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Survey of MRI technology

Mr. Amey S. Laddad[1], Mrs. Pranoti Aher[2]

Abstract:This is a survey paper of MRI technique.Magnetic resonance technology comprises the hardware, software, and imaging techniques used in Magnetic Resonance Imaging (MRI) and Magnetic Resonance Spectroscopy (MRS). MRI has become one of the most useful imaging techniques used in medical diagnosis [1]. Thousands of MRI systems have been produced and installed in clinics since the first introduction to hospitals in the early 1980s. In this paper we have studied different aspects of MRI technology. We have also compared MRI with some other techniques such as X ray, Sonography.

***Keywords:* MRI, X ray, Sonography, gradient coils, RF coils, magnet.**

I Introduction

In recognition of the importance of MRI to the practice of medicine, Dr Paul Lauterbur and Sir Peter Mansfield were awarded the 2003 Nobel Prize in Medicine for their discoveries concerning MRI.

MRI allows the visualization of internal structures of a body containing water and fat molecules. Since the human body consists of more than 50% water (about 90% in brain), MRI could be used to image practically any organ. Clinically, MRI is used for early disease diagnosis, while research areas cover new fast imaging techniques, high resolution human and animal anatomy, and details of physiology and pathology. Although the detected signal comes from water or fat molecules, MRI is sensitive to much more than simple Proton Density (PD). The contrast in MR images can come from blood flow, blood Oxygenation, water diffusion, or specific properties of tissues, and is called *relaxation times*[2].

To the patient, CT and MRI systems look much alike—resembling a tube or ring. However, this is the only similarity between the techniques, as both the principles and equipment are very different.

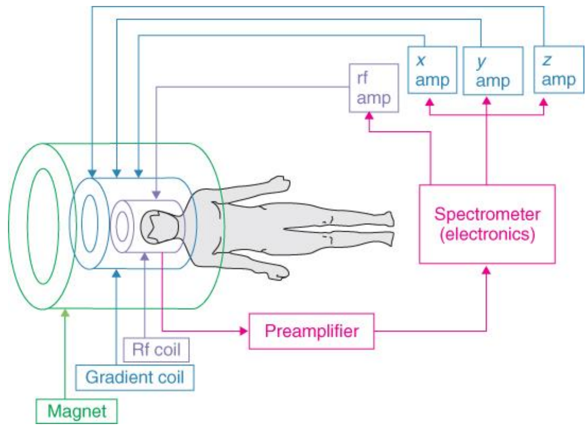

Fig 1: MRI Schematic

II MRI Hardware

The system can be broken down by physical assemblies: magnet, gradient coils, RFcoils, power amplifiers, and console [3].

Magnets

The basic parameters of a magnet are the strength of the magnetic field (expressed in tesla (SI) or Gauss; 1 T = 10, 000 Gs), the homogeneity of the field within the Volume of Interest (VOI) (ppm over Diameter of Spherical Volume (DSV)), and the fringe field that describes the distribution of the field around the magnet.

MR magnets must generate a field stronger than 0.1 T. Currently most clinical systems generate 1.5 T. However, human 3 T magnet systems, which recently obtained FDA approval, are more and more common. Seven-tesla whole-body magnets are used in human research systems, and even higher field whole-body systems are under construction. There are three types of magnets used in MRI depending on the manufacturing process: permanent, electromagnets, and superconductive.

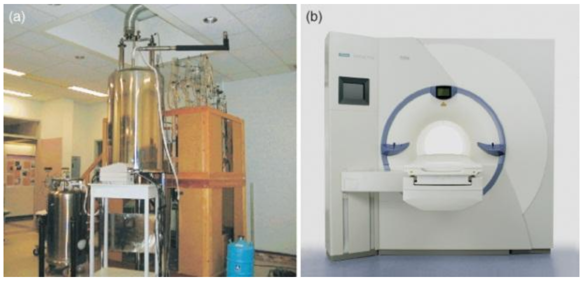

Figure 2: (a)Vertical experimental 11.7-T MRI system (IBD/NRC), magnet (Magnet Scientific, England), and console (Bruker, Germany). (b) 3-T Siemens Trio MRI system.

