Procedures for measurement and evaluation of EMF occupational exposure in MR environments

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Objectives

Devices based on nuclear magnetic resonance are widely used in clinical diagnosis because they allow a detailed anatomical and functional vision of patient's organs, without applying ionizing radiation.
During the exam patients are exposed to a static magnetic field, radiofrequency electromagnetic fields and to complex, non sinusoidal low frequency magnetic field gradients; those fields represent a source of exposure for various categories of workers too.
Aim of this work is the identification of a rapid, repeatable method, applicable to all cases for the evaluation of MRI personnel occupational exposure through specific instrumental measurements, numerical simulations and complex signal form studies and investigations.

Methods

The proposed method for exposure assessment presents several stages that can be summarized as follows:

1) Scanners and environment characterization and identification of high exposition impact zones
2) Identification of instruments and numerical models suitable to describe the different field components
3) Implementation of source bounded protocols and execution of specific measurements
4) Estimation, through numerical simulation, of electric, magnetic and electromagnetic field inside the scanner's bore
5) Evaluation and calculation of parameters relevant to occupational exposure (0.5 mT isoline position, peak magnetic flux density, current density induced by stationary into static magnetic field, head and torso current induced by movement in static magnetic field, SAR, average magnetic induction level from non sinusoidal low frequency B gradients, dB/dt ratio and related induced currents))

Results

The methodology was applied to 3 tomographs at 1.5 and 1.0 T and allowed to fully characterize the static magnetic field within the scanner's room and in the adjacent areas, showing that outside the bore the Directive 2004/40/EC limits for static field exposure and the 40 mA/m^2 basic restriction for current induced in head and body as a result of movement in static magnetic field, are not exceeded.
For what concerns RF fields exposure, we evaluated E and H fields components and in bore/out of bore SAR, verifying that out of bore all field values and dosimetric quantities

are below Directive 2004/40/EC limits. Those quantities consistently exceed the limits if we consider in bore exposure.
As for low frequency magnetic field gradients (100 Hz – 10kHz), measures to assess the average levels of magnetic induction and studies on signals shape were performed. Average levels of measured magnetic induction are all below the limit set out in Directive 2004/40/EC for the specific frequency range; dB/dt ratio at 85 cm from the iso-centre along z axis for a SE sequence, is dependent on the slice thickness and in some cases exceeds the limit of 0.22 T/s reported in ICNIRP Guidelines.

Conclusions

The proposed methodology allows to have a standard protocol applicable to all cases regardless of the MRI scanner's characteristics (i.e. specific use and location); this permits a quicker and repeatable execution of working exposure assessment and measurement.
It also permits to obtain a tabular form combining all the parameters under investigation and compare them with related base restrictions and levels imposed by current legislation for occupational exposure.