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Sudan University of Science and Technology

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Evaluation of Magnetic Resonance machines safety in Khartoum state

تقييم أمان أجهزة الرنين المغناطيسي في ولاية الخرطوم

A Thesis Submitted in Partial Fulfillment of the Requirements for the M.Sc. Degree in Medical Physics

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الآية

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

(أَمَّنْ هُوَ قَانِتٌ آنَاءَ اللَّيْلِ سَاجِدًا وَقَائِمًا يَحْذَرُ الْآخِرَةَ وَيَرْجُو رَحْمَةَ رَبِّهِ قُلْ هَلْ

يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لَا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُو الْأَلْبَابِ)

(الزمر 9)

Dedication

I WISH TO DEDICATE THIS THESIS WITH AFFECTION TO MY PARENTS SOULS. THEIR ENDLESS LOVE, KINDNESS, SUPPORT AND WISDOM WILL ALWAYS GUIDE MY JOURNEY …

TO MY BELOVED SISTER, TASNEEM, AND MY BROTHERS FOR THEIR SUPPORT …

TO MY FAMILY AND FRIENDS, FOR THEIR HUGE SUPPORT THROUGHOUT THIS JOURNEY …

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Abstract

Magnetic Resonance Imaging 'MRI' is one of the most important diagnostic techniques around the world. It gives high resolution to soft tissues. The MRI machines are costly, difficult to maintain, and need huge amount of time for maintenance. This study is conducted in Sudan, investigating ten medical centers in Khartoum state in period from June to November 2018 with different MR machines.

The critical measurements of superconductive machines showed a direct relation between the chiller temperature and compressor failure, also a direct relation between the workload/day and helium consumption/day. The results demonstrates the great effect of completing daily QC and of this study machines quarterly maintenance, on the reduction of the problems and failures associated with MR machines operating. Also shows that the lack of maintenance is one of the biggest problems in MRI department's, and that the economical and political situation of the country plays a major role in The study also compares the local centers' questionnaires with this matter. the international ones, finding that some of local centers don't have MRI safety questionnaire, and others ignored some important questions. This study concluded that the massive use of MR equipment and neglecting periodic maintenance are important factors in the breakdown of equipment.

المستخلص

التصوير بالرنين المغناطيسي أحد أهم الطرق التشخيصية حول العالم , فهو يعطي صور ذات وضوح عالي للأنسجة الرخوة , أجهزة الرنين المغناطيسي غالية الثمن وصعبة الصيانة وتحتاج الى زمنا طويل لصيانتها في حال حدوث أعطال, الهدف الأساسي من هذه الدراسة هو تقييم امان اجهزة الرنين المغناطيسي في الاستخدامات الطبية, أنجزت هذه الدراسة في السودان واستهدفت عشر مراكز طبيه في ولاية الخرطوم.

القياسات الحرجة للأجهزة فائقة التوصيل أظهرت علاقة مباشرة بين درجة حرارة المبرد وبين اعطال الكمبريسور , وأظهرت أيضا علاقة مباشرة بين عدد الحالات التي يتم تصويرها و إهلاك الهيليوم , كما أظهرت الدراسة الأثر الكبير لإجراء عمليات الصيانة الدورية وعمليات ضبط الجودة في تقليل أعطال أجهزة الرنين المغناطيسي , أظهرت الدراسة أن تأخير عمليات الصيانة أحد أكبر مشاكل أجهزة الرنين المغناطيسي ويعزى ذلك الى الأوضاع الاقتصادية والسياسية في السودان

قارنت الدراسة بين استمارات الأمان في مراكز السودان واستمارات الأمان في مستشفيات دولية خاضعة لمعايير السلامة الدولية , ووجدت أن استمارات بعض المراكز مستوفية للمعايير الدولية, والبعض ليس لديها استمارة أمان وبعضها تجاهلت أسئلة مهمة

خلصت الدراسة إلى أن اهلاك جهاز الرنين المغناطيسي وإهمال عمليات الصيانة عاملين مهمين في تعطل أجهزة الرنين المغناطيسي.

Table of contents

List of tables

List of figures

List of abbreviations

MRI	Magnetic Resonance Imaging
MR	Magnetic Resonance
SPSS	Statistical Package for Social Studies
QC	Quality Control
NMR	Nuclear Magnetic Resonance
NMRI	Nuclear Magnetic Resonance Imaging
CT	Computed Tomography
RF	Radio Frequency
NMV	Net Magnetization Vector
FID	Free Induction Decay
TR	Repetition Time
TE	Echo Time
ZBO	Zero Boil Off

Chapter one

Introduction

1.1 Introduction:

MRI, as similar to all medical imaging techniques, is a relatively new technology, originated during the year of 1946. Felix Bloch and Edward Purcell independently discovered the magnetic resonance phenomena during this year, and they were later awarded the Nobel Prize in 1952. Up until the 1970s MRI was being used for chemical and physical analysis. Then in 1971 Raymond Damadian showed that nuclear magnetic relaxation times of tissues and tumors differs from each other, motivating scientists to use MRI to study diseases. Accordingly, with the advent of computed tomography (using computer techniques to develop images from MRI information) in 1973 by Hounsfield, and echo-planar imaging (a rapid imaging technique) in 1977 by Mansfield, also with the efforts of many scientists over the next 20 years, MRI developed into the technology that we know today.(J.P. Hornak, 1996)

Perhaps one of the most exciting developments among these techniques was the advent of superconductors. These superconductors make the use of the strong magnetic fields possible in MRIs. Despite of all these developed technologies, the first MRI examination for humans did not occur until 1977. Since then, faster computing has made the MRI process much faster. The most significant advancement in MRIs occurred in 2003, when the Nobel Prize was won by Paul C. Lauterbur and Peter Mansfield, for their discovery of using MRIs as a diagnostic tool. (J.P. Hornak, 1996)

Nuclear magnetic resonance is intrinsically a quantum mechanical phenomenon. It deals with the dynamics of microscopic objects (atomic nuclei) that behave according to the seemingly curious (but well understood) laws of quantum mechanics. Fortunately, one doesn't need years of background study in quantum mechanics in order to appreciate and understand the essential elements of MRI. The reason is that MRI is invariably used to probe macroscopic objects, involving vast numbers of atomic nuclei. The collective behaviour of these nuclei usually washes out the oddities of quantum mechanics, leaving something that bears resemblance to a familiar problem in classical mechanics: the precession of a spinning top in the earth's gravitational field. It leads to a simple but powerful mathematical description of nuclear dynamics that accurately predicts the outcome of many experiments. In this sense it often provides a sufficient basis for developing intuition and interpreting experimental results. (Michael Hayden, etal, 2015)

Unfortunately, the perspective of many people, beginners and practitioners regarding NMR dynamics is alike, which is they tend to lose sight of the fact that the classical picture of NMR dynamics is simply an analogy: it is not a correct description of dynamics at the microscopic scale, and it can lead to nonsensical explanations of the underlying physics. Examples of situations in which the analogy has been carried too far can be found on popular websites purporting to explain NMR and MRI using pictures of toy tops or spinning charged nuclei."As a rule of thumb, caution is advised whenever such props are encountered. (Michael Hayden, etal, 2015)

This section is organized into two parts. The first part discusses the key factors that contribute to nuclear spin dynamics, leading to a set of phenomenological equations that encapsulate the essence of the classical description of the problem. These are the famous Bloch Equations. The second part then outlines the various means by which the practitioner interacts with the atomic nuclei, both in order to induce collective motions and to detect the resulting response. (Michael Hayden, etal, 2015)

1.2 Problem of study:

MR device is an important diagnostic imaging device, it is essential in the process of diseases investigation. Also MR device is sensitive and expensive. accordingly the breakdown of MRI machines cause significant delay on the diagnosis, and costs a lot of money and time.

1.3 Objectives:

1.3.1 General objective:

The general objective of this study is to evaluate Magnetic Resonance machines safety in Khartoum state.

1.3.2 Specific objectives:

The specific objectives is to evaluate

- safety for MR machines in Khartoum state, superconductive MR machines, and permanent MR machines.
- The local MRI safety questionnaire according to international hospitals.

1.4 Importance of this study:

This study will enhance the knowledge about MR machine safety, hence improve the health services, reduce the probability of faults, and saving a significant amount of replacement parts, engineers, and system downtime.

1.5 Thesis overview:

This dissertation contain five chapters, chapter one is the introduction, establishing the basis of this research, showing research problem, main objective, specific objectives, and the importance of study, chapter two Theoretical background, full explanation of physics and principles of MRI, discusses previous studies and researches that related to this subject, chapter three materials and methods, chapter four results, chapter five discussion, conclusion, recommendations, and Appendix .

Chapter two

Theoretical background

2.1 Nuclear magnetic resonance:

Nuclear magnetic resonance (NMR) is the spectroscopic study of the magnetic properties of the nucleus of the atom. The protons and neutrons of the nucleus have a magnetic field associated with their nuclear spin and charge distribution. Resonance is an energy coupling that causes the individual nuclei, when placed in a strong external magnetic field, to selectively absorb, and later release, energy unique to those nuclei and their surrounding environment. The detection and analysis of the NMR signal has been extensively studied since the 1940s as an analytic tool in chemistry and biochemistry research. NMR is not an imaging technique but rather a method to provide spectroscopic data concerning a sample placed in the device. (Westbrook.C etal 2011)

In the early 1970s, it was realized that magnetic field gradients could be used to localize the NMR signal and to generate images that display magnetic properties of the proton, reflecting clinically relevant information. As clinical imaging applications increased in the mid-1980s, the "nuclear" connotation was dropped, and magnetic resonance imaging (MRI), with a plethora of associated acronyms, became commonly accepted in the medical community. MRI is a rapidly changing and growing image modality. The high contrast sensitivity to soft tissue differences and the inherent safety to the patient resulting from the use of nonionizing radiation have been key reasons why MRI has supplanted many CT and projection radiography methods. With continuous improvements in image quality, acquisition methods, and equipment design, MRI is the modality of choice to examine anatomic and physiologic properties of the patient. There are drawbacks, including high equipment and siting costs, scan acquisition complexity, relatively long imaging times, significant image artifacts, and patient claustrophobia problems. (Westbrook.C etal 2011)

2.2 MRI physics:

All things are made of atoms , including the human body. Atoms are very small. Half a million lined up together are narrower than a human hair. Atoms are organized in molecules , which are two or more atoms arranged together. The most abundant atom in the body is hydrogen . This is most commonly found in molecules of water (where two hydrogen atoms are arranged with one oxygen atom, H_2O) and fat (where hydrogen atoms are arranged with carbon and oxygen atoms, the number of each depends on the type of fat). The atom consists of a central nucleus and orbiting electrons. Nuclei with an odd mass number (a different number of protons to neutrons) are important in MRI. (Westbrook.C etal 2011)

2.2.1 Motions in atom:

electrons moving on their own axis, electrons orbiting the nucleus, the nucleus itself moving about its own axis.

