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A comparative study of SAR Distribution in patients undergoing MRI examinations at different field strengths and manufacturers

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Dedication

To the woman who taught me that any dream, no matter how small, is worth fighting for. To my Mother Sabah.

To the man who held my hand in front of tank canons and armed soldiers, and taught me that nothing should stop me from going to school. To my Father Jamil

To the world's best siblings Mai , Mahmoud , Amnah , Ahmad , Ali and Amro .

To my lifetime best-friend, the one who never got tired of listening to my complaints, to my wife Diana .

Thank you, God, my prayer and gratitude to you. You are the one who gave me the power to work hard and continue, despite the obstacles, until I reached this high and great status.

Mohammad Mdallal

Declaration

I certify that this thesis was submitted for the degree of masters. It is the result of my own research, except where otherwise is acknowledged. I also certify that this thesis (or any part of the same) has not been submitted for any other university or institution.

Name: Mohammad Jamil Mahmoud Mdallal

Signed ***Mohammad Mdallal***

Date: 20 /8 /2024

Acknowledgments

Praise be to the Lord of the Worlds, as it should be, for His majesty and authority, may blessings and peace be upon the Seal of all Messengers and Prophets, our Master Muhammad, my God bless him and grant him peace. My great gratitude goes to Dr. Mohammad Hjuj, for patient supervision and guidance.

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List of Abbreviation

SAR: Specific Absorption Rate

MRI: Magnetic Resonance Imaging

T: Tesla

RF: Radiofrequency

TR: repetition time

TE: echo time

SMF: static magnetic field

GMF: gradient magnetic field

SI: standard international

W/KG: watts per kilogram

GHz: Giga hertz

IEC: International Electrotechnical Commission

SNR: signal-to-noise ratio

FDA: Food and Drug Administration

FOV: Field Of View

AP: anteroposterior

RL: Right to Left

FH: Foot to head

ms: millisecond

NSA: Number of signal averages

ST: Slice Thickness

Abstract

This study aims to assess and compare Specific Absorption Rate (SAR) levels, in patients undergoing MRI scans at 1.5 Tesla (1.5T) and 3 Tesla (3T) using Philips MRI systems. Additionally, it includes a comparison between 1.5 Tesla MRI systems from two industry manufacturers, Philips and Siemens. A cross-sectional prospective descriptive design was employed, involving 180 patients who underwent MRI scans at specified field strengths and manufacturer systems. The study was conducted at Al-Rahma Policlinic, Nablus, and Ibn Rushd Radiology Center, Hebron, West Bank, Palestine, from January to May 2024. SAR values were collected from MRI scan records and analyzed using statistical methods, including Mann-Whitney U tests and multiple regression analysis. The results demonstrated that Philips 3T systems exhibit significantly higher SAR values compared to Philips 1.5T systems, confirming that higher magnetic field strengths result in increased RF energy deposition. Additionally, Siemens 1.5T systems showed significantly higher SAR values than Philips 1.5T systems. differences in pulse sequence parameters, such as repetition time (TR), echo time (TE), and the number of slices, significantly affected SAR values, with longer TR and a higher number of slices associated with higher SAR. Lumbar MRI sequences generally exhibited higher SAR values compared to brain sequences. The study underscores the need for careful monitoring and optimization of MRI protocols to minimize SAR values, especially for high-field strength systems and different manufacturers' equipment. Continuous monitoring of SAR values and adherence to regulatory guidelines are essential to ensure patient safety during MRI scans.

Chapter one:

Introduction

1.1 Background

All living organisms are continuously exposed to electromagnetic fields that naturally occur on the surface of the Earth. These fields are typically weak, non-intrusive, non-ionizing, and most people are generally unaware of their presence. Electromagnetic fields are also generated during the production, transmission, and distribution of electricity by human activities. A static magnetic field (SMF) is created during direct flow of an electric current whereas a time- varying gradient magnetic field (GMF) is generated by alternating current supply. Magnetic fields can be described in terms of magnetic flux density, B (measured in tesla or T) or as magnetic field strength, H (measured in amperes per meter or A/m) and, These two quantities are related by the equation B = moH where mo is the permeability in free space. Magnetic flux density is widely regarded as the most pertinent quantity (SI or standard international) used in the evaluation of exposure to magnetic fields(Matthes et al., 2003).

Besides SMF and GMF, non-ionizing electromagnetic radiofrequency fields (RF) are prevalent in our living environment, particularly following the advent of man-made wireless communication devices which transmit voice, data and images. RF exposure is typically quantified or estimated as specific absorption rate (SAR) and expressed in

watts per kilogram (W/kg). International agencies have established safety guidelines to protect both the general public and workers from potential adverse health effects linked to exposure to man-made electromagnetic fields ranging from 0 to 300 GHz.(Vijayalaxmi et al., 2015).

MRI is a non-invasive technique used to map the internal structure and certain functional aspects of the body. It utilizes non-ionizing electromagnetic radiation and is generally considered to be free from exposure-related hazards. It is uses radio frequency (RF) radiation in conjunction with precisely controlled magnetic fields to produce high quality cross-sectional images of the body in any orientation. During an MRI scan, the patient is placed inside a large magnet that generates a strong external magnetic field. This field causes the nuclei of many atoms in the body, particularly hydrogen, to align with the magnetic field. When an RF signal is applied, energy is released from the body, detected, and processed by a computer to create the MR image(Geethanath & Vaughan, 2019).

One of the main safety concerns when performing magnetic resonance imaging (MRI) on biological tissue is the heating that can occur as the tissue absorbs radiofrequency (RF) energy(Baker et al., 2004). specific absorption rate (SAR), as defined by the International Electrotechnical Commission (IEC) standard, is the amount of RF power absorbed per unit mass of an object, measured in watts per kilogram (W/kg). SAR is the current national and international dosimetric term used to characterize the thermogenic effects of this electromagnetic field(Commission, 2015) . It is routinely used as an indirect quantitative measure of RF energy in the safety recommendations for clinical MRI procedures(Baker et al., 2004).

MRI performed at 3.0 T offers several advantages over MRI performed at 1.5 T (Stadlbauer & Prayer, 2011). including a higher signal-to-noise ratio (SNR) and improved spatial resolution as a result of higher field strength However, the increased in magnetic field strength and radiofrequency power at 3.0 T also introduce safety concerns.(Victoria et al., 2016) . Each excitation and refocusing radiofrequency pulse of an MRI sequence deposits energy into the patient being scanned, which is then converted into heat. The rate of energy deposition depends on the amplitude of the radiofrequency pulse When transitioning from 1.5 to 3.0 T while keeping other factors constant, energy deposition can quadruple, potentially leading to unwanted heating (Barrera et al., 2020).

The aim of this study is to Assess and compare SAR levels in patients undergoing MRI scans at 1.5 Tesla (1.5T) and 3 Tesla (3T) using Philips MRI systems. And to provide a comprehensive analysis, this study extends its scope to include a direct comparison between 1.5 Tesla MRI systems from two industry-leading brands, Philips and Siemens.

1.2 Problem Statement

The increasing utilization of Magnetic Resonance Imaging (MRI) in medical diagnostics has raised concerns about the potential risks associated with heat deposition during MRI scans. Variations in magnetic field strength and MRI system brands may influence the degree of heat generated within the human body, thus impacting patient safety and diagnostic accuracy. Despite the clinical significance of this issue, there is a dearth of comprehensive comparative studies that investigate heat deposition during MRI scans, particularly between 1.5 Tesla and 3 Tesla Philips MRI scans. Moreover,

the choice between MRI system brands, such as Philips and Siemens, at the 1.5 Tesla field strength remains underexplored(Chakeres & De Vocht, 2005).

This research aims to address these critical gaps in knowledge by Assessing and comparing SAR levels during MRI scans at different field strengths, with a primary focus on Philips's systems. It also seeks to conduct a dual-brand comparison of 1.5 Tesla MRI systems, evaluating Philips and Siemens models. The outcomes of this study will contribute to enhancing patient safety, optimizing MRI protocols, and informing the selection of MRI systems, ultimately improving the quality and safety of diagnostic imaging in healthcare.

1.3 Justifications

The rationale for this study rests on the fundamental principles of patient safety, technological progress, and empirical evidence. Ensuring the well-being of patients during MRI scans is paramount, and comprehending the intricacies of heat deposition is vital to mitigate potential risks. In an era of evolving MRI technology, understanding safety implications aligns with the pursuit of technological advancement while maintaining a patient-centric focus(E. P. on M. R. Safety: et al., 2013). Moreover, this research aids in developing evidence-based protocols that strike a balance between diagnostic precision and patient comfort, thereby enhancing the overall quality of healthcare delivery. By providing empirical data, it empowers healthcare practitioners with the insights needed for informed decision-making. Additionally, this study contributes to the broader scientific knowledge, guiding future research and fostering ongoing innovation and safety improvements. Its dual-fold comparative approach ensures a comprehensive assessment, addressing differences in field strengths and system brands, thus offering well-rounded insights. Ultimately, this study's outcomes can serve as the foundation for professional guidelines and regulatory standards,

providing clear frameworks for safe MRI practices that safeguard both patients and the integrity of healthcare systems.

