Gerda Meijler
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Neonatal Cranial Ultrasonography

Third Edition

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ISBN 978-3-319-77814-3 ISBN 978-3-319-77815-0 (eBook)
https://doi.org/10.1007/978-3-319-77815-0

Library of Congress Control Number: 2018966148

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

This is now the third edition of *Neonatal Cranial Ultrasonography* by Gerda Meijler and Sylke J. Steggerda, both well-known experts in the field of neuro-imaging in the newborn. The ultrasound images have improved even further in this edition with the use of better equipment showing the even more detailed information that can now be obtained using this non-invasive bedside technique. The book is very well illustrated and there are videos available online, showing those who are just starting to learn the technique how to place the probe for different acoustic windows, adjust the machine and what to look for. The size of the book makes it easy to have to hand for comparing images made by the trainee and those shown in the atlas.

Not only is normal anatomy very well shown, there is a chapter illustrating the progress in brain maturation from extremely preterm to term infants that can be visualised using cranial ultrasound. Scoring systems one can use for intraventricular and cerebellar haemorrhages and white matter injury are well described. There are some correlates with MRI of the brain which are also helpful and illustrate how much can be seen with both techniques. Calcification, for example lenticulostriate vasculopathy, will not be visible on conventional MRI techniques, small cysts are difficult to see on MRI and myelination cannot be seen on ultrasound, showing that these two techniques are complementary. Doppler ultrasonography is well explained and illustrated.

There is not enough space for all the different pathologies one may encounter in a newborn infant (metabolic disorders; neurocutaneous phacomatoses) but with the help of many references, one will find a relevant recent publication or book.

This pocket-sized book can and should be carried by every trainee who is learning how to perform cranial ultrasound, and he or she is likely to become as enthusiastic as these two authors have been for many years.

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Acknowledgements

We want to thank the children whose photographs and videos have been used for this book and their parents for their permission to use the photographs and videos.

We also want to thank Professor Frances Cowan for reviewing Chap. 9 and for her useful and thorough comments, and Professor Linda de Vries for her general advice and comments, and for providing some figures.

We thank Gerrit Kracht, medical photographer, for making the colour videos.

Contents

Abbreviations

ACA	Anterior cerebral artery
aCM	Callosal marginal artery
aFI	Frontal internal arteries
AHW	Anterior horn width
aPC	Pericallosal artery
CBH	Cerebellar haemorrhage(s)
CDI	Colour Doppler imaging
CNS	Central nervous system
c-PVL	Cystic periventricular leukomalacia
CUS	Cranial ultrasound/ultrasonography
CV	Convex
ECMO	Extracorporeal membrane oxygenation
GA	Gestational age
GMH	Germinal matrix haemorrhage
GMH-IVH	Germinal matrix-intraventricular haemorrhage
ICA	Internal carotid artery
ICV	Internal cerebral vein
ISS	Inferior sagittal sinus
IVH	Intraventricular haemorrhage
LA	Linear array
LSV	Lenticulostriate vasculopathy
MCA	Middle cerebral artery
MRI	Magnetic resonance imaging
NICU	Neonatal intensive care unit
PA	Phased array
PCA	Posterior cerebral artery
PHVD	Post-haemorrhagic ventricular dilatation

PVE	Periventricular echodensities or periventricular echogenicity
PVHI	Periventricular haemorrhagic infarction
PVL	Periventricular leukomalacia
PW	Pulsed wave
PWML	Punctate white matter lesions
RI	Resistance index
SCA	Superior cerebellar artery
SSS	Superior sagittal sinus
ST	Transverse sinus
TEA	Term equivalent age
TOD	Thalamo-occipital distance
TRV	Transverse sinus(es)
TV	Terminal veins
VI	Ventricular index
VOG	Vein of Galen

PART I THE CRANIAL ULTRASOUND PROCEDURE

1 Neonatal Cranial Ultrasonography: Advantages and Aims

1.1 Introduction

Cranial ultrasonography (CUS) is the preferred modality for visualising the brain of the sick and/or preterm neonate. It uses the unique features of the neonatal skull with its open fontanelles and sutures to look into the brain and has important advantages above other imaging modalities.

1.2 Advantages of Cranial Ultrasonography

Major advantages of CUS are:

- It can be performed at the bedside, on the lap or in the cot with little disturbance to the neonate (Fig. 1.1; *see also* Chap. 3).
- It can be performed immediately after birth and repeated as often as necessary. It thereby enables visualisation of ongoing brain growth and maturation and the changes of brain lesions over time. In addition, it can be used to assess the timing of brain injury.
- It is safe.
- It is a reliable tool for the detection of most haemorrhagic brain lesions in preterm and full-term neonates.
- It is a helpful tool for the detection of ischaemic brain lesions as well as cerebral infections, and major structural brain anomalies, in both preterm and full-term neonates.
- Some abnormalities (including lenticulostriate vasculopathy [LSV], calcifications and germinolytic cysts) are only or better detected by CUS as compared to other neuro-imaging modalities.

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https://doi.org/10.1007/978-3-319-77815-0_1

Fig. 1.1 Cranial ultrasound procedure performed in a neonate in its cot

- Doppler flow velocity measurements of the cerebral vessels can be performed during the same examination.
- It is relatively inexpensive as compared to other neuroimaging techniques and therefore also a very feasible neuroimaging modality in low-income countries.

