Magnetic Resonance Imaging Studies Without Sedation in the Neonatal Intensive Care Unit Safe and Efficient

Barbara Haney, RNC-NIC, MSN, CPNP-AC; Daphne Reavey, PhD, RN, NNP-BC; Linda Atchison, BSN, RNC-NIC; Janice Poull, BSN, RNC; Lisa Dryer, RN, CPN; Betsi Anderson, BSN, RN, CPHQ; Tracy Sandritter, PharmD; Eugenia Pallotto, MD, MSCE

Use of magnetic resonance imaging (MRI) in the neonatal intensive care unit has been increasing over the past several years because of improved MRI technology and increased clinical awareness of the prognostic and diagnostic information available. Historically, the use of sedation has been the standard for achieving quality imaging without motion artifact, but it exposed the patient to risks associated with sedation medications. In an effort to obtain MRI studies with elimination of risks associated with sedation, a quality improvement project was initiated. Implementing a standardized approach utilizing a vacuum immobilizer has led to successful neonatal MRI completion without the need for sedation in 94% of study attempts. Acceptable or excellent image quality was achieved in more than 97% of attempts. Time away from the neonatal intensive care unit significantly decreased with this approach, with the mean duration of time away decreasing from 60 to 48 minutes (P < .0001). Obtaining MRI studies without sedation can be successfully implemented in a neonatal intensive care unit, nearly eliminating patient risks associated with sedation while improving utilization of hospital resources and maintaining adequate quality imaging. **Key words:** efficiency, magnetic resonance imaging, NICU, nonsedated, safety

Magnetic resonance imaging (MRI) in neonates and infants is being increasingly utilized as a diagnostic and prognostic tool for patients treated in neonatal intensive care units (NICUs). In addition to the diagnostic utility of this imaging method for the body, MRI is particularly useful for brain imaging because of its sensitivity to changes in gray and white matter as well as the ability to differentiate myelinated and unmyelinated white matter. Magnetic resonance imaging does not use ionizing radiation but incorporates an extremely powerful magnetic field that produces detailed anatomic images of the brain or soft tissues of the body. Although biologically harmless, the use of such a powerful magnetic field does have associated risks. These risks mandate implementation of standard rules and education to ensure the safety of not only the patient but all staff members as well.

**Author Affiliations:** Children's Mercy Hospitals and Clinics, Kansas City, Missouri.

The authors thank Amit M. Mathur, MD, Division of Newborn Medicine, St Louis Children's Hospital, and Associate Professor, Pediatrics, Washington University School of Medicine; Jenny McCubbin, administrative assistant, Children's Mercy Hospitals and Clinics; and Dan Smock, BHS, RT (R) (MR) (CT), lead MRI radiology technologist, Children's Mercy Hospitals and Clinics.

**Corresponding Author:** Barbara Haney, RNC-NIC, MSN, CPNP-AC, Children's Mercy Hospitals and Clinics, 2401 Gillham Rd, Kansas City, MO 64108 (bhaney@cmh.edu).

Submitted for publication: April 1, 2010
Accepted for publication: May 19, 2010
Institutional MRI safety guidelines focus on safety in the MRI suite and are the responsibility of the radiology department in most hospitals but do not consider any patient-specific clinical concerns or unique needs managing intensive-care neonatal patients away from an intensive care unit.

Optimal MRI requires patients to lie quietly, in order to avoid any motion that causes artifact and may limit accurate interpretation of the scan. Since limitation of movement is difficult with a neonatal patient, sedation has often been utilized in an effort to reduce motion artifact and to ensure quality images. Many centers establish specific guidelines to care for patients requiring sedation for radiological imaging.\(^6\)\(^{-10}\) Sedation adds the potential for clinically significant additional patient risks including hypoxemia, hypotension, skin rash, and central nervous system as well as respiratory depression.\(^6\)\(^{-11}\) In addition, the use of sedation requires appropriate equipment and procedures as well as additional personnel resources from both radiology department and the NICU and, in some centers, anesthesia personnel in order to minimize the risks from the sedation itself.\(^2\)\(^,\)\(^5\)\(^,\)\(^6\)\(^,\)\(^8\)\(^,\)\(^10\)