Figure 2.1 show the motions in atom

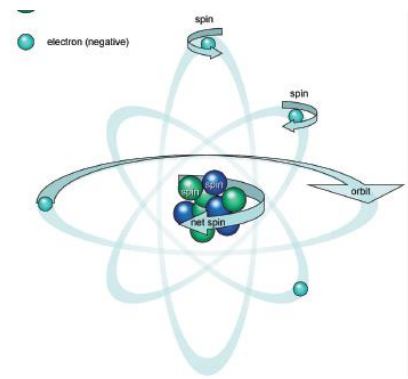


Figure 2.1 motions in atom

The principles of MRI rely on the spinning motion of specific nuclei present in biological tissues. This spin derives from the individual spins of protons and neutrons within the nucleus. Pairs of subatomic particles automatically spin in opposite directions but at the same rate as their partners. In nuclei that have an even mass number, i.e. the number of protons equals the number of neutrons, half spin in one direction and half in the other. The nucleus itself has no net spin. However, in nuclei with odd mass numbers, i.e. where the number of neutrons is slightly more or less than the number of protons, spin directions are not equal and opposite, so the nucleus itself has a net spin or angular momentum . These are known as MR active nuclei. MR active nuclei are characterized by their tendency to align their axis of rotation to an applied magnetic field. This occurs because they have angular momentum or spin and, as they contain positively charged protons, they possess electrical charge. The law of electromagnetic induction (set out by Michael Faraday in 1833) refers to three individual forces – motion, magnetism and charge – and states that if two of these are present, then the third is automatically induced. MR active nuclei that have a net charge and are spinning (motion), automatically acquire a magnetic moment and can align with an external magnetic field. (Westbrook.C etal 2011)

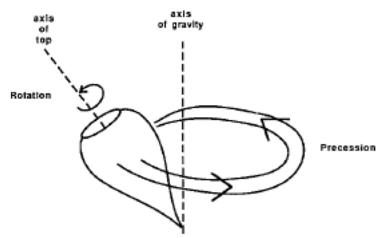
2.2.2 Hydrogen nucleus:

The isotope of the hydrogen nucleus is the MR active nucleus used in clinical MRI. This contains a single proton (atomic and mass number 1). In the classical interpretation the position of the hydrogen nucleus can be specified with any desired degree of precision, and its movements are assumed to be continuous and completely predictable. Each proton behaves as a small magnet with a magnetic moment that has both magnitude and direction . In a typical sample of hydrogen-containing material (such as the human body), the magnetic moments of the individual hydrogen nuclei are oriented in random directions. If a strong magnetic field is applied to the sample, the nuclei "align" their magnetic moments with the direction of the magnetic field in a manner similar to a compass needle aligned with the earth's magnetic field. The earth's magnetic field (0.5 gauss) is not strong enough to bring protons in a tissue sample into alignment. The field supplied by an MR system (e.g., 20,000 gauss) is strong enough to produce Alignment. (Hendee.w, etal, 2002)

2.2.3 Rotation and Precession:

In addition to aligning with a magnetic field, a magnetic moment also precesses about the field as shown in figure 2.2 . Precession is easily demonstrated in rotating objects (another reason why we infer the property of "spin" for protons). A spinning top, for example, will "wobble" about a vertical axis defined by the earth's gravitational field . This wobbling motion is precession. Precession is a type of motion that is distinct from rotation. Rotation is the spinning of an object about its axis (an imaginary line through the center of mass of the object). The rapid spin of a top that causes its surface to blur is rotation. Precession is a “second-order” motion. It is the “rotation of a rotating object.” (Hendee.w, etal, 2002)

2.2 Rotation and precession



2.2.4 The Larmor equation:

The value of the precessional frequency is governed by the Larmor equation. The Larmor equation states that:

$\omega_0 = B_0 \times \lambda$

where:

ω_0 i s the precessional frequency, B $_0$ is the magnetic field strength of the magnet, λ is the gyromagnetic ratio (Westbrook.C etal 2011)

2.2.5 Resonance:

Resonance is an energy transition that occurs when an object is subjected
to a frequency the same as its own. In MR, resonance is induced
by applying a radiofrequency (RF) pulse:

• at the same frequency as the precessing hydrogen nuclei;

• at 90° to B0.

This causes the hydrogen nuclei to resonate (receive energy from the RF pulse) whereas other MR active nuclei do not resonate because their gyromagnetic ratios are different from that of hydrogen. Owing to the Larmor equation their precessional frequency is different and therefore they only resonate if RF at their specific precessional frequency is applied.
(Westbrook.C, etal 2002)

2.2.5.1The results of resonance:

2.2.5.1.1 Energy absorption:

The hydrogen nuclei absorb energy from the RF pulse (excitation pulse). The absorption of applied RF energy at 90° to B0 causes an increase in the number of high energy, spin up nuclei as shown in figure 2.3 . If just the right amount of energy is applied the number of nuclei in the spin up position equals the number in the spin down position. As a result the NMV (which represents the balance between spin up and spin down nuclei) lies in the transverse plane as the net magnetization lies between the two energy states. As the NMV has been moved through 90° from B0, it has a flip or tip angle of 90° as shown in figure 2.4 .

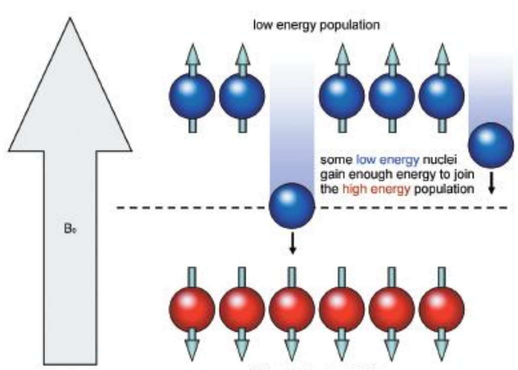


Figure 2.3 Energy transfer during excitation

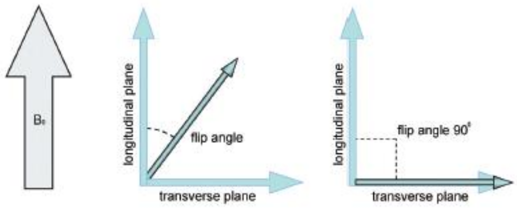


Figure 2.4 Flip angle

2.2.5.1.2 Phase coherence:

The magnetic moments of the nuclei move into phase with each other as shown in figure 2.5 . As the magnetic moments are in phase both in the spin up and spin down positions and the spin up nuclei are in phase with the spin down nuclei, the net effect is one of precession so the NMV precesses in the transverse plane at the Larmor frequency. (Westbrook.C, 2002)

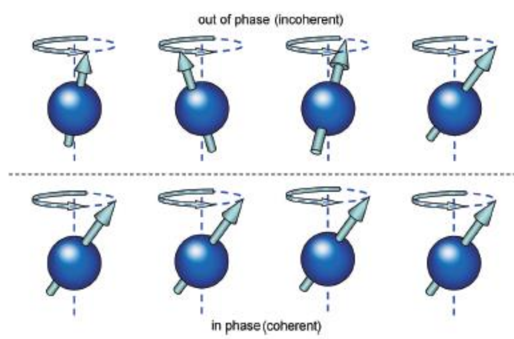


Figure 2.5 Phase coherence

2.2.6 The MR signal:

As a result of resonance, in phase or coherent magnetization precesses at the Larmor frequency in the transverse plane. Faraday ' s law of electromagnetic induction states that if a receiver coil or any conductive loop is placed in the area of a moving magnetic field as shown in figure 2.6 , i.e. the magnetization precessing in the transverse plane, a voltage is induced in this receiver coil. The MR signal is produced when coherent (in phase) magnetization cuts across the coil. Therefore the coherent moving transverse magnetization produces magnetic field fluctuations inside the coil that induce an electrical voltage in the coil. This voltage constitutes the MR signal. The frequency of the signal is the same as the Larmor frequency – the magnitude of the signal depends on the amount of magnetization present in the transverse plane . (Westbrook.C etal 2011)

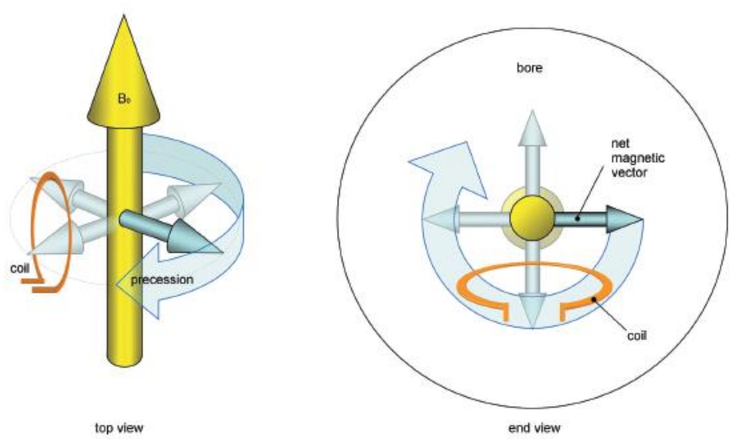


Figure 2.6 Generation of MR signal

2.2.7 The free induction decay signal (FID):

When the RF pulse is switched off , the NMV is again influenced by B_0 and it tries to realign with it. To do so, the hydrogen nuclei must lose the energy given to them by the RF pulse as shown in figure 2.7 . The process by which hydrogen loses this energy is called relaxation. As relaxation occurs, the NMV returns to realign with B_0 because some of the high - energy nuclei return to the low - energy population and align their magnetic moments in the spin - up direction.

• The amount of magnetization in the longitudinal plane gradually increases , this is called recovery .

• At the same time, but independently, the amount of magnetization in the transverse plane gradually decreases, this is called decay.

As the magnitude of transverse magnetization decreases, so does the magnitude of the voltage induced in the receiver coil. The induction of reduced signal is called the free induction decay (FID) signal. (Bushong.C etal 2015)

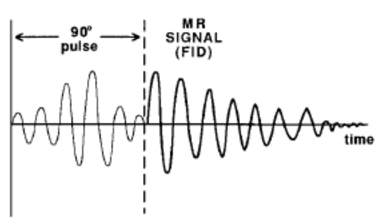


Figure 2.7 Free induction decay

2.2.8 Relaxation processes:

During relaxati on hydrogen nuclei give up absorbed RF energy and the NMV returns to B_0 . At the same time, but independently, the magnetic moments of hydrogen lose coherency due to de phasing. Relaxation results in recovery of magneti zation in the longitudinal plane and decay of magnetization in the transverse plane.

• The recovery of longitudinal magnetization is caused by a process termed T1 recovery, figure 2.8.

• The decay of transverse magnetization is caused by a process termed T2 decay, figure 2.9 . (Westbrook.C etal 2011)

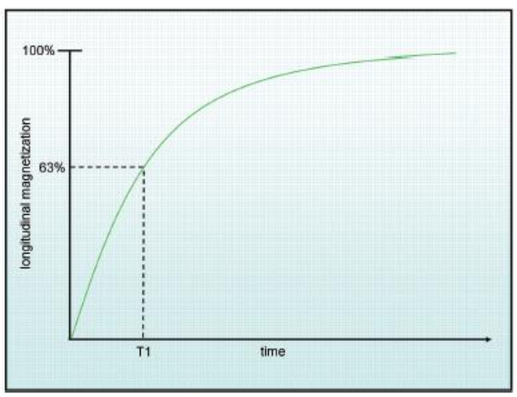


Figure 2.8 T1 recovery curve

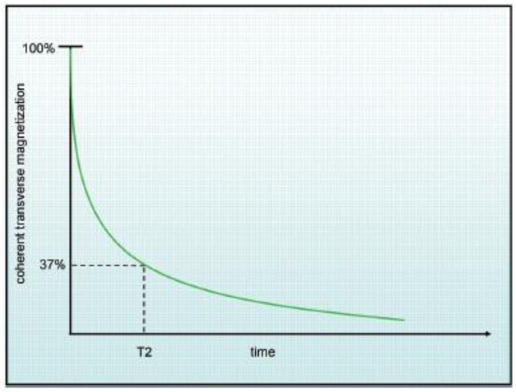


Figure 2.9 T2 decay curve

2.2.9 Pulse timing parameters:

• The repetition time (TR) is the time from the application of one RF pulse to the application of the next RF pulse for each slice and is measured in milliseconds (ms), figure 2.10 . The TR determines the amount of longitudinal relaxation that is allowed to occur between the end of one RF pulse and the applicat on of the next. TR thus determines the amount of T1 relaxation that has occurred when the signal is read. (Bushong.C etal 2015)

• The echo time (TE) is the time from the application of the RF pulse to the peak of the signal induced in the coil and is also measured in (ms), figure 2.10 . The TE determines how much decay of transverse magnetization is allowed to occur. TE thus controls the amount of T2 relaxation that has occurred when the signal is read(Westbrook.C etal 2011)

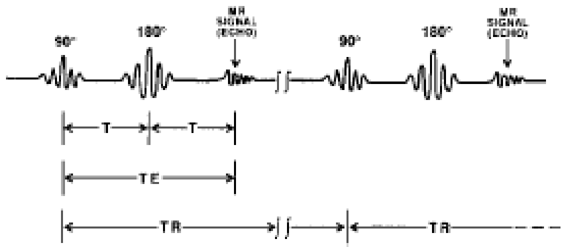


Figure 2.10 Pulse timing parameters

2.3 Magnets:

2.3.1 Permanent magnets:

Permanent magnets consist of ferromagnetic substances that have magnetic susceptibility greater than 1. They are easily magnetized and retain this magnetization . Examples of substances used are iron, cobalt and nickel. The most common material used is an alloy of aluminium, nickel and cobalt, known as Alnico. (Westbrook.C, etal,2002)

Advantages:

• They have open design; children, obese and claustrophobic patients are scanned with ease. Interventional and dynamic procedures are possible.

• They require no power supply and are therefore low in operating costs.

• The magnetic field created by a permanent magnet has lines of flux running vertically, keeping the magnetic field virtually confined within the boundaries of the scan room.

Disadvantages:

• They are excessively heavy; only low fixed field-strengths (0.2–0.3 T) can be achieved.

• Longer scan times are needed, due to lower field strengths.

2.3.2 Electromagnets:

Electromagnets utilize the laws of electromagnetic induction by passing an electrical current through a series of wires to produce a magnetic field . This physical phenomenon is utilized to produce RF coils and the static magnetic field.

2.3.2.1 Resistive magnets:

The magnetic field strength in a resistive magnet is dependent upon the current that passes through its coils of wire. The direction of the main magnetic field in a resistive magnet follows the right-hand thumb rule and produces lines of flux running horizontally from the head to the foot of the magnet.

