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Nuclear Technology May Help Bring Early Mammal Evolution Into Focus Using a neutron scanner at Los Alamos, paleontologists are generating high-resolution imagery of early mammal fossils A jaw of an Eoconodon coryphaeusâ€"a house cat-sized omnivore that lived between about 66 and 63 million years agoâ€"that Williamson collected in the San Juan Basin. Scientists think the first placentas appeared around this time, laying the groundwork for the largest group of mammals alive today, including us. Williamson is the first paleontologist to collaborate in this way with the lab, which has roots in nuclear defense. The partnership demonstrates how nuclear technology that could ultimately wipe us out as a species has also generated innovations, like this neutron scanner, that may help us understand our own origin as a species. Before dinosaurs disappeared, one of the most common and diverse groups of mammals scurrying around the planet were rodent-like creatures called multituberculates. Some of these survived the extinction, measuring the size of small mice. But new groups of mammals also started to appear after the extinction, and changed rapidly. Laura Poppick To get to a prime field site where Williamson has found ample evidence of this life, we drive several hours northwest of Albuquerque into the badlands of the San Juan Basin. When we arrive, we walk through barren grey hills the color of moon dust that were once the banks of a river. This marks one of the best places in the world to find mammal remains from this time period, Williamson explains as we hike down to a flat depression where he has had particular luck in his decades of fossil hunting. I start to train my eyes for fossils amidst the rubble on the ground and pick up a piece of whitish-gray rock the size of my fist. It has a directional grain that, to me, looks like it could be a bone. I show it to Williamson and he shakes his head. Over the next several hours, I train my eyes more acutely and find a slew of other fossils: But what Williamson is really after are mammal remains, especially teeth and skulls of animals including Eoconodon coryphaeusâ€"a small cat-sized omnivore capable of climbingâ€"and Pantolambda bathmodon, a sheep-sized herbivore that stayed closer to the ground. Tiny holes in the skull where blood vessels and nerves connect the brain to the rest of the body are especially helpful identifiers of different species, says Michelle Spaulding , a paleontologist at Purdue University Northwest in Westville, Indiana involved in the study. He tested out the neutron scanner on a large dinosaur skull with Williamson last year, successfully generating the highest-resolution scan of a tyrannosaur skull ever completed. Los Alamos National Laboratory was built in for nuclear defense research associated with the Manhattan Project, the efforts to develop the first nuclear weapons during World War II. Since then, it has increasingly expanded its collaborations with scientists ranging from botanists to physicists, especially in its Neutron Science Center that includes a half-mile long accelerator that generates neutrons â€" uncharged particles found inside atoms that offer imaging advantages over the electrons used in X-rays. Whereas X-rays get absorbed by and are good at imaging dense materials, neutrons detect the composition within atoms, regardless of density. That means neutrons can penetrate materials and capture imagery that X-rays cannot. A classic example demonstrating this phenomenon is an image of a rose inside a lead flask. Neutron imaging has a variety of applications in detecting explosives and nuclear material. But it also offers new solutions for imaging fossils stuck within and obscured by dense minerals in rocks. Breaking the fossils out of rock would destroy the sample, so neutron scanning gives scientists a non-destructive alternativeâ€"though the samples do become radioactive for a period of time after the scan, Williamson notes. His samples are usually safe to handle after a few days, but other materials would stay radioactive for much longer depending on their composition. Nelson says the partnership with the paleontologists is mutually beneficial, since it challenges the lab to overcome new problems. A neutron scan left and X-ray scan right can offer complimentary imagery for studying different components of fossils. The team will also look into data on molecular relationships between modern mammals and how they relate to some of these extinct species. This helps provide a time calibration and scaffolding for the tree, but the molecular data still has many gaps that need to be filled in. The resulting family tree will provide a

springboard for exploring more details about these ancient creatures, including the different types of landscapes and environments they roamed through, says Spaulding.

Chapter 2 : Open scanner gradients - Questions and Answers â€‹in MRI

Nuclear imaging is more concerned with the functional and molecular aspect of the problem. For instance, nuclear imaging can answer questions related to myocardial perfusion and ischemia, differentiate between malignant and benign thyroid nodules or confirm the diagnosis of acute cholecystitis.

