RF Safety Evaluation for Neonatal MRI at 3T

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Target Audience Researchers and clinicians interested in MR procedures involving neonates.

Purpose There is increasing interest in the use of MR procedures to image neonates. The algorithms used by MR scanner manufacturers to control specific absorption rate (SAR) are usually based on adult models and there is some uncertainty regarding safe exposure of neonatal patients. In this work we simulate exposure of a neonate to the RF field produced by a 3T generic birdcage coil using a commercial software package to solve the Maxwell equations by a time domain finite integration numerical technique. Two positions of the neonate relative to the coil - head and heart centred (see Figure 1)– are considered and the resulting whole body averaged and local 10g averaged SARs are predicted.

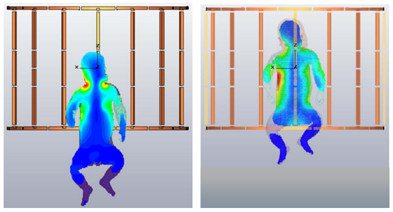

Figure 1: Neonate head-centred (left) and heart-centred (right) in birdcage body coil. Colour represents local SAR_{10g} values (relative scale) in coronal plane containing the maximum for each case.

Methods A generic, shielded 16 rung band-pass birdcage body transmit coil, 0.4 m long, 0.3 m radius, and tuned to 127 MHz and driven in quadrature, together with its shield (length 1m, radius 0.339m) were simulated within CST Microwave Studio® 2013. A voxel model simulating a newborn neonate of mass 3.02 kg (32nd percentile for females, 25th percentile for males) and length 0.513 m (88th percentile for females, 77th for males)[3] was created starting with an existing model of a deceased 8 week old female baby length 0.57 m and mass 4.2 kg (24 hours post mortem)[1,2] developed at Helmholtz Zentrum München, German Research Centre for Environmetal Health and acquired under a licensing agreement. This was achieved by scaling the original voxels (0.85 mm x 0.85 mm x 4 mm) to 0.76 mm x 0.76 mm x 3.6 mm. The voxel model was segmented into 31 tissue types. Neonatal permittivity and conductivity values used in this study were derived using a similar approach to that reported by Dimbylow et al[4] in which four classes of tissues were considered - bone, skin, soft tissues, and tissues whose properties did not change with age (blood, cerebrospinal fluid, gallbladder, and vitreous humor). Neonatal values were estimated using the ratios of newborn values/adult values from data on rats at 130 MHz[5] as multipliers of adult dielectric properties[6] (see table). An adult male (DUKE 2mm voxel model (ITIS Foundation, Zurich)) positioned heart centred in the same coil was also simulated to obtain whole body averaged and local 10 g averaged SARs for comparison. For practical comparison the SAR values were scaled to match the duty cycle used in a Philips 3T Achieva scanner when run at the SAR limits for body scanning (where 10 W/kg local 10 g torso average is the limiting factor) and head scanning (where the 3.2 W/kg head average value is the limiting factor). In order to do this the simulated fields were scaled so that B_1^+ averaged over a 5cm diameter region at the centre of the isocentre plane was equal to 13.5μT, which models the scanner set-up process during automated power scaling when a subject is present.

	bone	skin	brain	muscle	salivary gland	liver and spleen	tongue	kidney	all other tissues
Permittivity ratio (Neonatal/adult)	2.18	1.89	1.45	1.39	1.36	1.14	1.12	1.34	1.28
Conductivity ratio (Neonatal/adult)	3.9	2.1	1.7	1.7	1.7	1.3	1.3	1.5	1.5

Table 1: Ratios of neonatal to adult conductivity and permittivity

	Scanner set at 100% body scanning limit				Scanner set at 100% 'head' scanning limit			
	Whole body averaged SAR	Max local SAR_{10g} – torso	Max local SAR_{10g} – head	Max local SAR_{10g} – extremities	Whole body averaged SAR	Max local SAR_{10g} – torso	Max local SAR_{10g} – head	Max local SAR_{10g} – extremities
heart-centred	0.50	2.54	2.23	2.53	1.05	5.29	4.65	4.78
head-centred	0.34	2.28	2.34	2.34	0.70	4.77	4.89	3.21
adult heart-centred	1.24	11.4	3.79	18.1				

Table 2: Predicted whole body averaged SAR (W/kg) and maximum local 10g SAR (W/kg) for head- and heart-centred neonates and heart-centred adult

Results SAR estimates for 3 different models for two different scenarios ('body' limited and 'head' limited) are shown in Table 2.

Discussion & Conclusion These simulations indicate that the RF exposure of a neonate positioned head- or heart- centred in a generic body birdcage coil driven at the SAR limit of a 3 T scanner set up for body scanning results in a whole body averaged SAR of up to 0.5 W/kg, and a local maximum SAR_{10g} of up to 2.5 W/kg (approximately 30% and 20% of the respective values predicted for an adult subject). When the scanner is set up for head scanning, the neonate's whole body averaged SAR and local maximum SAR_{10g} values are predicted to be up to up to 1.05 W/kg and 4.78 W/kg respectively. Note that in both cases the body coil is used as the transmitter; however if a head coil is used for reception then this particular scanner adjusts SAR values assuming an adult subject whose body is less exposed, leading to actually elevated SAR in the baby. Neonates are often scanned in receiver coils designed for adult use and so such manufacturer specific effects must be taken into account. Nevertheless our finding is that exposure is still well within safety limits in this case. Results for the adult simulation are also in good agreement with those provided by the scanner software: this predicts 10W/kg local 10g SAR in the torso and 0.88W/kg global averaged SAR for the body limited scan, while we predicted 11.4W/kg and 1.24W/kg respectively. A further observation is that the predicted ratio 'maximum local SAR10g: whole body averaged SAR' for the adult is approximately 15 whereas that for the neonate is 5 – 7. In conclusion, our calculations show that when a scanner is limited by algorithms based on SAR values within adult subjects, exposure of a neonate is conservative from a safety point of view.

References 1. Veit R, Zankl M, Petoussi N, et al GSF-Bericht No. 3/89. Gesellschaft für Strahlen- und Umweltforschung mbH, München, Germany, 1989. 2. Zankl M, Veit R, Williams G, et al. Radiat Environ Biophys 1988;27:153-164. 3. WHO Anthro for personal computers, version 3.2.2, 2011: Software for assessing growth and development of the world's children. World Health Organisation http://www.who.int/childgrowth/software/en/ Accessed November 2013. 4. Dimbylow P, Bolch W, Lee C. Phys Med Biol 2010;55(5):1519-1530. 5. Peyman A, Rezazadeh A, Gabriel C Phys Med Biol 2001;46(6):1617-1629. 6. Gabriel S, Lau RW, Gabriel C. Phys Med Biol 1996;41:2271-2293.