Lowering the imager significantly reduces the field exposure of MRI occupational workers

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Synopsis: In MRI, healthcare workers can be exposed to strong static and time-varying magnetic fields outside the imager, which can lead to the stimulation of electric fields in the body. Tissue of the central and peripheral nervous system (CPNS) in the head and torso is particularly susceptible. Reported is a simple solution that can notably reduce the head/trunk exposure of MRI operators to both static and low-frequency magnetic fields. The numerical results indicate that the upper body CPNS exposure can be reduced by factors of up to 50 or more, when the scanner is lowered by 1 m in height relative to the normal operator position.

Method: Three realistic symmetric superconducting magnets (1.5T, 4T and 7T unshielded) and actively shielded, whole body, symmetric x, y and z-axis gradient coils were considered in this study. A heterogeneous whole-body male voxel phantom (*Brook*) was used to accurately model the exposure of an occupational worker to fields produced by the main magnet and gradient coils. The quasi-static finite-difference method was employed to compute the induced electric fields. For further details on the magnets, gradients, body model and the computational method, the reader is referred to (1).

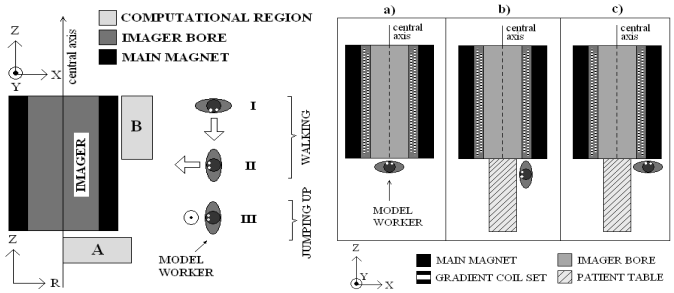

Fig.1 - Exposure setups: static field – worker (left), gradient field – worker (right).

Motion	Pos	1.5 T		4 T		7 T	
		R	Z	R	Z	R	Z
I	A	0.30	-0.90	0.30	-1.30	0.30	-1.55
	B	1.30	0.40	1.45	0.60	1.20	0.80
II	A	0.50	-1.00	0.20	-1.40	0.20	-1.70
	B	1.20	0.40	1.35	0.60	1.10	0.80
III	A	0.20	-1.00	0.20	-1.40	0.20	-1.70
	B	1.20	0.40	1.35	0.60	1.10	0.80

Table 1: Worker positions around main magnet. All distances are in meters. Positions are illustrated in Fig.1 (left).

The three magnets were placed 1.15m above ground (setup I) relative to central cylinder axis. At this elevation all exposures as detailed in Table 1 were carried out. Then the magnet was lowered to a vertical elevation of 0.15m (setup II) and all simulations were repeated (see Fig.2 b). All worker motions were normalized to 1 m/s.

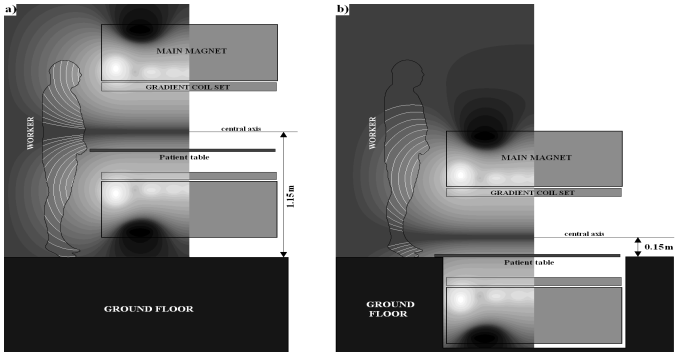

Fig.2 - (a) Setup I; (b) setup II.

Results and discussion:

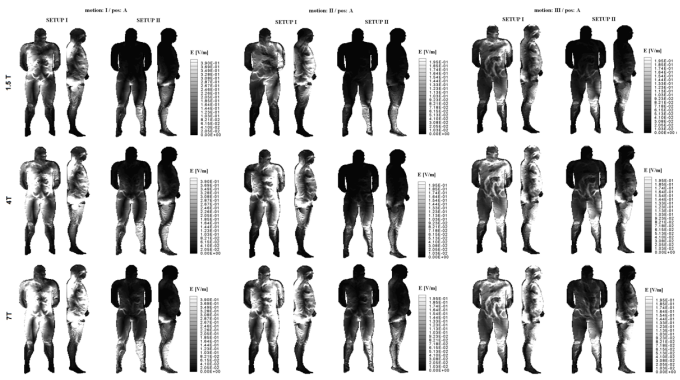

Fig.3 - Electric field distributions in the model worker induced during motion I–III at position A near each magnet.