Philips followed with its release of the Veradius system. Manufacturers say the flat-panel detectors offer better image quality and a smaller system that takes up less room in the OR. They also offer a larger field of view FOV that is unaffected by geometrical distortions, and the detector is not affected by magnetic distortions, so the system can be freely positioned. Philips says a smaller flat-panel detector offers fewer obstructions in the OR, allowing more room to see team members and coordinate tasks. For this reason, large fixed angiography systems are generally considered when creating these rooms, because the image quality has traditionally been much better than mobile C-arms. However, advances in detector technology and new imaging software have greatly improved mobile C-arm capabilities over the last few years. Fixed systems also use liquid cooling systems to prevent overheating during prolonged imaging. In March, Ziehm introduced its newest mobile C-arm, the Vision RFD, with a liquid cooling system to allow continued use during long procedures. The company hopes the system will compete as a less expensive alternative to fixed systems in hybrid ORs. The new system uses flat-panel technology to deliver distortion-free images with more than 16, shades of gray and a resolution of 1. The detector is not affected by magnetic fields, so it also produces distortion-free, detail-rich images when close to magnetic resonance MR scanners. The square display format creates a significantly larger visible area with up to 60 percent more information per X-ray than conventional image intensifiers. Another feature usually only found on fixed systems is a contrast media injector interface to synchronize injection of contrast with the imaging process. The Vision RFD offers this same interface. C-Arm Tables C-arms work in conjunction with patient tables that are specifically designed for X-ray imaging. A table should allow free positioning of the C-arm around the patient. Some tables are designed to move and rotate to allow better patient access for procedures and to aid imaging angles. Tables also need to be X-ray translucent so they do not interfere with imaging. Carbon fiber tables are usually used in this role because they are strong and lightweight. The chart includes all the players on the U. The chart requires a log-in, which is free and only takes a minute to sign up.

Chapter 3 : Medical Diagnostic & Therapeutic Services - Community College of Allegheny - Acalog ACMSâ

Blackband) for an introduction to basic mechanisms underlying nuclear magnetic resonance. Although we will go over some of the basic concepts of NMR to reinforce learning and in order to introduce functional MR, the.

Think of us as having microscopic compass needles precessing spinning on their axes like gyroscopes in an orderly direction. To make an MR image, this tendency of the nuclei to line up in the direction of a magnetic field can be manipulated and measured. Since the nuclei from different regions of the body can be made to precess at different frequencies their magneto-resonance frequencies , the electromagnetic energy at these frequencies yields signals that are location dependent. Computer images can be calculated, enhanced, and displayed. MRI is safe because only a very tiny amount of energy is absorbed or emitted, corresponding to the amount of energy in radio waves, to which we are constantly exposed. MRI does not affect any chemical processes. The atomic nuclei within the molecules just report what is happening. This is the Larmor Joseph Larmor, - relationship. Rabi Nobel Prize in Physics, demonstrated the phenomenon of nuclear magnetic resonance in , and Felix Bloch and Edward Mills Purcell , working independently and within one month of each other December and January , demonstrated the use of radio waves to detect nuclear magnetic resonance signals, for which they jointly received the Nobel Prize for Physics in With their discovery, nuclear magnetic spectroscopy was born, without which chemistry would not be modern chemistry and without which MRI could never have been invented. When the transient field is switched off, the nuclei emit radio waves as they return to their steady state condition. Many different atomic nuclei those that possess a net nuclear spin are susceptible to NMR, and a few produce signals that are strong enough for diagnostic MRI. The nucleus of the hydrogen atom a single proton has the largest magnetogyric ratio and, according to equation 3, has the highest energy and therefore the largest signal at any given field strength. Hydrogen is abundant as an element of water. The human body is about two thirds water, so the combination of natural abundance and signal strength determines that imaging with the hydrogen nucleus gives the highest possible resolution. Other nuclei such as 23Na and 31P are also used, although until now primarily in research. Equations 2 and 3 are modified to: Simple model of MR imaging Figure 2 models the first MRI study ever done2, and serves to illustrate the basic principle. Two capillaries of water are within a cylindrical test tube in the sample holder of an NMR spectrometer. This is not one of the large imaging systems of today, but a machine that will fit nothing larger than 5 mm in diameter. Magnetic field gradients are applied at intervals in the XZ-plane. As shown by the arrows, which represent changing magnetic field or signal frequency along each projection, humps of NMR signal appear at spectral frequencies corresponding to the positions of the water protons in the tubes. The physical positions of the nuclei are now encoded as spectral frequency. These are one-dimensional projections, from which a two-dimensional image can be made. Since that time many complex techniques of encoding position and computing images have been developed to improve quality, speed, resolution and contrast in MRI. Richard Ernst , Nobel Laureate for Chemistry in , and his colleagues3 provided an early enhancement by demonstrating that Fourier Transform methods mathematical conversion of the time decaying signals to their frequencies would greatly improve MR images. Another important early step was the realization that if one physical dimension is encoded by frequency, the phase, i. In Peter Mansfield and his colleagues4 introduced Echo-Planar Imaging EPI , a method that uses both frequency and phase encoding, thus allowing all physical directions to be observed simultaneously4. The increased speed of EPI makes possible imaging of structures that change quickly, such as the beating heart. New MRI methods are invented regularly, each having different advantages and disadvantages, depending on the type of image desired. While recent and current practices of MRI in medicine have used techniques to acquire two-dimensional images, in principle and increasingly in practice, the methodology can be extended to three-dimensions or more, the only limitation being the amount of resonance signal that can be acquired and the capability of the hardware and software used for image formation. MRI techniques are still evolving rapidly, as they are optimized for specific applications. A new concept in physics MRI is fundamentally different from all other imaging techniques. Image formation usually requires that the imaged object interact with a radiation field characterized by a wavelength comparable to or

