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Changes in brain magnetic resonance imaging patterns for preterm infants after introduction of a magnetic resonance-compatible incubator coil system: 5-year experience at a single institution

Hyun-Hae Cho [a], In-One Kim [a,b,c,*], Jung-Eun Cheon [a,b,c], Young Hun Choi [a,b], So Mi Lee [a], Woo Sun Kim [a,b,c]

[a] Department of Radiology, Seoul National University Hospital, 101 Daehak-ro, Jongno-gu, Seoul, 110-744, Republic of Korea
[b] Department of Radiology, Seoul National University College of Medicine, 103 Daehak-ro, Jongno-gu, Seoul, 110-799, Republic of Korea
[c] Institute of Radiation Medicine, Seoul National University Medical Research Center, 103 Daehak-ro, Jongno-gu, Seoul, 110-799, Republic of Korea

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ABSTRACT

Objective: To evaluate the changes in using patterns of brain magnetic resonance imaging (MRI) in preterm infants after introduction of a MR-compatible incubator coil system.
Materials and methods: Brain MRIs for preterm infants with the MR-compatible incubator coil from March 2010 to July 2014 (n = 154, group A) were compared with MRIs prior to the introduction of the incubator coil, from March 2005 to February 2010 (n = 65, group B). Clinical data, MRI findings, acquisition time, and incidence of adverse events during the study were retrospectively reviewed. For the qualitative analysis of the examinations, the presence of motion artefact, spatial resolution, and overall image quality were assessed. Signal uniformity of each sequence was evaluated for a quantitative comparison.
Results: Comparing with group B, Group A was significantly younger (36 + 3 vs. 38 + 3 weeks, $p < 0.001$), had a significantly lower body weight (2006.6 and 2390.3 g respectively; $p < 0.001$) at the time of MRI, and had shorter time interval (54.3 ± 2.6 vs. 70.5 ± 4.4 days, $p = 0.002$) between birth and examination. Abnormal findings were noted more frequently in group A (n = 100, 65%) than in B (n = 24, 37%. $p = 0.001$) with a significantly higher incidence of diffusion restriction (n = 21, 13.6% vs. n = 4, 6.2%, $p = 0.034$). Mean image acquisition time was significantly shorter in group A (21.4 ± 4.5 vs. 25.4 ± 5.5 min, $p < 0.001$) with significant lower adverse events during MRI (n = 26, 40 vs. n = 6, 3.9%, $p < 0.001$). Group A exhibited significantly less motion artefact, better spatial resolution, and better overall image quality with decreased signal variation than group B (all $p < 0.001$).
Conclusion: Application of the MR-compatible incubator for preterm brain MRI evaluation is safer and provides more timely evaluation of preterm infants with better image quality.

1. Introduction

Brain magnetic resonance imaging (MRI) is a very useful tool for evaluating intracranial abnormalities and the neurodevelopmental status of preterm infants, as it provides more detailed information than cranial ultrasonography [1–3]. Brain MRI evaluations are routinely performed on preterm infants around term (equivalent to gestational age, around 40 weeks) to evaluate brain growth and maturation and detect the chronic sequelae such as hydrocephalus, brain atrophy or periventricular leukomalacia which could be resulted by previous adverse events including haemorrhage, infarction, hypoxic ischemic insult [3,4]. However, earlier MRI evaluations may be necessary for the timely diagnosis and management of preterm infants, especially those suspected to have hypoxic-ischemic brain injury or intracranial haemorrhage [1,5].

Although brain MRI for preterm infants is widely used [1,2,5], there are many safety issues in clinical practice due to unstable vital functions, including cardio-respiratory instability. Many preterm infants are intubated, need continuous ventilator support, and oxygen supplementation [4,6]. Continuous monitoring of their vital signs and the maintenance of adequate temperature and humidity are also required for safe examination [4,6]. These safety issues are of concern during the transportation of preterm infants from the neonatal intensive care unit (NICU) to the MRI suite. In addi-

* Corresponding author at: Department of Radiology, Seoul National University Children's Hospital, 101 Daehak-ro, Jongno-gu, Seoul, 110-769, Republic of Korea.
E-mail address: kimio@snu.ac.kr (I.-O. Kim).

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tion to these safety concerns, technical issues are raised for the use of a special coil system fitted to their small heads to improve the signal-to-noise ratio and image quality.

The MR-compatible incubator coil system overcomes many of the problems related to brain MRI of preterm infants; several previous studies have reported the usefulness of an MR-compatible incubator coil and improved image quality [6–10]. This study was designed to evaluate the changes in brain MRI patterns in preterm infants by comparing the clinical data, imaging findings, and image quality, of preterm infants who underwent brain MRI, before and after the introduction of the MR-compatible incubator coil system.

2. Material and methods

2.1. Patient selection

This retrospective study was approved by our institutional review board with a waiver for obtaining informed patient consent. In March 2010, the MR-compatible incubator (LMT, Lammers Medical Technology, Luebeck, Germany) was introduced in our center. Since then, all brain MRI evaluations of preterm infants in our NICU have been performed using the MR-compatible incubator with the built-in neonate head coil. This MR-compatible incubator includes a monitoring system for oxygen saturation and heart rate, a ventilator system with pressure control, and an MR-compatible gas supply system with a trolley for its transportation. The oral sedative agent, chloral hydrate (25 mg/kg, Pocral syrup®, Hanlim Pharm. Co., Korea) was used to prevent movement during imaging in almost all of the patients who could take it. For the rest of the patients, an intravenous injection of sedative agent midazolam (0.025 mg/kg, midazolam®, Bukwang Pharm. Co., Korea) or ketamine hydrochloric acid (0.5 mg/kg, Ketamine®, Huons Co., Korea) was used.

