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STUDIES ON THE FACTORS AFFECTING THE ELECTRICAL IMPEDANCE CHANGES DUE TO HUMAN BLOOD CIRCULATION

THESIS

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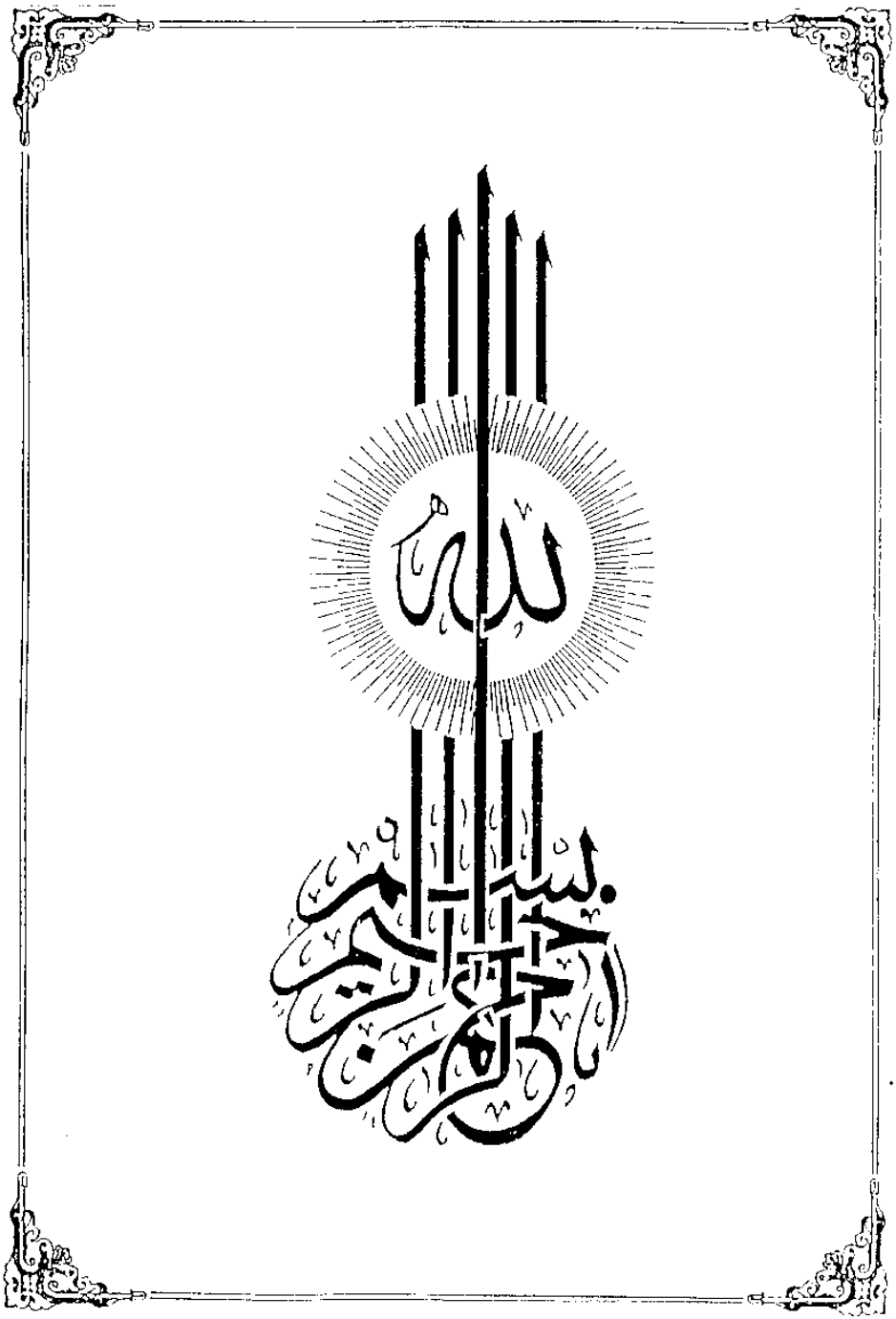

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CONTENTS

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SUMMARY

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SUMMARY

In this thesis the impedance cardiograph for measuring the cardiac stroke volume has been studied. The design and development of such technique are introduced.

Since the blood resistivity is one of the factors which affect the stroke volume values an investigation of its effect has been carried out.

An experimental investigation of the effect of some parameters such as the haematocrit (red cell volume) and body temperature on thorax content resistivity are presented.

A mathematical model of human blood sample in conductivity cell is used and solved by the computer to analyze and explain the electrical properties of the blood.

A theoretical analysis of the blood resistivity as function of haematocrit at different values of temperature are carried out using computer program. Applying this analysis to correlate the cardiac stroke volume values d
the electrical impedance techn
classical technique

The effect of
has been studied t
blood sample betwee

The results
follows :

1- At body temperat
the blood resist

2- The temperature coefficient of resistivity of normal blood is found to be 3.8 per cent per degree.

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3- The increase in haematocrit percent is found to increase the blood resistivity and also produce a considerable effect on the temperature coefficient.

4- It is found that the shape of the resistivity curves as function of temperature at different values of haematocrit percentage does obey regular behaviour.

5- Using the experimental results, an equation linking resistivity with both haematocrit and temperature has been developed in the form

$$\rho = 165.73663\ e^{(0.0164447H-0.0238085T)}$$

6- It is also found that the shape of the curve relating the stroke volume values determined by both the electrical impedance and classical technique, does not obey regular behaviour for a fixed value of blood resistivity.