The majority of human and all high field experimental MRI systems are equipped with *superconductive magnets*. These can produce very stable and strong magnetic fields up to about 20 T. Their shape usually resembles a vertical Fig a or horizontal Fig b cylinder. All human and most animal MRI systems are horizontal. The most important geometric parameter of the superconductive magnet is the diameter of its inner tube ("the bore") of the magnet. Shimming coils, gradients coils, and body RF coils (in humans systems) are placed within the bore of the magnet.

Shimming

Shimming is the process of fine-tuning the magnet field uniformity. There are three methods: passive, active with resistive coils, and active with superconductive coils.

The use of iron pieces for shimming is called *passive shimming* and is used for shimming to about 10 ppm. Washer-like iron pieces of about 1-cm diameter are placed on both poles of the magnet in very specific locations, as determined by computerized field analysis.

For high field human MRI, the homogeneity should be about 10 ppm over 30–50 cm DSV, while for MRS, local homogeneity should be in the order of 1 ppm over a voxel volume. (It can be proved that for MRS the variation in field frequency should not be larger than $1/\pi T_2$ over the sample volume . Although superconductive magnets produce highly uniform fields, homogeneity improvement of the field is often needed. Passive shimming, using iron pieces placed on the inner surface of the bore of the magnet, is used. Superconductive wires (cryoshims) submersed in liquid helium are also used in some magnets for active shimming. The shims are charged after the main wire is charged.

RF Shielding

The NMR signal is very weak, so the magnet is placed in an RF-shielded room to prevent any external RF interferences that could cause spurious signals to be detected by the system. The shielding efficiency should be about 100 dB. There must be special conductive doors installed to make sure that the room is "RF sealed" during imaging. All cables coming into and out of the magnet room must go through an RF filter panel to block unwanted signals, while nonconductive tubes may go through waveguides that prevent RF leakage.

Gradient System

To generate a time-variable gradient, needed for spatial spin encoding, the magnetic field gradient coils are made of resistive wires overlaid on the surface of a fiberglass tube. As three perpendicular gradients are needed.

Usually six layers of wire are used: three inner layers generating gradients within the VOI and three layers used as a magnetic shield to prevent eddy currents being induced in the cryostat.

MR Electronics -theConsole

The rack of low power electronics and the computers used to run the system is termed the *console*. A typical breakdown of a console would be into a Graphical User Interface (GUI), a synchronous high speed control assembly, and a low speed asynchronous control assembly.

The main tasks of the high speed synchronous control are to generate the gradient, rf, and timing waveforms and to acquire and digitize the NMR signals.

There is no console standardization in the industry each major and minor manufacturer, both clinical and otherwise, have their own designs. Thus, it can be a major task to transfer experience from one to another. On the bright side, however, all clinical manufacturers do comply to a standard clinical image data format (DICOM).

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Most commercial MR consoles are based on dedicated and sophisticated computers. However, recent progress in personal computers allowed their application to MRI. A few smaller commercial suppliers (e.g., ONI Corp, Maran (Oxford Instruments)) and even research institutions have created systems based on PCs. For example, the National Research Council of Canada has designed a console system that integrates simulation of the MR experiment with the acquisition of experimental data. The device consists of a magnetic resonance (MR) research console with a full-function hardware-independent pulse programming environment and a parallel computer cluster running Bloch equation MR physics simulations on a 3D digitally defined spin phantom [4].

RF Coils

The RF coils (RF probes) generate the RF (B_1) pulse fields and receive the MR signals. The basic construction principles are simple, based on the L-C resonance circuit. The parameters of the RF coil are B_1 (RF) field homogeneity, quality factor (Q), and the coil's FOV. MRI and MRS require both maximal SNR and homogeneous B_1 field. Unfortunately, these requirements usually conflict: the better the SNR the worse the B_1 and vice versa.

