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Spin Echo Magnetic Resonance Imaging

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1. Introduction

Magnetic Resonance Imaging (MRI), as its name implies, is based on a magnetic resonance signal originating in the "spins" of hydrogen protons of a given patient's tissue undergoing magnetic resonance imaging under the action of a magnetic field [1].

Concerning the identification and characterization of tissues, the potential of MRI began to become apparent only in 1971, when it was realized that the magnetic relaxation properties of the nuclei differ among biological tissues. Furthermore, in the same tissue, this relaxation relied on the state of the vitality and integrity of tissues [2].

P. C. Lauterbur was the pioneer of imaging techniques for medical practice using MRI. In 1973, he described a method that produced a generation of a two-dimensional projection showing the density of the protons and the distribution of the relaxation times in a sample consisting of two water tubes. His studies were further improved by groups led by Hinshaw and Mansfield in England, Hutchinson in Scotland, Ernst in Switzerland, and Cho in Korea. Thus, alternative techniques have been developed to generate images that can assist both medical diagnoses and "in vivo" studies of biochemical reactions that occur at the cell level [1,3,4].

The most important factor for the formation of MRI is the "spin." In essence, the "spin" is a fundamental property of particles that make up the nucleus of the atom. Its concept was proposed by Samuel Abraham Goudsmit and George Eugene Uhlenbeck in 1925 [1].

Unlike the known images of Rx and CT, MRI does not use ionizing radiation but radiofrequency pulses.

The phenomenon of Magnetic Resonance Imaging manifests itself in molecular, atomic, electronic, and nuclear levels. In the latter case, its nature is magnetic, and therefore it is called nuclear magnetic resonance (NMR). It arises from the fact that certain nuclei possess an intrinsic angular moment referred to as "spin" and an associated magnetic moment. In

medicine the term used is MRI. The term nuclear associated to it caused panic among patients, who believed the tests were harmful and painful to the tissues. In clinical trials, MRI is used to produce images of the body structures. This method has provided valuable assistance, since it is not invasive to biological tissues, and provides an excellent contrast between soft tissues [2,5,6].

2. MRI fundamental

In nuclei in which the "spin" protons are not paired, there is a resultant magnetic field which can be represented by a dipole magnetic vector. The magnitude of this field is called nuclear magnetic moment, and its existence causes the nuclei to respond actively to external magnetic fields. The nuclear magnetic vector does not remain static in one direction, but has a precessional motion or rotation around its axis (Figure 1).

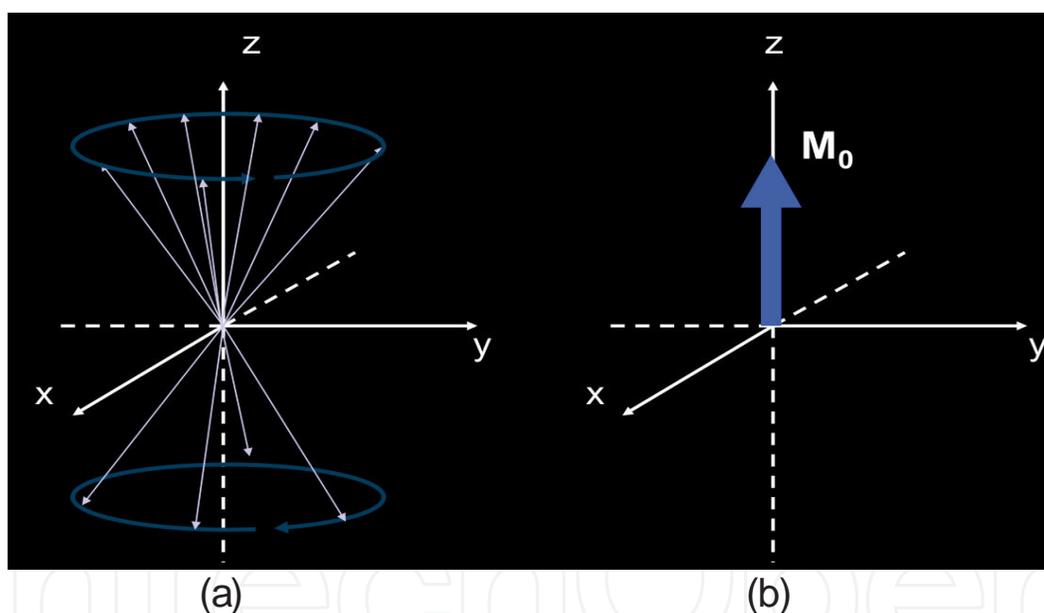


Figure 1. Schematic representation shows the spins in (A) the absence and (B) in the presence of an external magnetic field [3].

It is noted that in (A) without application of an external magnetic field, the protons are oriented in a random motion, while in (B) when placed in an external magnetic field B_0 , the protons are aligned in the same direction, or in an opposite direction to the magnetic field. The slight preponderance of the spins in the same direction of the field creates a small resulting magnetization vector named M_0 . This slight imbalance makes it possible to obtain images by RMI [3].

Two-thirds of the atoms that constitute the human body are hydrogen atoms, which contain only one proton in its nucleus. Therefore, they present a high-intensity magnetic vector, which increases their sensitivity to respond to external magnetic fields. In addition to hydrogen being the most abundant nucleus in biological tissues, its single proton results in more powerful magnetic moment than any other element. Due to these features, the hydrogen nucleus of biological tissues is the same one currently used to obtain the signal for the formation of images in MR procedures. However, other types of nuclei may be used to generate information on both the physiopathologic status and anatomy of tissues. Among other elements, we can cite carbon, oxygen, and sodium [7,8,9].

A radiofrequency pulse or excitation must be applied perpendicular to the main magnetic field in the frequency of precession or rotation of the hydrogen atoms (Larmor frequency) in order to obtain MR images. This radiofrequency pulse supplies energy to the resulting magnetization vector so that it is deflected to the transverse plane. Once the stimulation ceases, the magnetic vector returns to balance. This turning back to balance is measured and provides the generated resonance signal, which will be captured by the antennas of the MR apparatus [2,9].

3. Spin-echo sequence

In MRI, the most important pulse sequence is the "spin-echo" and its parameters are the repetition time (T_R) and echo time (T_E). Another important additional sequence is the "inversion-recovery" sequence, which promotes fat suppression, highlighting areas of injury with an additional parameter - the inversion time (T_I) [8,9,10].

Therefore, the keys to understanding MRI are physical principles, which include the magnetic properties of nuclei in biological tissues, the collective behavior of these biological tissues when excited by radio waves, and their relaxation properties, as well as the devices and techniques used to differentiate the tissues [7,9,10,11].

The technical parameters used to run a MRI were pulse sequences in "spin-echo" (SE) and "inversion-recovery" (Short T1 inversion STIR) to obtain images in T1 relaxation time (before and after injection of gadolinium contrast), in T2 relaxation time, and precontrast proton density (PD); Repetition time (TR), echo time (TE), and inversion time (TI); Section Plans (coronal or axial); Field of view (FOV), matrix size, number of acquisitions (NAQ), and number of sections, thickness, and interval between slices, and increment (F1), besides other functions to improve image quality [9,11].

The "spin-echo" pulse sequence [9,10,11] is used to obtain a signal by means of a 90° excitation pulse and a 180° inversion pulse, which were sent to the nuclei of hydrogen atoms of the tissues present in the region to be analyzed (Figure 2). These nuclei presented a rotating motion (precession), and when excited by a radio frequency coil (antenna), they start to rotate all at the same excitation frequency, resonating with each other. Once the stimulation is ceased, the MR signal is captured in form of signal or echo (Figure 3).