smaller than the smallest features to be distinguished, so that the region of interaction may be restricted and a resolved image generated. Light microscopy, electron microscopy, infrared and ultraviolet imaging and your own eyes all work in this way. The wavelengths of magnetic resonance signals approach a kilometer, and the frequencies are in megahertz. By the well-known half wavelength rule, imaging the human body by magnetic resonance is absurd. It is because of the novel method of coupling the two fields that imaging with the long wavelength and low energy magnetic resonance signals is possible. In principle zeugmatographic techniques can be used with any energy couplings, but it is only recently that they have been used in fields other than MRI or its companion technique, Electron Spin Resonance Imaging. All other things being equal, the resolution of an MR image depends upon the strength of the magnetic field; the higher the field strength, the bigger the signal Equation 3 and the more imaging resolution obtained. The first MRI systems used permanent magnets that could achieve field strengths up to about half a Tesla 5 x Tesla being the strength of the magnetic field of the earth. Clinical MRI systems use superconducting electromagnets that achieve field strengths of up to 10 Tesla, typically 1. The use of superconducting magnets may have been the single most significant contribution to making medical MRI possible. The gradients can be mixed freely, so MRI allows completely flexible orientation of images. These gradient coils are powered by amplifiers that permit rapid and precise adjustments to their field strength and direction. The power and precision of these adjustments determine the resolution and quality of the image obtained. Stronger gradients allow for higher resolution or faster imaging; gradients systems capable of faster switching can also permit faster imaging. Safety concerns determine the upper limit for strength and speed. RF system The varying electromagnetic field B1 is introduced into the magnet using an RF transmission system that consists of an RF synthesizer, a power amplifier, and a transmitting coil. Although the transmitting coil can also be used to receive the MR signals, better quality images are obtained using a separate receiving coil that fits closely to the part of the body being imaged. These are built for specific imaging purposes, e. The more sophisticated receiving coils use multi-element phased arrays that are capable of acquiring multiple channels of data in parallel. Parallel imaging uses unique signal acquisition schemes to replace some of the spatial coding provided by the magnetic gradients with the spatial sensitivity of the different coil elements, and yields large improvements in imaging time or resolution. Image acquisition and computation For the original MR images, Lauterbur attached a resistor to a wire and another wire to a capacitor, with a vacuum tube in between. Numbers were read and penciled onto a grid, thus creating the image. The first computer used to generate MR images had 14K of memory. It is no small coincidence that progress in MRI has closely tracked progress in computer technology. Image computation algorithms vary widely, and signal acquisition methods evolve for use with specific image processing methods. K-space, well known in other types of imaging, quickly became a useful concept in MRI. K-space is a temporary virtual space enclosing the phase and frequency of imaging data, and it functions to simplify their conceptualization. K-space is covariant with actual physical space, so that k and physical spaces are interconvertable with each other. The observed signals can be described in a much simpler way in k-space than in physical space and this simplicity has aided development of many alternative methods of sampling imaging data. Image contrast One of the most important attributes of MRI, which distinguishes if from all other human imaging techniques, is the high quality of contrast, especially among soft tissues. Different tissues may have different amounts of water and water proton relaxation times, and these may be changed by disease as, for example, shown by Raymond Damadian in the case of some cancers6. It is also common, first introduced experimentally7 in , to use external contrast agents to enhance the normal contrast among soft tissues. These agents may contain a paramagnetic substance, such as gadolinium, conjugated to other moieties to make it safer in the body. Paramagnetic agents have a strong magnetic effect on the surrounding molecules and greatly enhance the image of the regions in which it is located. There are now thousands of different MRI contrast agents available for various purposes. The invention and introduction of these agents requires attention not just to the strength of contrast, but to the possibility of directing the contrast toward specific diseases such as contrast agents that will link to receptors on the surface of cancer cells and very importantly, to the possibility of short term or long term adverse effects of their use. Physiological MR imaging The magnetic resonance behavior of the atomic nucleus is determined by the surrounding magnetic field it experiences, and thus by a large number of