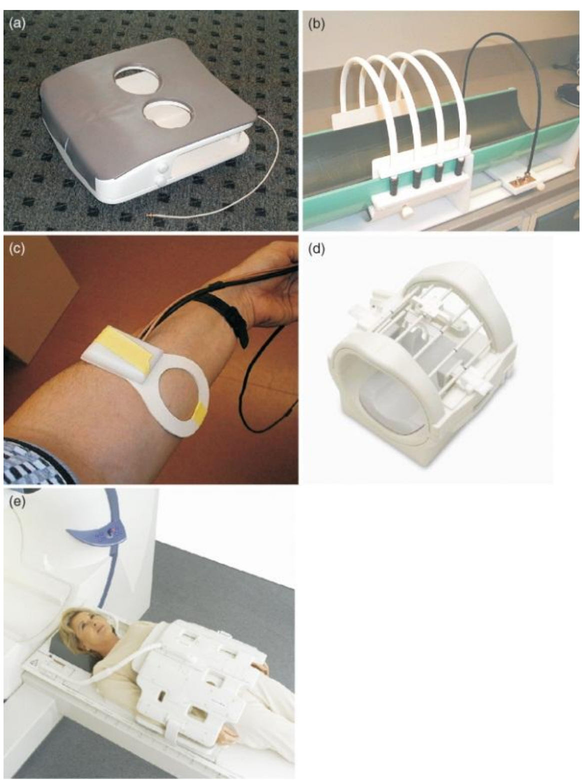

Figure 3: Examples of rf coils. (a) Breast coil (IBD/NRC), (b) solenoidal volume coil (IBD/NRC), (c) surface coil (IBD/NRC (Siemens, Germany),(d) head coil (Siemens, Germany), and (e) phase array torso coil (Siemens, Germany).

III MRI Safety

MRI is a noninvasive imaging technique with no long-term side effects observed. However, there are a few potential safety issues that should be considered when working with MRI systems or as a subject of MR examination: static magnetic field, RF power absorbed by the subject, and variable gradients of the magnetic field [5].

Magnet Safety

While long-term effects of the static magnetic field on living organisms have not been observed, the FDA, as a precaution, set up a limit of 3 T for human clinical MRIs. Other countries followed that limit. Potential subtle, long-term biological effects aside, there is always an immediate danger—projectiles.

Magnetic fields attract ferromagnetic objects, such as oxygen tanks, scissors, carts, computers, and so on. Such objects can become projectiles and injure or kill anyone between the magnet and the object.

In very rare cases, moving in the magnet may cause a temporal discomfort, depending on the individual's sensitivity, because of the eddy currents induced in the brain due to the motion in the magnetic field.

Clinical MRI systems are equipped with rf power amplifiers capable of generating up to 30 kW rf power in short pulses, which heat up tissues and can be potentially harmful. Therefore, the regulations do not allow the use of rf power that would heat the tissue by more than 1°C. However, this definition is not convenient in MRI; therefore, Specific Absorption Rate (SAR) is used. This is defined as rf power absorbed in tissue per unit mass, and is expressed in watts per kg (W/kg). The SAR limits vary from 3 W/kg to 12 W/kg depending on the total exposure time and on the part of the body.

Gradient Safety

Gradient coils produce a time-varying magnetic field (dB/dt) that can cause peripheral nerve stimulation and involuntary muscle contraction. Therefore dB/dt is also limited.

Because the gradient strength required increases with the field strength, the stronger the magnet, the noisier the pulse sequences are. But this is also the reason why there is practically no noise in low field MRI.(up to 0.3 T)

IV Advantages of MRI

-No radiation exposure, so it is safe scanning technique &excellent tissue resolution.

-The image quality obtained is very high.

-This test is not influenced by bone & air presence in the body.

-It is a versatilemethod; we can examine many medical conditions using it [6].

V Limitations of MRI

-It takes long time compared to other techniques to perform MRI Scan & It is costly.

-The MRI scan machine is huge in size & creates noise.

-Cannot be used for patients having pacemakers & other metal objects inside their body.

-We cannot get a Real time moving picture using MRI scan [7].

VI Applications of MRI

-Soft tissue evaluation.

-Study of ligaments & tendons.

-Brain tests.

-Spinal cord & junction study [8].