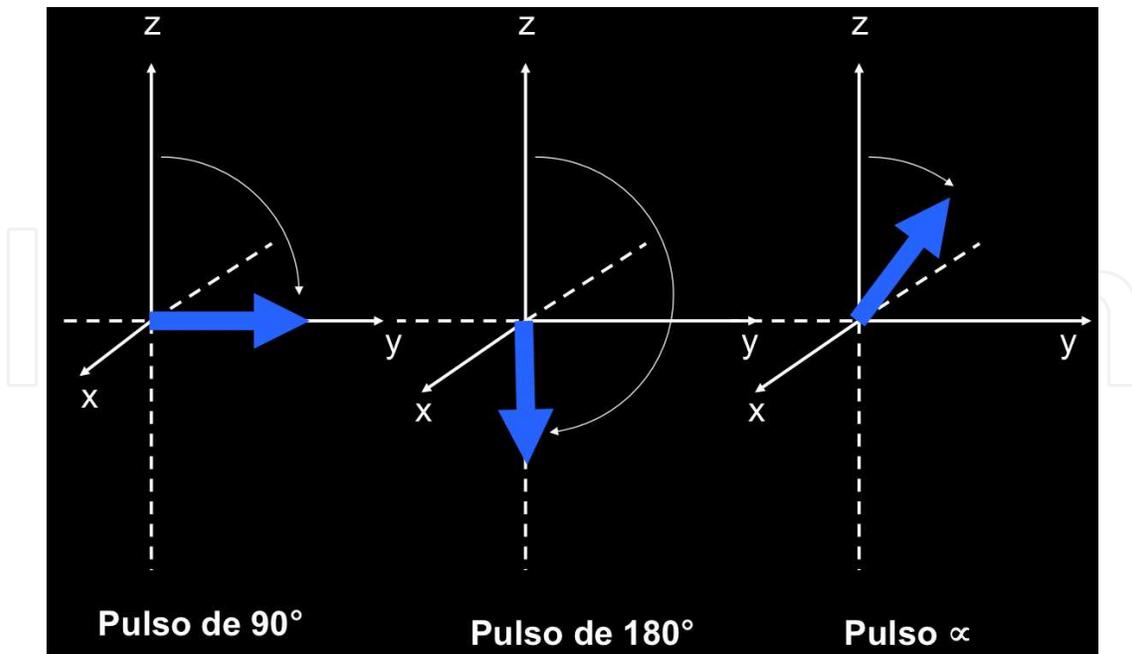


Figure 2. Radiofrequency pulse: 90° excitation pulse and a 180° inversion pulse, the pulse can be any value [3].

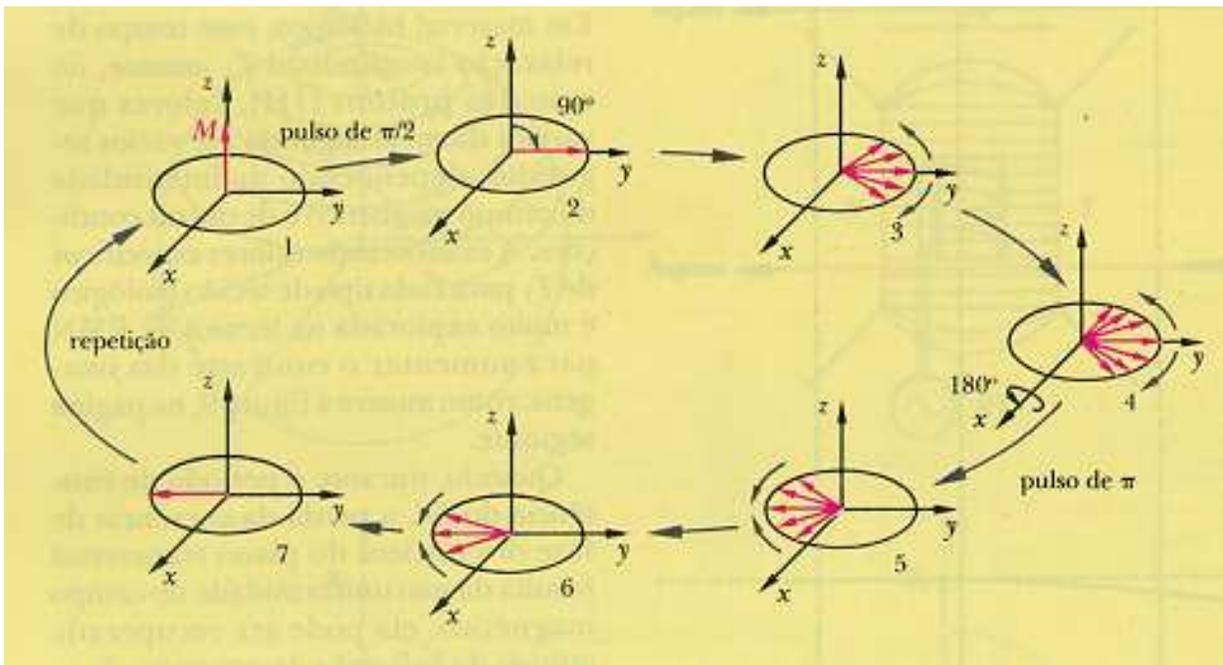


Figure 3. Illustration of the “spin-echo” (SE) imaging sequence [9,10].

When a pulse of 90° ($\pi/2$) is applied, the magnetization M initially in its equilibrium condition along the Z -axis (1) undergoes a 90°-displacement towards the y -direction (2). The tissues show a distribution of frequency of precession (3). There is a loss of coherence of the initial state (4). This loss can be reversed by applying a 180-degree pulse (π), which causes the spins of

individual nuclei around the X-axis to rotate 180 degrees (5), rephasing (6) and regenerating the signal, referred to as spin-echo (7).

The 90° pulse plus the 180° pulse produced an echo, which is repeated several times during the study in the analyzed region. This echo is referred to as the repetition time (T_R). The echo time (T_E) is the duration between the middle of a 90° pulse and the middle of an echo (Figure 4).

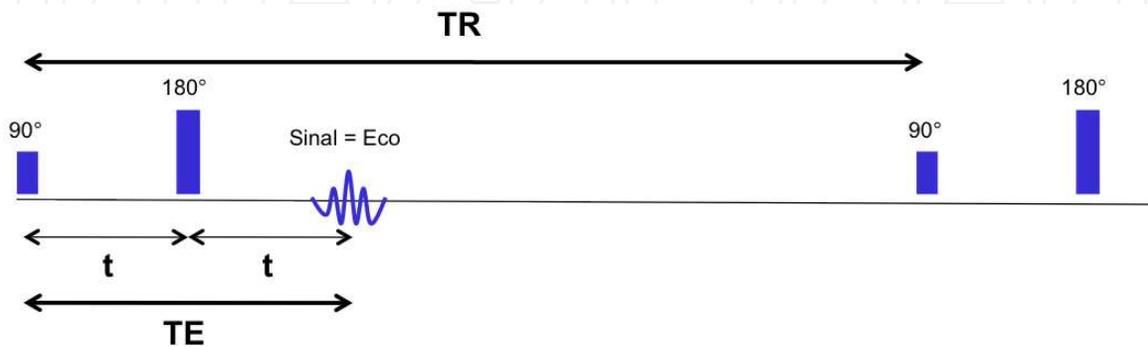


Figure 4. SE pulse of 90° and applied time ($T_E/2$) of pulse RF of 180° [3].

