CRANIAL ULTRASONOGRAPHY IN NEONATAL INTENSIVE CARE UNIT: NEONATOLOGISTS' PERSPECTIVE

FUAT E. CANPOLAT*
SADIK YURTTUTAN*

SUMMARY: Preterm neonates and sick full-term neonates are at risk for brain injury. Although advances in neonatal intensive care have greatly improved the survival and outcome of these 'micro' patients, brain injury remains of major concern. Early diagnosis is important for optimal treatment, and neurological outcome.

Cranial ultrasonography (cUS) is the preferred modality to image the neonatal brain. The advantages of cUS are numerous: it can be performed at the bedside with little disturbance to the infant, it is relatively safe, and can be repeated whenever needed, enabling visualization of ongoing brain maturation and the evolution of lesions. However, cUS also has several limitations: quality of imaging depends on the skills and experience of the ultrasonographer, some areas of the brain are difficult to visualize, and several abnormalities remain beyond its scope. In this paper, we discuss the applications and indications of neonatal cUS. We briefly describe the standard procedure and general informations.

Key words: cranial ultrasonography, newborn, intraventricular, hemorrhage

INTRODUCTION

Cranial ultrasonography was introduced into neonatology in the late 1970s and has become an essential diagnostic and imaging tool in modern neonatology. The non-invasive nature of ultrasonography makes it an ideal imaging technique in the neonate and preterm infant. In the neonate and preterm infant, the fontanels and many sutures of the skull are still open, and these can be used as acoustic windows to "look" into the cranium. Transfontanellar cUS allows the use of high-frequency transducers, with high near-field resolution. As a result of ongoing development in ultrasonography, image quality is high nowadays, provided optimal settings and techniques are applied. Therefore, cUS is a reliable tool for detecting congenital and acquired anomalies of the perinatal brain and the most frequently occurring patterns of brain injury in both preterm and full-term neonates. This review collects practical aspect to neonatal cranial ultrasonography from neonatologists' view.

*From Neonatal Intensive Care Unit of Zekai Tahir Burak Maternity Teaching Hospital, Ankara, Turkey.

Rationale

Cranial ultrasound is the diagnostic method of choice to detect intraventricular hemorrhage (IVH) and white matter disease (WMD) in the term and premature infant.

Intraventricular Hemorrhage

The incidence of IVH in infants <1000 grams is 50%-60%, and in infants 1000-1500 grams, the incidence is 10%-20%. Approximately 90% of IVH occurs by the 4th postnatal day with 50% occurring on the first postnatal day. Approximately 20%-40% exhibit progression of hemorrhage over 3-5 days. Infants with IVH are at risk for hydrocephalus and white matter injury.

White Matter Disease

White matter disease includes two primary lesions, periventricular leukomalacia (PVL) and periventricular hemorrhagic infarction (PVHI). PVL occurs in about 3-4% of infants of birth weight <1500g and PVHI occurs in approximately 10-15% of infants of birth weight <1000 grams. PVL occurs in relatively larger premature infants as the most vulnerable time for white matter injury is between the 28th and 32nd weeks of gestation. PVHI occurs at younger gestational ages and birth weights as it is associated with more severe IVH. WMD is usually associated with prolonged rupture of membranes and chorioamnionitis. WMD is often detectable on early ultrasounds as either an echodensity or echolucency but may not become apparent for 1-3 weeks after the initiating event when cysts begin to form. The echolucencies may then disappear after 1-3 months leaving enlarged ventricles.

Cranial ultrasounds may need to be repeated at more frequent intervals to evaluate for developing hydrocephalus if there is evidence of hemorrhage.

This screening programme is based on the following:

- A first cUS examination soon after birth will give information on congenital anomalies of the brain, congenital infections, some metabolic diseases, traumatic brain injury after traumatic delivery, and the antenatal onset of lesions. It can also serve as a baseline and comparison for the next cUS examinations.

- Haemorrhagic lesions usually become visible within hours of the incident.

- Most haemorrhagic lesions in newborn infants develop around birth.

- More than 90% of peri- and intraventricular haemorrhages (P/IVH) develop within the first 3 days of birth.

- Progression of an initial P/IVH usually occurs within 3 to 5 days.

Scanning Protocols

In summary, very preterm infants (gestational age < 32 weeks) admitted to an intensive care unit are scanned shortly after birth, on the third and seventh day of life and weekly thereafter until discharge. cUS is repeated around term equivalent age. Older, apparently healthy preterm infants (gestational age > 32 weeks) are scanned on the third day and, thereafter, weekly until discharge. In sick full-term neonates and full-term neonates with congenital malformations or neurological symptoms, we recommend a cUS examination shortly after birth and subsequent examinations depending on symptoms and previous cUS findings.

