الجامعة التقنية الوسطى
كلية التقنيات الصحية والطبية/ بغداد
قسم: تقنيات الاشعة المادة: فحوصات الرنين المغناطيسي
المرحلة: الرابعة

Title: MRI Terms **العنوان:**

Name of the instructor: **اسم المحاضر:**

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Target population: **الفئة المستهدفة:**

طلبه المرحلة الرابعة في قسم تقنيات الاشعة

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Introduction: المقدمة:

MRI technicians need to know MRI terms definitions for several reasons, including:

Understanding medical terminology: MRI technicians need to have a basic understanding of medical terminology to communicate effectively with physicians and other healthcare professionals Mastering MRI procedures: MRI technicians need to understand and master MRI procedures, including the terminology used in MRI imaging, to perform their job effectively

Ensuring MRI safety: MRI technicians need to have sound knowledge of the physical principles of the MRI scanner and understand the associated safety risks to avoid adverse events from occurring.

Encountering MRI terminology: MRI technicians are likely to encounter MRI terminology in the course of their work, and they need to be familiar with the terminology to perform their job effectively

Pretest: الاختبار القبلي:

Q: Why the radiology technicians need to know the MRI terms?

Q2: Mention the differentiation between MRI Terms of T1, T2?

Scientific Content: المحتوى العلمي:

2D volumetric acquisition: acquisition where a small amount of data is acquired from each slice before repeating the TR.

3D volumetric acquisition: acquisition where the whole imaging volume is excited so that the images can be viewed in any plane.

Actual TE the time between the echo and the next RF pulse in SSFP.

Aliasing artefact produced when anatomy outside the FOV is mismapped inside the FOV.

Alignment when nuclei are placed in an external magnetic field their magnetic moments line up with the magnetic field flux lines .

Ampere's law :determines the magnitude and direction of the magnetic field due

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to a current; if you point your right-hand thumb along the direction of the current, then the magnetic field points along the direction of the curled fingers.

Angular momentum: the spin of MR active nuclei that depends on the balance between the number of protons and neutrons in the nucleus.

Anti-parallel alignment describes the alignment of magnetic moments in the opposite direction to the main field atomic number sum of protons in the nucleus B0 the main magnetic field measured in tesla.

Acquisition : the process of measuring and storing image data.

Acquisition matrix : the total number of independent data samples in the frequency (f) and phase (f) directions.

Acquisition time : the period of time required to collect the image data. This time does not include the time necessary to reconstruct the image. ADC - analog-to-digital converter

Aliasing : the phenomenon resulting from digitizing fewer than two samples per period in a periodic function. Aliasing can occur in MR imaging whenever the area of anatomy extends beyond the field of view. These areas extending beyond the field of view boundaries are aliased back into the image to appear at artifactual locations.

Archiving : the storage of image and patient data for future retrieval.

Axial : a plane, slice or section made by cutting the body or part of it at right angles to the long axis. If the body or part is upright, the cut would be parallel to the horizon.

B or Bo : a conventional symbol for the constant magnetic field produced by the large magnet in the MR scanner.

B1 : the conventional symbol used for identifying the radio frequency (RF) magnetic field.

Band Width (BW) : an all-inclusive term referring to the preselected band or range of frequencies which can govern both slice select and signal sampling.

Bipolar : describes a magnet with two poles, north and south.

Black blood imaging :acquisitions in which blood vessels are black

Blood oxygen level dependent (BOLD) :a functional MRI technique that uses the differences in magnetic susceptibility between oxyhemoglobin and deoxyhemoglobin to image areas of activated cerebral cortex.

Bright blood imaging acquisitions in which blood vessels are bright.

Brownian motion internal motion of the molecules.

Claustrophobia : a psychological reaction to being confined in a relatively small area.

Coherence : the act of maintaining a constant phase relationship between oscillating waves or rotating objects.

Contrast : the relative difference of signal intensities in two adjacent regions of an image. Image contrast is heavily dependent on the chosen imaging technique (i.e., TE, TR, TI), and is associated with such parameters as proton density and T1 or T2 relaxation times.

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Contrast reversal : an image phenomenon where the darks become bright, and the brights become dark. This is usually most prevalent in sequences utilizing an extended TR.
Contrast – to –Noise Ratio (CNR) : the ratio of signal intensity differences between two regions, scaled to image noise. Improving CNR increases perception of the distinct differences between two clinical areas of interest.
Coronal :a plane, slice or section made by cutting across the body from side to side and therefore parallel to the coronal suture of the skull.

Central lines : area of K space filled with the shallowest phase encoding slopes.
Chemical shift : artefact along the frequency axis caused by the frequency difference between fat and water .
Co-current flow : flow in the same direction as slice excitation .
Counter-current flow : flow in the opposite direction to slice excitation.
Cross excitation : energy given to nuclei in adjacent slices by the RF pulse .
Cross talk : energy given to nuclei in adjacent slices due to spin lattice relaxation .
Cryogen bath : area around the coils of wire in which cryogens are placed .
Cryogens substances used to supercool the coils of wire in a superconducting magnet .
Coherent the magnetic moments of hydrogen are at the same place on the precessional path .

Dephasing : the fanning out or loss of phase coherence of signals within the transverse plane.

Diffusion : a term used to describe moving molecules due to random thermal motion .

Dipole : a magnetic field characterized by its own north and south magnetic poles separated by a finite distance.
Display matrix : the total number of pixels in the selected matrix, which is described by the product of its phase and frequency axis.

Electromagnet : a type of magnet that utilizes coils of wire, typically wound on an iron core, so that as current flows through the coil it becomes magnetized. See also Resistive Magnet, Superconducting Magnet.
Equilibrium : a state of balance that exists between two opposing forces or divergent forms of influence.

Excitation : delivering (inducing, transferring) energy into the "spinning" nuclei via radio-frequency pulse(s), which puts the nuclei into a higher energy state. By producing a net transverse magnetization an MRI system can observe a response from the excited system.

Echo spacing : spacing between each echo in FSE .

Echo train : series of 180° rephasing pulse and echoes in a fast spin echo pulse sequence .
Echo train length (ETL) : the number of 180° RF pulses and or turbo factor resultant echoes in FSE .

Effective TE : the time between the echo and the RF pulse that initiated it in SSFP and FSE sequences .
Electrons orbit : the nucleus in distinct shells and are negatively charged.

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External magnetic field (EMF) : drives a current in a circuit and is the result of a changing magnetic field inducing an electric field .

Entry slice phenomena : contrast difference of flowing nuclei relative to the stationary nuclei because they are fresh .

Even echo rephrasing : the use of evenly spaced echoes to reduce artefact .

Extrinsic contrast parameters :contrast parameters that are controlled by the system operator

Fast scanning : a specialized technique usually associated with short TR, reduced flip angle and repeated 180° rephasing pulses.

Fast Spin Echo (FSE) : a fast spin echo pulse sequence characterized by a series of rapidly applied 180° rephasing pulses and multiple echoes, changing the phase encoding gradient for each echo.

Fat Saturation (FAT-SAT) : A specialized technique that selectively saturates fat protons prior to acquiring data as in standard sequences, so that they produce negligible signal.

FAT Suppression : the process of utilizing specific parameters, commonly with STIR (short TI inversion recovery) sequences, to remove the deleterious effects of fat from the resulting images. See also STIR.

FDA : the United States Food and Drug Administration FID - see Free Induction Decay

Field of view (FOV) : defined as the size of the two or three dimensional spatial encoding area of the image. Usually defined in units of cm2.

FFT (Fast Fourier Transform) - a particularly fast and efficient computational method of performing a Fourier Transform, which is the mathematical process by which raw data is processed into a usable image.

Flare : Fast Low-Angle Recalled Echoes

Flip Angle (FA) : the angle to which the net magnetization is rotated or tipped relative to the main magnetic field direction via the application of an RF excitation pulse at the Larmor frequency. The Flip Angle is used to define the angle of excitation for a Field Echo pulse sequence.

Flow compensation : a function of specific pulse sequences, i.e., CRISP¿ (Complex Rephasing Integrated with Surface Probes) spin echo, wherein the application of strategic gradient pulses can compensate for the objectionable spin phase effects of flow motion.

Free Induction Decay (FID) : loss of signal due to relaxation ; if transverse magnetization of the spins is produced, e.g., by a 90É RF pulse, a transient MR signal at the Larmor frequency results that decays toward zero with a characteristic time constant of T2*. This decaying signal is the FID.

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Frequency : the number of cycles or repetitions of any periodic wave or process per unit time. In electromagnetic radiation, it is usually expressed in units of hertz (Hz), where 1 Hz = 1 cycle per second.

Field of view (FOV) area of anatomy covered in an image
FLAIR (fluid attenuated inversion recovery) : IR sequences that nulls the signal from CSF

Flip angle : the angle of the NMV to *B*0 .

Flow encoding axes : axes along which bipolar gradients act in order to sensitize flow along the axis of the gradient; used in phase contrast MRA .
Flow phenomena : artefacts produced by flowing nuclei

Flow related enhancement : decrease in time of flight due to a decrease in velocity of flow .

Fresh spins : nuclei that have not been beaten down by repeated RF pulses .

Fringe field :stray magnetic field outside the bore of the magnet .

Functional MR imaging (fMRI) a rapid MR imaging technique that acquires images of the brain during.

Frequency encoding the process of locating an MR signal in one dimension by applying a magnetic field gradient along that dimension during the period when the signal is being received.

Gadolinium (Gd) : gadolinium is a non-toxic paramagnetic contrast enhancement agent utilized in MR imaging. When injected during the scan, gadolinium will tend to change signal intensities by shortening T1 in its surroundings.

Gradient coils :three paired orthogonal current-carrying coils located within the magnet which are designed to produce desired gradient magnetic fields which collectively and sequentially are superimposed on the main magnetic field (Bo) so that selective spatial excitation of the imaging volume can occur. Gradients are also used to apply reversal pulses in some fast-imaging techniques.

Gyromagnetic ratio (g) : a constant for any given nucleus that relates the nuclear MR frequency and the strength of the external magnetic field. It represents the ratio of the magnetic moment (field strength) to the angular momentum (frequency) of a particle. The value of the gyromagnetic ratio for hydrogen (1H) is 4,258 Hz/Gauss (42.58 MHz/Tesla).

Ghosting : motion artefact in the phase axis.

Gradient amplifier : supplies power to the gradient coils .

Gradient echo pulse sequence : one that uses a gradient to regenerate an echo.

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Gradient echo : echo produced as a result of gradient rephrasing .

Gradient spoiling : the use of gradients to diphase magnetic moments; the opposite of rewinding.

Gyro-magnetic ratio: the precessional frequency of an element at 1.0 T .

Hertz : the standard unit of frequency equal to 1 cycle per second. The larger unit megahertz (MHz) = 1,000,000 Hz.

Homogeneity : uniformity of the main magnetic field.

Hydrogen density (H+) : the concentration of Hydrogen atoms in water molecules or in some groups of fat molecules within tissue. Initial MR signal amplitudes are directly related to H+ density in the tissue being imaged.

High velocity signal loss increase in time of flight due to an increase in the velocity of flow .

Image data acquisition time : the time required to gather a complete set of image data. The total time for performing a scan must take into consideration the additional image reconstruction time when determining how quickly the image(s) may be viewed.
Image reconstruction :the mathematical process of converting the composite signals obtained during the data acquisition phase into an image.

Inhomogeneity : lack of homogeneity or uniformity in the main magnetic field.

Inversion recovery (IR) :an imaging sequence that involves successive 180É and 90É pulses, after which a heavily T1-weighted signal is obtained. The inversion recovery sequence is specified in terms of three parameters, inversion time (TI), repetition time (TR) and echo time (TE).

Inversion time (TI) : the time period between the 180° inversion pulse and the 90° excitation pulse in an Inversion Recovery pulse sequence. ISOTOPE - Atomic nuclei that contain the same number of protons, but differ in the number of neutrons in the nucleus of the atom for the element concerned. K-SPACE - a data acquisition matrix containing raw image data prior to image processing. In 2DFT, a line of data corresponds to the digitized NMR signal at a particular phase-encoding level.

Incoherent : means that the magnetic moments of hydrogen are at different places on the processional path .
In-flow effect :another term for entry slice phenomenon .

Intra-voxel dephasing : phase difference between flow and stationary nuclei in a voxel .

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Intrinsic contrast mechanisms : contrast parameters that do not come under the operators control .

K space :an area where raw data is stored .

Larmor equation : an equation that states that the frequency of precession of the nuclear magnetic moment is directly proportional to the product of the magnetic field strength (Bo) and the gyromagnetic ratio (g). This is stated mathematically as W = g Bo.
Larmor frequency : the frequency at which magnetic resonance in a nucleus can be excited and detected. The frequency varies directly with magnetic field strength, and is normally in the radio frequency (RF) range.

Lattice : in MRI, the magnetic and thermal environment through which nuclei exchange energy in longitudinal (T1) relaxation.

Longitudinal magnetization : the component (MZ) of the net magnetization vector in the direction of the static magnetic field. After RF excitation, this vector returns to its equilibrium value at a rate characterized by the time constant T1.

Longitudinal relaxation time : the time constant, T1, which determines the rate at which excited protons return to equilibrium within the lattice. A measure of the time taken for spinning protons to re-align with the external magnetic field. The magnetization will grow after excitation from zero to a value of about 63% of its final value in a time of T1.

Magnetic susceptibility : ability of a substance to become magnetized .

Magnetic moment : a measure of the net magnetic properties of an object or particle. A nucleus with an intrinsic spin will have an associated magnetic dipole moment so that it will interact with a magnetic field (as if it were a tiny bar magnet).

Magnetic resonance the absorption or emission of energy by atomic nuclei in an external magnetic field after the application of RF excitation pulses using frequencies which satisfy the conditions of the Larmor equation.

Magnetization vector (Mz) : the integration of all the individual nuclear magnetic moments which have a positive magnetization value at equilibrium versus those in a random state.

MR Imaging MAGING : the use of magnetic resonance principles in the production of diagnostic views of the human body where the resulting image is based upon three basic tissue parameters (proton density, T1 relaxation time, T2 relaxation time) and flow characteristics. MRA - See Magnetic Resonance Angiography. MRS - See Magnetic Resonance Spectroscopy.

MR angiography method of visualizing vessels that contain flowing nuclei by producing a contrast between them and the stationary nuclei .
MR signal : the voltage induced in the receiver coil .

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Net magnetization vector : a vector which represents the sum of all of the contributions of the magnetic moments within the magnetic field; the magnitude and direction of the magnetization resulting from this collection of atomic nuclei.

Noise : an undesirable background interference or disturbance that affects image quality.
NSA the number of signal averages performed during the scan.

Nuclear spin : also known as inherent spin, this defines the intrinsic property of certain nuclei (those with odd numbers of protons and/or neutrons in their nucleus) to exhibit angular momentum and a magnetic moment. Nuclei that do not exhibit this characteristic will not produce an NMR signal.

Number of signal averages : the number of times an echo is encoded with the same slope of phase encoding gradient .

Oblique : a plane or section not perpendicular to the xyz coordinate system, such as long and short axis views of the heart.

Orthogonal : a plane or section perpendicular to the xyz coordinate system.

Oscillation : rhythmic periodic motion.

Paramagnetic substance : a substance with weak magnetic properties due to its unpaired electrons. Researchers are developing certain paramagnetic materials, such as gadolinium, as MRI invasive contrast media

Partial echo : sampling only part of the echo and extrapolating the remainder in K space

Perfusion : a measure of the quality of vascular supply to a tissue

Permanent magnets : magnets that retain their magnetism

Phase contrast angiography : technique that generates vascular contrast by applying a bipolar gradient to stationary and moving spins thereby changing their phase .

