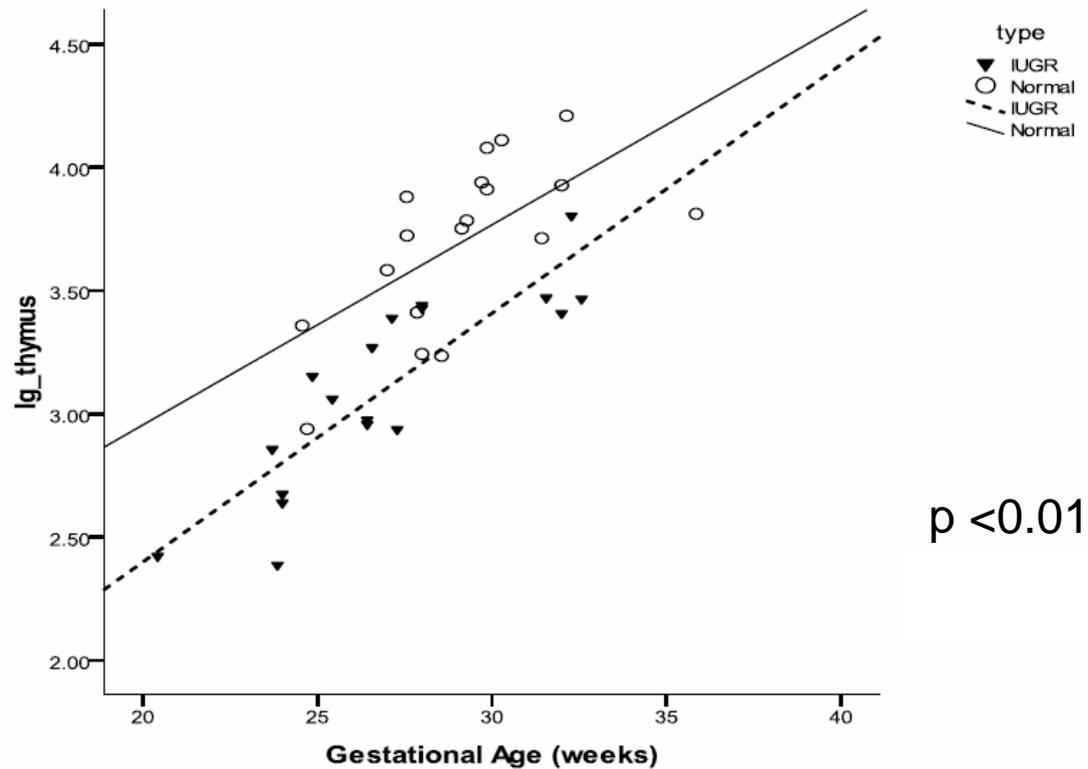
- ? Stress mediated thymic involution via hypothalamic-piuitary-adrenal axis

Damodaram (2012)

The Fetus with IUGR: brain volume
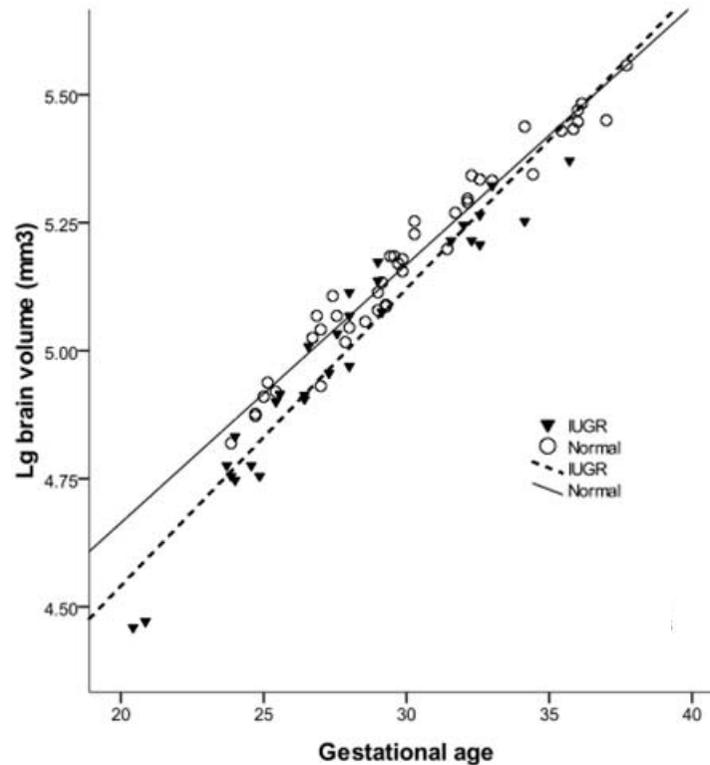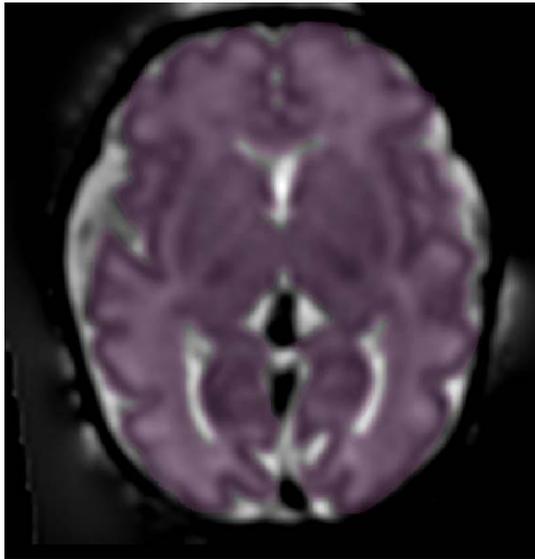
IUGR n=29
Normal n=45

