Lec4_ Medical imaging-part3

Ultrasound imaging

Working principle

Ultrasound imaging device depends on the principle of sending ultrasound waves with a frequency (1-20 MHz) to any area of the body by placing the ultrasound probe on the skin in a professional manner. Some ultrasound beams penetrate the body and are converted into heat, which is absorbed by the body. The reflected beams are detected by a transducer that converts ultrasound waves into an electrical signal and then translates the reflected signal into an image. There are several types of these sensors including curved and linear sensors. The linear probes operate at a high frequency (7-20MHz) which is suitable for imaging the surface areas of the body. Low frequency (<7MHz) curved surface probes are used to image deep areas of the body.

As for the ultrasound modes, there are three scanning modes for the ultrasound machine: Mode A, Mode B, and Mode M.

Mode A (Amplitude Mode) is related to the width of the ultrasound signal amplitude, while Mode B (Brightness Mode) is where the ultrasound echoes are as bright points to illustrate the 2D ultrasound image. As for the M mode, which is the movement mode, which is used to analyze moving body parts such as heart disease. But the most common ultrasound mode in imaging is B mode because it transmits ultrasound echoes as bright points and then converted into a 2D image.

The change in the angles of the ultrasound beam when holding the probe and imaging makes a big difference in the resolution of the image, for example, ultrasound images can be brighter than other images if the ultrasound beam is perpendicular to the tendon. Therefore, holding the probe incorrectly and not applying enough pressure during scanning will result in inaccurate information. If the angle between the probe and the skin is not perpendicular, then we will get an uncontracting image. This type of imaging depends on the direction and occurs commonly, as this technique can be used in muscle tendon imaging due to the nature of the tendon, which contains multiple linear and parallel interfaces 1]. However, in order to obtain a better image, a linear probe is often used to ensure that an orthogonal position is obtained on the surface of the object.

The philosophy of ultrasound technology is somewhat different from other techniques because it is directly related to the expertise of the technician or the specialist doctor working on the device. It is possible that we do not get the same imaging accuracy when scanning the area of the body for the same user of the device or what for different users and this may be due to a difference due to the different views of measuring the same scanning area between different experts. The same expert can give a different perspective when scanning the same area at a different time. However, it is possible to avoid this discrepancy in results and to obtain acceptable agreement on viewpoints by intensifying practice on imaging protocols and gaining more experience.

Acoustic impedance varies from tissue to tissue, which in turn affects the amount of ultrasound echo, which is reflected from tissues depending on the density, for example, the acoustic impedance of bone is greater than muscle.

Thus, user experience is the key to getting an accurate picture and avoiding some of the expected errors.

Figure (7) below represents an ultrasound device.

Ultrasound development challenges

Ultrasound imaging has become the most popular imaging method ever because the patient does not need to be exposed to X-ray radiation or pass through a magnetic field. Moreover, the device has other facilities related to low cost, efficiency and ease of transporting and carrying the device. Ultrasound imaging device can be used in two cases. The first case is static imaging (the sensor and the body is stationary) such as the two-dimensional image (single image and panoramic images) and the second case is dynamic imaging (either the sensor is moving or the object is in motion) such as the video clip. Where the case is selected according to the patient's need and the doctor for that.

The panoramic image has added a new development in ultrasound imaging applications where we can present several image clips in one image, it is something like a puzzle game where several clips can be combined to get the final image. That is, the panoramic image is one of the methods of photography that reflects an integrated reality in one image by compiling one view after another to show the full details in the same image. The technique of panoramic medical imaging is very similar to the technique of tomography in describing the cross-section.

Although the flexibility and ease of ultrasound imaging has attracted more patients and clinicians compared to other medical imaging devices, it still has some challenges. Some of them have been addressed and others are still being investigated. In addition, ultrasound imaging does not show any tangible risks except for a small thermal effect during imaging.

Finally, the calibration process is necessary in an ultrasound machine because the data is not the same in all ultrasound machines; Where equations and mapping are designed to apply calibration between ultrasound imaging devices in the event that imaging is done in one device and the patient is transferred to receive the examination from another device.

