Safety Evaluation of a 3T Neonate Head Coil using Numerical Calculations

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INTRODUCTION: In MR imaging, it is important to limit radiofrequency (RF) energy to safe levels. For this reason, the International Electrotechnical Commission (IEC) has devised limits on specific absorption rate (SAR) given as average and maximum SAR over any 10g region of tissue in the human body (1). This has led to the numerical evaluation of SAR from data calculated for parts of the human body, such as an adult head (2) and knee (3). In this work, we perform a safety evaluation of a new 3T neonate head coil with a neonate-sized head model using the finite difference time domain (FDTD) method. We calculate the maximum time-average input power for neonate head imaging without exceeding IEC limits on SAR.

METHOD: The 3T neonate head coil having an 18.57 cm inner diameter (ID) and 15.06 cm length is an integration of 12 rung high pass birdcage resonating at the ^{1}H frequency of 127.753MHz (3T) with a passive end cap (design by Advanced Imaging Research, Inc., Cleveland, Ohio). The superior and inferior end rings each contain twelve 27 pF tuning capacitors. The coil model was assembled and driven with four port quadrature feed, legs #2, 5, 8, and 11, having voltage sources of 1V in the superior end ring. The value of end ring capacitors (27 pF) was determined by iteratively tuning so that mode 1 resonated at the desired frequency. The neonate head model having 54 different tissue types, 1.5 mm resolution and matrix size of 187×190×202 was generated by scaling the head and shoulders of the 2mm-resolution 6-y.o. boy of the virtual family model (4) to 75% original size. The overall coil geometry and neonate head model is shown in Fig. 1. All simulation work was performed using commercially available software (xFDTD; Remcom, Inc; State College, PA) and analysis of the results was performed in Matlab (The MathWorks, Inc., Natick, MA). All simulation results of electromagnetic fields were normalized initially so that $|B_1^+| = 4\mu T$ at the coil center.

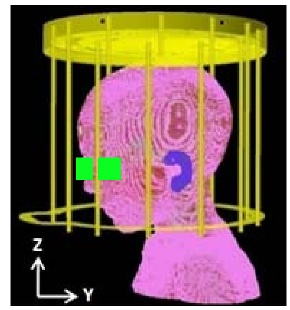

Figure 1 Geometry of head coil and head model. (Green blind to maintain anonymity).

RESULTS AND DISCUSSION: Based on SAR limits of IEC, the calculated maximum dissipated power to avoid exceeding the IEC limits on local SAR in a head (≤ 10 W/kg in any 10g region) (maximum dissipated power for limits of local SAR in Table 1) was 6.27 W. And the maximum dissipated power to avoid exceeding the IEC limits of the head average SAR (≤ 3.2 W/kg), (maximum dissipated power for limits of average SAR in Table 1) was 4.63 W. So the maximum time-average dissipated power considering both local and average SAR and a safety factor of 2 is approximately 2.3 W. Fig. 2 shows the calculated distributions of the B_1^+ field, the unaveraged SAR, and the 10g-SAR within the neonate head model. The methods and results presented here can provide useful information for designing various experiments with a neonate head imaging coil without exceeding the IEC suggested limits for local or average SAR levels.

REFERENCES
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Table 1 Calculated average and maximum SAR after normalization and the maximum allowed input power for local and average SAR within the neonate head model.

Mean $|B_1^+|$ in transverse slice (4µT at center)	3.60 µT
Averaged-SAR (4µT at center)	1.42 W/kg
Max-SAR-10g (4µT at center)	3.27 W/kg
Maximum dissipated power under limits of 10g SAR	6.27 W
Maximum dissipated power under limits of head average SAR	4.63 W

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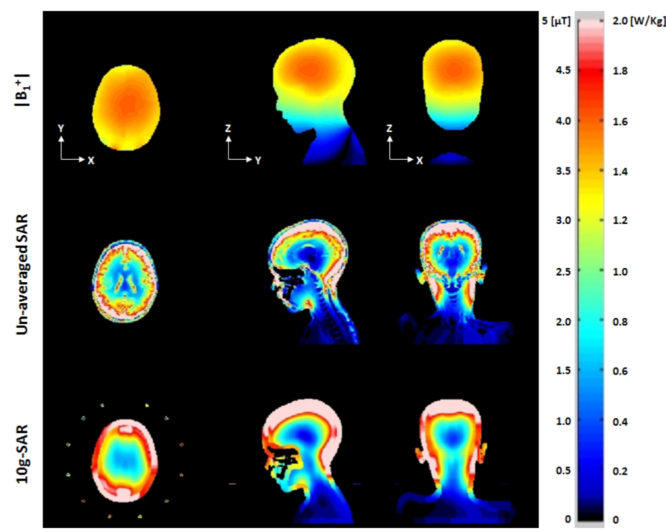

Figure 2 Distributions of B_1^+ (top row), unaveraged SAR (middle row), and 10g SAR (bottom row) after normalization on the central transverse (first column), sagittal (second column) and coronal (third column) slices of the neonate head model.