Phase encoding locating a signal according to its phase

Phase image subtracted image combination of flow sensitized data .

Phase the position of a magnetic moment on its processional path at any given time .

Precession :the secondary spin of magnetic moments around B0

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Protons : particles in the nucleus that are positively charged .

Proton density the number of protons in a unit volume of tissue .

Proton density weighting image that demonstrates the differences in the proton densities of the tissues .

Pulse control unit : co-ordinates the switching on and off of the gradient and RF transmitter coils at appropriate times during the pulse sequence .

Pulse sequence : a series of RF pulses, gradients applications and intervening time periods; used to control contrast .

Posttest: الاختبار البعدي

- Define the lattice, Flair, and Axial?

-Mention why we use the flip angle in MRI protocols?

References: المصادر:

- MRI A to Z : Gary Liney
- MRI at a Glance: Catherine Westbrook

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المرحلة: الرابعة

Title: MRI Terms 2 **العنوان:**

Name of the instructor: **اسم المحاضر:**

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Target population: **الفئة المستهدفة:**

طلبه المرحلة الرابعة في قسم تقنيات الاشعة

Introduction: **المقدمة:**

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MRI technicians need to know MRI terms to communicate effectively with healthcare professionals, understand and master MRI procedures, ensure MRI safety, and perform their job effectively. MRI terms can be found in MRI reports, glossaries, and educational resources. It is important for MRI technicians to keep up-to-date with the latest MRI technology and terminology to provide the best possible care for their patients and parameters.

Pretest: الاختبار القبلي :

Choose the right answer of the following?

- The diffusion a term used to describe ………. molecules due to random thermal motion?

  a- excited b- lattice c- moving d-stable

Scientific Content: المحتوى العلمي:

Phase : an angular relationship describing the degree of synchronism between two sinusoidal waveforms of the same frequency.

Phase encoding : the process of locating an MR signal by altering the phase of spins in one dimension with a pulsed magnetic field gradient along that dimension prior to the acquisition of the signal.

Pixel : acronym for a picture element, the smallest discrete two-dimensional part of a digital image display.

Precession : comparatively slow gyration of the axis of a spinning body so as to trace out a cone. Caused by the application of a torque tending to change the direction of the rotation axis and continuously directed at right angles to the plane of the torque.

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Presaturation (PRE-SAT) : a specialized technique employing repeated RF excitation of structures adjacent to the ROI for the purpose of reducing or eliminating their phase effect artifacts.

Proton density weighted image : an image produced by controlling the selection of scan parameters to minimize the effects of T1 and T2, resulting in an image dependent primarily on the density of protons in the imaging volume.

Pulse sequence : a preselected set of defined RF and gradient pulses, usually repeated many times during a scan, wherein the time interval between pulses and the amplitude and shape of the gradient waveforms will control NMR signal reception and affect the characteristics of the MR images.

Radio frequency : an electromagnetic wave with a frequency that is in the same general range as that used for the transmission of radio and television signals. Abbreviated RF.

Receiver coil : a coil , or antenna, positioned within the imaging volume and connected to the receiver circuitry that is used to detect the NMR signal. In certain applications, the same coil can be used for both transmission and reception. Receiver coils types include solenoidal, planar, volume, quadrature and phased array coils.

Reconstruction : the mathematical process by which the displayed image is produced from the raw k-space data obtained from the receiver circuitry, typically utilizing Fourier transformation and selective filtering.

Region of interest (ROI) : the area of anatomy being scanned that is of particular importance in the image.

Relaxation time : after excitation the spins will tend to return to their equilibrium distribution in which there is no transverse magnetization and the longitudinal magnetization is at its maximum value and oriented in the direction of the static magnetic field. After excitation the transverse magnetization decays toward zero with a characteristic time constant T2, and the longitudinal magnetization returns toward equilibrium with a characteristic time constant T1.

Repetition time (TR) : the amount of time that exists between successive pulse sequences applied to the same slice. It is delineated by initiating the first RF pulse of the sequence then repeating the same RF pulse at a time t. Variations in the value of TR have an important effect on the control of image contrast characteristics. Short values of TR (< 1000 ms) are common in images exhibiting

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T1 contrast, and long values of TR (> 1500 ms) are common in images exhibiting T2 contrast. TR is also a major factor in total scan time. See also TR. MRI Fourth class 1st and 2nd lectures

Phase contrast angiography : technique that generates vascular contrast by applying a bipolar gradient to stationary and moving
spins thereby changing their phase .

Quenching : process by which there is a sudden loss of the superconductivity of the magnet coils so that the magnet becomes resistive .

Ramp sampling : where sampling data points are collected when the gradient rise time is almost complete. Sampling occurs while the gradient is still reaching maximum amplitude, while the gradient is at maximum amplitude and as it begins to decline .

Readout gradient : the frequency encoding gradient .

Receive bandwidth : range of frequencies that are sampled during readout .

Recovery :growth of longitudinal magnetization.

Relaxation : process by which hydrogen loses energy .

Repetition time (TR) : time between each excitation pulse .

Rephasing : the process of returning out-of-phase magnetic moments back into phase coherence. Caused either by rapidly reversing a magnetic gradient (Field Echo) or by applying a 180É RF pulse (Spin Echo). In the spin-echo pulse sequence this action effectively cancels out the spurious T2* information from the signal., usually by using **RF amplifier** that supplies power to the RF transmitter coils.

Resistive magnet : a common type of magnet that utilizes the principles of electromagnetism to generate the magnetic field.

Resonance :a large amplitude vibration in a mechanical or electrical system caused by a relatively small periodic stimulus with a frequency at or close to a natural frequency of the system. The exchange of energy at a particular frequency between two systems. ROI - see Region Of Interest.

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Sagittal : a plane, slice or section of the body cutting from front to back through the saggital suture of the skull, and continued down through the body in the same direction, dividing it into two parts, then turning one half to view it from its cut surface.

Shim coils : coils positioned near the main magnetic field that carry a relatively small current that is used to provide localized auxiliary magnetic fields in order to improve field homogeniety.

Signal to noise ratio (S/N, SNR) : The ratio between the amplitude of the received signal and background noise, which tends to obscure that signal. SNR, and hence image quality, can be improved by such factors as increasing the number of excitations, increasing the field of view, increasing slice thickness, etc. SNR also depends on the electrical properties of the patient being studied and the type of receiving coil used.

RF spoiling : the use of digitized RF to transmit and receive at a certain phase .

RF transmitter coil : coil that transmits RF at the resonant frequency of hydrogen to excite nuclei and move them into a high energy state .

Rise time : the time it takes a gradient to switch on, achieve the required gradient slope, and switch off again .

Sampling rate : rate at which samples are taken during readout .

Sampling time :the time that the readout gradient is switched on for saturation occurs when the NMV is flipped to a full 180°.

Sequential acquisition : acquisition where all the data from each slice are acquired before going on to the next .

Shimming : process whereby the evenness of the magnetic filed is optimized .

Slice : the term describing the planar region or the image slice selection region.

Slice encoding : relates to the addition of phase encoding steps for 3D volumetric imaging.

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Slice selection : exclusive excitation of spins in one slice performed by the coincident combination of a gradient magnetic field and a narrow bandwidth or slice selective RF pulse at a specific Larmor frequency.

Slice thickness : the thickness of an imaging slice. Since the slice profile is not sharply edged, the distance between the points at half the sensitivity of the maximum (full width at half maximum) is used to determine thickness.

Spatial resolution : the ability to define minute adjacent objects/points in an image, generally measured in line pairs per mm.

Spin :the property exhibited by atomic nuclei that contain either an odd number of protons or neutrons, or both.

Spin Echo (SE) : re-appearance of the NMR signal after the FID has apparently died away, as a result of the effective reversal (rephasing) of the dephasing spins by techniques such as specific RF pulse sequences or pairs of field gradient pulses, applied in time shorter than or on the order of T2. Proper selection of the TE time of the pulse sequence can help control the amount of T1 or T2 contrast present in the image. Also a pulse sequence type that usually employs a 90° pulse, followed by one or more 180° pulses.

Spin lattice relaxation time - see T1 and Longitudinal Relaxation Time.

Spin- spin relaxation time **SPIN-SPIN RELAXATION TIME** - see T2 and Transverse Relaxation Time.

Steady state a situation when the TR is shorter than both the T1 and T2 relaxation times of all the tissues .

Stimulated-echo spatial localization technique used .

Spectroscopy provides a frequency spectrum of a given tissue based on the molecular and chemical structures of that tissue .

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Superconductive magnet : a magnet whose field is generated by current in wires made of a superconducting material such as niobium-titanium, that has no resistance when operated at temperatures near absolute zero(-273°C, -459°F). Such magnets must be cooled by, for example, liquid helium. Superconducting magnets typically exhibit field strengths of >0.5T and have a horizontal field orientation, which makes them prone to missile effects without significant magnetic shielding. See also Quenching.

Surface coil : a type of receiver coil which is placed directly on or over the region of interest for increased magnetic sensitivity. These coils are specifically designed for localized body regions, and provide improved signal-to-noise ratios by limiting the spatial extent of the excitation or reception. T - tesla T1 - spin-lattice longitudinal relaxation time. The characteristic time constant for spins to realign themselves with the external magnetic field after excitation.

T1 weighted : an image created typically by using short TE and TR times whose contrast and brightness are predominately determined by T1 signals.

T1 relaxation : see Longitudinal Relaxation Time.

T2 - spin-spin or transverse relaxation time: The time constant for loss of phase coherence among spins oriented at an angle to the static magnetic field due to interactions between the spins. Results in a loss of transverse magnetization and the MRI signal.

T2* ("T-two-star") : the time constant for loss of phase coherence among spins oriented at an angle to the static magnetic field due to a combination of magnetic field inhomogeneities and the spin-spin relaxation. Results in a rapid loss of transverse magnetization and the MRI signal.T2* < T2.

T2 weighted : an image created typically by using longer TE and TR times whose contrast and brightness are predominately determined by T2 signals. TAU (t) - the interpulse times (time between the 90° and 180° pulse, and between the 180° pulse and the echo) used in a spin echo pulse sequence. TE (Echo Time) - represents the time in milliseconds between the application of the 90° pulse and the peak of the echo signal in Spin Echo and Inversion Recovery pulse sequences.

TE (Echo Time) : represents the time in milliseconds between the application of the 90° pulse and the peak of the echo signal in Spin Echo and Inversion Recovery pulse sequences.

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TESLA (T) : the preferred unit of magnetic flux density. One tesla is equal to 10,000 gauss. The Tesla unit value is defined as a field strength of 1 Weber per meter 2, where 1 Weber represents 1 x 108 (100,000,000) flux lines.

Three dimensional imaging (3DFT) : a specialized imaging technique that uses computer processing to combine individual slice acquisitions together to produce an image that represents length, width and height. TI (Inversion Time) - the time between the initial (inverting) 180° pulse and the 90° pulse used in inversion recovery pulse sequences.

TR (Repetition Time) : the amount of time that exists between successive pulse sequences applied to the same slice.

Transceiver coil **:** an MRI surface coil that acts as both transmitter and receiver.

Transmitter **:**the portion of the MR scanner that produces the RF current and delivers it to the transmitting coil (antenna). The RF signal produced by the transmitter is used to excite the protons in the imaging volume.

Transverse magnetization **:** component of the net magnetization vector at right angles to the main magnetic field. Precession of the transverse magnetization at the Larmor frequency is responsible for the detectable NMR signal. In the absence of externally applied RF energy, the transverse magnetization will decay to zero with a characteristic time constant of T2, or more strictly T2*.

Time of flight angiography: technique that generates vascular contrast by utilizing the in-flow effect

Time of flight : rate of flow in a given time. Causes some flowing nuclei to receive one RF pulse only and therefore produce a signal void .

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Transverse relaxation time: the time constant, T2, which determines the rate at which excited protons reach equilibrium, or go out of phase with each other. A measure of the time taken for spinning protons to lose phase coherence among the nuclei spinning perpendicular to the main field due to interaction between spins, resulting in a reduction in the transverse magnetization. The transverse magnetization value will drop from maximum to a value of about 37% of its original value in a time of T2.

Vector :a quantity that has both magnitude and direction and that is commonly represented by an arrow. The length of the line segment represents the magnitude, and its orientation in space represents its direction. Vector quantities can be added to or subtracted from one another.

Velocity speed in a particular direction.

Voxel volume element; the element of the three-dimensional space corresponding to a pixel, for a given slice thickness.

Volume coil : coil that transmits and receives signal over a large volume of the patient .

Voxel volume : volume of tissue in the patient

Watergrams :FSE sequence using very long TRs, TEs and ETLs to produce very heavy T2 weighting .

Posttest: الاختبار البعدي:

-Define the MRI spectroscopy and diffusion?

- Fill in the blanks the suitable word or statement:

- **Time of flight angiography** technique that generates ………contrast by utilizing the in-flow effect
- **Saturation** occurs when the NMV is ………….

References: المصادر:

- MRI A to Z : Gary Liney
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الجامعة التقنية الوسطى

كلية التقنيات الصحية والطبية/ بغداد

قسم: تقنيات الاشعة   المادة: فحوصات الرنين المغناطيسي

المرحلة: الرابعة

Title: Concepts of MRI **العنوان:**

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Target population: **الفئة المستهدفة:**

طلبه المرحلة الرابعة في قسم تقنيات الاشعة

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Introduction: المقدمة:

MRI technicians' students need to understand MRI concepts for several reasons, including:

Performing MRI exams: MRI technicians need to have a thorough understanding of the physical principles of MRI and the general concepts of image contrast

MRI technicians need to understand MRI concepts to perform MRI exams effectively, ensure MRI safety, interpret MRI results accurately, and keep up-to-date with MRI technology. MRI concepts can be learned to the student through MRI technology theoretical and practical lectures, continuing education courses.

It is important for MRI technician students to stay up-to-date with the latest MRI technology and concepts to provide the best possible care for their patients in the future.

Pretest: الاختبار القبلي:

Choose the right answer of the following:

- **The water will appear ……. In the MRI exam T2?**

a- dark b-bright c-black d-dark grey

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Scientific Content: المحتوى العلمي:

The way magnetic resonance imaging (MRI) is generated is complicated and is much harder to understand than plain radiography, CT and ultrasound. It has strong underpinnings in physics which must be understood before any real sense of "how it works" is gained. What follows is a very abbreviated or "broad strokes" description of the process.

A magnetic resonance system (the actual machine) consists of the following components:

1. A large magnet to generate the magnetic field.
2. Shim coils to make the magnetic field as homogeneous as possible.
3. A radiofrequency (RF) coil to transmit a radio signal into the body part being imaged.
4. A receiver coil to detect the returning radio signals.
5. Gradient coils to provide spatial localization of the signals.
6. A computer to reconstruct the radio signals into the final image.

Concept of MRI image

An image has contrast if there are areas of high signal (white on the image), as well as areas of low signal (dark on the image). Some areas have an intermediate signal (shades of grey in-between white and black). A tissue gives an intermediate signal (grey). (Fig.1).

