MAGNETIC INDUCTION TOMOGRAPHY (MIT) SIMULATION STUDY FOR RENAL SCREENING USING DIFFERENT SYSTEM FREQUENCIES AND SIZES OF CALCIUM OXALATE

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DEDICATION

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ABSTRACT

Nephrolithiasis is the process of forming stone in the kidney by crystallization. Due to the increasing prevalence of nephrolithiasis from time to time, medical institutions look for more advanced technology of medical imaging which can tackle the disadvantages of current medical imaging devices for renal, which are non-invasive, free radiation and rapid use. The research encompassed the design simulation study of Magnetic Induction Tomography (MIT) system for renal screening by using COMSOL multiphysics. MIT is a soft field tomography and a non-contact imaging modality used to image the passive electromagnetic properties (conductivity, permittivity and permeability) by applying principle of electromagnetic induction. In this research, 8 copper trans-receiver coils were employed in the MIT system and fixed by the insulation belt. Meanwhile, geometric set-up of renal organ imitates the transverse section at renal level of human body. Sensor performance analysis of MIT system was done based on various frequency and radius of calcium oxalate inside kidneys. In conclusion, frequency and radius of calcium oxalate affect the sensitivity performance of MIT system and has inverse relationship with sensitivity performance.

ABSTRAK

Batu karang adalah proses pembentukan batu di buah pinggang dengan proses penghabluran. Disebabkan peningkatan kes batu karang dari semasa ke semasa, sektor perubatan berusaha untuk mencipta teknologi pengimejan yang lebih canggih yang dapat menangani kekurangan teknologi pengimejan yang terkini untuk buah pinggang, iaitu yang bersifat tidak invasif, tiada radiasi dan pantas. Kajian ini merangkumi kajian simulasi rekabentuk Sistem Tomografi Magnetik Induksi (TMI) bagi pemeriksaan buah pinggang dengan menggunakan *COMSOL Multiphysics*. TMI dikategorikan sebagai medan lembut dan teknologi tiada sentuhan yang menggambarkan sifat elektromagnet pasif (kekonduksian, ketelusan dan kebolehtelapan) dengan menggunakan prinsip induksi elektromagnetik. Dalam kajian ini, 8 gegelung penerima tembaga elektronik telah digunakan dalam sistem TMI yang dipasang pada tali pinggang penebat. Sementara itu, simulasi geometri buah pinggang direka berdasarakan buah pinggang sebenar manusia. Analisis prestasi kepekaan sistem TMI dilakukan berdasarkan variasi gelombang dan radius kalsium oksalat di dalam buah pinggang. Kesimpulannya, gelombang dan radius kalsium oksalat mempengaruhi prestasi kepekaan sistem TMI dan mempunyai hubungan terbalik dengan prestasi kepekaan.

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LIST OF ABBREVIATIONS

CEU	-	Contrast Enhanced Ultrasound
CT	-	Computed Tomography
CT-KUB	-	Computed Tomography of Kidneys, Ureters and Bladder
DCE-MRI	-	Dynamic Contrast Enhanced Magnetic Resonance Imaging
ECT	-	Electrical Capacitance Tomography
EIT	-	Electrical Impedance Tomography
ERT	-	Electrical Resistance Tomography
FEM	-	Finite Element Method
f-MRI	-	Functional Magnetic Resonance Imaging
HEI	-	Holographic Electromagnetic Induction
IDW	-	Inversed Distance Weighted
MIT	-	Magnetic Induction Tomography
MRI	-	Magnetic Resonance Imaging
NDE	-	Non Destructive Examination
PET-MRI	-	Positron Emission Tomography Magnetic Resonance Imaging
TMI	-	Tomografi Magnetik Induksi

LIST OF SYMBOLS

σ	-	Conductivity
ε	-	Permittivity
μ	-	Permeability
ε_r	-	Relative permittivity of material
ε_0	-	Relative permittivity of vacuum
E	-	Electric field intensity
B	-	Magnetic induction intensity
J_s	-	Electric current density
ω	-	Angular frequency of excitation source
ρ	-	Electric charge density
j	-	Imaginary part unit
ΔB	-	Secondary magnetic field
Δv	-	Induced Voltage
Sv	-	Sievert

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CHAPTER 1

INTRODUCTION

1.1 Background

Tomography is originally derived from the Greek word, it brings the meaning of ‘slice’ or ‘section’. The evolution of tomography started as Conrad Röntgen discovered the X-ray in 1895. The X-ray was found to be able to project the internal image of human body. Soon after the discovery, the need of tomography in medical line had been given more attention as it offers many advantages [1]. Tomography technology reduces cost of medication and risk of infection as it can diagnose the illness of patient without the need of dissecting the patient body anatomically.