For all these reasons, CUS is an excellent tool for serial brain imaging during the neonatal period and thereafter until closure of the fontanelles.

1.3 Aims of Neonatal Cranial Ultrasonography

The aims of neonatal CUS are to assess:

- Brain growth and maturation
- The presence of structural brain abnormalities and/or brain injury
- The timing of injury

CUS also helps in determining the neurological prognosis of the neonate.

In sick neonates and in neonates with serious brain abnormalities, either congenital or acquired, it plays an important role in decision making regarding the continuation or redirection of intensive care. In neonates with brain injury, it may help to optimise treatment and support of the neonate and its family, both during the neonatal period and thereafter.

Advantages of CUS	Aims of CUS
Safe	Follow brain growth and maturation
	Exclude/demonstrate brain pathology
Bedside-compatible	Follow lesions over time
	Assess timing of injury
Enables early imaging	Estimate neurological prognosis
Enables serial imaging	Optimise treatment and support
– Brain maturation	
– Brain growth	
– Evolution of lesions	
Inexpensive	
Suitable for screening	

Further Reading

Bracci R et al (2006) The timing of neonatal brain damage. Biol Neonate 90:145–155

Daneman A, Epelman M (2015) Neurosonography: in pursuit of an optimised examination. Pediatr Radiol 45:S406–S412

Epelman M et al (2012) Ultrasound and MR imaging in the evaluation of neonatal encephalopathy: competitive or complementary imaging studies? Magn Reson Imaging Clin N Am 20:93–115

Govaert P, De Vries LS (2010) An atlas of neonatal brain sonography, 2nd edn. MacKeith Press, Cambridge

Hagmann CF et al (2010) Cranial ultrasound findings in well Ugandan infants. Arch Dis Child Fetal Neonatal Ed 95:F338–F344

Leijser LM et al (2006) Using cerebral ultrasound effectively in the newborn infant. Early Hum Dev 82:827–835

Mazmanyan PA et al (2016) Preterm cranial ultrasound scanning is both feasible and effective in a middle-income country. Acta Paediatrica 105:291–299

Meijler et al (2016) Neonatal cranial ultrasonography. Diagnostic pediatric ultrasound, 1st edn. Beek and van Rijn

Neil, Volpe (2017) Specialized neurological studies. In: Volpe's neurology of the newborn, 6th edn. Elsevier

Plaisier A et al (2015) Serial cranial ultrasonography or early MRI for detecting preterm brain injury? Arch Dis Child Fetal Neonatal Ed 100:F293–F300

Sisman J et al (2018) Lenticluostriate vasculopathy in preterm infants: a new classification, clinical association and neurodevelopmental outcome. J Perinatol 38:1370–1378

Skiöld B et al (2019) A novel scoring system for term-equivalent-age cranial ultrasound in extremely preterm infants. Ultrasound Med Biol 45:786–794

Steggerda SJ et al (2009) Neonatal cranial ultrasonography: how to optimise its performance. Early Hum Dev 85:93–99

Tann CJ et al (2016) Early cranial ultrasound findings among infants with neonatal encephalopathy in Uganda: an observational study. Pediatr Res 80:190–196

The British Medical Ultrasound Society (BMUS) (2009) Guidelines for the safe use of diagnostic ultrasound equipment. www.bmus.org/static/uploads/resources/BMUS-Safety-Guidelines-revision-Final-Nov-2009.pdf

de Vries LS et al (2004) Ultrasound abnormalities preceding cerebral palsy in high-risk preterm infants. J Pediatr 144:815–820

de Vries LS et al (2006) The role of cranial ultrasound and magnetic resonance imaging in the diagnosis of infections of the central nervous system. Early Hum Dev 82:819–825

de Vries, Volpe (2017) Viral, protozoan and related intracranial infections. In: Volpe's neurology of the newborn, 6th edn. Elsevier

de Vries, Volpe (2017) Bacterial and fungal intracranial infections. In: Volpe's neurology of the newborn, 6th edn. Elsevier

Verboon-Maciolek MA et al (2006) White matter damage in neonatal enterovirus meningoencephalitis. Neurology 66:1267–1269

Verboon-Maciolek MA et al (2008) Human parechovirus causes encephalitis with white matter injury in neonates. Ann Neurol 64:266–273

Vollmer B et al (2003) Predictors of long-term outcome in very preterm infants: gestational age versus neonatal cranial ultrasound. Pediatrics 112:1108–1114

van Wezel-Meijler G et al (2010) Cranial ultrasonography in neonates: role and limitations. Semin Perinatol 34:28–38

van Wezel-Meijler G et al (2011) Ultrasound detection of white matter injury in very preterm neonates: practical implications. Dev Med Child Neurol 53(Suppl 4):29–34

van Wezel-Meijler GV, De Vries LS (2014) Cranial ultrasound—optimising utility in the NICU. Curr Pediatr Rev 10(1):16–27

Yikilmaz A, Taylor GA (2008) Cranial sonography in term and near-term infants. Pediatr Radiol 38:606–616

2 Cranial Ultrasonography: Technical Aspects

For good-quality and safe CUS examinations, the following conditions need to be fulfilled: a high-quality modern ultrasound machine with appropriate transducers to enable optimal image quality and a sonographer who is aware of the special needs of the sick and/or preterm neonate and who is sufficiently experienced in CUS.