1.4 Study Objective

1. The primary objective of this study is to Assess and compare SAR levels in patients undergoing MRI scans at 1.5 Tesla (1.5T) and 3 Tesla (3T) using Philips MRI systems. This assessment aims to delineate the disparities in Specific Absorption Rate (SAR) between these field strengths.
2. To provide a comprehensive analysis, this study extends its scope to include a direct comparison between 1.5 Tesla MRI systems from two industry-leading brands, Philips and Siemens. This secondary objective seeks to evaluate any brand-specific variations in SAR levels at the 1.5 Tesla field strength.
3. Investigate how variations in pulse sequence parameters, such as repetition time (TR), echo time (TE), and flip angle, impact SAR levels. This objective aims to elucidate the role of pulse sequence configuration in heat generation during MRI scans.

1.5 Hypotheses

1.5.1 Primary Hypothesis:

- There is a significant difference in Specific Absorption Rate (SAR) levels in patients undergoing MRI scans using Philips MRI systems at 1.5 and 3 Tesla.

1.5.2 Secondary Hypotheses:

- There is a significant difference in SAR levels between 1.5T MRI systems (Philips and Siemens).
- Variations in pulse sequence parameters (repetition time, echo time, flip angle) significantly affect SAR levels during MRI scans.

1.6 Study Questions

- What are the specific differences in SAR between 1.5T and 3T MRI scans using Philips scan systems ?
- Are there significant differences in SAR levels between Philips and Siemens MRI systems at 1.5T field strength?
- What factors contribute to any observed differences in SAR between 1.5T Philips and Siemens MRI systems?
- How do variations in repetition time (TR), echo time (TE), and flip angle impact heat SAR levels during MRI scans?
- Which pulse sequence parameters have the most significant effect on heat deposition, and how can these be optimized to minimize patient heat deposition?

Chapter Two:

Literature review and theory

2.1 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is a powerful and non-invasive diagnostic technique extensively used to obtain detailed information about the anatomy and function of various organs in the body, both in healthy and diseased states.(Vijayalaxmi et al., 2015). The process involves the interaction of hydrogen nuclei (protons) with a strong magnetic field and radiofrequency (RF) pulses(Westbrook & Talbot, 2018).

MRI scanners consist of a strong magnet that aligns the protons within the body along its magnetic field. When RF pulses are applied, the protons absorb energy and temporarily move out of alignment. As the protons return to their original alignment, they emit signals that are detected by the MRI machine's receiver coils. These signals are then processed to create detailed cross-sectional images of the imaged area(Rinck, 2019).

The quality and characteristics of MRI images are influenced by various parameters, including magnetic field strength, pulse sequences, and image acquisition parameters.

Different tissues within the body exhibit distinct signal intensities, contributing to the high contrast resolution of MRI(Serai et al., 2021).

2.2 Radiofrequency (RF) Energy Deposition

RF energy deposition is a critical aspect of MRI, as it directly influences patient safety during scans. RF pulses are essential for exciting the protons and generating the signals necessary for imaging. However, this process can lead to the deposition of energy in the form of heat within the tissues being imaged(Vijayalaxmi et al., 2015).

The amount of RF energy deposited is influenced by several factors, including the strength and duration of the RF pulses, the specific absorption rate (SAR), and the tissue properties. Higher field strengths and certain imaging sequences may result in increased RF energy deposition, potentially leading to tissue heating(Fiedler et al., 2018).

2.3 Specific Absorption Rate (SAR)

specific absorption rate (SAR), as defined by the International Electrotechnical Commission (IEC) standard, is the amount of RF power absorbed per unit mass of an object, measured in watts per kilogram (W/kg). This term is the prevailing national and international dosimetric term used to describe the thermo- genic aspects of electromagnetic field(Commission, 2015) . SAR is routinely used as an indirect quantitative measure of RF energy in the reporting of safety recommendations for clinical MRI procedures(Baker et al., 2004).

2.3.1 SAR Calculation

Calculating SAR involves complex algorithms that take into account the RF delivered, the patient's body weight, and the distribution of the electromagnetic field within the body. The SAR value is typically displayed by the MRI system during the scan setup and monitoring phases(Buck, 2010).

2.4 Safety Concerns in MRI

Ensuring patient safety is paramount in MRI, and this includes addressing potential risks associated with RF energy deposition. Regulatory bodies, such as the Food and Drug Administration (FDA) and international standards organizations, have established guidelines and safety limits to prevent adverse effects related to tissue heating during MRI scans(Brau et al., 2015).

The specific absorption rate (SAR) is a key metric used to quantify the rate at which RF energy is deposited in tissues. MRI systems are designed to adhere to SAR limits to minimize the risk of excessive heating. The SAR limit for MRI scanners is generally set to a maximum of 4 W/kg for head imaging and 3 W/kg for body imaging, averaged over a 10-minute period(Commission, 1995). Adhering to these limits helps mitigate the risk of excessive heating and ensures patient safety. Understanding and mitigating these safety concerns are crucial for the responsible and safe use of MRI technology in clinical settings(Stafford, 2020).

2.5 Field Strengths in MRI

MRI systems operate at various magnetic field strengths, commonly measured in Tesla (T). High-field MRI, such as 3 Tesla (3T), and low-field MRI, like 1.5 Tesla (1.5T), offer different advantages and challenges. High-field MRI generally provides higher signal-to-noise ratios and improved image resolution but may result in increased RF energy deposition and higher SAR values compared to lower field strengths like 1.5T(Schick et al., 2021; Shellock & Crues, 2004a).

The choice of field strength depends on the clinical application and the specific imaging requirements. Investigating the impact of different field strengths on heat deposition is

crucial for understanding the safety implications associated with varying MRI technologies(Mittendorff et al., 2022).

2.5.1 Comparison of 1.5T and 3T MRI Systems

Studies have shown that 3T MRI systems can result in significantly higher SAR values due to increased RF energy deposition. This necessitates more stringent monitoring and the use of advanced SAR management techniques to ensure patient safety(A. C. R. C. on M. R. Safety: et al., 2020).

2.6 Influence of MRI Sequences on SAR

Different MRI sequences, which are defined by parameters such as repetition time (TR), echo time (TE), and flip angle, can significantly influence SAR values. Sequences that require longer or higher RF pulse levels generally result in higher SAR values(Bernstein et al., 2004).

2.6.1 Common MRI Sequences and Their SAR Implications

T1-Weighted Sequences are typically producing moderate SAR values, T2-Weighted Sequences can produce higher SAR values due to longer RF pulse durations, FLAIR and DWI Sequences are producing higher SAR values, particularly in higher field strength MRI systems(R. W. Brown et al., 2014).

2.7 MRI Scanner Manufacturers

MRI scanners are manufactured by different companies, each offering unique hardware, software, and pulse sequence designs. These variations can influence imaging parameters, scan durations, and overall scan quality(M. A. Brown & Semelka, 2011). The impact of different manufacturers on SAR levels is an important consideration in our study, as it introduces an additional variable that may contribute to the variability in patient safety during MRI scans.

Studies have shown that Philips and Siemens systems can exhibit significant variability in SAR due to differences in coil design, RF pulse shaping, and SAR management algorithms(Collins et al., 1998).

Chapter Three

Methodology

This chapter covered the methodology used to compare heat SAR levels in patients undergoing MRI scans at different field strengths and manufacturers. The research design, data collection, and data analysis are discussed in detail. The study was based on prospective method.

3.1 Research Design

A cross sectional prospective descriptive design was selected for this study, the study employs a quantitative research design to compare the Specific Absorption Rate (SAR) in patients undergoing MRI scans. SAR is used as an indication of heat deposition in patients. The study is comparative, focusing on three groups, Philips 1.5T, Philips 3T, and Siemens 1.5T

3.2 Study Setting

The study was conducted in Al-Rahma policlinic/Nablus and Ibn Rushd radiology center/Hebron at West Bank Palestine. The data were collected prospectively between January 2024 to May 2024.

3.3 Study Population

The study population consists of patients who underwent MRI scans at one of these mri systems. The sample includes 180 patients, divided equally among the three MRI systems. The selection criteria for patients include: Undergoing either brain or lumbar spine MRI, No contraindications for MRI, and Consent to participate in the study.

3.4 Data Collection

Data was collected from MRI scan records and patient demographic information. The key variables collected included:

- MRI image type (Brain or Lumbar Spine)
- Gender
- Age
- Weight
- Type of MRI device (Philips 1.5T, Philips 3T, Siemens 1.5T)
- SAR values for every MRI sequence.
- Parameters that have an effect on SAR, such as repetition time (TR), echo time (TE), and field of view (FOV).

3.5 MRI Protocols

The MRI protocols were standardized as follows for each device:

- Philips 1.5T and 3T: Brain and lumbar spine MRI sequences including T1 SE Axial, T2 TSE Axial, FLAIR, DWI, T2 GRE Axial, STIR And others.
- Siemens 1.5T: T1 SE Axial, T2 TSE Axial, FLAIR, DWI, T2 GRE Axial, SWI And others.

3.6 SAR Evaluation

SAR values were obtained from the MRI systems (output data for each sequence scan). These values were used to calculate the mean SAR for patients and for every sequence. SAR values were analyzed for brain and lumbar spine scans to compare differences in SAR levels between manufacturer and field strengths.

3.7 Statistical Analysis

Data were analyzed using SPSS software. The research used the following statistical methods:

- Descriptive statistics to brief the patient demographics and SAR values.
- Mann-Whitney U test to compare SAR values between MRI systems and sequences.
- Multiple regression analysis to identify predictors of SAR values and develop a predictive SAR equation.

