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Using MRI to Detect and Diagnose Glioblastoma Multiform

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Abstract: Magnetic resonance imaging is a safe and high-quality diagnostic tool in detecting tumors, their size, determining their location, and diagnosing them accurately in the human body, especially in the brain. The most prominent of these tumors is glioblastoma multiforme. This type of imaging has high soft tissue contrast, compared to ionizing imaging technology as in X-rays and CT scans.

In MRI Imaging when we placed the human body in a strong external magnetic field of strength B_0, its magnetic spins of hydrogen nuclei of its tissues align parallel and anti-parallel to the external field. According to the Zeeman effect, this creates a net magnetic field toward the external magnetic field we call it a longitudinal magnetization which is responsible for creating an image of these tissues in human body.

Hydrogen nuclei of net longitudinal magnetization precess around the axes of the external field by Larmor frequency ω_0 giving from the Larmor equation

$\omega_0 = g \times B_0 \dots (1)$, where g is a magnetic gyroscope ratio.

To measure this longitudinal magnetization, we have to flip it into XY plane. This can be done by using radio frequency waves generated by radio frequency coils (Faraday-Lenz law), these waves excite the hydrogen nuclei to flip the magnetization from the longitudinal direction Z to the transverse plane XY away from the external field to enable it to be measured. This is done when the frequency of the transmitted radio pulse is equal to the precession Larmor frequency of the hydrogen nuclei to achieve the condition of magnetic resonance. After stopping the radio frequency pulse, we are able to obtain the signals coming from the hydrogen nuclei present in our bodies and record them via radio frequency coils according to Faraday-Lenz law and we obtain continuous composite electrical signals. Then we use the mathematical Fourier transform to convert these continuous composite signals into discrete values to fill the K-space. After processing the discrete signals, we use the inverse Fourier transform to obtain an image to give a visual representation of human tissue without surgical intervention for clinical diagnosis.

Keywords: Magnetic resonance, Zeeman effect, Lenz- Fraday law, Fourier transform, Inverse Fourier transform.

1. Introduction: The human body contains approximately 70% water. The water molecule is made up of an oxygen atom and two hydrogen atoms, and this makes it an abundant source of hydrogen nuclei. The hydrogen nucleus (H1) has magnetic properties, each hydrogen nucleus acts as a tiny magnet, and this is what makes it affected when placed in a strong magnetic field and exposed to radio waves. Hydrogen nuclei possess magnetic moments due to their intrinsic spin property. But it's net magnetization in human body equal zero because their spin orientations are randomly. But when we placed the human body in strong external field the hydrogen nuclei

magnetic moments align with the external field parallel (little bit more) and anti-parallel to external field, this creates a net magnetization parallel to the external field we call it longitudinal magnetization which is responsible for acquiring the images of the tissues of the human body.
One type of cancer is known as glioblastoma multiforme (GBM). It is found mostly in both hemispheres. It is a rapidly growing, aggressive brain tumor that arises from brain cells, especially in the frontal and temporal lobes. It appears as a heterogeneous mass in the white matter with irregular peripheral enhancement with peripheral vasogenic edema.

Equipment: The MRI machine used in this procedure consists of the following parts:

1. Strong permanent magnet: its type is open, with a strength of half a Tesla, which produces the initial magnetic field in which the patient is placed.

2. Gradient coils: Their function is to uniformly gradient the primary field for spatial localization of the signal.

3. Radio frequency coils: Used for the head: to send the radio frequency pulse to the tissues and receive the radio frequency signal from the tissues.

4. Computer system: Use to operate the MRI Machine and process, control and produce the MRI images. Patient table: The patient is placed in it and it is designed to bear the patient's weight to a certain extent.