Regardless of standard scanning protocols, the frequency of cUS examinations should be intensified in the following circumstances: sudden deterioration in clinical state, sepsis, necrotizing enterocolitis, episodes of apneas and/or bradycardias, sudden decrease in hemoglobin level, neurological symptoms such as convulsions, ventricular dilatation, and before and after major surgery.

Ultrasound Imaging of the Preterm Infant's Brain

In infants born prematurely, serial cUS throughout the neonatal period is indicated. This enables early detection of brain injury typically occurring in the preterm neonate (including peri- and intraventricular hemorrhage (P/IVH) and periventricular leukomalacia (PVL)) and following the evolution of lesions and brain maturation.

Peri- and Intraventricular Hemorrhage

In preterm infants, P/IVH usually originates from the immature germinal matrix and may subsequently spread throughout the ventricular system. Although the incidence of P/IVH has declined over the last decades, it is still high and P/IVH remains one of the major complications of premature birth. It is generally seen during the first few days after birth, mostly as low grade (grade 1 or 2) hemorrhage, but may extend over subsequent days and, in addition, lead to significant complications. The first well-recognized complication of P/IVH is posthemor-

Table 1: Guide for postnatal days of obtaining cranial ultrasounds according to birthweight.

	Day of life			
	3-5	10-14	28	Discharge
<1000 grams	*	*	*	*
1000-1250 grams	*		*	*
1250-1500 grams	*			*

rhagic ventricular dilatation (PHVD). The risk of PHVD is related to the amount of blood in the ventricular system. PHVD may develop days to weeks after the initial P/IVH. As ventricular dilatation may lead to parenchymal injury, prompt detection is necessary and treatment may be indicated. We therefore recommend early and repetitive cUS scans within the first week of birth in neonates born very prematurely and in case of P/IVH, repetitive cUS scans with measurements of the lateral ventricles throughout the subsequent weeks. If, after a few weeks, no or only mild, nonprogressive PHVD develops, the frequency of cUS can be decreased.

Limitations of cUS

Despite adapting the transducer frequency and focus, abnormalities at the brain's convexity (such as hemorrhages and cortical abnormalities) are not easily depicted, and MRI is needed to demonstrate or confirm these abnormalities. Although the use of supplemental windows greatly improves the abilities of cUS, the posterior fossa may not be well visualized, and MRI is necessary to confirm suspected abnormalities in this area. In addition, myelination is not depicted by cUS, whereas in case of very preterm birth or suspected brain injury, progress of myelination is of importance for prognostication, making MRI invaluable. Diffuse white matter injury is probably not well detected but of prognostic relevance. Finally, metabolic disease or metabolic disturbances, including hypoglycemia may cause serious brain injury, not always easily detected by cUS. We believe that, if the safety of the neonate during transportation and the scanning procedure are guaranteed and experience with neonatal MRI is available, MRI is an invaluable and excellent complimentary technique to image the neonatal brain. Indications for neonatal MRI examinations have recently been described. While there are many indications for MRI, there is hardly any indication for CT of the brain in modern neonatology, the only indication being (suspected) large hemorrhages at the convexity or in the posterior fossa, if emergency access to MRI is unavailable.

Table 2: Advantages and aims of cranial ultrasonography.

Advantages of cUS	Aims of cUS

- Safe
- Bedside-compatible
- Reliable
- Early imaging
- Serial imaging
  * Brain maturation
  * Evolution of lesions
- Inexpensive
- Suitable for screening
	- Exlude / demonstrate cerebral pathology
	- Asses timing of injury
	- Asses neurological prognosis
	- Help make decisions on continuation of neonatal intensive care
	- Optimise treatment and support

CONCLUSION

cUS is an excellent tool for serial, bedside imaging of the newborn infant's brain. Recent advances in cUS imaging, including the use of additional (high frequency) transducers and acoustic windows, allow reliable visualization of not only the ventricular system and periventricular white matter but also of the subcortical white matter, the cortical and deep grey matter, and the cerebellum.

The noninvasive character of this bedside tool enables frequent examinations in high-risk neonates, thereby allowing the monitoring of normal brain maturation and growth and the evolution of lesions. Very early imaging helps to determine the timing of injury. Some lesions are better depicted by cUS than by MRI. Because of these unique properties and the relatively low cost of cUS, it is an irreplaceable technique.

