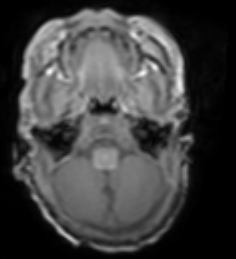
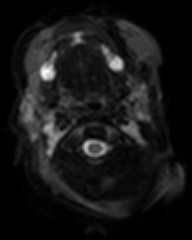
Imaging the very young at high magnetic field:

Challenges and Perspectives





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Honorary research fellow, Hammersmith Hospital, Imperial College London, cm1@imperial.ac.uk

Overview

- Characteristics of neonatal population
- High field benefits (high SNR, better MRA contrast, faster, better resolution)
- High field challenges (low contrast, SAR limitations)
- Perspectives: more space for optimisation
- An example: cerebral MRA at high magnetic field

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Philips 3.0 Tesla Achieva in NICU

Neonatal population considerations

- Small size→ Signal to noise ratio issues
- Fast developing→ change in brain water content and myelination
- Motion→ motion artefacts

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Size matters!

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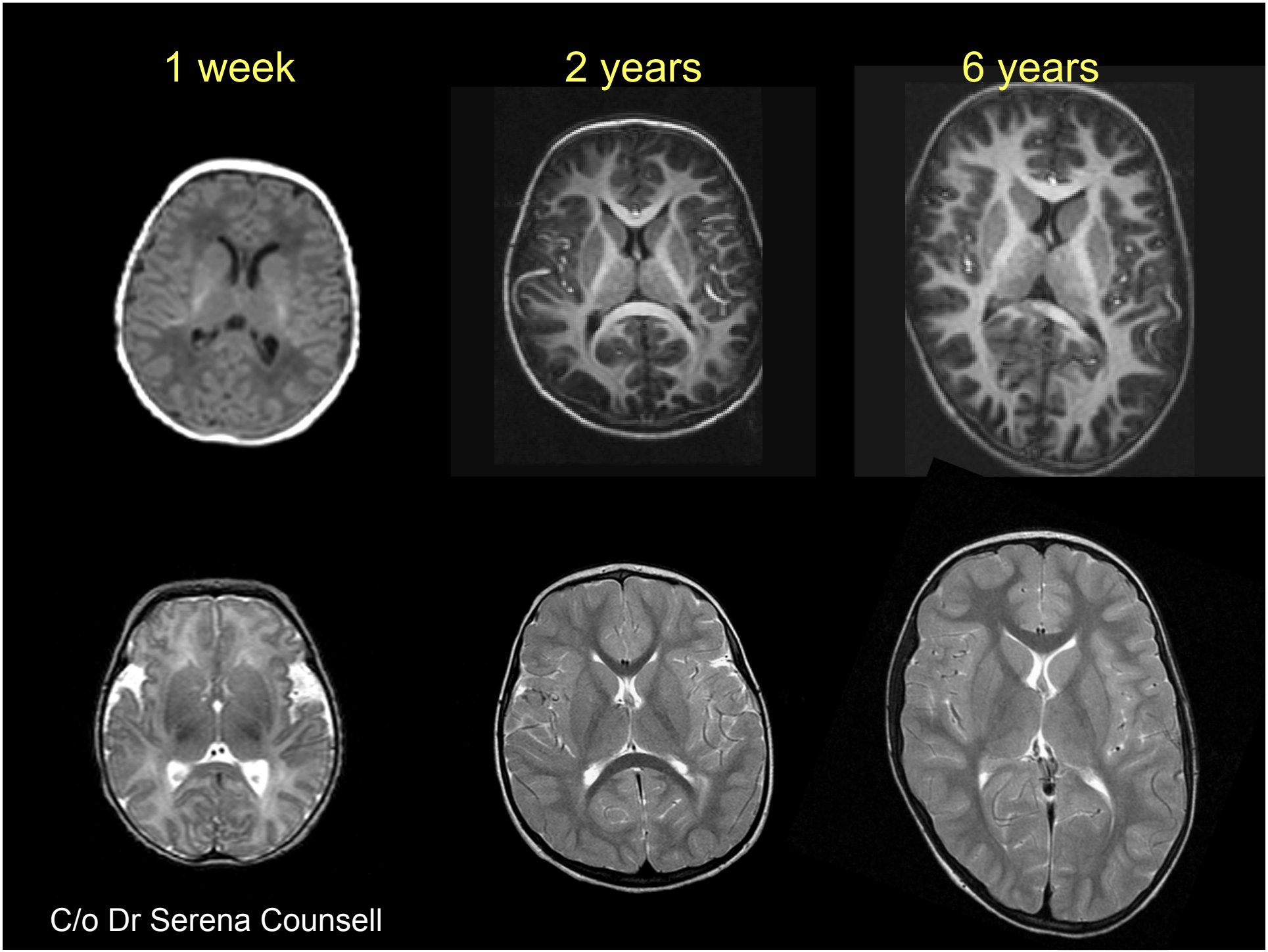
1 week
2 years
6 years
C/o Dr Serena Counsell

Image quality in neonatal brain MRI

- Anatomy is smaller→ Signal-to-Noise Ratio (SNR) and delineation of anatomical details
- Patient motion may occur more often→ motion artefacts
- Patient preparation, equipment used and imaging protocols should be modified and be dedicated for neonates

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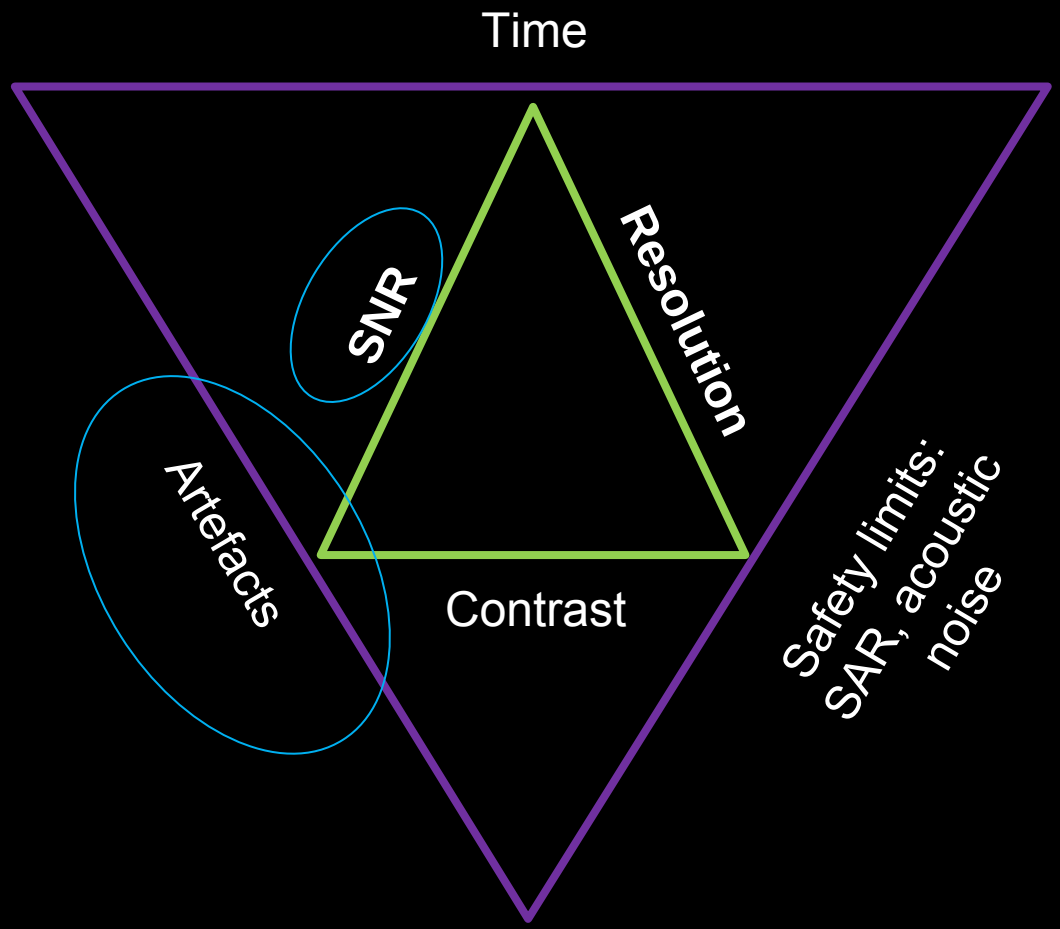
Image quality optimisation process in MRI