3.1. Conventional spin-echo sequence

The sequences of pulses in conventional spin-echo can be used in almost all tests. T1-weighted images are useful to demonstrate anatomy, but they can also demonstrate diseases when associated with contrast enhancement. T2-weighted images also demonstrated diseases. Tissues affected by diseases appear edematous and/or vascularized. They have higher water content and therefore, a strong signal on T2-weighted images. Thus, they can be easily identified.

Usually, in conventional spin-echo sequence a short T_R a short T_E will give a T1-weighted image, a long T_R and short T_E (first echo) will give a proton density image, and a long T_R and long T_E (second echo) will give a T2-weighted image [10].

3.2. Fast spin-echo sequence

The fast spin-echo sequence is a spin-echo sequence, but with the time of the exam dramatically shorter than the conventional spin-echo. To understand how rapid the fast spin-echo sequence is, we should review how data is obtained in the conventional spin-echo. A 90° excitation pulse is followed by a 180° rephasing pulse. Only one encoding phase step is applied by T_R in each section and just one K-space line is completed by T_R [10,12,13].

Generally, the contrast observed in fast spin-echo images is similar to that of the conventional spin-echo images. Therefore, these sequences are useful in many clinical applications. In the central nervous system, pelvis, and musculoskeletal regions, the fast spin-echo sequence has practically substituted the conventional spin-echo. In the chest and abdomen, however, the

respiratory artifacts are sometimes problematic in cases where the respiratory compensation techniques are not compatible with the programs fast spin-echo, which is counterbalanced to some extent by the fact that shorter examination times in fast spin-echo sequence enable the production of images with fewer respiratory artifacts in [9,10,11,13,14,15].

There are two differences in contrast between the pulse sequence of the conventional spin-echo and fast spin-echo, both of which are due to the 180° pulse repeated at short intervals following the sequence of echoes. First, the adipose tissue remains clear on T2-weighted images due to multiple RF pulses that reduce the effects of spin-spin interactions in this tissue. However, the fat saturation techniques may be used to compensate for this. Second, the 180° repeated pulses may increase the magnetization transfer, so that the muscles appear darker on the fast spin-echo images than on the conventional spin-echo images. Additionally, multiple 180° pulses reduce the effects of magnetic susceptibility, which may be detrimental when looking for small haemorrhages [10].

The advantages of fast spin sequence are that metal implant artifacts are significantly reduced in rapid sequences.

In fast spin-echo T1-weighted images, effective TE and TR are short; on T2-weighted effective TE and TR are long TR; on proton density weighting/T2-weighted images, effective TE is short and effective TR is long [10,11,13,15].

The advantages are: Greatly reduced examination times, better image quality, and more information on T2-weighted images. We can use high-resolution matrices and multiple numbers of excitations (NEX). However, some effects of increased flow and movement are incompatible with some options of image acquisition, such as fat tissue bright on T2-weighted images, blurred images can occur because data were collected at different TE time, decreased magnetic susceptibility effect, because multiple 180° pulses produce excellent returning phase, so that one must not use it in case of suspected bleeding [4, 9,10,13,14,15].

The “inversion-recovery” sequence is used to promote suppression or fat saturation, highlighting areas of injury. The process was the reverse of the “spin-echo” sequence. There was an inversion followed by a recovery by applying 180° inversion pulses, which inverted the spins of the fatty tissue region examined by 180° , followed by 90° recovery pulse. Subsequently, a 180° repolarizing pulse was applied to produce a spin-echo. In this sequence, the repetition time (T_R) is the time between each 180° pulse. The inversion time (T_I) is the length of time the fat (spins) took to recover from this complete inversion (Figure 5).

This process allowed the fat to become dark or hypointense, differing itself from the lesions. This happened because the inversion of its spins caused a total loss of energy/magnetization. Consequently, there is no sign for it [10].

The field of view (FOV) determines the size of the anatomy covered during the selection of the tissue section to be analyzed either in a coronal or axial plane. The forming unit of a digital image is the pixel. The brightness of each pixel represents the power of the MR signal produced by a volumetric imaging of the patient or volumetric pixel or Volumetric Picture Element (voxel). The voxel is a volume element representing the tissue inside the patient. It is deter-

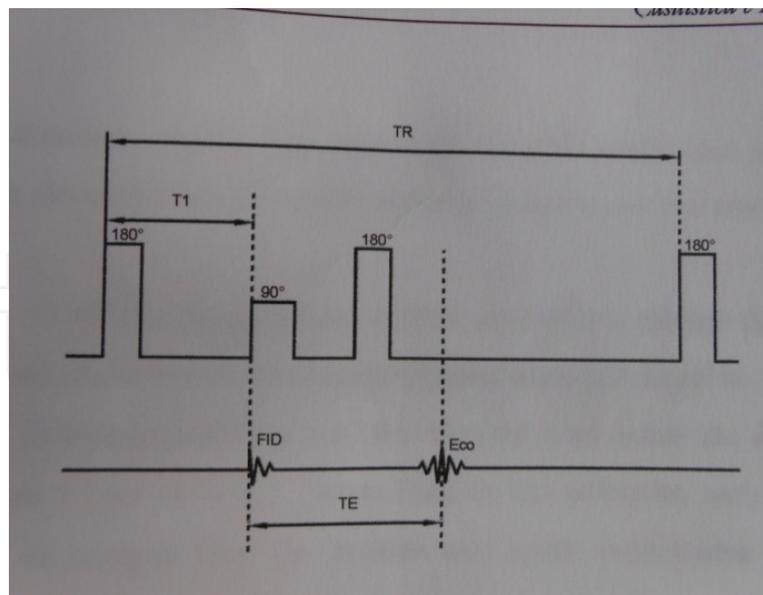


Figure 5. Illustration of the resonance image inversion-recovery pulse sequence. A 180° pulse inversion is applied followed by a 90° recovery pulse, as well as a 180° repolarization pulse. T_R , T_E and T_1 are also shown [16].

mined by the pixel area and the thickness of the section. Thus, the size of the matrix is determined by the number of pixels of the anatomy covered during the selection of the tissue section to be analyzed. This size is indicated by two values. The first one corresponds to the number of frequencies sampled and the second to the number of phase codings performed [7,10,13].

Frequency codification is the reading of a signal along the longest axis of the anatomy. The phase codification is the reading of a signal along the short axis of the anatomy. Thus, a matrix size of 256×192 indicates that 256 encoding frequencies and 192 encoding phases are performed during a sequence [9,10].

The number of acquisitions (NAQ) represents the number of times that data are acquired within/into the same pulse sequence [10,11].

The number, thickness and intervals of the sections are defined according to the type of lesion. Other functions are used to improve image quality. Its use allows viewing only the sections selected [10,11].

4. Tissue parameters

The images primarily reflect the distribution of free hydrogen nucleus and the way it responds to an external magnetic field. Thus, this response determines different relaxation times known as T_1 and T_2 . The pathological processes cause relaxation time to change in relation to the tissues of the nervous and musculoskeletal system, and the signal intensity is reflected [7,9,16].

4.1. Tissue relaxation time T₁

Required for recovery of about 63% of the magnetization along the longitudinal direction after a 90° pulse are generally more anatomical, since the fat planes are hyperintense, perfectly delimiting muscle planes and vascular structures. When paramagnetic agents (contrast) are associated, they demonstrate the skin changes with much more specificity. It is used to evaluate the anatomic structures of the injured limb in MRI and SE sequences before and after contrast. The mechanism is based on the application of a 90° RF pulse that diverted the longitudinal magnetization towards the transverse plane. Subsequently, there is a recovery of this energy diverted to the initial longitudinal axis. In a more simplified way, T₁ is the time required for the initial 63% recovery of the magnetization along the longitudinal axis after the application of 90-degree RF pulse (Figures 6 &7) [7,9,10].

