A PROSPECTIVE STUDY OF RELATIONSHIP OF VASCULAR PEDICLE WIDTH AND CENTRAL VENOUS PRESSURE WITH VENTILATOR PARAMETERS IN VENTILATED PATIENTS

BY

DR. MOHD FAHMI BIN LUKMAN

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

APACHE	Acute Physiology, Age and Chronic Health Evaluation
CI	Cardiac Index
cm	Centimeter
CTR	Cardiothoracic ratio
CT scan	Computed Tomography scan
CVP	Central Venous Pressure
EDVI	End Diastolic Volume Index
ICU	Intensive Care unit
L	Liter
LAEF	Left Atrial Emptying Fraction
MI	Myocardial Infarction
mm	Milimeter
p	Level of significance
PA	Posteroanterior
PAC	Pulmonary Artery Catheter
PAOP	Pulmonary Artery Occlusion Pressure
PEEP	Positive End Expiratory Pressure
r	Correlation coefficient
SD	Standard deviation
SVC	Superior Vena Cavae
TBV	Total Blood Volume
VPW	Vascular Pedicle Width

ABSTRAK

HUBUNGKAIT DI ANTARA VASCULAR PEDICLE WIDTH DAN TEKANAN VENA PUSAT BERSAMA PARAMETER MESIN BANTUAN HAYAT

Objektif kajian ini adalah untuk menentukan hubungkait di antara Vascular Pedicle Width (VPW), Tekanan Vena Pusat (TVP), Tekanan Positif Akhir Ekspiratori (TPAE) dan Tekanan Inspiratori Kemuncak (TIK) bagi pesakit – pesakit dewasa yang menerima rawatan mesin bantuan hayat menggunakan radiograf dada di dalam keadaan terlentang. Kajian ini bersifat prospektif dan pesakit dipilih secara rawak. Kajian ini telah diluluskan oleh Jawatankuasa Penyelidikan dan Etika , Pusat Pengajian Sains Perubatan, Universiti Sains Malaysia. Seramai 140 pesakit dewasa yang menerima rawatan mesin bantuan hayat di Unit Rawatan Rapi dan Unit Rawatan Rapi Neurosains terlibat di dalam kajian ini, bermula dari bulan Mei 2006 hingga Disember 2006. TVP, TPAE dan TIK dibaca dalam tempoh satu jam selepas radiograf dada diambil. VPW yang diukur menggunakan radiograf dada digital dilaksanakan oleh Penyelidik Radiologi pada tempat yang berasingan, di mana data klinikal pesakit tidak didedahkan. Terdapat hubungkait linear yang signifikan di antara TVP dan VPW. (p<0.001, CI 0.48 – 0.97 mmHg) dengan pesakit yang mempunyai TVP 10 mmHg akan mengalami kelebaran VPW lebih 7.3mm. Terdapat juga hubungkait yang signifikan di antara TPAE dan VPW (p<0.05, CI 0.00 – 0.97 cmH2O) dengan pesakit yang mempunyai TPAE 10 cmH2O akan mengalami kelebaran VPW lebih 4.9mm. Walaubagaimanapun, tiada

hubungkait signifikan antara TIK dan VPW. Tiada hubungkait antara TVP, TPAE dan TIK. TVP mempunyai hubungkait paling kuat dengan VPW, menujukkan penggunaan yang bermanafaat di dalam Unit Rawatan Rapi. TPAE dan TIK, yang bertindak sebagai parameter mesin bantuan hayat, mempunyai hubungkait yang lebih lemah dengan VPW. Oleh itu, pengukuran VPW untuk pesakit pesakit yang menerima rawatan mesin bantuan hayat dapat dilakukan tanpa mengira tahap rawatan yang diberikan.

ABSTRACT

A RELATIONSHIP OF VASCULAR PEDICLE WIDTH AND CENTRAL VENOUS PRESSURE WITH VENTILATOR PARAMETERS IN VENTILATED PATIENTS

The objective of this study is to determine relationship of Vascular Pedicle Width (VPW), Central Venous Pressure (CVP), Positive End Expiratory Pressure (PEEP) and Peak Inspiratory Pressure (PIP) in adult ventilated patients using single supine chest radiograph. This was prospective, randomized study and had been approved by the Research and Ethics Committee, School Of Medical Sciences, Universiti Sains Malaysia. One-hundred and forty adult ventilated patients in Intensive Care Unit (ICU) and Neuroscience Intensive Care Unit of Hospital Universiti Sains Malaysia (HUSM) involved, from May 2006 until December 2006. CVP, PEEP and PIP was taken within 1 hour after chest radiograph taken. VPW was measured on digitalized chest radiograph by Radiology Researcher at separate occasion without clinical data related to patient's condition. There was a significant linear relationship between CVP and VPW (p<0.001, CI 0.48 – 0.97 mmHg), with those who had CVP of 10 mmHg will have VPW wider for 7.3mm. There was also significant linear relationship between PEEP and VPW (p<0.05, CI 0.00 – 0.97 cmH2O) with those who had PEEP of 10 cm H2O have VPW wider for 4.9mm. However, there was no significant linear relationship between PIP and VPW. There was no interaction between independent variables. From these three variables, CVP has a strongest correlation with VPW, which indicate it's

usefulness in ICU. PEEP and PIP, served as ventilator parameters, have weaker relationship with VPW which makes implementation of VPW in ventilated patient regardless of ventilator setting become valuable.