Advantages:

• They are lighter in weight than permanent magnets.

• Capital costs are low.

Disadvantages:

• The operational costs of the resistive magnet are quite high due to the large quantities of power required to maintain the magnetic field.

• The maximum field strength in a system of this type is less than 0.3T due to its excessive power requirements. Therefore scan times are longer.

• The resistive system is relatively safe as the field can be turned off instantaneously. However, this type of magnet does create significant stray fringe magnetic fields. (Westbrook.C, etal 2002)

2.3.2.2. Superconducting electromagnets:

The resistance of the coils of wire is dependent upon the material of which the loops of wire are made, the length of the wire in the loop, the cross-sectional area of the wire and temperature. The latter can be controlled so that resistance is minimized.

As resistance decreases, the current dissipation also decreases. Therefore if the resistance is reduced, the energy required to maintain the magnetic field is decreased. As temperature decreases, resistance also decreases. As absolute zero of temperature (minus 273°C or 4°K) is approached, resistance is virtually absent, so that a high magnetic field can be maintained with no input power or driving voltage required. This is the basis of the function of the super cooled, superconducting magnet. The direction of the main magnetic field runs horizontally like that of the resistive system, from the head to the foot of the magnet. Initially, current is passed through the loops of wire to create the magnetic field or bring the field up to strength (ramping). Then the wires are supercooled with substances known as cryogens (usually liquid helium [He] or liquid nitrogen [N]), to eliminate resistance. Since He and N are stable, they can be placed in a vacuum so that they do not rapidly boil off or return to their gaseous state. This is called a cryogen bath and it actually surrounds the coils of wire and is housed in the system between insulated vacuums. (Westbrook.C, etal 2002)

2.3.2.2.1 Superconducting MRI magnet requirements:

The essential requirements for an MRI magnet are as follows:

* Field strength: The scanning speed and imaging resolution are proportional to this value because of the increase in signal-to-noise. This is the reason

higher and higher magnetic field strengths are considered, despite their technological challenges.

* Imaging volume: The larger the imaging region, the better. This does require a tradeoff owing to an increased cost.

* Field uniformity over the imaging volume: The greater the uniformity, the better. Non-uniformities should be due to the patient's image and the gradient coil used to reconstruct that image. The usual requirement is 5 ppm-15 ppm (parts per million) depending on the body region of interest being scanned.

* Field drift magnet persistence: The requirement here is less than 0.1 ppm per hour. This is a measure of the field stabilization.

* Loss of liquid helium: The "boil-off" of liquid helium must be less than 0.1L per hour. Currently, there is almost no loss throughout most of the main magnet systems, as the helium is recaptured through the 4K cryo-cooler re-condensing capability.

* External field shielding: The key here is the boundary outside of the magnet representing where the field has dropped off to 5 Gauss. This is usually described by a 5G line in its illustration.

* Diameter of the patient cylindrical access: This so-called bore size is usually 60 cm. However, 70 cm is increasingly the target to be used in North America, in view of the larger range of patient sizes.

* Length: The shorter, the better. The problem of claustrophobia has been a longstanding issue in the area of patient comfort.

* Weight: The limit on the weight of the magnet will depend upon the site conditions, the installation requirements, and the transportation capabilities. (Wang.z, etal, 2012)

2.3.2.3 Zero Boil-Off (ZBO) of a Cryogenic Propellant Tank:

Over the last decade zero boil off (ZBO) refrigeration system have become standard, allowing essentially unlimited normal operation without need for helium refill. Numerous future propulsion systems will utilize cryogenic propellants to improve performance. While the specific impulse is greatly increased over storable propellants, long duration missions can result in large amounts of propellant boil-off due to parasitic heat loads from the warm environment into the cold propellant tanks. Numerous studies have been conducted pointing out the overall system benefits from reduction of or elimination of this boil-off by refrigeration means. Since mechanical cryocoolers have now been established as high reliability systems, they represent a viable means to eliminate or reduce this boil-off. There are numerous approaches to employ cryocoolers for reduced boil-off. The optimum approach is system specific. These techniques include direct contact of the cryocooler cold tip with the tank wall, employment of a circulation loop to distribute the cooling over large surface areas or multiple tanks, or the employment of various Joule. (D. Frank, etal, 2007)

2.4 MRI system components:

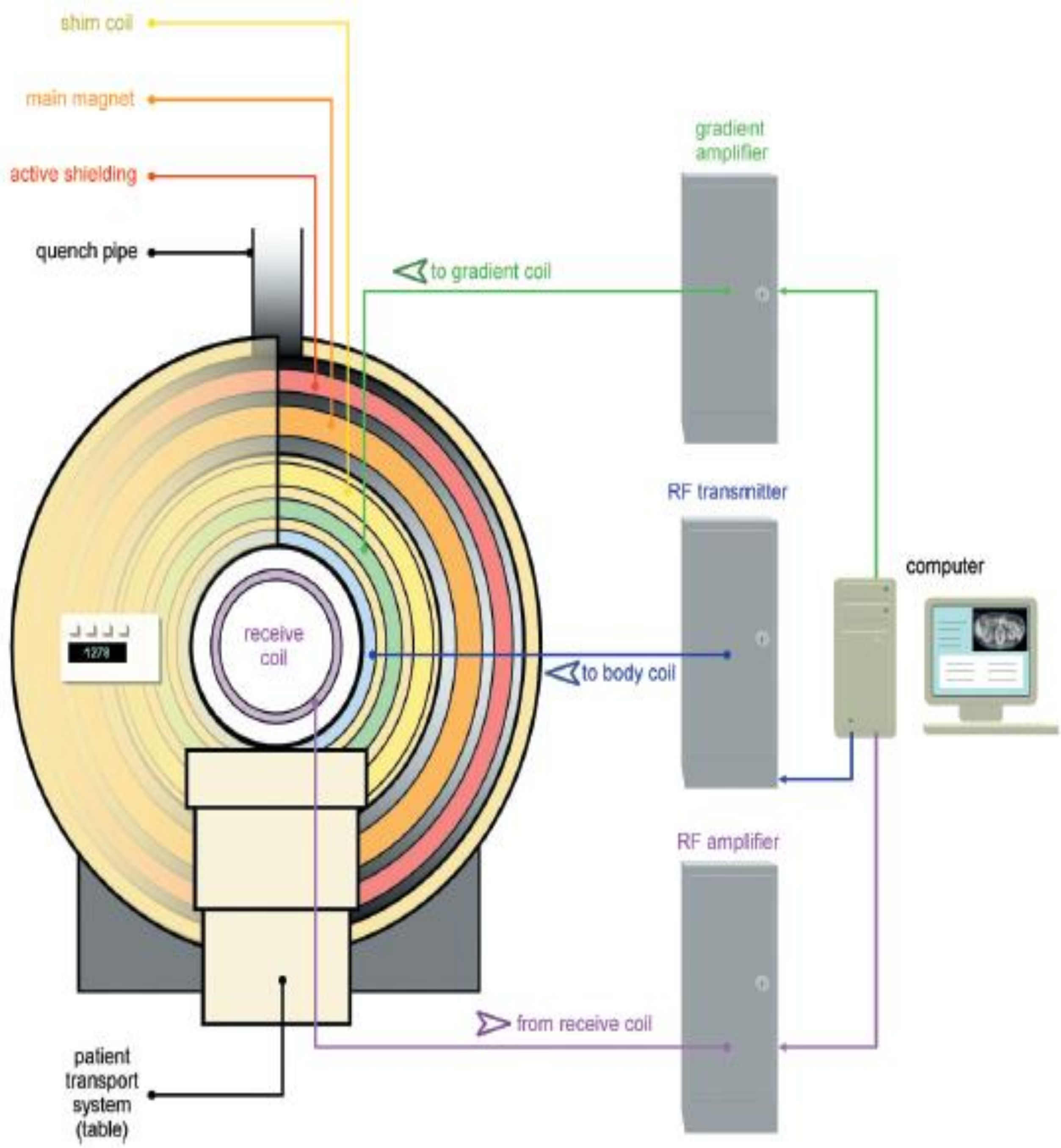


Figure 2.11 Closed bore MRI scanner in axial cross section

2.4.1 Magnetic shielding:

Magnetic shielding can significantly reduce the area affected by the fringe field. There are two methods of magnetic shielding – passive and active. Generally speaking active shielding implies current/activity, whereas passive shielding implies no current/passivity. Current standards state that shielding must restrict the fringe field to a limit of 5 G within the scan room (walls, floor and ceiling). (Westbrook.C etal 2011)

2.4.2 Shim coils:

Due to the tolerances of manufacture, an MRI superconducting magnet has field homogeneity of approximately 1000 ppm on delivery from the factory. Imaging requires homogeneity of approximately 4 ppm across the imaging volume to provide good geometric sharpness and to allow even spectral fat saturation. Spectroscopic procedures require better than 1 ppm. To achieve this, a process known as shimming is used, figure 2.11 . The term shimming comes from the discipline of carpentry where it refers to the use of wooden wedges (or shims) to level a surface. Like shielding, shimming can be achieved either actively or passively or by a combination of both. In the context of MRI, shimming makes the field even and is achieved by the use of metal discs/plates (passive shimming) and an additional solenoid magnet (active shimming). Passive shimming is achieved by placing small ferromagnetic plates in specially constructed non - ferrous metal trays located around the circumference of the warm bore of the magnet. This refers to the circumference of the *inner* wall of the cryostat, inside which are housed the shims, gradient coils and RF transmitter. These trays are typically 16 in number and each can hold about 15 shims. (Bushong.C etal 2015)

2.4.3 Gradient coils:

This is a cylindrical structure containing three individual electromagnets, figure 2.11 . On modern scanners this component also includes (for example) 18 individual solenoids that make up the active shim system. The gradient coils are each supplied by at least one, if not two, powerful amplifiers. As the gradient set is at room temperature (i.e. not superconducting) high - power gradients may require water - cooling. Each of the three components of the gradient set can be activated to create a slope in the static field in the x, y or z axes respectively. Gradient coils are used for spatial encoding and in certain imaging options such as GMN. In gradient echo sequences they are also used to re phase spins and produce echoes . (Westbrook.C etal 2011)

2.4.4 RF coils:

The instrumentation (hardware) required to achieve resonance is the RF coil assembly, figure 2.11 . which includes RF transmitter coils and RF receiver coils. Coils that transmit signals are known as RF transmit (or transmitter) coils, and those that detect signal are the RF receive (or receiver) coils. There are coils that both transmit and receive signal known as transceivers. (Westbrook.C etal 2011)

2.5 Superconducting MRI cooling Systems:

2.5.1 Cryogenic cooling system:

The process of creating an electromagnetic field initially involves passing current through the main superconducting coil of the scanner. This process is called ramping up. When the scanner is delivered and fixed in place, the magnetic field is ramped up by the service engineer. The temperature at which the niobium - titanium wire becomes superconducting is 4 K (Kelvin) (approximately − 269 ° C or − 450 ° F). To maintain superconductivity the current - carrying loops of wire are super - cooled with substances known as cryogens to eliminate resistance. Cryogens used in MRI include liquid helium (He) and in some cases liquid nitrogen (N). Helium is used to create superconductivity and, if two cryogens are used, nitrogen is used to keep the helium cold. The superconductive loops of wire are submerged in the cryogen. Helium is an increasingly rare resource that is extracted from natural gas. There are only a handful of helium - rich sites on the planet. When this is coupled with the fact that liquid helium boils away to gas fairly quickly at room temperature it becomes apparent that MRI scanners must be able to contain the helium in such a way as to prevent it being lost to the atmosphere.

