A COMPARISON OF THORACIC BIOIMPEDANCE AND PULSE CONTOUR ANALYSIS IN CARDIAC OUTPUT MONITORING IN CRITICALLY ILL

BY

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A dissertation submitted in fulfillment of the requirement for the degree of Master of Medicine (Anaesthesiology)

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ABSTRACT

Hemodynamic monitoring is an important tool especially in critical care unit. The monitoring is varied from invasive cardiac output monitoring to noninvasive cardiac output monitoring. The trends are shifted to non-invasive cardiac output monitoring because it has good correlations with gold standard cardiac output monitoring. Latest invention of thoracic bioimpedance using signal morphology impedance cardiology is new to measure of cardiac output especially in critical care. However, there is limited number of studies comparing this device and gold standard monitoring. Total of 23 patients admitted to intensive care unit, SASMEC that required PiCCO monitoring enrolled in this study. All patients were in septic shock with SOFA score of > 4. Cardiac output parameters were taken using both machines concurrently, at 1,6,12, and 24 hours. Parameters taken were cardiac output, cardiac index, stroke volume, stroke volume index, systemic vascular resistance, and systemic vascular resistance index. Correlation analysis was done by using Pearson's correlation, and mean difference was tested using paired t test and correlation between these two methods were tested using Bland Altman test. Pearson's r correlation coefficient where the result showed significant correlation for 4 different stages of reading for systemic vascular resistance with R of R: 0.92 at first hour, 0.543 at 6 hour, 0.638 at 12 hour, and 0.551 at 24 hour (P value of < 0.05). The first hour reading of systemic vascular reason showed strong correlation, with R 0.92 while the other next 3 readings were moderate in correlation. Other than that, there was moderate correlation of stroke volume r: 0.426 with P value < 0.005. Moderation correlation seen in stroke volume index at stage 2 (R 0.383), stage 3 (R 0.504) and stage 4 (R 0.411) together with stroke volume also showed moderate correlation at stage 3 (R 0.426) and stage 4 (R 0.411). There were significant differences at stage 3 and 4 (p-value <0.05) in stroke volume index while Cardiac index only showed significant in difference in stage 4. Bland Altman showed discrepancy result between both tools and presence of bias. In conclusion, all cardiac output parameters were statistically not significant except systemic vascular resistance. Reading hemodynamic parameters from Physioflow were not interchangeable with transpulmonary thermodilution.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Medicine (Anaesthesiology).

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This dissertation is dedicated to my wife Hanan Umairah binti Hamzah for her dedications, and shoulder for me to carry on this journey.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Critically ill patients are at risk to develop organ dysfunction. Factor contributing to the organs dysfunction is hemodynamic instability which arises from imbalance of circulating volume (e.g. hypovolemia), cardiac function, dysregulation of vascular tone (e.g. Loss of vascular tone in sepsis) and obstruction of blood flow to and from cardiac (tamponade and pulmonary embolism). These will contribute to the mismatch between oxygen demand and oxygen delivery especially in main organs that require high oxygen uptake which eventually leads to failure of an organ and loss of its function at optimal level.

As a result, these contribute to morbidity and mortality of a patient in intensive care. Hence, it is necessary to have hemodynamic monitoring in critically ill patients (Zunic, B., & Peter, S., 2018). The hemodynamic monitoring is important for the clinicians to assess changes of cardiovascular system and to tailor their treatment according to general needs and conditions of a patient. However, to find an optimal hemodynamic monitoring is always a challenge. In a basis of non-critical patients, the basic vital signs monitoring such as pulse rate, blood pressure, oxygen saturation and urine outputs are sufficient, however in critically ill patients, there are a lot of physiological changes occurred, for example in sepsis, there is depressed cardiac contractility secondary to vasodilatory effects from endotoxin , hence it needs to be monitored regularly. The endogenous reserved in the critically ill populations are different from the normal physiological response occurring in the normal population.

Normal person may have excellent physiological response to stress and the changes may not be detrimental to health status of that population. However, the capability of a critically ill patient to react to the stress is lesser compared to normal person, because they have depleted endogenous products to react to the stress cofounding to the comorbidities that she or he might have and with the disease affecting their health.