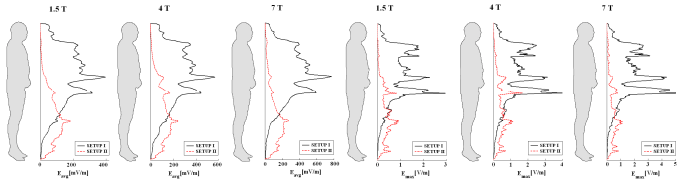

Fig.4 – Induced field comparison of each axial slice versus body height between setup I and II (motion I/ position A around three magnets).

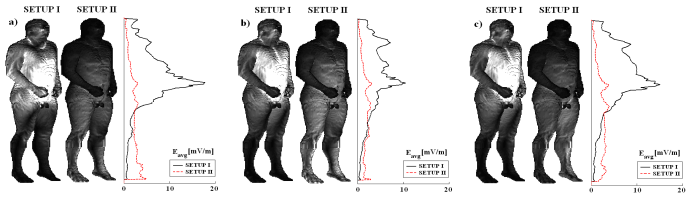

Fig.5 – Surface E-field distribution and comparison of each axial slice versus body height between setup I and II for the exposure of the worker to a combination of all three gradient coils. Subplots are analogous to positions illustrated in Fig.1 (right)

Table 2: Induced field reduction factors

B [T]	Spine		CSF		Grey Matter		White Matter	
	E_{avg}	E_{max}	E_{avg}	E_{max}	E_{avg}	E_{max}	E_{avg}	E_{max}
1.5	3.88	2.17	29.04	18.70	51.07	45.98	53.58	54.73
4	3.47	2.43	14.58	8.01	28.65	26.20	29.00	33.32
7	5.25	2.69	17.59	24.92	11.62	16.48	10.93	14.99

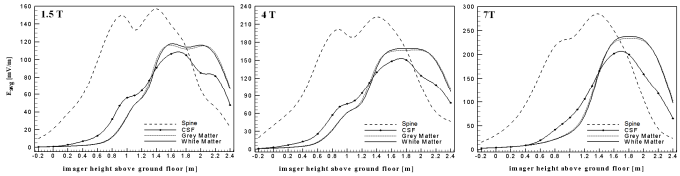

Fig.6 – Average electric field for CNS tissue as a function of magnet height.

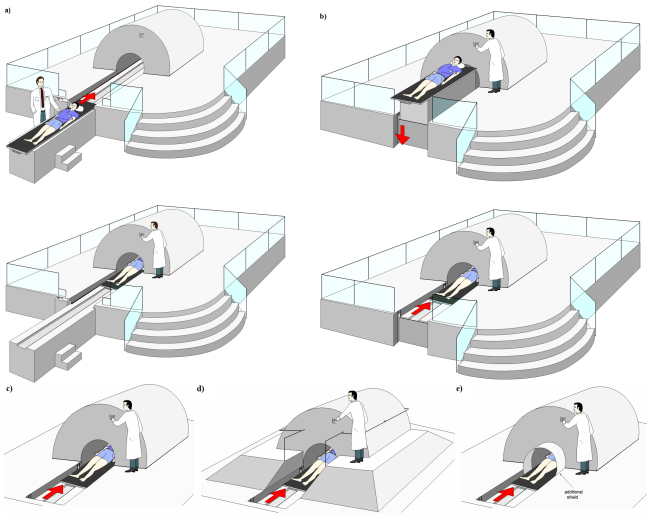

Fig.7 – Various MRI implementations for the reduction of induced fields in occupational workers. (a-b) worker elevation platform for existing systems where the patient is prepared some distance away from hazardous fields; (c-e) implementations for future/existing systems where the scanner is situated deeply into ground.

Conclusion: We note that this approach makes access to the patient during scanning more difficult (i.e. bending/kneeling motions towards the magnet bore should be avoided). However, lowering an imager could significantly reduce the upper body exposure and thus allow faster worker motions.

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References: [1] RR570 report, Health and Safety Executive, HSE Books, 2007.