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Magnetic Resonance Imaging (MRI) Safety in Pregnant (A Literature Review)

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ABSTRACT– Radiation is energy emitted by particles or photons (waves), classified as non-ionized and ionized. Ionizing radiation exhibits the ability to destroy matter along its path and has been shown to be helpful in medicine. Medical imaging commonly used in pregnancy is ultrasound (USG) and Magnetic Resonance Imaging (MRI). MRI is one of the modalities in medical imaging that utilizes a magnetic field. The use of MRI during pregnancy is on the rise, because it has the ability to produce clear images of cross-sectional anatomy without ionizing radiation. Until now, no research has shown the dangers of using MRI for pregnancy. So that through this literature study, it is hoped that the reader will be able to understand the available evidence regarding the safety of MRI during pregnancy. This literature study was carried out by the authors by collecting information or studies from previous researchers regarding the safety of using MRI in pregnancy and its effects on the fetus. In addition, the author also attaches some evidence stating that the use of MRI can be said to be safe for pregnancy because it does not use ionizing radiation, so there are minimal side effects.

KEYWORDS : MRI; ultrasound; non-ionizing radiation; the safety of MRI in pregnancy

INTRODUCTION

Radiation is energy emitted by particles or photons (waves), which are classified as non-ionized and ionized. Ionizing radiation exhibits the ability to destroy matter along its path and has been shown to be useful in medicine. In addition to its benefits, ionizing radiation has negative effects, one of which can damage tissues and trigger cancer and damage to the fetus. At this time the medical imaging modality of non-ionizing radiation is experiencing very rapid development. Magnetic resonance imaging (MRI) is one of the most advanced modalities commonly used in clinical diagnosis. MRI utilizes the magnetic properties of the constituent hydrogen atoms of water within tissue cells to produce images that can be used for both anatomical and functional evaluation (Bahado-Singh and Goncalves 2013). MRI can produce recordings of cross-sectional images of the body by utilizing magnetic fields with strengths between 0.064 - 1.5 Tesla and resonant vibrations of hydrogen atomic nuclei (Bradley and Stark 1988). MRI has proven to be an effective imaging technique for nongynecologic conditions, such as acute abdomen in pregnant patients. The use of MRI in the United States has increased significantly over the past decade. The number of scans per population almost quadrupled from 1996 to 2016 (OECD 2018). At the time of the introduction of this diagnostic tool, there were many concerns about the safety and effects of the different types of magnetic fields used on body tissues (Alorainy *et al.* 2006).

Ultrasonography (USG) and MRI are modalities often used for imaging in pregnant women as they do not use ionizing radiation (Lum and Tsiouris 2020). Fetal MRI should only be performed after a high-quality fetal Ultrasonography has been obtained and after the images from the study have been reviewed. This recommendation is based on the fact that Ultrasonography and MRI are complementary imaging modalities, with MRI being used as a further troubleshooting tool. Therefore, the medical officer that interpreting MRI should be knowledgeable about the history of ultrasonography (Bahado-Singh and Goncalves 2013).

For many years, Ultrasonography has been the only study for fetal imaging. To date Ultrasonography remains the primary modality used in prenatal imaging due to its availability, safety and low cost. MRI continues to be a powerful adjunct to Ultrasonography in the imaging evaluation of many clinical problems in pregnant women for both maternal and fetal indications. MRI has been shown to be an effective imaging technique for nongynecologic conditions, such as acute abdomen, in pregnant patients (Chartier et al. 2019). Overall, the use of MRI during pregnancy is increasing due to the non-use of ionizing radiation, increased availability, and advances in fetal MRI, which has continued to develop since 1980 (Kwan *et al.* 2019),(Chapman *et al.* 2018). The advantage of MRI imaging is that it can produce clear and more sensitive images to assess the anatomy of body tissues.