Thus, the signal intensity (brightness) emitted by the tissues depends solely on its ability to recover the magnetization faster or slower after the application of a 90-degree RF pulse.

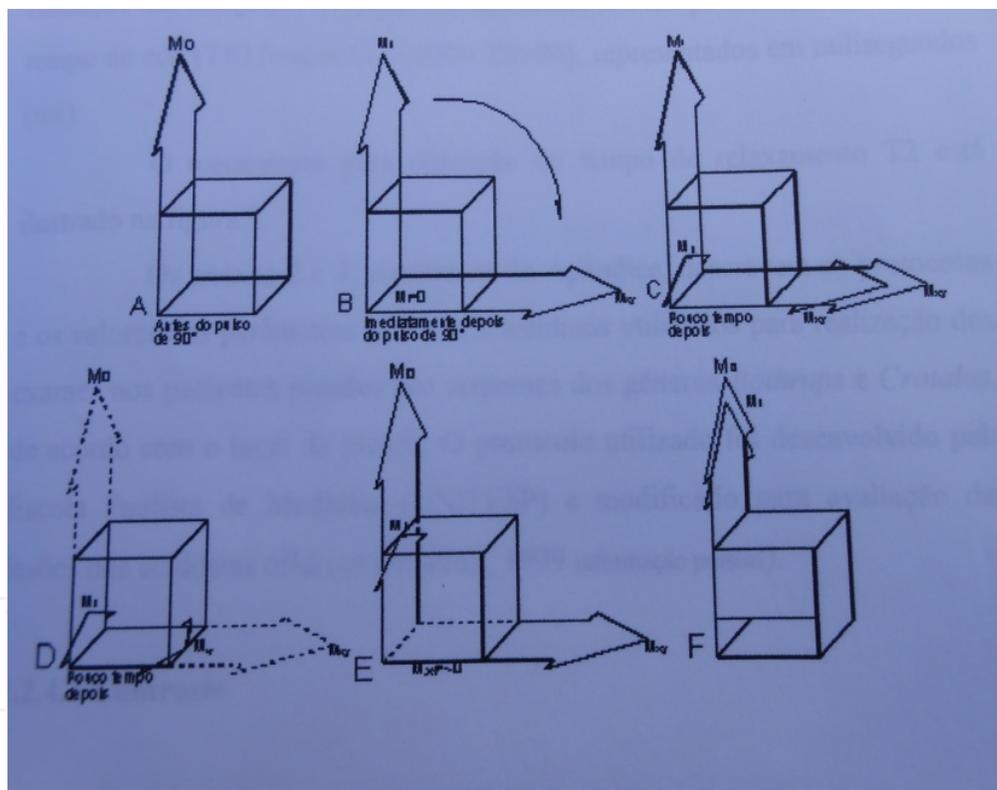


Figure 6. Schematic representation of T₁ relaxation time.

Note that the relaxation time T₁ begins in (A) before the 90° pulse when the magnetization M₀ is in the axis. Just after the 90° pulse, the magnetization is zero and the transverse is maximum (B). A short time later, there is the recovery of the resulting longitudinal magnetization (C) representing the start of recovery T₁ (D, E), and in (F) occurs the 63% recovery of the initial magnetization [16].

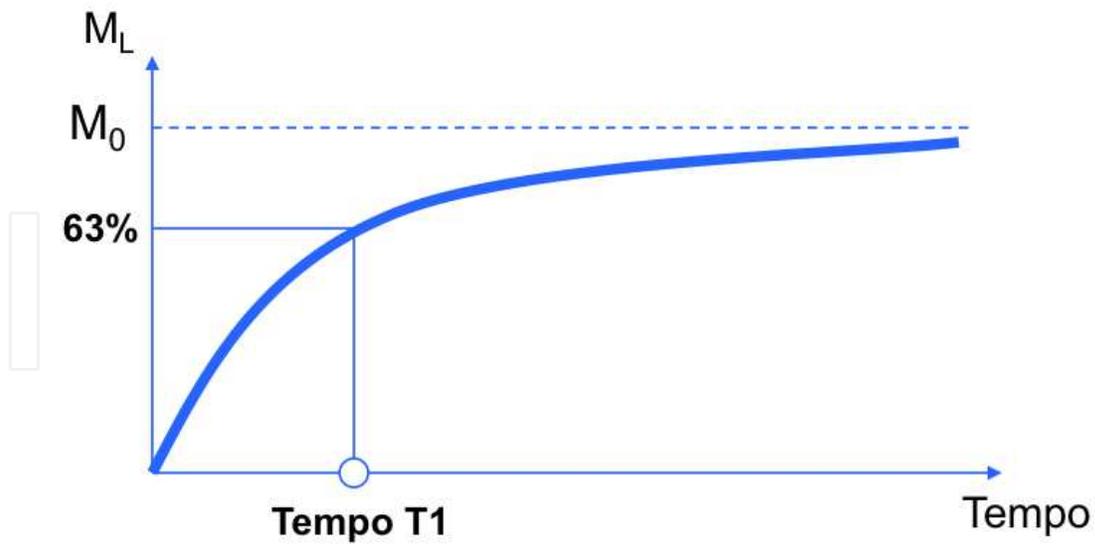


Figure 7. Relaxation time T1: recovery 63% of the magnetization along the longitudinal direction after a 90° pulse [3].

4.2. Tissue relaxation time T2

Tissue relaxation time T_2 is used throughout the SE sequence to detect lesions. At T_2 time, there is a magnetization shift or loss. The tissues' capacity to lose magnetization faster or slower is what determines the signal strength. T_2 time is the time required for the transverse magnetization to drop up to 37% of its initial value after the application of a 90-degree pulse (Figure 8 & Figure 9) [7,9,10].

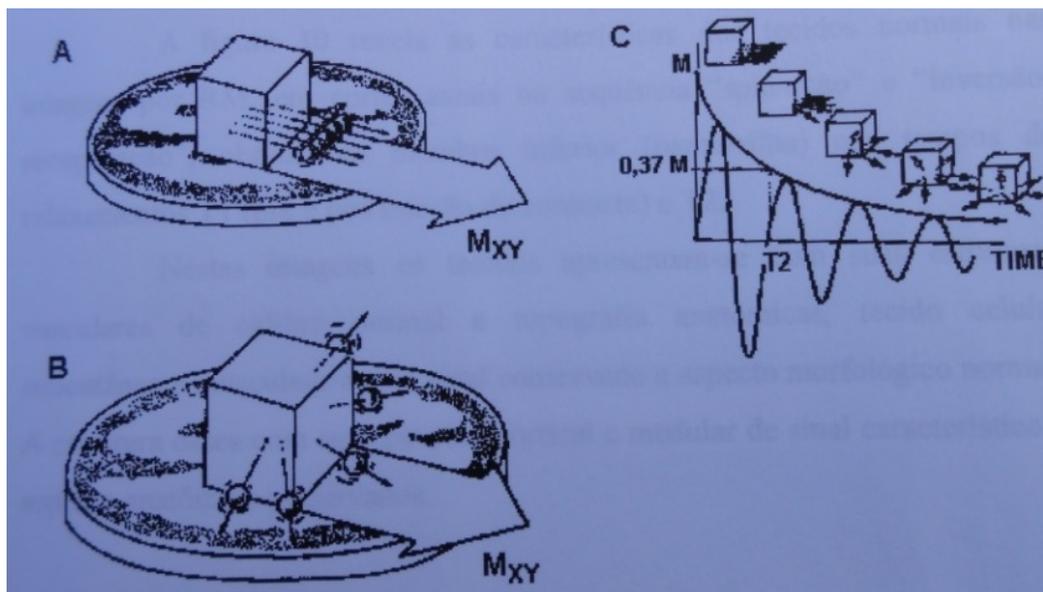


Figure 8. Schematic representation of T_2 relaxation time.

