

Understanding magnetic field spatial gradients and their impact on MR safety practice.

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The presentation is focussed on the variation of the main (B_0) magnetic field beyond the homogenous imaging volume. We will explore how this parameter impacts on the daily MR safety decision making within different jurisdictions by describing the nature of main field spatial gradients, how to interpret machine specific spatial gradient information and how to use this information and statements of safe conditions may tailor MR safety decisions.

The material is relevant to MR technologists, physicists, radiologists, MR safety officers, MR medical directors, and research users globally.

What is the Spatial Gradient?

The term Spatial Gradient does not refer to the “gradients” used for spatial encoding.

The spatial gradient (SG) of the static magnetic field is the measurement of how much the B_0 field strength changes in a given distance and direction (designated dB/dx or ΔB). The units of a spatial gradient in the international standard (IS) **MKS** system of units is Tesla per metre (T/m). The SG may also be expressed in Gauss per cm (G/cm), which is the superseded **cgs** system. Both units are encountered in material regarding MR/implant interactions, although T/m is the official unit. 1 T/m is equal to 100 G/cm.

How is this relevant to MR safety?

The attractive force exerted on an object near a magnet is proportional to the spatial gradient of the field. For unsaturated materials (paramagnetic or diamagnetic) the attractive force is also proportional to the local magnetic field strength ($\Delta B \times B$). This is sometimes referred to as the “Force Product”. The pattern of spatial gradients around an MRI magnet are highly variable, affected by field strength, bore length, internal magnet design considerations, the shape and size of magnet shrouding, and fringe field shielding methods including active shielding, and passive magnetic shielding in walls. Thus the attractive force on any object will vary significantly between MR installations of different field strength and different magnet designs; considering the field strength alone is not sufficient. The standard method for measuring and reporting attractive force on an object in MRI is ASTM F2052ⁱ. Its method is to measure the deflection angle of a vertically suspended test object in the magnetic field at the point where the deflection is greatest. The test report has to cite the spatial gradient of the magnetic field (ΔB), and the magnitude of the magnetic field (B).

In 2005 the FDA moved to enhance patient safety by mandating that manufacturers of new devices provide specific detailed information regarding MR/device interactions. Manufacturers are required to use standard test protocolsⁱⁱ and to state safe conditions for MR scanning. The FDA suggested format expresses conditions in terms of the static magnetic field strength, tissue heating and SAR levels, and the spatial gradient of the field. These statements have become familiar to many MR

technologists and MR safety officers, but the concept and utility of the spatial gradients remains confusing to many (as evidenced by frequent questions in MR Technologists' educational forums). The Radiologists, who typically carry the responsibility of MR safety decisions, may frequently choose to accept a MR technologist's' précis of the information available for a specific device and scanner combination; but they should also acquire and maintain a working knowledge of this element of the MR conditional statements.

If MR is being conducted in a jurisdictionⁱⁱⁱ where the standard of care includes working within the device's conditions for safe scanning, all staff involved in safe scanning decisions must particularly consider and understand the spatial gradient parameter. They need to know how to assess adherence to a safe scanning limit in their hardware and scanning setting. To make informed safe practice decisions, they must also consider likelihood and potential consequences of exceeding the conditional limits.

The presentation will conclude by demonstrating how to use existing MR Conditional device statements and the spatial gradient information from several MR scanners to determine under what circumstances the device conditions for safe scanning may be met.

ⁱ F2055-06(11). ASTM International. www.astm.org

ⁱⁱ F2055-06(11) F2182-02A

ⁱⁱⁱ United States, Australia, New Zealand.