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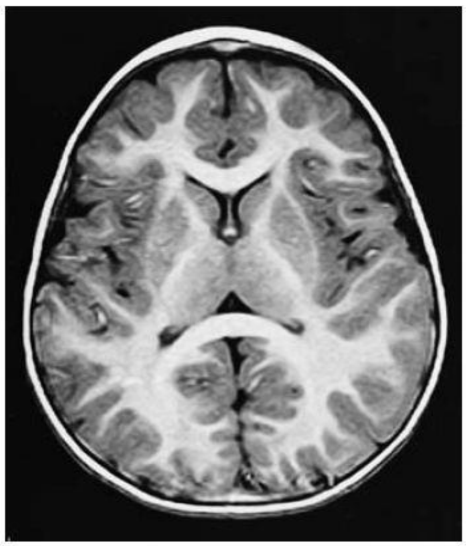

Fig.(1): Axial IR T1 weighted image using a TI of 700 ms. Note the exquisite contrast between grey and white matter.

The image contrast is controlled by two groups of parameters:

A. Extrinsic contrast parameters
B. Intrinsic contrast mechanism

A. **Extrinsic contrast parameters** : which are controlled by the system operator ;These include the following.

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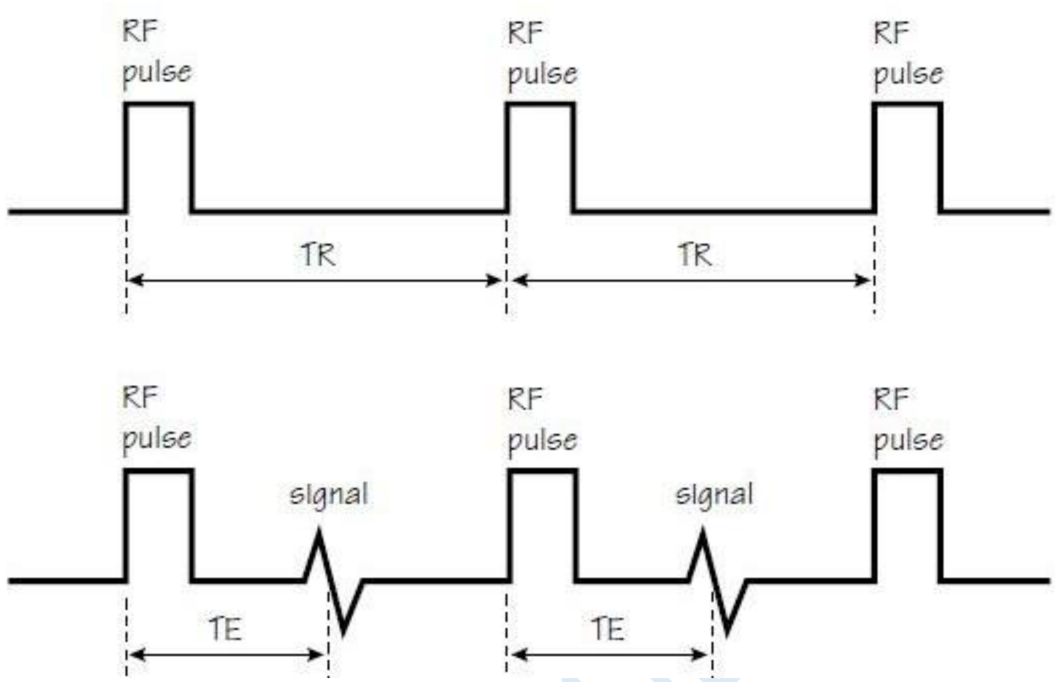

Fig.(2): A basic pulse sequence.

1• Repetition time (TR). This is the time from the application of one RF pulse to the application of the next. It is measured in milliseconds (ms). The TR affects the length of a relaxation period after the application of one RF excitation pulse to the beginning of the next (Fig. 2).

2• Echo time (TE). This is the time between an RF excitation pulse and the collection of the signal. The TE affects the length of the relaxation period after the removal of an RF excitation pulse and the peak of

the signal received in the receiver coil. It is also measured in ms (Fig .2).

3• Flip angle. This is the angle through which the NMV is moved as a result of a RF excitation pulse.

4• Turbo-factor or echo train length (ETL/TF) .

5• Time from inversion (TI).

6• 'b' value: is a factor that reflects the strength and timing of the gradients used to generate diffusion-weighted images .

B. Intrinsic contrast mechanism:

Which do not come under the operator's control; These include:

1. T1 recovery
2. T2 decay
3. Proton density
4. Flow
5. Apparent diffusion coefficient (ADC): is a measure of the magnitude of diffusion (of water molecules) within tissue.

The MRI Simplified

MRI uses a powerful magnetic field that makes the hydrogen protons in water molecules, which comprise between 70% and 80% of the average human brain, line up. This ubiquitous biological molecule has two protons, which by virtue of their positive charge act as small magnets on a subatomic scale. Then once they are all lined up from the magnetic field, they are then knocked out of line by radio waves. When the radio waves are stopped, the protons relax back into line, releasing resonance signals that are transmitted to a computer.

To have a better understanding or image of this, think of the hydrogen proton as if it were a gyroscope or even the planet earth, spinning on its axis, with a north-south pole. In this respect it behaves like a small bar magnet. Now under normal conditions, these hydrogen proton "bar magnets" spin in the body with their axes randomly aligned since nothing is pulling them magnetically in the same direction. An example could be a group of children on a playground running around with no sense of order.

When the body is placed in a strong magnetic field, such as an MRI scanner, the protons' axes all line up. This uniform alignment creates a magnetic vector oriented along the axis of the MRI scanner. Now think of those same children with no order and how each one will line up if someone yells "cookie." How loud you yell "cookie" depends on your strength and this is the same with different machines. Each scanners come in different field strengths, usually between 0.5 and 1.5 tesla (T).

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The strength of the magnetic field can be altered electronically from head to toe using a series of gradient electric coils, and, by altering the local magnetic field by these small increments, different slices of the body will resonate as different frequencies are applied.

When additional energy, in the form of a radio wave, is added to the magnetic field, the magnetic vector is deflected. The radio frequency (RF) wave that causes the hydrogen nuclei to resonate is dependent on the element sought (hydrogen) and the strength of the magnetic field.

When the RF source is switched off the magnetic vector returns to its resting state, and this causes a signal, or radio wave to be emitted. It's this signal which is used to create the MR images. Receiver coils are used around the body part in question to act as aerials to improve the detection of the emitted signal. The intensity of the received signal is then plotted on a grey scale and cross sectional images are built up.

Multiple transmitted RF pulses can be used in sequence to emphasise particular tissues or abnormalities. A different emphasis occurs because different tissues relax at different rates when the transmitted RF pulse is switched off. The time taken for the protons to fully relax is measured in two ways. The first is the time taken for the magnetic vector to return to its resting state and the second is the time needed for the axial spin to return to its resting state. The first is called T1 relaxation, the second is called T2 relaxation.

A MR examination is thus made up of a series of pulse sequences. Different tissues (such as fat and water) have different relaxation times and can be identified separately. By using a "fat suppression" pulse sequence, for example, the signal from fat will be removed, leaving only the signal from any abnormalities lying within it.

Spatial encoding of the MRI signal is accomplished through the use of gradients (smaller magnetic fields) which perturb the main magnetic field, and cause hydrogen protons in different locations to precess (move) at slightly different rates. The portion of the gradient coils and the associated current that is perpendicular to the main magnetic field cause a force (Lorentz force) on the coils. The gradients are turned on and off very quickly in this process causing them to vibrate causing the majority of the noise associated with the MRI environment. This still occurs even though they are embedded in an epoxy.

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Parameter Weighting

Terms such as "T1-weighted" and "T2-weighted" are among the most overused and least understood concepts in MR imaging. In the broadest sense, these terms are used to communicate to other physicians the type of MR pulse sequence employed to generate a series of images.

Most non-radiologists are often taught to look at the "color" of cerebrospinal fluid (CSF) or other fluids to determine the type of "weighting" — dark CSF means "T1-weighting" and bright CSF means "T2-weighting". Although this simple scheme worked fine in the past, now consider the brain image from the commonly used T2-FLAIR (fluid-attenuated inversion recovery) sequence. This sequence is known to have strong sensitivity to T2 changes, but the CSF signal has been suppressed by an inverting pulse and rendered black. This can lead to confusion for some since parts of "weighting" image has similar coloring to a "FLAIR" image.

A fundamental misconception about "weighting", is that contrast in the image is dominated by one specific tissue parameter to the exclusion of all others. Another common misconception is that T1-weighted or T2-weighted images are parameter "maps" whose pixel intensities are proportional to tissue T1 or T2 values.

It's alright to use terms like "T1-weighted" and "T2-weighted" as long as you realize they are imprecise, are not parameter "maps", and that nearly all images have mixed contributions from all the different tissue parameters.

T1 weighting

In a T1 weighted image, differences in the T1 relaxation times of tissues must be demonstrated.

-To achieve (T1 weighted image):

For T1 weighting differences between the T1 times of tissues is exaggerated and to achieve this the TR must be short.

To remove T2 effects the TE must also be short (Fig.3)

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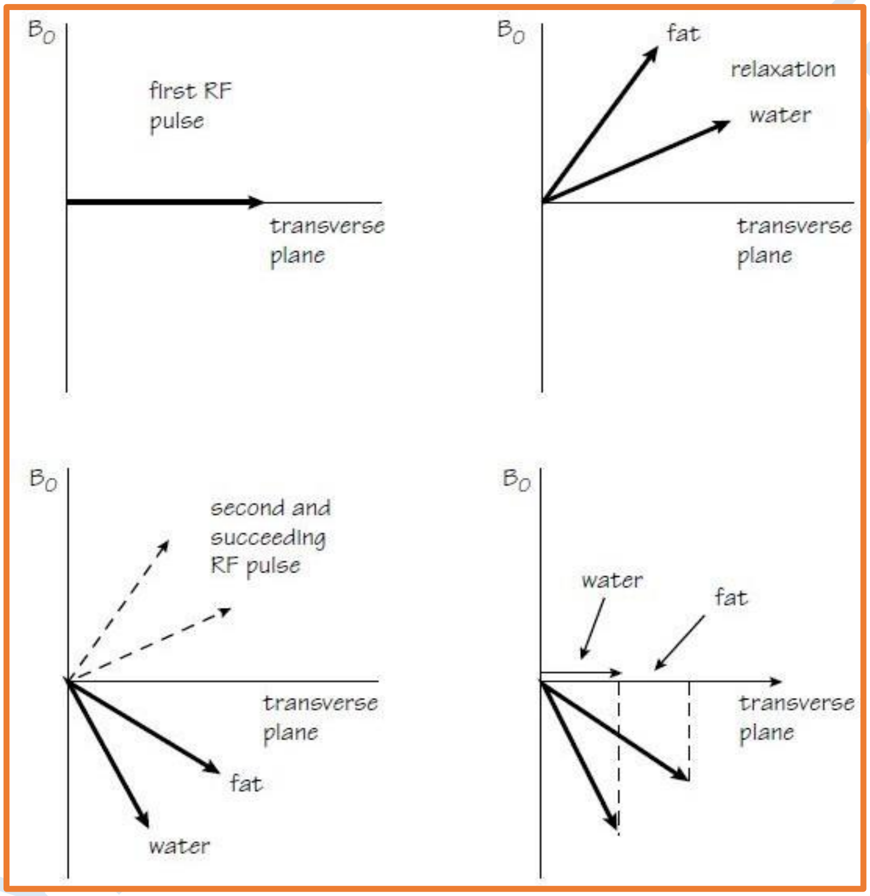

Fig.(3) : Short TR

Signal brightness could be seen in the T1:

In T1 weighted images, tissues with short T1 relaxation times such as fat, are bright (high signal), because they recover most of their longitudinal magnetization during the TR.

Tissues with long T1 relaxation times such as water, are dark (low signal) because they do not recover much of their longitudinal magnetization. T1 weighted images best demonstrate anatomy but also show pathology if used after contrast enhancement (to identify solid from cystic lesion).

High signal	fat haemangioma intra-osseous lipoma radiation change degeneration fatty deposition methaemoglobin cysts with proteinaceous fluid paramagnetic contrast agents slow flowing blood
Low signal	cortical bone avascular necrosis infarction infection tumours sclerosis cysts calcification
No signal	air fast flowing blood tendons cortical bone scar tissue calcification

Table (1) : Signal intensities seen in T1 weighted images.

T2 weighting

In a T2 weighted image the differences in the T2 relaxation times of tissues must be demonstrated.

-To achieve (T2 weighted image):

1• For T2 weighting the differences between the T2 times of tissues is exaggerated, therefore the TE must be long.

2. T1 effects are diminished by selecting a long TR (Fig.4).

Signal brightness could be seen in the T2:

Tissues with a short T2 decay time such as fat are dark (low signal) because they lose most of their coherent transverse magnetization during the TE period.

Tissues with a long T2 decay time such as water are bright (high signal), because they retain most of their transverse coherence during the TE period.

T2 weighted images best demonstrate pathology as most pathology has an increased water content and is therefore bright on T2 weighted images.

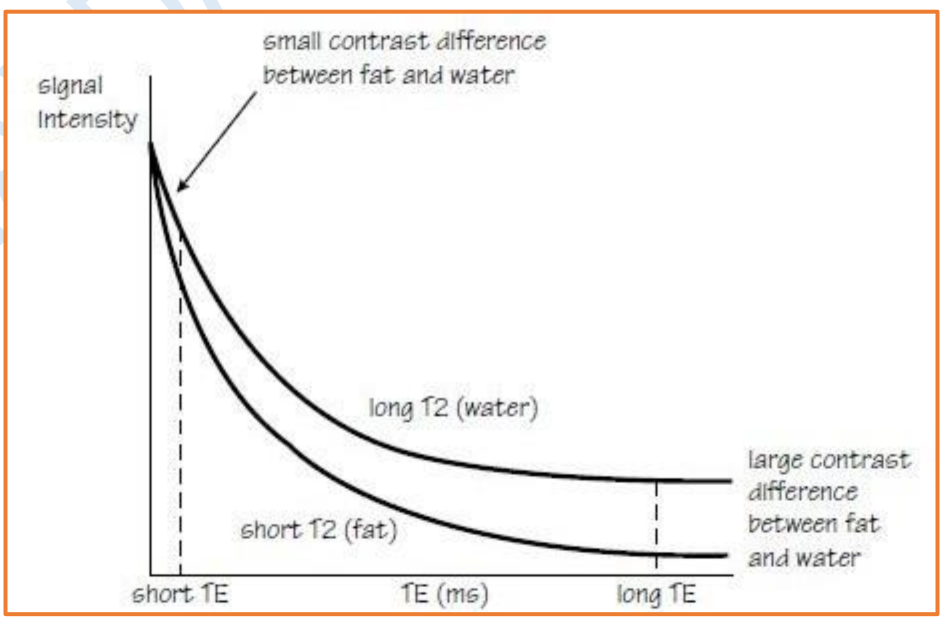

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Fig.(4): T2 differences between fat and water.

Typical parameters T2 W images

TR 2000 ms .

TE 70 ms .

High signal	CSF synovial fluid haemangioma infection inflammation oedema some tumours haemorrhage slow-flowing blood cysts
Low signal	cortical bone bone islands de-oxyhaemoglobin haemosiderin calcification T2 paramagnetic agents
No signal	air fast flowing blood tendons cortical bone scar tissue calcification

Table (2): Signal intensities seen in T2weighted images.

Fig.(5A): Sagittal T1 weighted image of spine. Intraspinal lipoma is bright as it contains fat.

Fig. (5.B): The intraspinal lipoma is now dark. Sagittal T2 weighted image through the spine in the same patient seen in

Proton density (PD) weighting

In a PD weighted image differences in the proton densities (number of hydrogen protons in the tissue) must be demonstrated.

To achieve this:

both T1 and T2 effects are diminished. T1 effects are reduced by selecting a long TR and T2 effects are diminished by selecting a short TE.