2.1 Equipment

2.1.1 Ultrasound Machine

The ultrasound machine should be a transportable real-time scanner, allowing bedside examinations without the need to transport the baby (*see* Fig. 1.1). It should be equipped with transducers that are appropriate for CUS, adapted software for CUS and Doppler assessments (*see* Chap. 9) and a reliable digital storage system. Settings need to be optimised for neonatal brain imaging. It is recommended that preprogrammed presets be used for CUS imaging in both preterm and full-term neonates. These settings can be further optimised in individual cases and under certain circumstances (*see* Chap. 3).

2.1.2 Transducers

The use of a convex (CV) or curved array transducer is recommended. The transducer should be appropriately sized for an almost perfect fit on the anterior fontanelle (Fig. 2.1). To allow good contact between the transducer and the skin, ultrasound gel is used. We preferably use a micro CV transducer (*see* Fig. 2.1). If the fontanelle is very small, or when hats are

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https://doi.org/10.1007/978-3-319-77815-0_2

used for fixation of ventilatory support systems, a smaller phased array (PA) probe can be used, but the field of view is smaller and the image quality less than that of the CV probe (Fig. 2.2).

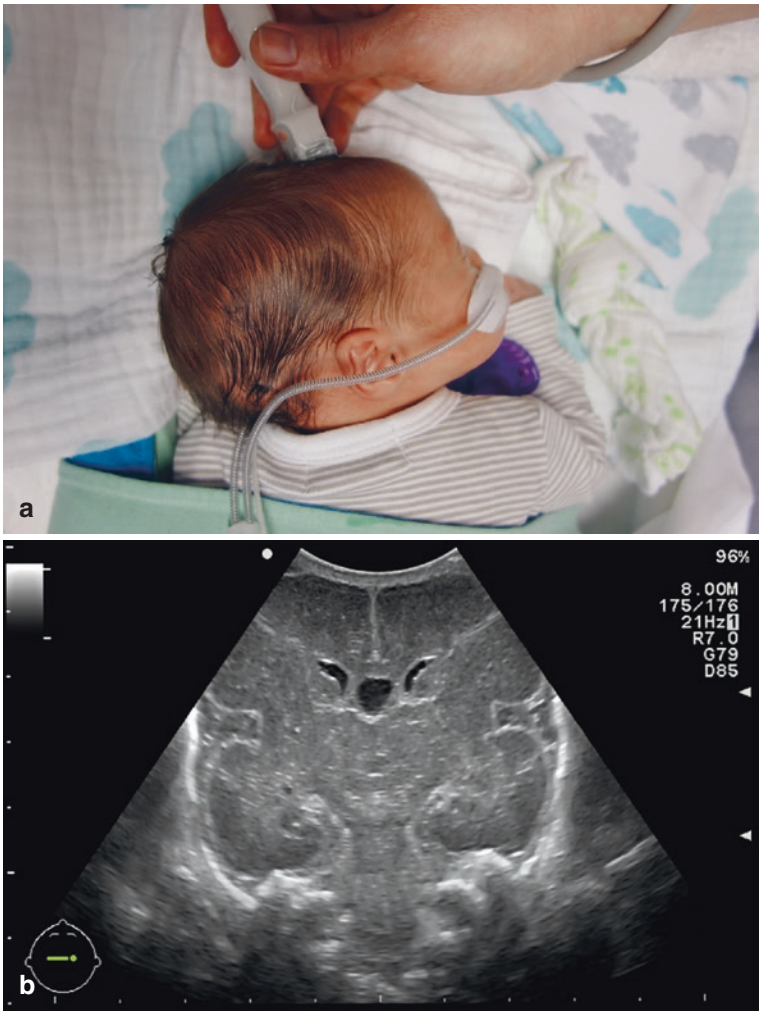


Fig. 2.1 (**a**) Well-fitting CV probe, positioned on the anterior fontanelle. (**b**) Coronal CUS scan at the level of the bodies of the lateral ventricles performed with micro CV probe in extremely preterm infant gestational age (GA) 25 weeks, scanned on the second day after birth. The whole brain is well depicted