different parameters, including blood flow, chemistry, chemical exchange, diffusion and other physiological phenomena. An image that contains information about these parameters provides information on how tissues and organs function, both normally and in disease. Specific MRI techniques have been developed and continue to be developed that highlight changes in these phenomena and emphasis different physiological states or differential diagnosis of disease. MR angiographpy was first introduced in the late s, and a number of different specific methods are now used. Deoxyhaemoglobin in blood is paramagnetic and therefore distorts the magnetic environment of the surrounding water molecules. In general, the brain uses more oxygen when it is active, and the local blood flow increases to supply even more oxygen than is required. This over-supply leaves its carrier, haemoglobin, more oxygenated and the magnetic distortion by deoxyhemoglobin decreases. It has been shown that the BOLD effect correlates directly with electrical communication among nerve cells , the synaptic activity. The technique is useful in observation of strokes, in which the water of edema diffuses particularly freely. These images are clinically useful in showing interuption of normal fiber anatomy by tumors or trauma. Spectroscopic imaging Spectroscopic imaging was first described9 by Paul Lauterbur in The technique combines the effect of molecular structure on the magnetic field experienced by an atomic nucleus, the Chemical Shift, with the effects the magnetic field gradients used in MRI. Chemical shifts show different chemical entities in a spectrum and are thus the basis of NMR in chemistry. Chemical shifts are combined with MRI to make physical maps of molecules that are important to cellular function. Spectroscopic MRI is difficult because of formidable sensitivity problems, and has not yet lived up to its promise. Metabolically important chemicals are best observed using insensitive atomic nuclei that are present in concentrations only one thousandth or less that of body water. Volumes Springer Verlag. Image Formation by Induced Local Interactions: Grannell PK, Mansfield P. Solid State Phys Augustine, M. USA , 87, Lauterbur, P.

Chapter 4 : Nuclear magnetic resonance - Wikipedia

Wiktionary (/ 0 votes) Rate this definition. nuclear magnetic resonance (Noun). The absorption of electromagnetic radiation (radio waves), at a specific frequency, by an atomic nucleus placed in a strong magnetic field; used in spectroscopy and in magnetic resonance imaging.