In (A) are representative protons of a tissue section. Soon after a 90-degree pulse, the protons are on the same transverse plane and in phase with each other. Their magnetic vectors all point in the same direction. (B) After a very short period of time, these protons are out of phase, and their magnetic vectors are pointing to different directions. This decreases the power of the transverse magnetization vector M_{xy} . (C) T_2 is shown as the time interval required for the transverse magnetization drops to 37% of its original value [16].

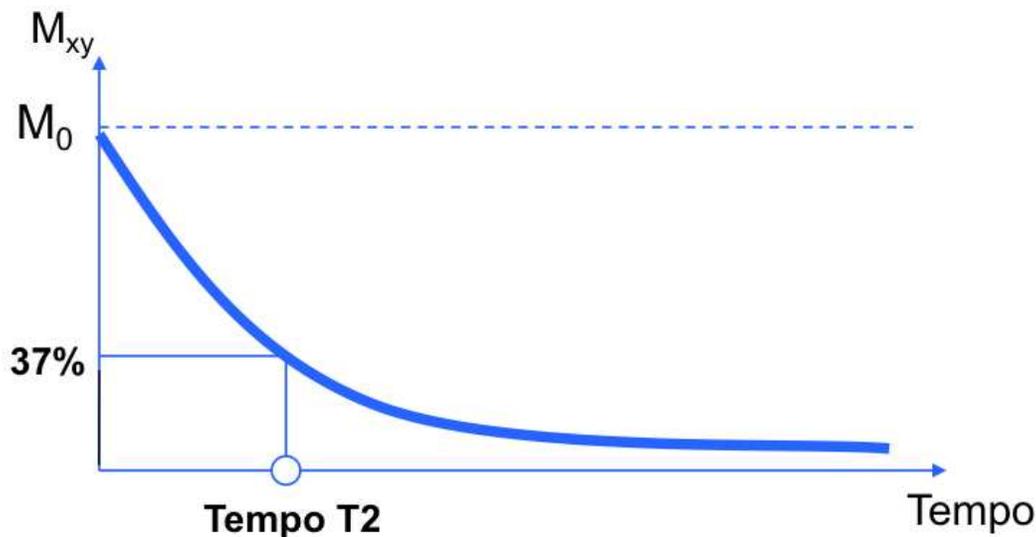


Figure 9. T_2 shown as the time interval required for the transverse magnetization drops to 37% of its original value [3].

5. Contrast

The contrast agent used is a paramagnetic metal called gadolinium (GDL). It is associated with a water-soluble component diethylenetriaminepentaacetic acid (DTPA) that acts on the damaged tissues facilitating their identification [17, 18].

It is administered intravenously at a dose of 0.2 mL/kg on T1-weighted images through section planes determined according to the location and type of injury [17,18].

Patients who receive contrast are asked to abstain from all food and liquid for two hours in order to avoid adverse effects [17,18].

Local lesions are studied for the presence or absence, type, and thickness of the damaged tissues. The determination of the type of lesion is accomplished through changing the signal presented by damaged tissues in relation to normal tissue. The classification of injured tissues into hypointense or hyperintense, depends on the signal intensity (darker or lighter) visualized on the images during the screenings and on an expert testimony (Figure 10) [17,18].

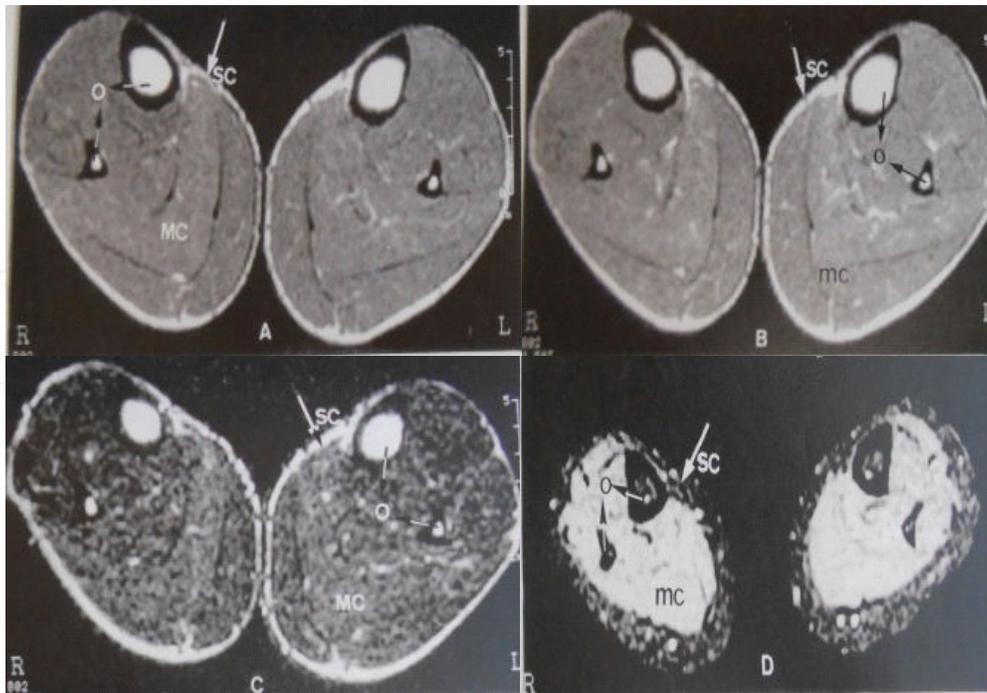


Figure 10. Normal tissue in MRI in axial sections in the "spin echo" sequence taken from the lower limbs (calf) in T₁ pre (A) and (B) post-contrast injection, T₂ relaxation times (C) and inversion-recovery" sequence (D) used to promote suppression or fat saturation [16].

In these images, the tissues present themselves with their normal calibre vascular structures and anatomic topography, as well as their musculature with preserved sign and normal morphological aspect. The images also present the bone structure of their cortical portions and characteristic medullar signal, and preserved anatomical aspect [16].

For images of the central nervous system, "Figure 11" illustrates the characteristics in normal tissue relaxation time T₁ before and after contrasts, which are used to differentiate normal tissue from the pathological ones [19,20].

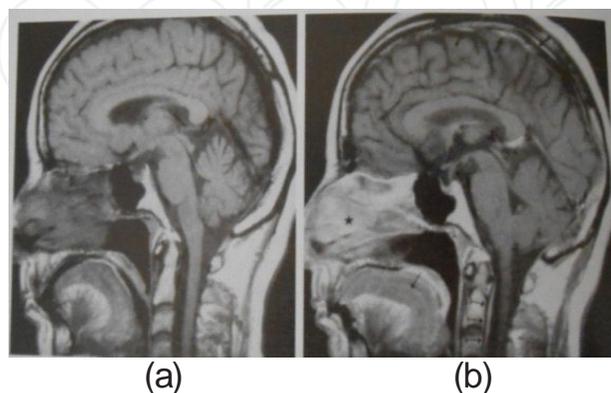


Figure 11. Image of a normal central nervous system (sagittal plane) on pre-contrast (A) and post-contrast (B) sequences spin-echo T1-weighted images.

Note all structures with normal anatomic aspects with enhancement in sequence with contrast, indicated by arrows [21].

