Seminars in Fetal & Neonatal Medicine 21 (2016) 295–304

Contents lists available at ScienceDirect

Seminars in Fetal & Neonatal Medicine

journal homepage: www.elsevier.com/locate/siny

Review

Cranial ultrasonography of the immature cerebellum: Role and limitations

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Keywords:
Cranial ultrasonography
Mastoid fontanel
Cerebellum
Preterm infant

S U M M A R Y

Cranial ultrasonography (CUS) is a reliable and non-invasive tool to detect frequently occurring brain abnormalities and to monitor brain development and maturation in high risk neonates. Standard CUS views are obtained through the anterior fontanel. However, evaluation of the posterior fossa is often suboptimal with this approach. Cerebellar injury occurs frequently in preterm infants and has important prognostic consequences. Early detection is therefore important. This review focuses on techniques that optimize the performance of CUS when studying the preterm cerebellum, including the use of the mastoid fontanel and the adaptation of focus points and scan frequencies. For illustration, CUS images of the normal posterior fossa anatomy as well as examples of abnormalities that may be encountered in preterm infants are included. We also discuss the limitations of CUS and the role of magnetic resonance imaging.

1. Introduction

Brain injury is an important complication of preterm birth. It may lead to neuromotor problems and significant cognitive, behavioral, attentional, and socialization deficits [1]. Until recently, supratentorial brain injury, especially white matter injury, was considered the main cause of impaired neurological outcome in preterm infants. Due to improved cranial ultrasound (CUS) techniques and the more widespread use of magnetic resonance imaging (MRI), cerebellar injury is now known to be an additional, clinically important risk factor associated with preterm birth [2–9]. The preterm cerebellum is especially vulnerable because of its extremely rapid growth and development during late gestation [4]. In the preterm infant, critical phases of cerebellar development occur within the context of early exposure to the extrauterine environment. Multiple insults may lead to cerebellar injury and impair further cerebellar development [3,10–13]. Neonatal cerebellar injury is associated with a broad spectrum of neurodevelopmental disabilities [14–16]. Early detection is therefore important.

Cranial ultrasonography is the most widely used technique for brain imaging in high risk neonates. Its major advantages are that it is safe, inexpensive, and can be performed early and repeatedly at the bedside with little disturbance to the infant [17]. CUS is routinely performed through the anterior fontanel (AF). With optimal settings, this provides excellent views of most supratentorial structures. The evaluation of infratentorial structures, however, is often suboptimal. MRI yields detailed images of the whole brain, including areas that are difficult to visualize with CUS, such as the posterior fossa. Nevertheless, MRI is more burdensome and therefore less suitable for routine, early or serial imaging in critically ill, very preterm infants.

This review focuses on the role of CUS imaging of the cerebellum in the preterm neonate and covers the following issues: (i) CUS examination of the preterm cerebellum through the AF; (ii) advantages and technical aspects of the use of the mastoid fontanel (MF) as an additional acoustic window; (iii) illustrations of the normal CUS appearance of the preterm cerebellum; (iv) examples of frequently occurring cerebellar abnormalities in the preterm infant; (v) indications and limitations of MF-CUS and the role of MRI.

2. Imaging the cerebellum through the anterior fontanel

In routine CUS, the AF is used as an acoustic window. The whole brain is scanned in coronal and sagittal planes, in order to

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http://dx.doi.org/10.1016/j.siny.2016.04.011
1744-165X/

obtain an overview of its appearance [18]. On images obtained through the AF, most supratentorial structures are located close to the transducer. This allows scanning with a high transducer frequency (8–10 MHz), yielding high resolution images. However, visualization of the posterior fossa is limited, mainly because of its location further away from the transducer [19,20]. In addition, the echogenic tentorium may impede image quality and the detection of lesions. In extremely preterm infants with a very small head, penetration may still be sufficient for visualization of the posterior fossa (Fig. 1), but in larger infants, this is less optimal. Additional scanning with a lower transducer frequency allows a better penetration and a better view of deeper brain structures, including the cerebellum, but this is at the cost of resolution. In addition to changing the scan frequency, the focus point(s) can be adapted to the area of interest to improve image quality [17,20] (Fig. 2).

3. Imaging the cerebellum through the mastoid fontanel

The MF is located at the junction of the posterior parietal, temporal and occipital bones [19,21]. When using the MF as an additional acoustic window, the transducer is placed closer to the posterior fossa. This allows the use of higher transducer frequencies, thus improving resolution. Furthermore, the structures are approached at a different angle, avoiding the echogenic tentorium. Previous studies have stressed the advantages of the MF approach for the detection of cerebellar injury in preterm infants [3,7,8,22,23]. Using MF views may lead to the detection of cerebellar hemorrhage (CBH) that might be missed when using only the routine AF approach. MF sonography is also a useful tool for detecting other types of cerebellar injury and posterior fossa abnormalities [19,21,24–26].