Ultrasonography

Ultrasonography is the first and often the only modality required in fetal evaluation. With Ultrasonography, it is possible to confirm the number and location of pregnancies early in gestation, evaluate and diagnose fetal and placental abnormalities, assess fetal health and provide guidance during invasive procedures. Ultrasonography has real time capabilities and is considered safe as it does not use ionizing radiation(Reddy *et al.* 2008). Ultrasonography can also be used to detect internal organs such as muscles, organ structures and pathological abnormalities of a tissue through a transducer. This transducer will emit and capture sound waves from the surface of the patient's skin and convert them into electrical energy. Usually, the transducer will be coated with a special gel so that there is no interference from the air between the transducer and the patient's skin which will affect the image quality.

However, Ultrasonography is highly dependent on the skill and experience of the sonographer, resulting in significantly different performance levels, with abnormality detection rates varying from 13% to 82%. Even in experienced hands, diagnosing subtle cortical brain anomalies, extra-intracranial axial collections, and lung masses can be difficult with ultra sound. The sensitivity and specificity of Ultrasonography also depend on fetal position, presence of oligohydramnios, degree of ossification, and maternal body habitus (Bulas and Egloff 2013).

Ultrasonography imaging should be performed efficiently and only when clinically indicated to minimize the risk of fetal exposure using the principle of keeping acoustic output levels as low as reasonably achievable (commonly known as ALARA). Ultrasonography involves the use of sound waves and is not a form of ionizing radiation. There have been no documented reports of adverse fetal effects for diagnostic Ultrasonography procedures, including duplex Doppler imaging (Jain 2019).

Magnetic Resonance Imaging (MRI)

MRI has many advantages such as MRI images that produce better soft tissue contrast and multi-visualization of all organs. The wide field of view allows experts to evaluate MRI images. This approach is essential for fetal and postnatal surgical planning, which is especially helpful when the newborn is unstable and cannot tolerate sedation (Bulas and Egloff 2013).

The disadvantages of using MRI are the dangers of pulsed electromagnetic gradient fields that cause biological effects, acoustic noise damage, peripheral nerve stimulation (twitching sensation arising from the process inside the MRI machine), peripheral muscle stimulation, cardiac fibrillation, and magneto phosphenes, miscarriage and heating effects (Houtchens *et al.* 2020). Noise occurs due to the rapid alternation of currents within the gradient coils. This, combined with the presence of a strong magnetic field, generates significant Lorentz forces. These forces make the coil vibrate producing a loud tapping sound. MRI produces loud knocking sounds when the coil is exposed to rapidly oscillating electromagnetic currents (De Wilde *et al.* 2005).

In an analysis including more than 1.4 million births, exposure to MRI during the first trisemester compared to non-exposure was not associated with an increased risk of harm to the fetus or early childhood (Hellwig 2016). The use of Gadolinium Based Contrast Agent (GBCA) in pregnancy has generally been restricted due to observations of Gadolium crossing the placenta which is relevant to the phenomenon of gadolinium deposition. Some of the theoretical risks to the fetus associated with MRI during pregnancy include teratogenic effects of static magnets, radiofrequency energy, and GBCAs. However, to date none of these risks have been shown to result in fetal harm (Lum and Tsiouris 2020).

The safety issue of MRI during pregnancy is not supported by strong evidence. However, at the same time, there is also no evidence of safety and further research in this area is needed to reach a solid conclusion (Gatta *et al.* 2022). It is not easy to ascertain the safety of MRI during pregnancy or otherwise with retrospective or prospective data as there are almost infinite possible combinations of factors affecting risk, such as static magnetic field strength, gradient magnetic field and radiofrequency energy variability, and scan timing (Jabehdar Maralani *et al.* 2022).

Relating to MRI potential hazard indicator during pregnancy, there is a real need for well-established institutional policies controlling the exposure of pregnant patients to magnetic fields. Such policies should provide appropriate medical care for both mother and fetus and avoid exposing the unborn fetus to undue risk. Surveys show that 43%-79% of hospitals write policies on imaging in pregnancy including the use of MRI consent (Jaffe *et al.* 2007, Shamitoff *et al.* 2015, Hansen *et al.* 2017).