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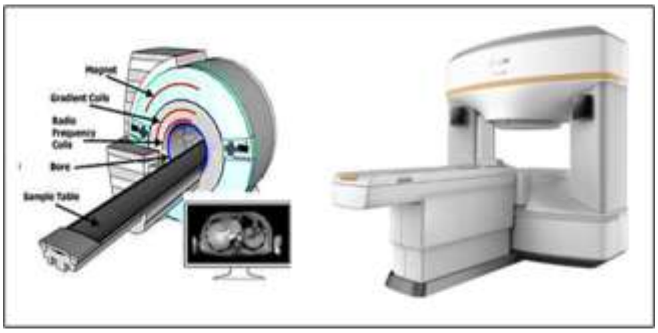


Figure shows the parts of the MRI machine

Characteristics of the MRI device used:

Machine name:	i_open 0.5T MRI system WDM
Company name	China Resources Wandong Medical Equipment Co. LTD
Software:	'OpenScaner 3.2' Microsoft XP (DICOM3.0, HL7)
Magnet field strength:	0.5T
Magnet type:	Permanent
RF Coils used:	Head
Protocols used:	T1WI, T2WI, FLAIR
Scanned Region:	Brain

Method: The patient is inserted into the middle of the magnetic field to ensure the uniformity and homogeneity of the primary magnetic field, using the laser identification located within the device. Before that, it is ensured that it is free of any ferromagnetic materials that move under the influence of magnetic fields like iron, nickel, cobalt or any device such as the pacemaker, cochlear implant, and other safety rules followed in magnetic resonance imaging. The patient must remain completely still so that no interference occurs and this affects the quality of the imaging. If he is unable, he is anesthetized, and also to ensure the efficiency of kidney functions to be able to inject a contrast medium to give a more accurate diagnosis.

1. Initially, when the human body is placed in the primary magnetic field, the hydrogen nuclei alignment in two ways, most of them are parallel to the direction of the primary magnetic field and some of them are anti-parallel in the opposite direction of the field. According to the Zeeman effect, this creates a net magnetization vector being in the direction of the primary magnetic field along the direction of the axes Z and precession around the direction of the primary field with Larmor frequency. We call this net magnetization a longitudinal magnetization. In order to measure this longitudinal magnetization vector, we have to flip it to the transverse plane XY by using a 90-degree RF pulse generated from RF coils furthermore, the frequency of these 90-degree RF pulse must be equal to the Larmor frequency of the proton's precession, which is known as magnetic resonance. After we flip the longitudinal magnetization completely to the transverse plane XY, we stop the 90-degree RF pulse and relaxation occurs through two separate processes.

a. The first process is transverse relaxation: in which the dephase is occurred in the transverse plane due to a spin-spin interaction, and the parameter of time T2 (the time when tissues preserve 37% of their transverse magnetism) varies from one tissue to another according to its molecular composition, and also between normal and pathological tissues.

b. The second process is longitudinal relaxation: where the time factor T1 that it takes for tissues to Recover 63% of their longitudinal magnetization changes due to the spin-lattice interaction according to the type of tissue and its molecular structure, and this gives a difference in T1 between different types of tissues and also between normal tissues and pathological tissues.

2. The RF coils measure the free induction decay signal resulting from the decay of transverse magnetization due to the interaction of the transverse magnetization with the inhomogeneous local field, which accelerates phase removal. This leads to damp and rapid disappearance of the free induction decay signal that we cannot measure it.

3. We apply a second rephase 180-degree RF pulse in the case of a spin echo sequences, or we apply an inverse rephase reading gradient field in the case of a gradient echo sequences. This is allowed us to measure an analog complex echo signal which induces an electrical current in the radio frequency coils installed in the head, according to Faraday's law.

4. The mathematical Fourier transform is used to separate the analog complex signal recorded by the radio frequency coils into its primary frequencies, the Fourier transform between object $\rho(\boldsymbol{r})$ and the signal $s(\boldsymbol{k})$ described by the following relationship:

$$s(\boldsymbol{k}) = \int \rho(\boldsymbol{r})\, e^{-2\pi i \boldsymbol{k}\boldsymbol{r}}\, d\boldsymbol{r} \;\ldots (2)$$

and then encoded them to fill k-space through the following stages:

• **The first stage-slice selection:** We activate the gradient coils in the Z direction simultaneously with the release of the γ-degree RF pulse in order to select and flip a specific slice.