Introduction Single photon emission computed tomography SPECT is a medical imaging technique that is based on conventional nuclear medicine imaging and tomographic reconstruction methods. The images reflect functional information about patients similar to that obtained with positron emission tomography PET. Both SPECT and PET see Chapter 6 give information based on the spatial concentration of injected radiopharmaceuticals, in contrast to the other medical imaging modalities used for clinical diagnostic purposes. A radioactive-labeled pharmaceutical radiopharmaceutical is administered to a patient. Typically, a scintillation camera system is used as the imaging device. The signals from an array of PMTs are processed by electronic circuitry to provide information about the position at which a photon interacts with the crystal. The scintillation camera provides a two-dimensional projection image of the three-dimensional radioactivity distribution or radiopharmaceutical uptake within the patient. The imaging process and the components of a typical nuclear medicine imaging system. SPECT takes conventional two-dimensional nuclear medicine images acquired at different views around the patient and provides an estimate of the three-dimensional radioactivity distribution using methods of image reconstruction from multiple projections. SPECT differs from x-ray computed tomography CT in that the radiation source is within instead of outside the patient. The goal of SPECT is to determine accurately the three-dimensional radioactivity distribution resulting from the radiopharmaceutical uptake inside the patient instead of the attenuation coefficient distribution from different tissues as obtained from x-ray CT. SPECT utilizes radiopharmaceuticals that are common in nuclear medicine clinics, rather than those that emit positrons with subsequent generation of two keV annihilation photons as is the case with PET. SPECT requires instrumentation and image reconstruction methods that differ from those used in other medical imaging modalities. The amount of radiopharmaceutical that can be administered is limited by the allowable dose of radiation to the patient. This requirement results in a limited number of photons that can be used for imaging. Also, the acceptance angle or geometric response of the collimator further limits the fraction of photons that are acceptable for the projection data. The collimator can be designed to allow detection of more photons, but increased detection efficiency usually can be achieved only with a concurrent loss of spatial resolution. A major goal of SPECT instrumentation development is to increase the detection efficiency while at the same time improving the spatial resolution of the imaging system, goals that are pursued by adding more detectors around the patient. When conventional reconstruction techniques e. Emphasis is placed on the physics, mathematics, and engineering aspects of SPECT, and future trends and potential areas of further investigation are discussed. In combination with new radiopharmaceuticals and clinical applications, these developments could ultimately improve patient care. The degree of attenuation is determined by 1 the pathlength between the source and the edge of the attenuating material, and 2 the linear attenuation coefficient, which is a function of photon energy and the amount and types of materials contained in the attenuating medium. For example, the attenuation coefficient for the keV photons from the commonly used isotope Tcm in water or soft tissue is 0. For the keV photons, this attenuation coefficient gives rise to a half-valued-layerâ€”the thickness of material that attenuates half of the incident photonsâ€”of 4. The attenuation effect is further complicated by the fact that different regions of the body have different attenuation coefficients. In particular, the non-uniform attenuation distribution in the thorax is a major problem in cardiac SPECT image reconstructions. Photons that have been scattered before reaching the radiation detector give erroneous spatial information about the origin of the radioactive source, and a significant fraction of the photons detected in SPECT have been scattered: As this measurement is about the same as the thickness of many organ subregions e. This relatively low resolution affects image quality as well as quantitative accuracy. The systems are designed to acquire projection data from multiple views around the patient. Multidetector SPECT systems provide the capability of high counting rates but are restricted to