6. MRI machine

A magnetic resonance imaging (MRI) machine consists of a main magnet that provides a closed or open scanning system. It is a permanent superconductor. Its power field ranges from 0.23, 0.5, 1.0, 1.5 up to 3.0 Tesla total power field. Internally, the main magnet is composed of homogenizing coils, gradient coils, and radiofrequency (RF) transmitter and receiver coils. These may be located internal or external to the main magnet. The function of these components is to capture the signal or echo generated by the tissues (tissue parameters) when in contact with the magnetic field and technical parameters used [9,10,12]. The machine also comprises computers and image processors, which make it possible to acquire and visualize the image on the operator's console monitor (Figure 12 & Figure 13).

The technical parameters are those dependent on the device and set up by the operator based on examination protocols.

Initially, the patients are placed on the examining bed. The region (lesion) being examined is highlighted by a source of light directed and positioned in the center of the magnet. Afterwards, the device is set up with a specific test protocol according to the limb damaged. Following, we made a first localization sequence in the desired section plane. Thus, we could design other section planes from the image formed [10,12].



Figure 12. Closed field magnetic resonance imaging machine [16].



Figure 13. Open field magnetic resonance imaging machine [9].

The physical principles of the open field MRI are the same as that of the closed field MRI, which uses a strong magnetic field created by the movement of electrical currents within a series of spiral coils located inside the machine [7,9].

The open field MRI is a breakthrough technology to obtain images of the human body without constraints for patients with claustrophobia (fear of closed spaces), obesity, as well as children and elderly people [7,9,12].

The advantages of the open-field MRI are associated to a machine having large side openings that allows the patient to be examined with more tranquillity, comfort, and convenience. It also helps to obtain a better quality of the images [7].

In practical terms, we can consider the MRI machine as a large and powerful magnet. The acquisition of spin-echo images can be understood as follows: The patient is placed into the MRI machine. Once inside the machine all hydrogen ions in the different body tissues will align parallel with the magnetic field of the machine. Then, a coil emits RF pulses that cause the axis of these ions to change 90° . When the coil turns off, the ions tend to realign with the magnetic field, but with different intensities and speeds according to the type of tissue in which they are found. This difference in intensity and time is captured and quantified by the device that locates and defines shades of grey for each point detected. The information is processed by a computer workstation that accomplishes the construction of images in the frontal, sagittal, and axial planes [10,12].

The technical parameters are those dependent on the device and set up by the operator based on examination protocols.

Initially, the patients are placed on the examining bed. The region (lesion) being examined is highlighted by a source of light directed and positioned in the center of the magnet. Afterwards, the device was set up with a specific test protocol according to the limb damaged. Following, we made a first localization sequence in the desired section plane. Thus, we could design other section planes from the image formed [16,19].

The obtained images are recorded and photographed on film (Figure 14). The final appearance will depend not only on intrinsic properties of tissues but also on technical aspects such as pulse sequences or time factors that are chosen and machine quality.

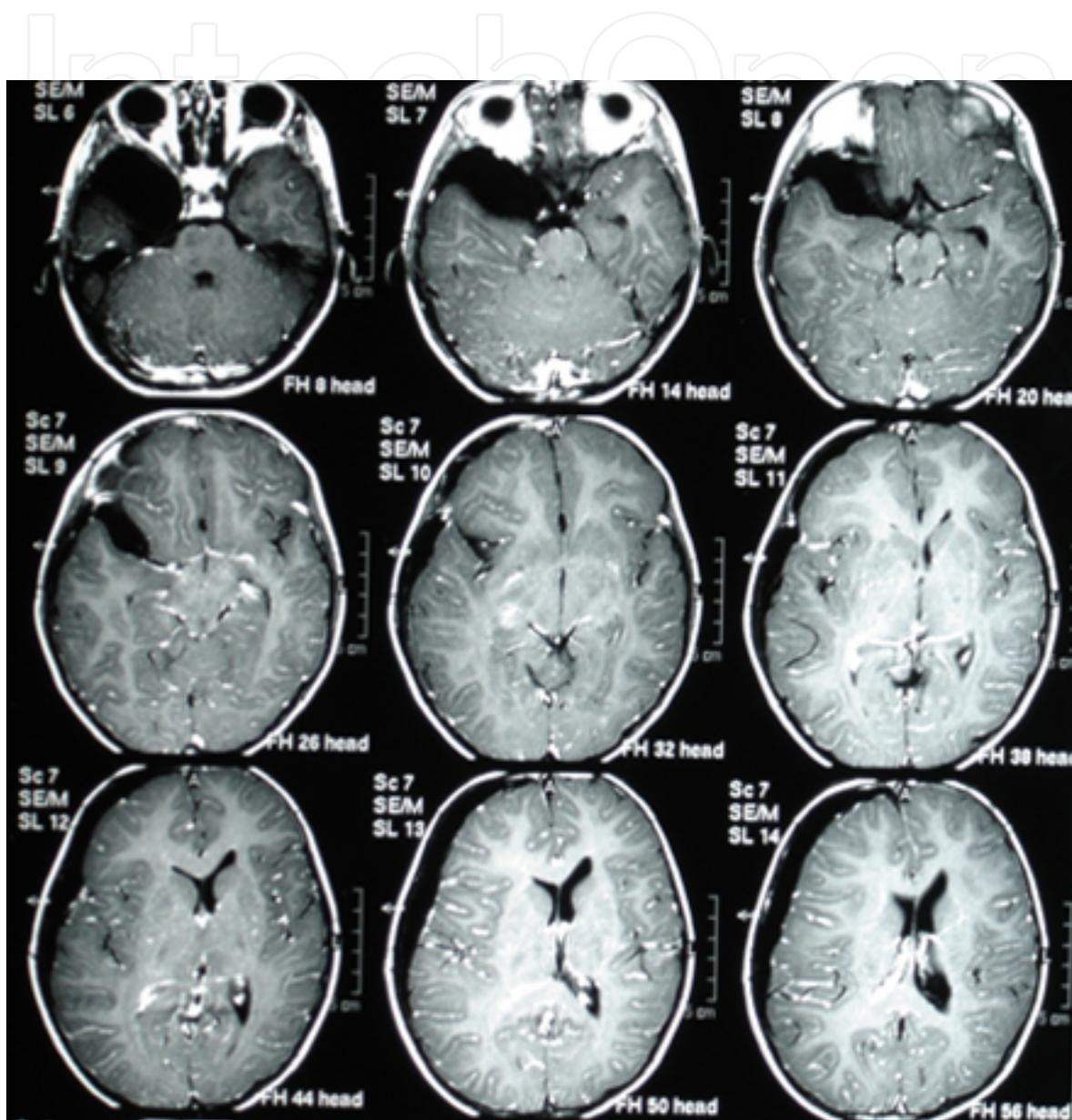


Figure 14. MRI obtained in SE sequence in the axial plane of the skull [19].

For each type of exam of any region of the human body, there is a specific protocol to obtain MR images, most are used for detecting soft-tissue lesions of the structures that make up the central nervous system and skeletal muscle.

7. Examples of MRI protocols and applications by SE sequence

This method has been widely used in the diagnosis of diseases located in the structures of the nervous and musculoskeletal systems. Thus, MRI is an imaging method that provides excellent contrast between soft tissues, due to its high spatial resolution. Therefore, from the anatomical point of view, MRI is the best choice for evaluation of the structures that make up the musculoskeletal system. The protocols on Table 1 and Table 2 were used to acquire the images of the following images which represents examples of very interesting applications of MRI.