Based on previous statements, critically ill populations need for more tools to properly monitor their general wellbeing from each aspect of the organ. Heart and cardiovascular system are considered most important organ in our body and it is integral for clinicians to thoroughly monitor the system. The main important function of cardiovascular system is, it delivers oxygen to the end of a cell, for cells to work by producing ATPs through aerobic glycolysis. Other than that, cardiovascular system is also responsible for delivery of other nutrients to the cells, removing toxin from an organ, oxygen storage in the bloods and regulations of pressure in the body (Muller, J. C et al, 2009). Alterations of any part of cardiovascular system may affect functions of other organs and can result in other acute organ injury.

Hemodynamic monitoring is not new. It has started from discovery of pulmonary artery catheter in 1960s, where, since its discovery into the medical society, the use of it has been massive up until in late 20th century. Cardiac output and other haemodynamic parameters were measured using thermodilution technique. However subsequent studies have shown that the usage of pulmonary artery catheter has no benefits but instead, causes more harm to the patients. Since then, there was massive change of interest in usage of the pulmonary artery catheter to the other modalities. For example, PiCCO, an invasive tool with same effectiveness as pulmonary catheter, is using transpulmonary thermodilution technique to measure cardiac output parameters, to development of semi-invasive measuring tools such as transeophageal

echocardiography to simply non-invasive haemodynamic parameters such as USCOM and Transthoracic Bio Impedance. Thoracic bio impedance is interesting due to many factors to the medical society. It is non-invasive tool to measure cardiovascular parameters and it has no complications as compared to invasive pulmonary artery catheterization and central venous line insertion. It needs 6 electrodes to be attached to the skins at the thoracic cage to measure resistance to the electrical current. And most importantly, it has no effect on inter individual factor (such as skills to scan and use echo probe and force to push water into the central line) affecting the reading of parameters.

1.2 PROBLEM STATEMENT

The key point to manage a critically ill patient is to monitor and measure their cardiac output, it is also important for guidance administration of anti-microbial therapy, administrations of inotropic/chronotropic drugs and other drugs since the pharmacokinetic of a patient in critical setting might differ from normal pharmacokinetic of a normal individual. Hence, it is very essential to observe the haemodynamic parameters patterns, trends and changes in critically ill patients . The choice of monitoring haemodynamic parameters from invasive to non invasive monitoring. The usage of swans ganz catheter is outdated because of the complications arises from the insertion of PAC and its use in the intensive care as mention in the studies done by Connors AF Jr, et al. (1996), Harvey S, et al (2006) and Wheeler AP, et al. (2006) and it has been replaced with the use of transpulmonary thermodilution such as PiCCO and since then, PiCCO has been considered as gold standard haemodynamic monitoring tool. The newest tehcnology of measuring haemodynamic parameters using thoracic bioimpedence is interesing, as the calculations are made from

reduction of electrical resistance as it travels through fluids inside thoracic cavity, and it is in the group of non-invasive cardiac output monitoring. Few studies also mentioned that its usage in the post coronary artery bypass graft operation is useful and has significant in patient's improvement; however there is limited study on its usage in critically ill. Some studies mentioned that old technology of thoracic bioimpedance is not efficient in its usage in critically ill. The latest technology in bioimpedance has limited data on its efficiency for cardiovascular monitoring in critically ill patients. Therefore, this study is very good to compare usage of thoracic bioimpedance in critically ill with comparison with PiCCO as a gold standard monitoring.

1.3 PURPOSE OF THE STUDY

To compare cardiac output by using Physioflow (Thoracic Bioimpedance) and Pulse Contour Analysis in critically ill.

1.4 RESEARCH OBJECTIVES

To compare haemodynamic parameters (Stroke Volume, Stroke volume index, cardiac index, systemic vascular resistance, systemic vascular resistance index, extra lung water index and end diastolic filling ratio) by using Physioflow and Pulse Contour Analysis in critically ill.

1.5 RESEARCH QUESTIONS

Are there any association(s) between haemodynamic measurement (Stroke Volume, Stroke volume index, cardiac index, systemic vascular resistance, systemic vascular resistance index, extra lung water index and end diastolic filling ratio) in critically ill patients by Picco and Physio?