This is achieved by the use of a cryostat, a stainless - steel tank configured in the shape of a hollow cylinder as shown in figure 2.12 . The inside of the cylinder contains layers known as heat shields, and the helium reservoir is isolated from the outer walls of the cryostat by an evacuated chamber (Westbrook.C etal 2011)

A cryogenic cooling system includes a cryocooler coldhead having a cold stage, figure 2.12 . A gas circulator has a low pressure input orifice and a high pressure output orifice, and a valve has a primary port and a secondary port. The valve makes and switches fluid connections between the valve's primary and secondary ports and the gas circulator's input and output orifices. A heat exchanger has a primary portion and a secondary portion each in thermal contact with the cold stage. The primary (secondary) regenerator is positioned between the primary (secondary) port of the valve and the primary (secondary) portion of the heat exchanger. A coolant flow

path has a first end in fluid communication with the heat exchanger's primary portion and a second end in fluid communication with the heat exchanger's secondary portion. The coolant flow path may be placed in thermal contact with a superconductive device. (Westbrook.C etal 2011)
The pressure involved generally range from approximately 100 psi to 500 psi (GE medical system 1997)

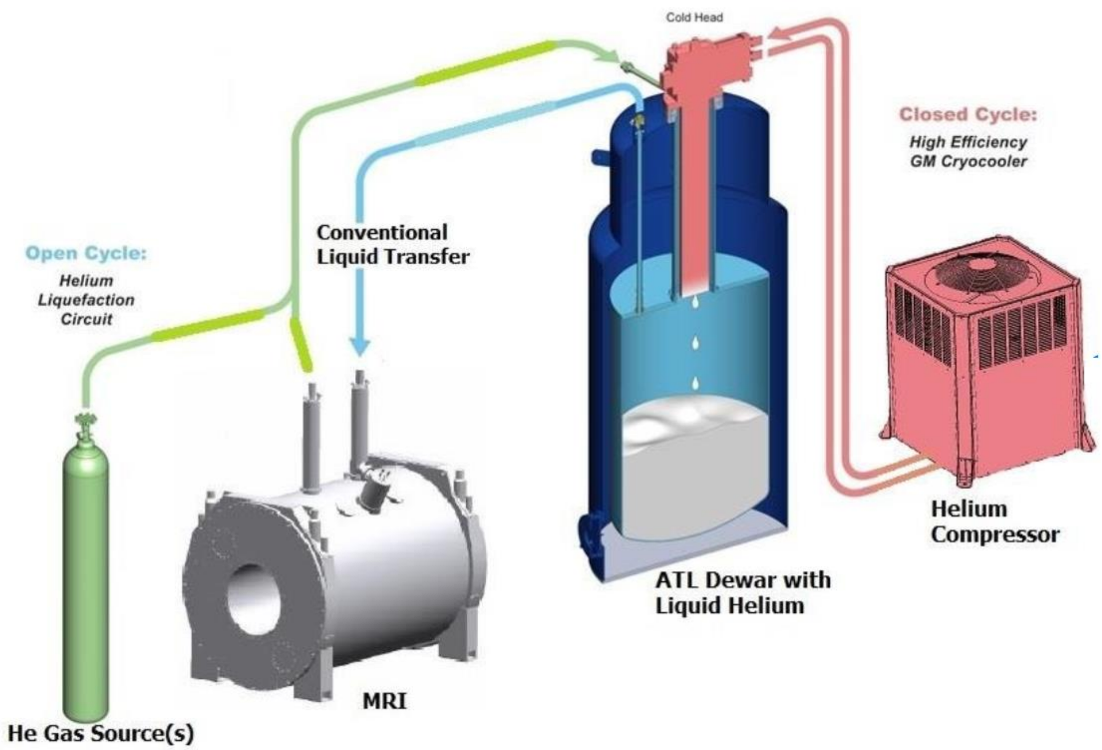


Figure 2.12 Cryogenic cooling system

2.5.2 Chiller Cooling System:

Medical chillers have a particularly complex job when it comes to keeping MRIs functional. As opposed to most cooling machines, a medical chiller isn't required to keep a constant temperature. The nature of an MRI's work is that it will experience periods of rest, and then suddenly ramp up to tremendous temperatures. The MR chiller must be able to meet a tremendous load immediately, then maintain a cool temperature over a stretch of time.

There are two principal types of medical chillers: air-cooled and water-cooled, figure 2.13 . Both have proven to be effective when dealing with MRI machines. The only difference is each machine transfers heat to different area. Water-cooled chillers transfer heat to a water source, while air-cooled chillers rely on the surrounding air to keep the MRI functioning at a high level. Air-cooled chillers, in particular, are helpful when there isn’t a constant, reliable water supply. (Wang.z, etal, 2012)

Chiller temperature normal range is from 5 ^{o}C to 27 ^{o}C (GE medical system 1997)

Figure 2.13 Chiller (outside components)

Figure 2.14 Chiller (inside components)

2.6 MRI Quality control:

Quality control is a series of distinct technical procedures that ensure the production of a satisfactory product, in this case, high-quality diagnostic images.

Four steps are involved:

1. Acceptance testing to detect defects in equipment that is newly installed or has undergone major repair
2. Establishment of baseline performance of the equipment
3. Detection and diagnosis of changes in equipment performance before they become apparent in images

4. Verification that the causes of deterioration in equipment performance have been corrected Acceptance testing should take place before the first patient is scanned and after major repairs. Major repairs include replacement or repair of the following subsystem components:

Gradient amplifiers, Gradient coils, Magnet, Radiofrequency (RF) amplifier, Digitizer boards, Signal processing boards, A baseline check should be carried out on the MRI system as a whole and on additional subsystems, such as repaired, replaced, or upgraded RF coils. All records should be kept at a central location near the MRI scanner(s). (ACR, 2015)

2.7 Potential Hazards and Risks:

Magnetic Field Risk The static magnetic field of the MRI system is exceptionally strong. A 1.5 T magnet generates a magnetic that is approximately 21,000 greater than the earth's natural field. In such an environment ferromagnetic metal objects can become airborne as projectiles. Small objects such as paper clips and hairpins have a terminal velocity of 40mph when pulled into a 1.5 T magnet and therefore pose a serious risk to the patient and anyone else in the scan room. The force with which projectiles are pulled toward a magnetic field is proportional to the mass of the object and distance from the magnet. Even surgical tools such as hemostats, scissors and clamps, although made of a material known as surgical stainless steel, are strongly attracted to the main magnetic field. Oxygen tanks, gurneys, floor buffing machines, and construction tools are highly magnetic and should never be brought into the scan room. However there are non-ferrous oxygen tanks and gurneys available, which are MRI compatible. Sand bags must also be inspected since some are filled, not with sand, but with steel shot which is highly magnetic. Consumer products such as pagers, cell phones, cameras and analog watches may be damaged by the magnetic field. Pacemakers may be reprogrammed or turned off by the magnetic field. The magnet field erases credit cards with magnetic strips. Patients with ferrous intra-cranial vascular clips may be at risk due to the possible movement of the clip. Figure 2.15 show Objects attracted to MRI machine . (Hoong Ng. K etal, 2003)

Figure 2.15 Objects attracted to MRI machine

Radio-frequency (RF) Field Risk The radio-frequency field may induce currents in wires that are adjacent or on the patient, causing skin burns. It may induce currents in intra-cardiac leads, resulting in inadvertent cardiac pacing. Prolonged imaging may cause the patient's core body temperature to rise. In practice, significant patient heating is only encountered in infants.

Due to the risk of RF current induced thermal burns:

* To minimize the risk of synthetic fibers in clothes acting as a current inducer, all patients having a MR exam must be changed into hospital provided clothing (gowns) prior to imaging.

* All patients having a MR exam must be padded during imaging in accordance to manufacturer guidelines to minimize skin to skin, and skin to magnet bore contact.

* All patients must be provided a working alert device (squeeze ball), to able to communicate with the MRI technologist during imaging when in distress.

Cryogen Risk During a planned or accidental shutdown of the magnetic field (aka "quench"), the liquid Helium in the magnet turns into gas and may escape into the scan room displacing the oxygen in the room leading to asphyxia. (Hoong Ng. K etal, 2003)

Biological Effects Due to Magnetic Field For the static magnetic fields currently used in MRI up to 2 Tesla, there are no known biological effects. The majority of studies show no effects on cell growth and morphology. Data accumulated by the National Institute for Occupational Safety, the World Health Organization, and the US State Department show no increased risk for leukemia or other cancer. Some reversible biological effects have been observed on human subjects exposed to 2.0 T and above. These effects include fatigue, headaches, hypotension and irritability. (Hoong Ng. K etal, 2003)

2.8 Quenching and Its Prevention:

Anomalous termination of magnet operation occurs in the abrupt change into the resistive state of the superconducting coil and is called “quenching.” Common causes resulting in a sudden transition to the quenching include an excessively large field within the magnet, a rapidly increasing rate of change of this field, or both. In rare cases, a defect in the magnet triggers rapid Joule heating, increasing the temperature of the encompassing regions, which are then forced into the resistive state. That change triggers a chain reaction of additional heating, and so on, until the magnet becomes completely quenched. Such a rapid transition is marked by a big, characteristic “bang,” as the energy converts to heat, and the cryogenic fluid boils off as shown in figure 2.17 . An accompanying, sudden decrease in current may cause spikes in the voltage, so while permanent damage to the magnet itself may be rare, localized heating and large mechanical forces pose a risk to its components as a result of the quench. (Wang.z, etal, 2012)

Quenching remains very difficult to eliminate completely, especially during the ramping training period when there are several mega joules of energy stored in the magnet and thousands of volts distributed throughout the layers. Accordingly, it is all too easy to break the insulation and potentially burn the magnet. The quench protection circuit is designed to protect the coil of the magnet and, in accordance with the IEC requirement, the magnetic field must be decreased to smaller than 200 gauss in no more than 20 seconds. Diode and resistance bridge networks are used for controlling the protection circuit, while quench heaters are used to avoid heat concentration. As an example, a full-field quench test has been performed in an All Tech environment, where the field has been shown to be decreased to 200 gauss in less than 15 seconds. Figure 2.16

shows the Centauri 1.5 T magnet quench trace when EMMU acts by CE test qualification. (Wang.z, etal, 2012)

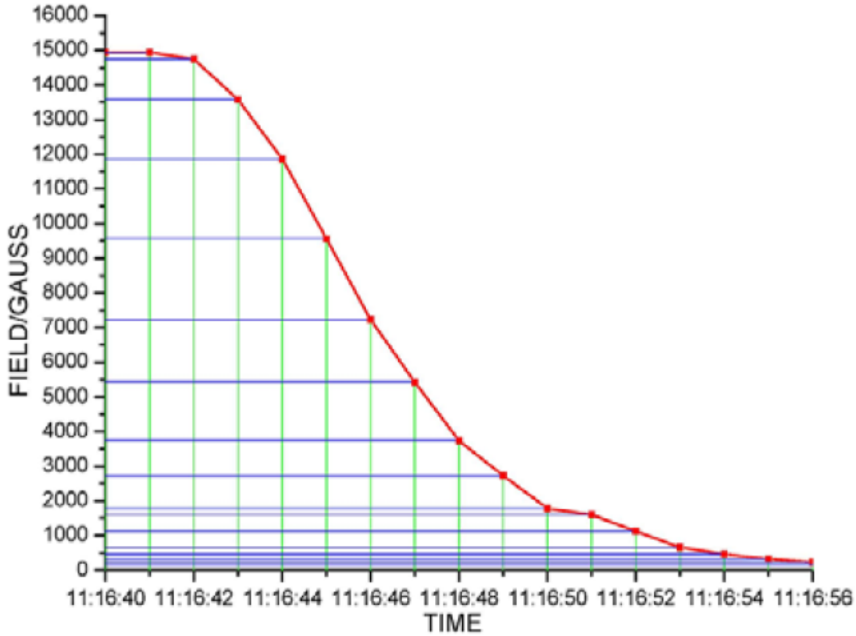


Figure 2.16 Magnet emergency quench test

Figure 2.17 MRI quenching

Figure 2.18 MRI quench pipe

2.10 Previous studies :

Marwa 2013 studied the MRI risks and knowledge of persons whom dealing with it about that risks and level of applications of the safety preparations. The study was done in Khartoum state and it applied on three diagnostic centers. The questionnaire was directed toward center groups (36 patients with different gender and age, 15 technicians, 6 managers, and 5 house workers). The study shows that the knowledge of both technologists and house workers about safety applications and using was (100%), but the using of safety application by managers was (50%), The patients knowledge about the safety applications was (68.8%), but (75%) of them didn't had an explanation of safety applications by the technicians. At the level of centers some of them didn't have the most simple safety preparation which is the personal data from that filled by the patients.

Shaza 2011 evaluated the national safety form in MRI centers as well as to compare the national safety forms with the international one. The study was done in Khartoum state and Madani state . The samples of the study was 50 patients from both gender with different ages and examinations. All patients were asked to fill and answer the national idea safety form before their examination, this to ensure the application of the safety procedures. The national MRI form were compared with the international one, so as to be able to evaluate what was applied in MRI departments in Sudan. Analysis showed that (32%) had prior surgery, (6%) had eye involving metallic objects, (20%) were injured by foreign body, (20%) were suspected to be pregnant, (14%) had external and internal metallic objects, (36%) of the sample with hearing aid and were examined by MRI, (6%) had cardiac peacemaker, (6%) had cochlear implant and implanted hearing aid, (2%) had metallic fragments and foreign body were not examined by MRI.

The study concluded that this application was not filling full by the international safety procedures guide lines.

Gould 2008 studied the comprehensive MRI safety for any health care provide with a zero tolerance for MRI errors. The study was built on three basic steps (Assess the hazard, Establish best practices in MRI suite safety and patient care, Educate and train all physicians, clinic and hospital staff working in the MRI suite) . Maintain an operator's manual for the suite's MRI machines in control room. The manual should include all manufacturers' bulletins and advisory information as well as a long sheet to document updates for equipment and software. Maintain an MRI safety manual for operations and protocols in the control room include all safety training documentation for MRI staff and attending physicians, noting MRI safety education levels and dates of certification and acceptance by MRI director or radiologist.