p<0.05
corrected for GA

- Increased reduction with increased severity of IUGR p<0.001

Damodaram (2012)

The fetus with IUGR:ventricular volume
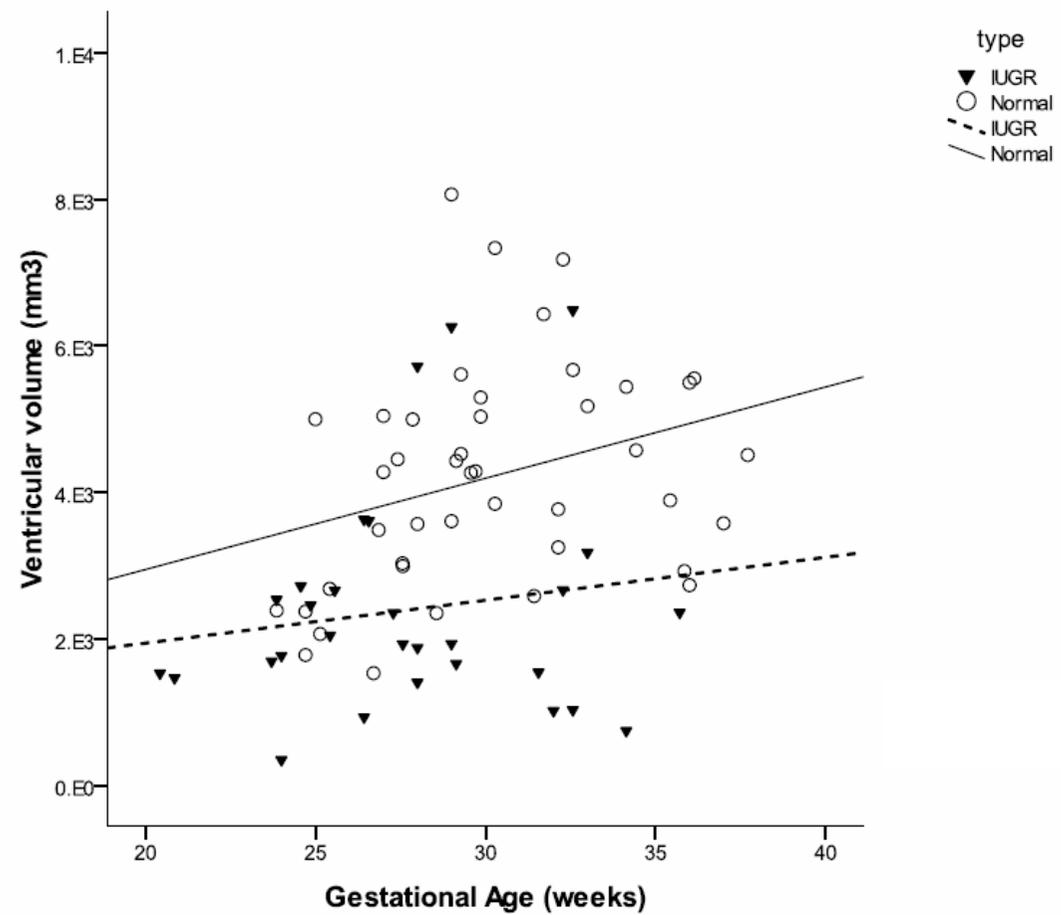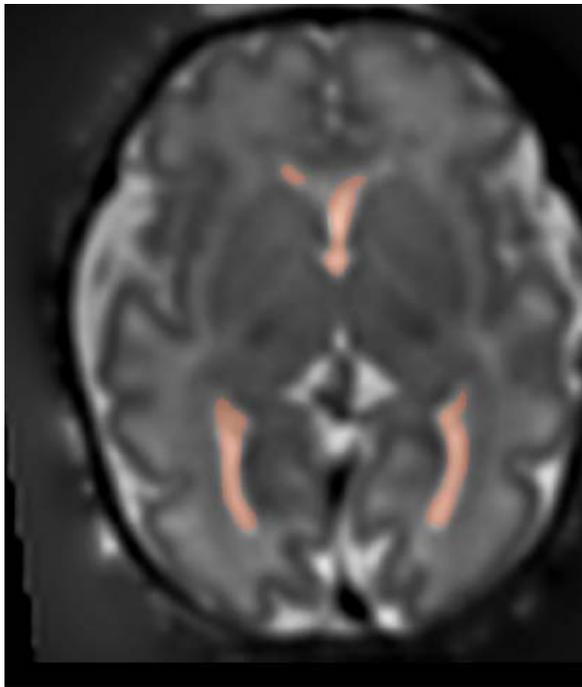
Damodaram (in prep.)