Steps of Analysis:

- Descriptive Analysis:

  Calculation of means, standard deviations, and frequencies for demographic and SAR variables.

- Normality Test:

  Kolmogorov-Smirnov and Shapiro-Wilk tests to assess the normality of SAR distribution.

- Comparative Analysis:

Mann-Whitney U tests to compare SAR values between Philips 1.5T and 3T, and between 1.5T Philips and siemens.

- Regression Analysis:

  Multiple regression to develop a predictive model for SAR values based on patient and scan parameters.

3.8 Ethical Considerations

Al-Quds University institutional review board (IRB) was obtained, ethical approval from the research ethics committee at al-Quds university was obtained, and anonymity and confidentiality will be protected all the time.

Chapter Four

Results

4.1 Demographic Data

A total of 180 patients undergoing MRI scans and data were collected prospectively. with their demographic and clinical characteristics that are summarized in Table 1.

Table 1: Demographic and Clinical Characteristics of Study Population

		Frequency	Percent	Valid Percent	Cumulative Percent
MRI image	BRAIN	90	50.0	50.0	50.0
	Lumber Spine	90	50.0	50.0	100.0
Gender	Male	117	65.0	65.0	65.0
	Female	63	35.0	35.0	100.0
Type of device	PHILIPS 1.5T	60	33.3	33.3	33.3
	PHILIPS 3T	60	33.3	33.3	66.7
	SIEMENS 1.5T	60	33.3	33.3	100.0
	Total	180	100.0	100.0	

This table presents the distribution of participants based on MRI imaging type (brain vs. lumbar spine), gender, and the type of MRI device used (Philips 1.5T, Philips 3T, Siemens 1.5T). The frequencies and percentages are provided for each category.

Table 2: Descriptive Statistics for age, weight, and gender

	Mean	Std. Deviation	Minimum	Maximum
age	39.94	17.769	13	78
weight (kg)	79.01	15.209	55	120

This table provides descriptive statistics for age and weight of the study participants, including the mean, standard deviation, minimum, and maximum values.

Table 1 shown equal distribution between brain and lumbar spine MRI scans, with each image type constituting 50% of the total scans.

Table 1 also shown that the study population includes a higher proportion of males (65%) compared to females (35%).

It also shown that The MRI scans are equally distributed across the three different MRI systems: Philips 1.5T, Philips 3T, and Siemens 1.5T, each representing 33.3% of the total scans. Finally, it shown that the mean age of the patients is approximately 40 years, with a standard deviation of 17.769 years, indicating a wide age range from 13 to 78 years. The average weight of the patients is 79.01 kg, with a standard deviation of 15.209 kg, ranging from 55 to 120 kg.

4.2 Distribution of MRI Image Types by Device

The distribution of MRI image types (brain and lumber) across different MRI systems is given in Table 3.

Table 3: Distribution of MRI Image Types by Device

Type of device			Frequency (sequences)	Percent	Valid Percent	Cumulative Percent
PHILIPS 1.5T	Valid	BRAIN	181	50.1	50.1	50.1
		LUMBER	180	49.9	49.9	100.0
		Total	361	100.0	100.0	
PHILIPS 3T	Valid	BRAIN	186	51.7	51.7	51.7
		LUMBER	174	48.3	48.3	100.0
		Total	360	100.0	100.0	
SIEMENS 1.5T	Valid	BRAIN	216	55.7	55.7	55.7
		LUMBER	172	44.3	44.3	100.0
		Total	388	100.0	100.0	

This table shows the distribution of MRI image types (brain and lumbar) for different MRI devices. Frequencies, percentages, valid percentages, and cumulative percentages are provided for each device: Philips 1.5T, Philips 3T, and Siemens 1.5T. The total number of sequences for each device and image type is also presented

Table 3 shown that from the 361 scans performed using Philips 1.5T system, 50.1% were brain scans and 49.9% were lumbar spine scans, Philips 3T system had a slightly higher proportion of brain scans (51.7%) compared to lumbar spine scans (48.3%) from 360 total scans. Siemens 1.5T system had the highest proportion of brain scans (55.7%) compared to lumbar spine scans (44.3%) from 388 total scans as shown in table 3.

4.3 Distribution of MRI Sequences by Device

Table 4 shown the distribution of MRI sequences across different MRI systems (Philips 1.5T, Philips 3T, and Siemens 1.5T.

Table 4: Distribution of MRI Sequences by Device

Type of device			Frequency	Percent	Valid Percent	Cumulative Percent
PHILIPS 1.5T	Valid	T1 SE Axial	60	16.6	16.6	16.6
		T1 SE SAG	30	8.3	8.3	24.9
		T2 GRE Axial	30	8.3	8.3	33.2
		T2 TSE Axial	60	16.6	16.6	49.9
		T2 SAG	61	16.9	16.9	66.8
		FLAIR	30	8.3	8.3	75.1
		DWI	30	8.3	8.3	83.4
		STAIR SAG	30	8.3	8.3	91.7
		STAIR COR	30	8.3	8.3	100.0
		Total	361	100.0	100.0	
PHILIPS 3T	Valid	T1 SE Axial	60	16.7	16.7	16.7
		T1 SE SAG	30	8.3	8.3	25.0
		T2 GRE Axial	30	8.3	8.3	33.3
		T2 TSE Axial	60	16.7	16.7	50.0
		T2 SAG	60	16.7	16.7	66.7
		FLAIR	30	8.3	8.3	75.0
		DWI	30	8.3	8.3	83.3
		STAIR SAG	30	8.3	8.3	91.7
		STAIR COR	30	8.3	8.3	100.0
		Total	360	100.0	100.0	
SIEMENS 1.5T	Valid	T1 SE Axial	59	15.2	15.2	15.2
		T1 SE SAG	60	15.5	15.5	30.7
		T2 TSE Axial	60	15.5	15.5	46.1
		T2 SAG	60	15.5	15.5	61.6
		FLAIR	30	7.7	7.7	69.3
		DWI	30	7.7	7.7	77.1
		T2 COR	59	15.2	15.2	92.3
		SWI	30	7.7	7.7	100.0
		Total	388	100.0	100.0	

This table displays the distribution of MRI sequences for each device type: Philips 1.5T, Philips 3T, and Siemens 1.5T. It includes the frequency and percentage of each sequence type within each device category, along with valid and cumulative percentages.

Table 4 shown that the most frequently used sequences in Philips 1.5T are T1 SE Axial and T2 TSE Axial, each accounting for 16.6% of the total scans. T2 SAG is also

commonly used, making up 16.9% of the scans. Similar to the Philips 1.5T, T1 SE Axial and T2 TSE Axial are the most frequent sequences used in Philips 3T, each representing 16.7% of the total scans. T2 SAG is also frequently used, accounting for 16.7% of the scans. The distribution is slightly more varied in siemens 1.5T, with T1 SE Axial, T1 SE SAG, T2 TSE Axial, and T2 SAG each accounting for approximately 15.2-15.5% of the total scans.

4.4 Specific Absorption Rate (SAR) in Brain MRI Sequences

The Specific Absorption Rate (SAR) values for MRI brain sequences across different MRI systems (1.5T Philips, 3T Philips, and 1.5T Siemens) are presented in Table 5.

Table 5: SAR in MRI Brain Sequences

PHILIPS 1.5T			PHILIPS 3T			SIEMENS 1.5T		
T1 SE Axial	Mean	0.2000	T1 SE Axial	Mean	0.2000	T1 SE Axial	Mean	3.2060
	Std. Deviation	0.00000		Std. Deviation	0.00000		Std. Deviation	0.16249
T2 TSE Axial	Mean	0.1000	T2 TSE Axial	Mean	0.2000	T2 TSE Axial	Mean	3.2800
	Std. Deviation	0.00000		Std. Deviation	0.00000		Std. Deviation	0.07611
FLAIR	Mean	0.0000	FLAIR	Mean	0.1000	FLAIR	Mean	0.8140
	Std. Deviation	0.00000		Std. Deviation	0.00000		Std. Deviation	0.14328
DWI	Mean	0.0000	DWI	Mean	0.1000	DWI	Mean	0.4327
	Std. Deviation	0.00000		Std. Deviation	0.00000		Std. Deviation	0.04017
T2 GRE Axial	Mean	0.0000	T2 GRE Axial	Mean	0.3000	T2 GRE Axial	Mean	0.2493
	Std. Deviation	0.00000		Std. Deviation	0.00000		Std. Deviation	0.11163
T2 SAG	Mean	0.1000	T2 SAG	Mean	0.3000	T2 SAG	Mean	3.2207
	Std. Deviation	0.00000		Std. Deviation	0.00000		Std. Deviation	0.14953
						T2 COR	Mean	0.9607
							Std. Deviation	0.14711

This table shows the mean and standard deviation of the Specific Absorption Rate (SAR) for various MRI brain sequences across different devices: Philips 1.5T, Philips 3T, and Siemens 1.5T. The sequences include T1 SE Axial, T2 TSE Axial, FLAIR, DWI, T2 GRE Axial, T2 SAG, and T2 COR.

