Numerical simulations of RF heating for infants within MR body coil

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TARGET AUDIENCE: Audience interested in RF safety, especially for neonatal/pediatric imaging.

PURPOSE: MRI is useful for neonatal/pediatric imaging since no ionizing radiation is used. Nevertheless, MRI has unique safety concerns: RF power deposition and the resultant tissue heating. Numerical simulations have been widely applied to investigate specific absorption rate (SAR) and tissue temperature rise[1-5]. However, most work published is focused on adults and only a few showed results for infants[6]. Infants' (especially neonates) thermoregulation is not as developed as adults, and may be further impaired under unique scan conditions (sedation, swaddling). Furthermore, there are no special considerations in regulatory limits for these patients. This work investigates SAR and temperature rise in infants due to RF heating.

METHODS: FDTD simulations used SEMCAD X (v14.8, SPEAG), an infant model[7] (8 week old, 4.2 kg, HMGU, Neuherberg, Germany) and a 16-rung generic birdcage quadrature body coil model (750mm diameter, 490mm length, ideal feed[2])[1,5]. EM and thermo simulations (Pennes Bioheat) performed at three different imaging landmarks (head, torso, lower extremities; Fig. 1) and at 64MHz and 128MHz. Permittivity, electric conductivity, thermal conductivity, and specific heat capacity were calculated based on adult tissue parameters and increased water content for young population[6,8]. Metabolic heat generation rate and basal blood perfusion rate were set at 180% of adult tissue values[9]. Constant (basal) blood perfusion generates conservative tissue heating estimates since infant thermoregulation is not as developed as adults and may be further impaired by sedation[10,11] . Two different skin thermal boundary conditions are considered: normal (ambient 25°C and 6W/m^2/K heat transfer[5]), and swaddling (ambient 28°C, no heat transfer, nominal heat flux 0.1W/m^2).

RESULTS: All results are shown with 2W/kg whole body SAR exposure. 64 MHz SAR averaged over 10g tissue shown in Fig.1. Peak local SAR is highest for lower extremity imaging (18.5W/kg). 128MHz results are similar. Tissue temperature after 60 minutes of continuous exposure (based on 64MHz SAR) is also shown in Fig.1, both with and without swaddling. Highest temperature (40.8°C) is observed at lower extremity landmark with swaddling and exceeds normal mode recommendations in IEC standards[12]. Table 1 shows peak local SAR and highest local tissue temperature.

Imaging landmark		Head	Torso	Lower extremity
Peak local SAR [W/kg]	64MHz	11.6	8.8	18.5
	128MHz	10.1	9.1	19.4
Highest tissue temperature [deg C]	no swaddling	38.7	38.5	40.0
	with swaddling	39.3	39.4	40.8

Table 1. Peak local SAR and highest tissue temperature calculated with 2 W/kg whole body exposure

DISCUSSION: Local SAR distribution and hotspots in infants are essentially equivalent between 1.5T and 3T imaging with whole body transmit coil. Although local SAR hotspots are much lower than those found in adults[1], infants are still subject to significant local tissue heating, and swaddling can compound such adverse effect. Since infants' thermoregulation is not as mature as adults and can be further impaired with sedation, and they cannot communicate the adverse effects, additional attention is required to ensure appropriate RF exposure during MR scans.

CONCLUSION: Simulation results show that infants who are swaddled may exceed normal mode temperature limits.

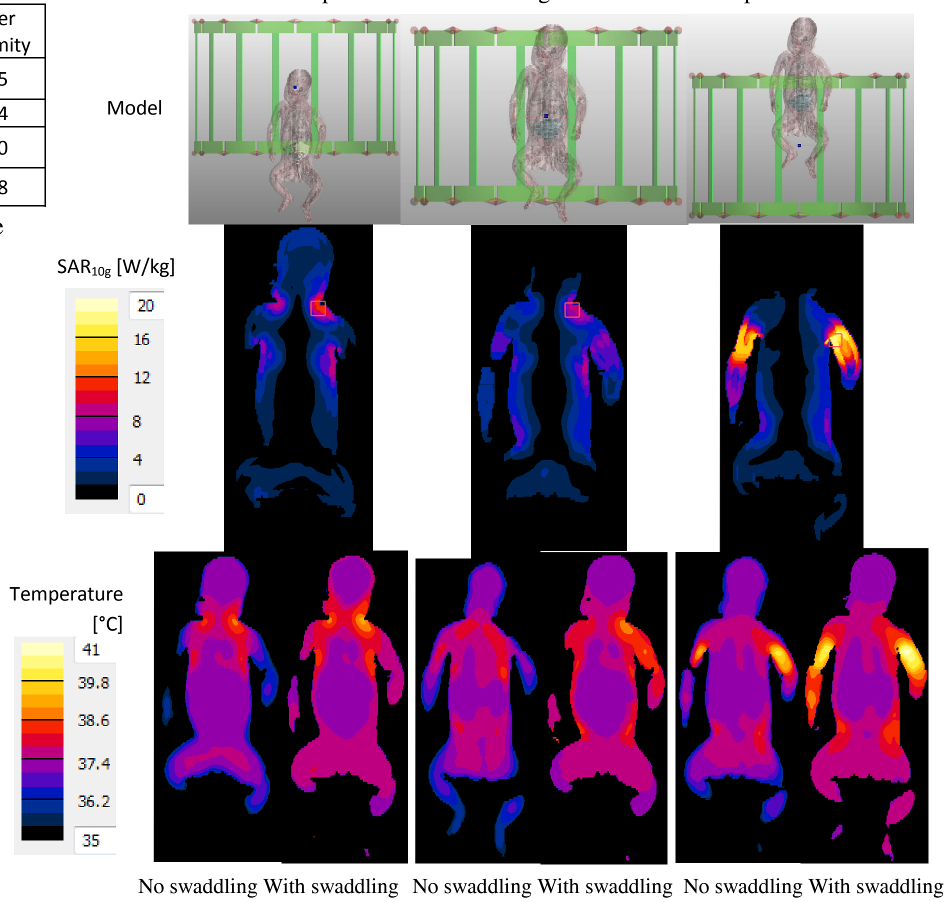

Fig.1. Top row: infant model positioned at different landmarks (head, torso, lower extremities) in the birdcage coil. 2nd row: SAR$_{10g}$ with hotspots (red cubic) calculated at 64MHz. 128MHz results are similar. 3rd row: tissue temperature without (left) and with (right) swaddling.

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