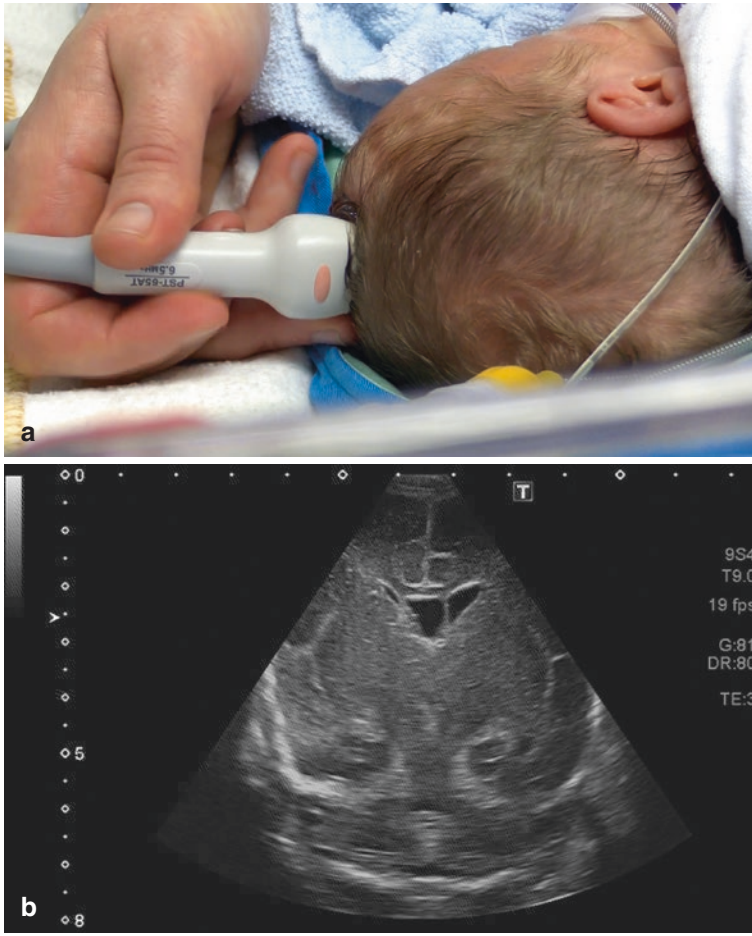


Fig. 2.2 (**a**) Smaller PA probe, positioned on the anterior fontanelle. (**b**) Coronal CUS scan in very preterm neonate performed with PA probe. Due to the small scan area, the periventricular white matter cannot be well assessed (compare with Fig. 2.1b). (**c**, **d**) Coronal CUS scans at the level of the bodies of the lateral ventricles in a preterm neonate with posthaemorrhagic ventricular dilatation (PHVD). (**c**) Performed with a PA probe: the wide ventricles are filling the image and hamper visualization of the periventricular white matter (*arrow*). (**d**) Performed with a CV probe: thanks to the larger scan area, the periventricular white matter (*arrow*) is now well depicted

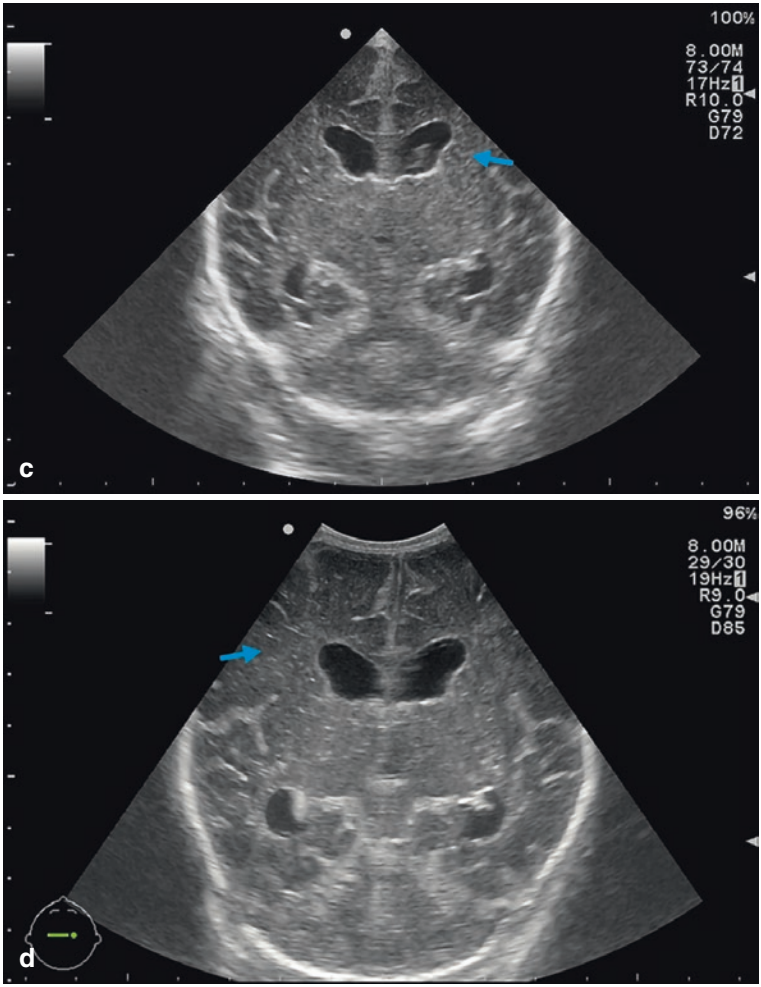


Fig. 2.2 (continued)

Thanks to the high scan frequency and the parallel ultrasound beam, linear array (LA) probes provide superb near-field resolution. Because of their large footprint (Fig. 2.3) and suboptimal far-field resolution, they are not suitable for routine CUS examinations. However, they provide detailed

