Neonatal Imaging Using an MR-compatible Incubator

Advances in neuroimaging utilizing MR imaging have opened up new insights into brain injury and disease. Sequences such as diffusion weighted imaging (DWI), diffusion tensor imaging, tractography, and perfusion have all contributed to the growing knowledge of how injury and disease impact this critical organ. Yet, understanding the impact of injury due to premature birth on the developing brain has historically been an area where clinicians and researchers have been limited due to the difficulty in imaging very small and ill neonates.

Catherine Limperopoulos, PhD, Director, Developing Brain Research Laboratory at The Children's Research Institute, Children's National Health System (Washington, DC), has focused her career on the causes and consequences of premature birth and injury. Central to her research is the utilization of advanced MR imaging techniques to identify and develop reliable biomarkers of risk. The goal of the imaging and biomarker development is to help guide medical and surgical interventions aimed at minimizing or, if possible, preventing injury.

A major obstacle to her ongoing research and the development of these biomarkers has been the inability to transport premature babies early on to the MR scanner. "We know that brain

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> *Dr. Catherine Limperopoulos*

injury in very premature infants occurs within the first hours or days of life,” Dr. Limperopoulos says. “Previously, that early window of assessment was unavailable to us until the baby was stable enough to transport to MR.”

That all changed with the introduction of the MR Diagnostics Incubator System nomag IC (LMT Medical Systems, Lübeck, Germany). Dr. Limperopoulos acquired one of the very first systems when she began her career a decade ago. “Having the ability to study babies and identify early indicators of brain injury is important in the prognostication and care of critically ill premature infants in the NICU,” she says.

Nomag IC is an MR-compatible incubator with an integrated head coil designed for neonates and small babies. It provides a comfortable transportation of the baby from the NICU to the MR scanner.[1]

Upon moving to Children’s National, Dr. Limperopoulos and her team were instrumental in working with GE Healthcare and LMT Medical Systems to upgrade the nomag IC so it could be used with a 3.0T MR system. The MR’s higher field strength coupled with the incubator’s transport of babies has helped propel early imaging of the smallest and sickest babies. While the higher field strength is preferred for neuroimaging, the nomag IC can also be used with 1.5T MR systems. That versatility is important at Children’s National; if there is a critical need for an immediate MR exam and the 3.0T scanner is not available, clinicians can still obtain the diagnostic information they need for patient management on the 1.5T scanner. Children’s National has a Discovery™ MR750, Discovery™ MR450, and a wide bore Optima™ MR450w.

With the nomag IC, there is very little handling of the patient. “Being able to provide an integrated environment without having to reposition the baby provides greater medical stability, which is critical for hemodynamically fragile infants. Once they are positioned, it is a hands-off approach thereafter, and that is really important,” Dr. Limperopoulos says.

Dr. Limperopoulos’ lab does not use sedation when it performs imaging on these vulnerable newborns. The lack of handling along with the acoustic protection for the infants in the nomag IC helps to facilitate imaging as the infants sleep. With the infant secured in the nomag IC, Dr. Limperopoulos has noticed a decrease in motion-related artifacts. Plus, the higher resolution and SNR of 3.0T has improved visualization of injuries or defects.

With the successful imaging of neonates and infants using nomag IC, Dr. Limperopoulos has been able to establish the presence of initial injury as well as secondary injuries. “We can time the initial injury and monitor the impact of that on subsequent brain development and plasticity,” Dr. Limperopoulos explains. “This allows us to study the brain longitudinally and intermittently. We are not just diagnosing the injury but identifying the effect of the injury on the developing brain.

“If we can’t prevent an initial injury, there may be a therapeutic window to prevent or minimize any secondary injury. The nomag IC has been instrumental in obtaining that baseline and impact of the injury during the maturational process,” she adds.

Dr. Limperopoulos anticipates her research can be extrapolated to other children and brain injuries such as traumatic brain injuries (TBI). “In the setting of children with a TBI, there are secondary evolving injuries affecting the developing brain. By imaging the critically ill infant early on, we can

define the extent of the injury and also, knowing that injury is not static, what is happening to the brain overall. This allows us to target therapeutic interventions to mitigate or minimize cascading events from the initial injury."

While Dr. Limperopoulos' research has been dedicated to the brain, she sees potential to also study the heart and multiple organs. "This technology is giving us an unprecedented opportunity to make meaningful strides in our understanding of the timing and evolution of injury in high-risk infants."

Clinical implementation

The Institute of Mother and Child is a tertiary referral neonatology center in Warsaw, Poland, with a SIGNA™ HDxt 1.5T that was last upgraded in 2011. According to Monika Bekiesińska-Figatowska, MD, Head of Diagnostic Imaging, prior to implementing the nomag IC, the hospital would perform neonatal MR examinations using an adult head coil in conjunction with a phantom. However, it limited the hospital to brain-only exams on stable, mainly term, neonates.