MRI suites should be designed to restrict access and limit exposure to static magnetic field. Commonly MRI suites restrict access by zone (1) open to general public access, Zone (2) this is the first interaction site for patients, visitors, attending physician and other with the technologist and nursing staff in the MRI suite. Zone (3) is the entry zone to the MRI machine room. Zone (4) is the MRI room should have clear demarcation of the five-gauss line taped or patient on the MRI suite floor indicating the area beyond which require MRI-safe (for the distance and tesla rating of the MRI) or MRI conditional equipment or instrumentation.

All MRI staff must take responsibility for providing an MRI safe environment for staff and patient.

E.Kanal 1996 studied the Magnetic Resonance Imaging (including spectroscopy, conventional, and fast imaging techniques) have been in use for over a decade and are viewed as a medical procedures associated with acceptable and well controlled risks. Technological advances in MRI (higher static field, faster gradients, stronger RF transmitter) have occurred rapidly, and many questions regarding the safety of these developments remain unanswered. This study provides an introduction to some of the safety concerns associated with MRI, the most immediate danger associated magnet with the environment is the attraction between the magnet and ferromagnetic metal objects. Ferromagnetic metal objects can become airborne projectile when placed on strong magnetic field. The strength of the field increases super linearly with distance from the magnet bore and even hand-held objects can be jerked free very suddenly as the holder moves closer to the magnet (small objects, such as paper clips and hairpins, have terminal velocity of 40 mph when pulled in to a 1.5T magnet. In addition to possibility of severely injuring someone, it is not good for the magnet to be bombarded with difficult to remove small metal “missiles”. Remember, even when you are not scanning, the magnet is not “off “. Never bring any metal objects in to the scanner rooms.

They found the dangers effects in (Metal in the body, gradient magnetic fields, acoustic noise, RF electromagnetic fields, electrical burns, pregnancy).

Chapter Three

Materials and Methods

3.1 Materials:

3.1.1 MR machines in the hospitals where the study was done

Table 3.1 show MR machines in the hospitals where the study was done

Company	Magnetic field	Number
SIEMENS	0.2 T	2
SIEMENS	0.35 T	1
SIEMENS	1.5 T	2
PHILEPS	1.5 T	1
TOSHIBA	1.5 T	3
GE	1.5 T	1

3.1.2 National and international MRI safety forms:

National MRI safety form samples was taken from local hospitals and international safety forms was taken from internet.

3.2 Method:

3.2.2 Method of data collection:

In this study, data was collected using several techniques in order to fulfill the main objectives of the study:

Questionnaires: MRI technologists were asked to fill questionnaire (see A and B in the appendix) the questionnaire was designed according to the study objectives, in order to evaluate the safety procedures applied, and to identify the most common sources of damage affecting MRI machines, first part of questionnaire deals with personal information, second part deal with MR machine and measurements related to machine in order to compare them with the tolerance, chiller temperature taken from the chiller, compressor pressure taken from the compressor indicator, Helium consumption\ day and work load\ day were taken from the records, and third part deal with maintenance operations. Hospital's safety forms were collected in order to compare them with the international forms that collected from internet .

3.3 Data analysis method:

The data was analyzed by using Statistical Package for Social Studies (SPSS), to verify the hypotheses of the study.

Chapter four

Results

Super conductive devices

Table 4.1 show manufacture companies for MR machines

Company	Number
Philips	1
Toshiba	3
Siemens	2
GE	1

Table 4.2 show the age of MR machines

Categories	Number
<5	1
5 and <10	5
>10	1

Table 4.3 show Chiller temperature of MR machine

Temperature	Percentage%
$<5^{o}$ C	20.0
5^{o} C and < 10^{o} C	30.0
10^{o} C and < 15^{o} C	20.0
15^{o} C and > 15^{o} C	30.0

Table 4.4 show compressor pressure of MR machine

Pressure	Percentage%
< 200 psi	10.0
200-250 psi	30.0
250-300 psi	30.0
300 and >300 psi	30.0

Table 4.5 show Helium Consumption/day for MR machine

Categories	Percentage%
< 0.5%	50.0
0.5% - 1.0%	20.0
> 1.0%	30.0

Table 4.6 show work load / day for MR machine

Categories	Percentage%
< 20	0.0
20 and < 40	40.0
40 and >40	60.0

Table 4.7 show software problems for MR machines

Occurs	Percentage%
Yes	60.0
No	40.0

Table 4.8 show reasons of chiller problems for MR machines

Reason	Percentage%
Chill water flow	60.0
Chiller direction with air direction	20.0
Fans problems	10.0
Didn't happen	10.0

Table 4.9 show compressor failure occurs for MR machines

Occurs	Percentage%
Yes	60.0
No	40.0

Table 4.10 show quench occurs for MR machines

Occurs	Percentage%
Due to emergency case	0.0
Due to high temperature	30.0
Didn't happen	70.0

Table 4.11 show RF station problems occurs for MR machines

Occurs	Percentage%
Yes	30.0
No	70.0

Table 4.12 show occurs of faults caused by patient or what he/she carries for MR machines

Occurs	Percentage%
Yes	60.0
No	40.0

Table 4.13 show reasons of table faults for MR machines

Reason	Percentage%
Over load	30.0
Things fell from patient	0.0
Both	20.0
Didn’t happen	50.0

Table 4.14 show availability of nonmagnetic assistance tools in the hospital

Availability	Percentage%
Yes	20.0
No	80.0

Table 4.15 show completion of daily QC for MR machines

Occurs	Percentage%
Yes	10.0
No	90.0

Table 4.16 show presence of permanent engineer in hospital

Presence	Percentage%
Yes	60.0
No	40.0

Table 4.17 show completion of quarterly maintenance for MR machines

Occurs	Percentage%
Yes	50.0
No	50.0

Table 4.18 show companies response when faults occurs for MR machines

Response	Percentage%
Good	20.0
Intermediate	40.0
Bad	40.0

Table 4.19 show duration of maintenance comparing with faults occurring to MR machines

Duration	Percentage%
Appropriate	0.0
Inappropriate	100.0

Permanent devices

Table 4.20 show the age of MR machines

Categories	Number
<5	0
5 and <10	1
>10	2

Table 4.21 show software problems for MR machines

Occurs	Percentage%
Yes	70
No	30

Table 4.22 show RF station problems occurs for MR machines

Occurs	Percentage%
Yes	70
No	30

Table 2.23 show occurs of faults caused by patient or what he/she carries

Occurs	Percentage%
Yes	40
No	60

Table 2.24 show reasons of table problems for MR machines

Reason	Percentage%
Over load	28.6
Things fell from patient	42.9
Both	0.0
Didn't happen	28.6

Table 4.25 show availability of nonmagnetic assistance tools in hospital

Availability	Percentage%
Yes	33.3
No	66.6

Table 4.26 show completion of daily QC for MR machines

Occurs	Percentage%
Yes	33.3
No	66.6

Table 4.27 show presence of permanent engineer in hospital

Presence	Percentage%
Yes	33.3
No	66.6

Table 4.28 show completion of quarterly maintenance foe MR machines

Occurs	Percentage%
Yes	33.3
No	66.6

Table 4.29 show companies response when faults occurs for MR machines

Response	Percentage%
Good	0.0
Intermediate	33.3
Bad	66.6

Table 4.30 show duration of maintenance comparing with faults occurs for MR machines

Duration	Percentage%
Appropriate	0.0
Inappropriate	100.0

Chapter five

Discussion, Conclusion, and Recommendations

5.1 Discussion:

The study shows that the MR machines in Sudan are divided into two parts, 70% are superconductive devices and 30% are permanent devices
Most technicians have post graduate degrees

For superconductive machines from table (4.1) we find that one of the machines are from Philips company, three are from Toshiba company, two are from Simeans company, and one is from GE company. From table (4.2) we find that one of machines are less than 5 years old, five are 5 and less than 10 years old, and one is more than 10 years, from this we conclude that the machines are relatively modern. From table (4.3) according to the measures of chiller's temperature, we find that, 20% are less than 5^{o} C , 30% are 5^{o} C and less than 10^{o} C , 20% are 10^{o} C and less than 15^{o} C , and 30% are 15^{o} C and more than 15^{o} C. Note that there is a convergence between measurement's categories, and all of them are within the normal range. From table (4.4) we find that from the measures of compressor pressure, 10% are less than 200 psi, 30% are between 200 psi and 250 psi, 30% are between 250 psi and 300 psi, and 30% are 300 psi and more. Note that there is a convergence between measurements' categories, and all of them are within the normal range. From table (4.5) according to the measures of Helium consumption/day, we find that, 50% are less than 0.5%, 20% are between 0.5% and 1.0%, and 30% are more than 1.0%. From table (4.6) according to the study of workload\day, we find that, 40% of the MRI machines receive 20 to 39 patients per day, while 60% of them receive 40 patients and more per day. From table (4.7) showing the occurring of Software problems, we find that 60% of MR machines had software problems, while 40% of them didn’t have software problems. From table (4.8) we find that the main reason behind chillers problem in 60% of chillers is chill water flow, in 20% of them is chiller position against wind flow, in 10% of them is fans problems, while in 10% of them didn’t have any chillers’ problems. From table (4.9) we find that 60% of the machines experienced compressor failure, while 40% of them didn’t. From table (4.10) we find that the quench occurs just in 30% of the machines, due to the high temperature, while it didn't occur in 70% of them. No emergency quench case was recorded. From table (4.11) we find that 30% of the machines experienced RF station problems, while 70% didn't. From table (4.12) we find that the faults in machines caused by patients or what he/she carries occurred in 60% of the cases, while in 40% of them didn’t occur. From table (4.13) we find that 30% of table faults happen due to patient overweight, 20% due to overweight and things fell from patients, and in 50% of the cases no problems occurred. From table (4.14) we find that the nonmagnetic assistance tools are available in 20% of the cases, while in 80% of them aren't available. From table (4.15) we find that just 10% of the hospitals completed daily QC, while 90% didn’t. From table (4.16) we find that 60% of the hospitals have a permanent engineer, while 40% don't have. From table (4.17) we find that 50% of the hospitals completed the quarterly maintenance, while 50% didn’t . From table (4.18) we find that the company or response when faults occurs is good in 20% of the cases, intermediate in 40% of them, and is bad in 40% of the cases. From table (4.19) we find that the duration of maintenance comparing with the faults occurring is 100% inappropriate in all the cases, specially when the problem demands the need for spare parts.

- The results showed a direct relation between completion of daily QC an quarterly maintenance of the machines as independent variables and the faults in superconductive machines as dependent variable.
- The results showed a direct relation between the chiller temperature as an independent variable and compressor failure as a dependent variable.
- Also the results showed a direct relation between the workload \ day as an independent variable and the helium consumption\day as a dependent variable.

For permanent devices from table (4.20) we find that one of devices is 5 to 10 years old, and two are more than 10 years old. Some machines have already been used before they where used in Sudan.

From table (4.21) we find that, 70% of the machines experienced software problems, while 30% of them didn't experience that. From table (4.22) we find that, 70% of the machines experienced RF station problems occurrence, while 30% of them didn't experience that. From table (4.23) we find that, 40% of the experienced occurrence of faults caused by patient or what he/she carries, while 60% of them didn't experience any faults occurrence. From table (4.24) we find that 28.6% of table problems occurred due to patient overweight, 42.9% due to things fell from patients, and in 28.6% of the cases no problems occurred. From table (4.25) we find that the nonmagnetic assistance tools are available in 33.3% of the cases, while in 66.6% of them aren't available. From table (4.26) we find that, 66.6% of hospitals didn't completed daily QC, and 33.3% didn't. From table (4.27) we find that, 33.3% of the hospitals have permanent engineer, and 66.6% of the hospitals don't have. From table (4.28) we find that 33.3% of the hospitals completed the quarterly maintenance, while 66.6% didn't. From table (4.29) we find that company or response when faults occurs is intermediate in 33.3% of them, and bad in 66.6% of them. From table (4.30) we find that the duration of maintenance comparing with the fault occurring is inappropriate in 100% of the cases.

For comparing the results of superconductive with permanent ,the RF station problems occur in permanent machines more than in the superconductive machines. The assistance nonmagnetic tools are not sufficiently available in both machines, this may increases the probability of machine damage when using it for case of ICU patients or patients using wheel chair

In both machines, it was proven that, if daily QC is performed, the risk associated with machines operation can be remedied. In both machines, the duration of maintenance is frequently inappropriate, this is due to the lack of direct agents of MR machines' companies in Sudan, also it is due to the lack of spare parts.