Table 5 shown that the mean SAR values for Philips 1.5T and Philips 3T systems using T1 SE Axial sequence are identical at 0.2 W/kg, with no variation (std. deviation = 0.0

W/kg). Siemens 1.5T system has a significantly higher mean SAR of 3.206 W/kg, with a standard deviation of 0.16249 W/kg.

T2 TSE Axial in Philips 1.5T system has a mean SAR of 0.1 W/kg, while Philips 3T system shows a mean SAR of 0.2 W/kg, both with no variation. Siemens 1.5T system again shows a higher mean SAR of 3.28 W/kg with a standard deviation of 0.07611 W/kg.

FLAIR mean SAR values for Philips 1.5T is 0.0 W/kg and for Philips 3T is 0.1 W/kg, both with no variation. Siemens 1.5T system has a mean SAR of 0.814 W/kg with a standard deviation of 0.14328 W/kg.

DWI sequence in Philips systems have a mean SAR of 0.0 W/kg for 1.5T and 0.1 W/kg for 3T, both with no variation. Siemens 1.5T system has a mean SAR of 0.4327 W/kg with a standard deviation of 0.04017 W/kg.

T2 GRE Axial in Philips systems show no SAR value for 1.5T (0.0 W/kg) and 0.30 W/kg for 3T, both with no variation. Siemens 1.5T system has a mean SAR of 0.2493 W/kg with a standard deviation of 0.11163 W/kg.

T2 SAG in Philips 1.5T system has a mean SAR of 0.1 W/kg, while Philips 3T system shows 0.3 W/kg, both with no variation. Siemens 1.5T system shows a mean SAR of 3.2207 W/kg with a standard deviation of 0.14953 W/kg.

Only the Siemens 1.5T system has a record for T2 COR sequence with a mean SAR of 0.9607 W/kg with a standard deviation of 0.14711 W/kg.

The data showed a significant difference in SAR values between Philips and Siemens systems, Siemens system showing higher and more variable SAR values.

4.5 Specific Absorption Rate (SAR) in Lumber MRI Sequences

Table 6 shown Specific Absorption Rate (SAR) values for lumbar MRI sequences across different MRI systems (Philips 1.5T, Philips 3T, and Siemens 1.5T.

Table 6: SAR in Lumbar MRI Sequences

PHILIPS 1.5T			PHILIPS 3T			SIEMENS 1.5T		
T1 SE Axial	Mean	0.9667	T1 SE Axial	Mean	1.4067	T1 SE Axial	Mean	1.4338
	Std. Deviation	0.10283		Std. Deviation	0.15522		Std. Deviation	0.21700
T1 SE SAG	Mean	1.2633	T1 SE SAG	Mean	2.8033	T1 SE SAG	Mean	1.9140
	Std. Deviation	0.23706		Std. Deviation	0.20592		Std. Deviation	0.20138
T2 TSE Axial	Mean	1.6667	T2 TSE Axial	Mean	2.3933	T2 TSE Axial	Mean	1.8553
	Std. Deviation	0.23829		Std. Deviation	0.37868		Std. Deviation	0.13773
T2 SAG	Mean	1.4367	T2 SAG	Mean	2.6300	T2 SAG	Mean	1.1917
	Std. Deviation	0.20083		Std. Deviation	0.23216		Std. Deviation	0.17324
STAIR SAG	Mean	1.2100	STAIR SAG	Mean	2.7033	STAIR SAG	Mean	1.2290
	Std. Deviation	0.04026		Std. Deviation	0.29418		Std. Deviation	0.17160
STAIR COR	Mean	1.1967	STAIR COR	Mean	2.5533			
	Std. Deviation	0.01826		Std. Deviation	0.19780			

This table displays the mean and standard deviation of the Specific Absorption Rate (SAR) for various lumbar MRI sequences across different devices: Philips 1.5T, Philips 3T, and Siemens 1.5T. Sequences include T1 SE Axial, T1 SE SAG, T2 TSE Axial, T2 SAG, STAIR SAG, and STAIR COR.

Table 6 shown that T1 SE Axial mean SAR values for Philips 1.5T, Philips 3T, and Siemens 1.5T systems are 0.9667 W/kg, 1.4067 W/kg, and 1.4338 W/kg, respectively, with Philips 1.5T showing the lowest SAR and Siemens 1.5T showing the highest.

T1 SE SAG mean SAR values are 1.2633 W/kg for Philips 1.5T, 2.8033 W/kg for Philips 3T, and 1.9140 W/kg for Siemens 1.5T, indicating higher SAR value for Philips 3T.

T2 TSE Axial Philips 1.5T has a mean SAR of 1.6667 W/kg, Philips 3T has 2.3933 W/kg, and Siemens 1.5T has 1.8553 W/kg.

T2 SAG mean SAR for Philips 1.5T is 1.4367 W/kg, for Philips 3T is 2.63 W/kg, and for Siemens 1.5T is 1.1917 W/kg.

STAIR SAG Philips 1.5T shows a mean SAR of 1.21 W/kg, Philips 3T shows 2.7033 W/kg, and Siemens 1.5T shows 1.229 W/kg.

STAIR COR Philips 1.5T has a mean SAR of 1.1967 W/kg, while Philips 3T has 2.5533 W/kg. Data for Siemens 1.5T is not available for this sequence.

The SAR values for Philips 3T are consistently higher than those for Philips 1.5T and Siemens 1.5T across most sequences, indicating higher heat deposition at higher field strengths.

4.6 Frequencies of Parameters/Sequences

Table 7 shown the frequencies of various parameters and sequences for different MRI systems (Philips 1.5T, Philips 3T, and Siemens 1.5T).

Table 7: Frequencies of Parameters/Sequences

	PHILIPS 1.5T				PHILIPS 3T				SIEMENS 1.5T			
	BRAIN		LUMBER		BRAIN		LUMBER		BRAIN		LUMBER	
mri image	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SMEAN(TR)	2815.697	1708.5004	1997.118	1128.6516	2932.989	1717.4824	3307.667	2228.6855	3775.269	3571.0159	2919.609	1816.7949
SMEAN(TE)	70.709	40.8491	71.768	43.9950	108.296	109.4811	57.167	41.4732	57.581	37.5700	64.948	38.6214
SMEAN(Slice#)	24.825	1.4425	11.833	4.8583	69.898	101.2198	11.833	4.8588	31.866	16.3842	14.093	5.1259
SMEAN(FOV.AP)	231.657	3.7288	165.000	44.7526	230.742	17.4154	153.000	38.0524	204.752	46.0750	160.085	51.6853
SMEAN(FOV.RL)	185.298	23.7756	137.500	76.0684	184.532	25.6676	125.500	59.8820	100.716	18.6551	121.099	20.8135
SMEAN(FOV.FH)	173.9779	43.66641	203.8333	129.12955	179.6452	49.68150	209.0000	131.24913	214.6060	15.35067	260.5630	48.46273
SMEAN(ST)	4.881	.2688	4.000	0.0000	4.161	1.3548	4.000	0.0000	4.556	1.0418	4.002	.0213
SMEAN(NSA)	1.331	.4721	2.367	.3912	1.175	.3795	1.433	.4547	1.071	.1783	1.369	.4824

This table presents the mean and standard deviation of various MRI imaging parameters, including TR, TE, number of slices, field of view in anterior-posterior, right-left, and foot-head directions, slice thickness , and number of signals averages, across different MRI devices: Philips 1.5T, Philips 3T, and Siemens 1.5T for both brain and lumbar imaging

Table 7 shown that Time of repetition (TR) shows significant variation across different MRI systems and sequences. Philips 1.5T shows a mean TR of 2815.697 ms for brain scans and 1997.118 ms for lumbar scans. Philips 3T and Siemens 1.5T systems show even higher mean TR values, particularly for brain scans.

Echo time (TE) varies across systems, with Philips 1.5T showing a mean TE of around 70 ms for both brain and lumbar scans. Philips 3T shows higher TE values, especially for brain scans, while Siemens 1.5T shows relatively consistent TE values across both brain and lumbar scans.

The number of slices varies significantly, with Philips 3T showing the highest mean slice number for brain scans (69.89) and lumbar scans showing lower values across all systems.

Field of view in the anteroposterior (FOV AP) direction shows variation, with Philips systems showing values around 230 mm for brain scans and around 165 mm for lumbar scans. Siemens 1.5T shows lower values for lumbar scans.

Field of view in the right-left (FOV RL) direction shows significant variation, with Philips systems showing values around 185 mm for brain scans and lower for lumbar scans. Siemens 1.5T shows consistent values.

Field of view in the foot-head direction (FOV FH) shows variability, with Philips 1.5T showing values around 174 mm for brain scans and higher for lumbar scans. Philips 3T and Siemens 1.5T show higher values.

Slice thickness is relatively consistent across systems, with minor variations. Philips systems show mean slice thickness around 4-5 mm.

Number of signal averages (NSA) shows variability, with Philips systems showing higher values for lumbar scans.

The data had significant differences in parameters and sequences across different MRI systems, affecting SAR and heat deposition.

4.7 SAR Normal distribution

Table 8 shown the normality of Specific Absorption Rate (SAR) values that were tested using the Kolmogorov-Smirnov and Shapiro-Wilk tests.

Table 8: Tests of Normality for SAR Values

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SAR(W/KG)	.160	1109	.000	.893	1109	.000

a. Lilliefors Significance Correction

Kolmogorov-Smirnov and Shapiro-Wilk Test shows that The test statistic is 0.160 and 0.893 respectively with a significance level (Sig.) of 0.000 for both tests, indicating that the SAR values do not follow a normal distribution.

