Early detection of ischemic brain injury using diffusion-weighted imaging (DWI)

By Eliel Ben-David, MD, and Elena Zharkov, MD
Department of Radiology, Shaare Zedek Medical Center, Jerusalem, Israel

Neonatal hypoxic-ischemic encephalopathy (HIE) occurs in 1.5 cases per 1,000 of all live births worldwide and is a devastating condition that may result in severe neurologic deficits or even death in children[1]. Factors such as gestational age, brain maturation, duration and severity of the injury influence the clinical findings and long-term outcomes associated with HIE.

Diagnostic imaging plays a critical role in the clinical assessment of suspected neonatal HIE. Imaging modalities such as cranial ultrasound (cUS), magnetic resonance imaging (MRI), and depending on the geographic area, computed tomography (CT), can be utilized to identify and characterize the location, extent, and severity of the brain injury. Cranial US is typically used as a first-line evaluation tool due to its bedside accessibility. However, the quality of cUS imaging is operator dependent which means some abnormalities may be missed based on the operator's experience. Also cUS images have limited soft tissue differentiation and have inadequate ability to define the exact site and extent of brain injury. Cranial CT may be used in urgent situations when MRI is not available, but is not recommended for use on neonates due to ionizing radiation exposure. For these reasons, MRI is the brain imaging modality of choice for assessing HIE due to its superior sensitivity and specificity for detecting and quantifying brain abnormalities[2], specifically ischemic brain tissue.

Appropriate timing of the MRI scan is crucial for accurately diagnosing HIE. Scanning too early can underestimate the extent of the injury as tissue abnormalities associated with HIE take time to manifest. Therapeutic hypothermia (i.e. cooling) has been proven to be the most reliable intervention for reducing the risk of death or disability associated with HIE[3]. MRI scanning performed after an infant has been rewarmed helps to further assess brain injury and predict neurological outcomes, and can assist clinicians in making both short- and long-term care decisions.

The NICU at Shaare Zedek Medical Center has 90 beds across two campuses and is the only medical facility in Israel using the Embrace® Neonatal MRI system for research purposes for the last 18 months. MRI scanning inside the NICU eliminates the risks of off-unit transport, keeping fragile babies safe inside the environment constructed to give them the best care.

Among all MRI scanning protocols, diffusion-weighted imaging (DWI) is the key sequence used to assess cerebral edema and ischemic lesions associated with HIE. Ischemic infarcts are

characterized as reduced water diffusion due to cytotoxic edema caused by the reduced blood flow in that area. Areas showing reduced blood flow appear hyperintense (bright) on diffusion-weighted images. This process allows for easy detection in a DWI sequence and is an excellent technique for detecting hypoxic and ischemic injuries at an earlier stage compared to conventional T1- and T2-weighted MR imaging[3]. The images created by the DWI sequence are constructed from signal contrast generation based on the differences in Brownian motion and is used to evaluate the molecular function and micro-architecture of the human body. While conventional imaging provides anatomical data, DWI offers more insight to the cellular level[4].

The Embrace® Neonatal MRI System from Aspect Imaging offers the capabilities and benefits of an adult MRI to diagnose ischemia but is situated inside the protective environment of the NICU. It's the world's first FDA-cleared, CE marked MRI system designed for neuroimaging inside the NICU. The Embrace® brings the technology closer to the baby, eliminating the risks associated with off-unit transport. Now, neonates can be scanned when they're ready, sometimes within minutes of an order, omitting the extra step of negotiating time on the radiology department schedule. Since its first installation in 2018, the Embrace® has been used for both applied medical research and clinical assessment, harnessing the diagnostic power MRI brings into the NICU.

Overview

In this case review, we demonstrate the diagnostic value of the Embrace® FSE-based DWI technique on four neonates admitted to the Shaare Zedek Medical Center NICU presenting clinical evidence of HIE. Three of the infants were term infants and underwent therapeutic hypothermia. All infants were scanned by the Embrace® Neonatal MRI system once clinically stable enough to be transported to the MRI suite within the NICU. The Embrace® scanning protocols included conventional T1 and T2 protocols as well as a 3-directional DWI protocol with b-value of 700 s/mm^2 and spatial resolution of 1.5 x 1.5 x 3 mm.

