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Research Article

Safety Considerations on MRI Systems for Firefighters and Paramedics

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Abstract

Background and Objectives: The use of magnetic resonance imaging (MRI) systems is on the rise and the number of installed systems is constantly increasing all over the world. This raises the possibility for emergency personnel to get in contact with these systems. However, the clothing and working material of paramedics and firefighters is not designed for the use on magnets. More research is needed to gain a deeper understanding of the risks for emergency personnel, working on MRI systems. Therefore, this study examined the effects of magnetic force on selected working materials and clothes of firefighters and paramedics.

Methods: This study was conducted as a field study, utilising a 1.5 T MRI system. Selected items were examined on their behavior in the magnetic field and the following parameters were measured: (*i*) the force of attraction and (*ii*) the distance to the magnet when a force of attraction is recognisable. Manual force meter and a wooden distance meter were used to measure the parameters.

Findings: The highest force of attraction can be researched in helmets (30 N), boots (90 N) and gloves (17 N). The measured force is high enough to pull these items into the magnet. Jackets and pants did not receive a high force of attraction. Working material can be influenced by eddy currents, according to the composition. The movement of the item can then be restricted.

Conclusions: Considering the results of this study, most of the clothing and working materials can be considered as MRI safe. However, the force of attraction of boots and helmets might be high enough to cause serious distraction for emergency personnel. There might be a high risk for emergency personnel to forget small items in their pockets which subsequently can act as dangerous projectiles. Additional tests might display the need for an independent MRI system. There is a high risk to damage the system (e.g. to break the cover by attracted objects) and hospitals might not be willing to take the risk in the future.

Keywords: Magnetic resonance imaging, Safety, Magnetic fields, Firefighters, Paramedics, Emergencies

Background and Objectives

The use of magnetic resonance imaging (MRI) systems is on the rise all over the world. MRI systems appear to be useful for various applications and the number of patient examinations is increasing constantly. Especially Europe shows an increase of installed systems and the countries Switzerland, Austria and Germany display the highest numbers of installed systems in 2009.[1,2] Moreover, relevant reports from the Organisation for Economic Co-operation and Development (OECD) confirms the rise of MRI systems in various countries.[3]

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The higher availability of MRI systems triggered an increase in the use to clarify medical-diagnoses.[4] One of the major MRI examinations constitutes the clarification of ischaemic insults and slipped disks. Additionally, MRI systems are increasingly used in scientific research and especially brain-research benefits form the ongoing development of MRI systems. Nowadays, MRI can be considered as standard-examination in various countries, which can be conducted in hospitals and private clinics.

Magnetic Influence by MRI Systems

MRI systems can be understood as large magnets, operating with high magnetic field. These magnets can possess a weight of up to 100 tons.[5,6] Magnets can either be implemented as permanent magnets, resistance magnets

(electrical) or superconductive magnets.[7] The high magnetic field is used to generate pictures by activating hydrogen atoms in the body and can reach up to 3 T for patient examinations. MRI systems used in research are using much stronger magnetic fields and can reach up to 20 T or more. The magnetic field of a 1.5 T magnet can be understood as 30.000 times stronger compared to the earth's magnetic field.[8] The magnetic fields around the magnet influence objects which are ferromagnetic, diamagnetic and paramagnetic.[8] The influence reduces by distance but can abruptly come into effect when getting closer to the magnet. Magnetic fields around the magnet can cover an area for about 30 m^2 (323 square foot) but are only high in force in close proximity to the magnet. The magnetic field declines fast to less than 0.5 mT (after approximately 1 to 2 m) and should be marked by an obvious line on the floor.[9] The effect of the magnet field is minimal outside the 0.5 mT areas and can therefore be considered as safe for ferromagnetic and metallic objects.

Safety on MRI Systems

However, next to all the improvements and development of these systems it seems that safety-aspects do not receive enough attention. Accidents on MRI systems seem to happen frequently and can be reported all over the world.[10-12] It seems that a misjudgement of the force of the magnetic field and a lack of understanding of how to deactivate the magnet triggered most of the accidents.