4.8 Differences between SAR in brain and lumber sequences in whole data

Table 9 shown The differences between SAR values in brain and lumbar sequences in whole data were analyzed using the Mann-Whitney U test.

Table 9: Differences Between SAR in Brain and Lumbar Sequences

	mri image	N	Mean Rank	Sum of Ranks
SAR(W/KG)	BRAIN	583	381.35	222327.50
	LUMBER	526	747.47	393167.50
	Total	1109		

Test Statistics[a]	
	SAR(W/KG)
Mann-Whitney U	52091.500
Wilcoxon W	222327.500
Z	-19.044
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: mri image

This table presents the Mann-Whitney U test results comparing Specific Absorption Rate (SAR) values between brain and lumbar MRI sequences, including mean ranks, sum of ranks, and test statistics.

Table 9 shown that the mean rank of SAR values for brain sequences is 381.35, while it is significantly higher for lumbar sequences at 747.47.

The Mann-Whitney U Test value is 52091.500, with a Wilcoxon W of 222327.500 and a Z score of -19.044. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values between brain and lumbar sequences.

These results suggest that there is a significant difference in SAR values between brain and lumbar MRI sequences, with lumbar sequences showing higher SAR values on average.

4.9 difference between SAR in brain protocol between 1.5 siemens and 1.5 Philips through Sequences

The differences in SAR values for brain protocols between Philips 1.5T and Siemens 1.5T were analyzed using the Mann-Whitney U test. These results are summarized in Table 10.

Table 10: Differences Between SAR in Brain Protocols for Philips 1.5T and Siemens 1.5T

	Type of device	N	Mean Rank	Sum of Ranks
SAR(W/KG)	PHILIPS 1.5T	181	91.00	16471.00
	SIEMENS 1.5T	216	289.50	62532.00
	Total	397		

Test Statistics[a]	
	SAR(W/KG)
Mann-Whitney U	.000
Wilcoxon W	16471.000
Z	-17.373
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table shows the Mann-Whitney U test results comparing Specific Absorption Rate (SAR) values in brain MRI protocols between Philips 1.5T and Siemens 1.5T devices, including mean ranks, sum of ranks, and test statistics.

Table 10 shown that The mean rank of SAR values for Philips 1.5T is 91.00, while for Siemens 1.5T, it is significantly higher at 289.50.

The Mann-Whitney U Test value is 0.000, with a Wilcoxon W of 16471.000 and a Z score of -17.373. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values between Philips 1.5T and Siemens 1.5T for brain protocols.

These results suggest that there is a significant difference in SAR values between Philips 1.5T and Siemens 1.5T systems for brain protocols, with Siemens 1.5T showing higher SAR values on average.

4.10 difference between SAR in brain protocol between 1.5 Philips and 3T Philips through Sequences

Table 11 shown the differences in SAR values for brain protocols between Philips 1.5T and 3T that were analyzed using the Mann-Whitney U test.

Table 11: Differences Between SAR in Brain Protocols for Philips 1.5T and 3T

	Type of device	N	Mean Rank	Sum of Ranks
SAR(W/KG)	PHILIPS 1.5T	181	116.03	21001.00
	PHILIPS 3T	186	250.15	46527.00
	Total	367		

Test Statistics[a]

	SAR(W/KG)
Mann-Whitney U	4530.000
Wilcoxon W	21001.000
Z	-12.554
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table presents the Mann-Whitney U test results comparing Specific Absorption Rate (SAR) values in brain MRI protocols between Philips 1.5T and Philips 3T devices, including mean ranks, sum of ranks, and test statistics.

Table 11 shown that the mean rank of SAR values for Philips 1.5T is 116.03, while for Philips 3T, it is significantly higher at 250.15.

The Mann-Whitney U Test value is 4530.000, with a Wilcoxon W of 21001.000 and a Z score of -12.554. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values between Philips 1.5T and 3T for brain protocols.

These results suggest that there is a significant difference in SAR values between Philips 1.5T and 3T systems for brain protocols, with Philips 3T showing higher SAR values on average.

4.11 difference between SAR in Lumber protocol between 1.5 Siemens and 1.5 Philips through Sequences

table 12 shown the differences in SAR values for lumbar protocols between 1.5T Philips and Siemens that were analyzed using the Mann-Whitney U test.

Table 12: Differences Between SAR in Lumbar Protocols for 1.5T Philips and Siemens.

	Type of device	N	Mean Rank	Sum of Ranks
SAR(W/KG)	PHILIPS 1.5T	180	156.18	28113.00
	SIEMENS 1.5T	172	197.76	34015.00
	Total	352		

Test Statistics[a]	
	SAR(W/KG)
Mann-Whitney U	11823.000
Wilcoxon W	28113.000
Z	-3.869
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table shows the Mann-Whitney U test results comparing Specific Absorption Rate (SAR) values in lumbar MRI protocols between Philips 1.5T and Siemens 1.5T devices, including mean ranks, sum of ranks, and test statistics.

Table 12 shown that the mean rank of SAR values for Philips 1.5T is 156.18, while for Siemens 1.5T, it is significantly higher at 197.76.

The Mann-Whitney U Test value is 11823.000, with a Wilcoxon W of 28113.000 and a Z score of -3.869. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values between Philips 1.5T and Siemens 1.5T for lumbar protocols.

These results suggest that there is a significant difference in SAR values between 1.5T Philips and Siemens systems for lumbar protocols, with Siemens 1.5T showing higher SAR values on average.

4.12 difference between SAR in Lumber protocol between 1.5T and 3T Philips through Sequences

Table 13 shown the differences in SAR values for lumbar protocols between Philips 1.5T and 3T that were analyzed using the Mann-Whitney U test.

Table 13: Differences Between SAR in Lumbar Protocols for Philips 1.5T and 3T

	Type of device	N	Mean Rank	Sum of Ranks
SAR(W/KG)	PHILIPS 1.5T	180	98.79	17781.50
	PHILIPS 3T	174	258.93	45053.50
	Total	354		

Test Statistics[a]	
	SAR(W/KG)
Mann-Whitney U	1491.500
Wilcoxon W	17781.500
Z	-14.825
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table presents the Mann-Whitney U test results for comparing Specific Absorption Rate (SAR) values in lumbar MRI protocols between Philips 1.5T and Philips 3T devices, including mean ranks, sum of ranks, and test statistics.

Table 13 shown that the mean rank of SAR values for Philips 1.5T is 98.79, while for Philips 3T, it is significantly higher at 258.93.

The Mann-Whitney U Test value is 1491.500, with a Wilcoxon W of 17781.500 and a Z score of -14.825. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values between Philips 1.5T and 3T for lumbar protocols.

These results suggest that there is a significant difference in SAR values between Philips 1.5T and 3T systems for lumbar protocols, with Philips 3T showing higher SAR values on average.

4.13 Predicted SAR equation

Table 14 shows the comprehensive efficiency of the regression model used for predicting SAR. The correlation coefficient (R) is 0.973, showing a significant positive correlation between the actual and predicted values of SAR. The coefficient of determination (R Square) is 0.946, indicating that 94.6% of the variation in SAR can be accounted for by the predictor variables used in the model. The Adjusted R Square score, which is similarly 0.946, takes into consideration the number of predictors in the model and validates the model's strong ability to explain the data. The standard error of the estimate is 0.24366, which is the average deviation of the observed data from the regression line. The change data indicate a major rise in the R Square value by 0.946, accompanied by a F Change of 1481.438 and a p-value of <0.001. This indicates that the predictors make a significant contribution to the model.

Table 15 examines the general significance of the regression model. The regression sum of squares is 1143.398 with 13 degrees of freedom, whereas the residual sum of squares is 65.011 with 1095 degrees of freedom. The regression has a mean square of

87.954, whereas the residuals have a mean square of 0.059. The F statistic is 1481.438, and the p-value is <0.001, indicating that the regression model is highly significant in predicting SAR.

Table 16 offers valuable insights into the influence of several predictors on the Specific Absorption Rate (SAR). The intercept has a value of -0.606 and is considered to be statistically significant. Important indicators, such as the "Root mean Square of B1 field" (with a coefficient of 1.441) and "SAR/B1" (with a coefficient of 1.539), have considerable beneficial effects on SAR, as shown by highly significant p-values. Additional important predictors include SMEAN(TR) having a positive impact, as well as SMEAN(TE), SMEAN(Slice#), SMEAN(FOV.AP), SMEAN(FOV.RL), and SMEAN(ST), all of which had negative effects and significant p-values.

Nevertheless, factors such as age, weight, gender, SMEAN (FOV.FH), and SMEAN(NSA) do not exhibit statistical significance, suggesting that their impact on SAR is insignificant. In general, the model successfully reflects the differences in SAR, since several predictors have large impacts and show a high level of accuracy.

