Occupational exposure assessment to static magnetic field in MRI environment

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AIM OF THE WORK

The aim of the present study is the evaluation of occupational exposure to static magnetic field in MRI environment, through direct measurements and relevant dosimetric parameters calculation.

MATERIALS AND METHODS

Measurements and evaluation were performed on a GE Signa Excite HDx 1.5 T scanner, used for diagnostic investigations and installed within a dedicated room. Static magnetic fields measurements were performed with no operative MRI clinical sequences active, using a Metrolab THM1176 isotropic Hall effect probe; the magnet room has been divided into four quadrants symmetrical with respect to x and z axis; the symmetry of the static magnetic field makes it possible to perform measurements only on a single quadrant. A 50 cm side square micro grid was traced in the selected area; the measuring instrument was placed at the top of every single square at three different heights (100-120-150 cm from the floor); other points, located outside the magnet room, have been added to the original grid to obtain a complete characterization of the compliance area.

To characterize the environment the following aspects have been taken into consideration:

a) static magnetic field pattern along x,y,z axis;
b) static magnetic field levels within gantry, magnet room, compliance area;
c) 0.5 mT isoline position;
d) magnetic flux density;
e) current density induced at aortic node by stationing into static magnetic field;
f) current density induced at head and trunk level due to movement within static magnetic field;
g) average whole body exposure weighted on working hours.

RESULTS

The full characterization of the static magnetic field can be obtained combining measurements on a standard grid in the area outside the bore, with numerical simulations for the in bore areas. For sensitive areas outside the scanner room, measurements performed at 120 and 150 cm from the floor have to be taken into consideration.

For what concerns magnetic induction, the Directive currently specifies an action value of 0.2 T, but the next revision may well display significant chances toward higher limits based on what reported in the 2009 edition of ICNIRP static magnetic fields related Guidelines .

Our measurements show that the proposed 2004/40/EC action value is exceeded at 40 cm

from the scanner bore along z axis and would be exceeded for a small amount within the near gantry manoeuvre area. The other working positions are to be considered safe. If we consider the spatial peak magnetic flux density of 2T recommended in ICNIRP Guidelines (2009), both magnet room and compliance areas are to be considered safe.
The 0.5 mT isoline is confined within the magnet room.

For what concerns induced current at aortic node, the values calculated for six different working positions are presented in the table below:

Position	B_{meas} (mT)	Working groups	J_c (mA/m^2)	Limit (mA/m^2)	Comparison
Near gantry manoeuvre area	209	Nurses, stretcher-bearer	45.64	40	Comparable
Middle transport table manoeuvre area	34.5	Nurses, stretcher-bearer	7.53	40	< factor 5
End transport table manoeuvre area	4.96	Nurses, stretcher-bearer	1.08	40	< factor 40
Operator workspace	0.24	Technicians, radiologists, physicians	0.05	40	Negligible
Patient support area	0.16	Nurses, clearing staff	0.03	40	Negligible
Technical room	0.06	Technicians, repairing staff	0.01	40	Negligible
Isocentre	1500	Physicians, nurses,	327.6	40	> factor 8

The calculated values, in the absence of a specific limit for the current density induced at heart level, were compared with the basic restriction for the current density at head and trunk level for fields up to 1 Hz, given in the Directive 2004/40/EC.

The calculation of the induced current density at level of head and trunk due to the movement within a static magnetic field was carried out for two movement trajectories commonly used by personnel during routine activities within the exam room; the chosen paths are the following:

a) across the magnet hall from the entrance to the middle transport table manoeuvre area;
b) across the magnet hall from the entrance to the near gantry manoeuvre area.

In both cases the estimated value of the induced current density at head and trunk level due to the rapid movement within a static 1.5 T magnetic field is contained in the range 0.02 – 8.59 mA/m^2, well below the Directive 2004/40/EC 40 mA/m^2 limit. The trajectory segmentation shows that the biggest contribution to the induced current density is referable to the last 70 cm of the path.

For what concerns whole body exposure weighted on a workday, data clearly shows that the daily exposure to static magnetic field produced by a 1.5 T MRI scanner in routine situation is, in all cases, less than 200 mT/day given in the 2004 Edition of ICNIRP Guidelines as limit for professionally exposed workers to static magnetic field.

CONCLUSIONS

We performed measurements on a 1.5 T scanner used in a big Hospital for standard diagnostic investigations. All relevant physical quantities and dosimetric parameters do not exceed the limits and the action values set in Directive 2004/40/EC and in 2009 ICNIRP Guidelines. Particular attention should be dedicated to induced current at aortic node level. Measurements and calculation performed within near gantry manoeuvre area may lead to values exceeding the limit for current density at head and trunk level related to fields up to 1 Hz, given in the Directive 2004/40/EC, chosen as reference in the absence of a more specific limit. Further investigations are needed.