CHAPTER 1: INTRODUCTION

Chest radiograph is the most common noninvasive radiology study requested in Intensive Care Unit (ICU). Chest radiograph not only helps medical personnel in ICU to confirm central line catheterization, nasogastric tube insertion or endotracheal tube placement, but also play a crucial role in diagnosing and treatment of the patient. Since past few decades, doctors in ICU incorporated chest radiograph as part of volume assessment. Together with central venous pressure, input and output of fluids and also hemodynamic parameters, chest radiograph considerably served well as part of diagnosing tool for estimation of adequacy of patient's fluid requirement.

However, even though chest radiograph taken daily, and without missed, every doctors in ICU should put eye on it, the question whether this radiology method is fully utilized or not is still questionable. On top of that, chest radiograph also exposed us into interobserver variability due to it's subjective reading rather than objective presentation. As we already know, subjective reading is experience dependence. Certain doctors with experience in interpreting chest radiograph may give different impression as inexperience ones would be. Therefore, qualitative measurement of chest radiograph is important to reduce these discrepancies.

Over last few decades, researchers have been trying to correlate between measurement of large vessels in chest radiograph with estimation of intravascular fluid volume and overall body fluid content. Fleischner & Udis (1952) studied the relationship of dilatation of the azygous vein as a sign of venous engorgement. Keats *et al.*, (1968) measured arch of the azygous vein in normal population and later followed by study of Heitzman in 1973 involving azygous veins in patients with cardiovascular diseases. Extensive study had been done by Milne *et al.*, (1984) in order to find a correlation of physiologic findings in chest radiograph. He used width of azygous and vascular pedicle as chest radiograph objective finding for estimation of circulation blood volume. Pistolesi *et al.*, (1984) used these measurements in patients with heart diseases. Later on, Ely *et al.*, (2002) studied relationship of width of vascular pedicle and Pulmonary Artery Occlusion Pressure.

In this research project, author determined to study relationship of central venous pressure and vascular pedicle width. Central venous pressure has been chosen because of it's frequency of insertion is higher and more common compared to pulmonary artery catheter. Beside that, as majority of the patients in ICU are ventilated, we would like to see the effects of ventilator parameters such as Positive End Expiratory Pressure and Peak Inspiratory Pressure on vascular pedicle width. As previous study had been done on Caucasians, who are majority having different body habitus compared to Asian, we believe this study needed to be done here, to tailor to our own population.

There is no intention to replace the role of pulmonary artery catheter (PAC) by conducting more studies in noninvasive methods. We believed pulmonary artery catheter still play a major role in Intensive Care Unit. However, with this noninvasive parameter such as vascular pedicle width, we might be able to choose patients appropriately and decide whether invasive monitoring such as PAC insertion is worth or not.

CHAPTER 2: LITERATURE REVIEW

2.1 MONITORING VOLUME IN INTENSIVE CARE UNIT

2.1.1 CENTRAL VENOUS PRESSURE

Central venous pressure (CVP) monitoring is the most common volume monitoring in intensive care unit. CVP is monitored using a central venous catheter. Central venous catheter also can be used for other purposes such as for fluid resuscitation, vasoactive drug infusion, and hyperalimentation in critically ill patients (Duane & Colice, 2000).

The main sites for central venous cannulation are the internal jugular vein and the subclavian vein. The external jugular vein and the cephalic vein in the arm can be used, but these routes appeared to be less successful due to anatomical reasons (Clarke, 2005). These routes however dose not carry the risk of pneumothorax that is inherent in central site access (Duane & Colice, 2000). National Institute for Clinical Excellence produced guidelines for insertion of central venous catheter using ultrasound guidance but identification of landmarks for blind central venous puncture remains a fundamental required skill (Clarke, 2005).