In 2013, thanks to a donation from one of the largest non-profit organizations in Poland, the Institute acquired the nomag IC, suitable for scanning infants with a body weight up to 4.5 kg and body length of 55 cm. "With the nomag IC, newborns, including premature ones, can be wheeled directly into the scanner and they lie protected inside it throughout the entire examination.

According to Dr. Bekiesińska-Figatowska, the nomag IC is equipped with an 8-channel, phase-array head coil and a whole-body 12-channel, phase-array coil consisting of two elements: an 8-channel part integrated with the incubator bed and a separate 4-channel surface coil.

"We have always seen the superiority of MR over transfontanelle ultrasonography (US) in the evaluation of the brain and the cerebellum," Dr. Bekiesińska-Figatowska says. In particular, diffusion-weighted imaging is capable of reliable assessment of central nervous system (CNS) injury.[2]

The nomag IC increased the availability of MR for young and unstable patients. With approximately 25% of patients weighing less than 2,500 g at the time of their MR, this solution created new opportunities to examine the most vulnerable patients at The Institute of Mother and Child. As an example, in one infant scanned at the gestational age of 26 weeks when his body reached 600 g, the MR images depicted bilateral intraventricular hemorrhages and intraparenchymal bleeding both in the supratentorial and infratentorial compartment. The just-forming cavity was also appreciated in his right frontal lobe (Figure 1A). The outcome at term equivalent was quite good in this patient, however, with only depositions of hemosiderin in subependymal localization in the ventricular system and the cavity in the frontal lobe that was a smaller size than on initial examination (Figure 1B).

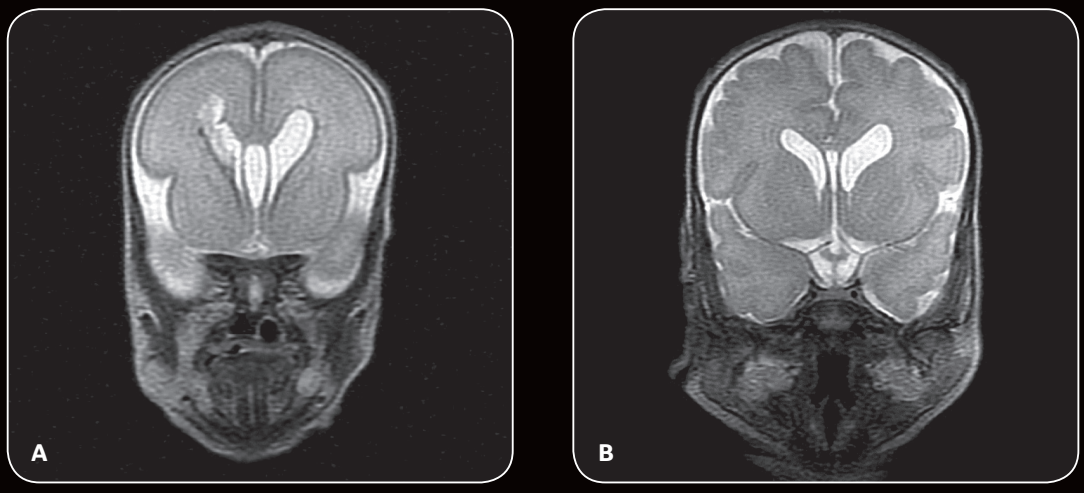

Figure 1. The youngest neonate examined at the Institute of Mother and Child was at the age of 26 gestational weeks. (A) Depicts the smooth brain and a cavity forming close to the right frontal horn. (B) At term equivalent: with gyration appropriate for the corrected age and the small porencephalic cyst on the right.

Neonatal MR can also help clinicians detect abnormalities or injuries when other diagnostic tests are unclear or indeterminate. “One of our patients with normal US and without neurological signs and symptoms turned out to have diffuse polymicrogyria involving almost the entire left cerebral hemisphere,” she adds (Figure 2).