• **The second stage-phase encoding:** We activate phase encoding gradients in Y direction in order to determine the line that will be filled in k-space.

• **The third stage-frequency encoding:** We activate the frequency coding gradients in the X direction in order to move to another new lines of K space.

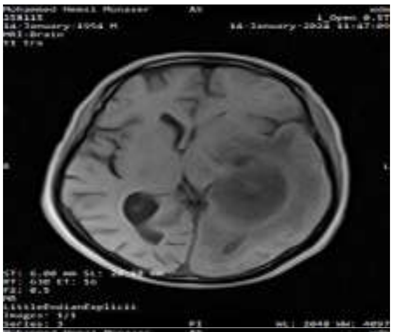
5. After filling the K space and processing the image, we apply the inverse Fourier transform to obtain different types of MRI brain images, to find the location of the body $\rho(\boldsymbol{r})$ we use the inverse Fourier transform, which is given by:

$$\rho(\boldsymbol{r}) = \int s(\boldsymbol{k}) e^{2\pi i \boldsymbol{k}\boldsymbol{r}} d\boldsymbol{k} \ldots (3)$$

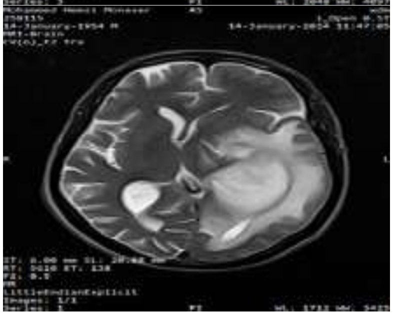
6. We compare healthy normal images with images taken from the patient in order to detect and diagnose the pathological lesion that the patient suffers from.

Results: We obtained four different types of images in the transverse plane that clearly show the location of the lesion and its effect on the surroundings, as shown in the figures below:

Type I: Longitudinal relaxation time weighted image (T1WI), this type was obtained using a spin echo sequence, but with a short repetition time and a short echo time as well, and the fluids appear black and the fats are white.

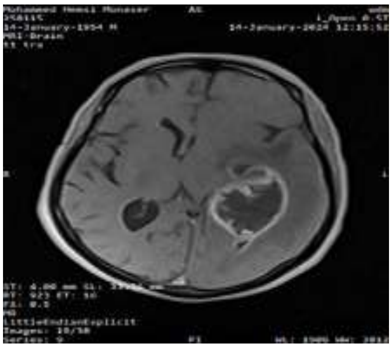


Type II: Transverse relaxation time weighted image (T2WI): This type was obtained using a spin echo sequence with a long repetition time and long echo time, and the fluids appear white and the fats are dark.



Type III: Fluid attenuated inversion recovery (FLAIR), using a spin echo sequence preceded by a 180 pulse with a very long repetition time and long echo time, shows a similar T2 image with the cancellation of the fluid signal**.**

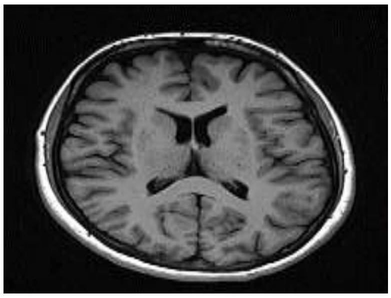
Type IV: The weighted image of the longitudinal relaxation time after injecting the contrast medium. The image appears as in T1 if it is normal, but an accumulation of gadolinium occurs in the disrupted blood-brain barrier. It is considered one of the magnetic materials that work to create a local magnetic field that works to shorten T1. If there is a tumor, it appears brightly.



Analysis: After we have obtained the different types of images for the MRI sequences mentioned above, we will compare them with normal images in each type of image of these sequences:

Fluid signal: In the normal image fluids have a long T1 (to recover their longitudinal magnetization). But the T1-weighted image uses a short TR, so the fluids in the image appear dark. As in cerebrospinal fluid (CSF).