In 2006, standardized MRI guidelines, including the use of sedation, were implemented successfully in our institution for NICU patients. Prior to 2006, there was a lack of standardized process and no policy or procedure for the safe transport, care, and monitoring of the infant undergoing MRI studies in our NICU. Variable study quality, patient safety risks, prolonged time away from the NICU, and negative interactions between NICU and MRI staff were identified as significant issues requiring a practice change. After this multidisciplinary project was successfully implemented, reports of successful MRI imaging without sedation were increasingly reported.\(^1\)\(^,\)\(^3\)\(^,\)\(^4\)\(^,\)\(^12\)\(^{-16}\) In 2008, our multidisciplinary team initiated a quality improvement (QI) project in an attempt to eliminate or minimize sedation risks to our patients undergoing this procedure. This article describes the process of developing a standardized approach to obtaining MRI studies without sedation in a tertiary NICU.

**METHODS**

Using the Plan Do Study Act QI model,\(^17\) the primary objective of this project was to transition to a process of obtaining MRI studies without sedation safely and efficiently. We predicted that this could be done successfully in the majority of MRI studies on the basis of our understanding of the successful implementation of this process at similar NICUs. There was concern that keeping the infant quiet and immobile, without the use of sedation, would utilize additional radiology scheduling time and/or would be a difficult task that would ultimately compromise MRI quality. Monitoring these outcomes and demonstrating we could maintain the efficient use of radiology services while maintaining study quality was critical to the success of this project.

In the planning stage, the multidisciplinary team involving the radiology department as well as NICU staff was reconvened. This same multidisciplinary group had previously established standardized guidelines for the MRI process using sedation. Established guidelines already addressed issues surrounding patient preparation, equipment, personnel, recommended sedation regimen, and monitoring outcomes. Facilitated by the NICU quality improvement coordinator, the team included a NICU clinical nurse specialist, neonatologist, neonatal nurse practitioner, NICU charge nurse, NICU PharmD, and hospital-wide pain/sedation team nurse. The lead MRI technician participated as a consultant in the final stages of implementing the nonsedated MRIs. The planning stage of this process involved a review of the literature, exploration of available equipment, and contact with a center known to be successful in nonsedated MRIs, along with an education plan for staff once a recommended process was outlined.

Exploration of possible tools for successful implementation occurred, including review of an MRI conditional transport incubator system with integrated radiofrequency coils\(^2\)\(^,\)\(^12\)\(^,\)\(^18\) (Advanced Imaging Research, Cleveland, Ohio) and a vacuum immobilizer\(^12\) (MedVac Infant Vacuum Immobilization Bag, Contour Fabricators, Inc, Fenton, Michigan). An MRI conditional ventilator was already in use within the hospital (Servo-I, Siemens Medical, Malvern, Pennsylvania). On the basis of available information, experience of other centers, and weighing the costs/benefits of the available equipment, a decision was made to utilize the vacuum immobilizer in our initial process. Education of radiology and neonatal staff including nurses, physicians, and neonatal nurse practitioners was planned and carried out.

An expert consultant, Amit Mathur, MD, Division of Newborn Medicine, St Louis Children’s Hospital, and Associate Professor, Pediatrics, Washington University School of Medicine, was engaged to provide on-site education to both nurses and physicians regarding nonsedated MRI with the use of the vacuum immobilizer. Dr Mathur provided hands-on practice with the immobilizer as well as advice regarding essential components to include in the guidelines for obtaining nonsedated MR images.

In addition, charge and resource nurses were specifically trained to be superusers of this equipment,
allowing them to provide support for bedside nurses as we integrated this practice into our culture. Additional education for all caretakers was provided by e-mail, nursing meetings, and nursing hands-on educational sessions. The electronic MRI order set was modified to support the recommendation that the immobilizer be used for all infants undergoing MRI and routine sedation was not necessary unless there was a specific patient indication. To facilitate successful implementation of this process, the original MRI guidelines were modified to include aspects of patient care for non-sedated MRI and a checklist was developed to ensure readiness of the patient and equipment for a successful procedure (see the Appendix).