Sr.No.	Attribute	MRI	X – RAY	SONOGRAPHY
1	Year of debut	1980	1971	1971
2	Technique used	State of water	Difference of mass	Passing of sound
3	Energy utilized	Magnetism	X ray	Ultrasound
4	Ionizing Radiation Exposure	No	Yes	No
5	Time taken for complete scan	About 1 hour	Few seconds	Few minutes
6	Cost	More expansive	Cheaper	Cheaper
7	General Image Quality	High	low	Comparatively low
8	Size of machine	Large	Moderate	Small
9	Exam location	Special Room	Special Room	May be besides
10	Invasive	Non-invasive	Non-invasive	Trans-Abdominal
11	Tissue Resolution	Excellent	Good	Good
12	Influence by Air, Bone	No	Yes	Yes
13	Examination Noise	Large	Comparatively Quiet	Quiet
14	Image Information	Reconstructed Image	Shading Image	Reconstructed Image
15	Versatility	High	Less	Less

Table 1: Comparative study of MRI, Sonography, and X-Ray [5]-[12]

VII Conclusion

MRI scan is an important tool in biomedical image processing field. We can diagnose various medical conditions using MRI test .Though this technique is very costly and requires long time we can find out perfect solutions for many complicated diseases .The application area is large & the image obtained are very informative having high resolution-Ray scan technique is a well-established & well known scan technique which is useful for various applications. It takes less time and it is a cheap test. X-Ray has some severe limitation that it uses ionizing radiations that may cause many disorders like DNA change, Tissue damage to human. Sonography technique is a well-established & well known scan technique which is useful for particular applications. It takes less time and it is a cheap test. It has a unique quality that we can generate a Real time image of any organ under test.

References

1) Westbrook C. MRI at a Glance. Osney Mead, Oxford: Blackwell Publishing Ltd; 2002.

2) Liang Z, Lauterbur PC. Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, IEEE Press Series in Biomedical Engineering. New York: IEEE Press.

3) Dujin JH, Matson GB, Maudsley AA, Hugg JW, Weiner MW. Human brian infarction: proton MR spectroscopy. Radiology 1992;183:711–718.

4) Sharp JC, Yin D, Bernhardt RH, Deng Q, Procca AE Tyson RL Lo K Tomanek B. The integration of real and virtual magnetic resonance imaging experiments in a single instrument. Rev Sci Instrum. 2009 Sep;80(9):093709.

5) Fitzsimmons JR, Beck BL, Brooker HR. Double resonant quadrature birdcage. Magn Reson Med 1993;30:107–114.

6) Setsompop K, Wald LL, Alagappan V, Gagoski B, Hebrank F, Fontius U, Schmitt F, Adalsteinsson E. Parallel RF transmission with eight channels at 3 Tesla. Magn Reson Med 2006;56:1163–1171.

7) Liang Z, Lauterbur PC. Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, IEEE Press Series in Biomedical Engineering. New York: IEEE Press.

8) Tomanek B. Radio frequency coils for magnetic resonance spectroscopy, “Medical Uses”. In: Mountford C, Himmelreich U, Webb G, editors. Volume 2, Modern Magnetic Resonance. London: Springer; 2006. pp. 1–8.

9) Duck FA. Physical Properties of Tissue. New York: Academic Press; 1990.

10) Evans DH. In: Wells PNT, editor. Advances in Ultrasound Techniques and Instrumentation. New York: Churchill Livingstone; 1993. Chapter 8.

11) Schrope BA, Newhouse VL. Second harmonic ultrasonic blood perfusion measurement. Ultrasound Med Biol 1993;19(7):567–579.

12) Eyding J, Wilkening WG, Reckhardt M, Schmid G, Meves SH, Ermert H, Przuntek H, Postert T. Contrast burst depletion imaging (CODIM): a new imaging procedure and analysis method for semiquantitative ultrasonic perfusion imaging.

Author 1: Mr.Amey S. Laddad, Pursuing M.E. VLSI & EMBEDDED SYSTEMS,

Savitribai Phule Pune University.

23 year’s age, 3 Years of Working Experience

Author 2: Mrs. Pranoti Aher, Lecturer at Sandip founation

2.5 Years of Working Experience