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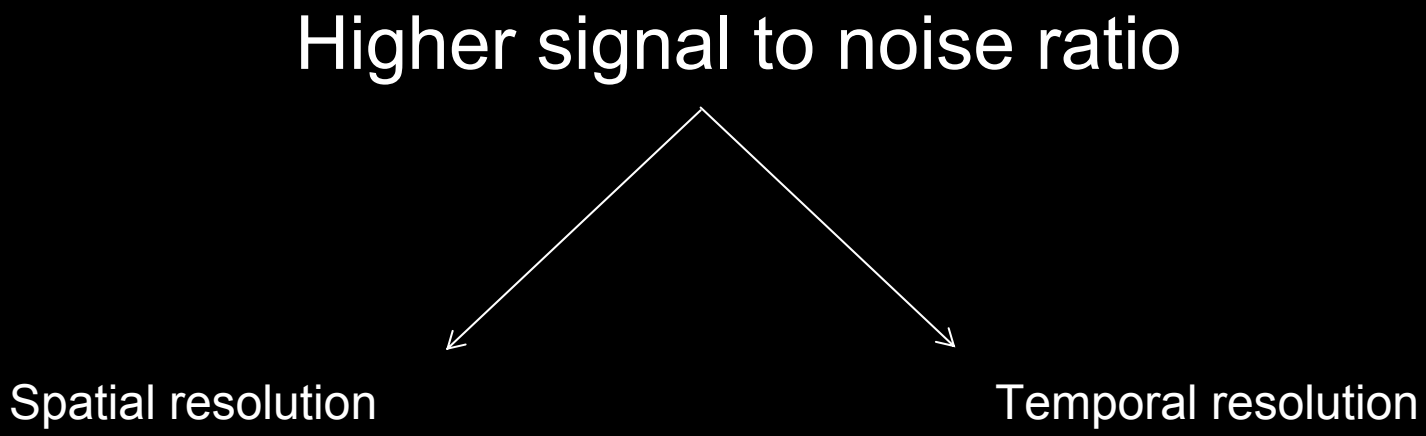
Advantages at high field MRI



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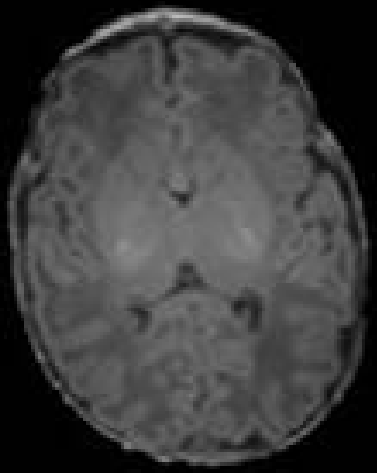
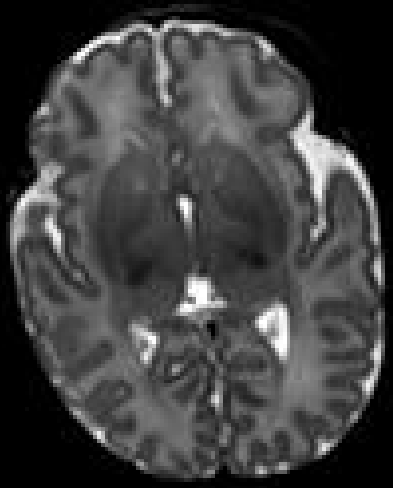
NEONATAL BRAIN IMAGING



T1-weighted



T2-weighted

Diffusion-weighted

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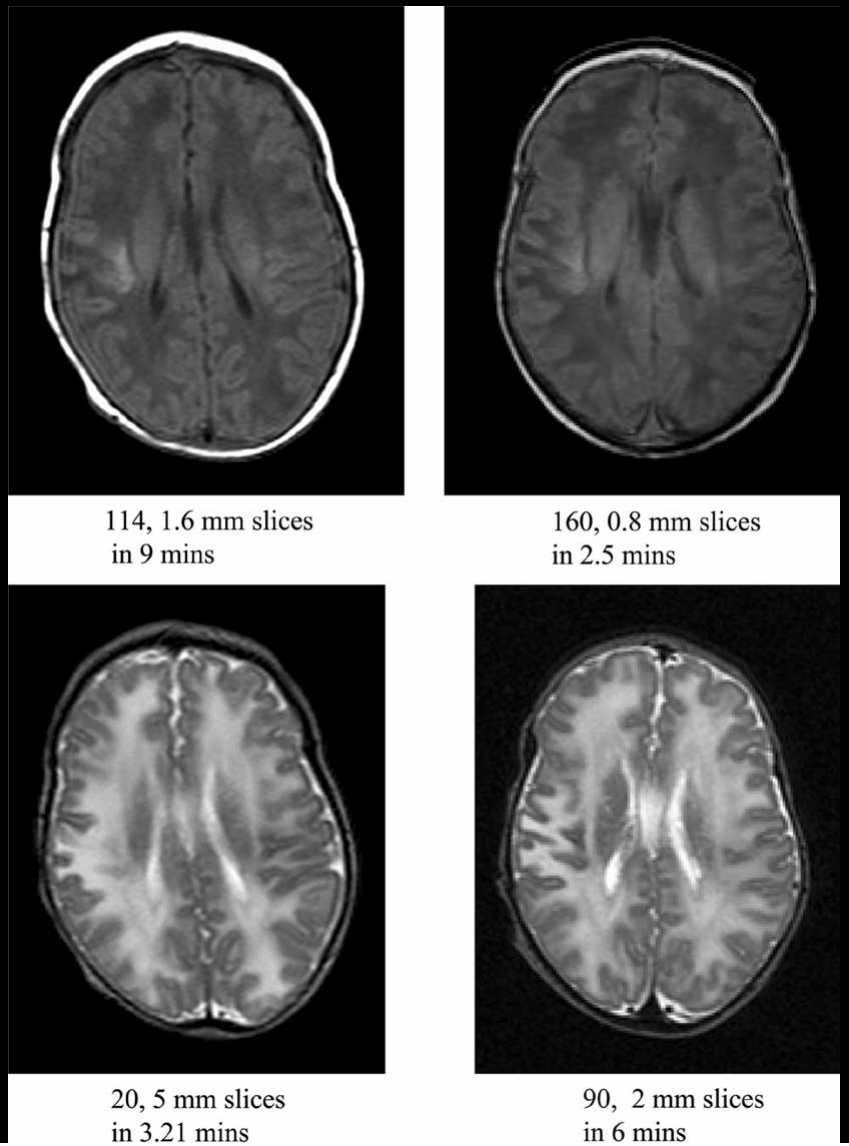
1.5T vs 3.0T

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.



114, 1.6 mm slices
in 9 mins

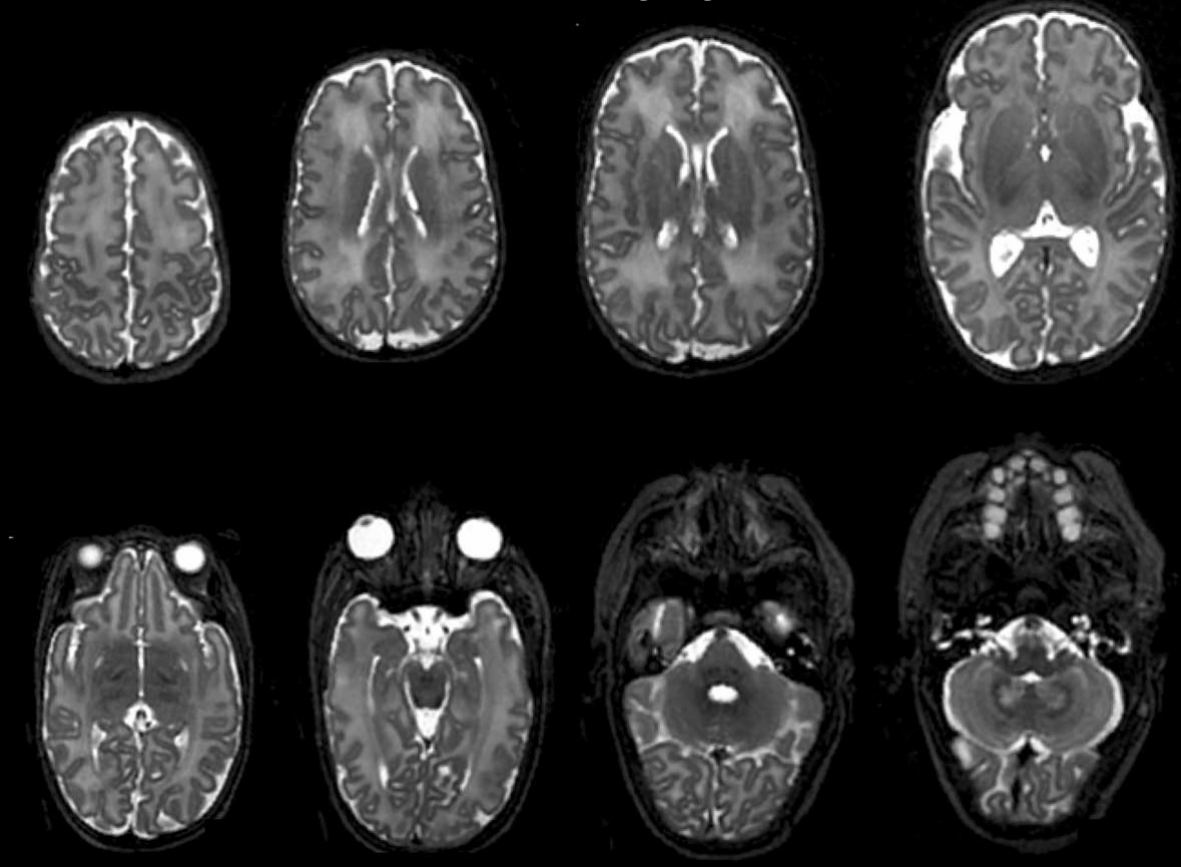
160, 0.8 mm slices
in 2.5 mins

20, 5 mm slices
in 3.21 mins

90, 2 mm slices
in 6 mins

T2 weighted scans

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.