Signal brightness could be seen in the PD:

Tissues with a high proton density are bright (high signal) because the high number of protons result in a large component of transverse magnetization.

Cortical bone and air are always dark on MR images regardless of the weighting as they have a low proton density and therefore return little signal.

Proton density weighted images show anatomy and some pathology (Fig. 6 and 7).

Typical values

TR 2000ms+ TE 10–30ms

Fig. 6 Proton density contrast.

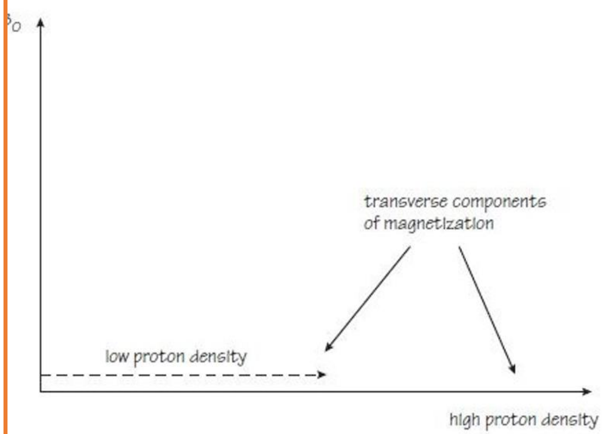
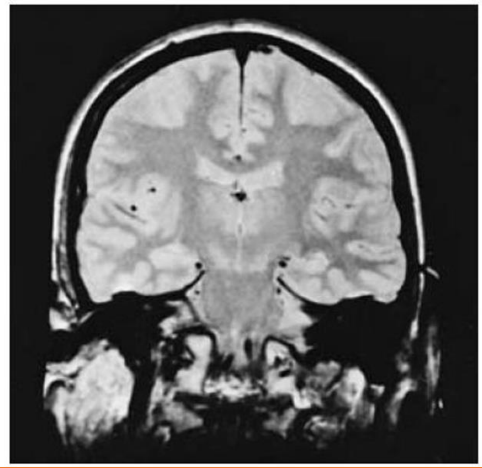


Fig.7 Coronal FSE PD weighted image of the brain.



Posttest: **الاختبار البعدي:**

Compare between by drawing the T1 and T2 relaxation time?

References: **المصادر:**

Principles of Magnetic Resonance Imaging: Physics Concepts, Pulse Sequences, & Biomedical Applications [Wang PhD, Yi]

HAYDAR ABDUL K

الجامعة التقنية الوسطى

كلية التقنيات الصحية والطبية/ بغداد

قسم: تقنيات الاشعة   المادة: فحوصات الرنين المغناطيسي
المرحلة: الرابعة

العنوان: **Title: Principles of MRI 5+6**

اسم المحاضر: **Name of the instructor:**

م. حيدر عبد القادر طاهر

Lecturer. Haydar Abdul Kader Taher

HAYDAR ABDUL KADER

Target population: الفئة المستهدفة:

طلبه المرحلة الرابعة في قسم تقنيات الاشعة

Introduction: المقدمة:

There are many factors available to the technologist when setting up a sequence. The appropriate selection of the parameters determines the weighting, improved quality of images and sensitivity to pathology. Therefore, the technologist should be aware of these factors and their interrelation so that optimal quality of the images can be obtained. The following are the factors discussed below which affect the quality of the image.

Performing an MR examination principles demands multiple choices:

i. The acquisition parameters

ii. The imaging plane orientation, Type of coil, slice thickness, matrix size, number of excitations, etc.

Pretest: الاختبار القبلي:

-Numerate the factors which effect the SNR on the image?

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- What are the relation between the SNR with the slice thickness and FOV.

Scientific Content: **:المحتوى العلمي**

FACTORS AFFECTING THE SNR

<u>Field of View (FOV)</u>

FOV is one of the important factors affecting the SNR.

An image consists of a FOV that relates to the region of interest (anatomy) covered The field of view ranges from 10 to 50 cm for most of the equipment. Therefore, if the entire spinal cord is to be imaged in the sagittal plane, its upper and lower parts need complementary series of pulse sequences.

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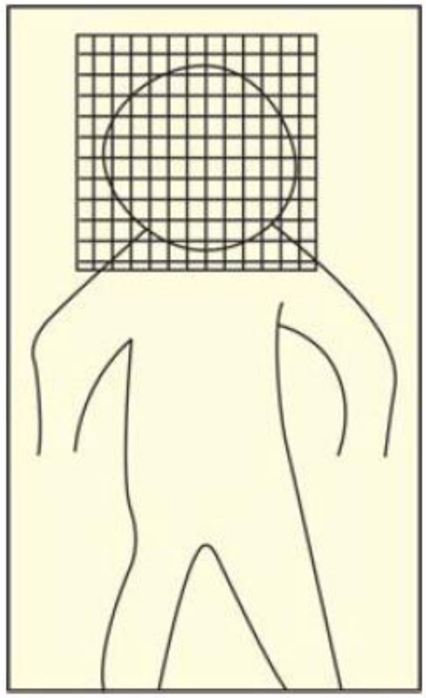

Fig . (1): Field of view

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<u>FOV controls spatial resolution and SNR.</u>

Small FOV produces ↑ (high) resolution ↓ (low) SNR

and increases the minimum TE value = SAT pulses

Decreases the number of slices in an acquisition.

At a given matrix size (i.e., number of pixels on the two image coordinates), the FOV determines pixel size, e.g. at a FOV of 24 cm and a matrix size of 256 × 256 pixels, the pixel size is 0.9 mm × 0.9 mm (240 mm/256).

FOV = 175 mm FOV = 325 mm

High-resolution Low-resolution SNR = 100 percent SNR = 345 percent. It is critical that the technologist should understand the relationship between signal-to-noise and FOV. SNR is proportional to square of the FOV.

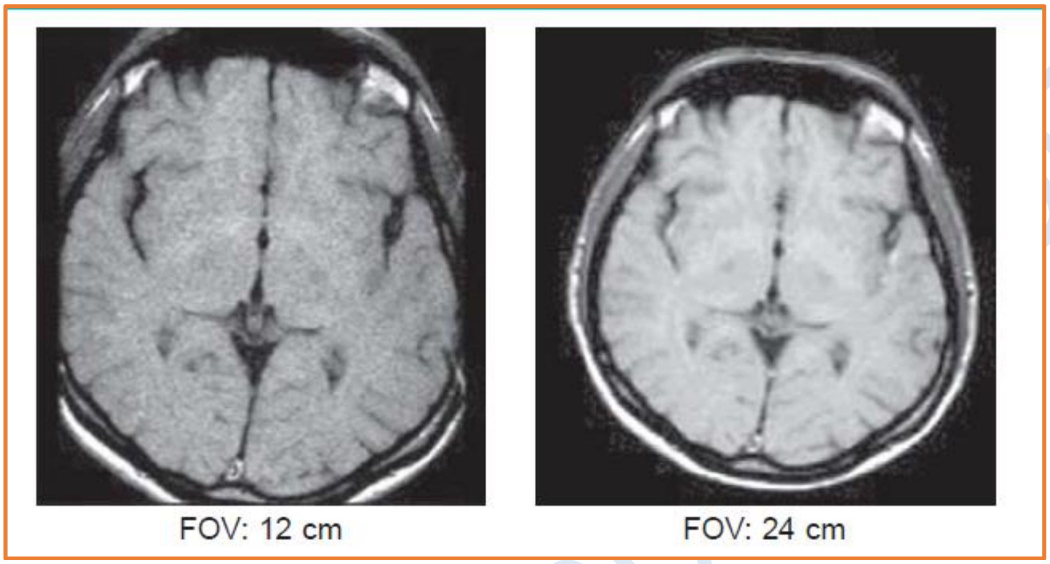

Fig .(2) : **SNR ~ FOV2**

For example, having a FOV reduced from 24 to 12 cm results in, a signal-to-noise reduction of 75 percent.

Note : In practice, the reduction in FOV requires some change that results in increased SNR

Spatial Resolution

Spatial resolution is defined as the ability to separate closely spaced anatomical details.

Slice Thickness

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To give each slice a thickness, a band of nuclei must be excited by the excitation pulse. Increase of slice thickness, increases SNR, coverage of anatomy and partial volume whereas spatial resolution is decreased. As slice thickness (increases), resolution (decreases) and SNR (increases). Decrease of slice thickness, reduces SNR, coverage of anatomy and partial volume whereas spatial resolution is increased.

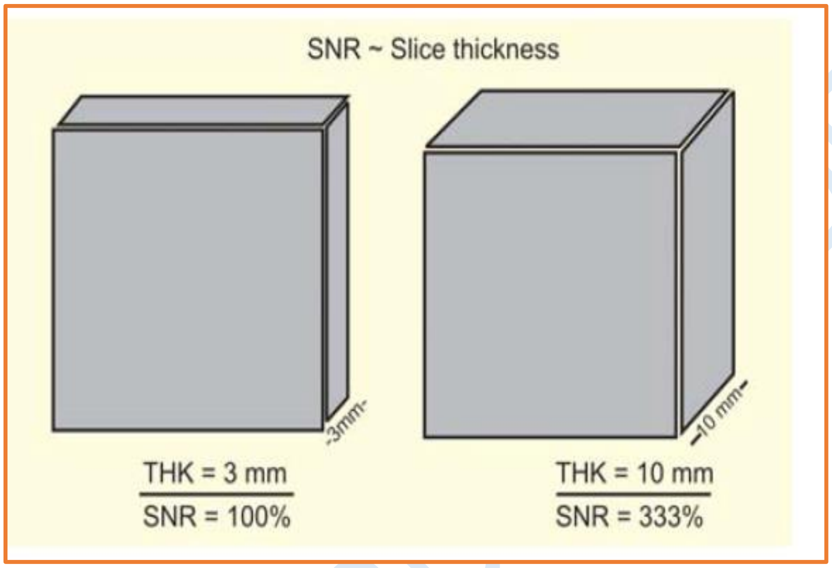

Fig.(3) : SNR-Slice thickness

The basic values of slice thickness ranges from 3 to 15 mm.Slice thickness controls resolution and SNR.

The technologist should be aware that as the slice thickness is increased or decreased, there will be a corresponding change in the S/N ratio for the image.If one slice is acquired at a 6 mm thickness, and another slice is acquired at a 3 mm thickness (with all other factors equal), the second slice will have one-half the signal of the first slice. Since the noise is essentially unchanged, the effect is that the S/N ratio will be cut in half for the second slice.

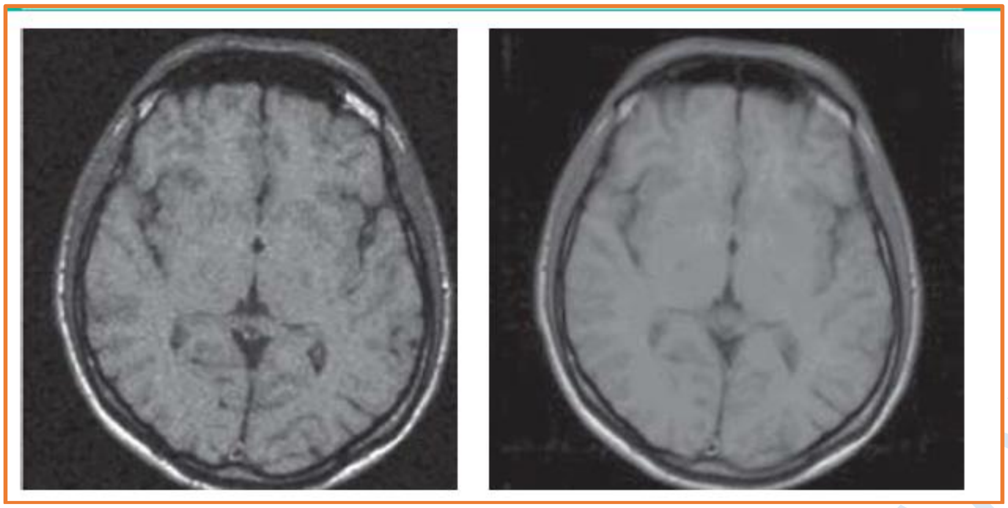

Fig.(4): MRI image , SNR-Slice thickness

Ideally, we would like to obtain images from, infinitely thin sections. The thicker the slice, the more partial volume, which implies that certain structures may be hidden by overlying tissues.
On the other hand, SNR and CNR are improved for larger slice thickness.

Spacing

Spacing is the gap between two slices. When acquiring a multiplanar, single acquisition, spacing controls cross-talk. As spacing ↑□(increases), cross-talk ↓□(decreases) Typically, a spacing that is 20 percent of the slice thickness is sufficient to minimize cross-talk.

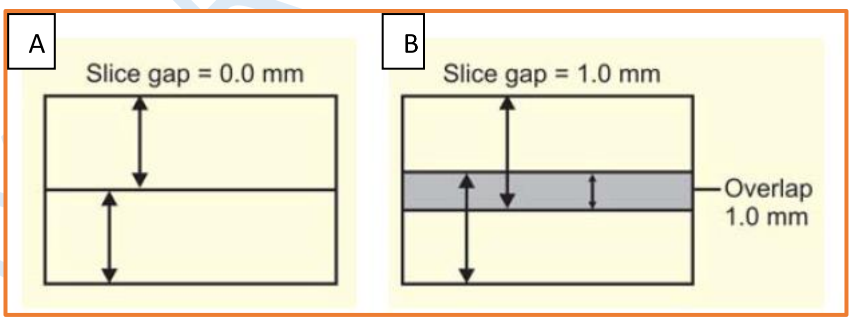

Fig.(5 A & B) : (fig A) Contiguous slice.(fig B) Overlapping slices

As no.of slices □(increases), scan time also □(increases) Ideally, we would like to obtain our images from completely contiguous slices. In practice, there is always some excitation outside the slice boundaries. This means that when exciting a particular slice with a RF pulse, partial excitation of neighboring slices will cause an alteration in image contrast, or the effective TR for every slice is less than determined by TR.

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Matrix Size

The matrix size is represented by two figures. The first figure usually relates to the number of frequency samples taken, whereas the second relates to the number of phase encodings performed. For example 256 × 128 indicates that 256 frequency samples are taken during readout and 128 phase encodings are performed. A course matrix corresponds to less number of pixels and fine matrix corresponds to more number of pixels. In all digital imaging methods, and therefore in MR too, the image is divided into small picture elements called pixels. Each individual pixel corresponds to the intensity and amplitude of MR signal represented on gray scale.

The dimensions of the matrix can be changed. The most commonly used matrix is 256 × 256. Some systems offer low-resolution (128 × 128) and or/high-resolution (512 × 512) matrixes. At a given FOV, matrix size determines pixel size and thus spatial resolution. Therefore, an image obtained with 128 × 256 pixels is typically less well resolved in the Y dimension than one obtained with 256 × 256 pixels. However, all other parameters being equal, the 256 × 256 image has a factor of 2 less SNR, while it requires twice the scan time.

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Pixel: Acronym for a picture element, the smallest discrete part of a digital image display.

Voxel: Volume element, the element of the three-dimensional space (3D-space) corresponding to a pixel, for a given slice thickness.

