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Original contribution

Brain magnetic resonance imaging using a customized vacuum shape-keeping immobilizer without sedation in preterm infants

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ABSTRACT

Objective: To validate that a customized vacuum shape-keeping immobilizer (VaSKI) can be used in preterm infants without sedation.

Methods: Preterm infants who underwent brain MRI from February 2008 to March 2017 at Osaka Medical College Hospital were retrospectively assigned to the sedation group (February 2008 to September 2013, n = 64) or VaSKI group (October 2013 to November 2016, n = 64). The examination success rates and diagnosable case classification were determined by pediatricians and radiologists. We compared the time from preparation to examination completion between the groups. Furthermore, we measured the time from immobilization to sleep in the preterm infants in the VaSKI group.

Results: The examination success rate was 90.6% in both of the groups. The median (interquartile range) times of preparation were 24.0 (15.3) and 18.0 (13.0) min in the sedation and VaSKI groups, respectively. In the VaSKI group, the time from immobilization to sleep was within 3 min in 87.1% of the preterm infants.

Conclusions: The brain MRI examination success rates and motion artifact suppression effects were equivalent between the groups, whereas the time from preparation to examination completion was much shorter in the VaSKI group. Therefore, the VaSKI was validated as an immobilizer for MRI in preterm infants without using sedation.

1. Introduction

Magnetic resonance imaging (MRI) is increasingly available as a diagnostic and prognostic tool for preterm infants. MRI is safer than radiographic techniques because it does not use ionizing radiation. In addition, because of the sensitivity of MRI to changes in gray and white matter, it is particularly useful for brain imaging [1]. In our hospital, brain MRI is required to check for complications with potentially serious effects, such as brain damage and intracranial bleeding, before preterm infants are discharged from the neonatal intensive care unit (NICU) [2–4].

However, optimal MRI examinations require patients to remain still to avoid motion artifacts [5,6]. Usually, because of the inability of preterm infants to remain still and understand instructions such as “Please do not move.”, they require sedation.

However, sedatives carry some risks [7–12], whereas several studies [13–19] reported that sedation is not required for MRI of preterm infants. MedVac (CFI Medical Solutions/Contour Fabrications, Fenton, MI, USA) removes air from the immobilizer device with a manual pump and has an additional belt for immobilization. Windram et al. [14] reported that the feed and sleep technique induced sleep by keeping a preterm infant hungry for several hours and then letting them drink milk.

In this study, we used a customized vacuum shape-keeping immobilizer (VaSKI) to prevent head and body movement in preterm infants without using sedation. The device as VaSKI used was customized Magic Gips (Nikko Fines Industries Co., LTD., Tokyo, Japan). The VaSKI can take a shape by quickly deflating air inside the device using a medical aspirator. Furthermore, it was confirmed that preterm infants slept in a state of not being full stomach when using the VaSKI. We speculated that the VaSKI might have the same motion artifact suppressing effects as sedatives. Furthermore, we hypothesized that we could reduce the time between preparation and examinations because there would be no risk of sedation [7–12] and no need to observe

Abbreviations: VaSKI, vacuum shape-keeping immobilizer; MRI, magnetic resonance imaging; NICU, neonatal intensive care unit

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preterm infants [20,21]. In this study, we compared the 1) examination success rate, 2) time of preparation between the sedation group and VaSKI group and 3) time from immobilization to sleep in the VaSKI groups. We verified that the VaSKI can be used for MRI of preterm infants without sedation.

2. Materials and methods

2.1. Subjects

The subjects in this retrospective study were preterm infants who weighted < 3 kg and who had been admitted to the NICU between February 2008 and November 2016. We investigated all the cases of sedation (64 preterm infants from February 2008 to September 2013) and VaSKI use (64 preterm infants from October 2013 to November 2016). The infants were examined by MRI after voluntary informed consent was obtained from their parents within the first week after NICU admission.

The VaSKI device was a customized Magic Gips (Nikko Fines Industries Co., LTD., Tokyo, Japan). The size of the VaSKI, the number of divisions inside the VaSKI, and the number of filled beads in the VaSKI can be customized while ordering.

Tzarouchi et al. [22] reported a head circumference of 273 ± 21 mm at birth. Meldere et al. [23] reported an abdominal circumference of approximately 273 mm when body weight reached 2500 g. From these reports, the width of the head area was customized to 300 mm to cover the ears of preterm infants. The width of the body area was customized to 600 mm to enable immobilization of the body along with the arms of preterm infants and amount of beads inside VaSKI (Fig. 1). The area within the VaSKI device was divided into two portions to encompass the head and body (Fig. 1). Since these portions are not physically separated, beads can move between the insides when the device is inflated. Thus, the thickness of the VaSKI can be changed depending on the preterm infant's physical constitution.

MRI was performed using a 1.5-Tesla MR system (GE Healthcare, Milwaukee, WI, USA) with an 8-channel high-resolution head coil. The administered sedative was triclofos sodium. An aspirator was used to remove air in the VaSKI. To reduce the noise heard by the preterm infants, a clay–polystyrene composite material was formed into a disk shape approximately 2 cm in diameter and placed over their ears.