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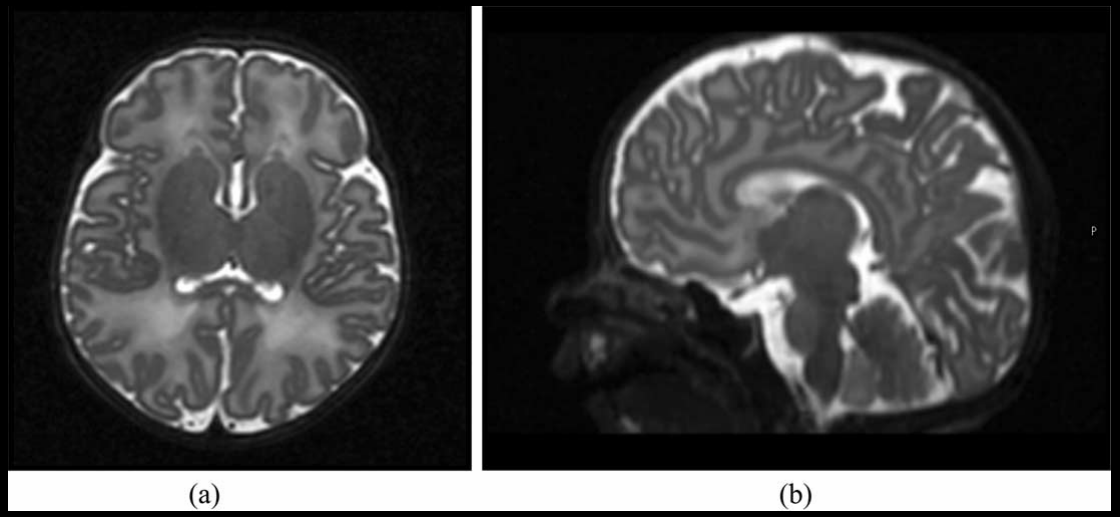
Multi-planar reconstructions

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.



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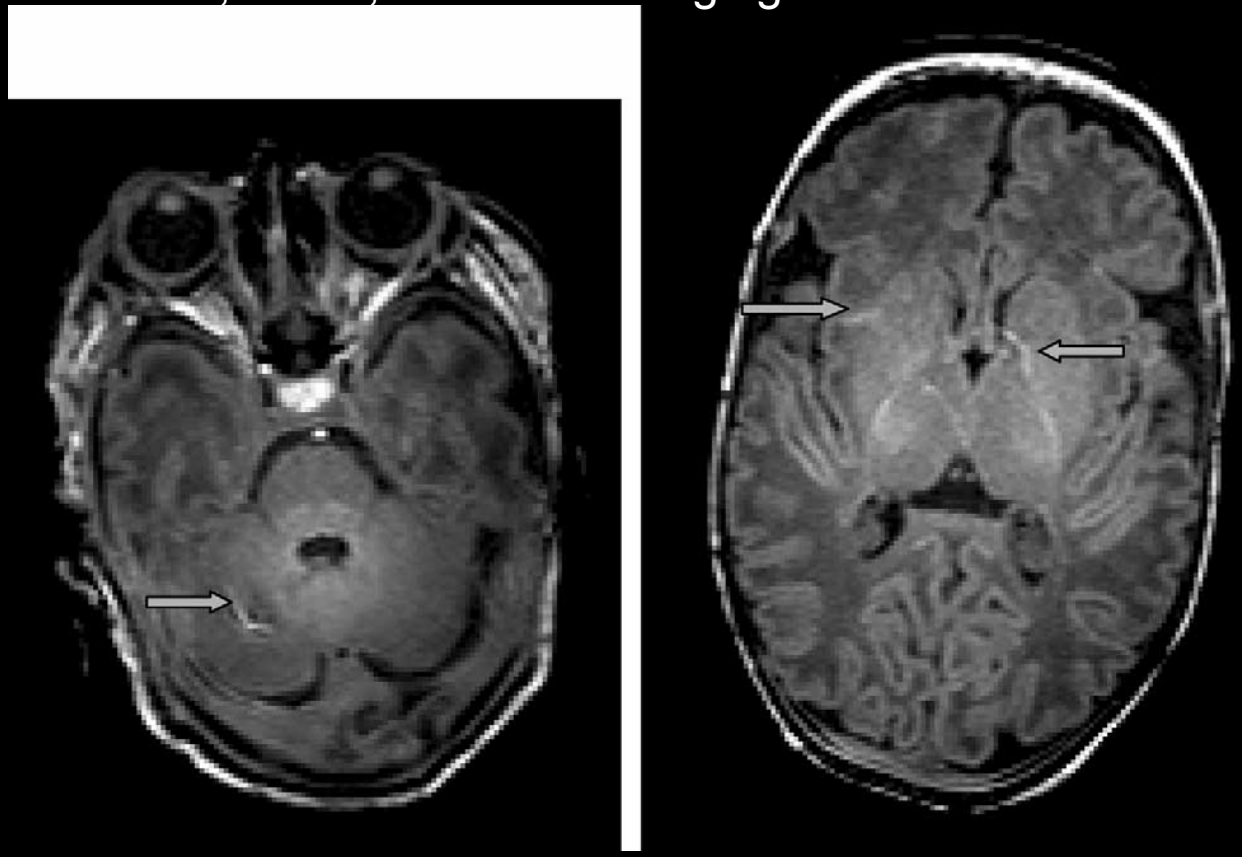
Increased vascular conspicuity

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.



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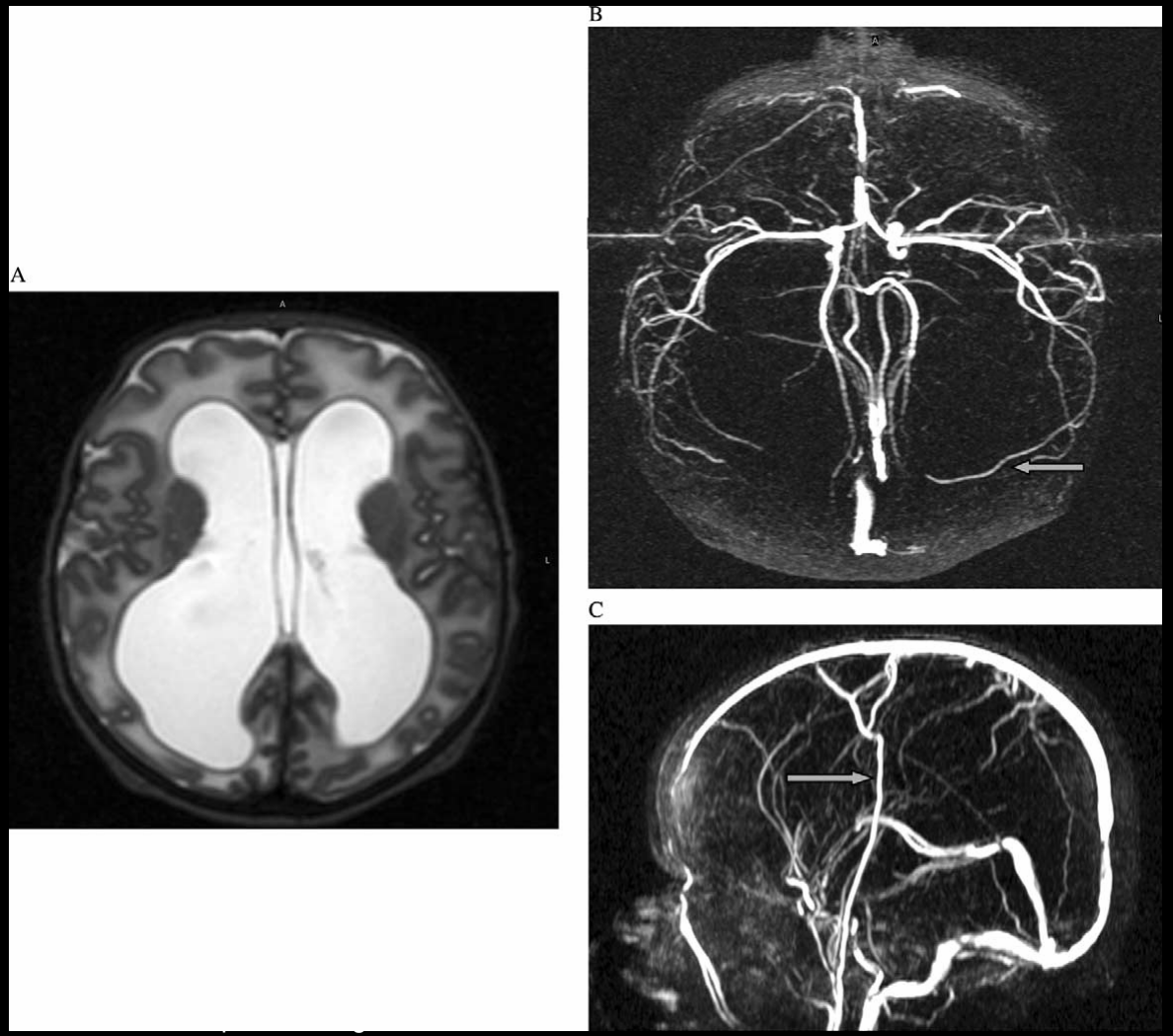
Venography