single or a limited number of image slices. The scintillation cameras allow acquisition of two-dimensional projection data that can be reconstructed to form multiple reconstructed image slices. Multiple-camera-based SPECT systems increase the number of cameras surrounding the patient to provide higher detection efficiency Fig. Different arrangements of multiple-camera-based SPECT systems, which increase the number of cameras surrounding the patient to provide higher detection efficiency. As shown in Figure 5. A set of pinholes on a hemispherical lead collimator allows formation of projection images from multiple views that can be reconstructed directly to form a three-dimensional reconstructed image. Since no rotation motion is required to collect the complete projection data set, the system is capable of acquiring fast dynamic three-dimensional SPECT data. A set of pinholes on a hemispherical more Special Collimators As shown in Figure 5. For the parallel-hole collimator design, the detection efficiency can be increased at the expense of a concurrent degradation of spatial resolution. The goal of special collimator designs in SPECT is to decrease the severity of this trade-off as compared to the parallel-hole design. Two collimator designs used in SPECT that improve efficiency with no resolution penalties are the fan beam and cone-beam geometries Fig. The gain in detection efficiency is obtained by the increased solid angle of acceptance. Typically, the fan beam and cone-beam collimators provide about 1. However, the geometries of the converging-hole collimator designs require special reconstruction algorithms and data acquisition strategies. Fan beam left and cone-beam right collimator designs, which improve efficiency with no resolution penalties. New Radiation Detector Technologies For over 3 decades the scintillation camera has been the most popular imaging device of nuclear medicine. During this time its performance has been thoroughly studied and optimized, and further improvement will likely be dependent on the development of solid-state detector arrays. Since the spatial resolution of a commonly used general-purpose collimator is on the order of 7 to 15 mm, the 3-mm intrinsic resolution of the camera has been regarded as adequate. However, new detector and collimator strategies such as those embodied in the design shown in Figure 5. Simulations from the research group at the University of Arizona have shown that a final tomographic resolution of around 2 mm is possible if detectors with very large areas and small pixels can be produced. Semiconductor detectors or combinations of scintillators and solid-state photon detectors offer good prospects for significant improvements in spatial and energy resolution. In the past, silicon and germanium detectors were investigated for use in conventional nuclear medicine imaging. However, their use was limited due to their lower stopping power, high material cost, and the requirement to operate at low-temperature. However, new room-temperature semiconductors with high stopping power are now available, offering numerous options for new detector designs. These new semiconductor detectors combined with optimized imaging geometries offer the prospect of major advances in the performance of SPECT imaging systems. The limit in useful resolution depends ultimately on the allowable patient dose of radionuclide and the solid angle effectively spanned by the detection system. The sensitivity of SPECT is much less than that of PET because of the necessity of using lead channels or collimators, which limit the solid angle subtended by the tomograph. Innovations suggested to improve the sensitivity of SPECT include not only methods of increasing A through collimator-detector arrangements, but also the use of methods for tracking the trajectory of each photon. The latter include Compton scattering angle determinations from energy discrimination. Assume an ideal situation in which the emission photons do not experience attenuation and scatter in the patient and the collimator-detector has perfect spatial resolution without blurring effects in the measured data. The SPECT reconstruction problem is different from the classical problem of image reconstruction from projections because each photon is attenuated and scattered by the material between its source and the detector. When attenuation is taken into consideration, the two-dimensional attenuated Radon transform can be written as where a u, v is the two-dimensional attenuation coefficient distribution and is the attenuation factor for photons that originate from x,y , travel along the direction perpendicular to the detector array, and are detected by the collimator-detector. See also section At each point on the projection image, unattenuated and scattered photons that fall within the field of view of the collimator-detector are detected. The inner integral of equation 5. The most commonly used techniques are based on the Fourier projection theorem. These techniques apply a ramp-shaped filter to the Fourier transform of the projections equation 5. The methods are generally known as filtered backprojection of filtered projection or, equivalently, convolution methods. The shape of the filter

depends on the amount of noise suppression desired. More detailed descriptions of these image reconstruction techniques are found in Chapter When used in routine clinical SPECT image reconstruction, these reconstructions ignore the effects of attenuation, scatter, and the collimator-detector response. Consequently, SPECT images obtained with these reconstruction techniques are quantitatively inaccurate. More importantly, these images have artifacts and distortion, resulting in poor image quality. However, analytical solutions to the inverse Radon transform expressed in equations 5. Hence, special reconstruction methods are needed to estimate accurately the true three-dimensional radiopharmaceutical distribution in the patient, and research in this area has been a major focus in the development of SPECT in recent years. In particular, iterative reconstruction algorithms have been used to provide estimates of the solutions of the SPECT reconstruction problem expressed in equations 5. Often, the image reconstruction algorithm is inseparable from the compensation technique, resulting in SPECT reconstruction methods that are not found in other tomographic imaging modalities. Iterative Reconstruction Algorithms A typical iterative reconstruction algorithm starts with an initial estimate of the object source distribution. Projection data are generated from the initial estimate using a projection matrix that models the imaging process. The calculated projection data are compared with the measured data at the same projection angles and their differences are determined. With application of a given statistical criterion, the differences are used to update the initial image estimate. A new set of calculated projection data is regenerated from the new image estimate and compared with the measured projection data. The procedure is repeated until the differences between the calculated and measured projection data are smaller than a preselected small value. Statistical criteria that have been used in formulating iterative reconstruction algorithms include the minimum mean squares error MMSE , weighted least squares WLS , maximum entropy ME , maximum likelihood ML , and maximum a posteriori MAP approaches. Iterative algorithms that have been used in estimating the reconstructed images include the Gauss-Seidel GS , conjugate gradient CG , and expectation maximization EM algorithms see section Iterative reconstruction methods differ in their assumptions about the statistical properties of the measured data, convergence rates, and noise characteristics. These properties are important considerations for assessing the applicability of particular reconstruction methods in SPECT. Interest in the applications of iterative reconstruction algorithms was initially propelled by the need to compensate for non-uniform attenuation in the imaging of heart muscle with radiopharmaceuticals, which illuminate relative perfusion. More recently, iterative reconstruction algorithms have been applied to compensate for the spatially variant system response function collimator-detector response and scatter. These compensations are achieved by modeling the imaging process in the projection and backprojection operations during the iterative steps. A major drawback of the iterative techniques is the long processing time involved. However, rapid advances in computer technology and in software implementation of these algorithms have significantly reduced the computation times. For example, the reconstruction time for 30 iterations of the iterative ML-EM algorithm with non-uniform attenuation compensation is 4 minutes for 32 64 x 64 image slices using a state-of-the-art DEC Alpha workstation. Continued development in computer hardware, algorithms, and codes will bring quantitative SPECT reconstruction methods to clinical use in the near future. Compensation Methods Methods of compensating for attenuation can be grouped into two categories: The assumption of uniform attenuation can be applied to SPECT imaging of the head and of the abdomen region. If uniform attenuation is assumed, i. In cardiac SPECT studies, iterative reconstruction methods have been used to compensate for the non-uniform attenuation distribution that arises from the heterogeneity of the chest region.

