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MRI (MAGNETIC RESONANCE IMAGING): THE INTERFACE BETWEEN NEUROIMAGING AND BRAIN MAPPING IN COGNITIVE PSYCHOLOGY IN MEDICAL DIAGNOSIS

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ABSTRACT

Magnetic resonance imaging (MRI) is a medical imaging technique that uses a magnetic field and computer-generated radio waves to create detailed images of the organs and tissues in your body. Most MRI machines are large, tube-shaped magnets. When you lie inside an MRI machine, the magnetic field temporarily realigns water molecules in your body. Radio waves cause these aligned atoms to produce faint signals, which are used to create cross-sectional MRI images — like slices in a loaf of bread. The MRI machine can also produce 3D images that can be viewed from different angles.

KEYWORDS: Neuroimaging, Radiology, Cognition, Scanner.

INTRODUCTION

MRI or magnetic resonance imaging is a radiology techinque scan that uses magnetism, radio waves, and a computer to produce images of body structures. The MRI scanner is a tube surrounded by a giant circular magnet. The patient is placed on a moveable bed that is inserted into the magnet. The magnet creates a strong magnetic field that aligns the protons of hydrogen atoms, which are then exposed to a beam of radio waves. This spins the various protons of the body, and they produce a faint signal that is detected by the receiver portion of the MRI scanner. A computer processes the receiver information, which produces an image.[1-8]

MRI image and resolution are quite detailed, and it can detect tiny changes of structures within the body. For some procedures, contrast agents, such as gadolinium, are used to increase the accuracy of the images.

HOW DOES MRI WORKS? MRIs employ powerful magnets which produce a strong magnetic field that forces protons in the body to align with that field. When a radiofrequency current is then pulsed through the patient, the protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field. When the radiofrequency field is turned off, the MRI sensors are able to detect the energy released as the protons realign with the magnetic field. The time it takes for the protons to realign with the magnetic field, as well as the amount of energy released, changes depending on the environment and the chemical nature of the molecules. Physicians are able to tell the difference between various types of tissues based on these magnetic properties.[9-14]

HOW DO X-RAYS WORK?

To obtain an MRI image, a patient is placed inside a large magnet and must remain very still during the imaging process in order not to blur the image. Contrast agents (often containing the element Gadolinium) may be given to a patient intravenously before or during the MRI to increase the speed at which protons realign with the magnetic field. The faster the protons realign, the brighter the image.[15-18]

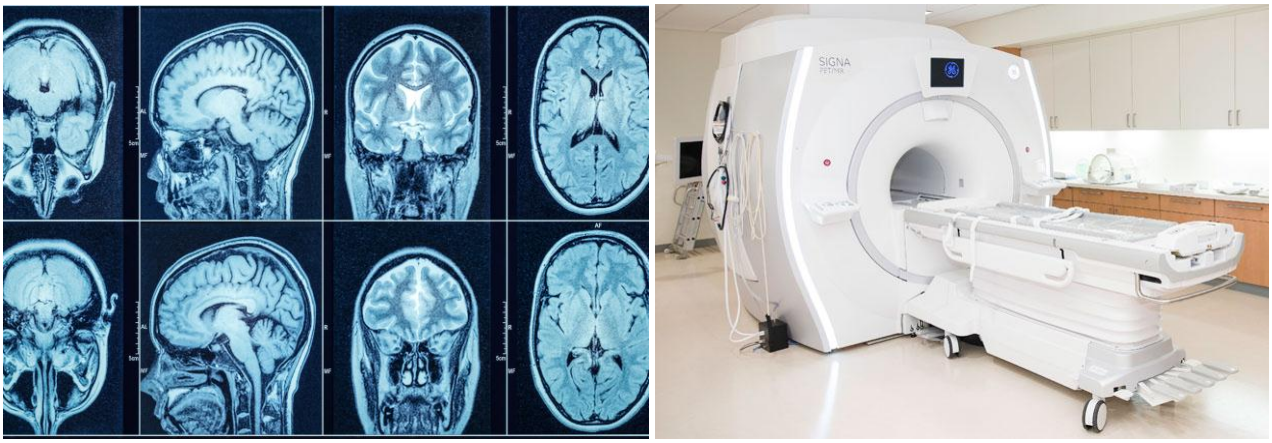

Figure-1: Magnetic Resonance Imaging.

