Effect of Head Size to B1, SNR and SAR

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Objective: To study how variation of human head size affect B1, SNR and SAR.

Introduction: Simulations of RF coils loaded with human head and body models are seen in the literature [1-5]. Little research, however, focuses on the loading effects of human head or body dimension on the B1 field, signal to noise (SNR) and specific absorption ratio (SAR). Human head sizes can vary greatly [6] and this may seriously affect these NMR parameters, especially at higher fields. This study investigates how head size variation affects B_1, ISNR and SAR.

Methods and Materials: A 16-rung unshielded high-pass birdcage coil was simulated at 3T and 4T with the Remcom® FDTD Package. Based on a 3T unshielded high-pass birdcage coil developed by USA Instruments, the coil model is 29 cm in both diameter and height.
Table 1 shows anthropometric measurements of different male and female head sizes [6]. These measurements are based on US population, and other countries may have variations. Figure 1(a) shows how the dimensions were measured. The original analytically-accurate male head model from Center for NMR Research, Pennsylvania State University, College of Medicine at Hershey, is also inserted into table 1. The original head mesh is of same size as the Remcom high fidelity (hifi) head mesh, which is widely used in simulation. This model was scaled linearly to the size of the average male (50th percentile) and to the small male (1st percentile). The Remcom head model was used for the large male (99th percentile). Figure 1(b) shows the male head models of different sizes. To further demonstrate the wide range of variations of human head size, the last column in table 1 lists the mass of the human head and shoulders for different head sizes. For all simulations, the center of the head was place in the isocenter of the coil. Following EM simulations, the steady state B_1 magnitude, mean B_{1+}, and ISNR were calculated in three central slices within human tissues. Maximal 1gram and 10gram local SARs, were also calculated. All values were first normalized to 1Watt tissue power; the ISNR was further normalized to the mean B_1 in the central axial slice. To show the difference caused by variation of head size, all calculated values were additionally normalized to the corresponding value for the original large male head at 3T (see table 2). B_1 field inhomogeneity was calculated as the percentage of B_1 drop from maximum to minimum value in the head.

Results: The mean B_{1+} magnitude, B_{1+} field inhomogeneity, and mean ISNR on the central axial slice, and the maximum 1gram and 10gram SAR values are listed in Table 2. While not shown, the mean B_{1+} and mean ISNR in the other two central slices follow similar trends. All maximum 1gram and 10gram SAR values occur either in the face muscle or the CSF in the top of the brain.

Discussion: (1) For a given power dissipated in the tissue, the maximum 1gram and 10gram SAR values increase with smaller heads. B_{1+} increases faster and therefore the maximum 1gram and 10gram SAR drops with smaller head for same B_{1+} or flip angle. (2) Maximum 1gram and 10gram locations may vary with head size. For example, the maximum 1gram SAR at 3T and 4T with original male head occurs in the face muscle, but in the medium male head it moves to the CSF in the top of the brain. (3) It is assumed here that human tissue dimensions scale linearly regardless with gender and size.

Conclusion: For same power dissipation in human tissue, B_{1+} magnitude increases and B_{1+} field is more homogeneous as the head becomes smaller. As a result, mean ISNR increases with smaller head. Maximum 1gram and 10gram SAR values decrease with smaller head based on same B1+ magnitude or flip angle. While these results are generally expected, the calculated data tabulated will perhaps find use in RF coil, pulse protocol, instrument, and safety protocol design.

References:

[1] Collins CM et al. MRM 45: 692-699 (2001). [2] Ibrahim TS, et al. MRI 19 (2001) 1339-1347. [3] Jin J et al. MRM 38: 953-963 (1997). [4] Vaughan JT et al., ISMRM (2006) p 214. [5] Vaughan JT et al ISMRM(2006). [6] Henry Dreyfuss Associates. The measure of Man & Woman. John Wiley & Suns, 2002. ISBN: 0-471-09955-4.

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Table 1 Dimension and Mass of USA male and female head of different size

Head (Percentile)	Width	Length	Height	Mass of head and Shoulders
Large Male (99)	170mm	214mm	252mm	
Original Hifi head	160mm	216mm	254mm	9.578Kg
Ave Male (50)	155mm	196mm	222mm	7.340Kg
Small Male (1)	142mm	180mm	204mm	5.766Kg
Large Female (99)	158mm	198mm	246mm	8.406Kg
Ave Female (50)	145mm	180mm	218mm	6.290Kg
Small Female (1)	132mm	162mm	194mm	4.527Kg

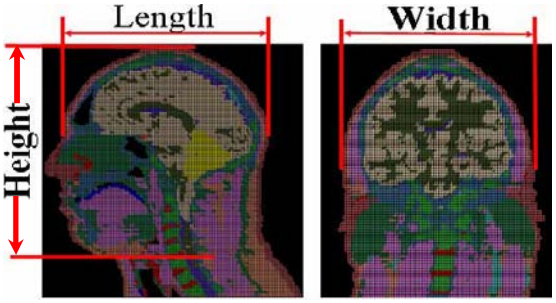

Figure 1 (a) human head dimension listed in

Table 2 Normalized B_1 and ISNR in the mid-transaxial slice, and maximum local SAR

	ω_o	LM	MM	SM	LF	MF	SF
Mean B_{1+} Magnitude	3T	1.000	1.144	1.316	1.083	1.296	1.525
Mean B_{1+} Magnitude	4T	0.779	0.858	0.976	0.827	0.957	1.123
B_{1+} InHomogeneity	3T	0.2895	0.2665	0.2569	0.2794	0.2632	0.234
B_{1+} InHomogeneity	4T	0.3350	0.3205	0.3179	0.3461	0.3396	0.323
Mean ISNR	3T	1.000	1.416	1.928	1.279	1.873	2.691
Mean ISNR	4T	1.311	1.785	2.430	1.642	2.338	3.336
Max 1g SAR	3T	1.000	0.869	0.728	0.919	0.763	0.605
Max 1g SAR	4T	1.602	1.511	1.249	1.490	1.306	1.092
Max 10g SAR	3T	1.000	0.852	0.710	0.956	0.745	0.563
Max 10g SAR	4T	1.601	1.447	1.221	1.541	1.265	1.101

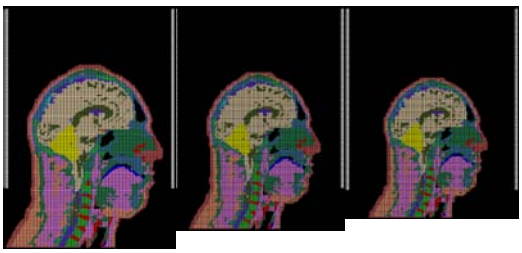

Figure 1 (b) male head models scaled to large, medium and small size