Low-field magnetic resonance imaging in a boy with intracranial bolt after severe traumatic brain injury: illustrative case

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BACKGROUND Conventional magnetic resonance imaging (cMRI) is sensitive to motion and ferromagnetic material, leading to suboptimal images and image artifacts. In many patients with neurological injuries, an intracranial bolt (ICB) is placed for monitoring intracranial pressure (ICP). Repeated imaging (computed tomography [CT] or cMRI) is frequently required to guide management. A low-field (0.064-T) portable magnetic resonance imaging (pMRI) machine may provide images in situations that were previously considered contraindications for cMRI.

OBSERVATIONS A 10-year-old boy with severe traumatic brain injury was admitted to the pediatric intensive care unit, and an ICB was placed. Initial head CT showed a left-sided intraparenchymal hemorrhage with intraventricular dissection and cerebral edema with mass effect. Repeated imaging was required to assess the brain structure because of continually fluctuating ICP. Transferring the patient to the radiology suite was risky because of his critical condition and the presence of an ICB; hence, pMRI was performed at the bedside. Images obtained were of excellent quality without any ICB artifact, guiding the decision to continue to manage the patient conservatively. The child later improved and was discharged from the hospital.

LESSONS pMRI can be used to obtain excellent images at the bedside in patients with an ICB, providing useful information for better management of patients with neurological injuries.

https://thejns.org/doi/abs/10.3171/CASE23225

KEYWORDS intracranial bolt; traumatic brain injury; low-field MRI; imaging

Magnetic resonance imaging (MRI) is a radiation-free imaging technique that offers high-quality images for various systems, including the central nervous system, making it a safe and reliable imaging modality.1 MRI utilizes a strong static magnetic field (ranging from 1.5 to 3 T) and radiofrequency pulse sequence to produce detailed images with excellent soft tissue contrast, particularly beneficial for visualizing brain structure and detecting pathologies.1,2 However, conventional magnetic resonance imaging (cMRI) has certain limitations, especially in time-sensitive scenarios. It is sensitive to motion, and any ferromagnetic object within the magnetic field range can cause image distortion or be displaced, rotated, or dislodged, with the potential to harm the nearby organs and cause serious injuries.3 Objects such as cardiac pacemakers, implantable cardioverter-defibrillators, cochlear implants, and hemodynamic support devices containing ferromagnetic material can be contraindications to MRI.3,4 Moreover, performing cMRI in patients with traumatic brain injury (TBI), particularly those requiring continuous intracranial pressure (ICP) monitoring with an intraparenchymal bolt (ICB), presents additional challenges, including the transportation of critically ill patients to MRI suites.5,6 Recently, a novel low-field (0.064 T) portable magnetic resonance imaging (pMRI) machine (Hyperfine Inc.) has been approved for use in clinical settings that could expand access to brain imaging.7–9 This pMRI machine provides several advantages, including reduced safety concerns, fewer image artifacts, and cost-effectiveness.9 Additionally, its portability eliminates the need to transport critically ill patients to radiology suites, resulting in reduced scan acquisition times.10,11 Previous studies utilizing this pMRI machine in
the intensive care unit (ICU) and neonatal intensive care unit (NICU) have demonstrated its safety and feasibility, yielding promising results. However, these studies have not explicitly reported a case involving the use of a pMRI machine in a critical care setting with an ICB in place, nor have they commented on how different metallic and surrounding objects affect the quality of images obtained with this machine.

Here we report a case of a pMRI in a child who was admitted to our pediatric intensive care unit (PICU) with severe TBI who had an ICB placed for ICP measurement.

Illustrative Case

A 10-year-old boy presented to the emergency department of our hospital after a road traffic accident (pedestrian versus automobile). On the primary survey, the airway was compromised due to profuse oral bleeding causing obstruction. He was also tachypneic with a bilateral wheeze and crepitations. The patient was hemodynamically stable with a response to painful stimuli only. His secondary survey and head-to-toe examination revealed a Glasgow Coma Scale score of 8/15, bilaterally sluggish pupils, abrasions on the forehead, right-sided raccoon eye, and multiple abrasions all over the body.

Endotracheal intubation was performed in the emergency room, and after initial stabilization and management, the patient was shifted to the PICU. Neuroprotective measures were started, and a computed tomography (CT) scan of the head, neck, chest, and abdomen was obtained, which showed an extensive left-sided intraparenchymal hemorrhage with intraventricular dissection and cerebral edema with mass effect (Fig. 1D). In the PICU, an invasive Codman metallic ICP monitoring bolt was placed in the left frontal cortex. The ICP ranged from 9 to 22 mm Hg throughout the admission, and cerebral perfusion pressure ranged from 65 to 85 mm Hg. Fluctuations in ICP were managed as per standard TBI guidelines.

