Impact of cardiac magnetic resonance imaging on human lymphocyte DNA integrity (Fiechter et.al., Eur Heart J. 2013): **What can we learn from this and what can we do?**

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Is electromagnetic field (EMF) dangerous?

- Electromagnetic fields are areas of energy that surround electronic devices.
- World Health Organization (WHO) explains that the electric fields are created by differences in voltage and magnetic fields are created when the electric current flows.

<table>
<thead>
<tr>
<th>Type of EMF</th>
<th>Extremely Low Frequency EMF (ELF-EMF)</th>
<th>Intermediate Frequency EMF (IF-EMF)</th>
<th>High Frequency EMF</th>
<th>Light</th>
<th>Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static EMF</td>
<td>Below 300 Hz (0.3 to 3 Hz; Power Transmission, and Distribution Facilities; ELF Waves)</td>
<td>300 Hz to 10 MHz (DC to 50 kHz; Soft X-rays, RF Waves)</td>
<td>10 MHz to 300 MHz</td>
<td>300 MHz to 3 GHz (2.45 GHz; Microwave Ovens)</td>
<td>3 GHz to 3,000 GHz (6 GHz)</td>
</tr>
<tr>
<td>Frequency</td>
<td>Zero</td>
<td>300 Hz to 10 MHz</td>
<td>10 MHz to 300 MHz</td>
<td>300 MHz to 3 GHz (2.45 GHz; Microwave Ovens)</td>
<td>3 GHz to 3,000 GHz (6 GHz)</td>
</tr>
<tr>
<td>Wavelength</td>
<td>None</td>
<td>Long</td>
<td>10¹ m</td>
<td>10¹ m</td>
<td>10¹ m</td>
</tr>
</tbody>
</table>

Known safety concerns performing MRI scan

The safety and tissue interactions of these three fields are independent of one another and can be dealt with separately.

**RF electromagnetic field:**
- Tissue heating
- Electrical burns
- Non-thermal effects

**Gradient magnetic field:**
- Nerve stimulation
- Muscle stimulation
- Acoustic noise

**Static magnetic field:**
- Projectiles
- Ferromagnetics in the Body
- Sensory effects (nausea, dizzy)

Schenck, Progress in Biophysics and Molecular Biology 87:185, 2005
What MRI-biological effects have been studied?

- Cell growth and morphology,
- Cell reproduction,
- DNA structure and gene expression,
- Pre- and post-natal reproduction and development,
- Blood brain barrier permeability, nerve activity, cognitive function and behavior,
- Cardiovascular dynamics,
- Hematological indices, temperature regulation, circadian rhythms,
- Immune responsiveness

**Effect from static magnetic field?**

**Effect from gradient magnetic field?**

**Effect from RF electromagnetic field?**

**Effect from combination of static, gradient, and RF fields?**

But the results are all contradictory.....

<table>
<thead>
<tr>
<th>Publication</th>
<th>Journal</th>
<th>Subject</th>
<th>Field strength</th>
<th>Target</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotoxic effects of 3 T magnetic resonance Imaging in cultured human lymphocytes</td>
<td>Bioelectromagnetics 32:535, 2011</td>
<td>human lymphocytes</td>
<td>3T</td>
<td>DNA damage</td>
<td>mixed</td>
</tr>
<tr>
<td>DNA integrity of human leukocytes after magnetic resonance imaging</td>
<td>Int J Radiat Biol. Jun 12., 2013</td>
<td>Human blood cells</td>
<td>3T</td>
<td>DNA damage</td>
<td>mixed</td>
</tr>
<tr>
<td>Impairment of chondrocyte biosynthetic activity by exposure to 3-tesla high-field magnetic resonance imaging is temporary</td>
<td>Arthritis Res. &amp; Therapy 8:R106, 2006</td>
<td>calves and steers</td>
<td>3T</td>
<td>bone</td>
<td>mixed</td>
</tr>
<tr>
<td>Total antioxidant capacity, total oxidant status and oxidative stress index in the men exposed to 1.5 T static magnetic field</td>
<td>Gen. Physiol. Biophys. 26:86, 2007</td>
<td>human</td>
<td>1.5T</td>
<td>oxidative stress</td>
<td>MF</td>
</tr>
<tr>
<td>Impact of contrast enhanced MRI on lymphocyte DNA damage and serum visfatin level</td>
<td>Clinical biochemistry 44:975, 2011</td>
<td>human</td>
<td>1.5T</td>
<td>DNA damage</td>
<td>mixed</td>
</tr>
<tr>
<td>Repeated exposure of the developing rat brain to magnetic resonance imaging did not affect neurogenesis, cell death or memory function</td>
<td>Bioche. and Birophy. Res.commu.404:291, 2011</td>
<td>rat</td>
<td>7.05 T</td>
<td>neurogenesis, cell death, memory function</td>
<td>mixed</td>
</tr>
<tr>
<td>Impact of cardiac magnetic resonance imaging on human lymphocyte DNA integrity</td>
<td>Eur Heart J. Jul 10., 2013</td>
<td>human</td>
<td>1.5T</td>
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Impact of cardiac magnetic resonance imaging on human lymphocyte DNA integrity

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Aims  
Magnetic resonance (MR) imaging is widely used for diagnostic imaging in medicine as it is considered a safe alternative to ionizing radiation-based techniques. Recent reports on potential genotoxic effects of strong and fast switching electromagnetic gradients such as used in cardiac MR (CMR) have raised safety concerns. The aim of this study was to analyse DNA double-strand breaks (DSBs) in human blood lymphocytes before and after CMR examination.

