



Technical Innovation Diagnostic Radiology

Experience with new technology: Point-of-care magnetic resonance imaging in the neonatal intensive care unit

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ABSTRACT

Neuroimaging is a crucial component of the management of neonates in the neonatal intensive care unit (NICU). Previously, challenges associated with the transport of neonates to a traditional 1.5-3T magnetic resonance imaging (MRI) machine have led to a reliance on ultrasound in the NICU, despite its limitations. Bedside availability of the neonatal MRI system has provided solutions to some of these challenges by decreasing the time of transport, providing continuous monitoring of the neonate, and cable management for lines and leads without an external magnetic field. We present our initial experience with the point-of-care NICU MRI through a clinical case. The point-of-care MRI successfully identified intracranial abnormalities, demonstrating its effectiveness in the NICU.

Keywords: Cranial ultrasound, Neonatal brain imaging, Neonatal intensive care unit, Neonatal MRI, Point-of-care imaging

INTRODUCTION

Premature infants in the neonatal intensive care unit (NICU) are at risk for intracranial hemorrhage and periventricular leukomalacia.^[1] Neonates with hydrocephalus and congenital brain anomalies diagnosed on prenatal ultrasound require magnetic resonance imaging (MRI) of the brain.^[2] MRI is more accurate in determining white matter injury compared to ultrasound. Neonatal ultrasound is a useful modality, but MRI is the preferred modality to evaluate the neonatal brain.

Although MRI has become a cornerstone in diagnostic imaging, the complex logistics of the machine limit the ability to image neonates in the NICU. Historically, these machines have been big and bulky and located in the radiology department of hospitals, making the transportation of critically ill patients challenging. Transportation can also result in equipment failure, inadequate monitoring, or resuscitation without a physician.^[3] Furthermore, the electric field created by MRI may prohibit the entry of certain equipment and ferromagnetic materials needed by critically ill patients.^[3] As a result of these challenges, cranial ultrasound has been the imaging modality of choice in the NICU. Ultrasound has traditionally been reliable for identifying intraventricular hemorrhage and ventriculomegaly; however, it is less sensitive than MRI in detecting white matter disease and complex congenital brain anomalies.^[4]

With the advent of point-of-care NICU MRI, the challenges presented above are significantly reduced. This machine can be located in close proximity to the NICU due to its compact size, zero external magnetic field, and because it does not require 4-zone rooms like traditional MRI, as shown

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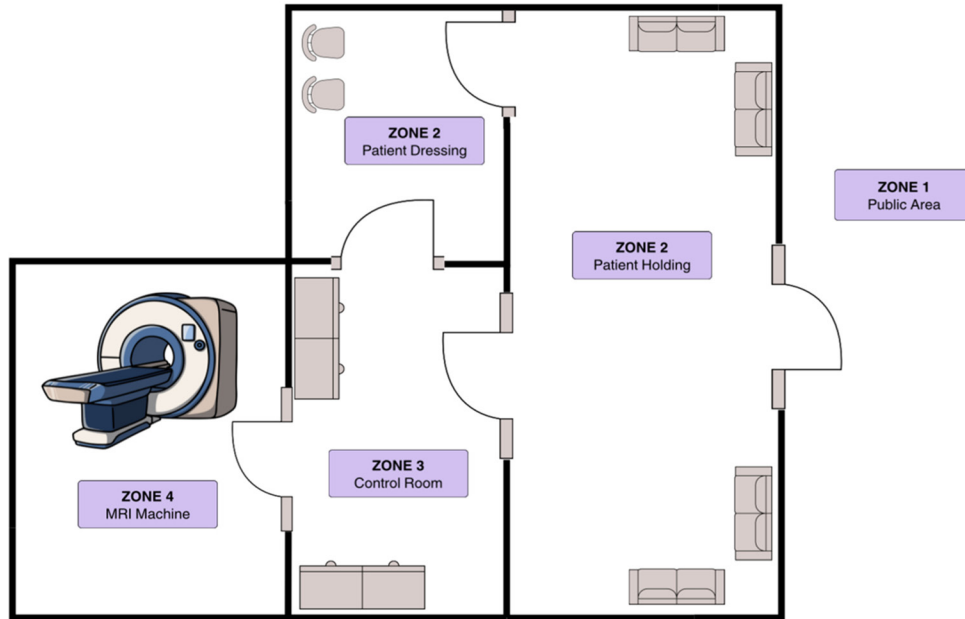


Figure 1: Example of a 4-zone magnetic resonance imaging facility layout as required by the American College of Radiology.

in Figure 1.^[5] The lower magnetic field and cable management for lines and leads allow support for critically ill patients.