For MRI safety questionnaire 50% of the study centers have MRI safety questionnaire, while 50% don't have, and the technician depends only on the oral question. When comparing the local safety questionnaires with the international ones, we find that 60% of the questionnaires are fairly close to the international questionnaires, 20% of the safety questionnaires don't cover the important aspects of International MRI safety guidelines, and 20% of the centers don't have safety questionnaires specially for MRI machines, they are only satisfied with one question among the general questionnaire of radiology department. And 20% of the centers don't have safety questionnaires, although they are using superconductive machines. All questionnaires are attached in appendix.

5.2 Conclusion:

This study designed to identifying the most common faults associated with MRI machines, their frequency of occurrence, and determining the main reasons behind them in Khartoum state. In superconductive machines, critical measurements were done, and a direct relation between the chiller temperature and compressor failure was found. Also a direct relation between the workload \ day and helium consumption \ day was established.

The results of this study demonstrated the great effect of completing daily QC and machines quarterly maintenance on the reduction of the problems and failures associated with MR machines operating. Also shows that the lack of maintenance is one of the biggest problems in MRI departments, and that the economical and political situation of the country plays a major role in this matter. The study compared the local safety questionnaires with the international one, it was found that, some of local centers don't have MRI safety questionnaire, and some centers ignored important questions.

This study concluded that the massive use of MR equipment and neglecting periodic maintenance are important factors in the breakdown of equipment.

5.3 Recommendations:

- Establish proper design of the MRI rooms according to the global standards, in order to contain MR machines and its accessories.
- The engineers must select properly the position and direction of chiller against air direction before installation, and use number of cooling units as backup in case of one fails.
- from the beginning, make sure to provide the total cost of MR machine including all its accessories, in order to avoid excluding any important accessories later.
- Completion of periodic maintenance to prevent chiller problems, taking into consideration the environmental conditions of the area in which the MRI machine is placed, in order to save sufficient amount of spare parts, engineers, and system downtime.
- In the future, it is recommended to focus on zero boil off (ZBO) refrigeration systems, it allows essentially unlimited normal operation of the machines without any need for helium refill.

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Appendix

MRI machines safety in Sudan

*The questionnaire aim to identify the causes of the equipment failures and their frequency.

*Answers will be used for scientific research purposes only.

* The questionnaire includes a set of statements, some require a mark (/) in selected answer, and some require direct answers.

Personal data:

Age: ....

Experience: ....

Academic qualification: BSc ☐ MSc ☐ PhD ☐

Questions related to MRI machine:

Company: ....

Magnetic field: ....

Age: ....

Measurements related to MRI machine:

Chiller temperature: ....

Compressor pressure: ....

Helium consumption \ day: ....

Work load \ day: ....

MRI machine faults:

Software problems: Yes ☐ No ☐ Frequency ☐

Causes of chiller failure: Chill water flow ☐ Chiller direction with air direction ☐

Other ☐ Didn't happen ☐

Compressor failure: Yes ☐ No ☐

A. Superconductive machines questionnaire

Quench: Due to emergency case ☐ Due to high temperature ☐

Didn't happen ☐

Has there been any problem in RF station? Yes ☐ No ☐

Has there any failure caused by the patient or what he carries? Yes ☐ No ☐

Causes of table failure: Over load ☐ Things fell from patient ☐

Both ☐ Didn't happen ☐

Nonmagnetic tools (tables- well chair- oxygen cylinder…etc.) available in hospital?

Yes ☐ No ☐

Are daily QC tests done? Yes ☐ No ☐

Maintenance:

Is there permanent engineer in the hospital? Yes ☐ No ☐

Are quarterly maintenance done? Yes ☐ No ☐

Company response when a failure occurs? Good ☐ Intermediate ☐ Bad ☐

Maintenance duration comparing with the failure: Appropriate ☐ Inappropriate ☐

A. Superconductive questionnaire

MRI machines safety in Sudan

*The questionnaire aim to identify the causes of the equipment failures and their frequency.

*Answers will be used for scientific research purposes only.

* The questionnaire includes a set of statements, some require a mark (/) in selected answer, and some require direct answers.

Personal data:

Age: ....

Experience: ....

Academic qualification: BSc ☐ MSc ☐ PhD ☐

Questions related to MRI machine:

Company: ....

Magnetic field: ....

Age: ....

MRI machine faults:

Software problems: Yes ☐ No ☐ Frequency ☐

Has there been any problem in RF station? Yes ☐ No ☐

Has there any failure caused by the patient or what he carries? Yes ☐ No ☐

Causes of table failure: Over load ☐ Things fell from patient ☐

Both ☐ Didn't happen ☐

Nonmagnetic tools (tables- well chair- oxygen cylinder…etc.) available in hospital?

Yes ☐ No ☐

Are daily QC tests done? Yes ☐ No ☐

B. Permanent machines questionnaire

Maintenance:

Is there permanent engineer in the hospital? Yes ☐ No ☐

Are quarterly maintenance done? Yes ☐ No ☐

Company response when a failure occurs? Good ☐ Intermediate ☐ Bad ☐

Maintenance duration comparing with the failure: Appropriate ☐ Inappropriate ☐

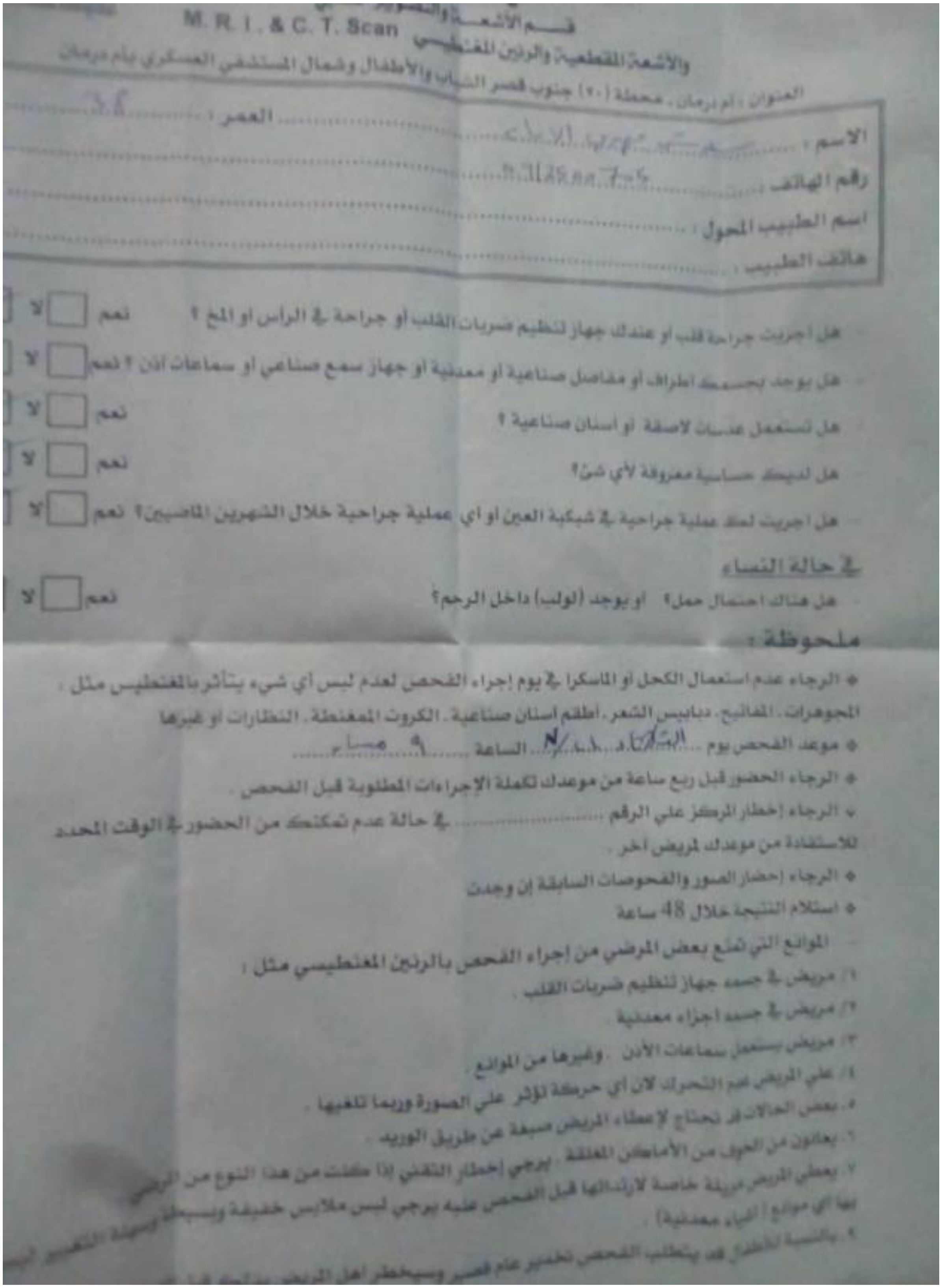
B. Permanent machines questionnaire

A list of casesthat is inconsistentwithmagnetic resonance imaging, which occurswithoverlappingimaging deviceresultingnegativelyas a result ofthe examination.
Pleaseansweryes or noin front ofallof the itemsbelow:

Have you been plantingor install:	Yes	No
pacemaker inside the body?		
Deviceregulatorheartfibrillation?		
Internalshell?		
Audio?		
Toolstabilize the spine?		
Toolmergeparagraphs?		
Metalvalveof the heart?		
Any kind ofsurgicalclampsorAlclaibsat?		
Extarterial?		
Prosthesesordetailedindustrial?		
Denturesorteethmovingindustrial?		
Contraceptiveintra-uterineorvaginal(screw)?		
Anyhairextensionsfor the purpose ofadornment(hair accessories)?		

CAUTION:
Magnetic resonancedevicewill issuecontinuous roadsvotes, the voteshave nothing to doanimatedobjects, Fargoto be carelessand do not worrystayfixedwithoutmovementduringthe examination.Anymovementwillleadtothe abolition ofexamination
Date:__/___/___Name:_________Age/weight: ______
I herebydeclare thatthe above answersare correctandI have seenthe contents of theabsorbedrocked
(Examination may be delayed for the given deadlines of yourselves y ou please wait)
Exam maybe need anjcation ?
Phone Number: ______________________________
Signature.............................

C. National MR safety form



M. R. I. & C. T. Scan

قسم الأشعة والأشعة المقطعية والرنين المغنطيسي

وشمال المستشفى العسكري بأم درمان

العنوان : أم درمان ، محطة (٢٠) جنوب قصر الشباب والأطفال

الاسم : .... العمر : ....

رقم الهاتف : ....

اسم الطبيب المحول : ....

هاتف الطبيب : ....

- هل اجريت جراحة قلب او عندك جهاز لتنظيم ضربات القلب أو جراحة في الراس او المخ ؟ نعم ☐ لا ☐
- هل يوجد بجسمك اطراف أو مفاصل صناعية او معدنية او جهاز سمع صناعي او سماعات اذن ؟ نعم ☐ لا ☐
- هل تستعمل عدسات لاصقة او اسنان صناعية ؟ نعم ☐ لا ☐
- هل لديك حساسية معروفة لأي شئ؟ نعم ☐ لا ☐
- هل اجريت لك عملية جراحية في شبكية العين او اي عملية جراحية خلال الشهرين الماضيين؟ نعم ☐ لا ☐