Extracerebral space/brain volume
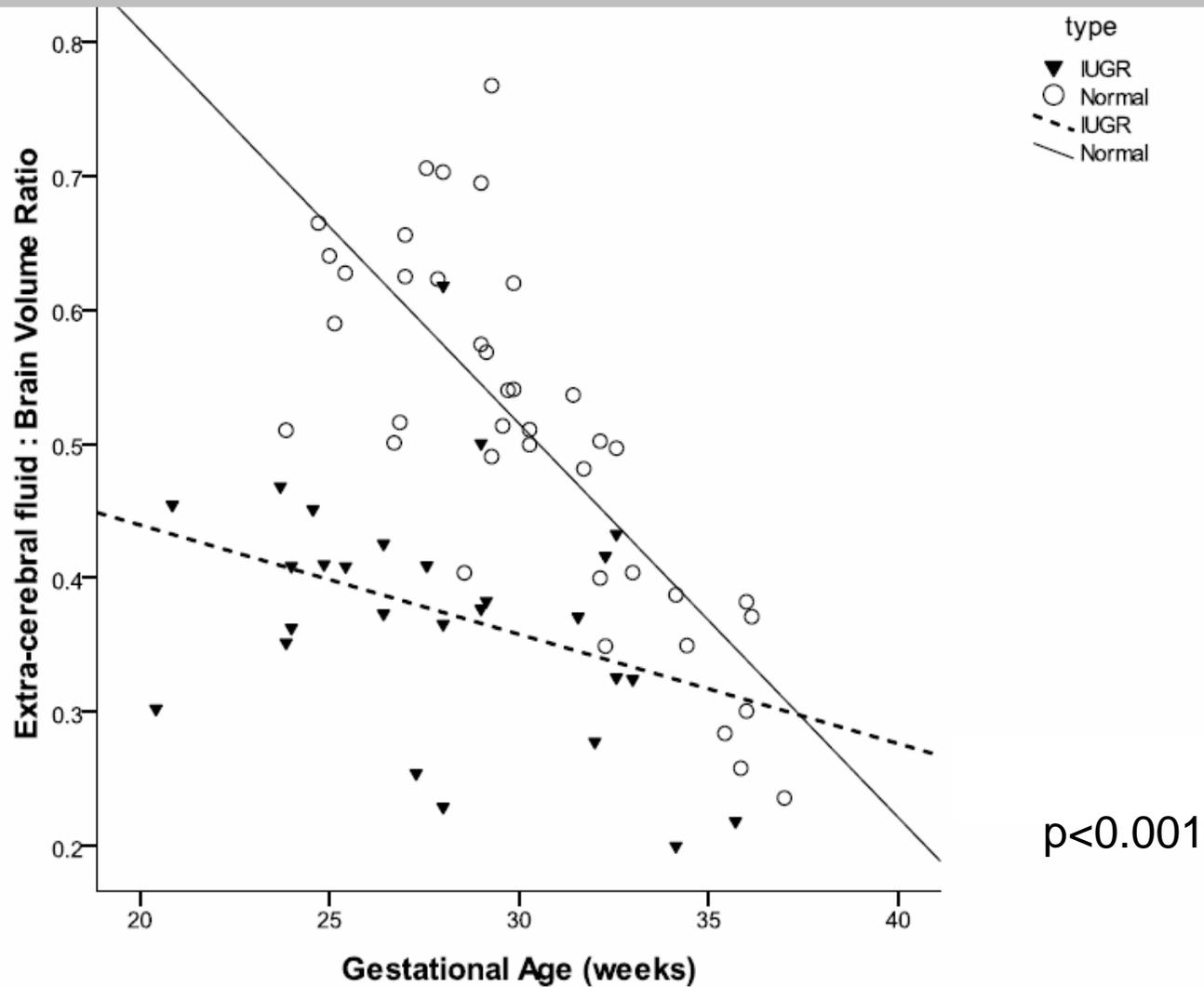
- **Measures of BPD will overestimate brain size** Damodaram (in prep.)