While purchasing this machine required careful fiscal consideration, the final decision was guided by discussions with other institutions that had already implemented point-of-care NICU MRI. Clinical cases presented from these institutions with this machine showed compelling data. Now, we present our experience and show an example case to demonstrate how this machine has identified intracranial abnormalities and impacted clinical care in the NICU.

MATERIALS AND METHODS

This report describes a descriptive institutional experience illustrated by a representative clinical case. The point-of-care NICU MRI system is shown in Figures 2 and 3. The MRI machine is installed in or near the NICU for easy access and to limit transport time. It has a magnetic field strength of 1 tesla, accommodating neonates under 4.5 kg with a maximum head circumference of 38 cm. Importantly, the 5-gauss line, the safety line around the perimeter of the scanner, is confined within the system. This results in an external magnetic field equal to zero.

The sequences obtained with point-of-care NICU MRI include MR angiogram (time of flight), MR venogram (without intravenous contrast administration), susceptibility-weighted, diffusion-weighted, T1-weighted gradient echo, T1-weighted spin echo, and T2-weighted fast spin echo. The

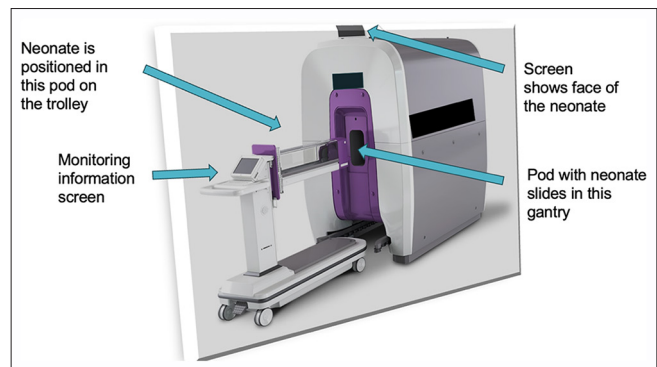


Figure 2: Open configuration of the neonatal magnetic resonance imaging system. The neonate is placed in the pod on a temperature-controlled bed that slides into the gantry. The screen allows for safe visual monitoring. The monitoring information screen displays essential information, including vital signs.

point-of-care neonatal MRI system is compatible with all standard picture archiving and communication systems.

Training of MRI technologists was done at the time of installation and required 2 days. At present, there are two trained MRI technologists on staff. Protocols for various indications are stored for reuse.

A newborn girl with a history of open-lip schizencephaly identified on fetal ultrasound was evaluated by ultrasound on day 1 of life and by point-of-care MRI on day 2 of life. Both the MRI and ultrasound findings were reviewed by a pediatric neuroradiologist.

RESULTS

Ultrasound [Figure 4A] performed on day 1 of life shows open-lip schizencephaly (arrow) on the left side. T2 coronal point-of-care MRI [Figure 4B] and T1 coronal

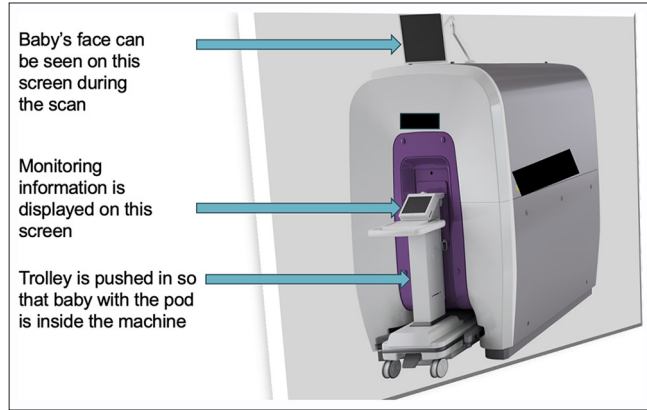


Figure 3: Closed configuration of the neonatal magnetic resonance imaging system. The neonate is advanced into the machine in the pod.