Mastoid fontanel sonography is performed after the standard AF examination. The infant is positioned with its head to one side. Generally, only one of the MFs is used, depending on the position of the infant. When abnormalities are suspected, these can be confirmed by using the opposite MF.

The transducer is placed over the MF, behind the helix of the ear, and then slightly moved and rotated until a good view of the posterior fossa is obtained. Images are recorded in axial and coronal planes. Axial images are obtained with the transducer almost parallel to the orbitomeatal line. Coronal views are obtained with the transducer placed along the coronal suture [18,19] (Fig. 3). Superior axial views include the cerebral peduncles, perimesencephalic and quadrigeminal cisterns, aqueduct and superior vermis. Middle axial views include the temporal lobes, pons, prepontine cistern, fourth ventricle, cerebellar vermis, hemispheres, and cisterna magna. Inferior axial views include the inferior part of both cerebellar hemispheres, inferior vermis, and cisterna magna (Fig. 4).

Anterior coronal views include the temporal lobes, hippocampus, tentorium, fourth ventricle, cerebellar vermis, hemispheres and cisterna magna. Posterior coronal views include the posterior part of the lateral ventricles, tentorium, posterior part of the cerebellar vermis and hemispheres, and cisterna magna (Fig. 5).

Color Doppler sonography may be performed additionally to visualize venous flow in the transverse and sigmoid sinuses and arterial flow in the circle of Willis (Fig. 6).

4. Abnormalities of the preterm cerebellum

4.1. Cerebellar hemorrhage

Cerebellar hemorrhage is the most frequent form of direct cerebellar injury in the preterm infant. It originates in the vulnerable germinal matrix layers of the cerebellum, the external granular layer, and the subependymal germinal matrix of the fourth ventricle, where fragile capillary networks may easily rupture [5]. Two main patterns of CBH are described in the literature. The first includes large focal CBH, mostly unilateral and hemispheric, and

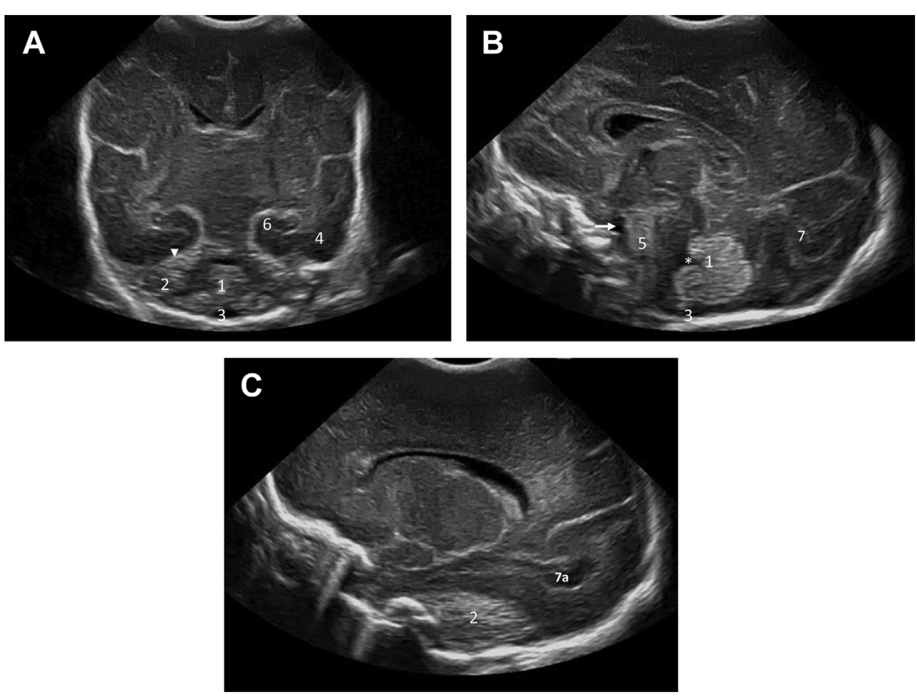

Fig. 1. Normal coronal (A), midsagittal (B) and parasagittal (C) ultrasound scans in preterm infant (gestational age 28 weeks) using the anterior fontanel as acoustic window, showing cerebellar vermis (1) and hemispheres (2), cisterna magna (3), temporal lobe (4), pons (5), hippocampus (6), occipital lobe (7) with occipital horn (7a), fourth ventricle (asterisk), prepontine cistern (arrow) and area of tentorium (arrowhead).