Section planes	Cor loc	AXT1	AXT2	AX	Cor
				T1	T1
				GDL	GDL
FOV	SE42	SE30 IR 25	SE30	SE 30	SE 35 IR 35
TR in ms	SE30	SE850 IR2000	SE 2000	SE 850	SE 750 IR2000
TE in ms	SE25	SE25 IR 90	SE 40	SE 25	SE 25 IR 90
TE(2°) in ms	-	-	SE80	-	-
TI in ms		IR 25			IR 25
Interval	SE15	SE10 IR 12	SE10	SE 10	SE 10 IR 10
Number of sections	SE 6	SE11 IR 12	SE 12	SE 11	SE 12 IR 12
Thickness in Mm	SE10	SE 5 IR 5	SE 5	SE 5	SE 5 IR 5
NAQ	SE 1	SE 4 IR 1	SE 2	SE 4	SE 4 IR 1
Matrix	SE	256x192			
	IR	192x192	224x256	256x192	256x192
	IR		256x192		192x256 256x256
(F1)	-	SE10 IR 11	SE 10	SE 10	SE 8 IR 11

Table 1. Exam protocol and values of technical parameters and tissue for evaluation of lesions in the lower limb (0.5 Tesla MRI). Body and head coils.

Section planes	AX LOC	COR T1	AX T2	AX T1	AX T1 GDL
FOV	25	15	25	22	22
TR in ms	SE 320	SE 750	SE 2000	SE 750	SE 750
TE in ms	25	30	40	25	25
TE(2°) in ms	-	-	80	-	-
Interval	7	5	5	8	8
Number of sections	4	12	13	12	12
Thickness in mm	5	5	5	5	5
NAQ	1	2	2	4	4
Matrix	192x192	192x192	256x192	192x160	192x160
(F1)	-	-	10-8	-	-

Table 2. Exam protocol and values of technical parameters and tissue for evaluation of upper limb injuries (0.5 Tesla MRI). Elbow in shoulder coil.

7.1. Application to musculoskeletal tissue lesions

The MR images on the axial plane (AX) show the skeletal muscle and central nervous system. In the sequence, lesions diagnosed as edema and blood in subcutaneous, perimuscular, and muscular tissues and central nervous system structures in pre- and post-contrast T1 and T2 times (Figures 15, 16 & 17). Edema presents as a hypointense signal on pre-contrast T1 time and enhanced on pre-contrast T1 time and hyperintense on T2 time. Lesions identified as haemorrhagic lesions present a hypersignal on pre- and post-contrast T1 and T2 times [21,22,23].

The edema corresponds to an increase of water content into the extracellular space and/or into the intracellular compartment. T2-weighted sequences are the main time interval that detects this increase in the form of an intense area of hypersignal in [21,22,23].

In haemorrhagic lesions or in the presence of degradation components of blood in any tissue often give the hyperintense signal on T1 and T2. They are a consequence of a local vascular injury [22,23].

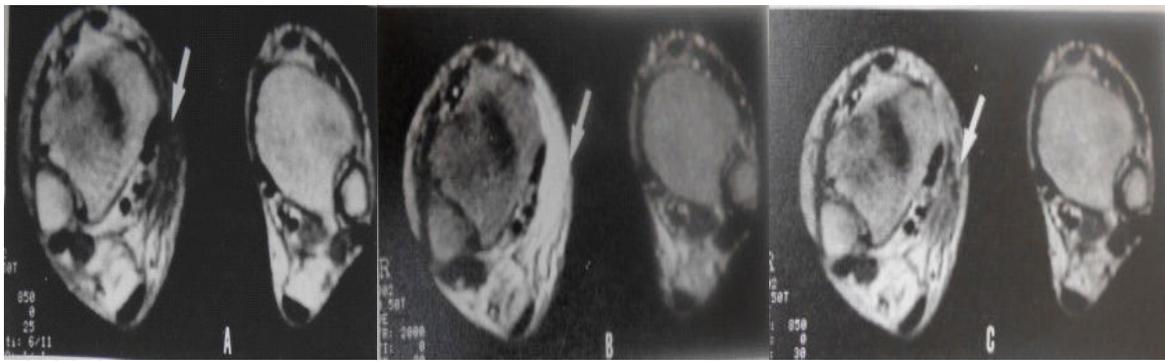


Figure 15. MRI of the right foot showing edema in subcutaneous tissue characterized by (A) hypointense on T1 (B) hyperintense on T2, and (C) enhanced on post-contrast T1. Musculature and perimuscular areas preserved [16].

Tissue lesion and inflammatory processes related to the musculoskeletal system cause changes in the relaxation times T1 and T2 and reflects the signal intensity. The inflammatory processes increase the signal intensity on T2-weighted images and the swelling causes an increase of water in the tissues that determines the signal changes observed [22].



Figure 16. MRI showing the left calf. The injury is consistent with subcutaneous tissue and perimuscular region mild haemorrhage characterized by (A) isointense to hyperintense signal on T1, (B) hyperintense signal on T2, and (C) enhanced on post-contrast T1. The presence of blood in the perimuscular region is well visualized on relaxation time T2.

Bleeding observed in subcutaneous and muscle tissues is generally different from that resulting from the degradation process known in the pathologies of the central nervous system. In these pathologies, the bleeding is presented in various stages of degradation and is known as oxyhemoglobin and/or deoxyhemoglobin, (intracellular or free) methemoglobin, and hemosiderin. Thus, these various stages interfere with the lesion signal intensity and stage interpretation [24,25].

As to the skeletal muscle, it may present in the form from an iso to hyperintense signal at all relaxation times before and after contrast injection [16].

It is noted that in these images the edema in association with haemorrhage usually presents themselves with signal hyperintensity on the T2-weighted images.



Figure 17. MRI of the right forearm indicating extravasation of blood into muscle tissue characterized by (A) isointense to hyperintense signal on T1-weighted image (B) hyperintense signal on T2-weighted image (C) enhanced on post-contrast T1-weighted image [23].

7.2. Tumor injuries detected in the central nervous system

The vast majority of intracranial tumors present a high-protein density, a long T1 and T2, so generally there is a hypo signal on T1-weighted (short TE-TR) and a hyperintense signal on T2-weighted sequences (long TE-TR). Thus, the signal variations are not very specific (Figure 18 & 19). The application presented in Figure 18 and Figure 19 concerns the examination of rectal adenocarcinoma and meningioma of left ventricle fibrous trigonum respectively.

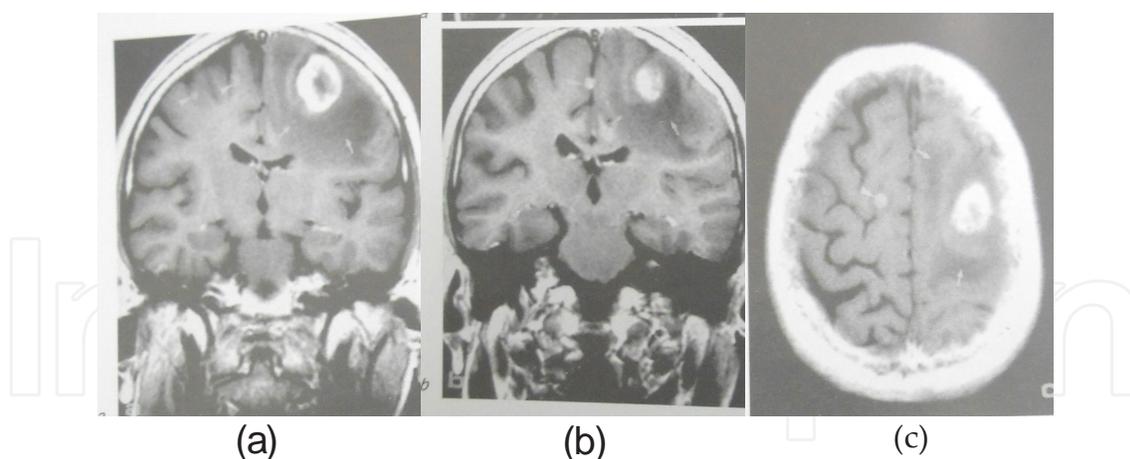


Figure 18. A and B are frontal section images on T1-weighted imaging. C After contrast injection. The hyperintense tumor (A, B, C) gives the perfect location of both the metastasis and the hypointense perilesional edematous reactions [21].