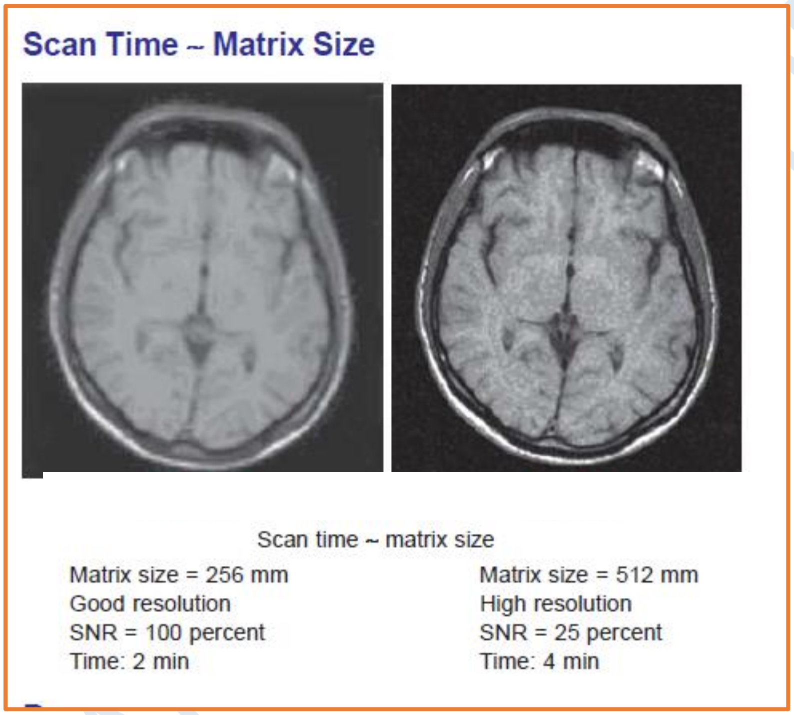

Fig (6) : Relation between scan time and matrix size.

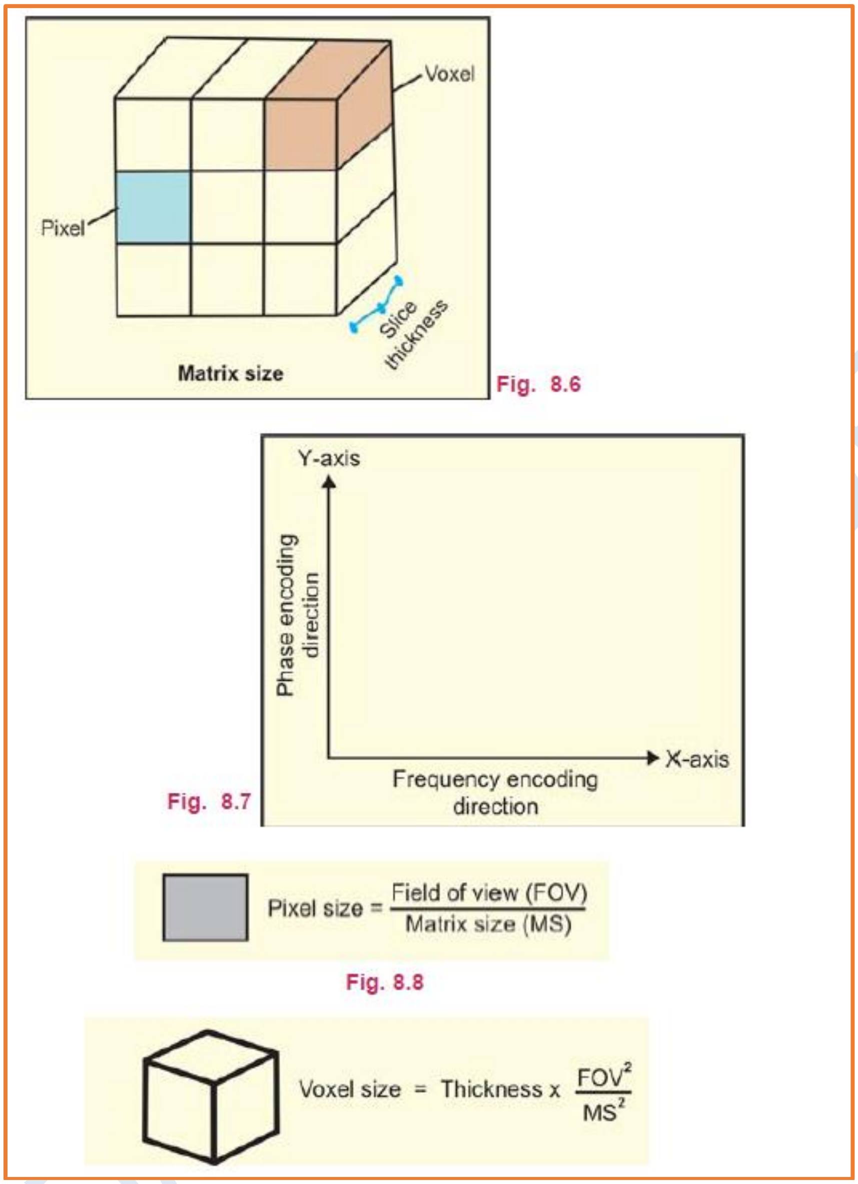

Fig (7) : Marix ,pixel & voxel

Number of Excitations or Number of Signal Averages (NEX/NSA)

Every individual signal which contributes to form a MR image, can be received once or collected several times using repeated excitations. Hence, the average signal value is used to generate the image. When the number of excitations are increased, the error (the noise) doubt and the measurements are more precise. In practice, the number of excitations ranges from 1 to 6. The number of excitations (Nex) implies the number of times a particular line in sampled in K space. K space refers to the raw data of an image.

A line in K space corresponds to the spin echo obtained at a particular setting of the phase encoding gradient. Scan time is proportional to Nex.

By increasing the number of excitations, the SNR is improved and *vice versa*.

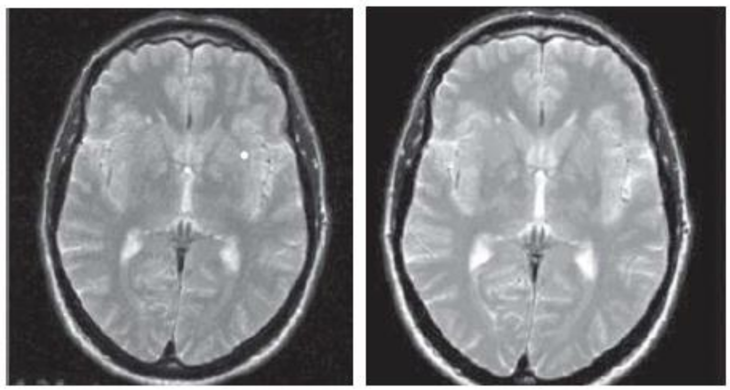

Fig. 8.12
Nex = 2
Scan time = 1.28 min
SNR = 100 percent

Fig. 8.13
Nex = 4
Scan time = 2.48 min
SNR = 141 percent

Image Acquisition Time (Examination Time)

The longer the scan time, the more chances that the patient moves and generates, more artifacts that prevent the interpretation of the images. Hence, optimum scanning time is to be maintained so that appreciable quality of images can be obtained which are free of artifacts (motion artifacts).

For a given patient, the duration of an MR examination depends on several factors.

• Getting the patient settled and centering the area to be studied.
• The number of areas to be examined.
• The number and characteristics of the pulse sequences used.
• The acquisition time (T) of a sequence is given by the following formula:

Acquisition Time (T) = TR × N × Nex
Where, TR is the repetition time,
N is the number of phase encodings in the matrix
Nex is the number of excitations
Acquisition Time = TR × N × Nex
= 400 × 160 × 2 = 128 000 milli sec = 128 sec = 2.14 minutes

Image (Data) Acquisition Time

The time required to gather a complete set of image data. The total time for performing a scan must be taken into consideration. The additional image reconstruction time when determining how quickly the image(s) may be viewed.

Increase of TR increases the scan time and similarly increasing the number of phase encodings in a matrix increases the scan time and *vice versa*. Improving the SNR by increasing Nex also increases the imaging time and *vice versa*.

Frequency

Frequency axis of the acquisiton matrix. The number of cycles or separations of a periodic process per unit time. In electromagnetic radiation, it is usually expressed in units of Hertz (Hz), where 1 Hz = 1 cycle.
Increase the frequency matrix to produce (high) resolution, (low) SNR and □less number of slices.

Phase

In a periodic function (such as rotational or sinusoidal motion), the position relative to a particular part of the cycle. Phase controls scan time for most pulse sequence database and may control resolution.
Nex: Select a Nex value that produces sufficient SNR.

Auto Shim

Auto shim is typically selected when the FOV center is not at isocenter. A preparation phase is performed in which small gradient amplitudes are determined which optimize the main magnetic field homogeneity. The small gradients remain present during the scan.

Signal-to-Noise Ratio (SNR)

It is defined as the ratio of the amplitude of the signal generated to the average amplitude of the noise. Quality of image is mainly characterized by its SNR. Increase of signal increases the SNR and *vice versa*. The following are the factors that affect the SNR:

- Coil type
- Volume of the voxel

Proton density of the region of interest under examination

- TR, TE and Flip angle
- Nex
- Receive bandwidth
- FOV

Scan time, spatial resolution, SNR are mathematically
related.

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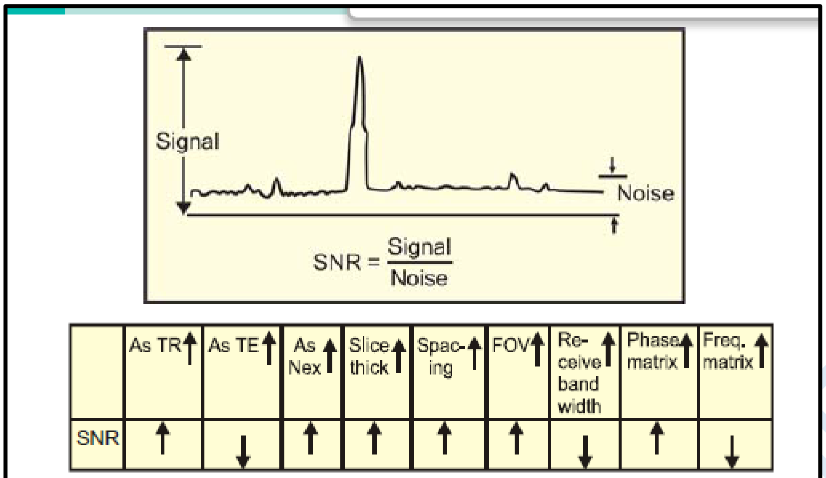

Fig. 8.14: Various factors which contributes to change of SNR

Fig. (9) : Various factors which contributes to change of SNR

Contrast-to-Noise Ratio (CNR)

It is defined as the difference in the SNR of two adjacent areas. The factors that affect CNR are the same as that of SNR.

Bandwidth (BW)

A general term referring to a range of frequencies (e.g.contained in a signal or passed by a signal processing system). This is the range of frequencies that are acquired by the readout gradient. As bandwidth is decreased, noise is reduced thereby increasing the SNR. If the bandwidth is reduced to half, SNR is increased by 40 percent but increases the sampling time. Bandwidth defines the number of frequencies. We can change the bandwidth with RF pulses. Frequency can be swapped with phase direction by champing the entry in (Freq DIR), following the table sum.

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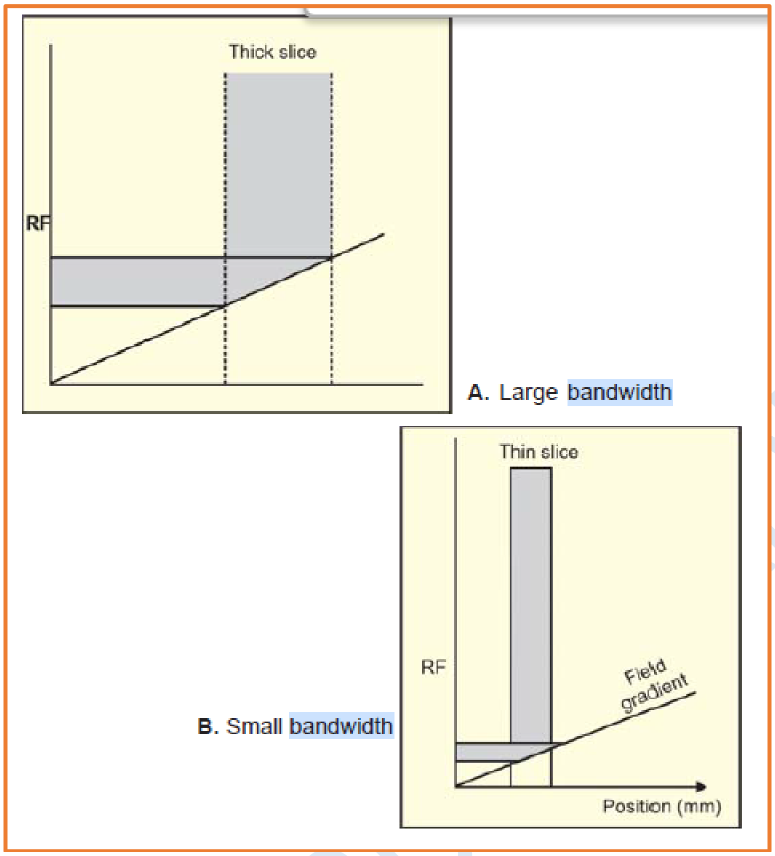

Fig (10 A&B): Selecting slice thickness

The principles of the Image reconstruction

The mathematical process of converting the composite signals obtained during the data acquisition phase into an image.

GRADIENTS

In order to spatially encode the NMR signal, a gradient magnetic field is superimposed on the static magnetic field. The gradients place the nuclei in a slightly different magnetic field depending on their location.

SLICE-SELECT

In order to confine excitation to a single slice only, an RF pulse containing a narrow band of frequencies is applied, in conjunction with the gradient located in the plane perpendicular to the imaging plane. In an axial image in the x-y plane, for example, the slice-selection gradient is Gz. The gradient is applied only during the RF excitation pulse. Only that plane of nuclei located with its z position such that its Larmor Frequency matches that of the applied RF will be excited to produce a signal.

Slice Orientation

- Superior Inferior (axial plane)
- Right Left (sagittal plane)

- Anterior Posterior (coronal plane.

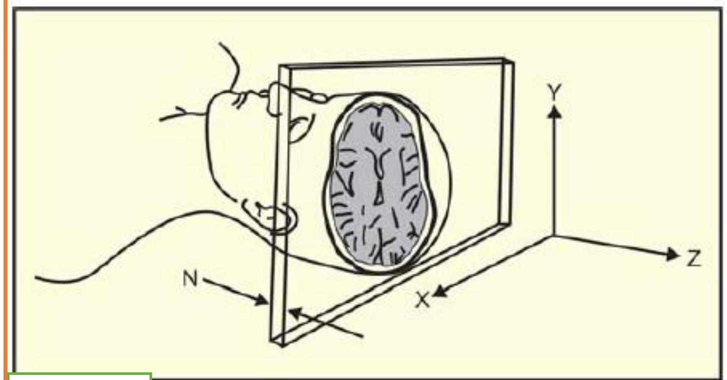

Fig (A) gradient is applied along the z-axis in conjunction with a narrow band RF pulse to confine excitation to a single slice only

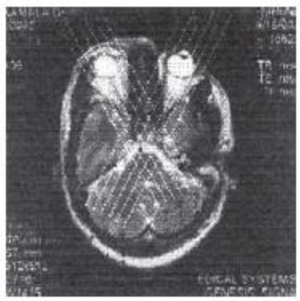

Fig (B) The orientation of simple oblique slices can be specified by rotating a slice

Fig (11) : A&B

Posttest: الاختبارالبعدي:

Compare in the table the relation which effect the time and resolution of image with the small anatomical structures like pituitary?

