Neonatal cranial ultrasound – Safety Aspects (2013)

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Introduction

Neonatal cranial ultrasound (CUS) is an essential non-invasive diagnostic tool in neonatal medicine. It is used to assess brain maturation as well as structural and acquired anomalies. Neonatal CUS is performed through the fontanels which provide 'acoustic windows' between the skull bones of the neonate.

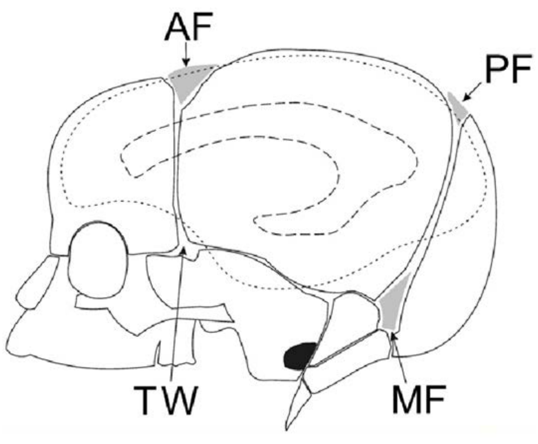

Fig.1 Illustration of the acoustic windows (fontanels) between the skull bones); AF: Anterior Fontanel; PF: Posterior Fontanel; TW: Temporal Window; MF: Mastoid Fontanel
Ref: Neonatal Cranial Ultrasound. Gerda van Wezel, 2007

CUS can be performed serially, at the neonate's bedside, to assess development of the brain maturation and/or anomalies by reproducible standard views systematically.

Indications for neonatal cranial ultrasound include: screening for anomalies in patients with symptoms of central nervous system disorders (e.g. seizures); screening for hemorrhage or parenchymal abnormalities in preterm infants; evaluation of evolution of hemorrhage or hydrocephalus; screening for vascular abnormalities or congenital malformations; screening for hypoxic ischemic encephalopathy and follow-up of anomalies (1,2).

Systematically assessing the neonatal brain over time provides insight about the presence of anomalies, and the timing of cerebral injury. Clinicians use the results of the ultrasound brain scans to predict the neurological prognosis for the individual neonate.

Standard multiplanar coronal and sagittal views are obtained by angling the transducer from anterior to posterior and left lateral to right lateral through the anterior fontanel, as suggested by van Wezel-Meijler (2). The six coronal planes should contain: the white matter of the frontal lobe and frontal horns of the lateral ventricles; the septum pellucidum, corpus callosum and portions of the frontal, parietal and temporal lobes; the caudothalamic groove and basal ganglia; the bodies of the lateral ventricles and the posterior portions of the temporal lobes, occipital lobes, fourth ventricle, cerebellum and cisterna magna. The five sagittal planes are acquired through the same anterior fontanel. The midline sagittal view should include: the corpus callosum; the cavum septum pellucidum and cavum vergae (if present); the third ventricle; the aquaduct of Sylvius; the fourth ventricle; the vermis of the cerebellum and the cisterna magna. The lateral sagittal views should contain the caudothalamic groove, the lateral ventricle with the choroid plexus, the periventricular white matter and the Sylvian fissure. (3)

A sweep through the entire brain (both coronal and sagittal) is necessary to confirm anomalies in both directions and to get a good overview of the total brain.

When additional views are necessary, they may be taken through the posterior, temporal or mastoid fontanels. (3,4,5)
The posterior fossa with the cerebellar vermis, cerebellar hemispheres and fourth ventricle can be visualized by obtaining views through the posterior and/or mastoid fontanel. Furthermore, additional scanning enables assessment of the occipital parenchyma, occipital horns and posterior fossa. Views obtained through the temporal fontanel allow assessment of the circle of Willis, and flow measurements. (2)
Additional brain scans are indicated for neonates of gestational age <30 weeks to show cerebellar haemorrhage, circulatory and/or respiratory instability; peri- and intraventricular hameorrhage; suspected posterior fossa haemorrhage or abnormalities; ventricular dilatation. (2)
Doppler ultrasonography can be applied to measure the flow velocity of major cerebral arteries in several planes, thereby studying local cerebral haemodynamics. Also, this technique can be used to analyse vascularisation of lesions. Use of Doppler is for example indicated in neonates with perinatal asphyxia; ischemic haemorrhagic damage or hydrocephalus. (2,13)

Advantages and limitations of technique

There are several imaging modalities available for use in the evaluation of the neonatal brain. Besides CUS, magnetic resonance imaging (MRI) has proven its value over the last decades. While the value of neuro-imaging has been well-established, the most appropriate modality (MRI or CUS) for depicting the neonatal brain has not. (6)
There are *important advantages* of cranial ultrasound. Firstly, it is a non-invasive technique; the fontanels are used as acoustic windows. Furthermore, CUS can be performed at any time and at the neonate's bedside. This enables the comparison of neonatal CUS images obtained after delivery with those obtained during pregnancy by means of fetal neurosonography. It also facilitates imaging of

