Occupational exposure assessment to static magnetic field in MRI environment

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INTRODUCTION

Recent developments in MRI-based diagnostic technologies are leading hospitals towards the use of high static magnetic field scanners; the current trend indicates the use of 1.5 or 3 T scanners for common diagnostics. This results in high levels of exposure to static magnetic fields (SMF) for patients and working staffs. The aim of the present study was to evaluate occupational exposure to static magnetic fields, through direct measurements, simulations, and the calculation of relevant dosimetric parameters. Particular attention was given to current induced by blood flow in the area of the aortic node during stationing (or slow movement) within a SMF, and induced-current density at the head and trunk level due to movement.

MATERIALS AND METHODS

Measurements and evaluations were performed on a GE Signa Excite HDx 1.5 T scanner, used for diagnostic investigations. SMF measurements were performed using a Metrolab THM1176 isotropic Hall effect probe; the magnet room was divided into four quadrants, symmetrical with respect to the x and z axes. The symmetry of the static magnetic field allowed to perform measurements only on a single quadrant. A 50-cm side square microgrid was traced in the selected area; the instrument was placed at the top of every single square at 100, 120, 150 cm from the floor; other points, located outside the magnet room, were added to the original grid to obtain a complete characterization of the compliance area.

To characterize the environment the following aspects were taken into consideration:

a) static magnetic field patterns along x,y,z axes;
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 in the area of the aortic node by stationing into the static magnetic field;
f) current density induced at the head and trunk level due to movement within SMF;
g) average whole body exposure weighted on working hours.

RESULTS

As regards magnetic induction, the 2004/40/EC Directive [1] currently specifies an action value of 0.2 T, but the next revision may display significant chances toward higher limits based on what reported in the 2009 edition of the ICNIRP static magnetic fields related Guidelines [2].

Our measurements showed that the 2004/40/EC action value was exceeded at 40 cm from the scanner bore along z axis and would be exceeded by 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 the ICNIRP Guidelines (2009) [2], both the magnet room and compliance areas are to be considered safe. The 0.5 mT isoline is confined within the magnet room. Regarding induced current at the 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[a]
Near gantry manoeuvre area	209	Nurses, stretcher-bearer	45.64	40	> factor 1.14 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, physicians, radiologists,	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

Table 1: Induced current at the aortic node for six different working positions

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

The induced current density at the head and trunk level due to movement within a static magnetic field was calculated for two trajectories commonly used by personnel in routine activities; the chosen paths were the following: a) across the magnet room from the entrance to the middle transport table manoeuvre area; b) across the magnet room from the entrance to the near gantry manoeuvre area. In both cases, the estimated value of the induced current density is contained in the range 0.02 – 8.59 mA/m^2, i.e. well below the Directive 2004/40/EC limit. The highest contribution to the induced current density is referable to the last 70 cm of the path. Regarding whole body exposure weighted on a workday, data clearly show that the daily exposure is, in all cases, lower than 200 mT/day.

CONCLUSIONS

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

REFERENCES

[1] Commission of the European Union. Physical Agents (Electromagnetic Fields) Directive 2004/40/EC, 2004
[2] ICNIRP. Guidelines on Limits to Exposure to static magnetic fields. Health Phys 96(4) 504-14, 2009