A novel acoustic quiet coil for neonatal MRI system

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Introduction:

Acoustic exposure is of particular concern to term and preterm neonates due to the potential to elicit autonomic instability and is believed to have direct and indirect detrimental effects on growth and neurologic development.[1,2] For these reasons, ambient acoustic noise in the Neonatal Intensive Care Unit (NICU) is typically limited to 65 dBA.[3] Unfortunately, even with hearing protection, babies in a whole-body scanner are routinely exposed to sound pressure levels in excess of 80 dBA. In addition, scanner acoustic noise and transient sounds can cause startle reflexes in the neonates thereby introducing undesired motion artifacts degrading overall image quality.

A dedicated 1.5T NICU MR scanner developed at our institution has an acoustic output that is inherently 11 dBA quieter than a conventional 1.5T scanner.[4] This 11 dBA reduction in sound pressure level is a direct consequence of the smaller gradient coil in the scanner. The inherent acoustic output of the NICU scanner in conjunction with passive hearing protection (i.e. earplugs and soft-shell earmuffs) is believed to reduce acoustic exposure to neonates below ambient limit. However, difficulty associated with proper device fitting and inability of the neonate to articulate the effectiveness of noise reduction creates a measure of doubt in true attenuation. Thus, the only guaranteed way to reduce noise exposure for a neonate undergoing MRI is to perform scanning more quietly.

A novel approach to reduce acoustic noise exposure to NICU patients is presented in this abstract. The approach uses acoustic noise dampening material for the construction of a transmit/receive birdcage imaging coil. Instead of a standard rigid plastic structure to support the coil components, the quiet coil design employs a former made from layers of mass loaded vinyl (MLV). The material acoustic properties in conjunction with minimal use of rigid components promotes attenuating of both radiated and structure coupled acoustic vibrations reducing the acoustic noise observed inside the bore. The acoustical benefits of the quiet coil were investigated using a sound level meter to measure sound pressure levels at isocenter compared to a conventional coil.

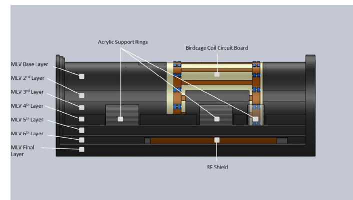

Figure 1: *Acoustic quiet coil sectional view*

Materials and Methods:

A 16-leg high-pass shielded birdcage coil with an inner diameter of 18 cm was constructed with an integrated custom-built acoustic abatement former. The former was constructed using a MVL (Acoustiblok Inc., Fl., USA) layered substrate approach with three internal acrylic rings for mechanical support. A layered sectional view of the quiet coil is shown in Figure 1. The birdcage coil was etched onto 4 oz. copper clad FR4 board (0.25 mm thick) and secured to the first layer of the former. The coil was tuned and matched to proton frequency at 63.8MHz. A radiofrequency shield was constructed from copper wire cloth secured to a 0.75 mm thick acrylic backing for shape retention and placed under the outermost MLV layer.

Acoustic characterization and image quality of the quiet coil were performed on a pre-clinical 1.5T NICU MRI scanner. Quiet coil performance in acoustic response and image quality was benchmarked to a standard clinical 18 cm birdcage coil in the same scanner. Acoustic characterization parameters of sound pressure level (SPL) and frequency response, in units of dBA on a one-third octave band over 50-20,000 Hz frequency range, were measured at isocenter for six standard clinical MR imaging protocols using a Brüel & Kjær model 2250 sound level meter with Type 4192 omnidirectional microphone (Brüel & Kjær Sound & Vibration Measurement A/S, Denmark). Body coil comparison of SPLs and frequency response per acquisition sequence are depicted in Table 1 and Figure 2, respectively. Image quality was evaluated using a QA phantom to measure geometric reproducibility and signal to noise ratio. Phantom images were acquired using a T1-weighted axial acquisition with a TR: 800 msec, a TE: 22 msec, a flip angle of 90°, a FOV of 20 cm x 20 cm, and a slice thickness of 3 mm.

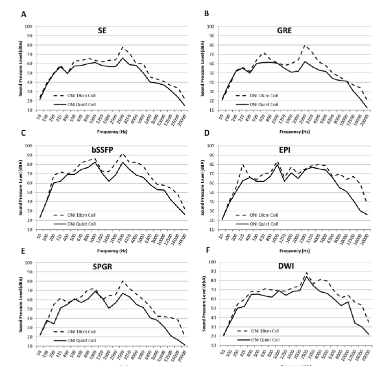

Figure 2: *Frequency response measurements in dBA.*

Results:

Sound pressure level values measured for the quiet coil during each of the six MR acquisitions were consistently lower than those of the conventional system body coil. Scanner acoustic output located at isocenter was, on average, approximately 9 dBA (range 6-10 dBA) quieter with the quiet coil. The highest sound pressure level measured with conventional body coil was 96.5 dBA, whereas, the highest measured for the quiet coil was 86 dBA. Acoustic frequency response comparisons show similar harmonic structure between the coils per sequence with the amplitude consistently lower for the acoustic quiet coil, by as much as 20 dBA.

Phantom T1-weighted axial images for the conventional and acoustic quiet coil presented in Figure 3 demonstrate comparable spatial resolution and geometric reproducibility. The signal to noise ratios measured for the acoustic quiet coil was comparable to those of the conventional body coil (S/N = 112.6 for quiet coil, S/N=118 for conventional coil).

Coil/Sequence	SE	GRE	bSSFP	EPI	SPGR	DWI	Average
NICU 18 cm Coil	80.2	83.1	96.4	91.9	85.7	90.9	91.1
NICU Quiet Coil	70.4	73.0	86.1	83.2	76.0	85.1	82.2

bSSFP balanced steady state free precession, *DWI* diffusion-weighted imaging, *EPI* echo planar imaging, *GRE* gradient recalled echo, *SE* spin echo, *SPGR* spoiled gradient echo

Table 1: *SPLs measurements in dBA*

Conclusion:

We have shown that a body coil that is built on layers of acoustic deadening material such as MLV can reduce the sound pressure levels in a small-bore NICU scanner by an average of 9 dBA. This reduction in combination with the inherent 11 dBA reduction obtained with a smaller scanner vs. a conventional whole-body scanner, means that neonates can be imaged with an average of 20 dBA less acoustic noise. Note that this approach does not require any modification or restriction in imaging pulse sequences. Note also, that the approach may find utility in reducing the acoustic noise levels of conventional MR scanners.

The acoustic quiet coil is a robust way of attenuating noise during MRI examinations that does not require any changes to imaging pulse sequences, is patient-independent, and is synergistic with other attenuation practices i.e. passive hearing protection. Reducing exposure to noise increases the probability that the MR exam can be completed without sedation and with fewer motion artifacts. The ability to perform MRI without sedation is particular important with growing evidence that sedation in the neonatal population has risk.[5]

References:

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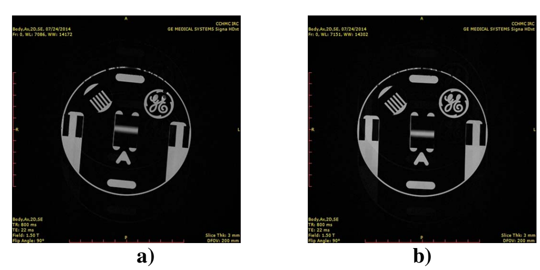

a) **b)**

Figure 3: *Axial images of DQA phantom a) conventional body coil b) acoustic quiet coil.*