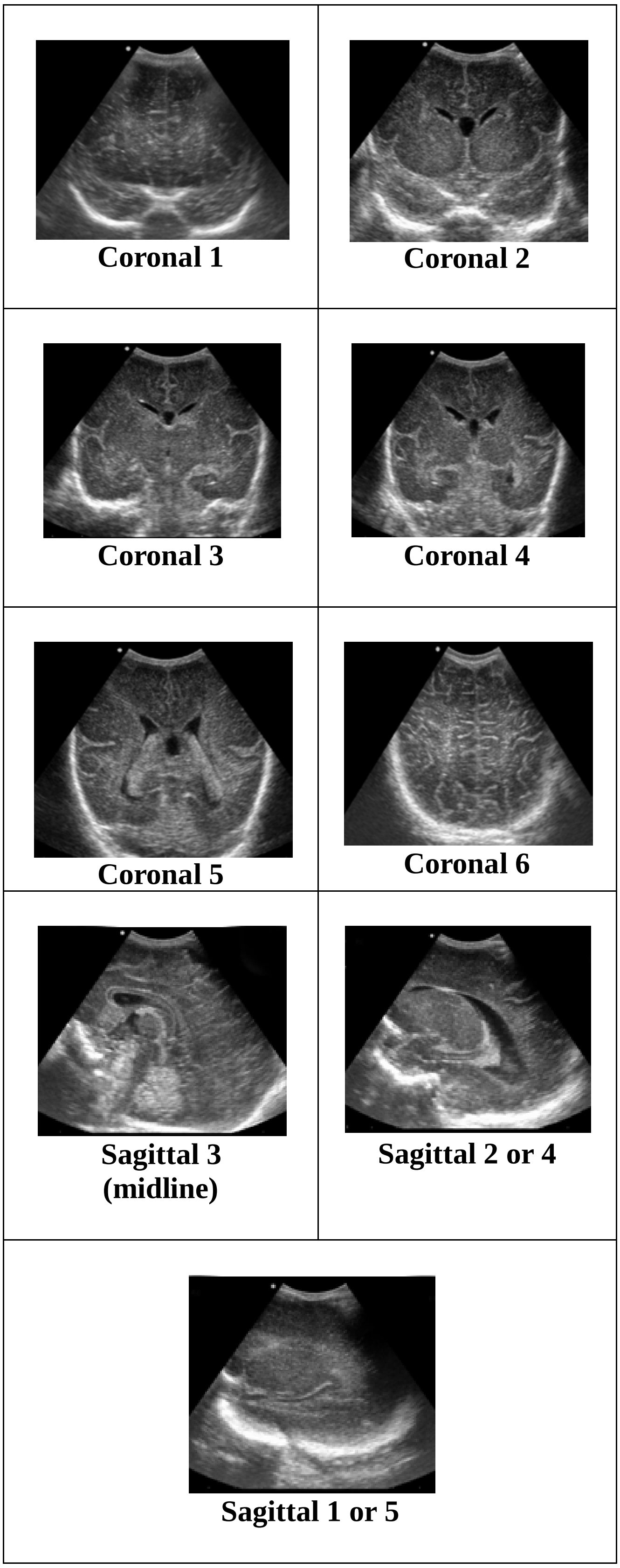

Fig. 2 Neonatal Cranial Ultrasound: Coronal and sagittal planes, images obtained in the neonatal department of VUmc in a neonate of 29+6 (coronal 2-5 and sagittal) and 40+3 (coronal 1 and 6) gestational weeks.

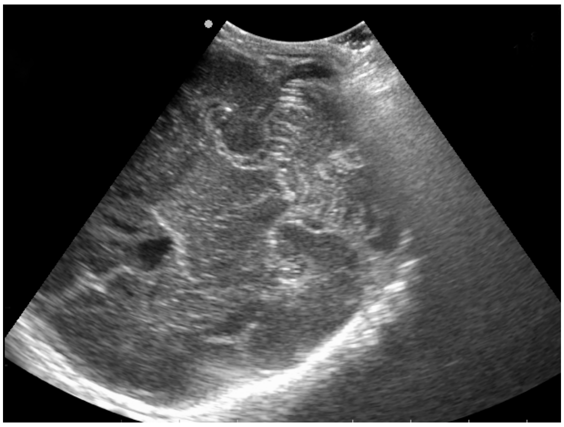

Fig. 3 Additional view through mastoid fontanel

an unstable neonate that cannot be transported. (1,2,3,7)The fact that CUS can be performed serially allows the clinician to compare the views obtained with those previously acquired and to assess development of brain maturation and/or anomalies. CUS is a reliable technique for assessing the supratentorial structures and for detecting calcifications and lenticulostriate vasculopathy, which can be signs of congenital infections (e.g. CMV). (2,4)