WHAT ARE THE USES FOR MRI? An MRI scan can be used as an extremely accurate method of disease detection throughout the body and is most often used after the other testing fails to provide sufficient information to confirm a patient's diagnosis. In the head, trauma to the brain can be seen as bleeding or swelling. Other abnormalities often found include brain aneurysms, stroke, tumors of the brain, as well as tumors or inflammation of the spine.[19-22]

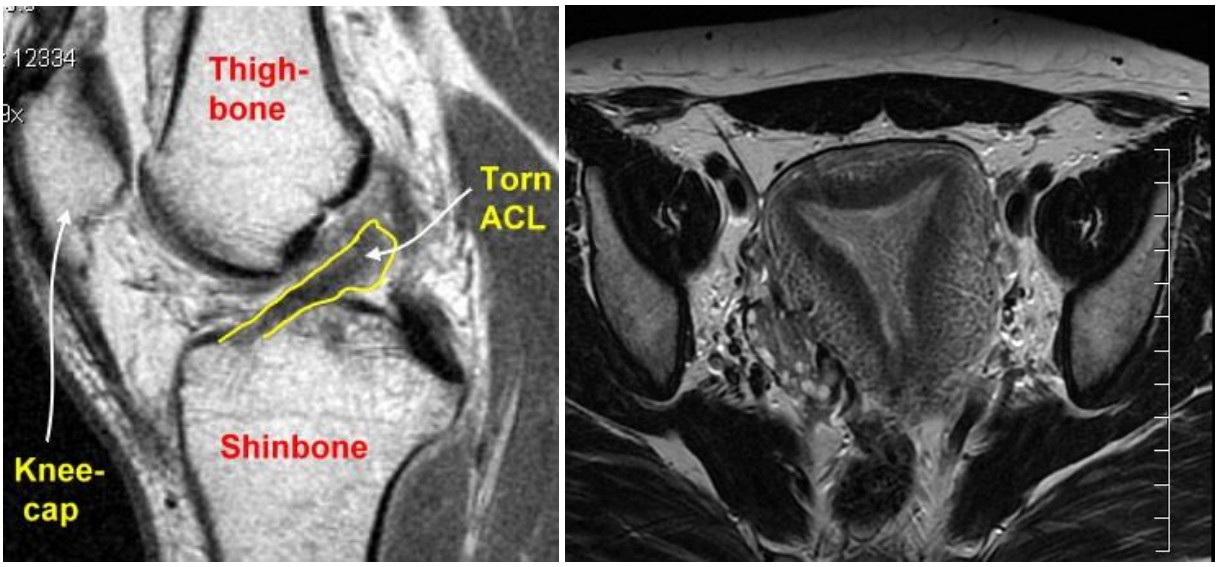

Figure-2: MRI of knee & pelvis.

Neurosurgeons use an MRI scan not only in defining brain anatomy, but also in evaluating the integrity of the spinal cord after trauma. It is also used when considering problems associated with the vertebrae or intervertebral discs of the spine. An MRI scan can evaluate the structure of the heart and aorta, where it can detect aneurysms or tears. MRI scans are not the first line of imaging test for these issues or in cases of trauma.