Due to the force of attraction, ferromagnetic and metallic objects are not compatible for the use on MRI systems.[13] This includes for example pacemakers and implants.[14,15] The force of the magnet would be able to displace objects within the body and also daily items like glasses, pens or watches can become dangerous projectiles.[9,16] Therefore, it is a strict provision for patients to remove all objects and clothing which might be magnetic and therefore constitute a risk to get pulled towards the magnet.[17]

Emergency Personnel and MRI

The increase of MRI systems might also increase the possibility for emergency personnel to get in contact with these medical devices.[18] Moreover, emergency personnel might now be more often contacted to assist in MRI accidents (for example when large objects were attracted by the magnetic force and pulled into the magnet).

However, the clothing and working-materials of firefighters and paramedics are not designed for the usage on MRI systems and it remains unclear if emergency personnel can operate in close proximity to the MRI.

A literature research on the safety of emergency personnel on MRI systems did not deliver an adequate result and it seems that no studies on this subject are conducted so far. Only the security measures, provided by manufactures, can be taken into account. More research is needed to gain a deeper understanding of the risks for emergency personnel, working on MRI system. Therefore, this field study examines the effect of magnetic force on selected working materials and clothes of firefighters and paramedics.

Methods

This study was conducted as a field study and aims to research the effect of a MRI's magnetic field on working materials and clothes of firefighters and paramedics. This study was conducted at the emergency hospital Bergedorf in Hamburg, Germany. The chosen MRI was a Philips Achieva with 1.5 T. This device is normally used for clinical examinations and no changes to the system have been conducted during the study. The hospital-management agreed to provide the system up to three hours to conduct this study. Within this time it was possible to examine 20 items: six different jackets, two different pants, three different gloves, three different boots, three different firefighting instruments, two different helmets and one firefighting belt. The test-objects are used by active firefighters and paramedics and no changes have been conducted to the items. Table 1 summarises the selected objects:

Each item was investigated in advance by a small hand magnet to determine the magnetic behaviour before entering the MRI room. The item was secured with ropes when the object appeared to be highly magnetic. In order to investigate the force of attraction, test persons wore the clothing and approached the magnet. If an influence by the magnetic force was recognisable, the item was investigated more specific. The helmets and firefighting boots needed additional safeguard by rope because the force of attraction was high. Without the rope-safeguard these items would have been pulled in the magnet (Figure 1).

Measured parameters included the force of attraction and the distance to the magnet when a force of attraction is recognisable. The force of attraction was measured by manual force meters and the distance of attraction by a wooden distance meter. In order to investigate as much objects as possible, four persons were present to cover the amount of work.

Results

The examination of the jackets and the pants did not show a high force of attraction. Only two items showed an influence because of magnetic buttons on the clothes. The jacket of the Fast Incident Group (see Table 2, No. 6) showed an influence within the distance of 30 cm (12

Table 1. Selected Test-Objects

No	Object	Type
		Jackets
1	Paramedic jacket Johanniter	Crings model type CR130, size M, EN471, EN343
2	Paramedic jacket Kiel	Toray Seeit Safe, Niemöller and Abel, size 48, EN13795
3	Paramedic jacket German Red Cross	GSG, size 50-52, EN 343 and EN 471
4	Standby jacket German Red Cross	Hortig, size M, EN471 and EN 343
4	Firefighting jacket Halstenbeck	Viking, size 56, CE 0493
6	Firefighting jacket Fast Incident Group	Hortig, size L, EN343 and EN471
		Pants
7	Paramedic pants Kiel	size 50
8	Firefighting pants Halstenbeck	Viking, size 56, CE0493, EN469:2005
	Gloves	
9	Paramedic gloves	Köninger, category 3, CE0516 and EN659
10	Firefighting gloves	Rosenbauer, Safe Grip 2, EN6592003, with carabiner
11	Firefighting gloves	Hygloves, Size L, EN388, from Weber Hydraulic
		Boots
12	Firefighting boots HAIX	Fireflash, size 43, EN15090: 2006
13	Paramedic boots HAIX	Airpower X1, size 45, ISO 20345: 2004
14	Emergency boots Rosenbauer	Tornado, size, EN15090
		Firefighting Armatures
15	Firefighting house coupling	including seal and snap ring
16	Adapter piece B to C	including seal and snap ring
17	Fog nozzle	Type Akron Brass 4820, Norm 1964
		Helmets
18	Paramedic and firefighting helmet	Schuberth, F120, CE0299 and EN 443:2008
19	Firefighting helmet	Schuberth, Type F210, CE0299 and EN443
		Firefighting Belts
20	Firefighting belt	Skylotec, Size 3, DIN 14927 and EN358

in) and the paramedic pants Kiel (see Table 2, No. 7) were attracted in a distance of 10 cm (4 in). However, the measured force of attraction was low in both cases and appeared to be less than 1 N.

