# A System for Attenuating and Monitoring Acoustic Noise during Infant MRI Studies

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**Target Audience:** Researchers and clinicians using MRI in infant populations

**Purpose:** MR imaging is a commonly used non-invasive pediatric research tool that provides critical insight into the neurodevelopment of children with developmental disabilities, such as Autism Spectrum Disorder. However, one disadvantage of MRI is the intense acoustic noise generated by the MR scanner. With sound levels reaching over 100 dBA, hearing protection is critical to ensure the comfort and safety of infant participants. Unfortunately, effectively reducing noise exposure to infants poses unique challenges that are not readily met by commercially available hearing protection devices (HPDs), such as earplugs, earmuffs, or headphones. These HPDs all require proper initial placement on the patient for effective noise reduction, and furthermore, none of these devices are equipped with a mechanism to gauge if proper placement is achieved and maintained throughout a scan session. Here we provide a solution by developing and testing a system consisting of 1) a patient-independent, sound attenuating hood and 2) a set of pediatric sound attenuating headphones with built-in MR-safe optical microphones for continuous monitoring of in-ear sound level during an MRI scan.

**Method:**
***Sound attenuating hood construction and placement:*** The hood was constructed using two layers of commercial noise absorbing materials wrapped on a core made of 20" OD PVC tube with vinyl covering for durability. The outer layer was made of 1" think low density humidity resistant polyurethane foam, with a 75% noise absorption and vibration damping rating. The inner layer was made of 1 3/8" thick melamine foam with a vinyl barrier, an 85% noise absorption rating and 28 dB noise barrier rating. All of these materials are MRI compatible. This combination of layers can, in theory, reduce penetrating noise by 34 dB and reduce the noise reflected through unavoidable openings by 8 dB. The front part of the PVC core was cut in half to allow for positioning over the patient table (Figure 1). The end board (Fig. 1d) and the circular segment (Fig. 1b) were covered with sound absorption materials to stop noise leakage from these sites. The hood slides into the scanner bore from the back of the scanner, leaving a 16.5" diameter space inside for the RF coil and the infant patient. When the patient table is inside the scanner bore, the front edges of the hood (Fig. 1a) and the circle segment (Fig. 1b) lie firmly against the patient table to prevent direct coupling of scanner noise inside the chamber through gaps. To ensure comfortable temperature and humidity levels inside the hood, a quiet non-MR compatible duct fan, located outside the scanner room, was used to force air circulation through a 6" non-magnetic duct attached to a 6" OD plastic tube on the back of the hood (Fig. 1c), creating about 0.3 ft/s air flow inside the scanner bore.

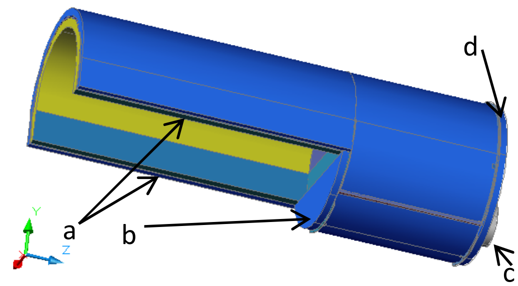


Fig 1. 3D model of the 5' long pediatric sound attenuating hood. a. edge for patient table seal; b. circular segment seal for front end of patient table; c. opening for the hose to a duct fan; d. noise blocking end board.

***Sound attenuating headphones:*** Optical microphones were affixed inside the left and right earpieces of pediatric sound attenuating headphones, to allow for continuous realtime monitoring of in-ear sound levels.

***Realtime sound level assessment:*** Sound attenuating properties of the acoustic hood and headphones were tested during phantom scans and during 3 infant scans conducted on a Siemens Magnetom Trio MR scanner with a 32 channel head coil. Localizer, 3D T2w (TR=3.2s, TE=561ms, 1mm isotropic), resting state fMRI (TR=720ms, TE=33ms, 2.5mm isotropic), and multiband DTI scans (b=700, TR=6.2s, TE=74ms, 2.0mm isotropic) were acquired on a phantom and on some of the infants. For the phantoms scans, the microphones were fixed on the surface of a spherical water phantom. The hood and headphones were tested separately and in combination, as listed in Table 1. All infants were scanned during natural sleep inside the hood. Headphones were placed over the infant's ears and secured with foam inside the RF coil. White noise, gradually increased to 65 dBA was played through the headphones to mask the start and end of the scanner noise. Labview was used to display and record in-ear sound levels.

**Result:** Table 1 shows the cumulative results of different test conditions for each scan sequence for both the phantom and infant scans. Baseline noise of each sequence (no attenuation) ranged from 85.4 dBA to 89.2 dBA.

***Phantom results:*** The acoustic hood attenuated 13~16 dBA; headphones attenuated 18~22 dBA. Both devices used in conjunction attenuated 23~30 dBA. The highest recorded average sound level when using both devices was 62.5 dBA.

***Infants results:*** Both sound attenuating devices were always used. No data were collected for each device separately. Attenuation of 20~24 dBA was recorded with participants experiencing average in-ear sound levels of 62~67 dBA. Spikes in noise level up to 74 dBA were observed when infant movement disrupted the seal between the headphones and the head. Our system quickly detected these spikes allowing the scan to be stopped within seconds, minimizing infant exposure to elevated sound level.

Table 1. Max Recorded dBA in 1 second LAeq, showing average level ± variation range. (P) indicates phantom data.

| Condition | Scan Sequence: Localizer | T2w | RS fMRI | B=700 DTI |
|---|---|---|---|---|
| No Attenuation(P) | 85.4±0.5 | 86.6±6.0 | 89.2±0.1 | 86.6±0.3 |
| Headphones Only (P) | 67.0±0.5 | 68.3±6.0 | 67.1±0.1 | 66.7±0.3 |
| Hood Only (P) | 69.0±0.5 | 73.9±6.0 | 73.0±0.1 | 71.0±0.3 |
| Headphones+Hood (P) | 62.5±0.5 | 61.9±6.0 | 59.4±0.1 | 60.7±0.3 |
| Infant scans | 63.0±1.0 | 62.5±6.5 | 65.0±1.0 | 66.5±1.5 |

**Discussion:** Our acoustic hood and headphones reduce infant in-ear peak noise level below 70 dBA, the limit recommended by NICU standards.[1] By attenuating and monitoring sound levels, our system minimizes noise exposure and may reduce the likelihood that infants will wake up during a scan, thereby increasing the rate of successful data acquisition and parent satisfaction.

**Conclusion:** The sound attenuation system described herein can be used by clinicians and researchers to effectively limit and monitor noise exposure during an MRI scan. This system attenuates noise levels to lower than 70 dBA, the recommended NICU standard, and provides several improvements over existing HPDs that rely on proper placement on the patient for effective sound attenuation. First, real-time monitoring of in-ear sound levels allows headphone displacement to be detected within seconds, limiting infant exposure to elevated sound levels. Second, the acoustic hood, which does not depend on proper patient placement for noise reduction, maintains 13-16 dBA of sound attenuation in the event of headphone displacement.

1. R. D. White, Recommended Standards for Newborn ICU Design. Jan. 26, 2012. http://www3.nd.edu/~nicudes/stan%2027.html, updated Sept. 18, 2012