The fetus with IUGR
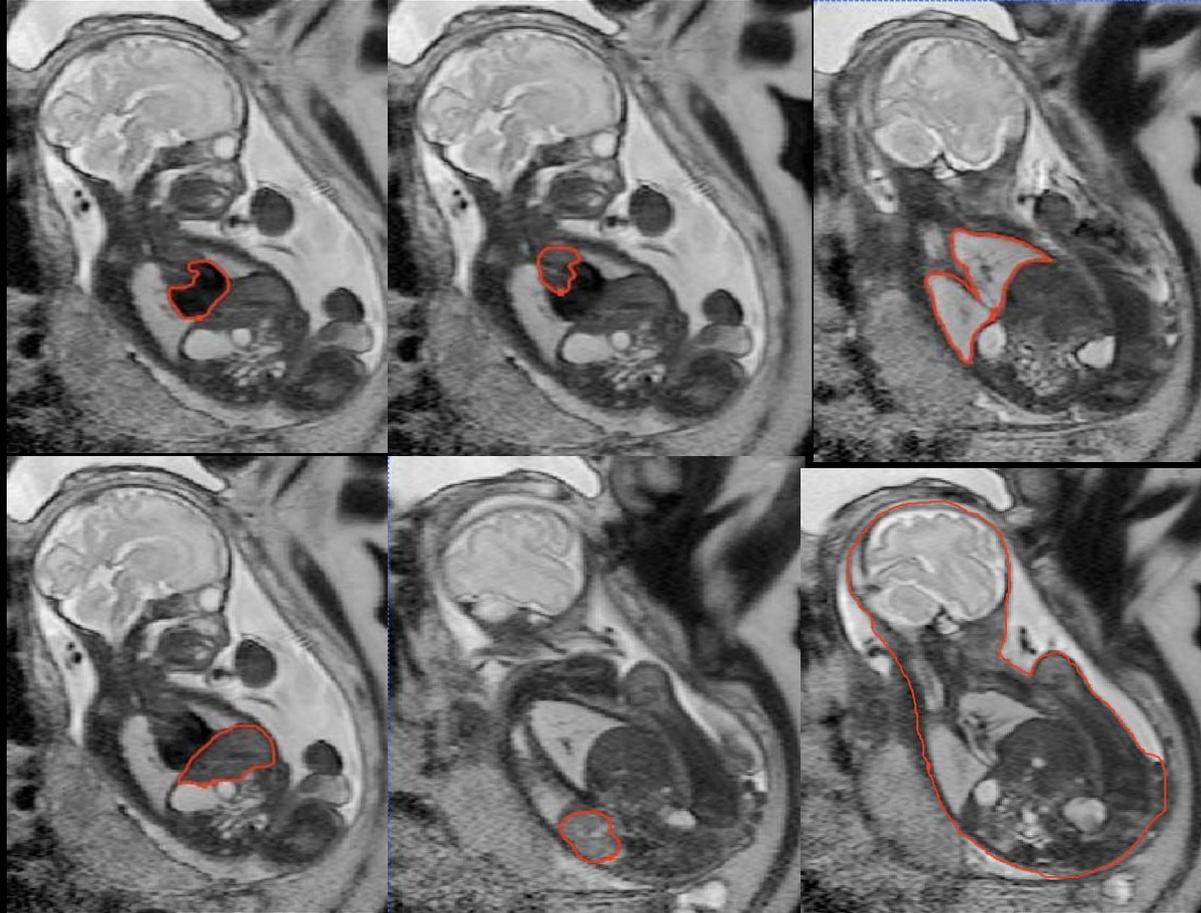
Is there any evidence of organ "sparing" ?   NO

The fetus with IUGR: cortical folding

- Is there evidence of abnormal maturation of the cortex?