في حالة النساء

- هل هناك احتمال حمل؟ او يوجد (لولب) داخل الرحم؟ نعم ☐ لا ☐

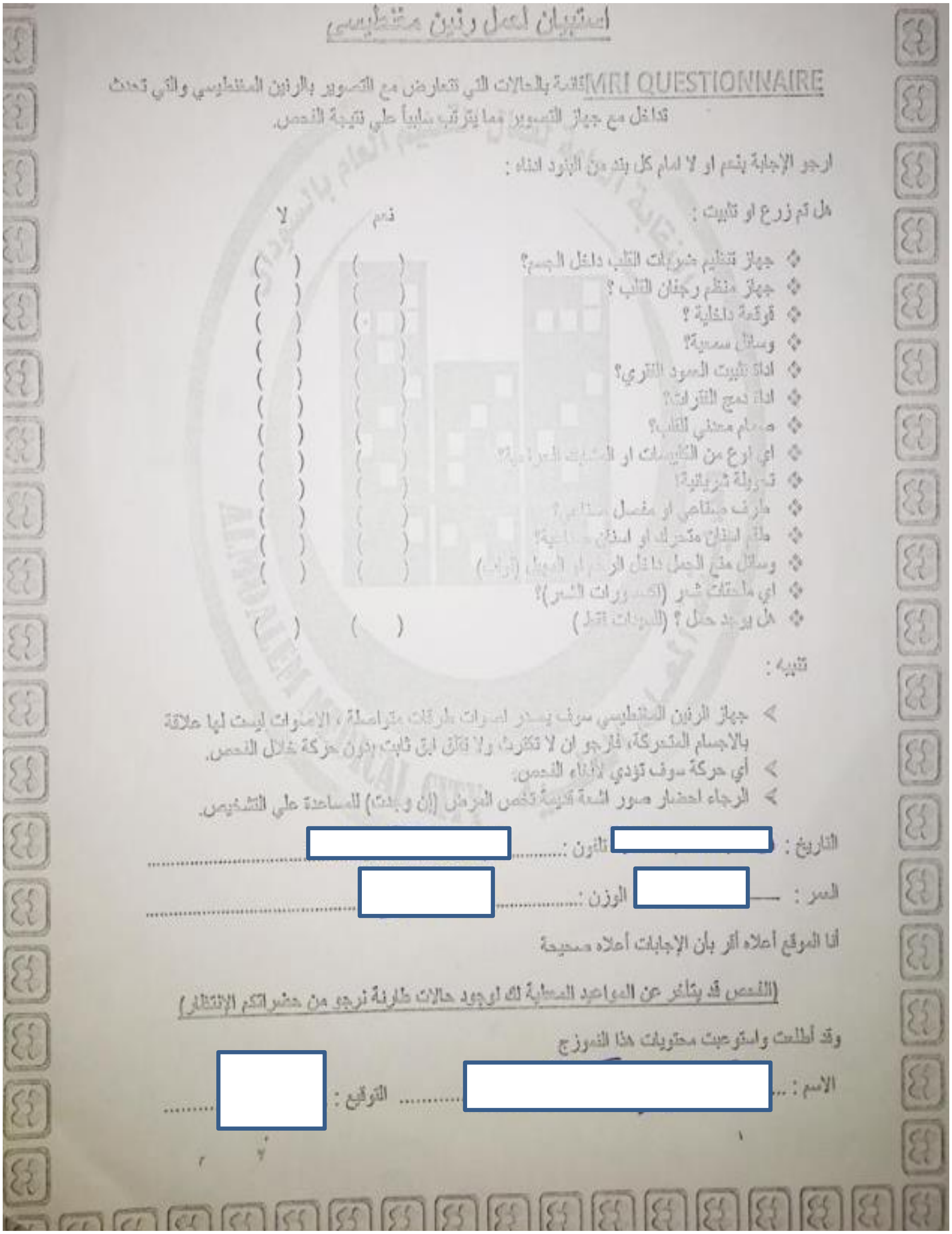
ملحوظة :

- الرجاء عدم استعمال الكحل او الماسكرا في يوم إجراء الفحص لعدم لبس أي شيء يتأثر بالمغنطيس مثل : المجوهرات ، المفاتيح ، دبابيس الشعر ، أطقم اسنان صناعية ، الكروت الممغنطة ، النظارات او غيرها
- موعد الفحص يوم .... الساعة .... مساء
- الرجاء الحضور قبل ربع ساعة من موعدك لكملة الإجراءات المطلوبة قبل الفحص .
- الرجاء إخطار المركز علي الرقم .... في حالة عدم تمكنك من الحضور في الوقت المحدد للاستفادة من موعدك لمريض اخر .
- الرجاء إحضار الصور والفحوصات السابقة إن وجدت
- استلام النتيجة خلال 48 ساعة

- الموانع التي تمنع بعض المرضي من إجراء الفحص بالرنين المغنطيسي مثل :

١/ مريض في جسمه جهاز لتنظيم ضربات القلب .
٢/ مريض في جسمه اجزاء معدنية .
٣/ مريض يستعمل سماعات الأذن . وغيرها من الموانع .
٤/ علي المريض عدم التحرك لان اي حركة تؤثر علي الصورة وربما تلغيها .
٥. بعض الحالات قد تحتاج لإعطاء المريض صبغة عن طريق الوريد .
٦. يعانون من الخوف من الأماكن المغلقة . يرجي إخطار التقني إذا كنت من هذا النوع من المرضي
٧. يعطي المريض مريلة خاصة لارتدائها قبل الفحص عليه يرجي لبس ملابس خفيفة وبسيطة وسهلة التغيير ليس بها اي موانع (اشياء معدنية) .
٩. بالنسبة للأطفال قد يتطلب الفحص تخدير عام قصير وسيخطر اهل المريض

D. National MR safety form



استبيان لعمل رنين مغناطيسي

MRI QUESTIONNAIRE قائمة بالحالات التي تتعارض مع التصوير بالرنين المغناطيسي والتي تحدث تداخل مع جهاز التصوير مما يترتب سلبياً على نتيجة الفحص.

ارجو الإجابة بنعم او لا امام كل بند من البنود اتناه :

هل تم زرع او تثبيت :

	نعم	لا
جهاز تنظيم ضربات القلب داخل الجسم؟	( )	( )
جهاز منظم رجفان القلب ؟	( )	( )
قوقعة داخلية ؟	( )	( )
وسائل سمعية؟	( )	( )
اداة تثبيت العمود الفقري؟	( )	( )
اداة دمج الفقرات؟	( )	( )
صمام معدني القلب؟	( )	( )
اي نوع من التثبيتات او المشابك الجراحية؟	( )	( )
تحويلة شريانية؟	( )	( )
طرف صناعي او مفصل صناعي؟	( )	( )
طقم اسنان متحرك او اسنان صناعية؟	( )	( )
وسائل منع الحمل داخل الرحم او المهبل (لولب)	( )	( )
اي ملحقات شعر (اكسسوارات الشعر)؟	( )	( )
هل يوجد حمل ؟ (للسيدات فقط)	( )	( )

تنبيه :

- جهاز الرنين المغناطيسي سوف يصدر اصوات طرقات متواصلة ، الاصوات ليست لها علاقة بالاجسام المتحركة، فارجو ان لا تتحرك ولا تقلق ابق ثابت بدون حركة خلال الفحص.
- أي حركة سوف تؤدي لالغاء الفحص.
- الرجاء احضار صور اشعة قديمة تخص المرض (إن وجدت) للمساعدة على التشخيص.

التاريخ : [redacted] التليفون : [redacted] ....

العمر : [redacted] الوزن : [redacted] ....

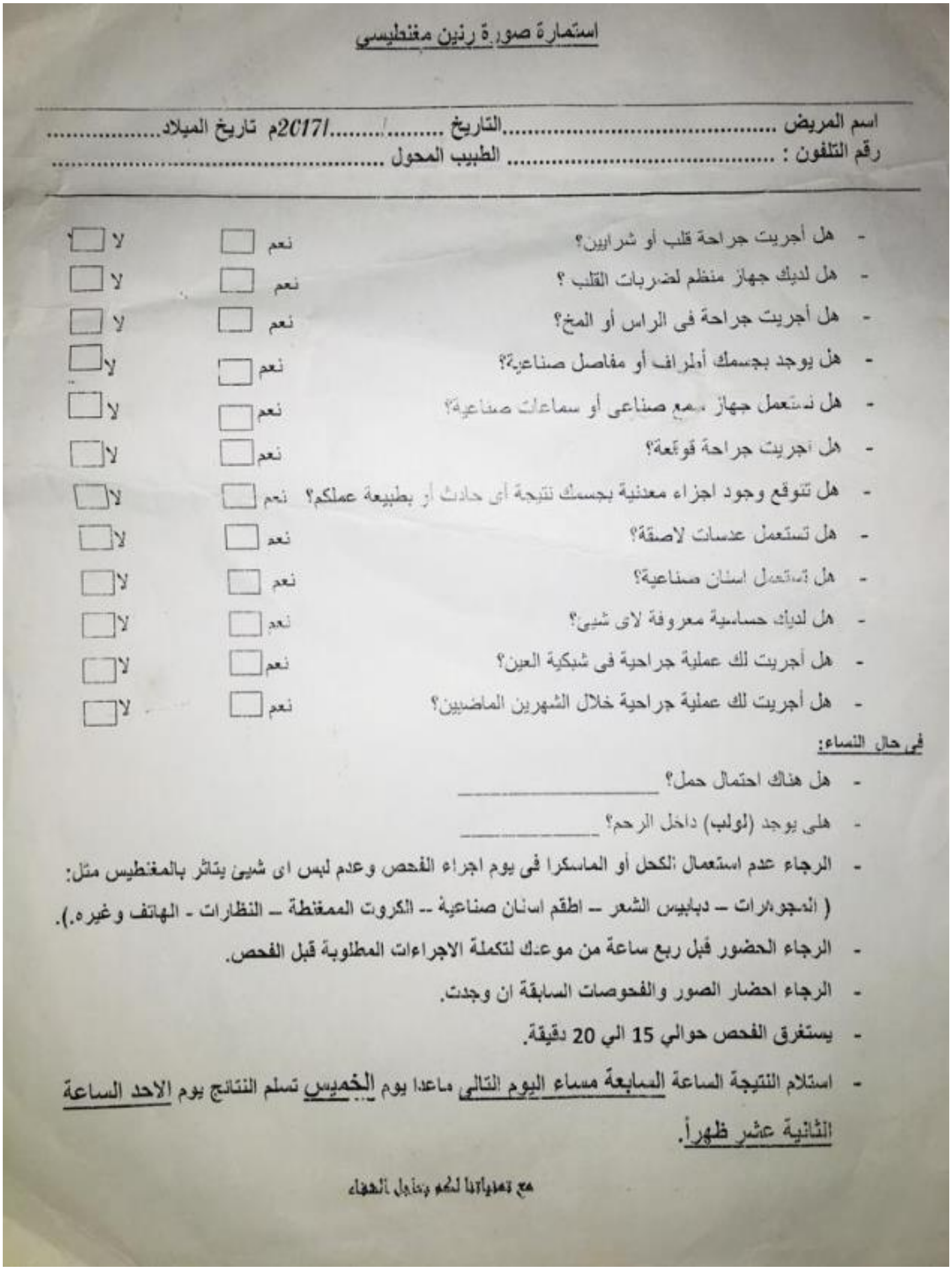
أنا الموقع أعلاه أقر بأن الإجابات أعلاه صحيحة

(الفحص قد يتأخر عن المواعيد المعطاة لك لوجود حالات طارئة نرجو من حضراتكم الانتظار)

وقد أطلعت واستوعبت محتويات هذا النموذج

الاسم : ... [redacted] .... التوقيع : [redacted] ....

E. National MR safety form



استمارة صورة رنين مغنطيسي

اسم المريض ....التاريخ ..../......../2017م تاريخ الميلاد.................

رقم التلفون : .... الطبيب المحول ....

- هل أجريت جراحة قلب أو شرايين؟	نعم ☐	لا ☐
- هل لديك جهاز منظم لضربات القلب ؟	نعم ☐	لا ☐
- هل أجريت جراحة فى الراس أو المخ؟	نعم ☐	لا ☐
- هل يوجد بجسمك أطراف أو مفاصل صناعية؟	نعم ☐	لا ☐
- هل تستعمل جهاز سمع صناعى أو سماعات صناعية؟	نعم ☐	لا ☐
- هل اجريت جراحة قوقعة؟	نعم ☐	لا ☐
- هل تتوقع وجود اجزاء معدنية بجسمك نتيجة أى حادث أو بطبيعة عملكم؟	نعم ☐	لا ☐
- هل تستعمل عدسات لاصقة؟	نعم ☐	لا ☐
- هل تستعمل اسنان صناعية؟	نعم ☐	لا ☐
- هل لديك حساسية معروفة لاى شيئ؟	نعم ☐	لا ☐
- هل أجريت لك عملية جراحية فى شبكية العين؟	نعم ☐	لا ☐
- هل أجريت لك عملية جراحية خلال الشهرين الماضيين؟	نعم ☐	لا ☐

فى حال النساء:

- هل هناك احتمال حمل؟ ____________________
- هلى يوجد (لولب) داخل الرحم؟ ______________
- الرجاء عدم استعمال الكحل أو الماسكرا فى يوم اجراء الفحص وعدم لبس اى شيئ يتاثر بالمغنطيس مثل: (المجوهرات – دبابيس الشعر – اطقم اسنان صناعية -- الكروت الممغنطة – النظارات - الهاتف وغيره).
- الرجاء الحضور قبل ربع ساعة من موعدك لتكملة الاجراءات المطلوبة قبل الفحص.
- الرجاء احضار الصور والفحوصات السابقة ان وجدت.
- يستغرق الفحص حوالي 15 الي 20 دقيقة.
- استلام النتيجة الساعة السابعة مساء اليوم التالى ماعدا يوم الخميس تسلم النتائج يوم الاحد الساعة الثانية عشر ظهراً.

مع تمنياتنا لكم بتمنيل الشفاء

F. National MR safety form

Name .... الإسم : ....

Sex .... الجنس : ....

Age .... العمر : ....

Address .... العنوان : ....

Mobile No .... رقم التلفون : ....

Referring Physician .... الطبيب المحول : ....