Signal of fats and proteins: In the normal image, fats and proteins have a short T1 to restore their longitudinal magnetization, so although the TR is short in the T1WI-weighted image, the signal is still high and the fats and proteins appear bright.



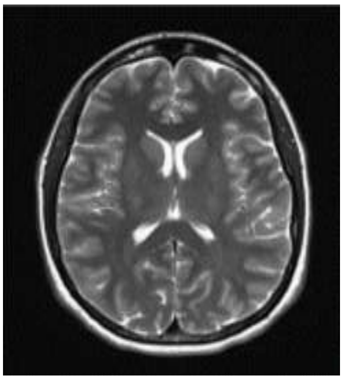
Short TR 300-600 msec.
Short TE 10-30 msec.
T1WI

In the abnormal image, the fat signal and the water signal appear as in the normal condition, except for the area marked with a red circle that appears in a darker color than normal, and this indicates the presence of abundant fluids in this place. This indicates the presence of a pathological lesion. Usually, the pathological tissues have a higher water content than normal. There was also a mass effect that led to the displacement of the midline and pressure on the ventricles, and therefore the most likely occurrence of a multiplication of cells - i.e. a cancerous tumor - and an increase in the percentage of fluid, and this is confirmed by viewing other types of images such as T2-weighted images and FLAIR.

T1WI

Fluid signal: In the normal image fluids have a long T2 (when their transverse magnetization is lost). They re-tain their magnetism for a long time and the recorded signal is strong, so the fluids in the image appear bright. As in cerebrospinal fluid (CSF).

Signal of fats and proteins: In the normal image, fats and proteins contain a short T2 when their transverse magnetization decays. Therefore, they lose their mag-netization quickly, and the recorded signal is weak and appears dark in the image.

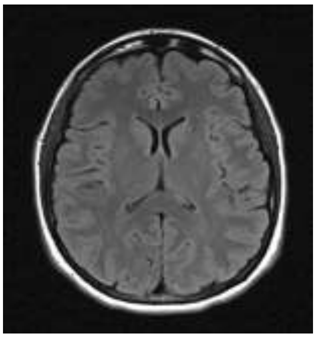


TR long over 2000 msec
TE long 80-140 msec
T2WI

In the abnormal image, the fat signal and the water signal appear as in the normal case, except for the area marked with a red circle that appears bright and lighter in color than normal. This indicates the presence of water in abundance in this place, and this indicates the presence of a pathological lesion. Usually, pathological tissues have a higher water content than normal, but in this type of image, no distinction is made between lesions and ventricles, and therefore we use the FLAIR sequence to confirm this.

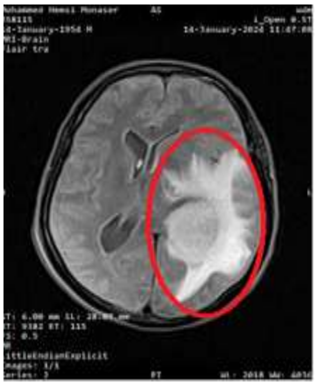
T2WI

In the normal image, when the FLAIR sequence is used to suppress the fluid signal, it is similar to the weighted image transverse relaxation (T2WI) time in the spin echo sequence, except that the free fluid appears black and the restricted fluid appears white.



FLAIR

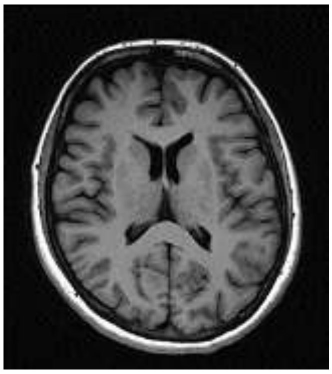
In the abnormal image after suppressing the signal of free fluid, the specific place appeared in a bright color, and this is evidence that it is a tumor and not fluid. This tumor is surrounded by edema whose signal appears brighter than the tumor because it contains a lot of restricted fluid. The tumor, by its nature, causes a significant multiplication of cells, so the fluid increases. Therefore, the protons increase, and the amount of magnetization increases, so the signal is strong here.