Additionally there is considerable knowledge about normal brain development in the fetus and neonate (2,8), which makes CUS an easily assessable and reliable tool in both term and pre-term neonates. Also, CUS is relatively inexpensive in comparison to other neuro-imaging diagnostic techniques. Finally, CUS is a relatively safe procedure, as stated by the British Medical Ultrasound Society (9) and the American Institute of Ultrasound in Medicine. (10)

Although there are numerous advantages to CUS, some *limitations* should be mentioned:

it may be difficult to depict all structures in the brain with CUS; this is especially true for the superficial structures located at the brain's convexity and the posterior fossa and for structures far away from the transducer (such as the cerebellum)(2,5). In order to overcome this problem, alternative acoustic windows (for example the posterior fontanel and/or the mastoid fontanel) can be used, and the transducer frequency/focus can be adopted (higher frequencies provide better resolution and give better views of focal infarction or white matter injury in the peripheral regions of the brain)(5). However, at a higher frequency, penetration loss occurs. A lower frequency can be used to show the deep grey matter and posterior fossa. (5) When these adjustments do not provide a solution, an additional MRI may be necessary to confirm suspected anomalies in these areas. Regarding brain maturation and/or anomalies, myelination is not seen with CUS, and therefore MR imaging is necessary. (4,5,6) Small punctuate lesions of the cerebellum are missed on CUS and are more easily detected with MRI (2,11)

Last of all, CUS is operator dependent and should therefore only be performed by an experienced sonographer who is familiar with the pathophysiology of the neonatal brain. The same applies to MRI, since specially adapted MR sequences and knowledge about normal brain development are needed.

Ultrasound exposures involved

High frequency transducers with high resolution can be used for CUS because of the proximity of the neonatal brain. The use of sector or curved linear array transducers that are small enough to fit the (anterior) fontanel (1-3,5) is recommended . Because of the difference in resolution and penetration of low and high frequency transducers (as mentioned above), the ultrasound system should be equipped with a multifrequency transducer or different frequency transducers (5.0, 7.5, 10 MHz). In most circumstances, images obtained by a 7.5 MHz transducer can be properly assessed. (2)

Thermal index (TI) and mechanical index (MI) are considered to be useful for estimation of the risks of thermal and non-thermal effects of ultrasound. (12)

MI values can vary from 0.48 to 0.6 during neonatal CUS in B-mode settings. Temperature increases may be generated when using Doppler mode, and TI values during Doppler mode in neonatal CUS vary widely (from <0.4 to 1.1) between machines.

Even though these values are within safe ranges (TI should be as low as possible and preferably not exceed 1.5), operators should always be aware of possible bioeffects of ultrasound. For example, in a study by Shaw et al (14) where a phantom which mimicked the neonatal head was used to estimate the thermal effects of different types of ultrasound (gray scale, color Doppler, spectral Doppler), there was no useful correlation between the TI displayed and the temperature measured in the phantom: the average skin surface temperature on the phantom was 6 times higher than the average TI value, and the temperature at a depth of 3mm (supposed to correspond to the surface of the brain) was usually much higher (up to 6 times higher) than the TI value shown on the ultrasound screen. This is because the model used for calculating TI completely ignores the self-heating of the transducer. For scanning of the neonatal brain the British Medical Ultrasound Society recommends that TI never exceeds 3.00 and suggests restriction of the duration of ultrasound exposure if TI is > 0.7 (15).

Safety implications

'Ultrasound of the neonatal brain is now accepted as being of considerable diagnostic value. There is no evidence that diagnostic ultrasound has produced harm to patients (10,12). However, exposing the neonatal brain to more ultrasound energy (or self-heating of the transducer) than necessary to obtain the necessary medical information should be avoided (the shortest possible examination time, lowest possible power and lowest possible MI and TI values should be used).

Conclusions

- CUS is an essential diagnostic tool in neonatology;
- It is safe, relatively inexpensive, non-invasive and can be used at the neonate's bedside.
- CUS can be used serially to assess the development of brain maturation and of structural or acquired anomalies.
- Standard views are obtained through the anterior fontanel and provide an overview of the brain using six coronal and five sagittal views.
- Changes in transducer frequency and focus or use of alternative acoustic windows enable a good view of the entire neonatal brain. However, some areas are difficult to depict with CUS and therefore additional MR-imaging is necessary for these areas.
- The TI values displayed during neonatal scanning are usually lower than the maximum recommended by BMUS and agreed by EFSUMB. However, there is experimental evidence that transducer self heating can lead to a significant temperature rise at the skin surface, and so scanning times, and exposure levels should be kept as low as possible.

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