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.



Post-mortem studies

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.

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SNR and anatomy delineation

Malamateniou C. PhD thesis, Imperial College 2007

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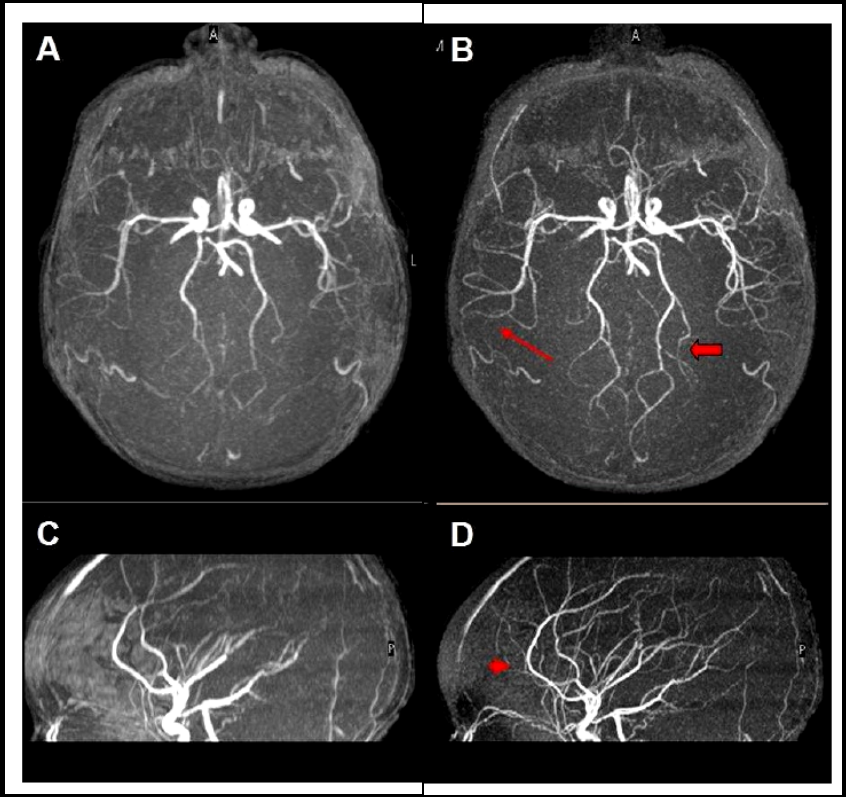
Optimised neonatal 3D TOF MRA protocol

preset

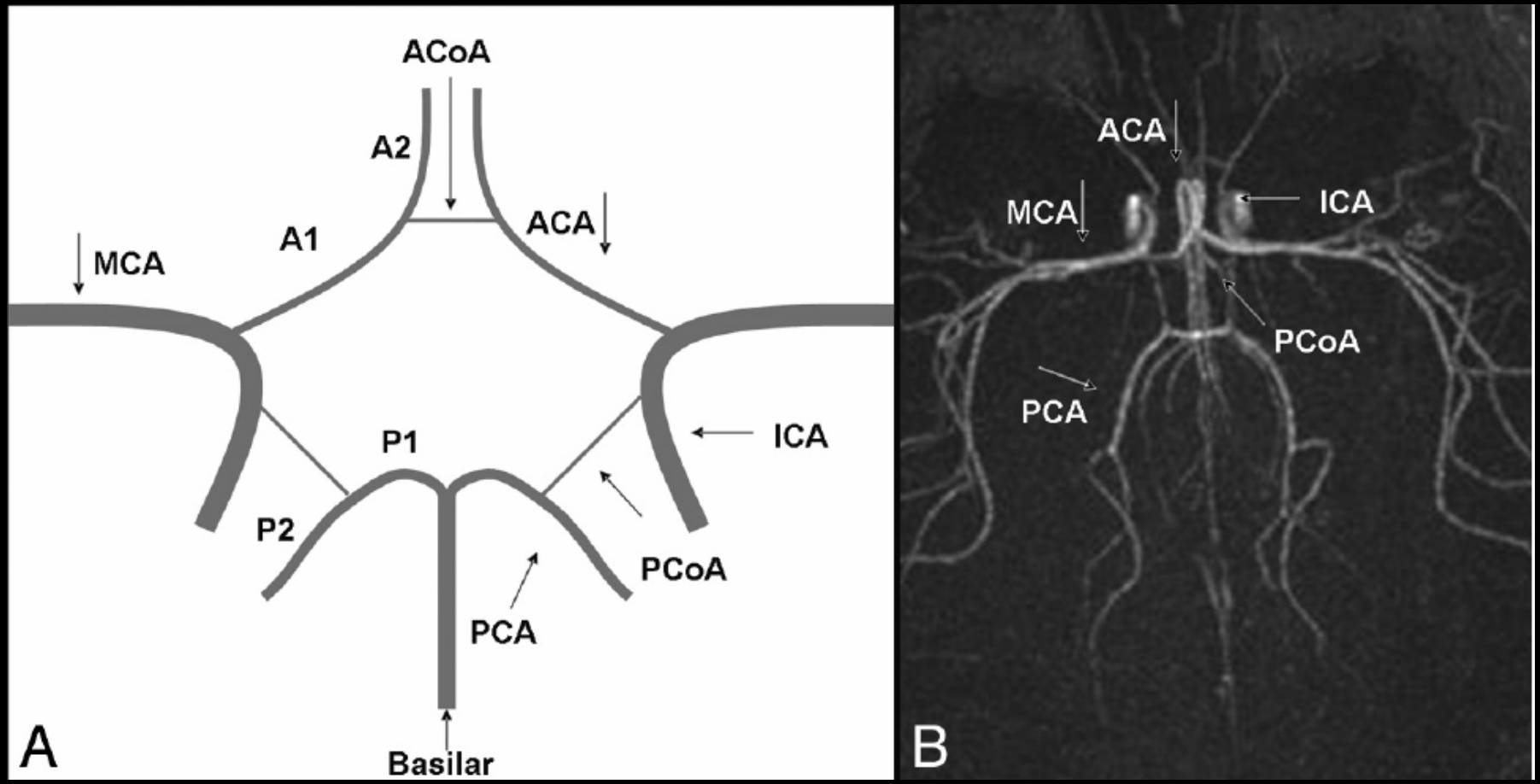


optimised

Malamateniou C.et al, Neuroimage, 2006. The effect of preterm birth on neonatal cerebral vasculature studied with magnetic resonance angiography at 3 Tesla

MRA IMAGING PARAMETERS	TR (msecs) FA (deg)	Echo TE	FOV (mm)/RFOV(%) Resolution (mm3) Voxel size (mm3)	Number of slices Slice thickness (mm) Coverage (cm)	Chunks	Parallel Imaging	Scan time (mins)
ADULT STANDARD PROTOCOL	23 20	Partial 3.5	200/100 1.03x0.66x0.7 0.475 (anisotropic)	100 0.7 7	1	OFF	05:11
NEONATAL OPTIMISED PROTOCOL	19 16	Full 5.75	175/80 0.6x0.6x0.6 0.216 (isotropic)	100 0.6 6	5	ON SENSE FACTOR OF 2.00	05:20

Neonatal cerebrovascular anatomy detail at 3 T



Malamateniou C et al, AJNR, 2009. The Anatomic Variations of the Circle of Willis in Preterm-at-Term and Term-Born Infants: An MR Angiography Study at 3T