PROCEDURE FOR USE OF VACUUM IMMOBILIZER

In the planning stage, several steps were identified as important in ensuring the success of non-sedated MRI using the vacuum immobilizer. Magnetic resonance imaging studies may be obtained in infants who are nil per os (nothing by mouth) or who are neurologically compromised using the vacuum immobilizer, but many are enterally feeding. In infants who are tolerating enteral nutrition, perhaps the most important step begins with coordination of the infant’s feeding schedule with the MRI schedule. Success comes with a drowsy infant who is snuggled in the immobilizer. Failure could occur simply because of inadequate coordination of feedings. Infant states are influenced by internal physiologic needs; hunger is known to cause activity and crying, whereas satiety quiets and induces sleep. A hungry infant may not be still or quiet enough despite using the immobilizer. When coordinating the scheduled time with the MRI department, it is also important to identify if contrast will be needed, on the basis of the MRI test ordered. If contrast is needed, intravenous (IV) access will need to be obtained prior to patient preparation in the NICU. If no contrast is needed, no IV is started. It is important to prevent the need for opening the immobilizer, unwrapping, and awakening the baby in the radiology department, as disturbing the baby in a cold environment will likely lead to irritation for the baby with too much motion for successful good-quality images.

The second most important factor is preparation of the patient at the bedside, in the NICU rather than down in the radiology suite. All the MRI non-conditional electrodes, probes, and tapes must be removed and MRI conditional ones (Neonatal Quatrode, Invivo, Orlando, Florida) applied (Fig 1). Often just undressing, unwrapping, and replacing these adhesive products will cause a baby to cry. If done immediately before the MRI, the baby may not be quiet enough for successful quality MR images. Adequate preparation in the NICU with time for recovery from this stimulation will facilitate a quiet and sleepy state at the time of the imaging. The oxygen saturation (SpO2) probe is best placed on the great toe and secured with paper tape. Because the SpO2 probe may become dislodged, it is important to make it easily accessible without opening the immobilizer. Once the MRI electrodes and SpO2 probe have been applied and the monitor is in place and functioning appropriately, the baby should be swaddled, comforted, and then fed. Parents are encouraged to be involved with this preparation. The swaddled infant is then placed in the center of the vacuum immobilizer and the edges wrapped around the baby and straps clipped snugly (Fig 2). The immobilizer is an airtight, chambered vacuum bag full of beads. It is important that the beads be evenly distributed, especially up around the head/neck area, so that when the vacuum is applied the bag will become snug against the baby. Attach a vacuum (wall suction) to the black valve; as the vacuum removes the air, the beads will become snug against the baby. The bag is manually depressed around the back of the baby’s neck as the air is removed so it conforms to the baby’s head/neck shape. Once the air is removed, rotate the black valve and remove the suction tubing. In addition, it is important to make sure that the IV tubing and the electrode wires are not caught inside the immobilizer so they are readily accessible during the MRI procedure. The straps are secured across the baby’s forehead in a crisscross manner to prevent lateral movement. A gauze pad is placed

Figure 1. Patient preparation for immobilizer.
Figure 2. Patient secured in immobilizer.

on the baby’s forehead under the straps to prevent any pressure irritation (Fig 3). The baby is now prepared and should be taken to MRI immediately (Figs 4 and 5).

Figure 3. Head immobilization.

MEASUREMENT

Measurement is critical to the implementation and monitoring of any QI process. Ongoing monitoring of the MRI process for neonatal patients was in place since 2007. Along with patient demographic data including weight, gestational age, age at the time of MRI, and MRI site, data were collected to monitor time away from the NICU, successful completion of MRI with adequate imaging, and adverse events in MRI as well as need for increased respiratory support 12 to 24 hours after the MRI procedure. The 2007 MRI monitoring provided the baseline measurement for clinical quality outcomes of interest to this project. Grading of image quality was available starting in 2009. Image quality was determined to be excellent, acceptable, poor, or

Figure 4. Immobilized patient ready for transport.

Figure 5. Immobilized patient in magnetic resonance imaging (MRI).
unacceptable by the MRI technician at the time the imaging study was completed. The hospital institutional review board reviewed and approved this QI project before data were collected. Following revision and implementation of the nonsedated MRI guidelines, data were prospectively collected by members of the multidisciplinary QI team to monitor the impact of our change in process and to describe any unanticipated outcomes of the new process.