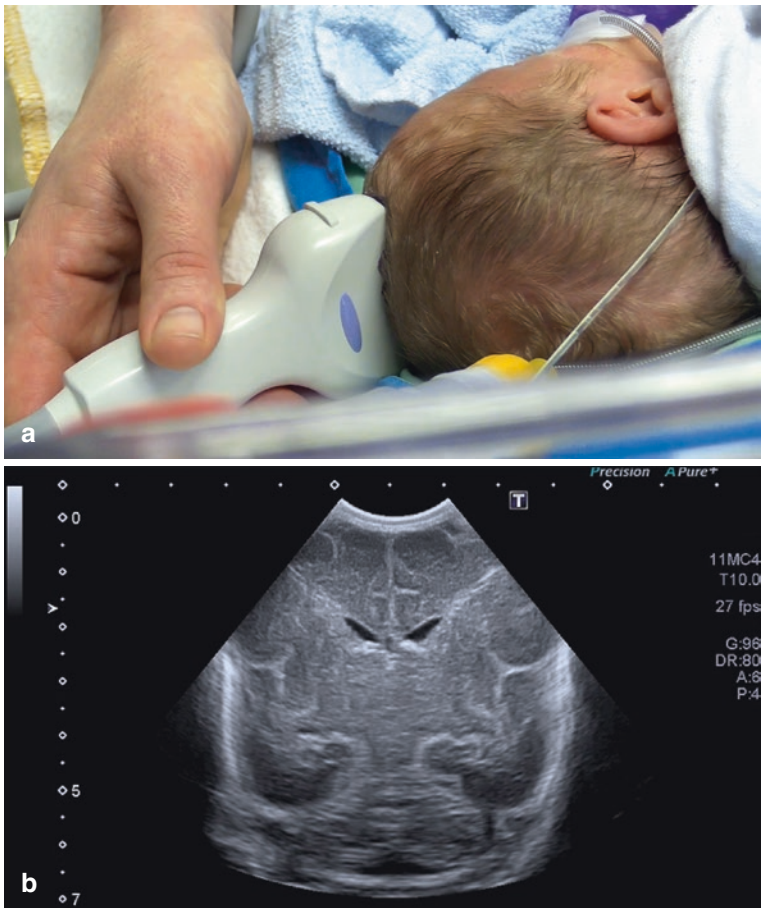


Fig. 2.3 (**a**) LA probe, positioned on the anterior fontanelle. (**b**, **c**) Coronal CUS in a very preterm neonate at the level of bodies of the lateral ventricles, using the CV probe and transducer frequency of 10 MHz (**b**) and LA probe with transducer frequency set at 18 MHz (**c**), showing the superb near-field resolution of the LA probe. However, the overall view of the brain is less well defined using the LA probe

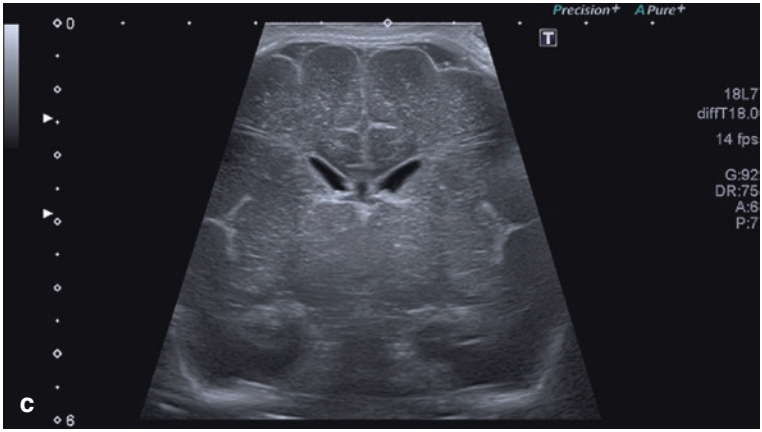


Fig. 2.3 (continued)

views of superficial structures (cortex, subcortical white matter, subarachnoidal and subdural spaces) and can demonstrate flow in the superior sagittal sinus (*see* Chap. 9) (Fig. 2.4).

The higher the transducer frequency, the better the near-field resolution. A lower transducer frequency will provide a lower resolution, but a better penetration (*see* Chap. 3). The ultrasound system should therefore be equipped with multifrequency transducers (5–7.5(8)–10 (11) MHz).

Neonates have relatively small heads. Therefore, high-quality images can usually be obtained with the transducer frequency set at 7.5–8 MHz. In most neonates this enables good visualisation of the whole brain. For better evaluation of the most superficial structures and/or in very tiny infants with tiny heads, we advise performing additional scanning, using a higher frequency up to 10 or 11 MHz, thus obtaining a higher near-field resolution (Fig. 2.5). If, on the other hand, deeper penetration of the beam is required, as in larger, older infants or infants with thick, curly hair or to obtain a better view of the deeper structures, additional scanning with a lower frequency (around 5 MHz) is recommended (Fig. 2.6).