References: المصادر:

-Step by step MRI Jaganmohan Reddy v parsed

الجامعة التقنية الوسطى

كلية التقنيات الصحية والطبية/ بغداد

قسم: تقنيات الاشعة   المادة: فحوصات الرنين المغناطيسي

المرحلة: الرابعة

Title: Pulse sequences and Image Contrast **العنوان:**

Name of the instructor: **اسم المحاضر:**

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Target population: **الفئة المستهدفة:**

طلبه المرحلة الرابعة في قسم تقنيات الاشعة

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Introduction: المقدمة:

There are many different pulse sequences available, and

each is designed for a specific purpose. The image weighting, contrast and quality is determined by the type of pulse sequence we use. MRI Technion students need to know pulse sequences for several reasons, including:

Performing MRI exams: Pulse sequences are the fundamental building blocks of MRI exams, and MRI students need to understand pulse sequences to perform MRI exams effectively.

Interpreting MRI results: Pulse sequences determine the contrast and resolution of MRI images, and MRI students need to understand pulse sequences to interpret MRI results accurately Optimizing MRI parameters: Pulse sequences can be optimized by adjusting various parameters, such as repetition time (TR) and echo time (TE), to improve image quality and reduce scan time Keeping up-to-date with MRI technology: MRI technology is constantly evolving, and MRI students need to keep up-to-date with the latest advances in pulse sequences and MRI technology to provide the best possible care for their patients.

Overall, MRI Technion students need to know pulse sequences to perform MRI exams effectively, interpret MRI results accurately, optimize MRI parameters, and keep up-to-date with MRI technology. Pulse sequences can be learned through MRI tech programs, continuing education courses, and on-the-job training. It is important for MRI students to stay up-to-date with the latest MRI technology and pulse sequences to provide the best possible care for their patients.

Pretest: الاختبار القبلي:

Compare between spine echo sequences and fast spin sequences?

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Scientific Content: المحتوى العلمي:

PULSE SEQUENCES

Types

1. Spin echo (SE) pulse sequences
a. Conventional spin echo (CSE) pulse sequence
b. Fast spin echo (FSE) pulse sequence
2. Inversion recovery (IR) pulse sequences
a. STIR (short inversion recovery)
b. FLAIR (fluid attenuated inversion recovery)
3. Gradient echo (GE) pulse sequences
a. Coherent gradient echo pulse sequence
b. Incoherent gradient echo pulse sequence
4. Steady state free precession (SSFP)
5. Ultrafast imaging
6. Echoplanar imaging

Conventional Spin Echo (CSE) Pulse Sequence

In this pulse sequence, a 90° excitation RF pulse is given followed by 180° rephasing RF pulse.

Uses

• These are the most commonly used pulse sequences
• May be used for almost every examination
• Produce optimum signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR)
• T1, T2 and proton density weighting is possible

Advantages

• Good image quality
• True T2 weighting is possible.

Disadvantages

• Scan times are relatively long
• More RF power deposition in the body

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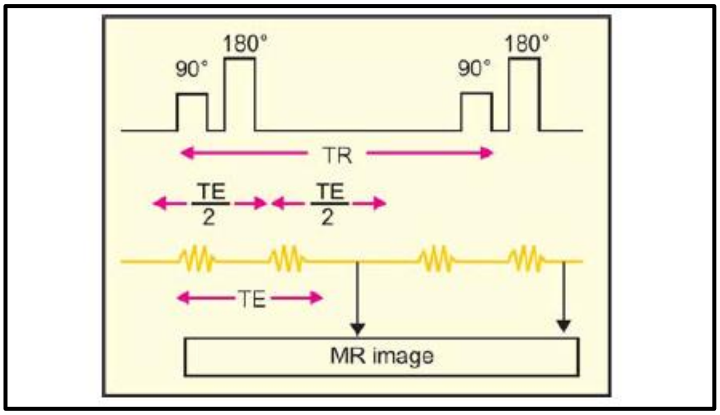

Fig .(1): Schematic illustration of spin echo pulse sequence

Fast Spin Echo (FSE) Pulse Sequence

In this type of pulse sequence, 90° excitation RF pulse will be delivered followed by several 180o rephasing RF pulses. In conventional spin echo (CSE), only one line of K-space is filled per TR. So the CSE takes longer scan time. But in fast spin echo several lines of K-space will be filled per
TR. Because of this reason, the scan times are reduced in fast spin echo. The number of lines of K-space filled per TR is referred to as Turbo Factor (tf) (or) echo train length (ETL). More the ETL, less the scan time (Fig. 1).

Uses

- Can be used as an alternative to spin echo
- Reduction in the scan time compared to conventional spin echo.

Advantages

- Scan times are greatly reduced
- High resolution matrices and multiple NEX can be used
- Improved image quality.

Disadvantages

- Fat remains bright on T2 weighted images
- Image blurring may result

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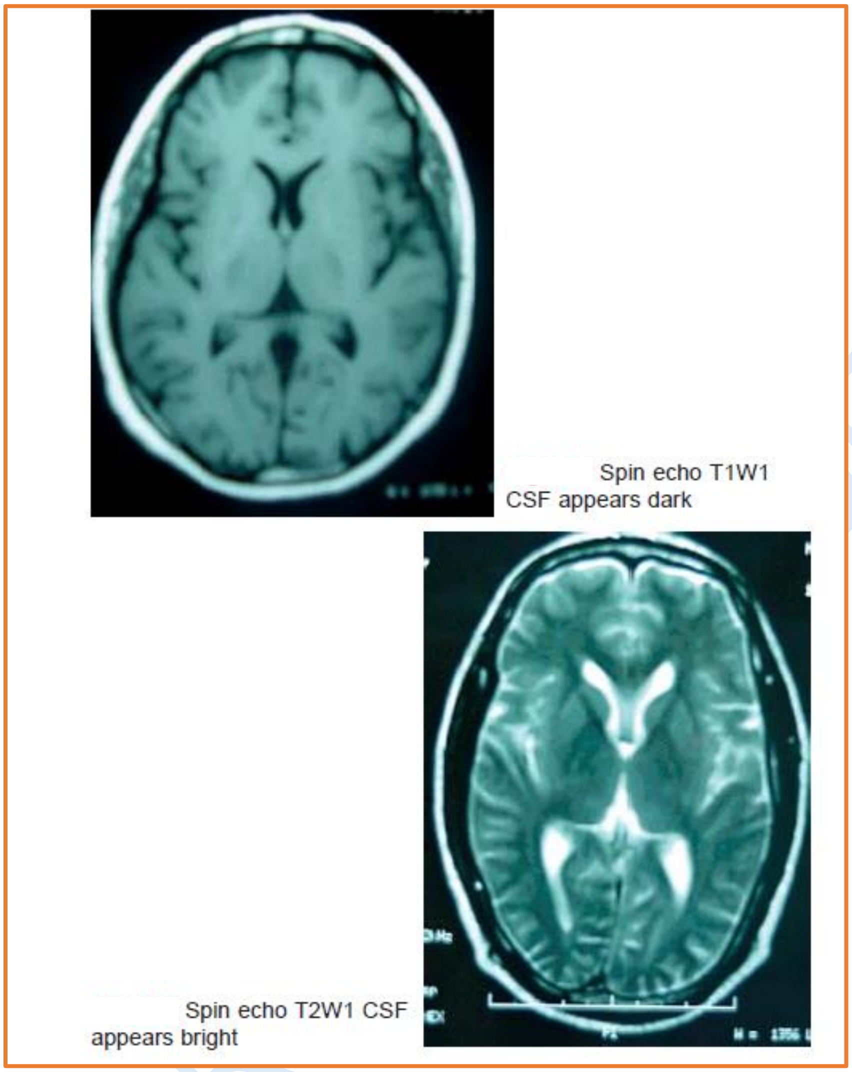

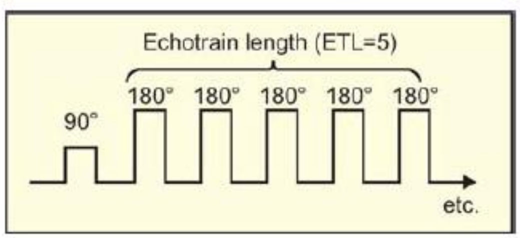

Fig .(2): Schematic illustration of fast spin echo

Inversion Recovery (IR) Pulse Sequences

These pulse sequences use 180° inverting RF pulse followed by 90° excitation RF pulse after certain time [Inversion Time (IT) or Time from Inversion (TI)].

Depending on the TI value, we can classify the IR sequences into:

1. Short inversion recovery (STIR)
2. Fluid attenuated inversion recovery (FLAIR)

If we apply 180° inverting RF pulse, the NMV (net magnetic vector) will be inverted through 180° into full saturation. When we remove the inverting pulse, the NMV begins to relax back to Bo (static external magnetic field) A 90° excitation pulse is then applied at a time from the 180° inverting pulse known as the TI time (Time from Inversion). The contrast of the image depends on the TI value (Fig. 3&4).

These sequences are used to generate heavily T1 weighted images bringing large difference between fat and water.

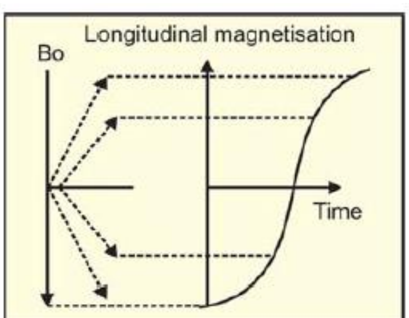

Fig 3 Recovery from inversion

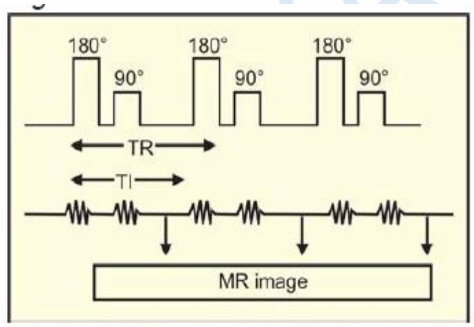

Fig 4 : Schematic illustration of the inversion recovery (IR) pulse sequence

Advantages

- Produces heavily T1 weighted images
- Very good signal-to-noise ratio (SNR).

Disadvantage

- Long scan times.

STIR (Short Inversion Recovery) Pulse Sequence

This sequence is used to suppress the fat signal from the anatomy of interest. Here we use a TI value that corresponds to the time it takes fat to recover from full inversion to the transverse plane so that there is no longitudinal magnetization corresponding to fat. When the 90° RF excitation pulse is applied, the fat is flipped 90_{o} to 180°, so there will not be any fat signal. It will suppress the fat in STIR. Generally, a TI value of around 100-200 ms is used. This TI value may slightly vary depending on the field Strength.

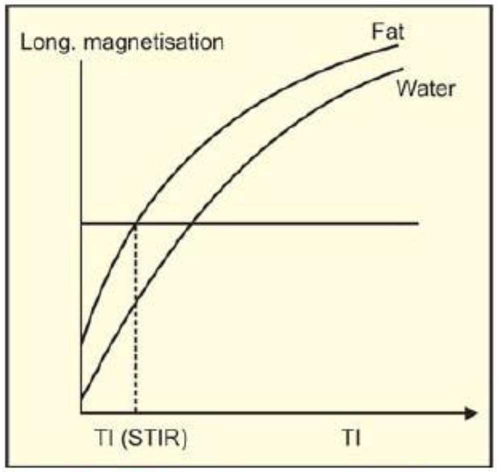

Fig. 5.7: T1 determination of STIR

Uses

• Used to suppress the fat signal in T1 weighted image.

Disadvantage Should not be used with contrast enhancement.

Parameters

FLAIR (Fluid Attenuated Inversion Recovery)

It is another variation in the IR pulse sequence which uses a TI value around 2000 ms. Usually, this sequence is used to suppress the signal from CSF containing areas.

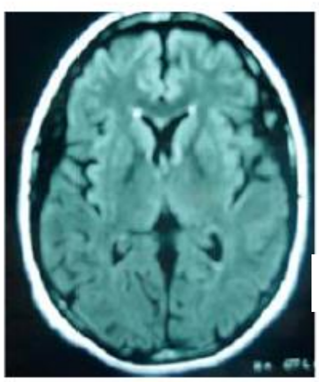

Fig (6) FLAIR image (CSF appears more dark since it is heavily T1 weighted image)

Gradient Echo (GE) Pulse Sequences

These sequences use variable flip angles and lesser repetition time (TR). The gradients are used to rephase the protons. We can apply the gradients quickly to rephase the protons (unlike 180° rephasing pulses in spin echo which takes some time to apply) (Figs 6 and 7). Because of the quicker application of gradients and reduced repetition time and smaller flip angles, the scan times are greatly reduced in gradient echo pulse sequences. With this sequence, we can get T1 weighting, proton density weighting and T2* weighting.

Fig. 5.9: Image obtained with gradient echo pulse sequence. Blood vessels appear bright on gradient echo pulse sequences

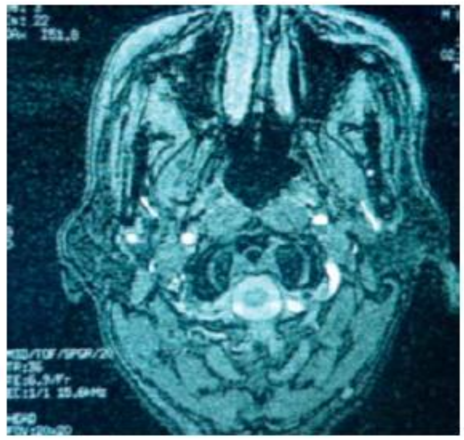

Fig.(7): Image obtained with gradient echo pulse sequence .blood vessels appear bright on gradient echo pulse sequences

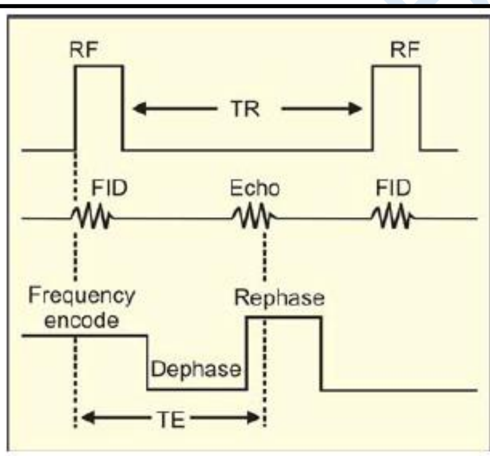

Fig. 5.10: Schematic illustration of gradient echo pulse sequence

Fig.(8): schematic illustration of gradient echo pulse sequences.

Since the gradient does not compensate for magnetic field inhomogeneities, we will get T2* weighting (Fig. 8).

Uses

- Can be used to produce T1, proton density and T2*weighting
- Very minimal scan times

• Can be used for single slice breath hold acquisitions in abdomen and dynamic contrast enhancement
• Since these sequences are flow sensitive, can be used for MR angiography/MR myelography
• Less RF deposition into the body, i.e. less specific absorption rate (SAR).

Disadvantages
• Less signal-to-noise ratio when compared to SE pulse sequences
• True T2 weighting is not possible (T2* contrast rather than true T2)
• More work for the gradients
• More noise to the patient.

Steady State

In this state, the selected TR will be shorter than the T1 and T2 times of the tissues. In this state, there will be coexistence of both longitudinal and transverse magnetization.Most gradient echo sequences use the steady state.
Generally, flip angles of 30° to 45° with TR of 20 to 50 ms favours the steady state.
Depending on the residual transverse magnetization
in phase (or) out of phase GE pulse sequences are classified
into:
1. Coherent (in phase) gradient echo pulse sequence
2. Incoherent (out of phase) gradient echo pulse sequence.