After application of the MR-compatible incubator, 154 brain MRI scans were performed on preterm infants between March 2010 and July 2014. These patients were included as the post-MR-compatible incubator group (group A). For comparison, we collected brain scans of preterm infants in the NICU prior to the application of the MR-compatible incubator for a duration similar to that of Group A, from March 2005 to July 2009. As a result, 65 brain MRI scans were included in the pre-MR-compatible incubator group (group B). Review of the medical records was performed to obtain gestational age and body weight at birth as well as age at the time of MRI. The officially reported MRI findings, including diffusion abnormalities, were recorded. Acquisition time of the MRI study as well as incidence and types of adverse events during imaging were also recorded.

2.2. MRI protocol

The routine brain MRI protocols used in our institution include the following: an axial T1-weighted spin-echo sequence; a T2-weighted turbo spine-echo sequence; a fluid-attenuation inversion recovery (FLAIR); a 3D magnetization-prepared rapid gradient-echo (MP–RAGE) sagittal sequence with axial and sagittal reformation; an axial diffusion-weighted images (DWI) with b values of 0 and 1000; an apparent diffusion coefficient (ADC) map and axial susceptibility-weighted imaging (SWI) sequence.

2.3. Qualitative analysis

To compare the image quality between Groups A and B, a subjective scoring system was devised to quantify and score the sequence performance on three imaging categories. Motion artefact was assessed using a 4-point scale (0 = absent; 1 = mild; 2 = moderate; and 3 = severe). Spatial resolution was scored using a 3-point scale (0 = limited; 1 = adequate; 2 = good). The overall image quality was assessed by using a 5-point scale (1 = unacceptable; 2 = poor; 3 = average or acceptable; 4 = good; and 5 = excellent or ideal).

We reviewed the axial imaging series in a random order and these series were scored on the three aforementioned categories. The reviewers evaluated all image series on a standard Picture archiving and communication system (PACS, Maroview; Marotech, Seoul, Korea) in stack mode; no restrictions were applied regarding time, window level setting adjustment, or ability to scroll through the images. The radiologists were blinded to imaging information that would reveal the examination date and to all clinical information, such as the patient's age and reason for evaluation.

Table 1
Comparison of the clinical data between the group A and B.

	Group A(n = 154)	Group B(n = 65)	*P*-value
Gestational age (weeks)	28^{+2}	28	$p > 0.05$
Birth weight (g)	1021.4	1027.1	$p > 0.05$
Gestational age at the time of MRI (weeks)	36^{+3}	38^{+3}	0.000
Time interval from birth to MRI (days)	54.3 ± 2.6	70.5 ± 4.4	0.002
Number of patient who underwent MRI exam within 1 week after the birth (n)	18 (11.7%)	1 (1.5%)	0.000
Body weight at MRI (g)	2006.6	2390.3	0.000
Number of abnormal findings on MRI (n)	100 (65%)	24 (37%)	0.000
Number of cases with diffusion restriction (n)	21 (13.6%)	4 (6.2%)	0.034
Mean acquisition time (min)	21.4 ± 4.5	25.4 ± 5.5	0.000
Event during study (n)	6 (3.9%)	26 (40%)	0.000

2.4. Quantitative analysis

Axial T2-weighted image at the level of thalamus was selected for quantitative analysis. For each study, 3 circular regions of interest (ROIs) of the same size (25 mm^2) were drawn on the images at the same level, corresponding to the periventricular white matter, grey matter (within thalamus), and air. The coefficients of variation were determined within each ROI. The coefficient of variation was defined by a ratio of the standard deviation (SD) to the mean value within the ROIs.

2.5. Statistical analysis

For the comparison between the two groups, independent samples *t*-tests were conducted using the commercially available statistics software SPSS, version 20.0 (SPSS Inc., Chicago, IL, USA) was used. A *p*-value of less than 0.05 was considered statistically significant.

3. Results

Table 1 summarizes the clinical data of groups A and B. In this study, 154 brain scans (Group A) were performed after the installation (77 male and 77 female; mean gestational age, 28^{+2} weeks; mean birth weight, 1021.4 g) and 65 (Group B) were performed prior to the MR-compatible incubator application (41 male and 24 female; mean gestational age, 28 weeks; mean birth weight, 1027.1 g). The mean gestational age and birth weight did not significantly differ between the two groups ($p > 0.05$).

Postmenstrual age at the time of the MRI study was about 36 + 3 weeks (range 27^{+2}–46^{+4} weeks) for group A and 38^{+3} weeks (range 32^{+4}–47^{+5} weeks) for group B. Group A was significantly younger than group B ($p < 0.001$). The mean body weight at the time of the MRI was about 2006.6 g (range 620–4980 g) in group A and 2390.3 g (range 1650–4140 g) in group B, which was significantly different