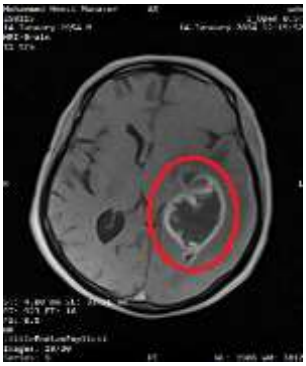
FLAIR

Suppression of the free fluid signal allowed us to distinguish between the CSF in the ventricles and the tumor and demarcate the boundaries between them.

In the normal image, we find that magnetic materials such as gadolinium possess small local magnetic fields that shorten the relaxation times of the surrounding protons, noting that gadolinium does not pass through the normal blood-brain barrier, but rather through the disturbed blood-brain barrier, and this leads to shortening of T1, which enhances the vascularization of the tumor tissue. It makes the tumor bright and the surrounding edema is not affected, and this does not happen normally in the case of a normal blood-brain barrier.



In the abnormal image after injecting the patient with the contrast agent (gadolinium), there was absorption and accumulation of the contrast agent in the patient's blood-brain barrier, which led to a shortening of T1 and an irregular enhancement of the edges of the tumor, and no effect of edema around the tumor.



T1+ (Gd)

Conclusion & Diagnosis: Through the images obtained by the MRI machine in different sequences and comparing them with the normal images, we find out that there is a large, ill-defined, irregularly shaped lesion located in the left temporal lobe with midline shift. It exerts mass effect and compresses on the ventricles. It is a glioblastoma multiforme surrounded by edema - a cancerous tumor.

References:

1) Schild, H. H. (1990). *MRI: made easy* (1st ed.). Schering AG, Berlin. https://rads.web.unc.edu/wp-content/uploads/sites/12234/2018/05/Phy-MRI-Made-Easy.pdf
2) Sprawls, P. (2000). *Magnetic Resonance Imaging: Principle, Methods, and Techniques*. Medical Physics Publishing, USA. http://www.sprawls.org
3) Bushberg, J. T., & Others. (2001). *The essential physics of medical imaging* (2th edition). 394-489. Williams & Wilkins. https://www.scribd.com/document/552750338/The-Essential-Physics-of-Medical-Imaging-2nd-Edition
4) Gossuin, Y., & Others. (2011). *Physics of magnetic resonance imaging: from spin to pixel*. Journal of Physics D: Applied Physics, 43(21), 1-41. https://hal.science/hal-0056911/document
5) Porter, A. (2012). *A Dead End: A Review of Glioblastoma Multiforme*. Eukaryon, 8, 64-68. https://www.lakeforest.edu/live/files/porterreviewprint-removedpdf.pdf
6) Idress, M. (2014). *AN OVERVIEW ON MRI PHYSICS AND ITS CLINICAL APPLICATIONS*. International Journal of Current Pharmaceutical & Clinical Research, 4(4), 185-193. https://www.researchgate.net/publication/270586622-AN-OVERVIEW-ON-MRI-PHYSICS-AND-ITS-CLINICAL-APPLICATION
7) Hanif, F.,& others. (2017). *Glioblastoma Multiforme*. A Holistic Review, 18(1), 3-9. https://journal.waocp.org/article_42593b0f79bc0c790bfac0.pdf
8) Maier, A., & Others. (2018). *Medical Imaging Systems: An introductory guide*.91-118. Springer International Publishing AG. https://link.springer.com/content/pdf/10.1007/978-3-319-96520-8.pdf
9) SILVER SWAN. (2018, January 5). *SEKTION* (1-23) [video]. YouTube. https://youtu.be/Khn-azofAD4
10) Abdulla, S., & Clark, C. (2018). *FRCR Physics Notes: Beautiful revision notes for the first FRCR Physics exam*. Radiology Café Publishing, UK. www.radiologycafe.com
11) DR. Eslam Kamal. (2020, January 16). *MRI Physics Part1 Basic Structure* [video]. YouTube . https://youtu.be/yMyi_6wN3VU
12) Radiopedia. (2023). *MRI| Radiology Reference Article*. Retrieved from https://radiopeadia.org/articles/mri-2
13) Radiology Café. (2023*). MR imaging*. Retrieved from https://www.radiologycafe.com/frcr-physics-notes/mr-imaging/
14) Radiopedia. (2024). *Glioblastoma, IDH-wildtype*. Retrieved from https://radiopeadia.org/articles/glioblastoma-idh-wildtype?lang=us
15) Elster, A. D. (2024). *Questions And Answers in MRI*. Retrieved from https://mriquestions.com
    Case Western Reserve University. (n.d.). *MRI Basics*. Retrieved from https://Case.edu/med/neurology/NR/MRI%20Basics.htm