RESULTS

The baseline MRI monitoring period used to compare our change in process was January through December 2007; all NICU patients receiving MRI studies during this time period were included.

Planning and implementation of the nonsedated MRI process began in September 2008. It took approximately 5 months to complete the revision of the guidelines, obtain the appropriate equipment, and educate providers in both neonatology and radiology. Postimplementation monitoring continued from March 2009 through February 2010. There were 154 imaging studies attempted in 2007 (baseline period) and 155 imaging studies attempted in the 12-month period after implementation of this process (nonsedated period).

The patient demographics were very similar between the baseline and nonsedated periods. Infants undergoing MRI were born between 23 and 42 weeks of gestation. The mean gestational age at birth was 36 weeks. The mean age of the patient at the time of the MRI was 28 days (range, 0–370 days). The mean weight at the time of obtaining imaging was 3.1 kg (range, 1.3–6.7 kg). The head or brain was imaged 91% of the time (280 imaging events). Additional body sites imaged included the spine (7 events), the abdomen (8 events), the chest (4 events), and the pelvis (1 event). In 9 (3%) imaging events, multiple body sites were imaged.

Sedation was utilized in 96% (148/154) of the studies attempted during the baseline period. Six imaging attempts did not use sedation. During the nonsedated period, sedation was used in only 6% (9/155) of imaging attempts, with 94% (146/155) of imaging attempts done without sedation. The reasons for using sedation during the nonsedated time period included failed first imaging attempt (2 events), patient-specific factors (1 event), technical issues related to imaging needs (2 events), and unidentified factors (4 events). All body sites (brain/head, spine, abdomen, chest, and pelvis) were successfully imaged without sedation including 3 of the 9 events when imaging of more than 1 body site occurred. There was a significant decrease in the mean time patients were away from the NICU after implementation of nonsedated MR imaging. During the baseline period, the mean duration away from the NICU was 60 minutes (range, 15–160; 95% confidence interval, 56–65). This compares to a mean duration away from the NICU of 48 minutes (range, 20–165; 95% confidence interval, 45–51; P < .0001) in the nonsedated period (Table 1).

During the nonsedated period, 151 (97%) MRI attempts were successfully completed on the first attempt at imaging. Image quality during this time was excellent for 52% (80 events) of the images and acceptable for 46% (71 events) of the images (Fig 6). Only 4 of the 155 images (3%) during the nonsedated period were considered poor or unacceptable and the study was not completed. During the baseline period, 143 (93%) imaging attempts were successful on the first attempt whereas 11 (7%) imaging events were unsuccessful. Assessment of study quality (excellent vs acceptable) was not available during the baseline period.

Although providing enteral nutrition for the infant was part of the recommendation for use of the immobilizer and successful MRI without sedation, there were patients who were nil per os due to their clinical status during the nonsedated period. There were 51 nonsedated imaging events attempted in patients who were nil per os due to clinical reasons. Ninety-two percent (47/51) of these imaging events were successfully completed without sedation despite the patient’s nil per os status. During the baseline period, all patients were nil per os for imaging events and IV access was obtained if not already present as dictated by the sedation protocol. Intravenous access during the nonsedated period was obtained only if needed for contrast during the MRI study. In many patients during both periods, the imaging was required before

Table 1. Clinical outcomes during baseline and nonsedated periods

<table>
<thead>
<tr>
<th>Clinical Outcome</th>
<th>Baseline (n = 154)</th>
<th>Nonsedated (n = 155)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedation utilized (%)</td>
<td>148 (96)</td>
<td>9 (6)</td>
</tr>
<tr>
<td>Study completion (%)</td>
<td>143 (93)</td>
<td>151 (97)</td>
</tr>
<tr>
<td>Patient complications (%)</td>
<td>13 (8)</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Mean time away from NICU</td>
<td>60 min</td>
<td>48 min</td>
</tr>
</tbody>
</table>

aMagnetic resonance imaging (MRI) guidelines during baseline period included the use of sedation. During the nonsedated period, MRIs were attempted without the use of sedation.

bStudy completion with initial attempt.