Clinical benefits of high field

Dagia C, Ditchfield M, EJR, 2008. 3 T MRI in paediatrics: Challenges and clinical applications

Table 1
Specific paediatric applications that benefit from the improved spatial and temporal resolution at 3 T

	Application	Examples of specific diseases
Neonate	All structures	
Nervous system	Brain	Cortical dysplasia, migrational abnormalities
	Inner ear	Congenital sensory neural hearing loss
	Cranial nerves	Neuritis, e.g. bells palsy
	Brachial plexus	Birth trauma
Abdomen	Biliary tree	Sclerosing cholangitis, post liver transplant assessment
Musculoskeletal system	Small joints	Post reduction of dislocated hips in DDH, pre operative congenital deformity correction
	Polyarthropathy	Haemophilia
MR angiography	Vasculitis	Takayasu's arteritis, Moya Moya, Kawasakis disease
	Vascular malformations	Characterising type of vascular malformation
	Congenital heart disease	Pulmonary arterial and aortic abnormalities, anomalous pulmonary venous return
Whole body MRI	Neoplasia	Neuroblastoma, lymphoma, leukaemia, ewings sarcoma
	Bone infarction	Sickle cell disease, post chemotherapy and steroid therapy
	Multifocal diseases	Chronic recurrent multifocal osteomyelitis, polymyositis
	Osteoporosis (compression fractures)	Metabolic bone disease, steroid therapy

3T challenges

- Longer relaxation times
- Higher specific absorption rate
- Increased acoustic noise
- Susceptibility artefacts and b1 field in-homogeneity not a big problem in neonates

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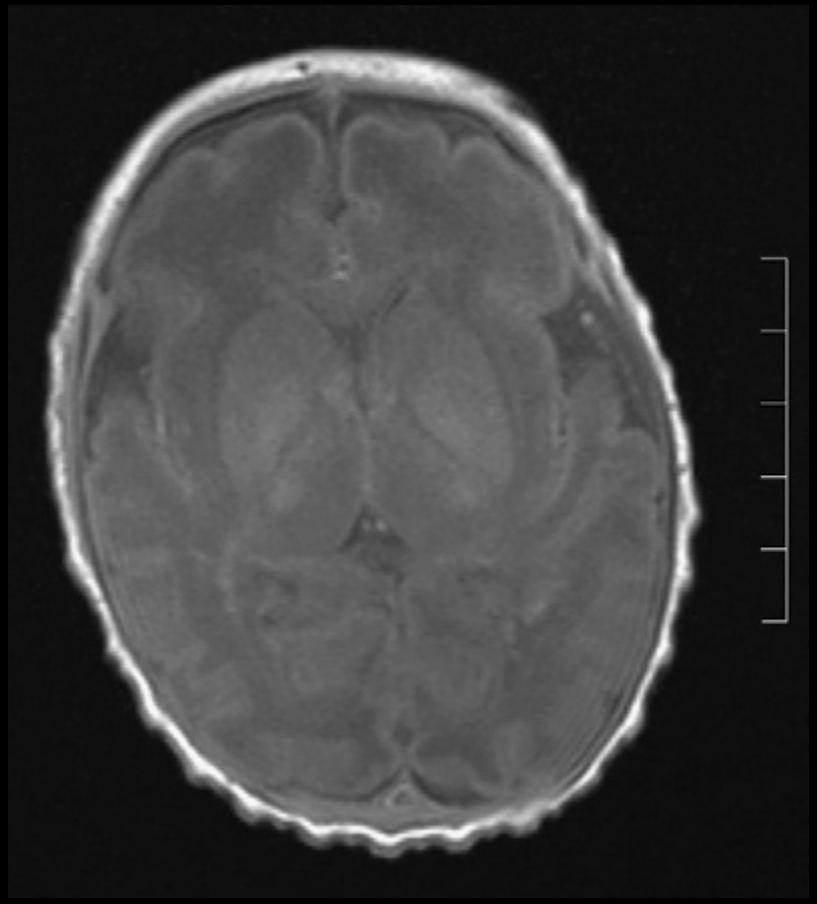
Change in T1 relaxation times

Dagia C, Ditchfield M, EJR, 2008. 3 T MRI in paediatrics: Challenges and clinical applications



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Adapting 1.5T protocols to address 3T challenges

Dagia C, Ditchfield M, EJR, 2008. 3 T MRI in paediatrics: Challenges and clinical applications

	Effect	Compensation	Effect of compensation (trade off)
↑T1 value	↓T1 tissue contrast	Increasing TR	↑Scan time
		Parallel imaging techniques	↓SNR*
		IR or MT sequences	
↓T2* values	Change T2* contrast	↓TE	↓SNR*
↑Chemical shift	Artefact at fat–soft-tissue interfaces and MRS mis-registration	Doubling the readout bandwidth	↓SNR, permits↑, number of slices acquired for given TR
		↓FOV	↓SNR
		Fat suppression	Allows imaging at low readout bandwidth, SNR remains high
		↓Voxel Size	
↑SAR	↑Body temperature	SAR monitor (legal limits)	
		Special RF pulses	
		↓FOV	↓SNR
		Longer sequence duration	
		↓Flip angle	
		↓Number of slices	
		Longer TR	
↑Magnetic susceptibility	Image distortion, dark bands	Frequency encode parallel to long axis of implant	
		Remove cause	
		↓Voxel size	
		↓Slice thickness	
		↓TE	↓SNR*
		↑Receiver bandwidth	↓SNR
		↑Spatial resolution	
		↑ETL (FSE better than SE)	↑SAR
		Parallel imaging	↓SNR
		Shimming	
		GRE sequence most affected	
B1 inhomogeneity	Bright central region, signal loss	B1 insensitive (Adiabatic) pulses	
		Shimming	
		Dielectric pads	
↑Signal	↑Flow artefact	Saturation band	
		Phase encode direction other than AP	
		Gradient moment nulling	
		Cardiac gating	

Protocol parameters

Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.

Table 1 Image parameters for T1 weighted volume acquisitions at 1.5 and 3 T.

	1.5 T	3 T	1.5 T	3 T
Sequence	RF spoiled gradient echo	MP rage	T2 weighted TSE	T2 weighted TSE
Echo time (ms)	6	4.6	210	160
Repetition time (ms)	27	17	4200	≈10,000
Flip angle (degrees)	30	13	20	90
Matrix	192×256	256×256	192×56	224×256
Slices	114	160	20	90
Slice thickness (mm)	1.6	0.8	5	2
Gap	-	-	-	-
Scan duration (min)	9	2.5	3:21	6
Field of view	240	200	240	220
Number signal averages	1	1	2	1

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MR safety

- **Static field**→ Metal check (missile effect)
- **Gradient fields**→ ear protection
- **RF fields**→ heat deposition →follow SAR limits (W/kg) (MHRA)

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Acoustic noise

Acoustic protection must be used when imaging infants and children

Soundproofing material – “Ultra Barrier” American Micro Industries, Chamberburg, PA, USA
Williams et al. Magnetic Resonance Imaging 2007; 25: 1162-1170

Additional patient safety

- Baby specific metal check
  - Arterial lines
  - Shunts
  - Electronic name tags
  - Poppers on baby-grows
  - Check inside blankets

- Additional ear protection
- Monitoring of vital signs
- Resus equipment in place
- Clinician always present