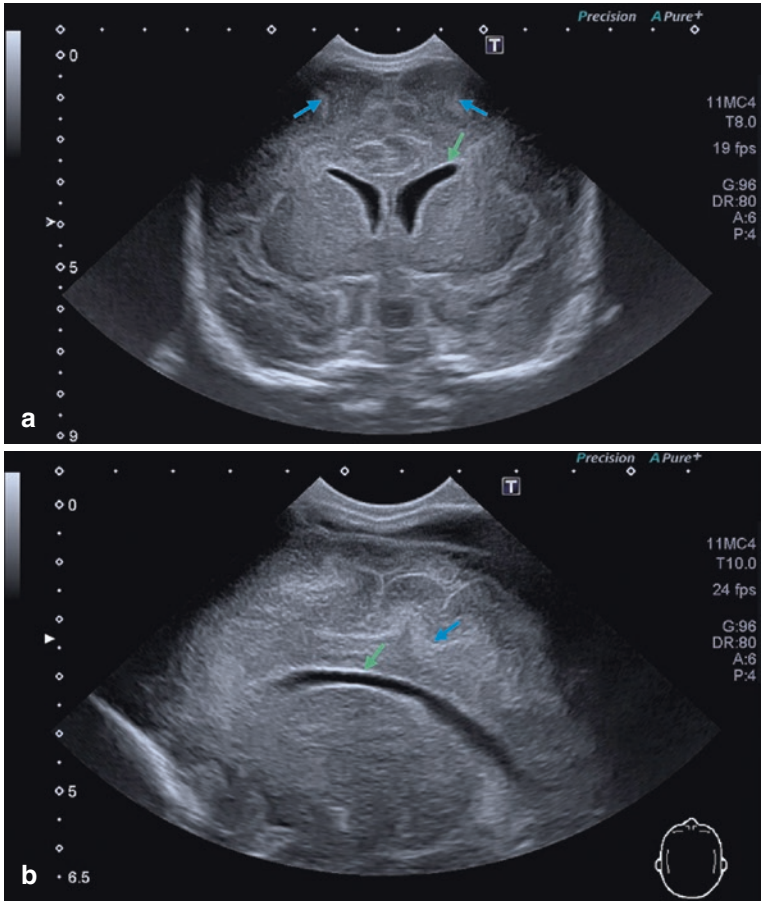
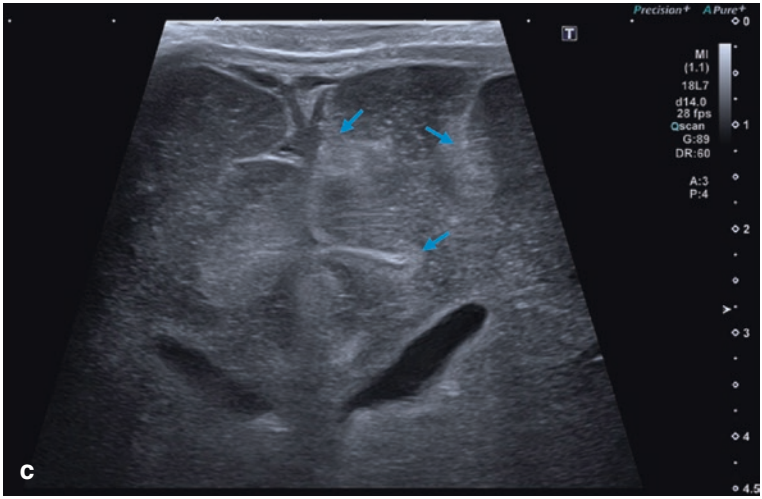


Fig. 2.4 (**a**–**d**) CUS in full-term neonate with GBS sepsis/meningitis. (**a**) (coronal) and (**b**) (parasagittal) scans performed with CV probe, (**c**) (coronal) and (**d**) (parasagittal) scans performed with LA probe. With the CV probe, a good overview of the brain is obtained, showing increased echogenicity around the cortex (*arrows*), indicating cortical injury, and in the ventricular wall (*green arrows*), suggesting ventriculitis. The images performed with the LA probe are of superb resolution and show more detail of the cortical injury (*arrows*), but the overview of the brain is lost. (**e**–**g**) CUS scans performed in a full-term baby with intractable seizures. (**e**) Parasagittal scan performed with a CV probe. (**f**) Parasagittal scan performed with a LA probe, showing the swollen cortex (*arrows*) in more detail.



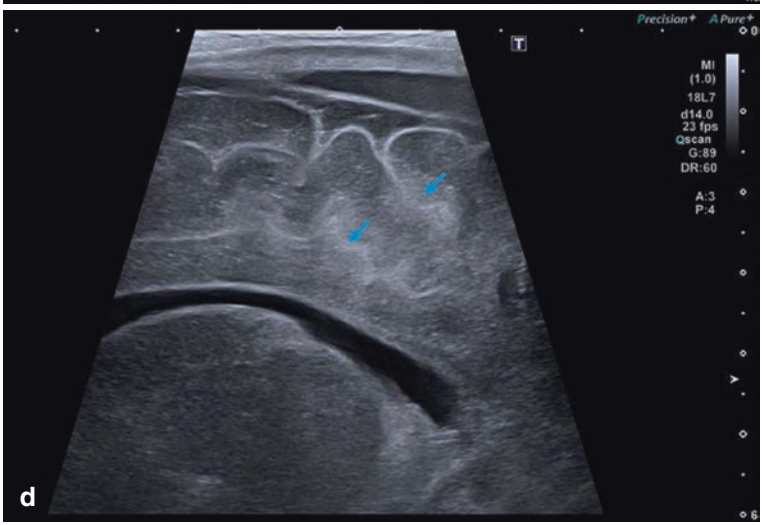
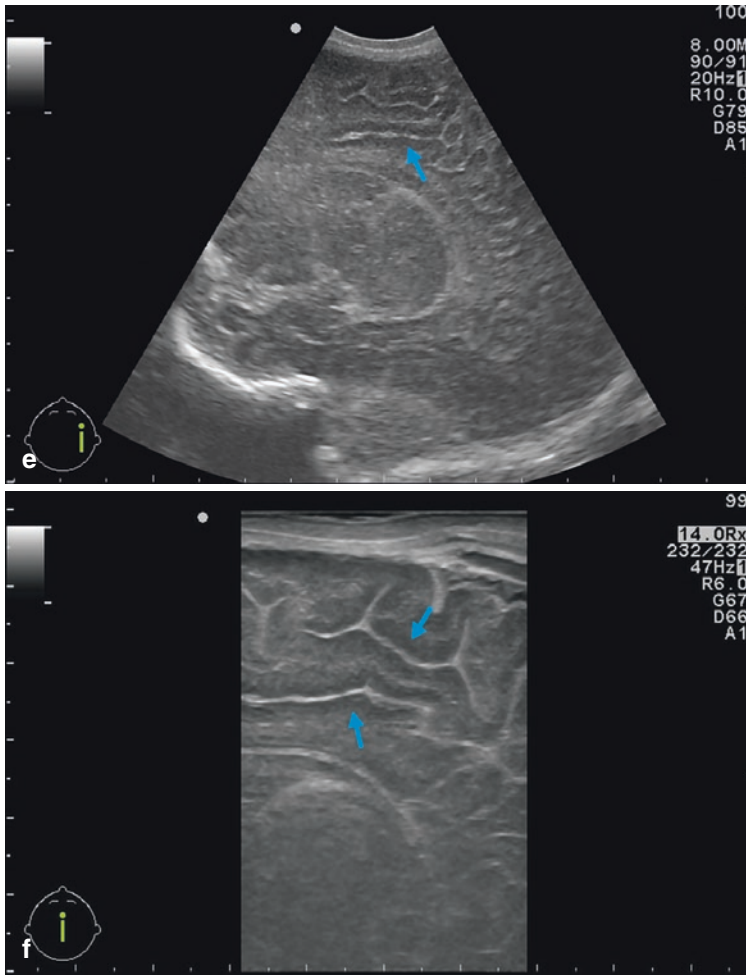