Monika Bekiesińska-Figatowska, MD,

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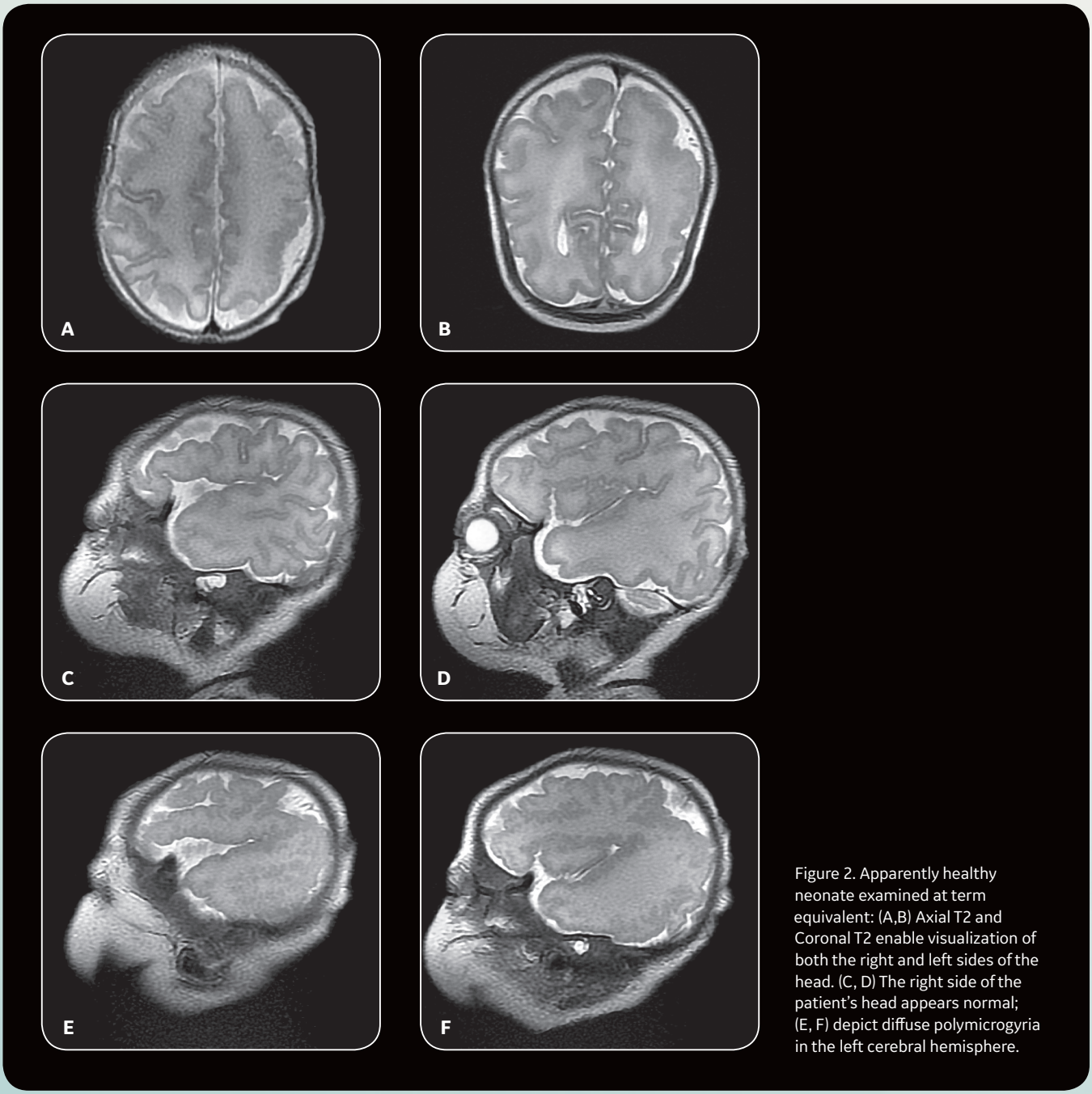

Figure 2. Apparently healthy neonate examined at term equivalent: (A,B) Axial T2 and Coronal T2 enable visualization of both the right and left sides of the head. (C, D) The right side of the patient’s head appears normal; (E, F) depict diffuse polymicrogyria in the left cerebral hemisphere.

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Another case involved an infant born preterm after the death of a twin intrauterine who underwent MR after an unclear sonographic picture of diffuse hyperechogenicity of the left cerebral hemisphere. The MR demonstrated a stroke in the region supplied by the left middle cerebral artery and a smaller one in the right hemisphere, accompanied by pre-Wallerian degeneration involving the corpus callosum and the corticospinal tracts on the left side.

MR is also utilized for body imaging in infants with the Neonatal Body Array Coil from LMT. So far, over 380 MR examinations have been performed with the nomag IC, with 18% involving the neck, thorax, abdomen, and pelvis.

"We found that not only standard sequences but also more sophisticated ones, such as Cube/3D, DWI or MR-hydrography, are feasible and provide significant information," Dr. Bekiesińska-Figatowska explains.

"One example is a neonate with a sacrococcygeal teratoma who was operated on and required early control due to an unclear sonographic picture. On MR we found the abscess in the pelvis, which was treated and regressed on the subsequent MR."

The literature concerning neonatal MR using nomag IC is limited, Dr. Bekiesińska-Figatowska says, with 20 articles in a PubMed search on the topic. In 2014, she and her colleagues reported in their initial experience that the incubator with integrated neonatal coils provided the information they needed for better visualization of abnormalities than when using adult coils.[3] More recently, they published a study demonstrating the feasibility of MR imaging in preterm newborns with low or extremely low birth weight.[4]

"After the introduction of our nomag IC in our clinical practice, our team helped publish new standards for the care of newborns in Poland," Dr. Bekiesińska-Figatowska says.[5] "These standards clearly place MR in the diagnostic algorithm."

References

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