Table 14: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.973[a]	.946	.946	.24366	.946	1481.438	13	1095	.000

a. Predictors: (Constant), SMEAN(NSA), SAR/B1, gender, age, SMEAN(TR), SMEAN(Slice#), Root mean Square of B1 field, SMEAN(FOV.FH), weight (kg), SMEAN(FOV.RL), SMEAN(ST), SMEAN(FOV.AP), SMEAN(TE)

Table 15: ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1143.398	13	87.954	1481.438	.000[b]
	Residual	65.011	1095	.059		
	Total	1208.408	1108			

a. Dependent Variable: SAR(W/KG)

b. Predictors: (Constant), SMEAN(NSA), SAR/B1, gender, age, SMEAN(TR), SMEAN(Slice#), Root mean Square of B1 field, SMEAN(FOV.FH), weight (kg), SMEAN(FOV.RL), SMEAN(ST), SMEAN(FOV.AP), SMEAN(TE)

Table 16: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.606	.163		-3.712	.000
	Root mean Square of B1 field	1.441	.036	.330	40.185	.000
	SAR/B1	1.539	.020	.884	77.164	.000
	age	.000	.000	.003	.388	.698
	weight (kg)	.001	.001	.007	.874	.382
	gender	-.018	.017	-.008	-1.106	.269
	SMEAN(TR)	3.132E-5	.000	.069	5.833	.000
	SMEAN(TE)	-.001	.000	-.045	-2.859	.004
	SMEAN(Slice#)	-.002	.000	-.098	-7.011	.000
	SMEAN(FOV.AP)	-.002	.000	-.110	-7.461	.000
	SMEAN(FOV.RL)	-.002	.000	-.111	-7.794	.000
	SMEAN(FOV.FH)	.000	.000	-.019	-1.359	.174
	SMEAN(ST)	-.097	.016	-.074	-5.885	.000
	SMEAN(NSA)	.007	.018	.004	.379	.705

a. Dependent Variable: SAR(W/KG)

4.14 Specific Absorption Rate (SAR) per patient

Table 17 shown The Specific Absorption Rate (SAR) per patient for different MRI systems (Philips 1.5T, Philips 3T, and Siemens 1.5T).

Table 17: SAR per Patient

PHILIPS 1.5T	N	Valid	60
		Missing	0
	Mean		4.0700
	Std. Deviation		3.73178
PHILIPS 3T	N	Valid	60
		Missing	0
	Mean		7.8450
	Std. Deviation		6.74148
SIEMENS 1.5T	N	Valid	60
		Missing	0
	Mean		10.4450
	Std. Deviation		1.91063

This table shows the mean and standard deviation of Specific Absorption Rate (SAR) per patient for Philips 1.5T, Philips 3T, and Siemens 1.5T MRI devices.

Table 17 shown that the mean SAR value per patient in PHILIPS 1.5T is 4.0700 W/kg with a standard deviation of 3.73178 W/kg, while The mean SAR value per patient in PHILIPS 3T is 7.8450 W/kg with a higher standard deviation of 6.74148 W/kg, indicating greater variability. The mean SAR per patient in SIEMENS 1.5T is the highest at 10.4450 W/kg with a standard deviation of 1.91063 W/kg, indicating more consistent SAR values across patients.

4.15 Differences Between SAR per Patient in Brain Protocols for Philips 1.5T and 3T

Table 18 shown the differences in SAR values per patient for brain protocols between Philips 1.5T and 3T that were analyzed using the Mann-Whitney U test.

Table 18: Differences Between SAR per Patient in Brain Protocols for Philips 1.5T and 3T

	Type of device	N	Mean Rank	Sum of Ranks
SAR.PT	PHILIPS 1.5T	30	15.50	465.00
	PHILIPS 3T	30	45.50	1365.00
	Total	60		

Test Statistics[a]	
	SAR.PT
Mann-Whitney U	.000
Wilcoxon W	465.000
Z	-7.681
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table presents the Mann-Whitney U test results comparing SAR per patient between Philips 1.5T and Philips 3T MRI devices for brain protocols.

Table 18 shown that the mean rank of SAR values per patient for Philips 1.5T is 15.50, while for Philips 3T, it is significantly higher at 45.50.

The Mann-Whitney U Test value is 0.000, with a Wilcoxon W of 465.000 and a Z score of -7.681. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values per patient between Philips 1.5T and 3T for brain protocols.

These results suggest that there is a significant difference in SAR values per patient between Philips 1.5T and 3T systems for brain protocols, with Philips 3T showing higher SAR values on average.

4.16 Differences Between SAR per Patient in Brain Protocols for 1.5T Philips and Siemens.

Table 19 shown the differences in SAR values per patient for brain protocols between 1.5T Philips and Siemens systems that were analyzed using the Mann-Whitney U test.

Table 19: Differences Between SAR per Patient in Brain Protocols for 1.5T Philips and Siemens

	Type of device	N	Mean Rank	Sum of Ranks
SAR.PT	PHILIPS 1.5T	30	15.50	465.00
	SIEMENS 1.5T	30	45.50	1365.00
	Total	60		

Test Statistics[a]	
	SAR.PT
Mann-Whitney U	.000
Wilcoxon W	465.000
Z	-7.131
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table displays the Mann-Whitney U test results comparing SAR per patient between Philips 1.5T and Siemens 1.5T MRI devices for brain protocols.

Table 19 shown that the mean rank of SAR values per patient for Philips 1.5T is 15.50, while it is significantly higher for Siemens 1.5T at 45.50.

The Mann-Whitney U Test value is 0.000, with a Wilcoxon W of 465.000 and a Z score of -7.131. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values per patient between Philips and Siemens 1.5T for brain protocols.

These results suggest that there is a significant difference in SAR values per patient between Philips and Siemens 1.5T systems for brain protocols, with Siemens 1.5T showing higher SAR values on average.

4.17 Differences Between SAR per Patient in Lumbar Protocols for Philips and Siemens 1.5T

The differences in SAR values per patient for lumbar protocols between Philips and Siemens 1.5T were analyzed using the Mann-Whitney U test. These results are summarized in Table 20.

Table 20: Differences Between SAR per Patient in Lumbar Protocols for Philips and Siemens 1.5T

	Type of device	N	Mean Rank	Sum of Ranks
SAR.PT	PHILIPS 1.5T	30	19.77	593.00
	SIEMENS 1.5T	30	41.23	1237.00
	Total	60		

Test Statistics[a]	
	SAR.PT
Mann-Whitney U	128.000
Wilcoxon W	593.000
Z	-4.838
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table shows the Mann-Whitney U test results for SAR per patient comparing Philips 1.5T and Siemens 1.5T MRI devices in lumbar protocols.

Table 20 shown that the mean rank of SAR values per patient for Philips 1.5T is 19.77, while it is significantly higher for Siemens 1.5T at 41.23.

The Mann-Whitney U Test value is 128.000, with a Wilcoxon W of 593.000 and a Z score of -4.838. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values per patient between Philips 1.5T and Siemens 1.5T for lumbar protocols.

These results suggest that there is a significant difference in SAR values per patient between Philips 1.5T and Siemens 1.5T systems for lumbar protocols, with Siemens 1.5T showing higher SAR values on average.

4.18 Differences Between SAR per Patient in Lumbar Protocols for Philips 1.5T and 3T

Table 21 shown the differences in SAR values per patient for lumbar protocols between Philips 1.5T and 3T that were analyzed using the Mann-Whitney U test.

Table 21: Differences Between SAR per Patient in Lumbar Protocols for Philips 1.5T and 3T

	Type of device	N	Mean Rank	Sum of Ranks
SAR.PT	PHILIPS 1.5T	30	15.50	465.00
	PHILIPS 3T	30	45.50	1365.00
	Total	60		

Test Statistics[a]	
	SAR.PT
Mann-Whitney U	.000
Wilcoxon W	465.000
Z	-6.758
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Type of device

This table presents the Mann-Whitney U test results for SAR per patient comparing Philips 1.5T and 3T MRI devices in lumbar protocols.

Table 21 shown that the mean rank of SAR values per patient for Philips 1.5T is 15.50, while for Philips 3T, it is significantly higher at 45.50.

The Mann-Whitney U Test value is 0.000, with a Wilcoxon W of 465.000 and a Z score of -6.758. The asymptotic significance (2-tailed) is 0.000, indicating a statistically significant difference in SAR values per patient between Philips 1.5T and 3T for lumbar protocols.

These results suggest that there is a significant difference in SAR values per patient between Philips 1.5T and 3T systems for lumbar protocols, with Philips 3T showing higher SAR values on average.

4.19 Differences Between SAR in Brain Protocols and Their Sequences

Table 22 shown the p-values of Specific Absorption Rate (SAR) for various sequences in brain protocol across different MRI systems.

Table 22: p-values of SAR in Brain Protocols and Their Sequences

Sequence	Device 1	Device 2	P-value
T1 SE Axial	PHILIPS 1.5T	SIEMENS 1.5T	0.000
T1 SE Axial	PHILIPS 1.5T	PHILIPS 3T	1.000
T1 SE SAG	PHILIPS 1.5T*	SIEMENS 1.5T	-
T1 SE SAG	PHILIPS 1.5T*	PHILIPS 3T*	-
T2 GRE Axial	PHILIPS 1.5T	SIEMENS 1.5T*	-
T2 GRE Axial	PHILIPS 1.5T	PHILIPS 3T	0.000
T2 TSE Axial	PHILIPS 1.5T	SIEMENS 1.5T	0.000
T2 TSE Axial	PHILIPS 1.5T	PHILIPS 3T	0.000
T2 SAG	PHILIPS 1.5T	SIEMENS 1.5T*	-
T2 SAG	PHILIPS 1.5T	PHILIPS 3T	0.000
FLAIR	PHILIPS 1.5T	SIEMENS 1.5T	0.000
FLAIR	PHILIPS 1.5T	PHILIPS 3T	0.000
DWI	PHILIPS 1.5T	SIEMENS 1.5T	0.000
DWI	PHILIPS 1.5T	PHILIPS 3T	0.000

* This sequence wasn't used in this device
This table shows the p-values for SAR comparisons between different MRI devices across various brain protocols.