Magnetic Resonance Imaging (MRI)

Working Principle

Many researchers have been interested in introducing magnetic resonance imaging technology in their research to develop and update the technology of this device. The initial idea of the device was presented in 1971 where it was applied to mice to detect tumors in 1974. A full-body vision examination was performed in 1980. The three-dimensional MRI became 3D in 1981, but it took a lot of time to complete the scanning and imaging process. Subsequently, the work of the 3D MRI was updated using parallel imaging, as it is possible to use it more flexibly than before. Then it was applied to imaging the human musculoskeletal system in 1986. Where the knee joint was photographed. The researchers focused on developing an MRI technology to produce a higher-resolution image compared to the previous image. In the same year, the first article was published on the possibility of imaging the upper extremities (hand and wrist), by passing a patient through a high-strength magnetic field of 1.5 Tesla.

This technology relies on the magnetic field and radio waves. The use of the magnetic resonance imaging device has made a quantum leap in the field of medical imaging. There are five main components of an MRI. First, a magnet that produces a constant magnetic field; The second component is the changing magnetic field, and the third component is the radio frequency generator. The resonance occurs when the radiofrequency corresponds to the frequency of the specific area of the imaging. Finally, the fourth and fifth parts are the receiver and computer system, respectively. The basic principle of the magnetic resonance imaging device stems from the idea of hydrogen protons polarizing water molecules; This means that the protons are arranged in parallel and antiparallel alignment under the influence of the magnetic field. Thus, the quality of the resulting image depends on the amount of water molecules in the body. At resonance, the protons are excited to store energy by moving them into reverse alignment rather than parallel alignment. In the relaxation phase, there are two main factors for expressing time: the time required for the proton to return to its previous position (T1) and the time of the echo signal (T2), which have a significant effect on the contrast of the image. Proton density (PD) is another contrast factor that has an impact on image quality, and also has a clear imprint on image contrast. The PD value varies based on the area of the body to be imaged. In addition, the choice of slice thickness is critical because it affects image quality and clarity, see Figure (8).

Challenges of developing magnetic resonance

One of the limitations of using the MRI device is the inability of the magnetic resonance imaging device to scan dynamically, meaning that it is difficult to image with movement within a specific program or protocol. However, researchers have proposed new ideas and applied an upgraded version of MRI (dynamic MRI) such as kinetic MRI , real-time MRI and cinematic phase-contrast MRI. Although these types of MRIs have been successful, they still suffer from some limitations. As the first type has the ability to detect some pathological conditions and depict what happens during movement, but in a short time. The second type of dynamic MRI is limited to one cycle and cannot cover all imaging cycles. Therefore, in this case, the shooting will have to be repeated several times until the entire process is completed. However, not all patients have the ability to tolerate repetition to reach the desired result.

Another limitation of these types is the low image contrast. However, increasing the strength of the magnetic field can increase the level of contrast, but again, not all patients can tolerate the increase in magnetic fields during the examination. Moreover, they are expensive. In addition, there are other restrictions for patients who have implanted heart substitutes (pacemakers). It is important to pay attention to this fact because of its harmful effect on the patient . The main limitation of using MRI in the musculoskeletal imaging system is that it is time consuming due to redundancy; This may overburden patients; Especially the elderly and the disabled, it is also very expensive. However, automated, programmed techniques can improve MRI images by addressing the contrast problem and overcoming this limitation. This could be an effective step to add this option to the MRI machine.

Functional Magnetic Resonance Imaging

It is one of the advanced medical imaging devices. The fMRI technology was invented in 1990 by a group at Bell Laboratories led by Seiji Ogawa of Japan.

An fMRI machine works by detecting changes in blood oxygenation and blood flow that occur in response to neural activity. When an area of the brain is more active, it consumes more oxygen and to meet this increased demand, blood flow to the active area increases.

fMRI technology can be used to examine the functional anatomy of the brain (identify the parts of the brain that deal with critical functions), assess the effects of stroke or other diseases, or to guide brain therapy. Functional MRI may reveal abnormalities within the brain that cannot be found with other imaging techniques.

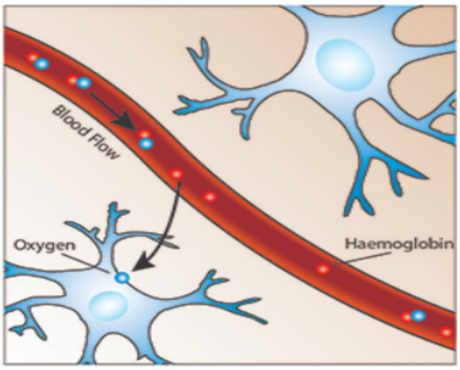
The basic principles of the atomic physics of MRI and fMRI scans are similar, but the MRI shows by imaging the anatomy of the brain, while the fMRI technique shows us the metabolism of an image of the brain.