Figure 1. Examples of Selected Test-Items; (A) Gloves, (B) Firefighting house coupling and adapter piece B to C, (C) Fog nozzle and (D) Firefighting belt.

The investigation of the gloves displayed a force of attraction for every different type. The measured forces of 3, 5 and 17 N are already high enough to pull the glove in the magnet. The influence by the magnetic field started within a distance of 20 cm (8 in) (Figure 2).

Measurement of the boots displayed the highest force of attraction and it was possible to measure 90 N for every pair of boots. In this case the force of attraction is already very high and the boots would have been pulled in the magnet with high speed. All values were measured with a distance of 40 cm (15.7 in) to the magnet.

The examination of the firefighting armatures displayed no attraction by the magnetic field. However, an attraction due to the snap ring of the firefighting house coupling and the firefighting adapter piece could be measured within a distance of 10 cm (4 in). Moreover, it was recognisable that all firefighting armatures receive an influence by the magnetic field due to eddy-currents. Eddy-currents restrict the movement of the devices as long as they are under the influence of magnetic fields and it appears difficult to

Figure 2. Testing of Gloves With the Manual Force Meter.

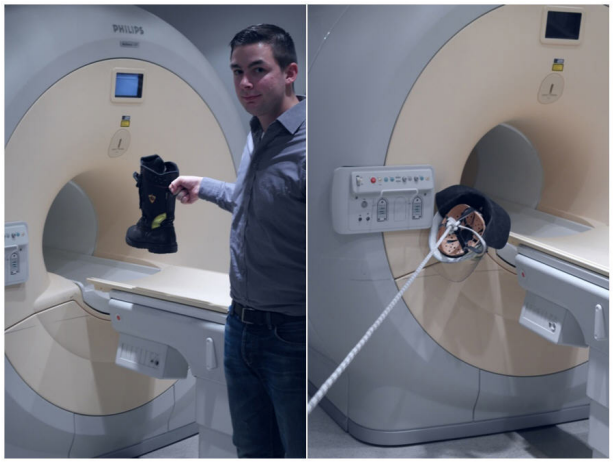

Figure 3. Testing of Boots and Helmet. The boot is floating freely due to the high force of attraction and the helmet needed to be secured by ropes.

move the devices.

The measured force of attraction of the paramedic and firefighting helmet is attributable to the sight of the helmet (see Table 2, No. 18). The measured force of attraction was measured within a distance of 30 cm (12 in) to the magnet and values 30 N. This force is already high enough to pull the helmet in the magnet (Figure 3).

All results are summarised in Table 2.

Discussion

Results show that jackets and pants do not receive a high force of attraction. Slight attraction could be measured on two items and was caused by buttons on the clothes. It can be assumed that most of the clothing of firefighters and paramedics can be considered as MR safe. Even when there will be a slight attraction, it can be assumed that the force might not be strong enough to pull the clothes from the person.

However, boots received a high force of attraction and with a force of 90 N it was even difficult for the test-person to remove the boot from the magnet. This force of attraction was caused by the steel-caps within the boot and might lead to serious distraction during emergencies. However, the force was not high enough to pull the boot from the test person's foot. One of the tested helmets also showed a higher force of attraction and might also cause distraction during emergencies. Without the security strap of the helmet the force would be high enough to pull the helmet in the magnet. Additional features of helmets (e.g. visor of helmet) might increase the force of attraction. Considering these results, it might be advantageous to remove helmets before entering MRI rooms.

All the tested gloves display a force of attraction and must be handled with caution next to MRI systems. The force of attraction is high enough to pull the tested gloves in the magnet and additional attachments to the gloves (like carabiners) can increase the force of attraction considerably.