RESEARCH METHOD

The research method carried out was a literature study or literature review of previous studies with relevant topics.

RESULTS AND DISCUSSION

Working Principle of MRI

MRI is a non-invasive method of mapping internal structures and certain aspects of function within the body. It uses non-ionizing electromagnetic radiation and poses no exposure-related hazards. It uses radio frequency (RF) radiation in the presence of a carefully controlled magnetic field to produce high-quality cross-sectional images of the body in any plane. MRI images are constructed by placing the patient inside a large magnet, which induces a relatively strong external magnetic field. This causes the nuclei of many atoms in the body, including Hydrogen, to align with the magnetic field. The application of RF signals results in energy being released from the body, detected and used to create MR images by a computer.

Figure 1 illustrates a tool from the Magnetic Resonance Imaging (MRI) machine as medical equipment that is using the principle of utilizing magnetic fields.

Figure 1 The Machine of Magnetic Resonance Imaging (https://www.philips.co.in/healthcare/solutions/magnetic-resonance n.d.)

According to the existing conditions, the basic rule of any Magnetic Resonance Imaging (MRI) work procedure should be safe. The hydrogen atom nucleus in the human body is in a random position, therefore when the person enters an area with a large enough magnet, the position of the hydrogen atom nucleus will become misaligned with the magnet. When getting the right energy, also known as Larmor energy, hydrogen atomic nuclei can move from low energy levels to high energy levels known as Free Induction Decay (FID) or energy leakage.

Figure 2 illustrates the energy levels of an atomic nucleus where the energy level has a Quantum spin number of 3.

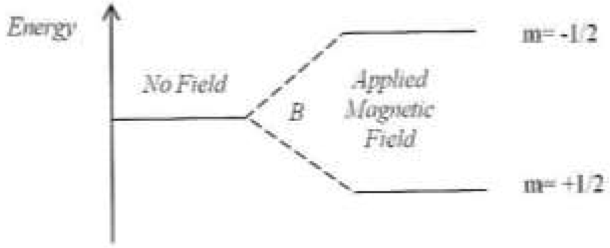

Figure 2 Energy Levels of an Atomic Nucleus with a Quantum Spin Number of 3 (NMR Spectroscopy Working Principle n.d.)

Then, when another hydrogen atom enters the region of a large enough magnetic field, it will exert pressure. This will allow the other hydrogen atoms to detect a signal known as Free Induction Decay (FID) which will be generated in the form of imaging. Figure 3 shows the behavior of the hydrogen atom core.

According to conventional wisdom, the Magnetic Resonance Imaging (MRI) procedure shows that when the patient's tubules are placed in a strong magnet, the fluid inside will start to swell and move in the direction of the

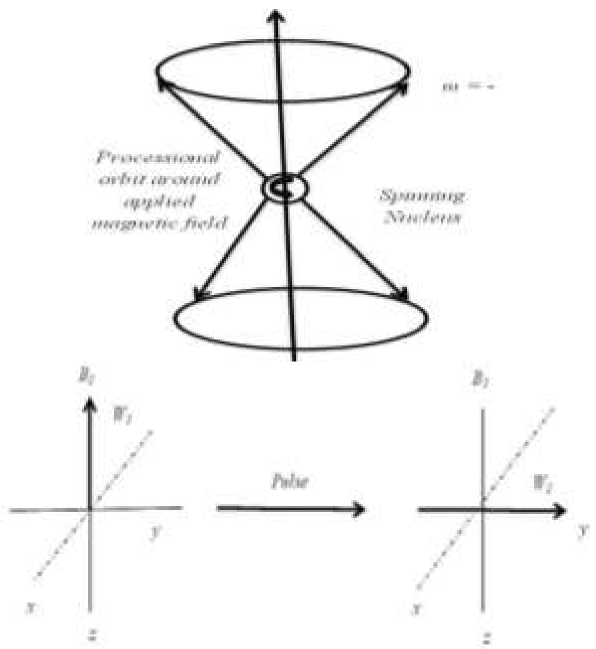

Figure 3 Behavior of the Hydrogen atom (Pauli and Wilson 2022)