point-of-care MRI [Figure 4C] performed on day 2 of life show open-lip schizencephaly (arrow) on the left side lined by polymicrogyria (arrowhead). T2-weighted images from point-of-care MRI [Figure 4D-F] performed on day 2 of life show closed-lip schizencephaly (straight arrow) on the right with a dimple on the lateral wall of the right lateral ventricle in addition to open-lip schizencephaly (curved arrow) on the left side. Bilateral schizencephaly is lined by polymicrogyria (arrowhead). Due to the lower spatial resolution of ultrasound compared to point-of-care MRI, the closed-lip schizencephaly and polymicrogyria were not well appreciated on ultrasound. Point-of-care MRI clearly helped identify these additional abnormalities with more confidence compared to ultrasound.

DISCUSSION

Indications for point-of-care NICU MRI include hypoxic ischemic encephalopathy, neonatal intracranial hemorrhage, neonatal hydrocephalus, periventricular leukomalacia, congenital brain anomalies, neonatal brain tumours, or intracranial cysts.

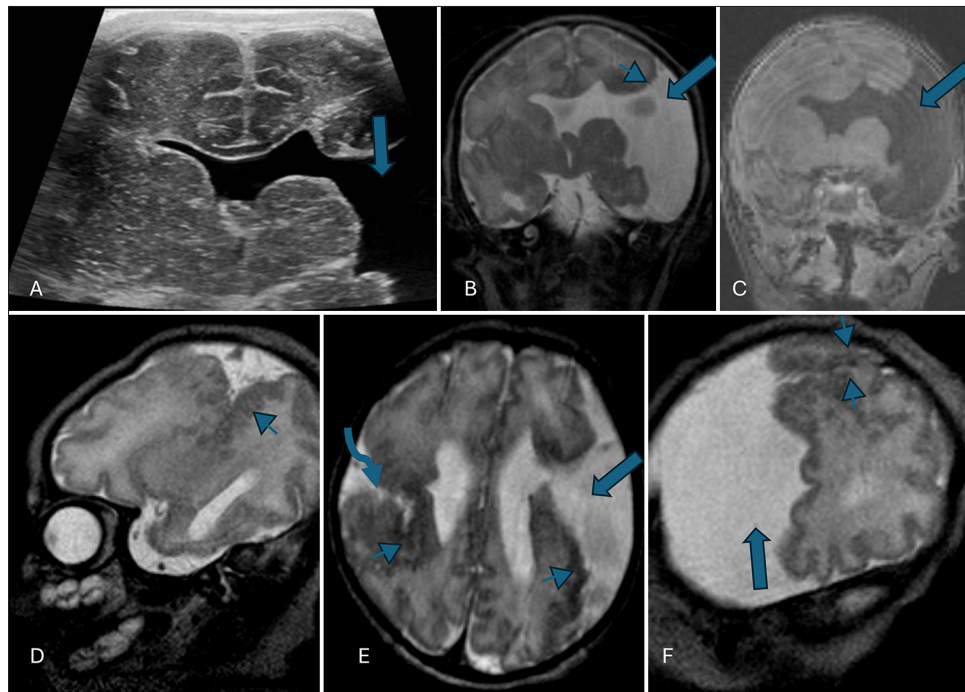


Figure 4: A newborn girl with a history of abnormal fetal ultrasound. (A) Ultrasound performed on day 1 of life shows open-lip schizencephaly (blue arrow) on the left side. (B) T2-weighted coronal point-of-care magnetic resonance imaging (MRI) performed on day 2 of life shows open-lip schizencephaly (blue arrow) on the left side, lined by polymicrogyria (blue arrowhead). (C) T1-weighted coronal point-of-care MRI image shows open-lip schizencephaly (blue arrow) on the left side. (D) T2-weighted sagittal point-of-care MRI image shows schizencephaly lined by polymicrogyria (blue arrowhead). (E) T2-weighted axial point-of-care MRI image shows closed-lip schizencephaly (blue curved arrow) on the right with a dimple on the lateral wall of the right lateral ventricle in addition to open-lip schizencephaly (straight blue arrow) on the left side. Bilateral schizencephaly are lined by polymicrogyria (blue arrowhead). (F) T2-weighted sagittal point-of-care MRI image shows open-lip schizencephaly (straight blue arrow) lined by polymicrogyria (blue arrowhead).

This system has allowed MRIs to be performed in situations where they had previously not been feasible. The NICU is generally located in a different area of the hospital than the radiology department, and transportation of critically ill patients may be risky. However, point-of-care MRI can minimize transportation challenges. While the patient must still be moved from the bed to the NICU MRI, transport time and distance are greatly reduced compared to transport to the radiology department. In addition, the system has a temperature-controlled bed. Notably, there is no expensive or complex electrical or MRI construction required for this machine, facilitating MRI in the safe environment of the NICU.

In addition to transportation challenges, neonates in the NICU often have many lines and leads in place, which previously hindered MRI for neonates. Due to the lower magnetic strength of this machine, 1T compared to 1.5-3T, neonates can be imaged with certain lines and leads in place without removal. The machine also includes cable management for lines and leads. In addition, metal items can be taken to the edge of the bore because there is no external magnetic field. Thus, this machine allows for other essential equipment and people to be in the room and removes the need for 4-zone rooms. Continuous monitoring of hemodynamics, ventilation, and temperature is possible during the scan. As a result, if there is an emergency and the patient requires support, there is no need to move the patient to the safest zone of a 4-zone room.