Chapter 5 : Nuclear Magnetic Resonance and Magnetic Resonance Imaging / Spectroscopy - MagLab

Nuclear magnetic resonance (NMR) is a physical phenomenon in which nuclei in a strong static magnetic field are perturbed by a weak oscillating magnetic field (in the near field and therefore not involving electromagnetic waves) and respond by producing an electromagnetic signal with a frequency characteristic of the magnetic field at the nucleus.

This gives a temporal resolution of 20â€”30 ms for images with an in-plane resolution of 1. Interventional magnetic resonance imaging The lack of harmful effects on the patient and the operator make MRI well-suited for interventional radiology , where the images produced by an MRI scanner guide minimally invasive procedures. Such procedures use no ferromagnetic instruments. Some specialized MRI systems allow imaging concurrent with the surgical procedure. More typically, the surgical procedure is temporarily interrupted so that MRI can assess the success of the procedure or guide subsequent surgical work. This technology can achieve precise ablation of diseased tissue. MR imaging provides a three-dimensional view of the target tissue, allowing for the precise focusing of ultrasound energy. The MR imaging provides quantitative, real-time, thermal images of the treated area. This allows the physician to ensure that the temperature generated during each cycle of ultrasound energy is sufficient to cause thermal ablation within the desired tissue and if not, to adapt the parameters to ensure effective treatment. However, any nucleus with a net nuclear spin could potentially be imaged with MRI. Such nuclei include helium -3, lithium -7, carbon , fluorine , oxygen , sodium , phosphorus and xenon Gaseous isotopes such as 3He or Xe must be hyperpolarized and then inhaled as their nuclear density is too low to yield a useful signal under normal conditions. However, potential applications include functional imaging and imaging of organs poorly seen on 1H MRI e. Inhaled hyperpolarized 3He can be used to image the distribution of air spaces within the lungs. Injectable solutions containing 13C or stabilized bubbles of hyperpolarized Xe have been studied as contrast agents for angiography and perfusion imaging. Multinuclear imaging holds the potential to chart the distribution of lithium in the human brain, this element finding use as an important drug for those with conditions such as bipolar disorder. Molecular imaging MRI has the advantages of having very high spatial resolution and is very adept at morphological imaging and functional imaging. MRI does have several disadvantages though. This problem stems from the fact that the population difference between the nuclear spin states is very small at room temperature. For example, at 1. Improvements to increase MR sensitivity include increasing magnetic field strength, and hyperpolarization via optical pumping or dynamic nuclear polarization. There are also a variety of signal amplification schemes based on chemical exchange that increase sensitivity. To date, many studies have been devoted to developing targeted-MRI contrast agents to achieve molecular imaging by MRI. Commonly, peptides, antibodies, or small ligands, and small protein domains, such as HER-2 affibodies, have been applied to achieve targeting. To enhance the sensitivity of the contrast agents, these targeting moieties are usually linked to high payload MRI contrast agents or MRI contrast agents with high relaxivities. Pre-polarizing MRI PMRI systems using resistive electromagnets have shown promise as a low-cost alternative and have specific advantages for joint imaging near metal implants, however they are likely unsuitable for routine whole-body or neuroimaging applications.

Chapter 6 : What does nuclear magnetic resonance mean?