Nephrolithiasis is the process of forming stone in the kidney by precipitation or crystallization [2]. In the paper, Sreenevasan, G analysed that the occurrence of nephrolithiasis in peninsular Malaysia had increased linearly from 1962 to 1981 from around 225 cases to 425 cases per 100,00 people [3]. It was observed too, that male has higher tendency to develop nephrolithiasis compared to female which is much more related to diet of male group which favour more on protein-based diet [3–5].

Due to the increasing prevalence of nephrolithiasis from time to time, medical institutions look for more advanced technology of medical imaging which can tackle the disadvantage of current medical imaging devices such as Computed Tomography (CT) scanner, ultrasound and Magnetic Resonance Imaging (MRI). CT scanner is limited to pregnant woman as it projects X-ray which is harmful to the development of fetus in mother’s womb [6]. Ultrasound which produces heat can give thermal effect to the patients if used rapidly in long time [7]. Meanwhile, MRI consumes long time for each session of imaging to complete [8].

Thus, in this thesis, Magnetic Induction Tomography (MIT) simulation study had been studied to tackle all the mentioned disadvantages of current medical imaging devices.

1.2 Problem Statement

Current medical imaging devices used for renal screening have respective limitations. In instance, CT scanner cannot done on pregnant woman or children as it projects radioactive substances which can kill or mutate living cells.

Ultrasound which produces heat can cause skin inflammation due to thermal effects which are directly applied on skin. Patients with sensitive skin, such as rashes, deep wound etc, are not advised to use ultrasound as screening method.

MRI takes long time to screen patient which is time ineffective for medical sector, other than gives difficulties to claustrophobic patient as patient needs to be placed inside the capsule for long time. Due to its time ineffective and limited number of device in hospital, many patients have to wait for their scheduled session before their turn to be screened.

Other than that, there is none from previous reseaches on MIT had been done in the application for renal screening. Lack of research input gives gaps of research and difficulties in developing MIT system (hardware).

As the prevalence of nephrolithiasis cases that keep increasing from time to time, a newer and more advanced medical imaging devices for renal screening need to be produced which are convenience to all kinds of people and more time effective.

1.3 Research Objectives

The objectives of the research are:

i. To design sensor configuration of an 8 electrode channel MIT.

ii. To analyze the sensor performance of 8 electrode channel MIT for renal screening using Finite Element Method (FEM).

1.4 Research Scope

In fulfilling the objective i, the research encompassed the design of transverse section of renal organ of human and sensor configuration of an 8 electrode channel MIT. The passive electrical properties (permittivity, permeability and conductivity) of transverse section of renal organ and the 8 electrode channel MIT were then fully defined respectively.

Meanwhile, in order to fulfil the objective ii, the study simulation of 8 electrode channel MIT on renal were done by changing the manipulated variables (frequencies of MIT and radii of kidney stone). The frequencies of MIT were set from 50KHz, 100KHz, 500KHz, 1MHz, 1.5MHz and 2MHz. Meanwhile, the radii of kidney stone ranged from 0.000cm to 0.030cm with increment of 0.003cm of interval for each study simulation. The analyses of sensor performances of MIT were done based on the graphs' trends of sensitivity value.

1.5 Significant of Research

MIT had been used in various applications either in geophysics [9,10], industrial processes [11,12] and biomedical applications [10,13,14]. Focusing in biomedical application alone, researches on MIT only been done on lungs [10], liver

[15], heart [16], heart [16], brain [9,17–20], and cancer cell [9], which all these will be further discussed in Chapter 2.

Research of MIT for renal screening had never been done before. By employing this study simulation, this study could give insight for researchers to develop the hardware of MIT for renal screening application based on the results of MIT sensor performance.

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