هل تعالج من حساسية على الصدر أو أزمة صدرية	نعم	لا
هل تعاني من تشنجات	نعم	لا
هل سبق عمل فحوصات أو أشعات لنفس السبب	نعم	لا
هل سبق إجراء عمليات جراحية	نعم	لا

حدد نوع الجراحة : ________________________________

هل تتناول علاج السكر	نعم	لا
هل تستعمل علاج لضغط الدم	نعم	لا
للنساء: هل هناك احتمال وجود حمل	نعم	لا

- بالنسبة لمرضى فحص الرنين المغنطيسي الرجاء خلع أي مواد قابلة للتمغنط والتي تشتمل (المجوهرات – الساعات – المفاتيح – دبابيس الشعر – أطقم الأسنان الصناعية – أو أي مواد ممغنطة) .

ما هي الشكوى الحالية بالتفصيل :

____

____

____

____

ملحوظات هامة :

1. ضرورة إحضار الفحوصات السابقة عند الفحص .
2. إستلام النتائج اليوم التالي للفحص كما سيوضحه موظف الاستقبال إلا في الحالات الطارئة فتسلم في نفس يوم الفحص.
3. لن يتم تسليم الأشعة إلا بكارت الإستلام من موظف الإستقبال .
4. يجب عدم تعريض الأشعة للحرارة أو ضوء الشمس المباشر .
5. القسم غير مسئول عن الفحوصات بعد مرور اسبوع من تاريخها .

مع أفضل التمنيات بالشفاء العاجل

G. National MR safety form

ST VINCENT'S HOSPITAL SYDNEY

A FACILITY OF ST VINCENT'S HEALTH AUSTRALIA

MRI SAFETY SCREENING QUESTIONNAIRE

For your own SAFETY all questions must be answered before entering MRI

Patient Name:	Date of Birth:	Weight : Kg	Height: cm
		Male ☐	Female ☐
Referring Dr:	Next Appointment with your Dr:		

Do you have any of the following? **Please circle either YES or NO**

1. Cardiac Pacemaker? YES NO
2. Artificial Heart Valve? YES NO
3. Blood Vessel Stents/Shunts? YES NO
4. Aneurysm Clips? YES NO
5. Metal Fragments in your eye (Now or Ever)? YES NO
6. Cochlear or Stapes Implant? YES NO
7. Neurostimulator or Implanted Wires? YES NO
8. Recent endoscopy clips? YES NO
9. Bone screws, nails or pins? YES NO
10. Shrapnel, bullets or foreign bodies? YES NO
11. Any dentures or prosthetic devices? YES NO
12. Metal body piercing or tattoos? YES NO
13. Intrauterine Contraceptive Device (IUD)? YES NO
14. Magnetically Activated Implant or Device? YES NO
15. Are you or could you be pregnant? YES NO
16. Are you breastfeeding? YES NO
17. Kidney / Renal Function problems? YES NO

If you answered "Yes" to any of these questions please inform the staff ASAP to assess your suitability for a MRI scan.

If any previous surgery please list: ______________________________

Have you had an MRI before? YES NO

Please Tick the following to indicate that you agree:

- I will remove all metal from myself including keys, coins, piercings, jewellery, hearing aids, bobby pins etc before entering the room. (locker available in your change room) ☐
- I acknowledge that this form is accurate to the best of my knowledge, I have read and understood the questionnaire and I have had the opportunity to ask questions about this questionnaire. ☐
- I acknowledge that St Vincent's Hospital Medical Imaging Department has taken reasonable precautions and is not liable for any event that might result from incorrect answers on this form. ☐
- I consent to the MRI procedure that has been requested by my referring physician. ☐

Signature______________________________ Date____________________

Safety Screening Questionnaire - Diagnostic Services Department Version 6- Date: February 2017

H. International MR safety form

UCLA Health System	MRN: Patient Name: (Patient Label)

MRI SAFETY SCREENING QUESTIONNAIRE (OUTPATIENTS)

Sex:_______ **Age:**_______ **Height:**______ **Weight:**______

The following items may be harmful to you during your MR scan or may interfere with the MR examination. Please provide a "yes" or "no" answer for every item.

YES	NO	
☐	☐	Cardiac pacemaker or implanted cardioverter defibrillator/ICD
☐	☐	Internal electrodes or wires (pacing wires, DBS or VNS wires)
☐	☐	Artificial heart value, coil, filter and/or stent (Gianturco coil, IVC filter)
☐	☐	Aneurysm clip(s)
☐	☐	Neurostimulator-TENS Unit, Biostimulator, bone growth stimulator, DBS, VNS
☐	☐	Implanted drug pump (for chemotherapy medicine, pain medicine)
☐	☐	External drug pump (for Insulin or other medicine)
☐	☐	IV access port (Port-a-Cath, Broviac, PICC line, Swan-Gantz, Thermodilution)
☐	☐	Implanted post surgical hardware (pins, rods, screws, plates, wires)
☐	☐	Artificial joint and /or limb
☐	☐	Artificial eye and/or eyelid spring
☐	☐	Eye injury from a metal object (metal shavings, metal slivers)
☐	☐	Ear (Cochlear) implant, middle ear implant
☐	☐	Hearing aid(s)
☐	☐	False teeth/dentures, metallic removable dental work, braces, retainers
☐	☐	Any type of implant held in place by a magnet
☐	☐	Injured by a metal object (shrapnel, bullet, BB) and required medical attention
☐	☐	Medication patch (nitroglycerine, nicotine, contraceptive, estrogen)
☐	☐	Shunt or Sophy adjustable and programmable pressure valve
☐	☐	Spinal fixation device, spinal fusion and/or halo vest, spinal cord stimulator
☐	☐	Surgical clips, staples or surgical mesh
☐	☐	Tissue expander (breast)
☐	☐	Penile implant
☐	☐	Pessary, IUD, Diaphragm
☐	☐	Radiation seeds (cancer treatment)
☐	☐	Body piercing, tattoo or permanent makeup
☐	☐	Wig, hair implants

Do you have a history of:

YES	NO		YES	NO	
☐	☐	Kidney disease	☐	☐	Latex Allergy
☐	☐	Diabetes	☐	☐	Allergic reaction to MRI contrast (Gadolinium based)
☐	☐	Liver disease			
☐	☐	Claustrophobia			
☐	☐	Drug Allergy, Type: _______________			

Are you on dialysis? ☐ YES ☐ NO If YES, Hemodialysis or Peridialysis? (circle one)

Female Patients:

Are you pregnant? ☐ YES ☐ NO Are you breast-feeding ☐ YES ☐ NO

If you are still menstruating, please provide the date of your last period___________________

UCLA Form #10956 Rev. (04/12) Page 1 of 2

I. International MR safety for

UCLA Health System

MRN:
Patient Name:

(Patient Label)

MRI SAFETY SCREENING QUESTIONNAIRE (OUTPATIENTS)

If you answered **YES** to any of the questions on the front page, please discuss any concerns and/or issues you may have, with your MR Technologist, MR Assistant or Radiology Nurse.

Instructions for the Patient, Parent, Guardian:
We will provide a locker so **ALL** items you remove may be stored and locked safely during your scan. You may bring the key in the scan room with you.

1. Remove **ALL** jewelry and **ALL** body piercing jewelry and **ALL** hair accessories.
2. Remove dentures, false teeth, partial dental plates, retainers.
3. Remove hearing aids and eyeglasses.
4. Remove **ALL** clothing and change into a hospital gown. Slippers will be provided.
5. Lock your clothes and valuables in the locker provided and remove the key.
6. Please use the restroom before your MRI exam.
7. Please make sure that you receive a pair of earplugs and/or the headphones before your MRI exam begins. Some patients may find the noise levels unacceptable, and the noise levels may affect your hearing.

I attest the above information is correct to the best of my knowledge. I have read and understand the entire contents of this form and I have had the opportunity to ask questions regarding the information on this form.

______________________________ ________ ________
Patient/Parent/Guardian/Other Signature Date Time

______________________________ ________ ________
MR Tech/MR Assistant/RN Signature Date Time

____
Print Name of MR Tech/MR Assistant/RN

FOR MRI STAFF USE ONLY

CONTRAST ORDER/SIGNATURE	To Be Filed in the Medical Record
Contrast Type:__________________ Injection Rate:______ Injection Amount: _______	
Creatinine Value: ______ GFR Value: ________ Date Acquired __________________	
Creatinine/GFR screening waived by: ____	
MR Technologist/RN/MD Signature: _______________________ Date: ________ Time: ______	
Radiologist Signature: _________________________________ Date: ________ Time: ______	

UCLA Form #10956 Rev. (04/12) Page 2 of 2

I. International MR safety for

Regional Imaging
Comprehensive care. Uncompromising quality.

MRI Safety Questionnaire

Name ______ Date of Birth ______ Age ______

Weight ______ Height ______

Certain implants, devices and objects may be hazardous to you or may interfere with the MRI

Have you:	
Had a previous MRI?	◯ Yes ◯ No
If yes, when and where? ______	
Ever had an eye injury caused by metal?	◯ Yes ◯ No
If yes, has this been removed?	◯ Yes ◯ No
Had any operations in the last 6 weeks?	◯ Yes ◯ No
Are you pregnant, or do you suspect you may be pregnant?	◯ Yes ◯ No
Do you have, or have you ever had:	
Cardiac Pacemaker or Intra-Cardiac Defibrillator?	◯ Yes ◯ No
An artificial heart valve or wires?	◯ Yes ◯ No
Heart clips from Cardiac surgery?	◯ Yes ◯ No
Aneurysm clips?	◯ Yes ◯ No
Shunt in brain or spinal cord?	◯ Yes ◯ No
Ear implants (Cochlear implant) or ear surgery?	◯ Yes ◯ No
Ocular prosthesis (eye implant)?	◯ Yes ◯ No
Any implanted drug or other infusion pump?	◯ Yes ◯ No
A neurostimulator?	◯ Yes ◯ No
A bone growth stimulator?	◯ Yes ◯ No
An intra-uterine device (IUD)?	◯ Yes ◯ No
Removable plates / dentures?	◯ Yes ◯ No
Tattoo or permanent makeup?	◯ Yes ◯ No
Hearing aids?	◯ Yes ◯ No
Piercings?	◯ Yes ◯ No
Hair extensions / wig / toupee?	◯ Yes ◯ No
Vascular stents, filters or coils? Where: ______	◯ Yes ◯ No
Any metal fragments or foreign bodies? Where: ______	◯ Yes ◯ No
Any joint replacements, orthopaedic pins / plates / screws? Where: ______	◯ Yes ◯ No
Any other prosthesis, implants or devices? Please list: ______	◯ Yes ◯ No
Have you had any surgeries / operations in your lifetime? Please list: ______	◯ Yes ◯ No
Have you ever been diagnosed with cancer? Please specify: ______	◯ Yes ◯ No
Please describe your injury. What symptoms (ie. Pain) do you have at present? ______	

I acknowledge that to the best of my understanding the above answers are true and consent to the MRI examination.

Patient Signature ______ Date ______

Person completing the form if not the patient ______ Relationship ______

STAFF USE ONLY: ☐ Correct Patient ☐ Correct Procedure ☐ Patient is MRI Safe ☐ Radiographer Initials

J. International MR safety form

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MRI Administration of Contrast Consent

<Insert Patient Label>

As part of the MRI examination, you may need to have an injection of a contrast agent (dye) known as Gadolinium. This medication is administered intravenously (injection into a vein) through a fine needle.

This is not the same contrast agent used for CT scans.

Overall an MRI contrast injection is a safe procedure. Occasionally patients feel a little nauseous but this only lasts momentarily. More serious allergic type reactions, although possible, are extremely rare. The staff in the MRI department are fully trained to deal with an allergic reaction should it occur.

In order to administer the MRI contrast the MRI technologist will need to exclude any renal (kidney) disease.

Please answer the questions below to help the MRI staff in determining whether a contrast injection is appropriate.

Have you ever had an injection of contrast for MRI?	○ Yes ○ No
If yes, did you have any kind of reaction?	○ Yes ○ No
Are you breast-feeding?	○ Yes ○ No
Do you have asthma?	○ Yes ○ No
Do you have any history of kidney disease?	○ Yes ○ No
Do you have diabetes?	○ Yes ○ No
Have you had a recent blood test to look at kidney function?	○ Yes ○ No

If YES, which Pathology service? ____________________

List any known allergies: ____________________

I have read and understand the explanation of the risks involved in contrast administration. I have been given the opportunity to ask any questions about its use. I give my consent for the administration of contrast and for the examination.

Signature of Person giving consent ____________________ Date ____________

Printed Name of Person giving consent ____________________ Relationship ____________

Signature of MRI Radiographer ____________________

STAFF USE ONLY:

Creatinine: ____________ eGFR: ____________ Date: ____________

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