arc or vector of the magnet. If a radio signal is received through the tubules, some of the nuclei of the hydrogen atoms will pick up the energy from the radio signal and deflect the beam, or in other words, cause resonance. When the radio signal is activated, the atomic nuclei will return to their original position, using the energy that has been released to amplify the signal captured by the antenna and then transferred to the computer in the form of a radiograph (McMahon *et al.* 2011).

In Figure 4 is a process of the basic computation of a Magnetic Resonance Imaging

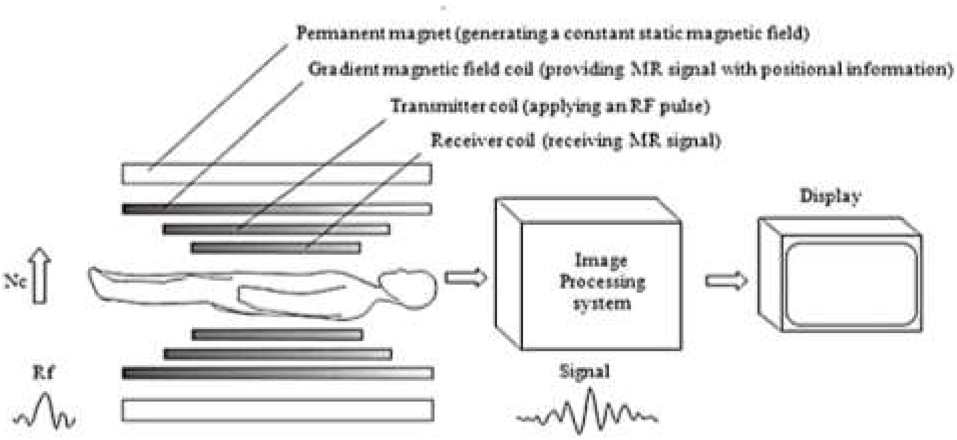

Figure 4 Basic computation of an MRI system (Blink 2004)

(MRI) system. Some of the advantages of MRI such as its capacity to create coronal, sagittal and axial sections without extensively manipulating the patient's body position, make it highly appropriate for diagnosing soft tissues. Anatomical pathologies and body tissues can be precisely evaluated thanks to high-quality MRI images. It can provide highly detailed images of human tubules with unmatched comparison.

Components of Ultrasonography

Transducer

The transducer is the main tool of the ultrasonography machine which will be in direct contact with the patient's skin surface. Inside the transducer there is a piezoelectric crystal material that produces the piezoelectric effect (electric pressure) discovered by Pierre and Jacques Curie in 1980. The piezoelectric effect means that if electrical energy is given to the piezoelectric crystal, vibrations will arise that produce sound waves, and vice versa if there are sound waves reflected by the organ, they will be captured by this effect and converted into electrical signals. Transducers come in many shapes and sizes such as:

1. Linear array transducer
   This transducer has a frequency between 5-10 MHz which is used to examine superficial structures.
2. Curved array transducer
   This type of transducer has a frequency of 2-5 MHz and has a convex surface.
3. Phased array transducer

This transducer has a frequency of 1-5 MHz and is used to examine deeper structures, is shown in Figure 5 (Mathis 2008, Gardelli *et al.* 2012)

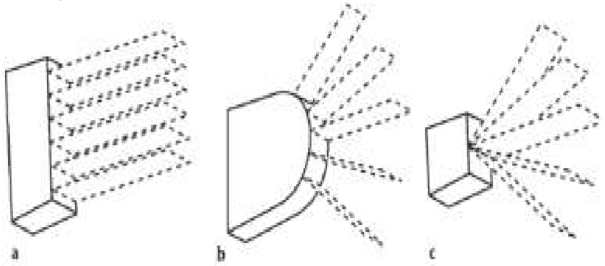

Figure 5. Types of transducers (a) linear array transducer, (b) curved array transducer, (c) phased array transducer (Eurle B 2004)

Monitor

A monitor is a kind of screen that displays images generated by computer processing. The Ultrasonography monitor was still a tube screen separate from the Ultrasonography device at the time of its invention. The Ultrasonography monitor became one with the Ultrasonography device as technology progressed, and the monitor was already in color.