P < .0001.
complete resolution of their critical illness so that the MRI was obtained while they were intubated and required ventilator support. During the baseline period, 31% (48/154) of patients were intubated at the time of the MRI study whereas 20% (31/155) of patients were intubated during the nonsedated period. Of all 79 intubated patients, 29 (37%) did not receive sedation and only 1 of these studies was incomplete. Of the 50 intubated patients who were sedated, 5 (10%) studies were incomplete.

Complications were monitored because of risks of respiratory depression specifically associated with sedation. Mild complications were described as need for increased oxygen, brief desaturation, or bradycardia events in MRI that were self-resolved or required brief cessation of imaging for patient stimulation. Moderate complications were the events requiring cessation of the study to provide bag-valve mask ventilation or continuous positive airway pressure for the patient. Complications were considered severe if there was a need for intubation or reversal of sedative drugs due to respiratory depression or unintended extubation of a patient during MRI. Although there were fewer complications in the nonsedated period compared with the baseline period, 6 of 155 (4%) versus 13 of 154 (8%), respectively, this was not statistically significant (Table 1). When combining the patients from the 2 periods to assess complications due to sedation itself, there were 157 patients who were sedated for imaging and 152 patients who were not sedated. There were significantly fewer complications in the patients who did not receive sedation (Table 2). Fourteen complication events occurred in the sedated group as compared with 5 complication events in the nonsedated group ($P < .04$). Both groups had a similar number of mild events (5 in the nonsedated patients vs 8 in the sedated patients). There was a statistically significant

<table>
<thead>
<tr>
<th>Table 2. Complications due to sedation$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complications</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Any complication$^b$ (%)</td>
</tr>
<tr>
<td>Mild (%)</td>
</tr>
<tr>
<td>Moderate$^e$ (%)</td>
</tr>
<tr>
<td>Severe (%)</td>
</tr>
</tbody>
</table>

$^a$Mild complications were described as need for increased oxygen, brief desaturation, or bradycardia events in magnetic resonance imaging that were self-resolved or required brief cessation of imaging for patient stimulation. Moderate complications were those events requiring cessation of the study to provide bag-valve mask ventilation or continuous positive airway pressure for the patient. Complications were considered severe if there was a need for intubation or reversal of sedative drugs due to respiratory depression or unintended extubation of a patient during magnetic resonance imaging.

$^b P < .04$.

$^e P < .01$. 
A difference in the moderate events that required bag-valve mask ventilation or continuous positive airway pressure. There were 6 (4%) of these more significant events in the sedated patients as compared with no (0%) events in the non-sedated patients ($P < .01$). There were no patients in either period with severe events (intubation or reversal of sedation medication due to respiratory depression or accidental extubation).

The sedated patients also required increased respiratory support (oxygen or increased pressure support from nasal cannula, continuous positive airway pressure, or ventilator support) during the 12- to 24-hour period following sedation. Nine percent (12/132) of sedated patients required increased respiratory support as compared with 2% (3/151) in non-sedated patients ($P < .008$). In 26 patients, all imaged during the baseline period, this respiratory support information was not available.

**DISCUSSION**

Using the Plan Do Study Act process of QI, we successfully implemented obtaining non-sedated MRI studies in our NICU. The success of this project resulted from a multidisciplinary team working together to champion and troubleshoot all issues surrounding implementation of this project. Comprehensive education of all care providers in both NICU and radiology department was the first step in adapting this process in our unit, but ultimately the case and successful outcomes of the approach helped integrate non-sedated MRIs into the culture of our hospital. Monitoring of outcomes clinically relevant to this process has been important to the continued success of the project. Biases against the non-sedated process at the start of this project were largely centered around the length of time it would take in radiology if the patient continued to move during the study, as well as the resultant poor quality images that would occur because of motion artifact. The fewer incomplete studies and shorter duration for the patient to be away from the NICU while still maintaining quality imaging were surprising outcomes of this project. These results have led the radiology department to purchase neonatal and pediatric vacuum immobilizers to use with infants and children managed outside the NICU. In these cases, the preparation is completed in radiology. To date, the vacuum immobilizer has also been used for a small number of outpatients and has decreased the use of sedation for some patients who would have otherwise needed general anesthesia according to the sedation protocol in our hospital.