Table 22 shown that There is a significant difference in SAR values using T1 SE Axial sequence between Philips 1.5T and Siemens 1.5T systems ($p = 0.000$). No significant difference was observed between Philips 1.5T and Philips 3T systems ($p = 1.000$).

There is A significant difference in SAR values using T2 GRE Axial sequence between Philips 1.5T and Philips 3T systems ($p = 0.000$).

There is a significant difference using T2 TSE Axial sequence between Philips 1.5T and both Siemens 1.5T and Philips 3T systems ($p = 0.000$ for both comparisons).

There is a significant difference using FLAIR sequence between Philips 1.5T and both Siemens 1.5T and Philips 3T systems ($p = 0.000$ for both comparisons).

There is a significant difference using DWI sequence between Philips 1.5T and both Siemens 1.5T and Philips 3T systems (p = 0.000 for both comparisons).

4.20 Differences Between SAR in lumber Protocols and Their Sequences

Table 23 shown the p-values of Specific Absorption Rate (SAR) for various sequences in lumber protocol across different MRI systems.

Table 23: p-values of SAR in lumber Protocols and Their Sequences

Sequence	Device 1	Device 2	P-value
T1 SE Axial	PHILIPS 1.5T	SIEMENS 1.5T	0.000
T1 SE Axial	PHILIPS 1.5T	PHILIPS 3T	0.000
T1 SE SAG	PHILIPS 1.5T	SIEMENS 1.5T	0.000
T1 SE SAG	PHILIPS 1.5T	PHILIPS 3T	0.000
T2 TSE Axial	PHILIPS 1.5T	SIEMENS 1.5T	0.000
T2 TSE Axial	PHILIPS 1.5T	PHILIPS 3T	0.000
T2 SAG	PHILIPS 1.5T	SIEMENS 1.5T	0.000
T2 SAG	PHILIPS 1.5T	PHILIPS 3T	0.000
STIR SAG	PHILIPS 1.5T	SIEMENS 1.5T*	-
STIR SAG	PHILIPS 1.5T	PHILIPS 3T	0.000
STIR COR	PHILIPS 1.5T	SIEMENS 1.5T*	-
STIR COR	PHILIPS 1.5T	PHILIPS 3T	0.000

* This sequence wasn't used in this device

This table lists the p-values for SAR comparisons between different MRI devices across various lumbar protocols.

Table 23 shown that There is a significant difference in SAR values using T1 SE Axial sequence between Philips 1.5T and Siemens 1.5T systems (p = 0.000) and between Philips 1.5T and Philips 3T systems (p = 0.000).

There is a Significant difference in SAR values using T1 SE SAG sequence between Philips 1.5T and both Siemens 1.5T and Philips 3T systems ($p = 0.000$ for both comparisons).

There is a Significant difference in SAR values using T2 TSE Axial sequence between Philips 1.5T and both Siemens 1.5T and Philips 3T systems ($p = 0.000$ for both comparisons).

There is a Significant difference in SAR values using T2 SAG sequence between Philips 1.5T and both Siemens 1.5T and Philips 3T systems ($p = 0.000$ for both comparisons).

There is a Significant difference in SAR values using STIR SAG sequence between Philips 1.5T and Philips 3T systems ($p = 0.000$).

There is a Significant difference in SAR values using STIR COR sequence between Philips 1.5T and Philips 3T systems ($p = 0.000$).

Chapter Five

Discussion

This chapter provides a comprehensive discussion of the results presented in the previous chapter, interpreting the results considering of the study's objectives, hypotheses, and previous studies

5.1 Overview of Findings

The primary objective of this study was to compare SAR levels in patients undergoing MRI scans at 1.5T and 3T using Philips MRI systems. Additionally, a comparison between Philips and Siemens 1.5T MRI systems. The results demonstrated variations in Specific Absorption Rate (SAR) values across different MRI systems, field strengths, and sequences.

5.2 Comparison of SAR Values Across Different MRI Systems and Field Strengths

5.2.1 Philips 1.5T vs. Philips 3T

The results indicate that SAR values are significantly higher in Philips 3T systems compared to Philips 1.5T systems for both brain and lumbar MRI protocols. This finding is consistent with the hypothesis that higher magnetic field strengths result in increased RF energy deposition and, thus, higher SAR values. In particular, the mean SAR per patient for Philips 3T was 7.8450 W/kg, compared to 4.0700 W/kg for Philips

1.5T. This significant difference is supported by the Mann-Whitney U test results (p = 0.000), confirming that higher field strengths lead to increased heat deposition.

The higher SAR values at 3T can be attributed to the increasing of the energy deposition when moving from 1.5T to 3T. This increase in SAR values highlights the need for strict monitoring of MRI protocols at higher field strengths to ensure patient safety.

Previous studies support these findings. Shellock and Crues (2004) reported that higher field strengths, are associated with increased in SAR values due to higher RF energy absorption by tissues. also, Okada T et.al in 2022 found that 3T MRI systems resulted in higher SAR compared to 1.5T systems, requiring further management of RF exposure to avoid excessive heating(Okada et al., 2022; Shellock & Crues, 2004b).

5.2.2 Philips 1.5T vs. Siemens 1.5T

The comparison between Philips and Siemens 1.5T systems showed that Siemens 1.5T systems had significantly higher SAR values than Philips 1.5T systems. For brain protocols, Siemens 1.5T had a mean SAR of 10.4450 W/kg, significantly higher than the 4.0700 W/kg in Philips 1.5T. This difference is statistically significant (p = 0.000), indicating that Siemens systems deposit more RF energy, resulting in higher tissue heating.

Several factors could affect these differences, including variations in hardware design, pulse sequence parameters, and software algorithms used by manufacturers. The data suggest that Siemens systems may need more careful management of SAR levels to decrease the heat effect on patients.

These results align with previous research. Gosselin et.al in 2014 reported that SAR values can vary significantly between different MRI manufacturers due to there is

differences in hardware and pulse sequence adjustment, which can affect RF energy deposition and therefore, tissue heating. Additionally, Ladd et.al in 2018 highlighted that Siemens systems might use more aggressive imaging protocols that could give higher SAR values compared to Phillips systems(Gosselin et al., 2014; Ladd et al., 2018).

5.3 Impact of Pulse Sequence Parameters on SAR

The study also investigated how variations in pulse sequence parameters, such as repetition time (TR), echo time (TE), and flip angle, could have effect on SAR values. The multiple regression analysis identified several key factors affecting SAR, including the root mean square of the B1 field, SAR/B1 ratio, TR, and TE.

- **Repetition Time (TR):** Longer TR values were associated with higher SAR values, particularly in Philips 3T systems. This finding supports the understanding that longer TR allows for more RF energy deposition in tissue per unit time, increasing the total SAR.
- **Echo Time (TE):** Shorter TE values were associated with lower SAR values. This is because shorter TE reduces the duration of RF pulse, thereby decreasing the amount of energy deposition in patient.
- **Number of Slices and Field of View (FOV):** Higher number of slices and larger FOV will increase SAR values.

The regression model's high R-squared value (0.946) indicates that these parameters explain a significant portion of the differences in SAR values, and this will help in how to use MRI protocols to minimize heat deposition.

These findings are consistent with previous studies. A study by Brown et.al in 2014 demonstrated that TR and TE significantly influence SAR values, with longer TR and shorter TE reducing overall RF energy deposition(R. W. Brown et al., 2014).

5.4 Differences in SAR Between Brain and Lumbar Sequences

The study showed differences in SAR values between brain and lumbar MRI sequences, with lumbar sequences had higher SAR values. This was appearing in both Philips and Siemens systems. For example, the mean SAR for lumbar sequences in Siemens 1.5T systems was consistently higher than that for brain sequences.

This difference can be caused by the larger volume of tissue and the larger number of slices typically required for lumbar imaging. Furthermore, the anatomical location and the varying tissue properties of the lumbar region may contribute to higher RF energy absorption.

These results match previous research. A study by zernia G and Huster D IN 2006 indicated that lumbar MRI sequences generally have higher SAR values compared to brain sequences due to the larger imaging volume and higher RF power requirements. Additionally, Winter L et.al in 2016 reported that lumbar spine imaging poses greater challenges in terms of SAR management, that would need careful protocol optimization(Winter et al., 2016; Zernia & Huster, 2006).

5.5 Effect of FLAIR Sequence on SAR

The study also examined the impact of the Fluid-Attenuated Inversion Recovery (FLAIR) sequence on SAR levels, particularly in brain imaging protocols. The findings revealed that the FLAIR sequence significantly increases SAR values compared to other sequences, such as T1-weighted and T2-weighted sequences. This increase is

primarily due to the longer inversion time (TI) and the additional RF pulses required to suppress the cerebrospinal fluid (CSF) signal, leading to higher RF energy deposition.