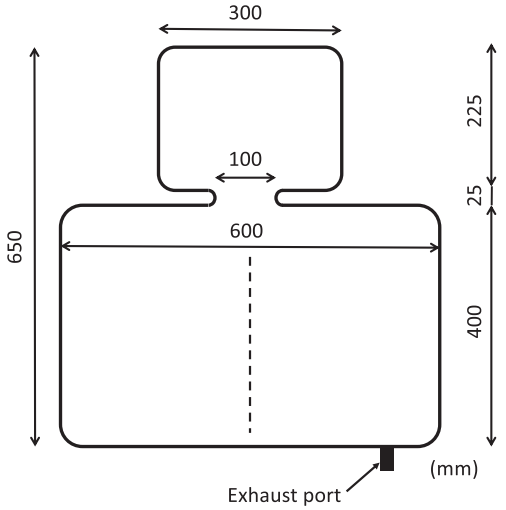

Fig. 1. The dimensions of the customized vacuum shape-keeping immobilizer (VaSKI) are shown. The upper part immobilizes the head, and the lower part immobilizes the trunk. After adjusting the shape, when the inside air is removed through the exhaust port, the VaSKI hardens and does not collapse. Pinching the side of the exhaust port allows air to flow in, which softens the VaSKI. The dotted line indicates the inside partition wall of the body part.

The VaSKI was spread out on the examination bed (Fig. 2a), and a bath towel was placed over the device.

We laid each infant on the bath towel (Fig. 2b). An SpO_2 probe was attached to the foot to monitor blood oxygen (Fig. 2c). Immobilization of the preterm infants was performed by two or more persons. We wrapped the arms and body of each infant using a towel, positioning their arms along the trunk during immobilization. We placed paper clay over the infants' ears and inserted a wedge-shaped sponge between the headrest and the VaSKI. One person softly pressed the ear of the infant from above the VaSKI (Fig. 2d), and another person softly wrapped the infant's body by lifting both ends of the VaSKI. An adapter attached to the tube of the aspirator was inserted into the exhaust port (Fig. 2e). Air was aspirated until the VaSKI hardened, thus, completing the immobilization procedure (Fig. 2f). To stop the immobilization, the VaSKI can be softened by pinching the side of the exhaust port.

The duration of the actual MRI sequence was 25 min after preparation. The following sequence parameters were used:

For T1-weighted imaging [T1WI]

Axial and sagittal slices covering the whole brain; fast spin echo sequence [FSE]; no parallel imaging; echo time [TE], 9 ms; repetition time [TR], 600 ms; echo train length [ETL], 3; field of view [FOV], 220 mm; spatial resolution, 0.69 × 0.98 × 5 mm^3 (matrix 320 × 224, slice thickness, 5 mm; slice gap, 1 mm; # of slices, 20).

For T2-weighted imaging [T2WI]

Axial slice covering the whole brain; FSE; no parallel imaging; TE, 85 ms; TR, 4050 ms; ETL, 16; FOV, 220 mm; spatial resolution, 0.69 × 0.98 × 5 mm^3 (matrix 320 × 224; slice thickness, 5 mm; slice gap, 1 mm; # of slices, 20).

For fluid-attenuated inversion recovery [FLAIR]

Axial and coronal slices covering the whole brain; FSE; no parallel imaging; TE, 115 ms; TR, 100,000 ms; inversion time, 2200 ms; ETL, 16; FOV, 220 mm; spatial resolution, 0.86 × 0.98 × 5 mm^3 (matrix 256 × 224; slice thickness, 5 mm; slice gap, 1 mm; # of slices, 20).

For diffusion-weighted imaging [DWI]

Axial slice covering the whole brain; echo planner imaging [EPI] spin echo type; parallel imaging factor, 2; TE, 68 ms; TR, 5400 ms; b value, 2200 ms; FOV, 240 mm; spatial resolution, 0.86 × 0.98 × 3 mm^3 (matrix 128 × 192, rectangular, 80%; slice thickness, 3 mm; slice gap, 0 mm; # of slices, 50).

In addition, the imaging techniques and parameters were not changed during the study period.

2.2. Measurements

A radiologist and pediatrician who were blinded to the group assignment rated each examination method as follows: “Excellent,” diagnosable case without motion artifacts; “Acceptable,” diagnosable case with motion artifacts; “Unacceptable,” un-diagnosable case with motion artifacts; “Cancelled,” examination cancelled or not completed. If the scores of the raters differed, the lower assessment was accepted. “Excellent” and “Acceptable” were defined as successful examinations, and “Unacceptable” and “Cancelled” were defined as unsuccessful examinations. When repositioning was necessary due to an infant's awakening, it was categorized as “Excellent (repositioning)” or “Acceptable (repositioning)”. The percentages other than “Unacceptable” and “Cancel” were expressed as success rates both of the groups.

The time of preparation was defined as the time from the NICU ward contact to MRI examination. The preterm infants in the sedation group