استخدام التصوير بالرنين المغناطيسي لاكتشاف وتشخيص الورم الأورمي الدبقي متعدد الأشكال

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الملخص: يعد التصوير بالرنين المغناطيسي أداة تشخيصية آمنة وعالية الجودة في الكشف عن الأورام وحجمها وتحديد موقعها وتشخيصها بدقة في جسم الإنسان وخاصة في الدماغ. وأبرز هذه الأورام هو الورم الأرومي الدبقي متعدد الأشكال، يتميز هذا النوع من التصوير بتباين عالي للأنسجة الرخوة، مقارنة بتقنية التصوير المؤين كما هو الحال في الأشعة السينية والأشعة المقطعية.

في التصوير بالرنين المغناطيسي عندما وضعنا جسم الإنسان في مجال مغناطيسي خارجي قوي شدته B_0، فإن العزوم المغناطيسية لنواة الهيدروجين في أنسجته تكون متوازية وغير متوازية مع المجال الخارجي، وبحسب تأثير زيمان فإن ذلك يخلق مجالاً مغناطيسياً صافياً باتجاه المجال المغناطيسي الخارجي نسميه المغنطة الطولية وهي المسؤولة عن تكوين صورة لهذه الأنسجة في جسم الإنسان.

تسبق نوى الهيدروجين ذات المغنطة الطولية الصافية حول محاور المجال الخارجي بتردد لارمور ω_0 المعطى من معادلة لارمور: $\omega_0 = g \times B_0 \ldots (1)$ ، حيث g هي نسبة الجيروسكوب المغناطيسي.
لقياس هذه المغنطة الطولية، علينا أن نقلبها إلى المستوى XY. يمكن القيام بذلك عن طريق استخدام موجات التردد الراديوي المتولدة من ملفات التردد الراديوي (قانون فاراداي-لينز)، تعمل هذه الموجات على إثارة نوى الهيدروجين لقلب المغنطة من الاتجاه الطولي Z إلى المستوى العرضي XY بعيدًا عن المجال الخارجي لتمكن من قياسها، ويتم ذلك عندما يكون تردد النبضة الراديوية المرسلة مساوياً لتردد لارمور لسبق نواة الهيدروجين لتحقيق شرط الرنين المغناطيسي، بعد إيقاف نبضة التردد الراديوي نستطيع الحصول على الإشارات القادمة من نواة الهيدروجين الموجودة في أجسامنا وتسجيلها عبر ملفات التردد الراديوي حسب قانون فاراداي- لينز ونحصل على إشارات كهربائية مركبة مستمرة، ثم نستخدم تحويل فورييه الرياضي لتحويل هذه الإشارات المركبة المستمرة إلى قيم منفصلة لملء فضاء K، بعد معالجة الإشارات المنفصلة، نستخدم تحويل فورييه العكسي للحصول على صورة لإعطاء تمثيل مرئي للأنسجة البشرية دون تدخل جراحي للتشخيص السريري.

الكلمات المفتاحية: الرنين المغناطيسي، تأثير زيمان، قانون لينز- فاراداي، تحويل فورييه، تحويل فورييه العكسي.