All the firefighting armatures and the firefighting belt did not display a force of attraction. All the tested materials are manufactured by non-ferromagnetic materials (aluminium and brass) and can therefore be considered as MR safe. The slight attraction of the house coupling and the adapter piece are attributable to the snap ring in these devices. However, these components still receive a major influence by eddy-currents and display a limitation in movement next to MRI systems. The difficulty to move these devices might lead to serious distraction during emergencies and should be considered in advance.

Additional training for firefighters and paramedics should be considered to highlight the danger of ferromagnetic objects close to MRI systems. Emergency personnel might forget small items in their pockets which can subsequently become dangerous projectiles. MRI personnel are used to perform a check of their pockets before entering the examination room; introducing this check to firefighters and paramedics might be a first possibility to increase the safety of emergency personnel. Moreover, firefighters and paramedics might benefit to invest in MRI safe boots without a steel cap.[19] Additionally, it is possible to invest in MRI safe breathing protection systems (composite bottles) and non-magnetic fire extinguisher.[20]

Study Limitations

The results of this study must be considered under the right of the following limitations. First, due to the magnetic field this study utilised manual force meters to measure the force. These meters did not deliver a very high accuracy and therefore the measured results do not display a high accuracy. Secondly, due to a limitation in time it was only possible to test some selected objects from firefight-

Table 2. Results of Tested Objects

No	Object	Measured Force (N)	Comment
		Jackets	
1	Paramedic jacket Johanniter	0	
2	Paramedic jacket Berufsfeuerwehr Kiel	0	
3	Paramedic jacket German Red Cross	0	
4	Standby jacket German Red Cross	0	
4	Firefighting jacket Halstenbeck	0	
6	Firefighting jacket Fast Incident Group	<1 (at 30 cm [12 in] distance to magnet)	Attraction because of buttons
		Pants	
7	Paramedic pants Berufsfeuerwehr Kiel	<1 (at 10 cm [4 in] distance to magnet)	Attraction because of buttons
8	Firefighting pants Halstenbeck	0	
		Gloves	
9	Paramedic gloves	5 (at 20 cm [8 in] distance to magnet)	
10	Firefighting gloves	17 (at 20 cm [8 in] distance to magnet)	
11	Firefighting gloves	3 (at 20 cm [8 in] distance to magnet)	
		Boots	
12	Firefighting boots HAIX	90 (at 40 cm [15.7 in] distance to magnet)	Steel cap included
13	Paramedic boots HAIX	90 (at 40 cm [15.7 in] distance to magnet)	Steel cap included
14	Emergency boots Rosenbauer	90 (at 40 cm [15.7 in] distance to magnet)	Steel cap included
		Firefighting Armatures	
15	Firefighting house coupling	<1 (at 10 cm [4 in] distance to magnet)	Snap ring is magnetic
16	Adapter piece B to C	<1 (at 10 cm [4 in] distance to magnet)	Snap ring is magnetic
17	Fog nozzle	0	Restriction in movement
		Helmets	
18	Paramedic and firefighting helmet	30 (at 30 cm [12 in] distance to magnet)	Attraction because of the sight
19	Firefighting helmet	0	
		Firefighting Belts	
20	Firefighting belt	0	

ers and paramedics. However, the spectrum of clothing and working-materials consists of more items and additional research is needed to gain a deeper understanding of which items can be considered as MR safe. Additional tests might display the need for an independent MRI system. There is a high risk to damage the system (e.g. to break the cover by attracted objects) and hospitals might not be willing to take the risk in the future.

Conclusions

Considering the results of this study, most of the clothing and working materials can be considered as MRI safe. However, the force of attraction of boots and helmets might be high enough to cause serious distraction for emergency personnel. There might be a high risk for emergency personnel to forget small items in their pockets which subsequently can act as dangerous projectiles. Additional tests might display the need for an independent MRI system. There is a high risk to damage the system (e.g. to break the cover by attracted objects) and hospitals might not be willing to take the risk in the future.

Abbreviations

(MRI): magnetic resonance imaging.

Competing Interests

The author declares no competing interests.

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