Other logistical factors allow for greater comfort of the newborn. This machine has less acoustic noise than the traditional system, improving neonatal comfort and safety. Decreasing noise can decrease physiologic stress responses and startle reflexes, which can help improve the quality of the scan. In addition, a camera within the system allows continuous visual contact with the neonate for both the clinicians and parents. This is an advantage compared to traditional MRI, where there is limited visibility of the patient during the scan, and the inability to hear alarms on essential equipment should an emergency occur.

The system can only accommodate a neonate under 4.5 kg with a maximum head circumference of 38 cm; thus, older infants, older children, and adults do not fit in the system. This does limit the patient population that can be scanned. We perform approximately 100 studies each year. Conventional 1.5T and 3T MRI systems are still required for patients who need spectroscopy, as the point-of-care MRI does not support this capability. There are a handful of such MRI machines in NICU in the United States; our estimate is less than 10 such units in NICUs in the United States. The sequences of this machine are geared for neonates and premature babies. There is no fluid-attenuated inversion recovery (FLAIR) sequence, although FLAIR has limited utility in neonates. Although the resolution is lower than a 1.5-3T MRI, the resolution is still diagnostic. Ultimately, by remaining in the NICU and decreasing transport

time, this machine facilitates MRI in neonates to provide more detailed diagnostic information than ultrasound. This system also optimizes resources by reserving traditional 1.5-3T MRI for other patient populations, including children and adults.

CONCLUSION

The point-of-care NICU MRI is an important technical advancement from traditional 1.5-3T MRI machines for neonatal imaging. This system provides solutions for logistical challenges that have previously prevented critically ill neonates from receiving necessary imaging. In the presented case, the point-of-care NICU MRI has successfully imaged intracranial abnormalities, revealing advantages to transcranial ultrasound. Despite limitations in patient size and sequences, the advantages of this machine significantly improve neonatal imaging and management.

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Declaration of patient consent: Patient's consent is not required as patients identity is not disclosed or compromised.

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Conflicts of interest: Chetan Chandulal Shah is a consultant with Aspect Imaging Inc., the manufacturer of the point-of-care NICU MRI system.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation: The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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