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Further improvements

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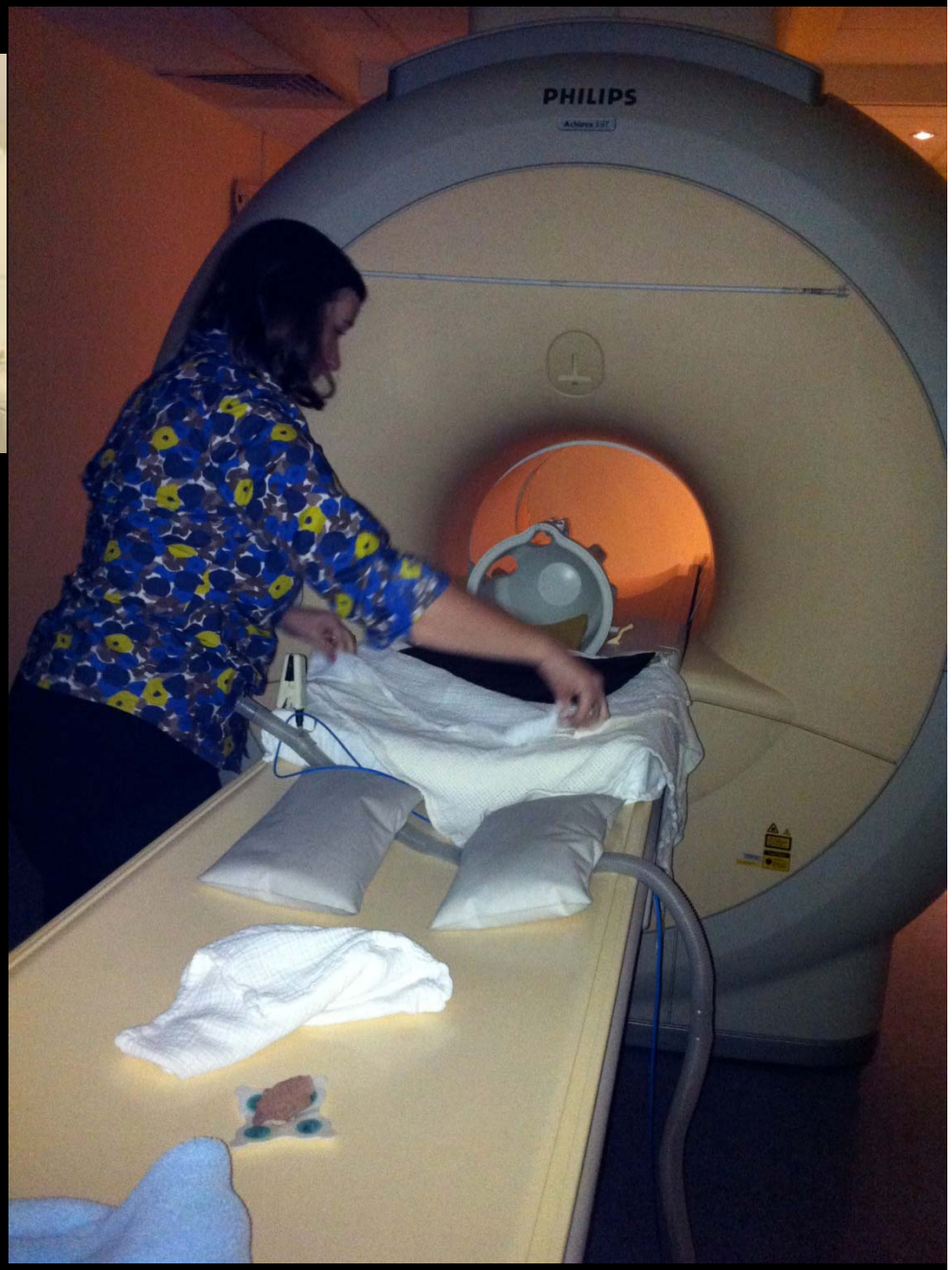
Coil choice



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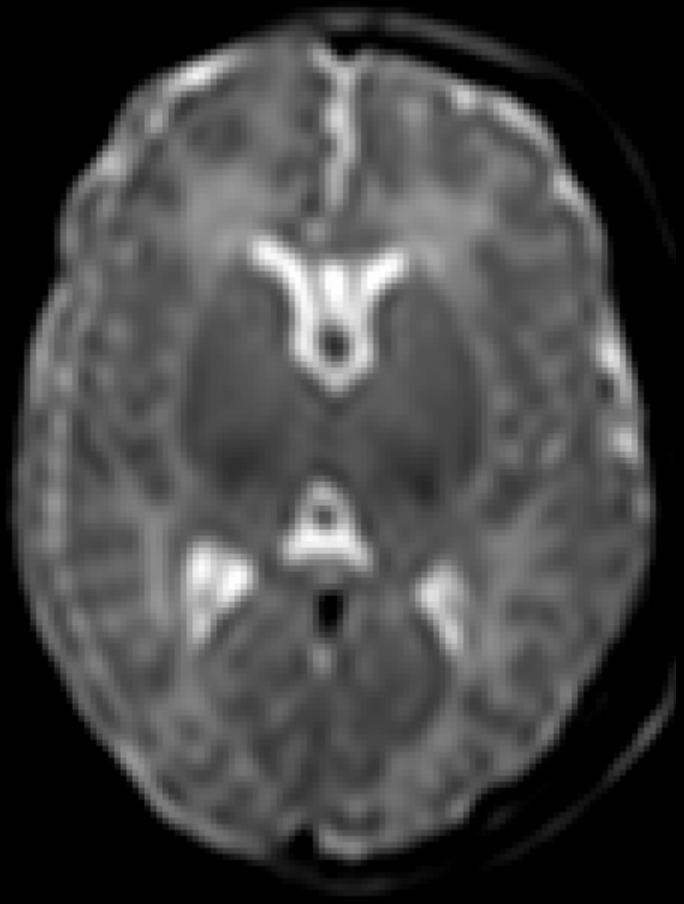
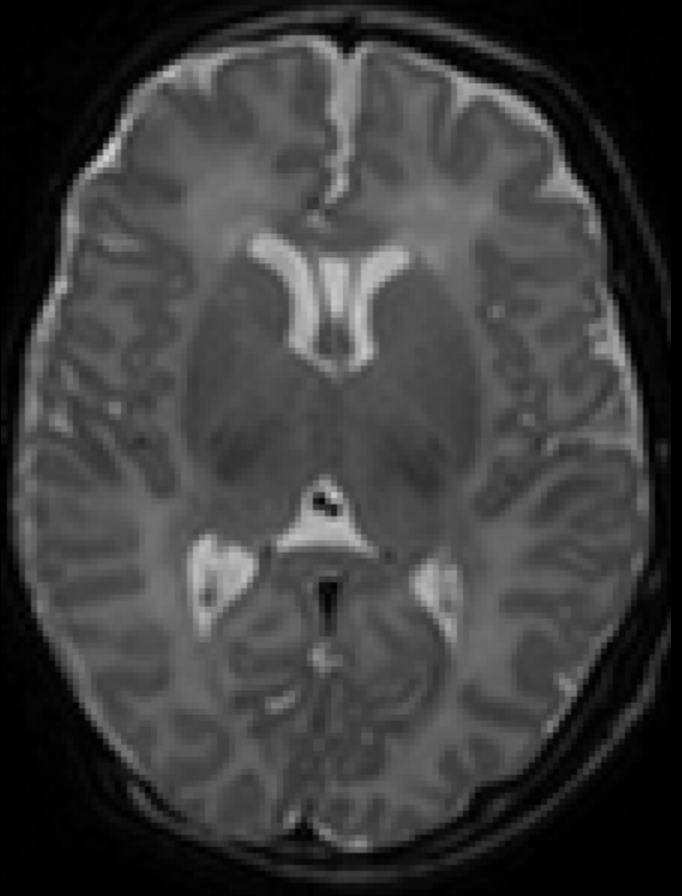
Imaging parameter choice-
Voxel size & spatial resolution



Low resolution
2x2 mm^2
2:30mins



High resolution
1.15x1.15 mm^2
4:30mins

How to optimise image quality without increasing scan time?

- Parallel Imaging (SENSitivity Encoding, SENSE)
- Developed by Klaas Pruessmann , (MRM,1999)
- Additional reference scan & multiple receiver coils
- images with different but complementary views of a patient
- SENSE factor =time reduction factor

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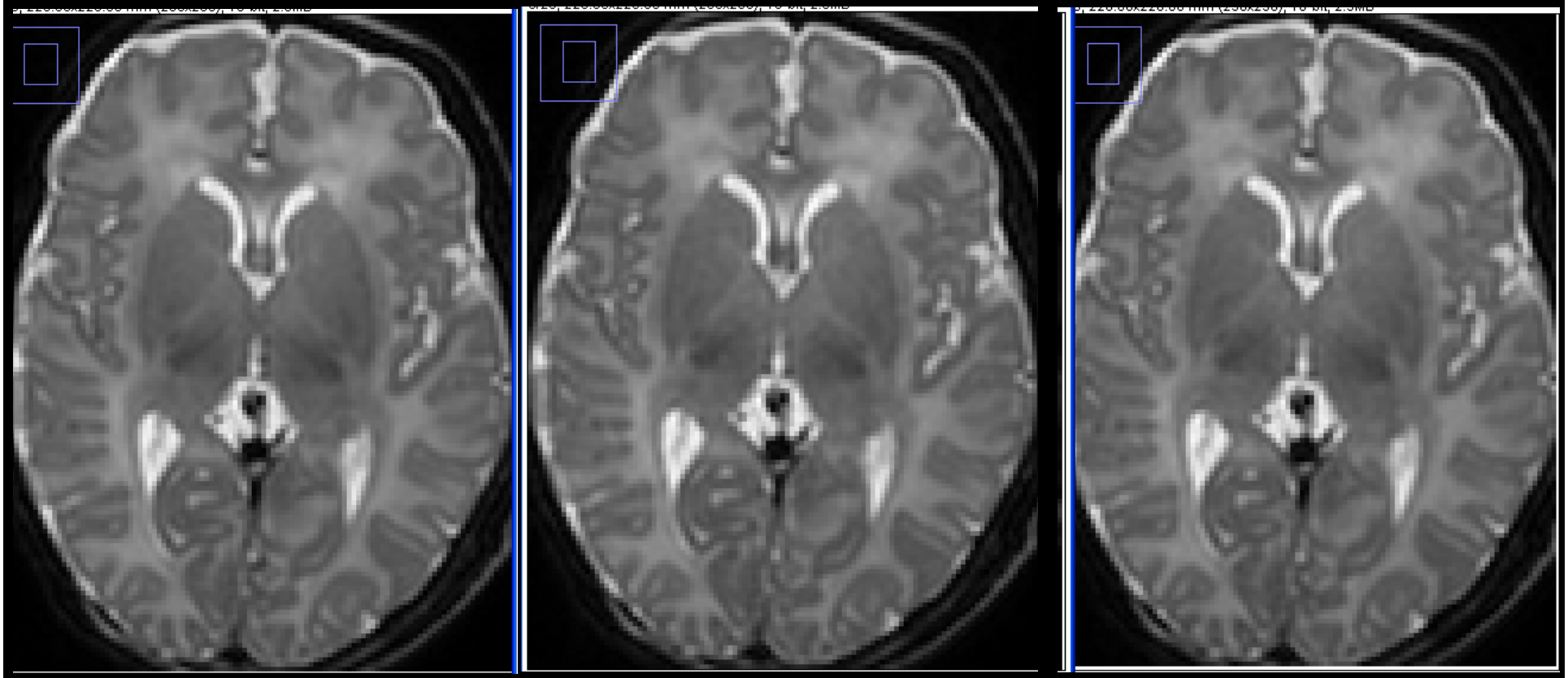
Imaging parameter choice-Parallel imaging