Ultrasonography machine

The ultrasonography machine device is illustrated by Figure 6 helps on the processing of waveforms from previously received data. The same components are found in an Ultrasonography machine as in a computer CPU. The transducer sends an audio signal to the ultrasonic device, which is converted into an electrical signal and sent to the machine. The computer then converts the electrical signals into image data and reconstructs the results on the screen.

Figure 6. USG Machine (Ultrasonic Sonixtouch 4D Ultrasound Machine n.d.)

Printer

The ultrasonography printer is showed by Figure 7 serves as the output of images generated by computer processing in Ultrasonography. The output of the printer was a Polaroid photo at the time of its invention, but now it is a thermal film according to current technological advances.

Currently, there are two types of printers: color printers and black and white printers.

Figure 7. Printer of USG (Dye Sublimation Printer Sony Inkjet n.d.)

Working Principle of Ultrasonography

The working principle of ultrasonography is shown by Figure 8, starts with an electrical signal generated by a generator converted into acoustic energy by a transducer. The sensor radiates in a specific direction depend on which part of the body is being examined. Some of the energy is reflected and processed into an image. The image is then received by the receiver and displayed on the screen.

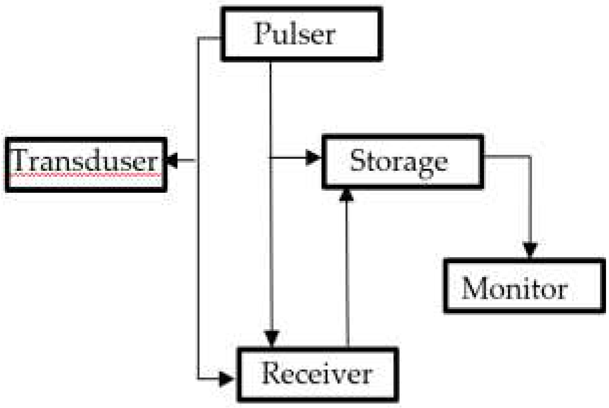

Figure 8. Schematic of Ultrasound Imaging (Narayanan and Wahidabanu 2009)

In Table 1, Mark Lum and John Tsiouris (Lum and Tsiouris 2020), provide some evidence that MRI is safe for pregnant women.

Table 1 Evidence that MRI is safe for pregnant women

Author	Year	publisher	Country	Purpose	Result/conclusion	pages
Chartier *et al*	2019	American Journal of Roentgenology	America	Evaluate the effects of 3-T MRI during pregnancy on fetal growth and hearing in neonates at low risk of congenital deafness or brain abnormalities.	No difference in hearing loss or birth weight	1-4
Strizek *et al*	2015	Radiological Society of North America (RSNA)	South America	Evaluate the effects of exposure to MRI imaging at 1.5 T during pregnancy on fetal growth and neonatal auditory function in relation to dose and timing of in utero exposure in a group of newborns at low risk for congenital hearing loss or deafness.	No difference in hearing loss or birth weight	7
Ray *et al.* 2016	2016	Journal of the American	America	Evaluate the long-term safety after	There is no difference between	61