- Assessed cortical folding visually with 8 point score

The fetus with IUGR: cortical folding

- No difference in cortical folding

Damodaram
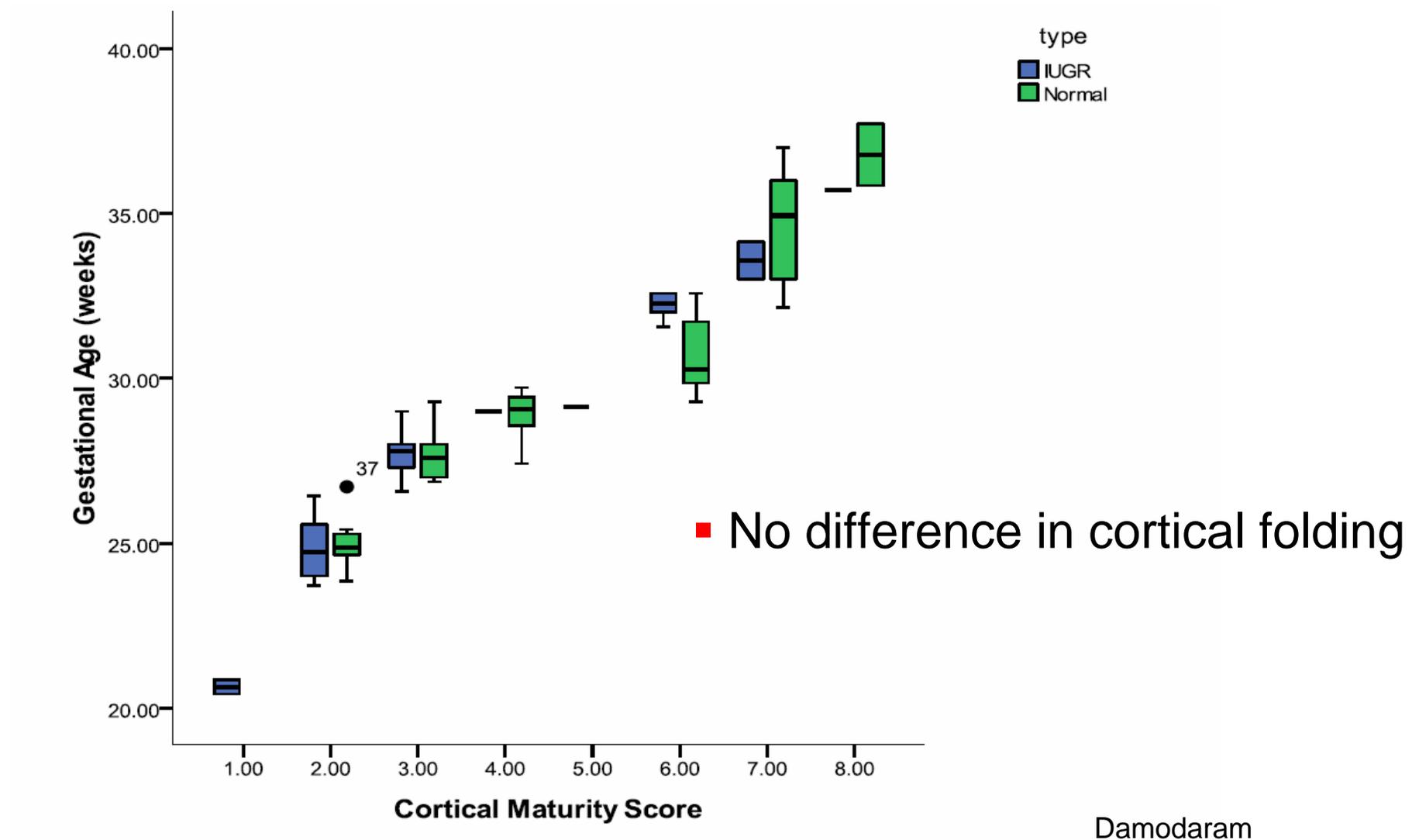
Automatic cortical segmentation
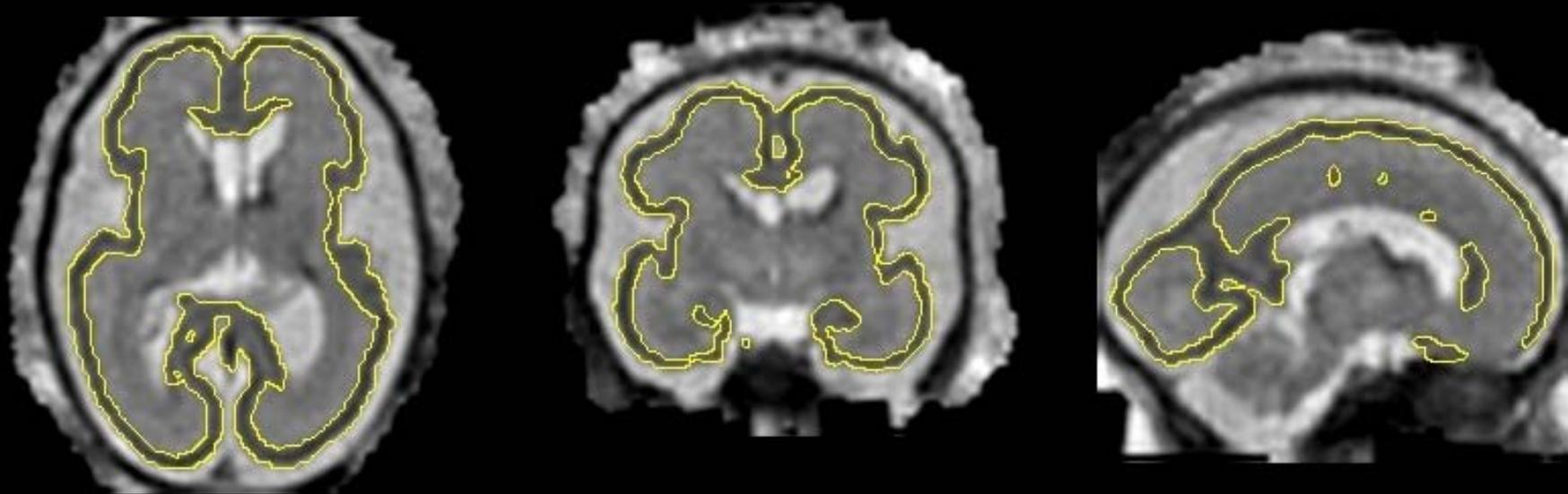
Optimisation of an automatic segmentation technique would allow quicker analysis of group date for research or individual data for clinical practice