Fig. 2.4 (continued) (**g**) Colour Doppler scan using the LA probe, demonstrating flow in superficial cortical arteries *and* the superior sagittal sinus (*green arrow*). (**h**, **i**) CUS in a very preterm neonate. (**h**) Parasagittal scan through the insular area performed with the CV probe shows inhomogeneous echogenicity of the white matter (*arrow*). (**i**) The LA probe shows that the echogenicity extends deeper into the white matter (*arrow*). However, the overall view of the brain is lost



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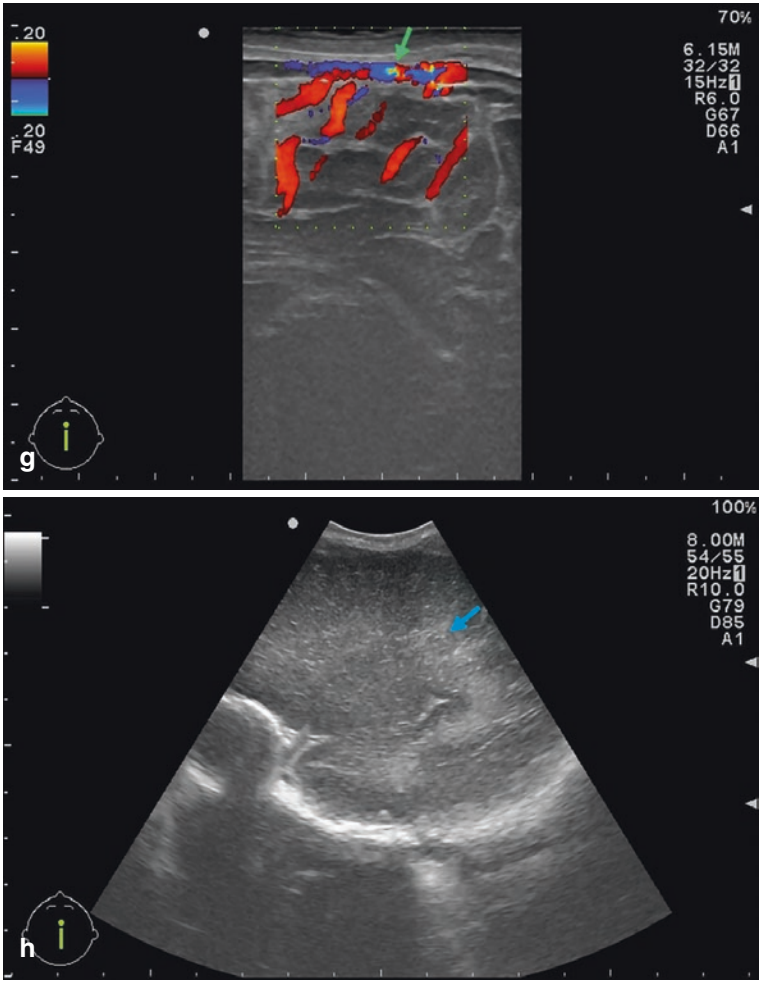