Methods and results  
In 20 prospectively enrolled patients, peripheral venous blood was drawn before and after 1.5 T CMR scanning. After density gradient cell separation of blood samples, DNA DSBs in lymphocytes were quantified using immunofluorescence microscopy and flow cytometric analysis. Wilcoxon signed-rank testing was used for statistical analysis. Immunofluorescence microscopic and flow cytometric analysis revealed a significant increase in median numbers of DNA DSBs in lymphocytes induced by routine 1.5 T CMR examination.

Conclusion  
The present findings indicate that CMR should be used with caution and that similar restrictions may apply as for X-ray-based and nuclear imaging techniques in order to avoid unnecessary damage of DNA integrity with potential carcinogenic effect.
Experiment design

20 people
(10 patients with cardiomyopathy and 10 for myocardial ischaemia)

10 ml blood

Bolus: gadobutrolum

1.5T gradient strength 42mT/m
maximum gradient speed 180mT/m/ms

GE, steady-state free precession, FastSE, T2W double-inversion black-blood SE for oedema imaging, balanced SSFP sequence for perfusion and inversion recovery segmented GE for late gadolinium enhancement.

10 ml blood

DNA damage detection: γ-H2AX
1. Immunofluorescence microscopy
2. Flow cytometry
Basic genetics for dummies

Disc drive

PC

Tape to fix the disc

Disc

Code

DNA (double helix)

Sugar phosphate backbone

Adenine
Guanine

Cytosine
Thymine

Nucleotides

virtualmedicalcentre.com
DNA damage and repair

A

Damaging Agent
- UV
- CPD
- SoxoG
- Mismatch
- ICL
- O₂ Radicals
- Replication errors
- Chemotherapeutic agents

IR

DSB

B

Consequences

DNA repair
- BER
- MMR
- NER
- HR

Checkpoin

a

b

Cell Death
- Mutation
- Aging

Evolution
Cancer
γ-H2AX – a biomarker for DNA damage

Histones

Cellular stress

Phosphorylation

Transcriptional and chromatin regulatory pathways leading to cellular response to stress

Molecular and cellular biology 31:4858, 2011
Results - Immunofluorescence microscopy

Figure 1

Before CMR

After CMR

Figure 2

Median values (foci per lymphocyte)

Individual values (foci per lymphocyte)
Results - FACS cytometry

Figure 3

Before CMR

SSC-A \(\times 10^2\)

FSC-A \(\times 10^2\)

Lymphocytes

Count

1000

2000

3000

CD 3 signal

After CMR

SSC-A \(\times 10^2\)

FSC-A \(\times 10^2\)

Lymphocytes

Count

1000

2000

3000

CD 3 signal

Figure 4

Median MFI

(arbitrary units)

Before CMR

After CMR

Red: Before CMR

Blue: After CMR

Overlay
Discussion

- 20 is not enough.
- No proper negative control and positive control
- The effect of gadolinium?
- Method for detecting DNA damage
- Didn’t specify the cell type.
- Dose dependent effect (1.5T, 3T, and 7T)?
- Long term effect?

Diagram:

- Ethic committee
- ? Volunteer
- Blood
- 3T
- 7T
- Blood cell
- DNA damage detection
  (Several methods)
Feelings are also important!!!!!!

Perception of health risks of electromagnetic fields by MRI radiographers and airport security officers compared to the general Dutch working population: a cross sectional analysis

Diana van Dongen¹, Tjabe Smid¹,² and Daniëlle RM Timmermans¹

Environmental Health 2011, 10:95

Abstract

Background: The amount of exposure to electromagnetic fields (EMF) at work is mainly determined by an individual's occupation and may differ from exposure at home. It is, however, unknown how different occupational groups perceive possible adverse health effects of EMF.

Methods: Three occupational groups, the general Dutch working population (n = 567), airport security officers who work with metal detectors (n = 106), and MRI radiographers who work with MRI (n = 193), were compared on perceived risk of and positive and negative feelings towards EMF in general and of different EMF sources, and health concerns by using analyses of variances. Data were collected via an internet survey.

Results: Overall, MRI radiographers had a lower perceived risk, felt less negative, and more positive towards EMF and different sources of EMF than the general working population and the security officers. For security officers, feeling more positive about EMF was not significantly related to perceived risk of EMF in general or EMF of domestic sources. Feeling positive about a source did not generalize to a lower perceived risk, while negative feelings were stronger related to perceived risk. MRI radiographers had fewer health concerns regarding EMF than the other two groups, although they considered it more likely that EMF could cause physical complaints.

Conclusions: These data show that although differences in occupation appear to be reflected in different perceptions of EMF, the level of occupational exposure to EMF as such does not predict the perceived health risk of EMF.

Keywords: concerns, occupational exposure, risk perception, MRI radiographers, security officers
Acknowledgement

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