Courtesy of Paul Aljabar

Fetal MR proton spectroscopy

- Metabolic information
  - Obtain chemical peaks Choline, Creatine, N Acetyl Aspartate, Lactate, *Myo*-inositol

- Technical difficulties
  - Motion
  - Small region of interest
  - Not possible to differentiate tissue types reliably-   use large region of interest

MR spectroscopy

- In vivo assessment of brain metabolism in normal and IUGR fetuses n=28 (controls 46)

- Large voxel 2x2x2 cm^3
- 70% success rate

Story et al 2011

24 week normal fetal control.
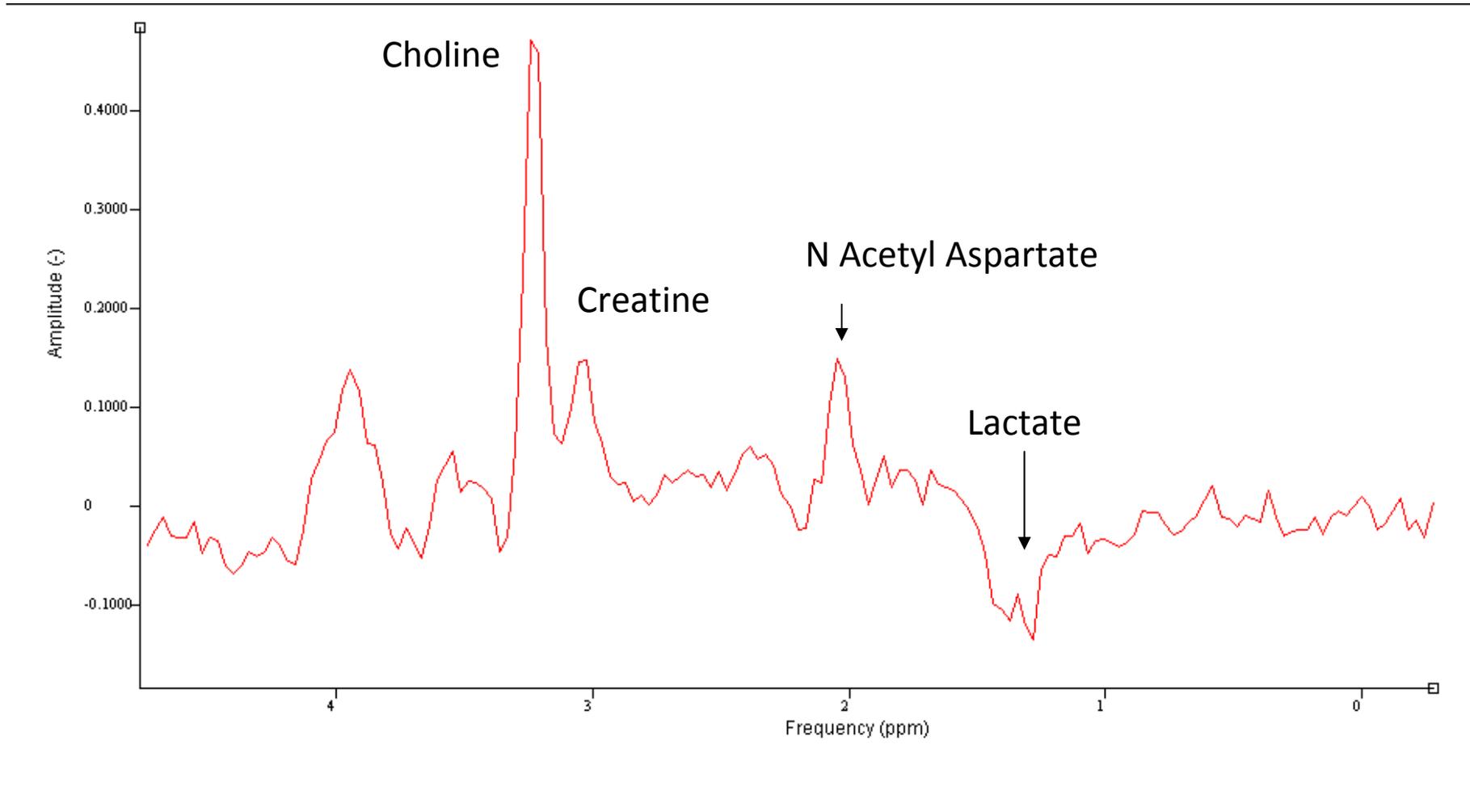
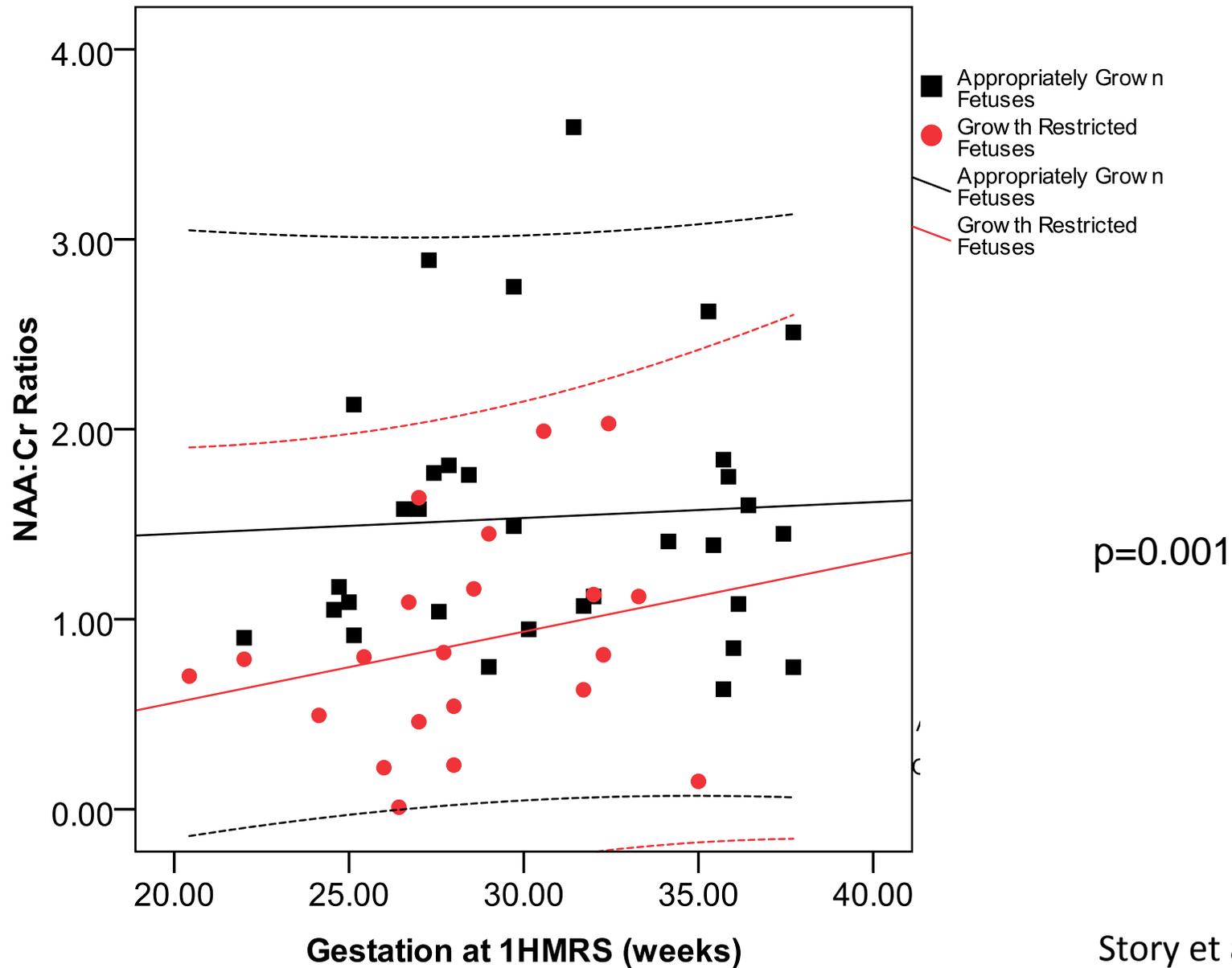- Spectrum obtained with TE= 144 ms