		Medical Association (JAMA)		exposure to MRI in the first trisemester of pregnancy or gadolium at any time during pregnancy.	prenatal mortality, congenital abnormalities, vision loss, hearing loss and tumor appearance.	
Bouyssi-Kobar *et al.*	2015	Springer Journal	German y	Assessing the safety of 1.5T fetal MRI by evaluating functional outcomes of preschool children exposed in utero.	No hearing or functional impairment	1823-1830
Reeves *et al.*	2010	Radiological Society of North America (RSNA) Journal	South America	Evaluate the effects of 1.5-T magnetic resonance (MR) imaging surgery noise on the fetus associated with cochlear injury and subsequent hearing loss in neonates.	There is no increased risk of hearing loss	9
Kok *et al.*	2004	Science Direct	Netherla nd	Identify possible side effects of exposure to 1.5 T MRI in utero	No adverse effects caused by MRI for Health 41 children (1-9 years old)	4
Bulas and Egloff	2013	Seminars In Perinatology	USA	Identify the benefits and potential risks of MRI to the fetus	No adverse indications for the use of clinical MRI during pregnancy	4
De Wilde *et al.*	2005	Progress in Biophysics and Molecular Biology	England	Reviewing the risk to the fetus by considering the three components of harm in the MRI system	MRI can provide additional information for fetal central nervous system abnormalities identified by Ultrasonography examination	19
Gatta *et al*	2022	Journal of Personalized Medicine	Italy	Conduct a literature review focusing on the use of contrast and non-contrast of MRI during pregnancy	To date, no negative effects on the fetus have been found following exposure to MRI without a contrast agent	16

					during any trimester of pregnancy.	
Chartier *et al*	2019	Journal AJR	Japan	To evaluate the clinical effects of 3-T MRI during pregnancy on fetal growth and neonatal hearing in neonates with low risk of congenital hearing loss or brain or chromosomal abnormalities	Despite the proposed safety risks of intrauterine growth restriction and hearing loss, 1.5-T MRI studies have not shown any deleterious effects.	4
Jabehdar Maralani *et al*	2022	Canadian Association of Radiologists' Journal	Canada	To provide updated evidence-based recommendations that address the domain energy-related safety, deposition, acoustic noise, and use of gadolinium-based contrast material based on magnetic field strength (1.5T and 3T) and trimester of scanned, in addition to the effects of sedative use and occupational exposure.	No adverse effects from the use of MRI have been reported	12
Jain	2019	ACOG	USA	To determine the safety of the modality for pregnant and lactating women	No acoustic injury to the fetus during prenatal MRI.	7
Alorainy *et al*	2006	Journal Ann Saudi Med	Saudi Arabia	Observing the attitudes of radiology staff in Saudi Arabia towards MRI safety issues during pregnancy	Exposure of pregnant patients carries risks and may benefit the patient and/or fetus, but exposure of pregnant healthcare workers only carries risks to the fetus with no benefits.	4

Mervak *et al.*	2019	Journal of Magnetic Resonance Imaging	USA	Define current safety guidelines and practical considerations when photographing pregnant women using Magnetic Resonance Imaging (MRI) and describe the most common conditions for which MRI may be indicated in pregnant patients.	There is no literature to inform us of the specific fetal consequences of exposure to noncontrast MRI during any trimester.	11
Lum and Tsiouris	2020	Clinical Imaging	USA	To understand the available evidence regarding the safety of MRI during pregnancy where the data found will help radiologists as a valuable resource for patients and referral providers.	With respect to teratogenesis, there are no published studies documenting the harms and risks of MRI use in pregnant women.	7
Bahado-Singh and Goncalv es	2013	Seminars In Perinatology	USA	Determining the role of fetal MRI in functional neuroimaging at higher magnetic field strengths (3 T)	No adverse events have been reported for fetal exposure to MRI.	6

CONCLUSION

Ultrasonography and MRI are the main modalities for imaging in pregnant women. MRI is supiierior because it can produce better cross-sectional anatomical images. After conducting a literature review from various sources and studies from previous researchers, it can be said that MRI is safe to use in pregnant women and has no significant biological effects for both the mother and the fetus. MRI is said to be safe to use because in its working principle, MRI utilizes non-ionizing radiation so that it has minimal side effects.

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