Effect of model and voxel size on the simulated gradient induced electric fields

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Introduction: Strong, rapidly switched gradient fields are desirable in MRI because they can be used to increase image resolution, improve image signal-to noise ratios, or be parlayed into other imaging benefits. Gains in gradient strength can be made by increasing amplifier strength, or improving coil efficiency. However, improved performance does not always translate into an increased useable range, because with increased gradient strength and slew rate comes an increased risk of peripheral nerve stimulation (PNS)[1].

PNS is thought to occur because the changing magnetic fields induce electric fields in the subject, and these fields activate the nerves in ways that are interpreted as sensations of tingling, pinpricks, and pressure.

Experimental gradient PNS thresholds differ from coil to coil[2], possibly because of the variation in the electric field profiles generated by the combination of the wire pattern and subject positioning. In order to predict patient stimulation we need to be able to accurately assess the electric field experienced by a subject during an MRI protocol. In this abstract we investigate the effect of model size and resolution on the calculation of gradient induced electric fields.

Methods: A quasi-static[3], finite-difference algorithm implemented in C++ was used to iteratively converge on the scalar potential [4]. The contributions of both the scalar and vector potential were combined into a calculation of the total electric field for each coil/model pair. The wire elements for a customized head/neck gradient coil [5] were used to represent the gradient coil effects and the visible man model was manipulated to simulate the effect of a conductive subject in the gradient coil. The model was manipulated in two ways: 1) the model resolution was adjusted, and 2) the relative size of the model was adjusted. The model was positioned in a neck imaging mode, with the shoulders flush with the edge of the coil. The voxel size was investigated with the original 3 mm X 3mm X 3mm, as well as 6 mm X 6 mm X 6 mm voxels, and 9 mm x 9 mm X 9 mm, voxels. The subject size investigated at 100% (1.9 m height) original size, as well as 90% (1.7m) and 80% (1.5m) of the original size.

Results and discussion: Table 1 summarizes the maximum magnitude of the electric field exposure at the surface for four locations on the model and the maximum over all, for each of the simulations. Changes in the resolution of the model have a significant impact on the calculated electric field, both for magnitude and position. As the resolution decreases, the sinus air cavities collapse into a more homogenous-looking structure and the location of the maximum electric field moves from the nasal/sinus area to the forehead. Figure 1 shows graphically the effect of decreasing size and resolution on a cross section of the electric field profile. The finest resolution investigated, 3 mm, is the minimum required to captured the detail of the air-cavities and sinus passages in the body which contribute to the complexities of the electric field

The size of the model affects the magnitude of the electric field to a lesser degree than the resolution. The magnitude of the total field shrinks as the boundaries of the model are moved away from the edges of the coil, and the regions of higher vector-potential induced field. Model size has an effect on the magnitude of electric field exposure, but not on the location of the maximum induced field. In order to accurately gauge the field experience during imaging models customized to the subjects shape should probably be used. However, since model resolution has a significant effect on both the location and magnitude the electric field models must first have adequate resolution before individualized field simulations are attempted.

Region	(a)100%	(b)90%	(c)80%	(d)3mm	(e)6mm	(f)9mm
Maximum	0.1779	0.1553	0.1187	0.1779	0.0850	0.0800
Forehead	0.1276	0.1235	0.1056	0.1276	0.0850	0.0800
Nose	0.1779	0.1553	0.1187	0.1779	0.0492	0.0428
Chin	0.0537	0.0524	0.0391	0.0537	0.0559	0.0521
Neck/shoulder	0.0957	0.0985	0.1033	0.0957	0.0692	0.0787

Table 1: Magnitude of the maximum electric field in V/m simulated for each region for the original image size(a), at 90% initial size (b), at 80% initial size(c), with 3mm voxel sides(d), with 6mm voxel sides (e), and with 9mm voxel sides (f).

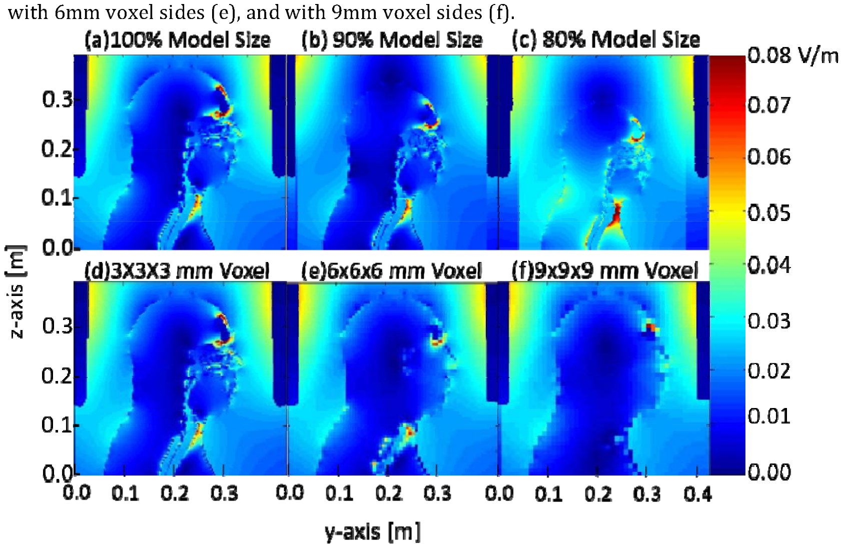

Figure 1: Magnitude of maximum electric field in V/m simulated with size and resolution adjustments

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