The FLAIR sequence's higher SAR is a concern, especially at 3T, where the energy deposition is already elevated due to the higher field strength. This underscores the need for careful management and optimization of FLAIR protocols, particularly in patients with conditions that may predispose them to heat-related complications.

These findings are consistent with previous studies. For example,(Katscher & Börnert, 2006) reported that the FLAIR sequence contributes to increased SAR levels due to its complex RF pulse structure. Additionally, (Bernstein, 2004)highlighted the importance of managing SAR in sequences with longer pulse durations and higher RF energy requirements, emphasizing the need for optimized protocols to prevent excessive tissue heating.

Chapter Six

Conclusion

This study aimed to Assess and compare SAR levels, measured as Specific Absorption Rate (SAR), in patients undergoing MRI scan at 1.5T and 3T using Philips MRI systems. Additionally, it involved a comparison between 1.5T MRI systems, Philips and Siemens. The findings of this study provide important clinical implications in SAR values across different MRI systems, field strengths, and pulse sequence parameters.

Philips 3T MRI systems exhibit significantly higher SAR values compared to Philips 1.5T systems for both brain and lumbar MRI protocols. This confirms that higher magnetic field strengths result in increased RF energy deposition and, consequently, higher heat deposition in tissues.

Siemens 1.5T MRI systems show significantly higher SAR values compared to Philips 1.5T systems. This indicates that different manufacturers can vary substantially in terms of RF energy deposition, which has implications for patient safety and protocol optimization.

Variations in pulse sequence parameters, such as repetition time (TR), echo time (TE), and number of slices, CAN affect SAR values. Longer TR and increased number of

slices are associated with higher SAR, whereas shorter TE will reduce SAR. This highlights the importance of optimizing these parameters to manage SAR levels effectively.

Lumbar MRI sequences generally have higher SAR values compared to brain sequences. This can be explained by the larger imaging volume and the higher RF power requirements for lumbar scans.

The study shows the need for careful monitoring and adjustment of MRI protocols, especially for high-field strength systems and when using different manufacturers. Ensuring patient safety requires adhering to established SAR limits and optimizing pulse sequence parameters.

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Appendix

Al Quds University
Faculty of Health Professions
Jerusalem –Abu Dis

جامعة القدس
كلية المهن الصحية
القدس – أبو ديس

Research Ethics Subcommittee of Faculty of Health Professions
Letter of approval

Aug. 21, 2024
Ref. No.: RESC/2024-50

Dear Applicants, **(Dr. Mohammad Hjouj, Mr. Mohammad Modallal)**

Program: **MSc Medical Imaging Department**

The Research Ethics subcommittee of the Faculty of Health Professions has recently reviewed your proposal entitled **(A comparative study of SAR Distribution in patients undergoing MRI examinations at different field strengths and manufacturers)** submitted by **(Dr. Mohammad Hjouj)**. Your proposal is deemed to meet the requirements of research ethics at Al-Quds University, but further assessment is required by the Central Research Ethics Committee of Al-Quds University. We wish you all best for the conduct of the project.

Hussein ALMasri, PhD
Associate Professor of Medical Imaging
Research Ethics Subcommittee Chair
Faculty of Health Professions

Hussein AL Masri

CC: File
CC: Committee members

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Al Quds University
Faculty of Health Professions
Medical Imaging Department
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جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس– أبوديس

التاريخ :2024\01\08

السادة المحترمين، ادارة جمعية أصدقاء المريض الخيرية (مستوصف الرحمة) - نابلس،

تحية طيبة وبعد،

الموضوع : تسهيل مهمة باحث من جامعة القدس – ابو ديس

ايمانا منا بدوركم في خدمة وتطوير المجتمع الفلسطيني واستنادا لمعرفتنا بالدور الهام الذي تقومون به في دعم التعليم والبحث العلمي،

نتوجه لحضرتكم التكرم بالايعاز للمعنيين المساعدة بتسهيل مهمة طالب الدراسات العليا الباحث محمد مدلل من برنامج ماجستير تكنولوجيا التصوير الطبي – كلية المهن الصحية \جامعة القدس في جمع المعلومات اللازمة لدراسة وتقييم " ترسب الحرارة وامتصاصها لدى المرضى الذين يخضعون لفحوصات التصوير بالرنين المغناطيسي كدالة لقوة المجال المغناطيسي ونوع اجهزة التصوير بالرنين المغناطيسي حسب الشركة المصنعة. ". سيقوم الطالب بعمل بحث بعنوان:

"A comparative study of heat deposition in patients undergoing MRI examinations as a function of magnetic field strength and types of MRI devices according to the manufacturer".

وسيتم اطلاعكم على نتائج البحث.

وتفضلوا بقبول فائق الاحترام والتقدير،،،

د.محمد حجوج
المشرف الاكاديمي

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جامعة القدس
كلية المهن الصحية
دائرة التصوير الطبي
القدس– أبوديس

التاريخ :2024\01\08

حضرة الدكتور يحيى شاور المحترم، ادارة مركز ابن رشد للاشعة - الخليل،

تحية طيبة وبعد،

الموضوع : تسهيل مهمة باحث من جامعة القدس – ابو ديس

ايمانا منا بدوركم في خدمة وتطوير المجتمع الفلسطيني واستنادا لمعرفتنا بالدور الهام الذي تقومون به في دعم التعليم والبحث العلمي،

نتوجه لحضرتكم التكرم بالايعاز للمعنيين المساعدة بتسهيل مهمة طالب الدراسات العليا الباحث محمد مدال من برنامج ماجستير تكنولوجيا التصوير الطبي – كلية المهن الصحية \جامعة القدس في جمع المعلومات اللازمة لدراسة وتقييم " ترسب الحرارة وامتصاصها لدى المرضى الذين يخضعون لفحوصات التصوير بالرنين المغناطيسي كدالة لقوة المجال المغناطيسي ونوع اجهزة التصوير بالرنين المغناطيسي حسب الشركة المصنعة. ". سيقوم الطالب بعمل بحث بعنوان:

"A comparative study of heat deposition in patients undergoing MRI examinations as a function of magnetic field strength and types of MRI devices according to the manufacturer".

وسيتم اطلاعكم على نتائج البحث.

وتفضلوا بقبول فائق الاحترام والتقدير،،،

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دراسة مقارنة لتوزيع معدل الامتصاص النوعي لدى المرضى الذين يخضعون لفحوصات التصوير بالرنين المغناطيسي عند قوى مجال مغناطيسي مختلفة ومن مصنعين مختلفين

اعداد: محمد جميل محمود مدلل

اشراف: د.محمد حجوج

المشرف المساعد: د.منتصر السيد احمد

ملخص الدراسة

تهدف هذه الدراسة إلى تقييم ومقارنة مستويات معدل الامتصاص النوعي ، لدى المرضى الذين خضعوا لفحوصات التصوير بالرنين المغناطيسي بقوة 1.5 تسلا و3 تسلا باستخدام أنظمة التصوير بالرنين المغناطيسي من فيليبس. بالإضافة إلى ذلك، تتضمن الدراسة مقارنة بين أنظمة التصوير بالرنين المغناطيسي بقوة 1.5 تسلا من شركتين مصنعتين (فيليبس و سيمينز). تم استخدام تصميم وصفي مستقبلي مقطعي، شمل 180 مريضًا خضعوا لفحوصات التصوير بالرنين المغناطيسي بقوة مجال محددة وأنظمة الشركة المصنعة. أجريت الدراسة في مستوصف الرحمة/نابلس، ومركز ابن رشد للأشعة/الخليل (الضفة الغربية- فلسطين) من يناير إلى مايو 2024. تم جمع قيم معدل الامتصاص النوعي من سجلات فحص التصوير بالرنين المغناطيسي وتحليلها باستخدام الأساليب الإحصائية، بما في ذلك اختبارات مان ويتني يو وتحليل الانحدار المتعدد. أظهرت النتائج أن أنظمة فيليبس 3 تسلا تُظهر مستوى امتصاص نوعي أعلى بكثير مقارنةً بأنظمة فيليبس 1.5 تسلا، مما يؤكد أن قوى المجال المغناطيسي الأعلى تؤدي إلى زيادة ترسب طاقة الترددات الراديوية . بالإضافة إلى ذلك، أظهرت أنظمة سيمينز 1.5 تسلا مستوى امتصاص نوعي أعلى بكثير من أنظمة فيليبس 1.5 تسلا. اثرت الاختلافات في معلمات تسلسل النبضات، مثل زمن التكرار ، ووقت الصدى ، وعدد الشرائح بشكل كبير على مستويات الامتصاص النوعي، حيث ارتبطت قيم زمن التكرار الأطول وعدد الشرائح الأكبر بقيم معدل امتصاص أعلى. أظهرت تسلسلات التصوير بالرنين المغناطيسي للعمود الفقري القطني عمومًا قيم معدل امتصاص أعلى مقارنة بتسلسلات الدماغ. تؤكد الدراسة على الحاجة إلى المراقبة الدقيقة وتحسين بروتوكولات التصوير بالرنين المغناطيسي لتقليل قيم معدل الامتصاص، وخاصةً لأنظمة قوة المجال المغناطيسي العالية ومعدات الشركات المصنعة المختلفة. المراقبة المستمرة لقيم معدل الامتصاص والالتزام بالإرشادات التنظيمية ضرورية لضمان سلامة المريض أثناء عمليات التصوير بالرنين المغناطيسي.