Future perspectives of cUS include the standard use of supplemental acoustic windows. In addition, efforts should be directed toward reliable detection of diffuse white matter injury in very preterm infants and of ischemic cerebellar injury in both preterm and high-risk full-term neonates. Although further improvement of image quality will probably expand the possibilities of cUS, the role of 3D and 4D imaging techniques may be explored. Finally, while the use of neonatal CT should be discouraged, we feel that frequent and standard use of cUS should be stimulated among neonatologists and radiologists involved in neonatal care, thereby increasing the experience and skills of these specialists with this invaluable imaging technique.

REFERENCES

1. van Wezel-Meijler G : Neonatal Cranial Ultrasonography, Springer-Verlag, Heidelberg, Germany, 2007.

2. Leijser LM, Liauw L, Veen S et al: Comparing brain white matter on sequential cranial ultrasound and MRI in very preterm infants, Neuroradiology 50, pp 799-811, 2008.

3. Leijser LM, de Bruïne FT, Steggerda SJ et al: Brain imaging findings in very preterm infants throughout the neonatal period: part I: Incidences and evolution of lesions, comparison between ultrasound and MRI, Early Hum Dev; 85: 101-109, 2009.

4. Leijser LM, de Vries LS, Cowan FM: Using cerebral ultrasound effectively in the newborn infant, Early Hum Dev, 82: 827-835, 2006.

5. Steggerda SJ, Leijser LM, Walther FJ et al: Neonatal cranial ultrasonography: how to optimize its performance, Early Hum Dev 85, pp 93-99, 2009.

6. Volpe JJ : Intracranial hemorrhage: germinal matrix-intraventricular hemorrhage of the premature infant. In: JJ Volpe, Editor, Neurology of the Newborn (ed 5), WB Saunders, Philadelphia, PA, pp. 517-588, 2008.

7. Sheth RD: Trends in incidence and severity of intraventricular hemorrhage. J Child Neurol 13, pp 261-264, 1998.

8. Brouwer A, Groenendaal F, van Haastert IL et al: Neurodevelopmental outcome of preterm infants with severe intraventricular hemorrhage and therapy for post-hemorrhagic ventricular dilatation. J Pediatr 152, pp 648-654, 2008.

9. de Vries LS, Roelants-van Rijn AM, Rademaker KJ et al: Unilateral parenchymal haemorrhagic infarction in the preterm infant. Eur J Paediatr Neurol 5, pp 139-149, 2001.

10. Bassan H, Feldman HA, Limperopoulos C et al: Periventricular hemorrhagic infarction: risk factors and neonatal outcome, Pediatr Neurol 35, pp 85-92, 2006.

11. Bassan H, Limperopoulos C, Visconti K et al: Neurodevelopmental outcome in survivors of periventricular hemorrhagic infarction, Pediatrics 120, pp 785-792, 2007.

12. Khwaja O, Volpe JJ: Pathogenesis of cerebral white matter injury of prematurity, Arch Dis Child Fetal Neonatal Ed 93, pp F153-F161, 2008.

13. De Vries LS, Eken P, Dubowitz LM: The spectrum of leukomalacia using cranial ultrasound, Behav Brain Res 49, pp 1-6. Abstract | View Record in Scopus | Cited By in Scopus (243), 1992.

14. De Vries LS, van Haastert IL, Rademaker KJ et al: Ultrasound abnormalities preceding cerebral palsy in high-risk preterm infants, J Pediatr 144, pp 815-820, 2004.

15. Hamrick SE, Miller SP, Leonard C et al: Trends in severe brain injury and neurodevelopmental outcome in premature newborn infants: the role of cystic periventricular leukomalacia, J Pediatr 145, pp. 593-599. Abstract | View Record in Scopus | Cited By in Scopus (72), 2004.

16. Childs AM, Cornette L, Ramenghi LA et al: Magnetic resonance and cranial ultrasound characteristics of periventricular white matter abnormalities in newborn infants. Clin Radiol 56, pp 647-655, 2001.

17. Maalouf EF, Duggan PJ, Counsell SJ et al : Comparison of findings on cranial ultrasound and magnetic resonance imaging in preterm infants, Pediatrics 107, pp 719-727, 2001.

Correspondence:
Fuat E. Canpolat
Dr. Zekai Tahir Burak
Kadin Sagligi Egitim ve Arastirma Hastanesi
Yenidogan Yogun Bakim Ünitesi
Ankara, TURKIYE.
e-mail: femrecan@gmail.com