Mag Res Imaging Qing-ming H, Shan-shan C, Hong-zhi W et al. The optimized scheme of performance parameters of gradient coils for permanent magnetic open architecture nuclear magnetic resonance system.

Play media Visualization of the T1 and T2 relaxation times. The process of population relaxation refers to nuclear spins that return to thermodynamic equilibrium in the magnet. This process is also called T1 , " spin-lattice " or "longitudinal magnetic" relaxation, where T1 refers to the mean time for an individual nucleus to return to its thermal equilibrium state of the spins. After the nuclear spin population has relaxed, it can be probed again, since it is in the initial, equilibrium mixed state. The precessing nuclei can also fall out of alignment with each other and gradually stop producing a signal. This is called T2 or transverse relaxation. Because of the difference in the actual relaxation mechanisms involved for example, intermolecular versus intramolecular magnetic dipole-dipole interactions , T1 is usually except in rare cases longer than T2 that is, slower spin-lattice relaxation, for example because of smaller dipole-dipole interaction effects. There is also a smaller but significant contribution to the observed FID shortening from the RF inhomogeneity of the resonant pulse. Thus, a nucleus with a long T2 relaxation time gives rise to a very sharp NMR peak in the FT-NMR spectrum for a very homogeneous "well-shimmed" static magnetic field, whereas nuclei with shorter T2 values give rise to broad FT-NMR peaks even when the magnet is shimmed well. Both T1 and T2 depend on the rate of molecular motions as well as the gyromagnetic ratios of both the resonating and their strongly interacting, next-neighbor nuclei that are not at resonance. A Hahn echo decay experiment can be used to measure the dephasing time, as shown in the animation below. The size of the echo is recorded for different spacings of the two pulses. In simple cases, an exponential decay is measured which is described by the T2 time. Peak splittings due to J- or dipolar couplings between nuclei are also useful. NMR spectroscopy can provide detailed and quantitative information on the functional groups, topology, dynamics and three-dimensional structure of molecules in solution and the solid state. Since the area under an NMR peak is usually proportional to the number of spins involved, peak integrals can be used to determine composition quantitatively. Additional structural and chemical information may be obtained by performing double-quantum NMR experiments for pairs of spins or quadrupolar nuclei such as 2. Furthermore, nuclear magnetic resonance is one of the techniques that has been used to design quantum automata, and also build elementary quantum computers. Although NMR spectra could be, and have been, obtained using a fixed constant magnetic field and sweeping the frequency of the oscillating magnetic field, it was more convenient to use a fixed frequency source and vary the current and hence magnetic field in an electromagnet to observe the resonant absorption signals. This is the origin of the counterintuitive, but still common, "high field" and "low field" terminology for low frequency and high frequency regions, respectively, of the NMR spectrum. One radio coil operated continuously, sweeping through a range of frequencies, while another orthogonal coil, designed not to receive radiation from the transmitter, received signals from nuclei that reoriented in solution. Since the NMR signal is intrinsically weak, the observed spectrum suffers from a poor signal-to-noise ratio. This can be mitigated by signal averaging, i. While the NMR signal is the same in each scan and so adds linearly, the random noise adds more slowly â€” proportional to the square root of the number of spectra see random walk. Hence the overall signal-to-noise ratio increases as the square-root of the number of spectra measured. Early attempts to acquire the NMR spectrum more efficiently than simple CW methods involved illuminating the target simultaneously with more than one frequency. A revolution in NMR occurred when short radio-frequency pulses began to be used, with a frequency centered at the middle of the NMR spectrum. In simple terms, a short pulse of a given "carrier" frequency "contains" a range of frequencies centered about the carrier frequency , with the range of excitation bandwidth being inversely proportional to the pulse duration, i. Applying such a pulse to a set of nuclear spins simultaneously excites all the single-quantum NMR transitions. In terms of the net magnetization vector, this corresponds to tilting the magnetization vector away from its equilibrium position aligned along the external magnetic field. The out-of-equilibrium magnetization vector then precesses about the external magnetic field vector at the NMR frequency of the spins. This

oscillating magnetization vector induces a voltage in a nearby pickup coil, creating an electrical signal oscillating at the NMR frequency. This signal is known as the free induction decay.

Chapter 7 : An Introduction to Mobile C-Arm X-Ray Systems | Imaging Technology News

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