1.6 THEORETICAL FRAMEWORK

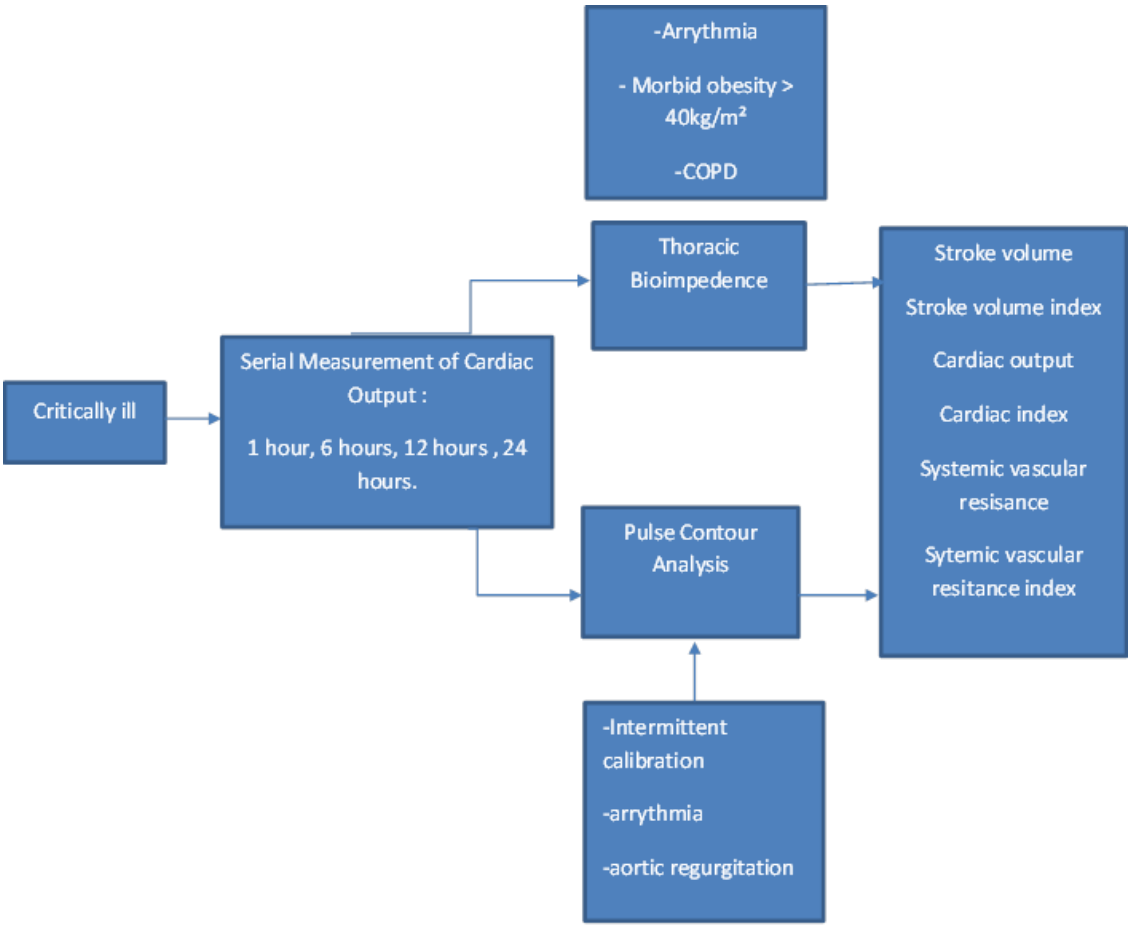

Figure 1.1: Theoretical framework

1.7 RESEARCH HYPOTHESIS

The main hypothesis of this study is, the measurement of haemodynamic measurements using thoracic bioimpedence has significant difference to measurement of haemodynamic monitoring using Pulse Countour Analysis.

1.8 SIGNIFICANCE OF THE STUDY

The outcome of this study is beneficial as it will open more study of thoracic bio impedance in critical care. As far as I know, there is limited no of studies to compare the efficiency of thoracic bioimpedance, especially PHYSIOFLOW and to compare it with gold standard cardiovascular monitoring, PiCCO. The result of this study will further accelerate its function and usage later in ICU.