4:30 mins, no SENSE

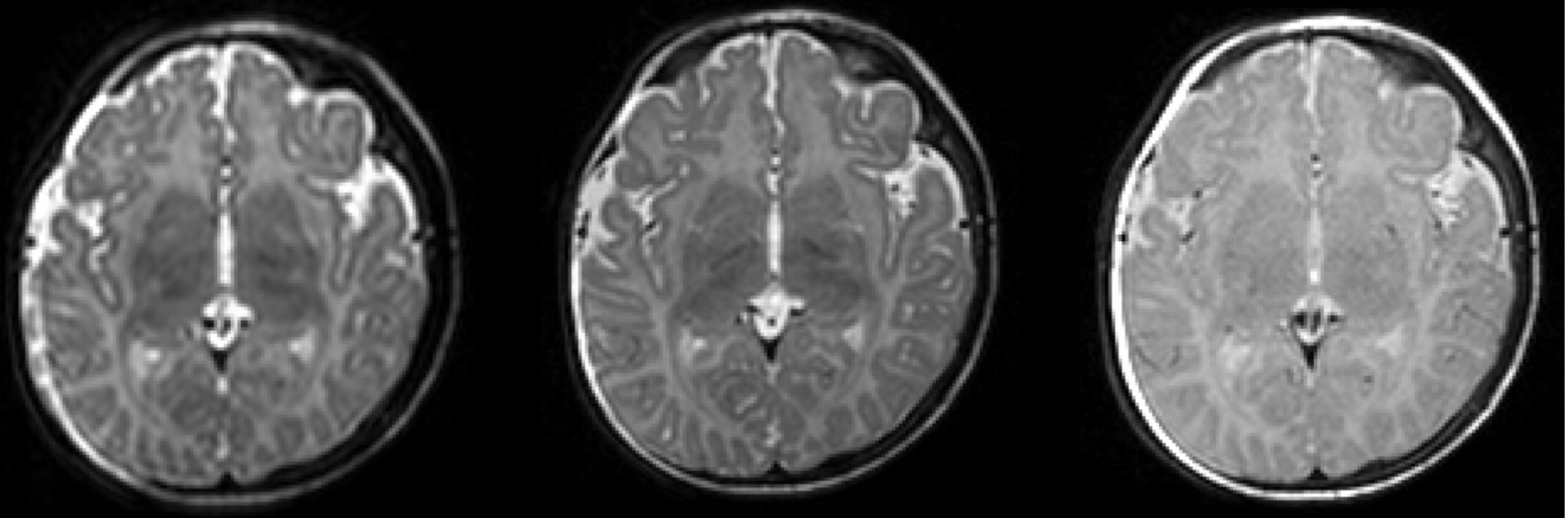
3:15 mins, SENSE=1.5

2:25 mins, SENSE=2.0

Important to know trade-offs in MRI

SNR →

Contrast ←



TE=160ms

TE=130ms

TE=100ms

Scan time ↓

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MOTION ARTEFACTS

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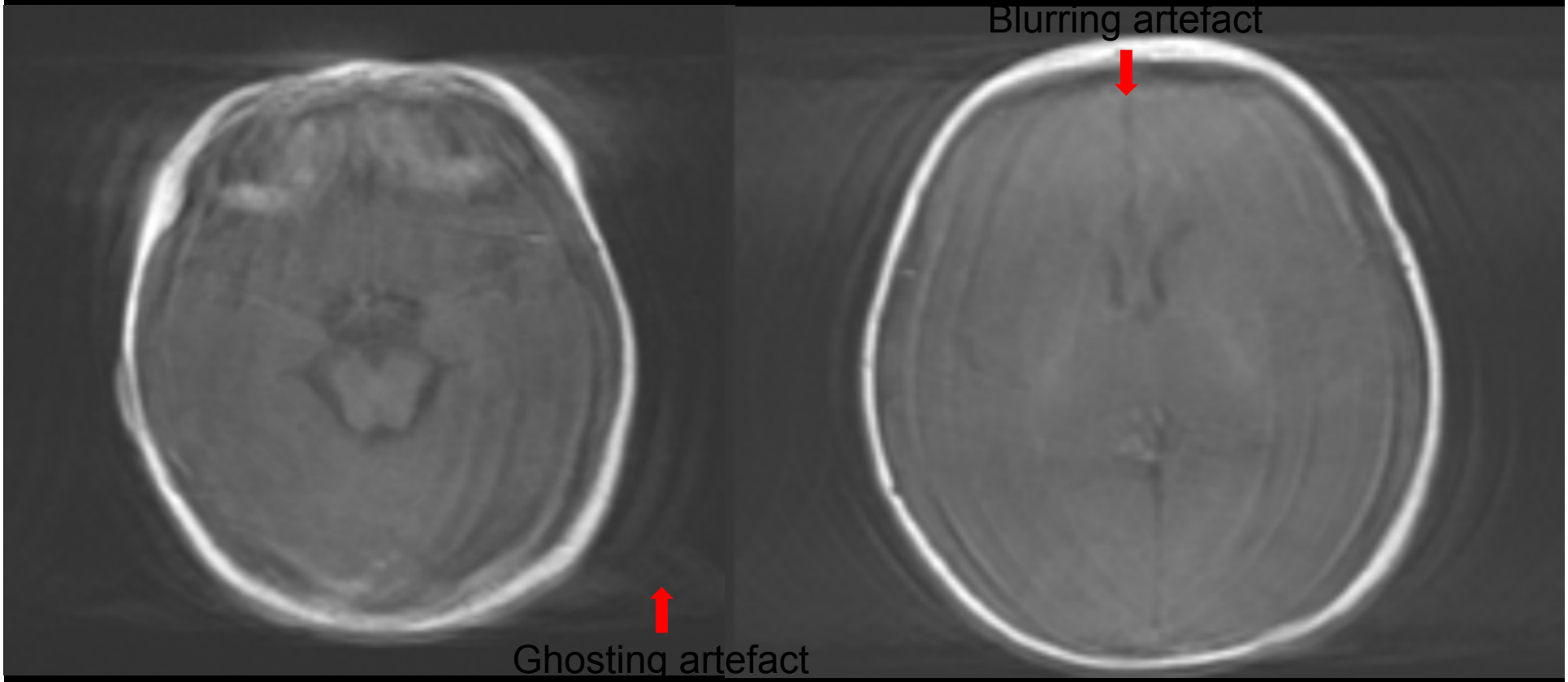
T1-weighted images