23 week fetus with IUGR
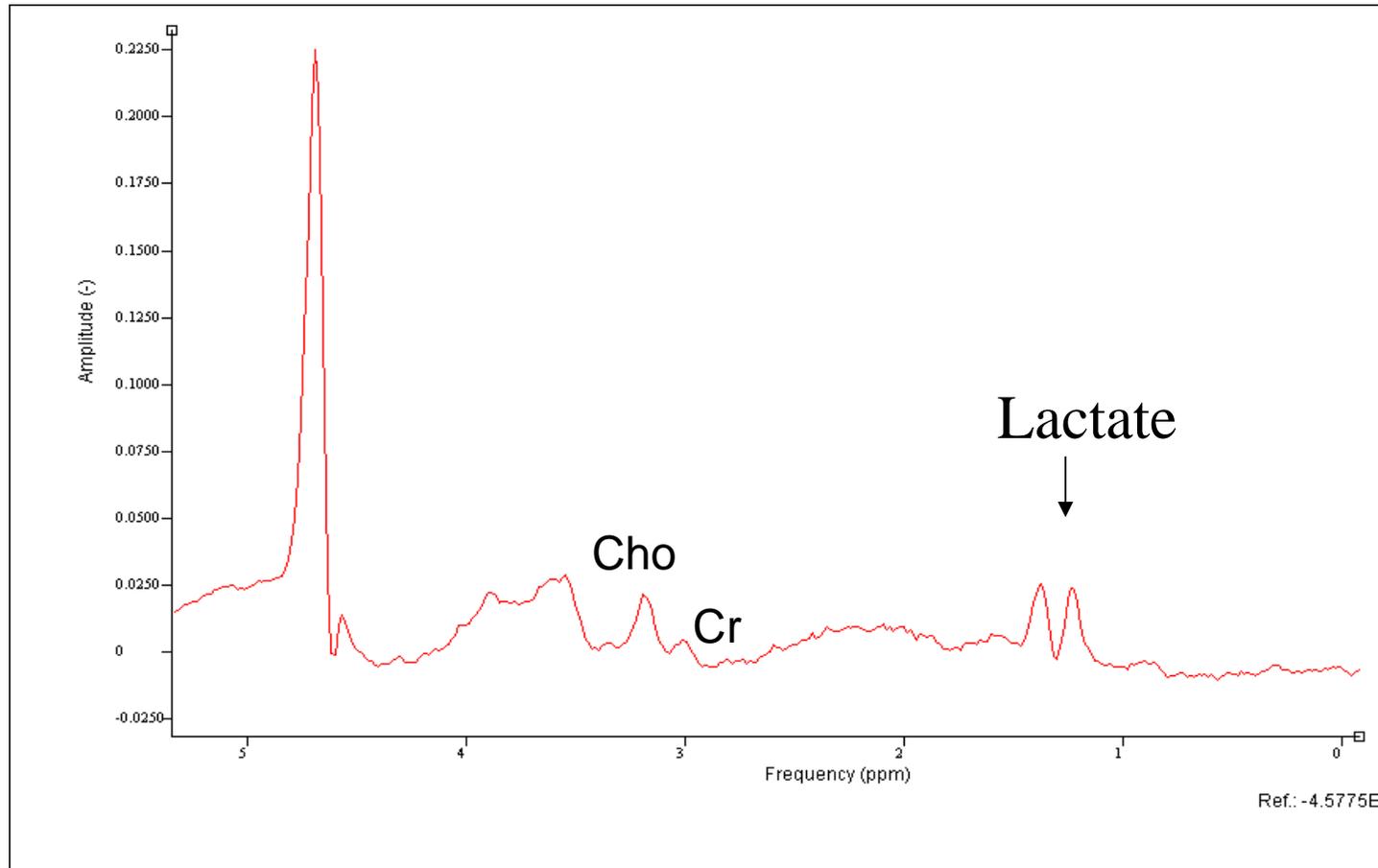
- Spectrum obtained with (TE) 36 ms.
- A large bifid lactate peak is present at 1.3 ppm
- No NAA visible at 2ppm

NAA reduced in IUGR

p=0.001

Story et al 2012

# Reduced NAA in brain of IUGR fetus

- NAA is synthesised in neuronal mitochondria, then transported to oligodendrocytes

- Reduced NAA may be sign of immaturity but may also reflect mitochondrial dysfunction

- Rat models of IUGR demonstrate mitochondrial dysfunction in brain other organs e.g pancreas

- Use MRS to quantify NAA in rat IUGR model and then assess mitochondria phenotypes and function.

Overview

- Practicalities and Sequences

- Clinical applications

    - Non CNS

    - CNS

- Research and development in IUGR pregnancies
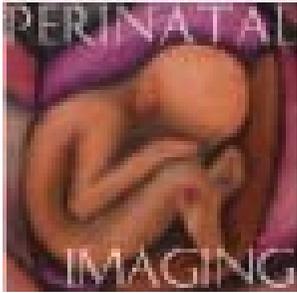
To all the staff in the Robert Steiner MR Unit and
the Centre for Fetal Care, Queen Charlotte's Hospital.

Shuzhou Jiang   Joanna Allsop
Tayyib Hayat   Lisa Story
Alpa Patel   Amy McGuiness
Daniel Rueckert   Paul Aljabar
Jo Hajnal   Mellisa Damadoram
Sailesh Kumar   Prachi Patkee
Ruwan Wimalasundera   Elisenda Eixarch

The Moonbeam Trust