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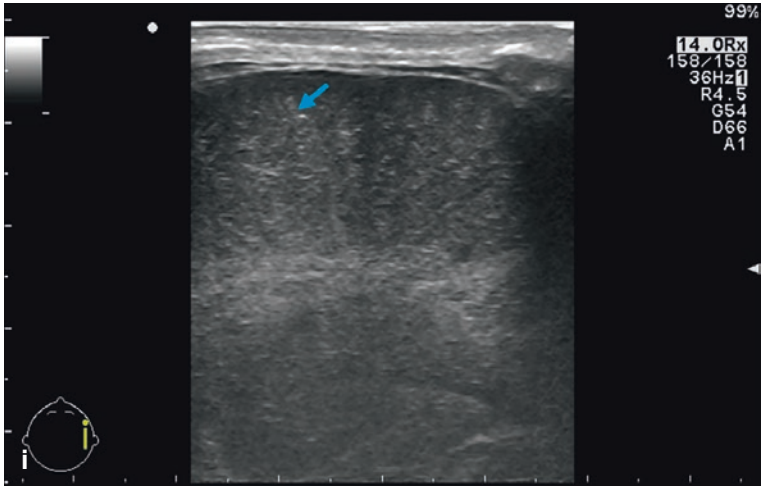


Fig. 2.4 (continued)

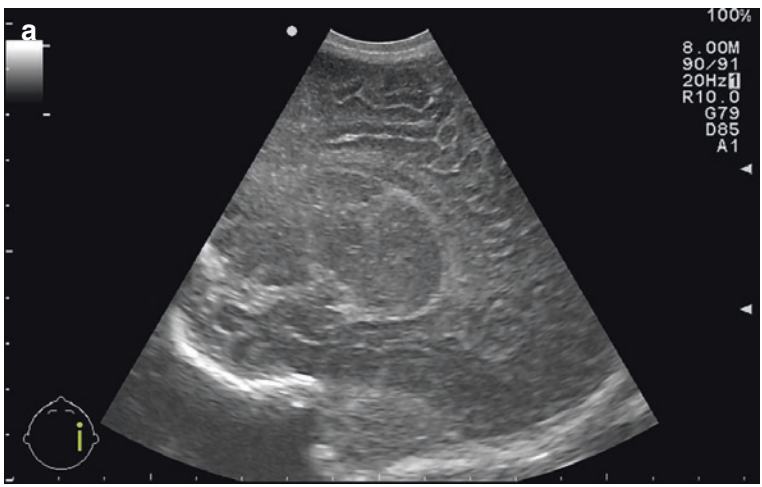
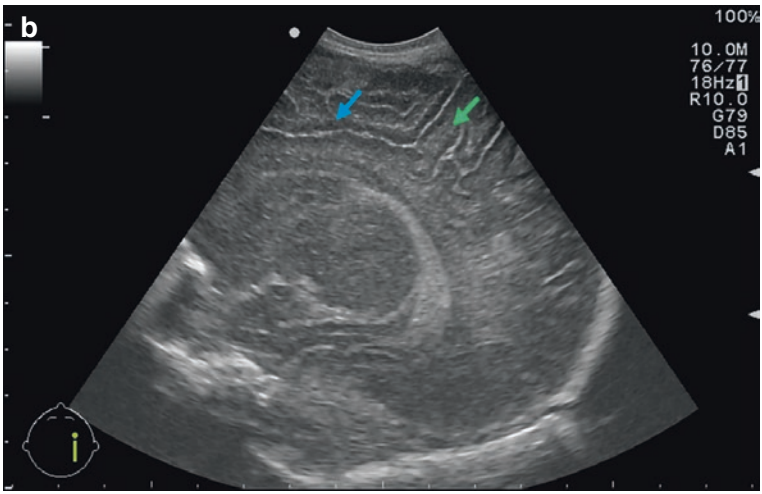


Fig. 2.5 Same full-term baby with intractable seizures as Fig. 2.4e–g. (**a**) Parasagittal scan performed with scan frequency set at 8 MHz. (**b**) scan frequency set at 10 MHz. In (**b**) the resolution is better, and the superficial structures (cortex *(arrow)*) and subcortical white matter (*green arrow*) are depicted in more detail



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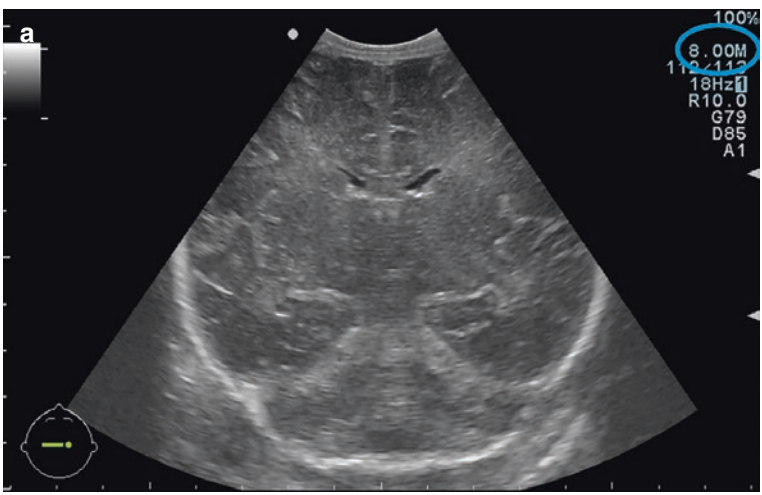

Fig. 2.6 (**a**, **b**) Coronal CUS scans in a full-term neonate, scanned with a transducer frequency of, respectively, 8 (**a**) and 5 (**b**) MHz. A good resolution is obtained with the high scan frequency, while with the lower frequency, the resolution is less, but the cerebellum (*arrow*) is somewhat better depicted.