It provides valuable information on glands and organs within the abdomen, and accurate information about the structure of the joints, soft tissues, and bones of the body. Often, surgery can be deferred or more accurately directed after knowing the results of an MRI scan.[23,24]

WHAT ARE THE RISKS AND SIDE EFFECS OF AN MRI? An MRI scan is a painless radiology technique that has the advantage of avoiding x-ray radiation exposure. There are no known side effects of an MRI scan. The benefits of an MRI scan relate to its precise accuracy in detecting structural abnormalities of the body. Patients who have any metallic materials within the body must notify their physician prior to the examination or inform the MRI staff. Metallic chips, materials, surgical clips, or foreign material (artificial joints, metallic bone plates, or prosthetic devices, etc.) can significantly distort the images obtained by the MRI scanner. Patients who have heart pacemakers, metal implants, or metal chips or clips in or around the eyeballs cannot be scanned with an MRI because of the risk that the magnet may move the metal in these areas. Similarly, patients with artificial heart valves, metallic ear implants, bullet fragments, and chemotherapy or insulin pumps should not have MRI scanning. During the MRI scan, patient lies in a closed area inside the magnetic tube. Some patients can experience a claustrophobic sensation

during the procedure. Therefore, patients with any history of claustrophobia should relate this to the practitioner who is requesting the test, as well as the radiology staff. A mild sedative can be given prior to the MRI scan to help alleviate this feeling. It is customary that the MRI staff will be nearby during MRI scan. Furthermore, there is usually a means of communication with the staff (such as a buzzer held by the patient) which can be used for contact if the patient cannot tolerate the scan.[25]

WHEN DO I RECEIVE THE RESULTS OF AN MRI? After the MRI scanning is completed, the computer generates visual images of the area of the body that was scanned. These images can be transferred to film (hard copy). A radiologist is a doctor who is specially trained to interpret images of the body. The interpretation is transmitted in the form of a report to the practitioner who requested the MRI scan. The doctor can then discuss the results with the patient and/or family**.**[26]

ARE THERE RISKS? Although MRI does not emit the ionizing radiation that is found in x-ray and CT imaging, it does employ a strong magnetic field. The magnetic field extends beyond the machine and exerts very powerful forces on objects of iron, some steels, and other magnetizable objects; it is strong enough to fling a wheelchair across the room. Patients should notify their physicians of any form of medical or implant prior to an MR scan.[27]

When having an MRI scan, the following should be taken into consideration: People with implants, particularly those containing iron, — pacemakers, vagus nerve stimulators, implantable cardioverter-defibrillators, loop recorders, insulin pumps, cochlear implants, deep brain stimulators, and capsules from capsule endoscopy should not enter an MRI machine.

Noise—loud noise commonly referred to as clicking and beeping, as well as sound intensity up to 120 decibels in certain MR scanners, may require special ear protection.[28]

Nerve Stimulation—a twitching sensation sometimes results from the rapidly switched fields in the MRI.

Contrast agents—patients with severe renal failure who require dialysis may risk a rare but serious illness called nephrogenic systemic fibrosis that may be linked to the use of certain gadolinium-containing agents, such as gadodiamide and others. Although a causal link has not been established, current guidelines in the United States recommend that dialysis patients should only receive gadolinium agents when essential, and that dialysis should be performed as soon as possible after the scan to remove the agent from the body promptly.[29]

Pregnancy—while no effects have been demonstrated on the fetus, it is recommended that MRI scans be avoided as a precaution especially in the first trimester of pregnancy when the fetus' organs are being formed and contrast agents, if used, could enter the fetal bloodstream.[30]

Claustrophobia—people with even mild claustrophobia may find it difficult to tolerate long scan times inside the machine. Familiarization with the machine and process, as well as visualization techniques, sedation, and anesthesia provide patients with mechanisms to overcome their discomfort. Additional coping mechanisms include listening to music or watching a video or movie, closing or covering the eyes, and holding a panic button. The open MRI is a machine that is open on the sides rather than a tube closed at one end, so it does not fully surround the patient. It was developed to accommodate the needs of patients who are uncomfortable with the narrow tunnel and noises of the traditional MRI and for patients whose size or weight make the traditional MRI impractical. Newer open MRI technology provides high quality images for many but not all types of examinations.

WHAT NEW MRI SCANNERS AVAILABLE? Scientists are developing newer MRI scanners that are smaller, portable devices. These new scanners apparently can be most useful in detecting infections and tumors of the soft tissues of the hands, feet, elbows, and knees. The application of these scanners to medical practice is now being tested.[31]

Figure-3: MRI of Cervical spine.