Coherent (in phase) Gradient Echo Pulse Sequences

These sequences use a variable flip angle excitation pulse followed by a frequency encoding gradient rephasing to produce a gradient echo. Here the steady state is maintained by selecting a TR shorter than the T1 and T2 times of the tissues. In this sequence, the tissue with long T2 values appear with high signal intensity.

Uses
• Increased T2* Dependence
• Very fast scans
• Preserves the transverse signal

• Good for angiography

• Can be acquired in a volume acquisition.

Disadvantages
• More gradient noise to the patient

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• Poor SNR in 2D acquisitions compared to spin echo.
• More magnetic susceptibility.

Incoherent (Spoiled) Gradient Echo Pulse Sequences

These pulse sequences begin with a variable flip angle excitation pulse and use frequency encoding gradient rephasing to give a gradient echo. These sequences spoil (or) dephase the residual transverse magnetization so that its effect on image contrast is minimal.

Uses

• Increased T1 weighting
• Spoils the transverse signal
• Only the longitudinal signal contributes to the next RF pulse
• Good SNR in volume acquisition
• Can be acquired in 2D (or) volume
• Breath holding is possible.

Disadvantages

• Decreased SNR in 2D
• Loud gradient noise

Steady State Free Precession (SSFP)

These sequences are used to attain more T2 weighting. In this sequence the steady state is maintained.

Advantages

• True T2 weighting is achieved
• Can be acquired in volume or 2D

Disadvantages

• Loud gradient noise
• Poor image quality

Ultrafast Sequences

• These sequences use coherent (or) incoherent gradientecho pulse sequences
• Only a portion of the RF pulse is used
• Only a portion of the echo is read

Because of the above reasons, the scan time is drastically reduced.

Echoplanar Imaging (EPI)

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• The fastest scan acquisition modes in MRI are the EPI and the gradient echo pulse sequences.
• In echoplanar imaging all the lines of K-space will be filled in one shot. This is called single shot EPI (SS-EPI).
• If the echoes are generated by multiple 180° pulses, this is termed as spin echo echoplanar imaging (SE-EPI).
• If the gradients are used for the purpose of rephasing in EPI, then this sequence is called GE-EPI.
• GE-EPI and SS-EPI are faster than SE-EPI.
• SS-EPI sequences are more prone to artifacts such as chemical shift, distortion and blurring.
• In EPI the image may contain more T2* weighting which can be minimized by using 180° inverting pulse before excitation pulse.

Uses

• Improved cardiac and abdominal imaging
• Used in perfusion weighted imaging
• Useful in real time and interventional MR-guided procedures.

PERFUSION WEIGHTED IMAGING (PWI)

This is a type of dynamic MR imaging by using GRE (or) EPI sequences with contrast enhancement to study the uptake of contrast medium by the lesion. This technique can be used in abnormalities of brain, pancreas, liver and prostate.

DIFFUSION WEIGHTED IMAGING (DWI)

In this type of MR imaging either GRE (or) EPI sequences are used to demonstrate the areas with restricted diffusion of extracellular water such as infarcted tissue. High signal intensity appears at the area of restricted diffusion. DWI is mainly useful in brain to differentiate salvageable and non salvageable tissue after brain stroke.

FUNCTIONAL MRI (FMRI)

It is a dynamic MR imaging Technique that acquires images of the brain during stimulus and also at rest. Then the two sets of images are subtracted to demonstrate functional brain activity. This technique is called BOLD (blood oxygenation level dependent). At the activated areas of brain, there will be increased signal intensity. fMRI is useful in evaluating the brain activity in the disorders of epilepsy, stroke and behavioural problems.

MAGNETIZATION TRANSFER (MT) CONTRAST

This is a technique used to suppress the background tissue thereby increasing the conspicuity of vessels and certain disease processes. MT contrast is useful in

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diagnosing hemorrhage, AIDS, multiple sclerosis and also to improve contrast in TOF-MRA images by suppressing background tissue.

MAGNETIC RESONANCE ANGIOGRAPHY (MRA)

MRA is a technique which allows us to acquire the images with high signal from flowing nuclei and low signal from stationary nuclei. This technique will allow us to see the blood vessels more clearly than surrounding. Generally, GRE pulse sequences are used to show flowing vessels as bright.

There are two types of MRA techniques available. They are: 1) Time of flight (TOF-MRA and 2) Phase-contrast MRA (PC-MRA).

Time of Flight MRA (TOF-MRA)

This technique commonly uses incoherent GRE pulse sequences in conjunction with TR and flip angle combinations that saturate background tissue but allowing moving spins to show high signal intensity. This technique is used in demonstrating arterial and venous flow in head, neck and peripheral vessels.

Phase Contrast MRA (PC-MRA)

This technique usually uses coherent GRE sequences. It provides excellent background suppression. But the scan times with PC-MRA are longer than the scan times of GE pulse sequences are flow sensitive hence used for MRA (magnetic resonance angiography).

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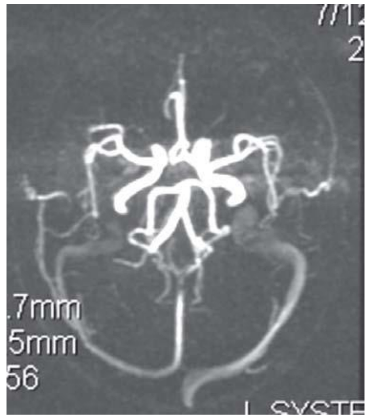

<u>Posttest</u>: <u>الاختبار البعدي</u>:

Mention the types of sequences and explain three of them?

<u>References</u>: <u>المصادر</u>:

Step by step MRI Jaganmohan Reddy v parsed

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الجامعة التقنية الوسطى

كلية التقنيات الصحية والطبية/ بغداد

قسم: تقنيات الاشعة   المادة: فحوصات الرنين المغناطيسي
المرحلة: الرابعة

Title: Artifacts and their compensation **العنوان:**

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lecturer. Haydar Abdul Kader Taher

Target population: **الفئة المستهدفة:**

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طلبه المرحلة الرابعة في قسم تقنيات الاشعة

Scientific Content: المحتوى العلمي:

Artifacts may be defined as the false features in the image produced during the imaging process. The random fluctuation of intensity due to noise can be considered separately from artifacts. Artifacts can be rectified easily when the causes are known. It is necessary to be familiar with specific artifacts since they can conceal pathological elements or simulate pathology that does not exists.

Artifacts can be classified into different categories, *viz.*

- Aliasing
- Chemical shift
- Gibbs/truncation
- Magic angle
- Motion
- Point
- Slice overlap
- Susceptibility
- Zipper
- Array processing
- Coil selection

Wrap Around/Aliasing

Wrap around or aliasing appears when the diameter of the scanned area is greater than the dimensions of the field of view used a part of the image is 'folded' on itself.

Fold over artifacts also known as:

i. Back folding
ii. Aliasing

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iii. Wrap around artifact

Phase of the signal just outside of the field of view, increase FOV, changes preparation direction increased phase encoding.

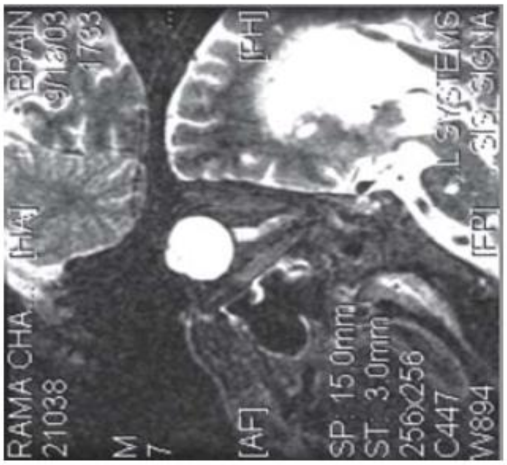


Fig. 7.1: FOV: 18 cm Aliasing of the back of the head onto the forehead in the phase direction is seen

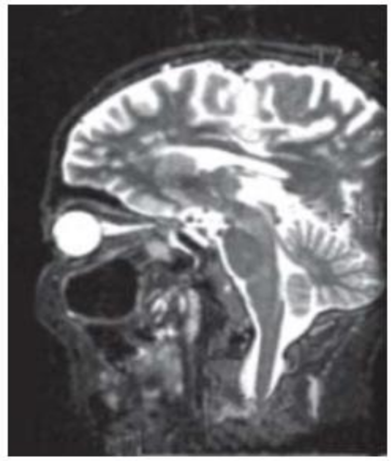


Fig. 7.2: FOV: 32 cm

Fig. 7.3: Back folding artifact

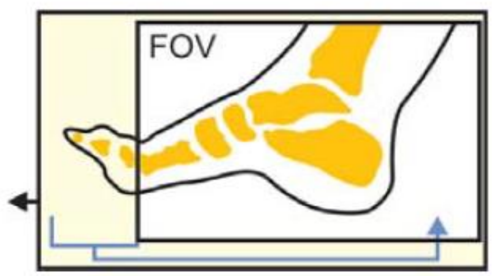
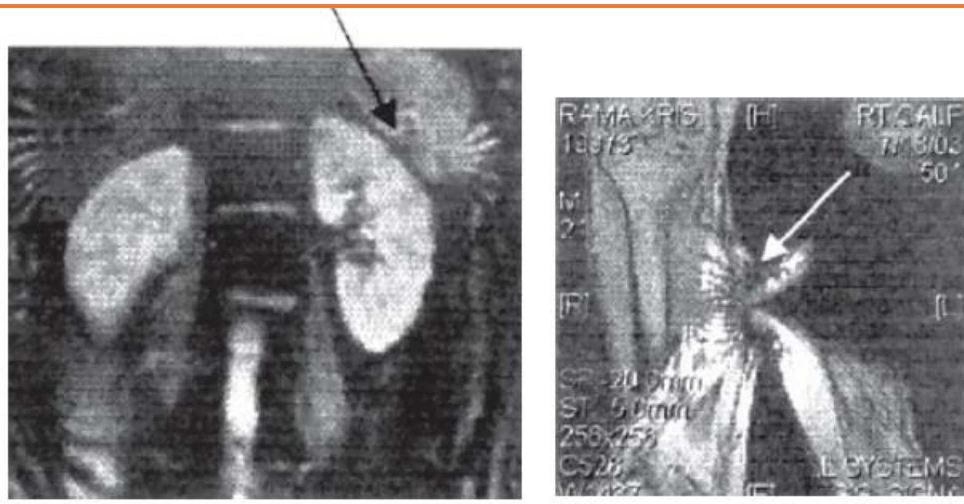


Fig. 7.4: Fold over artifact

Remedies

1. Increase FOV
2. Filtering the frequency encoded direction
3. Oversampling in the phase encoded direction



Figs 7.5A and B: Tissues outside the FOV are folded back and appear other side of the image (zebra type)

Chemical Shift Artifacts

Chemical shift artifacts appear at the interfaces between water and fat because the precessional frequency of protons is slightly different in these two substances. This leads to misregistration of the signals. They are displayed by the equipment as dark region of signal void on one side of water containing tissue and a region of bright signal at the other end of the water fat interface due to super imposition of fat and water signals on the frequency encoding direction.

The chemical shift artifacts is commonly noticed in the abdomen, spine and orbits where fat and other tissues from boarders.

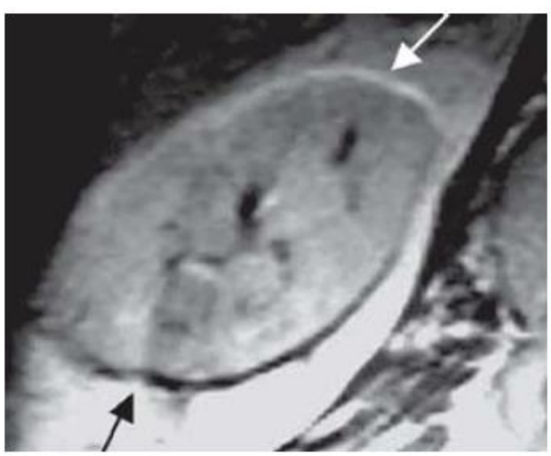


Fig. 7.6: Chemical shift misregistration artifact water in the kidneys is misregistered along the frequency axis. This causes black signal (arrow) voids at the kidneys left margins and white lines at their right margin (arrow)

This artifact is greater at higher field strengths and can be reduced by increasing the bandwidth. The only way to eliminate this artifact is to use a fat suppression technique.

Gibbs or Truncation Artifacts

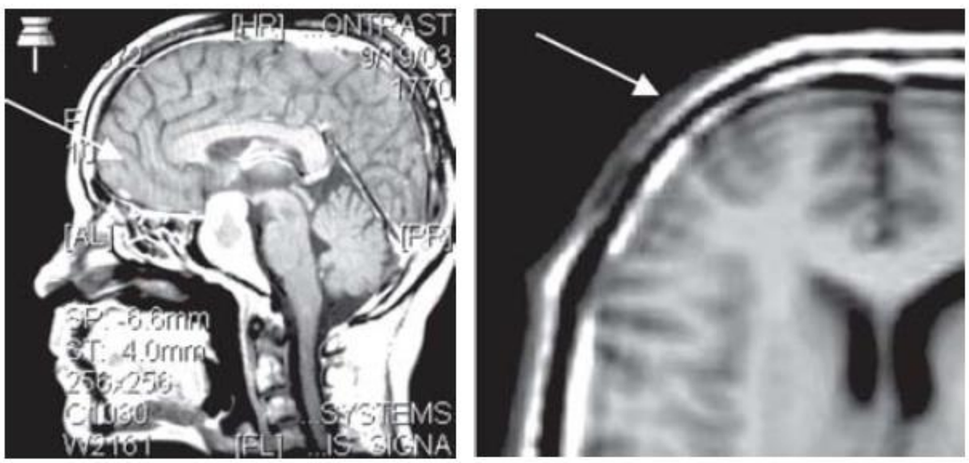
Gibbs or Truncation artifacts are bright and dark lines that are seen parallel and adjacent to boarders of abrupt intensity change, as many be seen at CSF, spinal cord, fat and muscle.

These artifacts are commonly seen in phase encoding direction. They can be reduced by

a. Increasing the matrix

b. Using a filter

c. Change the direction of phase and frequency.



Figs 7.7A and B: Low intensity lines appearing near the boundaries of the brain/skull interface, are characteristic of a 160 phase encoding acquisition

Magic Angle Artifacts

Magic angle artifact is seen mostly in tendons and ligaments of knee-joint that are oriented at a magic angle, i.e. 55° to the main magnetic field. This artifact is seen commonly in the rotator cuff and occasionally in the patellar tendon region and elsewhere

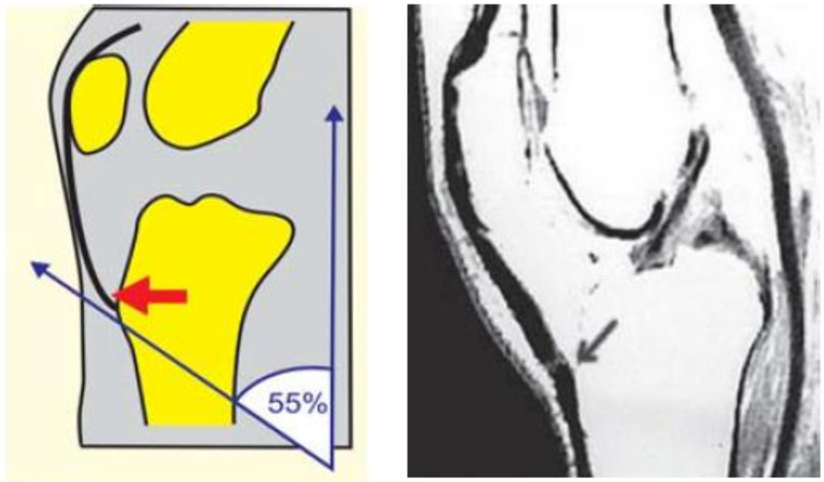


Fig. 7.8: Magic angle artifacts

Motion Artifact

Motion artifacts appear as repeating densities oriented in the phase direction occurring as the results of motion during acquisition of a sequence. These artifacts may be seen from arterial pulsations, swallowing, breathing, peristalsis and physical movement of a patient.This type of artifact is caused by the motion of the patient voluntarily on involuntarily during the scanning. The various types of motion artifacts are as follows: Patient motion Since all the images in one sequence are taken at the same time, it is important not to use excessively long sequences, as movement for a brief period spoils all the images.