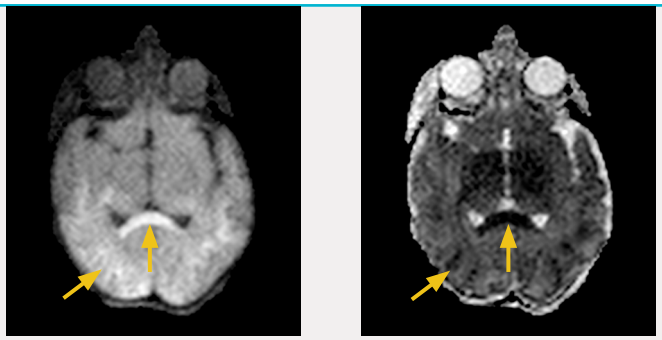
Case 1

History

Twin delivery at 37 weeks by STAT C-section for non-reassuring heart tones during labor. Apgar scores were 2/6/8 at 1/5/10 minutes. The aEEG showed an abnormal background pattern with seizures and the infant received therapeutic hypothermia for 72 hours. The clinical course was complicated by multi-system organ failure, hypotension treated with dopamine and hydrocortisone x 6 days. The MRI scan was completed on DOL 6.

MRI Findings

The DWI showed restricted diffusion in a posterior distribution and in the corpus callosum. Diffuse hypoxic ischemic injury (HIE) was diagnosed.



DWI trace (left) and ADC map image (right) shows corpus callosum (arrow) and occipital lobe acute Ischemia (arrow).

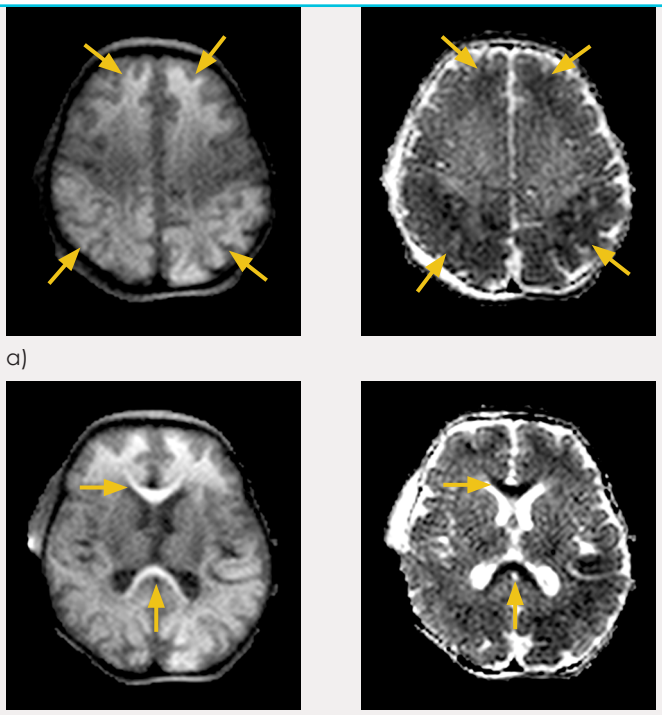
Case 2

History

Term infant born via emergency C-section, nuchal cord x 5 noted at delivery, and low Apgar scores. Infant received therapeutic hypothermia. MRI scan on DOL 6.

MRI Findings

MRI scan showed diffuse restricted diffusion in anterior frontal lobes, bilateral parieto-occipital lobes and in corpus callosum.



a)

b)

Extensive ischemia in bilateral frontal and parietal-occipital lobes (a, or upper panel) and corpus callosum (b, or lower panel) are observed as hyper signal intensity in DWI trace image (left) and hypo signal intensity in DWI ADC map (right).

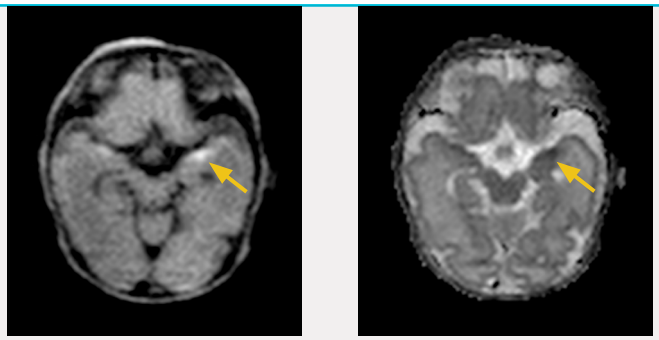
Case 3

History

Premature infant born at 30 weeks gestation. Infant presented with cardiac tamponade at 7 days old. MRI Scan completed on DOL 12 (adjusted age 31 5/7 weeks)

MRI Findings

Restricted diffusion in left temporal lobe.