NEW MRI JUST FOR KIDS: MRI is potentially one of the best imaging modalities for children since unlike CT, it does not have any ionizing radiation that could potentially be harmful. However, one of the most difficult challenges that MRI technicians face is obtaining a clear image, especially when the patient is a child or has some kind of ailment that prevents them from staying still for extended periods of time. As a result, many young children require anesthesia, which increases the health risk for the patient. NIBIB is funding research that is attempting to develop a robust pediatric body MRI. By creating a pediatric coil made specifically for smaller bodies, the image can be rendered more clearly and quickly and will demand less MR operator skill. This will make MRIs cheaper, safer, and more available to children. The faster imaging and motion compensation could also potentially benefit adult patients as well.[32]

Another NIBIB-funded researcher is trying to solve this problem from a different angle. He is developing a motion correction system that could greatly improve image quality for MR exams. Researchers are developing an optical tracking system that would be able to match and adapt the MRI pulses to changes in the patient's pose in real time. This improvement could reduce cost (since less repeat MR exams will have to take place due to poor quality) as well as make MRI a viable option for many patients who are unable to remain still for the exam and reduce the amount of anesthesia used for MR exams**.**[33]

DETERMINING THE AGGRESSIVENESS OF A TUMOR: Traditional MRI, unlike PET or SPECT, cannot measure metabolic rates. However, researchers funded by NIBIB have discovered a way to inject specialized compounds (hyperpolarized carbon 13) into prostate cancer patients to measure the metabolic rate of a tumor. This information can provide a fast and accurate picture of the tumor's aggressiveness. Monitoring disease progression can improve risk prediction, which is critical for prostate cancer patients who often adopt a wait and watch approach**.**

CONCLUSION

In the general population of persons 45 to 97 years old, we found a high prevalence of potentially clinically relevant incidental brain abnormalities, including subclinical vascular pathologic changes. The prevalence of asymptomatic brain infarcts and meningiomas increased with age, as did the volume of white-matter lesions, whereas aneurysms showed no age-related increase in prevalence. A major strength of our study is the large sample of persons 45 years of age or older. The MRI protocol was uniform for all subjects, and the reviewers were unaware of characteristics of the subjects, making detection bias unlikely. We used high-resolution, state-of-the-art imaging sequences representing the advanced imaging techniques that are increasingly used in brain research. A potential limitation with respect to the generalizability of our study results is the fairly homogeneous composition of our geographically defined study population, which consisted mainly of white, middle-class persons. Our results may not be generalizable to populations that include other ethnic or socioeconomic groups. Another potential limitation of our study is that not all scans were read by neuroradiologists. However, all scans with abnormalities detected on initial review were reviewed again by two neuroradiologists. In addition, a randomly chosen subgroup of all scans was reviewed by two neuroradiologists, who did not detect any incidental findings missed on initial review. Therefore, our initial review by physicians who were not neuroradiologists had a very high sensitivity for the detection of brain abnormalities, and we do not think the results would have been different if the scans had been read primarily by neuroradiologists. The sensitivity may be lower when scans are read by professionals who are not medically qualified, as is reportedly the case in many research centers in the United States. The incidental brain findings in our study were all diagnosed on the basis of imaging. Pathological confirmation of presumed brain tumors was not obtained, since none of these tumors required surgery after referral of the subject. We did not use contrast-enhanced MRI. Because our study population consisted of volunteers without neurologic symptoms who were participating in a research study, the risks associated with the administration of contrast material were not considered warranted. However, the effect of the absence of contrast material, if any, would have been to leave some small lesions undetected, which would have resulted in an underestimate of the prevalence of incidental findings. The prevalence of subclinical vascular pathologic changes in our population was high and increased with advancing age. This finding was not unexpected, since age-related changes, such as asymptomatic brain infarcts and white-matter lesions, have been reported to be very frequent in the general elderly population. Although such changes have been shown to be associated with increased risks of stroke and cognitive decline, preventive therapies for patients with these MRI findings have not been evaluated in randomized trials.