Whatever the sequence used after contrast injection, the parenchymatous reaction edema is visualized with hypointense signal on T1 pre- and post-contrast (A, B) and with hyperintense signal on T2 (C, D). Note the displacement to the right of the median structures of the septum pellucidum.

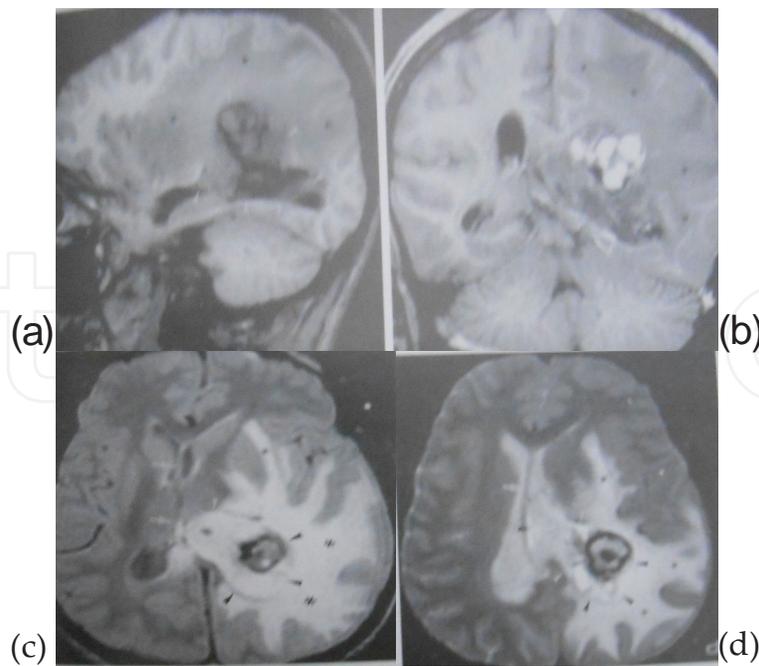


Figure 19. T1-weighted imaging sequences in sagittal plane (A) and T2-weighted imaging sequence in axial plane (C, D) after contrast injection on T1-weighted sequence in frontal plane (B) [21].

Cerebral edema can be of three types: vasogenic corresponding to a disruption of the blood-brain barrier to the passage of a protein-rich filtrate in the brain extracellular spaces, nonspecific outcome of multiple pathological processes (primary tumors, metastases, haemorrhage, trauma, inflammatory processes and infection). It manifests as a hyperintense signal area of white matter, respecting the gray matter. The accomplishment of a sequence with strong T2-weighted can evidence that it is due to the edema's persistent hyperintense signal in contrast to the tumour's decreasing signal. However, the sequences on T1 post-contrast are the ones bounding the lesion; the earliest manifestation form of infarction is the cytotoxic edema. The ischemia leads to an early failure of the membrane pump, which allows water and sodium to enter the cells. It presents itself as a hyperintense signal involving the white and gray matter [21,24,25,26].

Interstitial edema is found in hydrocephalus with passage of transependymal water into the brain tissue from the ventricular cavities, essentially around the lateral ventricles [21].

The water being highly bound to the neighboring proteins displays a significant decrease of T1. The interstitial edema can be viewed paradoxically under the form of a hyperintense signal on T1-weighted sequences, while still naturally with hyperintense signal on T2-weighted sequences [21,27,28].

Thus, the contrast injection increases the specificity in the detection of lesions. The paramagnetic agents such as the gadolinium (GDL) associated with a chelating agent - diethylenetriamine pentaacetic acid (DTPA) - is a safety water soluble. After its application, around 80% is excreted by the kidneys in three hours, and the remaining is recovered in stools and eliminated within a week [18].

The MRI scan is the method of choice for the evaluation of tumors. The sequence systematic practice, mainly of spin echo sequences in different space planes (particularly in axial and sagittal planes), and the intravenous injection of GDL allows a perfect assessment of the tumours [21,27,30].

8. MRI and artifacts

The quality of MR images depends on multiple factors that can significantly alter the outcome of the tests and therefore, the diagnosis of lesions. The so-called artifacts can determine impairment in the image formation and may be inherent to the method (apparatus, pulse sequence) and those related to the patient (involuntary physiologic recurrent movements and involuntary non recurrent movements). The physiological recurrent movements are related to breathing and heartbeat, while involuntary non periodic can be determined by swallowing or spontaneous movements of patients. The artifacts generally can alter the quality of the image during its acquisition. Therefore, in some cases, they interfere with the interpretation of the diagnosis [21,31].

9. MRI scanning: Risks and contraindications

Up to 2.5 Tesla, the magnetic field does not trigger any biological or genetic risk.

The risks and contraindications for MRI are very rare, but they should be known to avoid an accident or scheduling of an unnecessary exam.

Risk factors are associated to a magnetic field that can produce heat, suffocation in case of discharge of a supra-conductor magnet with brutal gasification of the fluids that cools the magnet, patients' local burns caused exceptionally by the twisting of the antenna surface wire or its deterioration by the "coil" effect [21,32,33].

The exam is contraindicated for patients with cardiac pacemakers that can be affected temporarily or permanently with risk of heart failure or rhythm disturbances; these risks exist regardless of the intensity of the magnetic field, metal and ferromagnetic bodies, and pregnant women [32,33].

10. Conclusions

Studies in MRI to diagnose soft-tissue injuries, mainly of the skeletal muscle and central nervous system, indicated that the most-used pulse sequence is the spin echo. Through this sequence it is possible to obtain images in axial, frontal, and sagittal planes. According to these studies, the images obtained in the axial plane are those that show the lesions in detail.

The sequences with contrast images obtained on T1-weighted images are the most important to determine areas of injury with greater specificity. T2-weighted images allow accurately diagnosed injuries. Paramagnetic agents are of primary importance and its use in MRI provides information about the behavior of the lesions.

MRI scans can be conducted in all regions of the body such as brain, spine, joints (shoulder, knee), extremities, chest, abdomen, and others. It is an excellent method for detecting tumours and other soft-tissue lesions based on the criteria of patient safety in relation to the magnetic field, pathology and site to investigate, as well as technical parameters and tissue, which are critical in image acquisition.

Nomenclature (list of symbol)

The nomenclature represents the protocols used to acquire the images of tissues in MR spin echo sequence of skeletal muscle and central nervous system.

AX LOC. Axial section plane locate

COR LOC. Coronal section plane locate

COR T1. Coronal section plane tissue relaxation time T1

AX T2. Axial section plane tissue relaxation time T2

AX T1. Axial section plane tissue relaxation time T1 pre-contrast

AX T1 GDL. Axial section plane tissue relaxation time T1 pos-contrast

GDL. Contrast agent paramagnetic metal (gadolinium)

SE. Spin Echo sequence

IR. Inversion-recovery sequence

FOV. Field of view determine the size of the anatomy covered during the selection of the tissue section

TR. Repetition time

TE. Echo time

TE(2^o). Two sequences in echo time

TI. Inversion time

Interval. Interval between slices to image quality

Number of sections. Number of slices to image quality

Thickness. Thickness of slices image quality

NAQ. number of acquisitions represents the number of times that data are acquired within/ into the same pulse sequence

Matrix. Codification frequency and phase codification along the longest and short axis of the anatomy

F1. Increment to image quality

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