Due to fluctuations in ICP and the child’s critical condition, the care team had to decide on conservative versus surgical management, and imaging was required. Therefore, we decided to perform pMRI at the bedside on the third day of the PICU admission. The total acquisition time was 42 minutes, and sequences including T1 weighted, T2 weighted, apparent diffusion coefficient (ADC), diffusion weighted, and fluid-attenuated inversion recovery (FLAIR) were acquired. The pMRI machine was placed at the patient’s head, requiring minimal movement of the patient while all other monitoring and support devices were left in place (Fig. 2). Based on the pMRI scan (interval improvement in edema and no progress in the bleed or midline shift), it was decided to continue conservative management (Figs. 1 and 3). After 5 days in the PICU, the ICP started stabilizing, so the neuromuscular blocking agent was withheld, and analgesodation therapy and ventilation support were weaned off. The ICP monitoring bolt was removed on the eighth day of admission. Later, the patient was operated on for the orbital and mandibular fractures on the tenth day and transferred to the stepdown unit, followed by discharge after 20 days. The patient was doing well by the first follow-up visit a week after discharge.

Patient Informed Consent

The necessary patient informed consent was obtained in this study.

Discussion

To the best of our knowledge, this is the first report describing the use of pMRI for brain imaging in a child with an ICB in the critical care setting.

Observations

No artifacts were produced on imaging despite the presence of an ICB (graded as good-quality images by the radiologist), and no changes were noted in the invasive ICP readings from the bolt during the scan. A single pediatric radiologist evaluated the magnetic resonance images. The image quality assessment was based on the radiologist’s high confidence level in interpreting pMRI brain studies and comparing the findings to the subsequent CT, which is considered the standard imaging modality for patients with intracranial

FIG. 1. A: Axial T2 pMRI showing the burr hole (arrow). B: Corresponding axial bone window CT scan showing the ICP bolt through the burr hole (arrow). C: Axial T2 pMRI image showing hypointense abnormal signals in the left basal ganglia (arrows). D: Corresponding axial plain bone window CT sections confirming the findings (arrow) and intraventricular hemorrhage in the bilateral lateral ventricles’ occipital horns (black arrowhead).

FIG. 2. Low-field pMRI at the bedside with surrounding ventilator and other patient support equipment.
ICP metallic bolts. The image quality assessment also considered factors such as image resolution and artifacts. Our scan time was long (42 minutes) because we sought to obtain all sequences (T1-weighted, T2-weighted, ADC, diffusion weighted, susceptibility weighted, and FLAIR, and in more than one plane) to get maximum details and see the effects of the ICB on images in different sequences; however, as we have learned more, we have realized that these sequences can be customized according to the clinical question, and the scan time can be significantly reduced (up to 15 minutes in the authors’ experience in some cases).

A pMRI has been recently used in many settings, including in ICU settings for stroke, hydrocephalus, brain tumors, TBI, and other indications. It has a low-field strength, has received Food and Drug Administration clearance during the early coronavirus disease 2019 pandemic, offers reduced or nullified electromagnetic interference, has reduced noise during the scan, and has low to no patient-perceived claustrophobia.

ICP monitoring is the standard of care in children with severe TBI. Advances have been made to integrate the pressure monitoring modality into MRI technology by creating more MRI-compatible systems. However, because of a large static magnetic field, a switching magnetic field gradient, and radiofrequency pulses in conventional standard MRI, the challenge of obtaining a scan with an ICB would persist, and in most settings it would require these patients to be disconnected from the continuous monitoring systems before obtaining a scan. Performing early MRI in a clinical environment at the bedside with a low-field strength compatible with an ICB through a pMRI machine will facilitate prompt decisions and improve patient outcomes. Additionally, the scanner uses a permanent magnet, eliminating the need to cool down and reducing the waiting time for scan acquisition. Previously published reports by Sheth et al. and Turpin et al. indicated that the pMRI machine could correctly identify abnormal findings in 40% and 63% of patients, respectively. They also highlighted that in five cases, the pMRI machine guided changes in patient management. Moreover, studies have also evaluated and accurately diagnosed midline shift in stroke, hydrocephalus, and multiple sclerosis using pMRI and compared its findings to standard imaging. Another study done in a NICU showed it was safe and possible to image the neonatal brain in the ICU using pMRI, images were without any major artifacts, and images were concordant with cMRI in 59% of cases. However, the main limitation of our study is the single-case report. Further prospective multicenter studies are required for comparing pMRI to cMRI and CT scans for discrete brain pathologies for validation.

Lessons

The pMRI machine can obtain adequate magnetic resonance images in patients with an ICB at the bedside. It has immense potential to be used as a time-sensitive, noninvasive neuroimaging investigation of choice in children with TBI, producing no disruption in continuous patient monitoring.

Acknowledgments

We thank the PICU and radiology staff for helping us acquire images and the clinical team who cared for this child.

References


FIG. 3. A: Sagittal T2 pMRI showing the burr hole (arrow). B: Corresponding sagittal bone window CT scan showing the ICP bolt through the burr hole (arrow). C: Coronal FLAIR pMRI showing the burr hole (arrow). D: Corresponding coronal bone window CT section showing the ICP bolt through the burr hole (arrow).

**Disclosures**
The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

**Author Disclosures**
Conception and design: Q Abbas, A Abbas, Hilal, Zahidi, Shamim. Acquisition of data: Q Abbas, A Abbas, Hilal, Zahidi. Analysis and interpretation of data: Q Abbas, Hilal. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: Q Abbas, Hilal, Rasool, Zahidi, Shamim. Approved the final version of the manuscript on behalf of all authors: Q Abbas. Statistical analysis: Hilal. Administrative/technical/material support: A Abbas, Hilal. Study supervision: A Abbas.

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