The prevalence of incidental brain findings other than subclinical vascular pathologic changes in our population was much higher than that reported in previous studies, even when the subjects were of similar age to the patients in our study.1 We found an especially high prevalence of small aneurysms. This difference can partly be explained by differences among study populations, since aneurysms are very infrequent in children and young adults. However, the population-based study by Yue et al. showed aneurysms in only 0.11% of persons 65 years of age or older. We feel that a more likely explanation for the difference is that our scanning protocol, especially the high-resolution, proton-density–weighted sequence, permitted very good visualization of the circle of Willis as compared with conventional T1-weighted and T2-weighted sequences.

Of course, the use of even more sensitive sequences, such as magnetic resonance angiography, might have resulted in the detection of even smaller aneurysms. However, in a systematic review of autopsy and angiographic studies, Rinkel et al. concluded that aneurysms can be found in approximately 2% of adults without risk factors for subarachnoid hemorrhage, 33 a proportion very close to the 1.8% detected by MRI in our study.

Meningiomas and small aneurysms were highly prevalent in our study population of persons 45 years of age or older. The rate of growth of meningiomas is typically slow, and most meningiomas remain asymptomatic throughout life, which explains why 50% of all meningiomas are discovered at autopsy. The prevalence of meningiomas found at autopsy in persons over 60 years of age is 3%, and the majority of the lesions are less than 1 cm in diameter. Nevertheless, it is generally believed that asymptomatic meningiomas require close clinical and radiologic follow-up to rule out rapidly enlarging tumors. The current practice of many clinicians is to perform MRI yearly for at least 2 to 3 years to ascertain that rapid tumor growth does not occur. If this were done for all persons incidentally found to have meningiomas, many MRI examinations would be performed in otherwise healthy asymptomatic persons. In view of the resulting medical costs, as well as the psychological burden for those undergoing examination, it would be of great interest to review these guidelines on the basis of the natural course of meningiomas incidentally found on brain MRI.

Guidelines for the management of small aneurysms might also be reviewed. More than 90% of unruptured, asymptomatic aneurysms found by means of autopsy or angiography are less than 10 mm in diameter. In our study, all but three aneurysms were smaller than 7 mm, and all but two were located in the anterior circulation. The reported risk of rupture for aneurysms of this size in the anterior circulation over a period of 4 years is 0%.40 This finding was based on follow-up of a group of patients who had no history of subarachnoid hemorrhage. However, in this group there was an overrepresentation of persons with a family history of aneurysm and of persons with symptoms that had led to the detection of the unruptured aneurysm. The risk of rupture associated with asymptomatic aneurysms in the general population would be expected to be even lower than the reported risk in the described patient population.33 Preventive surgery or treatment of risk factors may thus not be indicated in the general population, and the benefit of longer follow-up has not yet been proven. Therefore, persons in our study with aneurysms of the anterior circulation that were under 7 mm in diameter were not referred for follow-up or medical treatment.

Several large, population-based MRI studies in the elderly are ongoing, and more will be conducted because of the increasing scientific interest in age-related brain diseases such as dementia. Moreover, imaging at higher MRI field strengths and with increased resolution, as well as the use of new MRI sequences that are more sensitive to subtle structural changes, will probably increase the number of small brain abnormalities detected. Incidental findings from brain MRI in middle-aged and elderly persons will therefore become an important issue that should be considered in designing studies. The present study, as well as some previous studies, provides information on the prevalence of clinically asymptomatic brain abnormalities. This information is especially important in view of the ethical and practical issues involved in the management of incidental findings. In conclusion, incidental findings on brain MRI in the general population are common. The most frequent findings are brain infarcts, followed by cerebral aneurysms and benign primary tumors. Such findings should be anticipated in the design of research protocols and the use of neuroimaging in clinical practice. Information on the natural course and prognosis of these lesions is needed to inform clinical management.

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