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MRI safety: myths and maths

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In recent years MRI safety has received increased media attention with growing public concern. From controversies over the side-effects of gadolinium to projectile accidents, a serious MRI incident always makes news. It doesn't have to. It is possible to practice completely without incident, as long as one can distinguish between the myths and maths of MRI safety. Surely, we don't need *maths*?

We do. It is essential because MRI safety without a solid theoretical and numerical foundation is just guesswork, folklore or worse. Here are some examples.

Myth: the various magnetic fields involved in MRI- the static field (B_0), switched gradients and radiofrequency (RF) - are different entities, to be treated differently when considering MR safety.

> ***Maths***: they are *all* magnetic fields. They display different spatial characteristics and frequencies, but they are *all* subject to the same physical laws of magnetisation and induction. Only the relative strength of these two interactions vary.

Myth*:* the tesla is the SI unit of magnetic field strength.

> ***Maths****:* the tesla is the SI unit of *magnetic flux density.* Magnetic field strength or intensity is measured in amperes per metre. We have been using the wrong terminology for decades!

Myth*:* the translational force on a ferromagnetic object depends upon its magnetic susceptibility.

> ***Maths***: for all strongly ferromagnetic objects (iron, steel, nickel, etc.) the value of magnetic susceptibility does not matter. They are all subject to the same amount of force and are equally dangerous in the MR environment.

Myth: the 'resonant lengths' of conductors, resulting in excess heating, in 1.5 and 3 T scanners are 26 and 13 cm.

> ***Maths***: 26 and 13 cm are RF half-wavelengths in water. Values in tissue may be more than double depending upon the type of tissue.

Myth: titanium is a safer implant material than 316LVM stainless steel.

> ***Maths***: the mechanical forces on a similar implant made from either material are negligible. However, titanium has a higher electrical conductivity and will be more susceptible to heating.

Myth: the most common fatal accidents in MRI arise from pacemaker malfunction or projectiles.

> ***Maths***: according to recent incident records in the USA (the MAUDE database[1]), implantable infusion pump malfunction is currently the most common cause of fatal accidents caused by MRI.

As it turns out, it appears that we may not understand magnetic fields that well. Magnetism has often been regarded as mysterious or esoteric, but there is no place for mysticism in our knowledge and practice of MR safety. The purpose of *Essentials of MRI Safety*[2] is to frame our MR safety practice on solid scientific basis, enabling readers to recognise and assess potential risk and also its absence, and equipping them for the roles of MR Safety Officer and MR Safety Expert.

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1. US Food and Drug Administration: Manufacturer and User Facility Device Experience https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/search.cfm
2. McRobbie D.W. (2020) Essentials of MRI Safety. Hoboken, NJ: Wiley Blackwell.