1.9 LIMITATIONS OF THE STUDY

There were few limitations to this study, which were:

i. It is a single centered study
ii. Small sample size
iii. Purposive sampling

1.10 DEFINITION OF TERMS

I. Cardiac output: Cardiac output is product of stroke volume x heart rate in a minute. It is an amount of blood pumps from the heart in a minute in L/min (Driessen, B., 2012)
II. Stroke volume Stroke volume is amount of blood pump from the each ventricle of the heart per beat in milimeters (Driessen, B. , 2012)
III. Cardiac Index is a cardiac output to body surface area in L/min/m2 (Driessen, B. ,2012)
IV. Stroke volume index is stroke volume to body surface area ml/ min/m2(Nekic, P et all 2016)

V. Systemic Vascular Resistance is a resistance of blood flow by arterioles in PRU (Nekic, P et all 2016)

VI. Systemic Vascular Resistance Index is systemic vascular resistance divided by BSA in PRU (Nekic, P et all 2016)

VII. PAC is balloon tipped thermo dilution catheter 110cms long, that is inserted via a large vein and floated into the pulmonary artery (Nekic, P et all 2016)

VIII. Thermodilution technique is a method of measuring cardiac output by using changes in temperature from proximal lumen and detected at the distal lumen (Opotowsky, A. R, 2017)

IX. PICCO is Pulsion Medical System, Munich, Germany(Opotowsky, A. R, 2017)

X. Transpulmonary Thermodilution technique is a method of measuring cardiac output by using changes in temperature from proximal lumen, which travel through pulmonary circulation before travels into systemic circulation. The changes of temperature will be detected at the thermistor located at the abdominal aorta (Opotowsky, A. R, 2017)

XI. USCOM is ultrasonic cardiac output monitor that measures cardiac output by calculating velocity of the blood flow through aorta and pulmonary valve (Opotowsky, A. R, 2017)

XII. TBE is Thoracic Bioimpedance (Opotowsky, A. R, 2017)

XIII. VO2 is oxygen consumption (.Liu et all, 2016)

XIV. CaO2 is oxygen concentration in the arterial system (.Liu et all, 2016)

XV. CvO2 is oxygen concentration in the venous system (.Liu et all, 2016)

1.11 CHAPTER SUMMARY

This chapter provides the readers with an insight regarding the background of the study with the statement of the problem and the knowledge gap that present. This chapter also provides information on the purpose of the study, the research objectives, the research questions, the research hypothesis and also the significance of the study. Finally, this chapter outlines the theoretical framework related to this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This study is about comparison between two cardiac output and hemodynamic monitoring between thoracic bioimpedence and pulse contour analysis in critically ill. The literature review will focus on the evolution and types of cardiac output monitoring and its efficacy in critically ill from previous randomised control study and systematic review.

2.2 BASIC OF HAEMODYNAMIC MONITORING

All patients admitted to the ICU are critically ill, but the haemodynamic monitoring must be tailored case to case basis. Critically ill patients without haemodynamic instability require less monitoring such as continuous electrocardiographic (ECG) monitoring, regular non-invasive blood pressure measurement, and peripheral pulse oximetry (peripheral oxygen saturation or SpO2 (Zunic, B., & Peter, S. (2018) & Malbrain, et. al, 2016). Patients who are haemodynamically unstable or patients who at risk of haemodynamic instability such as patients with ongoing sepsis likely to develop into septic shock, should have an arterial line for continuous invasive blood pressure monitoring and for analysis of arterial blood gasses (Mehta, 2014). In relation with any critically ill patients requiring inotropic supports, they need central venous line for the administration of the drugs as well and measurement of central venous pressure (CVP) and central venous oxygen saturation (ScvO2). The requirement to use advance haemodynamic monitoring is based on clinical conditions of the patient, for example

clinical deterioration of general status of patient despite optimum of medical therapy and fluid resuscitation (Malbrain, et. al, 2016). The usage of advance medical apparatus for haemodynamic components will help medical personnel to monitor cardiac output parameters and adjust the medications based on haemodynamic measures such as preload, afterload and contractility and at the same time will helps in term of guiding us for fluid resuscitations and initiation or adjustment of inotropic supports. At the same time, haemodynamic monitoring tools can be used as a diagnostic tool to determine the type of shock (hypovolemic, cardiogenic, obstructive, or distributive) according to the hemodynamic profile (Teboul, et. al, 2016) and also as a guide for deresuscitation as fluid overload is a significant negative prognostic factor after resuscitation phase. (Thiel, et al, 2009).