7- A considerable improvement in the curve has been obtained when the resistivity values has calculated from the above equation.

8- The impedance of the blood becomes more accurate in the range of frequency above 20 KHz, where it is found to be independent on frequency.

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INTRODUCTION

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The basic function of the heart has been described as a blood pump, so the cardiac stroke volume is considered a useful physiological parameter for indicating the efficiency of this pumping action. The most widely used classical techniques for measuring such parameter are the dye dilution and Fick principle techniques which are invasive and not suitable for all patients. Obviously, a greet need exists for a simple technique to obtain the information concerning the activity of the heart, such technique is the electrical impedance technique. This technique based on the assumption that, the electrical impedance of the heart is related to the volume of that heart, and the change in this volume causes change in impedance.

Some authors [1], [2] & [7] compared the estimated cardiac stroke volume obtained from the electrical impedance and the classical techniques. The results obtained from both techniques gave different values. This may be attributed to either the complex structure of the thorax or to the uncorrect value of the resistivity of the thorax content. To make the electrical impedance method acceptable for general use modification must be done to correct the error.

The aim of this thesis is to establish a theoretical investigation of the mechanism involved in the generation of the impedance variation and to study experimentally the effect some physiological parameters such as haematocrit and body

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temperature on the blood resistivity, besides a computer analysis has been done to develope a theoretical relationship relate those parameters to the resistivity and finally using the obtained relation to correlate the impedance values of cardiac stroke volume to the classical dye dilution values by an imperical relation.

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CHAPTER I

METHODS OF EVALUATION OF CARDIAC STROKE VOLUME

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In this chapter a review of the classical techniques (the dye dilution technique and Fick principle technique), for measuring the cardiac stroke volume, is given.

Also the electrical impedance technique has been studied. In order to obtain acceptable results from this method, a modification has been suggested.

1.1) MEASUREMENTS OF CARDIAC STROKE VOLUME USING THE CLASSICAL TECHNIQUES :

As the heart beats, each ventricle pumps out certain volume of blood known as the stroke volume (S.V.). The cardiac output (C.O.) is given by [9] :

$$C.O. = S.V. \times H.R. \qquad (1.1)$$

where H.R. is the heart rate.

The most commonly techniques used to measure the cardiac output are the dye dilution technique and Fick principle technique which could be reviewed as follows :

i) The Dye Dilution Technique :

In this method a known quantity of dye is injected into the vein of the patient. The change in colour due to the passage of dyed blood in a systemic artery is observed using a photo electric device. The imperical formula used for the calculation of cardiac output by this method is given by [9]:

$$\text{Cardiac output in (L/min)} = \frac{60 \cdot I}{C \cdot T} \qquad (1.2)$$

where I is the mean concentration of dye during the first calculation in mg/L and T is the time taken for the first circulation in seconds.

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ii) Fick Principle Technique :

Fick principle involves the analysis of the oxygen content of blood samples taken from different parts of the circulation and the measurement of the oxygen up take in the lungs. The cardiac output is given by [9] :

$$\text{Cardiac output (litre/min.)} = \frac{\text{oxygen uptake (in ml/min)}}{\text{arterial - venous oxygen content difference (in ml/litre)}} \quad (1.3)$$

The oxygen in the blood leaving the lungs is obtained from an arterial blood sample. The determination of the oxygen in the blood arriving at the lungs involves a cardiac catheterization to obtain a sample of blood from the pulmonary artery. The difference in their oxygen concentration (arterial - venous oxygen difference) gives the amount of oxygen taken up by each millilitre of blood passing through the lungs. The oxygen uptake per minute is determined using a spirometer.

1.2) MEASUREMENTS OF CARDIAC STROKE VOLUME USING THE ELECTRICAL IMPEDANCE TECHNIQUE

In searching for a technique which may be able to provide a non invasive measurements of cardiac output, the impedance cardiograph (the electrical impedance technique) is more suitable because of its simplicity and safity for the patients.

The thoracic impedance changes accompanying cardiac activity in the human were recorded firstly by Atzler and Lehmann [16], their technique depends on placing the thorax

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of the subject between two fixed plates of capacitor connected to a tuned circuit of an oscillator operating at approximately 150 MHz. The variations in the resonant frequency of this circuit, produced by the small changes in the effective dielectric accompanying cardiac activity, appeared as voltage changes, which can be rectified, amplified and then recorded using an oscilloscope. An improvement in this method was made by Nyboor [14], who has used electrodes applied directly to the body surface. The obtained radiocardiogram shows a very close relation to the mechanical volume changes of the heart.

Kubicek [12] made a new development in the investigation of the electrical impedance technique.

Fig. (1.1) represents the basic system for measuring cardiac output by the electrical impedance method in which four electrodes have been used, A 100 KHz, 6 MA r.m.s. current signal from the oscillator is applied through electrodes 1 and 4. The potential changes on the surface of the thorax Produced by modifications in the current-density distribution associated with cardiac activity, are picked up by electrodes 2 and 3 and recorded as change of impedance ΔZ.

The method used by Kubicek to measure the cardiac output is based on the familiar equation :

$$R = \rho L/A \qquad (1.4)$$

Nyboer [14] has extended this equation to :

$$R = \rho L^2/V \qquad (1.5)$$

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