DWI trace *ADC map*

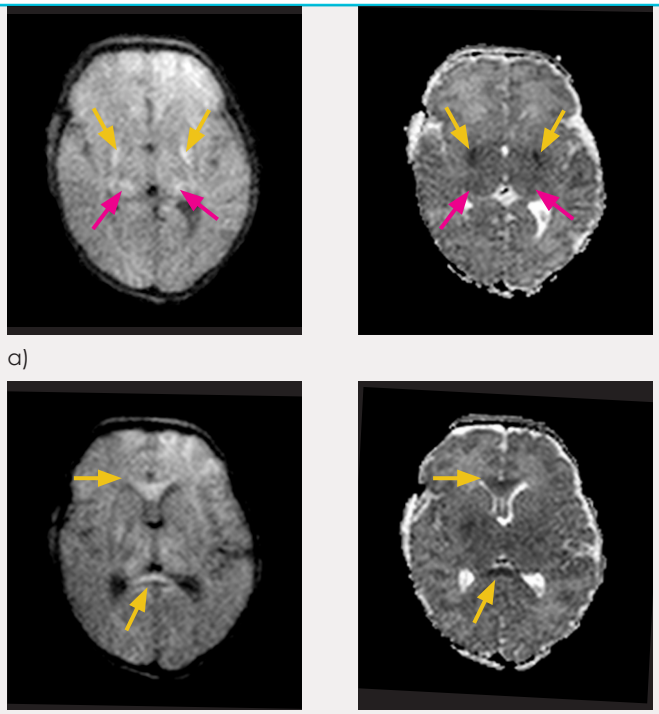
DWI shows left temporal lobe ischemia.

History

Term infant with SGA, placental separation prior to delivery, received 40 minutes of CPR. Infant had seizures and received therapeutic hypothermia for 72 hours. MRI scan was completed on DOL 8.

MRI Findings

Bilateral restricted diffusion in globus pallidus, thalamus and corpus callosum.



a)

b)

DWI shows bilateral globus pallidus (yellow arrows), thalamus (red arrows) (a, or upper panel) and corpus callosum acute ischemia (b, or lower panel).

Discussion

MRI with DWI has been shown to be highly reliable at identifying diffuse and localized ischemic brain injury in both term and preterm infants. For term infants with HIE who have undergone hypothermia treatment, the presence of injury on DWI within the first week of life has been strongly correlated to adverse long-term outcomes[2].

The early identification of the extent and timing of brain injury is significant for an accurate diagnosis and clinical management. Therapeutic interventions are most effective when delivered to the right patients at the right time and DWI can be used to identify injury and edema patterns long before the conventional T1- and T2-weighted images appear abnormal[5].

In this review, we have demonstrated the use of the Embrace® Neonatal MRI system with four cases of neonatal hypoxia and ischemia injury. We have further demonstrated that this 1.0T permanent MRI scanner can give diagnostic quality images without the need to transport a critically ill neonate to the radiology department.

The Embrace® delivers point-of-care, high-quality images needed to make a conclusive diagnosis to help care providers develop effective treatment plans and tailor post-discharge referrals based on the needs of the infant.

"Availability of MRI imaging in the NICU that includes DWI is a game changer in the diagnosis, treatment and management of neonates with suspected HIE," says Eliel Ben-David, MD, Neuroradiology Section Chief, Shaare Zedek Medical Center. *"I truly hope this will become a standard imaging tool in NICUs everywhere to assist neonatology teams to improve outcomes."*

References

1. Bano, S., Chaudhary, V., & Garga, U. C. (2017). Neonatal hypoxic-ischemic encephalopathy: A radiological review. Journal of Pediatric Neurosciences, 12(1):1-6
2. Sorokan, Todd S., Jeffries L. Ann, Miller P. Steven: Imaging the term neonatal brain. Canadian Paediatric Society, Fetus and Newborn Committee. Paediatr Child Health 2018, 23(5): 322-328
3. Eman A.Sh. Genedi, Noha Mohamed Osman, Marwa Talaat El-deeb: Magnetic resonance imaging versus transcranial ultrasound in early identification of cerebral injuries in neonatal encephalopathy. The Egyptian Journal of Radiology and Nuclear Medicine 2016; Vol. 47 Issue 1: 297-304
4. Vinit Baliyan, Chandan J Das, Raju Sharma, and Arun Kumar Gupta: Diffusion weighted imaging: Technique and applications. World J Radiol. 2016 Sep 28; 8(9): 785–798.
5. Huang Y. Benjamin, Castillo, Mauricio: Hypoxic-Ischemic Brain Injury: Imaging Findings from Birth to Adulthood. RSNA RadioGraphics: Vol. 28, No 2.

DOC10002231