The most important feature of the fMRI machine is that it does not use radiation such as X-rays, computerized tomography (CT) and positron emission tomography (PET). And if done correctly, an fMRI has almost no risks. Where we can evaluate brain function safely, non-invasively and effectively.

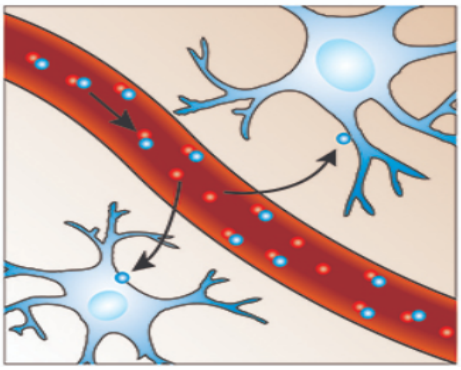
Oxygen is delivered to nerve cells by hemoglobin in capillary red blood cells. When neuronal activity increases, there is an increased demand for oxygen and the local response is to increase blood flow to areas of increased neuronal activity.

Where hemoglobin is non-magnetic when oxygenated but magnetic when the oxygen is removed. This difference in magnetic properties results in slight differences in the blood's MRI signal depending on the degree of oxygenation. Because blood oxygenation varies with different levels of neural activity, these differences can be used to detect brain activity. This type of MRI is known as a blood oxygen level-dependent (BOLD) scan.

One point to note is the direction of oxygen change with increasing activity. You might expect low blood oxygen with activation, but the reality is more complicated. There is a temporary decrease in blood oxygenation immediately after the increase in neural activity, known as an "initial decrease" in the hemodynamic response. This is followed by a period in which blood flow increases, not only to the level at which the demand for oxygen is being met, but to compensate for the increased demand. This means that blood oxygenation is already increased after nerve activation. Blood flow peaks after about 6 seconds and then returns to baseline Look at Figure (9), which shows the difference in blood flow and neuronal activity, and Figure (10), which represents the monitoring of disease progression in the brain.



The blood vessel inside the brain is



Active blood vessels in the brain

Figure (9), an illustration of the activity of blood vessels inside the brain depending on oxygen

The image shown below is the result of the simplest type of fMRI experiment.

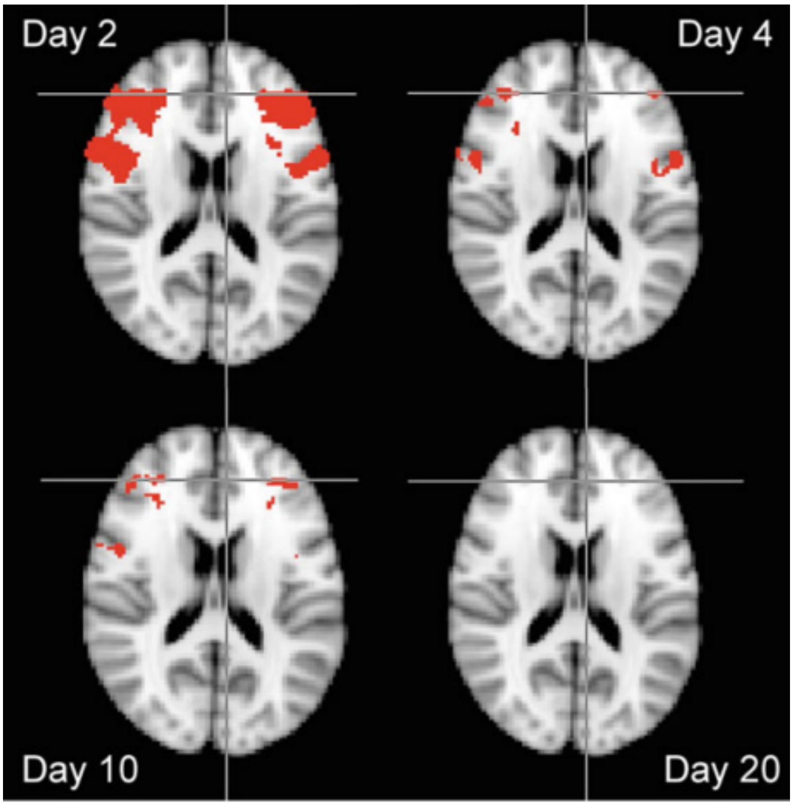


Figure (10), shows the monitoring of activity in a section of the brain after two, four, ten and twenty days.