Furthermore, cardiac output is important for optimization of drug dosing, because cardiac output is an important factor for metabolism of the drugs as well as clearance in the kidney (Udy, et. al, 2012). Pharmacokinetic changes in critically ill patients such as augmented renal clearance further warrants clinician to deeply investigate cardiac output monitoring to have optimization of the drug dosing. Previous study has shown that augmented renal clearance that occurred in critically patients may promote drug clearance and in return this will results in inadequate drugs dosing and optimization (Udy, et. al, 2012). Hence, it is really important to emphasize on correct dosing of antimicrobial especially in critically ill. Overdosing may results in damage in the organs and underdosing may leads to toxicity of the medications, as well as failure of antimicrobial therapy especially in critically patients which may lead to an increase patient's mortality and morbidity secondary to the treatment failure and growing up a resistant strain of bacteria to the antimicrobial. There have been 2 case reports on development of multi drugs resistant acinatobacter baumani with low level of

tigecycline (Peleg and Potoski, et. al, 2007). Thus, the influences of the cardiac output monitoring in the initiation, and maintenance of antimicrobial should be sought further. (Udy, et. al, 2012).

2.3 FICK PRINCIPLE

Theoretical measurement of cardiac output was initiated by Adolph Fick back in 1870 (Lee, A. J , et all , 2011) where he computed animal's cardiac output by analysing oxygen concentration in the arterial and venous system where cardiac output is calculated based on this equation.

$$CO = VO2/ CaO2 – CvO2$$

Where in this formula CO is cardiac output, VO2 is oxygen consumption, CaO2 is arterial oxygen content and CvO2 is venous oxygen content (Sangkum, and Liu et. al, 2016). Back in that era, they have performed pulmonary artery catheterisation in the dog, however, PAC introduced in human study after 50 years later. Fick principle states that the flow of blood in a given period of time is equal to the amount of substance entering the stream of flow in the same period of time divided by the difference between the concentrations of the substance in the blood upstream and downstream from its point of entry into the circulation. In human, arterial, and mixed venous oxygen are measured using blood samples from a peripheral arterial line (oxygenated blood) and a pulmonary artery catheter (PAC) (deoxygenated blood), respectively (Malbrain et. al,2016). When shunt is assumed to be absent, the flow between systemic circulation and pulmonary circulation is the same, and hence the right and left cardiac output is also the same, with minimal differences because of presence of bronchial circulation (true shunt). (Nacul, et. al, 2016). At the meantime, VO2 is measured using a spirometer within a closed rebreathing circuit.

Fick principle is considered as gold standard in measurements of cardiac output; however, it is very invasive and it consumes an amount of time, henceforth why, nowadays, why it is rarely performed (Malbrain et. al, 2016). First of all, VO2 Oxygen consumption is calculated by calculating the expired gas volume over a known time and the difference in oxygen concentration of expired and inspired breath. To get an accurate collection of the gas is challenging unless the patient is intubated, because the test is inaccurate in patients with oxygen mask, due to leaking of gas in each breathing (Jaffe, 1999). However in case of high concentration of oxygen gas, two problems will arise. Firstly, high concentration of oxygen may alter and result in inaccuracy of the reading of the analysis due to the non-constancy of the inspired oxygen concentration. Secondly, it is not easy to calculate small changes in oxygen concentration at the top end of the gauge. The denominator of the equivalence, the arteriovenous oxygen content difference, presents a further problem, in that the mixed venous (i.e. pulmonary arterial) oxygen content must be measured and therefore a pulmonary artery catheter is needed to obtain the sample (Jonas, 2001). However, complications may arise from these invasive catheters. In conclusion, the result of cardiac output monitoring will be precise if measurements are done correctly, but it is difficult to perform, especially in intensive care patients (Allsager, et. al, 2003).