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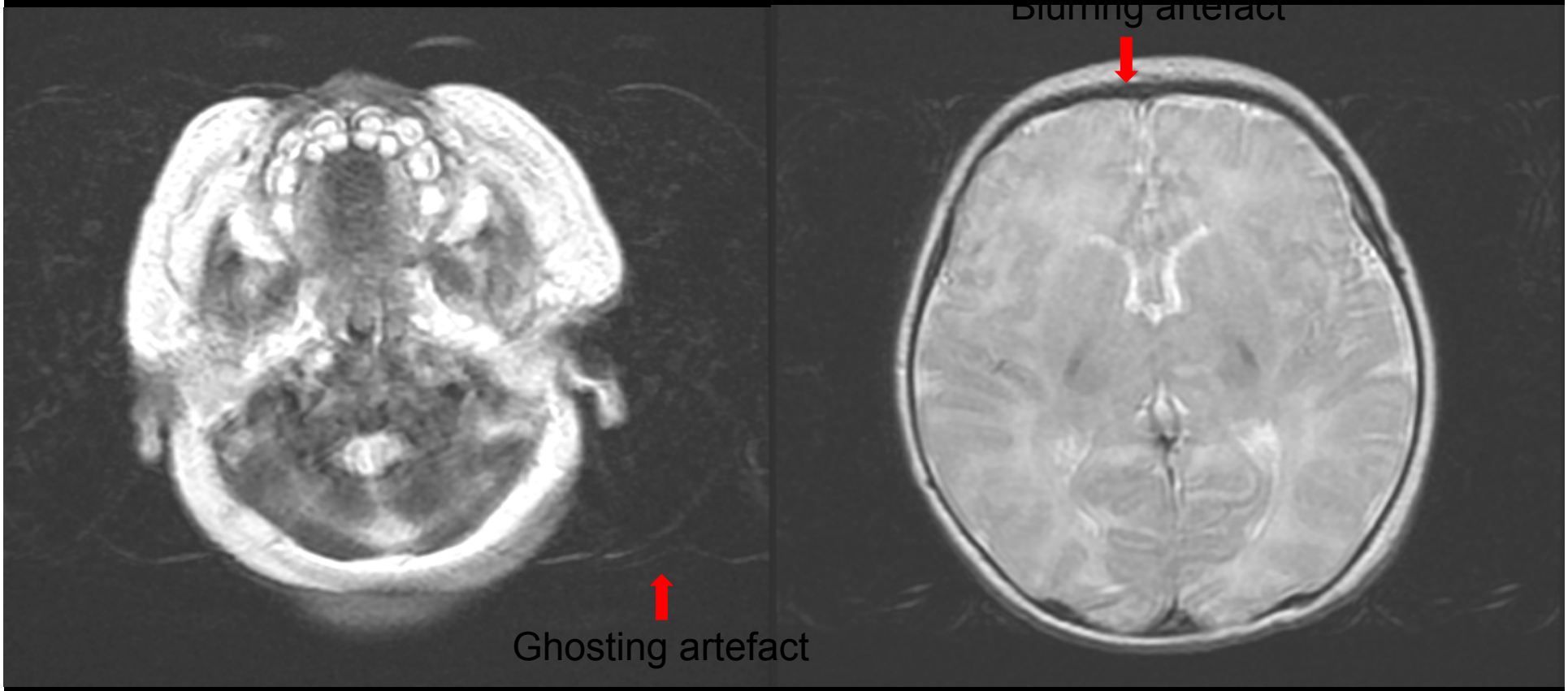
T2-weighted images



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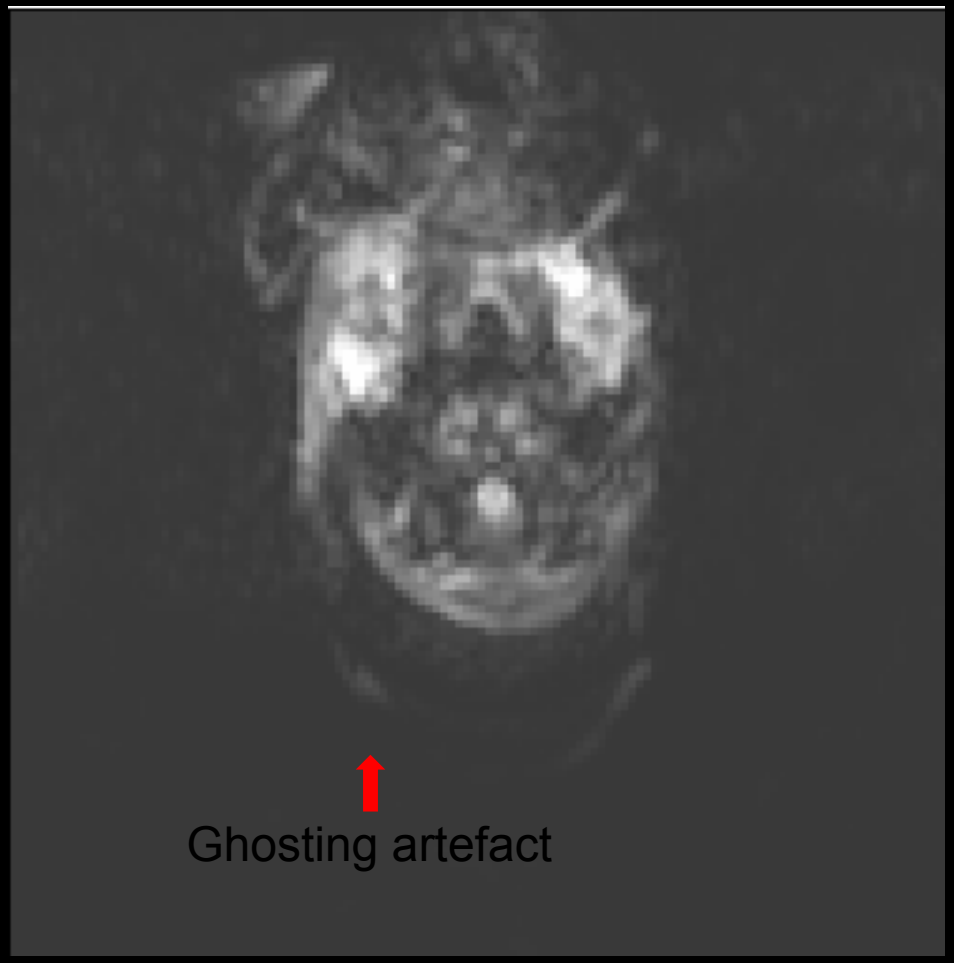
Diffusion-weighted images



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I. Patient preparation

- Sedation (oral chloral hydrate)

  Cowan FM. Sedation for magnetic resonance scanning of infants and young children. In: Whitwam JG, McCloy RF,editors. Principles and Practice of Sedation.Publishers Blackwell Healthcare; 1998. p. 206—13.

- Feed and sleep
- Change nappies
- Acoustic noise reduction
- Comfortable, soft and snug
- Temperature maintained

(23-24º for term born infants and approx. 28º for preterm infants)

II. Data acquisition

- Fast imaging
  - Shortening scanning time by reducing TR, # of phases, # of averages
  - Half scan (on Philips scanners)
  - Inherently faster sequences (FSE, EPI, Single shot etc)
- Different data sampling strategies
  - Radial
  - Spiral
  - PROPELLER/BLADE/Multi-VANE
- Parallel imaging (SENSE, GRAPPA, ASSET)
- Dynamic scans
- Navigators

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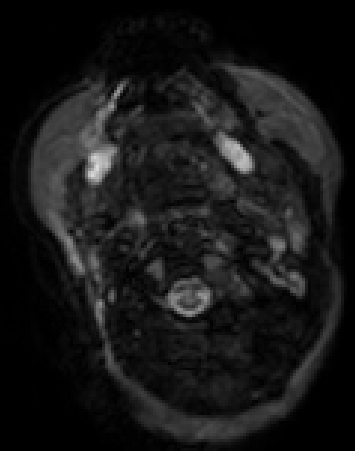
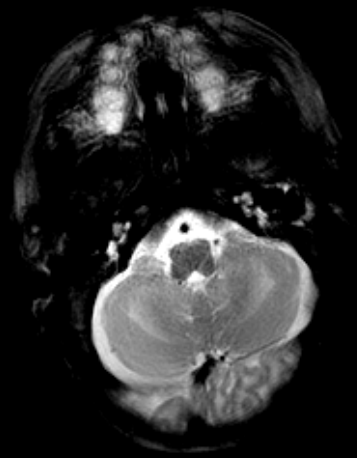
Neonatal standard T2-w and T2-w Multi-vane





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Multi-shot FSE vs Single-shot FSE

Conclusions

- Signal increase at high static magnetic field is beneficial for different neonatal MRI applications
- Common challenges at 3.0 Tesla can be overcome by careful image parameter optimisation
- Optimal use of hardware (coils) and software (Parallel Imaging) is essential to take full advantage of the high field gains

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References

- Merchant N et al, EHD, 2009. A patient care system for early 3.0 Tesla magnetic resonance imaging of very low birth weight infants.
- Rutherford MA et al, EJPN, 2004. MR imaging of the neonatal brain at 3 Tesla.
- Malamateniou C et al, Neuroimage, 2006. The effect of preterm birth on neonatal cerebral vasculature studied with magnetic resonance angiography at 3 Tesla.
- Dagia C, Ditchfield M, EJR, 2008. 3 T MRI in paediatrics: Challenges and clinical applications

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