Additional needs identified for success after initial implementation included ready access of all tools in the NICU where the patient preparation is to occur. Success of non-sedated studies depends on the infant sleeping in the vacuum immobilizer and this is best accomplished by having all the patient preparations done before the baby’s feeding while still in the NICU and then immediately transporting the full, drowsy baby to radiology. Ensuring that all the patient preparations be done in the NICU mandated that all the MRI conditional supplies be immediately available to NICU nursing staff. Hospital administrative support was essential to purchase a MRI conditional monitor (Invivo, Orlando, Florida) that would remain in the NICU and also be the transport monitor for these patients. Additional supplies needed for every patient using the immobilizer were conveniently stocked in the NICU with the MRI monitor and included ear protection (MiniMuffs, Natus, San Carlos, California) and electrodes. Some patients require additional monitoring such as blood pressure, temperature (Fiberoptic temperature probe, Invivo, Orlando, Florida), or end-tidal CO$_2$ monitoring (Invivo, Orlando, Florida), and these supplies were also stocked immediately available in the NICU.

As the infant is prepared for the MRI in the NICU, there is supportive staff readily available to assist with the preparation, thus improving the coordination of coverage and care for the other patients assigned to this nurse. The time the patient is away from the controlled environment of the critical care unit is shorter, providing a benefit to both the patient and the NICU staff. This decreased time in radiology department also results in more efficient use of MRI scheduling time that allows more studies to be completed and potentially presents an overall revenue benefit for the hospital.

Initially, using the immobilizer stimulated some nursing concerns with specific patients. It is impossible to fully visualize the infant’s body in the immobilizer, just as it is when an infant is swaddled in a blanket. We have used the immobilizer successfully in patients with endotracheal tubes, tracheostomy tubes, umbilical catheters, and peripheral IVs in every location and have not found any adverse events associated with use of the immobilizer. Since patient visualization is limited during MRI scanning even without the immobilizer, taking the time to properly prepare the patient in the NICU is essential. Another concern was the need for flat, supine positioning while undergoing the MRI procedure. Since our patients are cared for in the supine position while in the NICU, in accordance with the American Academy of Pediatrics Back to Sleep recommendations, this was not felt to be a significant issue. Of interest, a few patients in the immobilizer did
have some mild bradycardia and desaturation events despite not receiving sedation. In 1 patient it seemed clearly related to the patient’s diagnosis, in 4 additional patients the exact reason was not clear with our monitoring tool, although there were no documented aspiration or reflux events. Although patient positioning in the immobilizer could have been a contributing factor in these events, sedation could have potentially posed a greater risk to these specific patients.

There were a small number of patients in whom completion of the study without sedation was not successful. In 2 events, this failure was attributed to suboptimal coordination of scheduling and communication between the radiology department and NICU providers related to enteral feeding of the patient. One patient had multiple fractures and providers were concerned about the potential for increased pain with the use of the immobilizer. In 2 additional patients, technical issues surrounding MRI were present so the immobilizer was not used. One patient required specific positioning in the scanner that the immobilizer prevented and the second patient required paralysis for cardiac imaging. In 4 events, the reasons for the use of sedation by the team were not entirely clear although one study was very prolonged (165 minutes) and it was likely that excessive movement led to the use of sedation. We can speculate that providers perhaps not as familiar with the nonsedation protocol were involved in the cases of the additional patients. Follow-up education needs must be ongoing in a large system with many providers.

The safety of this process is evident in reviewing the complications due to sedation itself. Although at times, alternative options are not available and sedation must be used, elimination of sedation in 94% of patients undergoing MRI is a clinically important benefit to the individual patient. Decreasing known risks of the respiratory depressive effects of sedative medications, and decreasing exposure to possible errors and the costs associated with medication administration, is a priceless benefit to the individual patient. Nearly eliminating these patient risks while maintaining quality imaging is a success we plan to maintain over time.

In a tertiary NICU, we have successfully implemented MRI without sedation through a change in culture in both the NICU and radiology department. Quality imaging and decreasing exposure to sedation risks for the patient are the clinical outcomes achieved. Benefits to radiology process flow and scheduling have also been demonstrated. Continued success with this process relies on ongoing education of providers and, most importantly, ongoing communication between the NICU and radiology staff.

REFERENCES