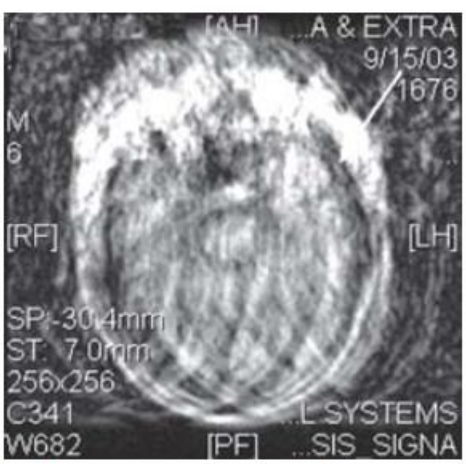


Fig. 7.9: Patient moving head. Axial section of the brain caused by motion of the head

Fig. 7.10: Patient lying still

Remedy: Make patient lie comfortably, stabilize, with straps and cushions.
Cardiac motion This type of artifact is caused by the contraction and relaxation of heart (chest) while the scanning is going on.
Remedy: To avoid this type of artifact, cardiac gating is mandatory during the procedure.

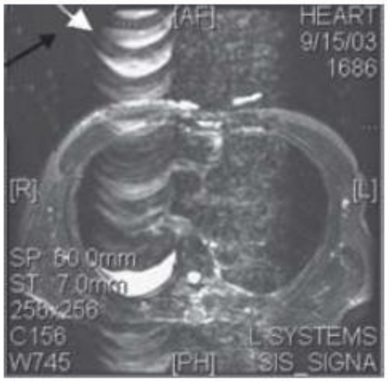
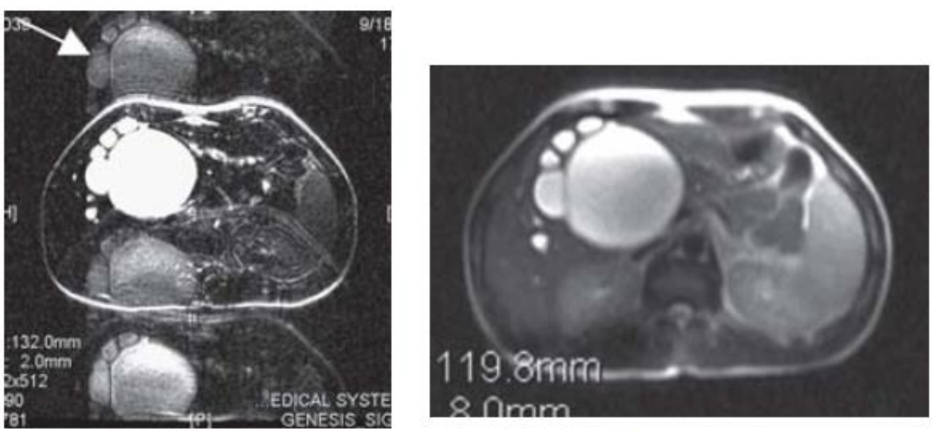


Fig. 7.11: Motion of the heart has produced ghost images without cardiac synchronization, (ECG)

Fig. 7.12: With cardiac synchronization

Respiratory motion This type of artifact is caused by respiration during the scanning.



No breath hold

Breath hold

Figs 7.13A and B: Respiration-induced artifact on axial section of the abdomen. (This can be corrected by breath holding)

Remedy*:* This can be avoided by respiratory gating and respiratory compensation. It can be avoided by placing bellows (pressure transducers) around the patient's chest or abdomen.

Blood flow motion This type of artifact is caused by the flow of blood throughout the cardiac cycle. The artifact are prominent in axial images.
Remedy: An effective remedy for blood flow motion artifact is ‘Spatial Presaturation (SAT)’.

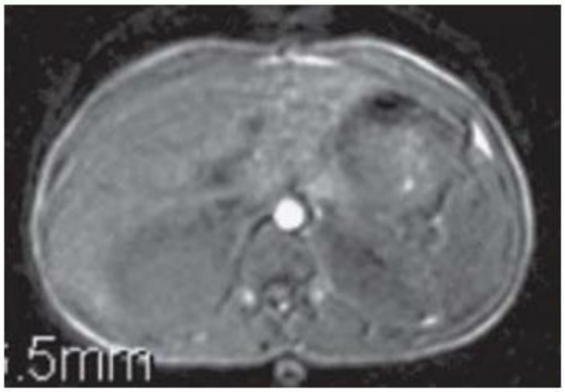
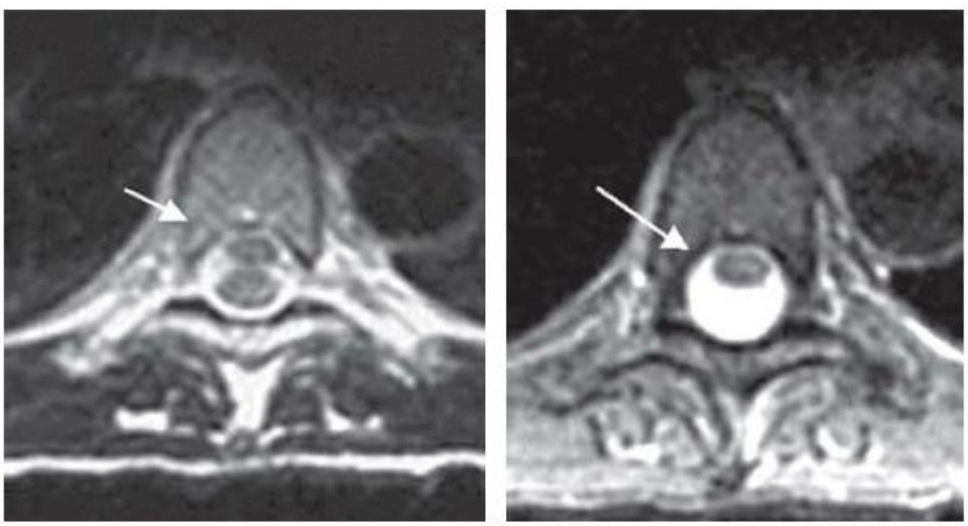


Fig. 7.14: On spoiled gradient echo images, the distance between aorta and ghost artifacts (without triggering)

CSF pulsation The remedy for CSF pulsation ghosting is ‘Gating’ to the cardiac cycle, e.g. plethysmograph (peripheral gating). However, combination of ‘Gating’ and flow compensation (flow comp) is optimal for cervical and thoracic imaging.



Figs 7.15A and B: Transversal image of the T spine showing flow voids in CSF

Point Artifact

Point artifact is seen as a bright spot of increased signal intensity in the center of the image. This is caused due to constant offset of DC voltage in the receiver coil which after Fourier transformation appear as a bright spot in the center of the image.

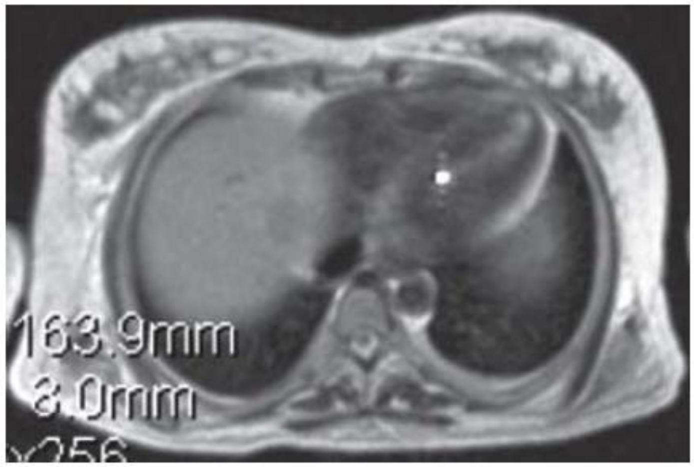


Fig. 7.20: This is an axial image of the cardiac showing a central point artifact

Slice Overlap Artifact

The slice overlap artifact is a name given to the loss of signal seen in an image from a multiangle, multislice acquisitions, as is obtained commonly in the lumbar spine. If the slices obtained at different disk spaces are not parallel, then the slices may overlap.

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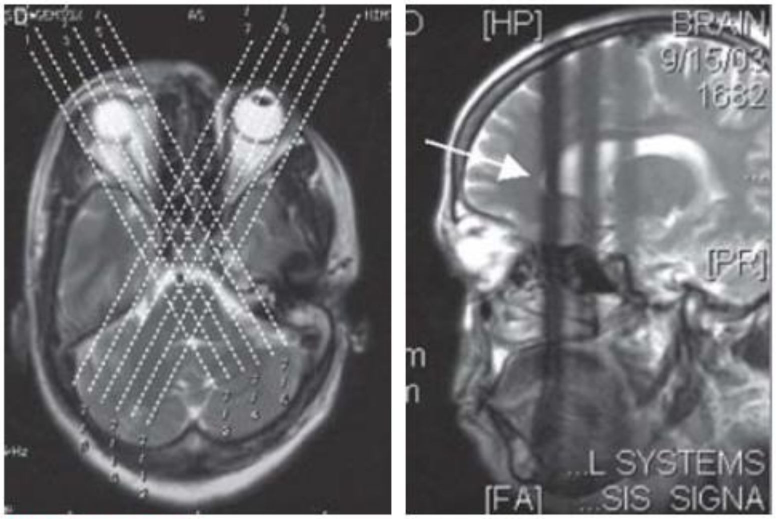
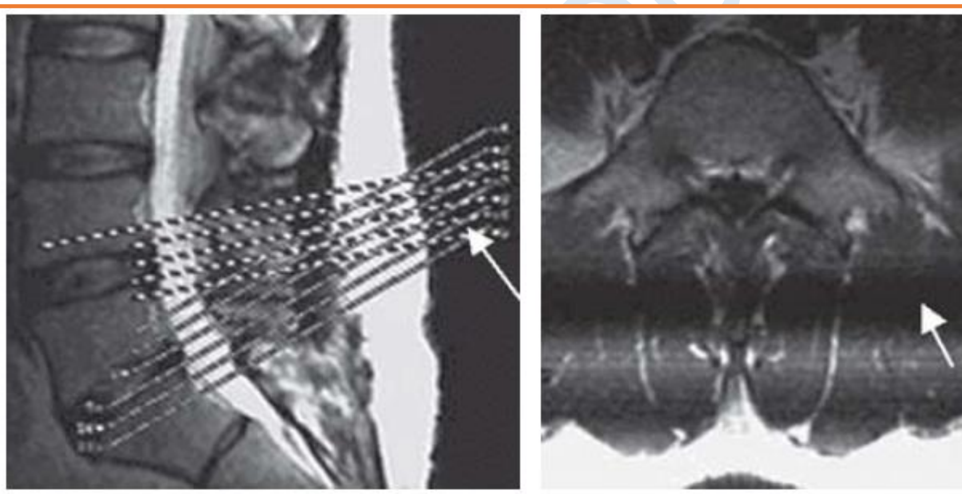


Figs 7.21A and B: Para-axials (oblique) T2 weighted images through optic nerves from a multiangle. This causes a band of signal loss crossing vertically in sagittal image



Arrow shows signal loss from overlap

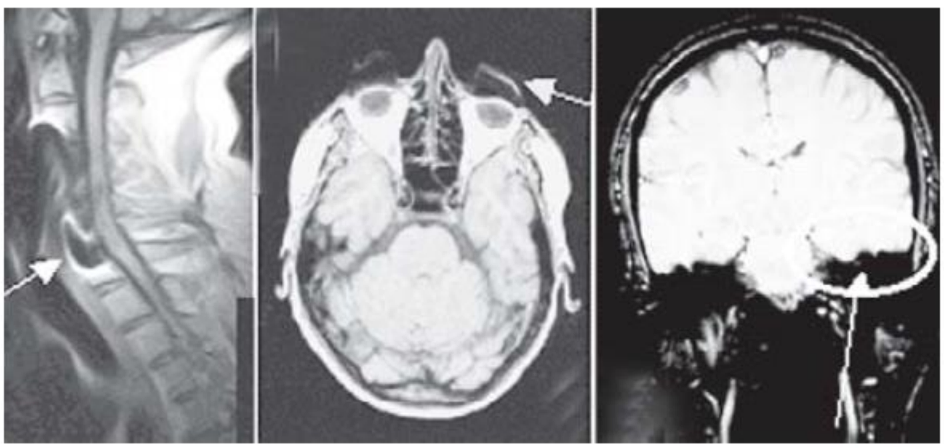
Figs 7.22A and B: This is a para-axial T2 weighted image through L5/S1 from a multiangle, multislice acquisition, as is obtained commonly in the lumbar spine

If two levels are done at the same time, e.g. L4/L5 and L5/S1 then the level acquired second will include spins that have already been saturated. This causes a band of signal loss crossing horizontally or vertically in our image, usually prominent posteriorly.

Susceptibility Artifacts

The susceptibility of a tissue fells us how easily it can be magnetized. Normally most of the tissues have susceptibilityvalues which fall in a fairly narrow range. However, presence of paramagnetic material like hemoglobin degradation products or tissue-air interphases lead to local variations in the susceptibility. This is turn results in reduction in the quality of the local field.

Tissue air interphases related artifacts are commonly seen around the para nasal sinuses and the lungs. These susceptibility artifacts can be removed by using spin echosequences.



A Make up eyeliner

Zipper Artifacts

This artifact is caused by external RF entering the room at a certain frequency and interfering with inherently weak signal coming from the patient.

There are various causes for zipper artifacts in images. Most of them are related to hardware or software problems. The zipper artifacts that can be controlled easily are those due to RF entering the scanning room when the door is open during acquisition of images. RF from radio transmitters will cause zipper artifact that are oriented perpendicular to the frequency axis of the image. Frequently there is more than one artifact line on an image from this cause.

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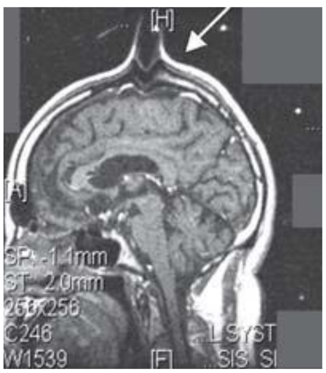
Remedy: System generated artifacts should be reported service engineer.

Figure :Effect of right interface causing streak artifacts. This can be caused by a leaking RF, causing pick-up of external RF signals

<u>Posttest:</u> <u>الاختبار البعدي:</u>



Q: As MRI technician detect the type of this artifact and suggest the remedies you could do to fix the image?

<u>References:</u> <u>المصادر:</u>

Step by step MRI Jaganmohan Reddy v parsed

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