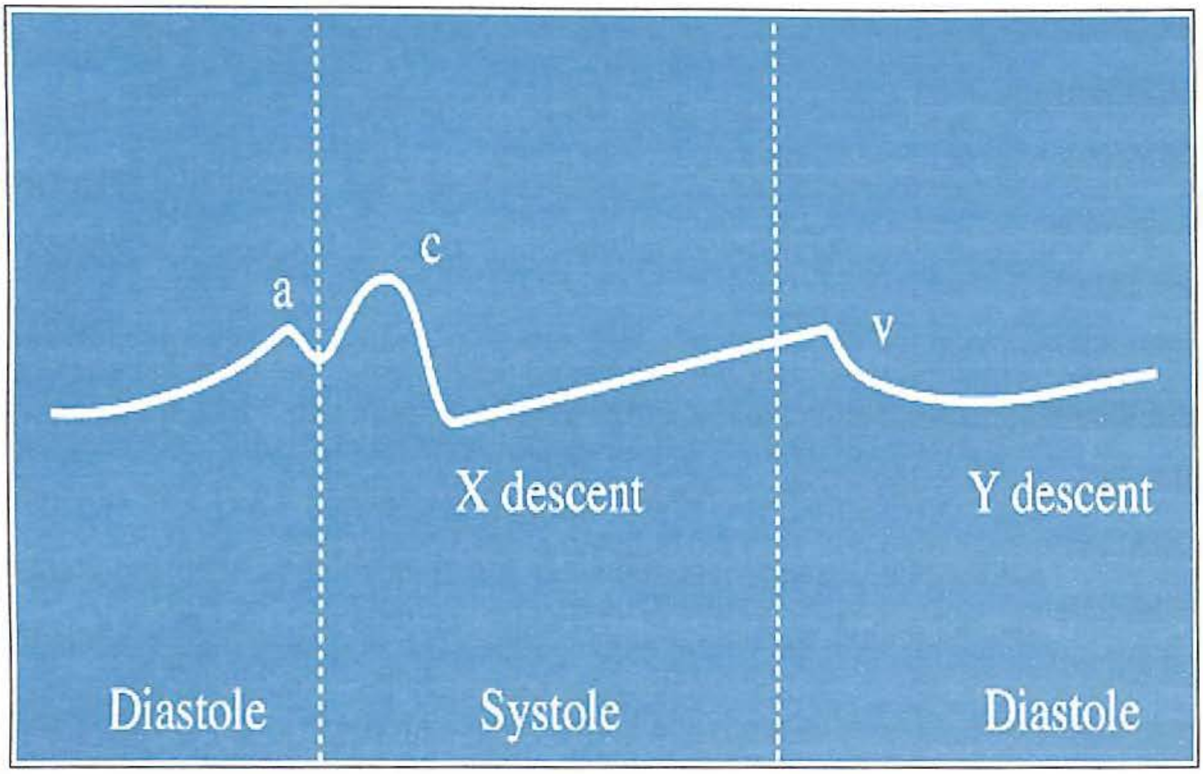

Figure 2.1: Central venous pressure waveforms

CVP waveforms consists three positive deflections (*a, c and v*) and two descents (*x and y*). *a* wave produced by increase venous pressure due to atrial contraction. *c* wave occurred when tricuspid valve displace into right atrium during initial ventricular contraction. *x* descent corresponds to the period of ventricular ejection. *v* wave is produced by increase in atrial pressure that takes place as venous return continues while the tricuspid valve is closed. The *y* descent occurs when the tricuspid valve opens at the conclusion of ventricular contraction and blood enters the right ventricle (Waxman *et al.*, 2003).

Numerous studies argue about validity of central venous pressure for blood volume monitoring, even though CVP has been used for monitor of central venous blood volume for many years (Duane & Colice, 2000). This is because substitution of central venous pressure for right ventricular end-diastolic volume is not always reliable, as ventricular contractility and afterload may alter end-diastolic volume at the same right atrial pressure (Waxman *et al*, 2003). Jellinek *et al.*, (2000) conducted prospective open clinical study involving twenty-two consecutive ventilator dependent patients with mild to severe acute lung injury. The study objective was to evaluate if the preexistant filling state, assessed by right atrial pressure, PAOP and right end-diastolic volume index (EDVI) would define the subsequent hemodynamic effects of increases in airway pressure. They found that those subjects who had CVP that was less than 10 mmHg had a decreased cardiac output when challenged with increasing PEEP. Those subject whose CVP has greater than 10 mmHg showed variable response – they can be increased, decreased or had similar cardiac output. They concluded that patients with right atrial pressure < 10 mmHg if subjected to aggressive positive pressure ventilation, are at risk of hemodynamic deterioration and organ hypoperfusion. They also found that apneic positive airway pressure decreased cardiac output mainly by reducing venous return, and right atrial pressure was the most sensitive in predicting the hemodynamic response followed by PAOP and right ventricular EDVI. This study shows that CVP values more than 10 mmHg cannot be used in blood volume assessment.

CVP monitoring is best used for patient without preexisting cardiac disease as one indicator of the adequacy of venous return and cardiac filling. However, there are affected by ventilation because transthoracic pressure is transmitted through the pericardium and thin – walled venae cavae. During spontaneous ventilation, inspiration lower CVP while exhalation increases it. The situation is reversed in patient with mechanical ventilator (Waxman *et al.*, 2003). Magder *et al.*, (2001) conducted a study with purpose to determine whether the pattern of respiratory variation in right atrial pressure predicts the cardiac output response to positive end – expiratory pressure (PEEP). They studied eighteen patients with variety of cardiac and pulmonary disorders requiring ventilatory support. They used an inspiratory decrease of more than 1 mmHg in CVP in the setting of an adequate inspiratory effort, here defined as an intrathoracic pressure decrease of > -2 mm Hg, as a test to predict preload responsiveness. Patients whose CVP decreased were preload responsive, whereas patients whose CVP did not decrease did not have an increased cardiac output in response to fluid challenge (Duane & Colice, 2000).

2.1.2 Pulmonary artery catheter

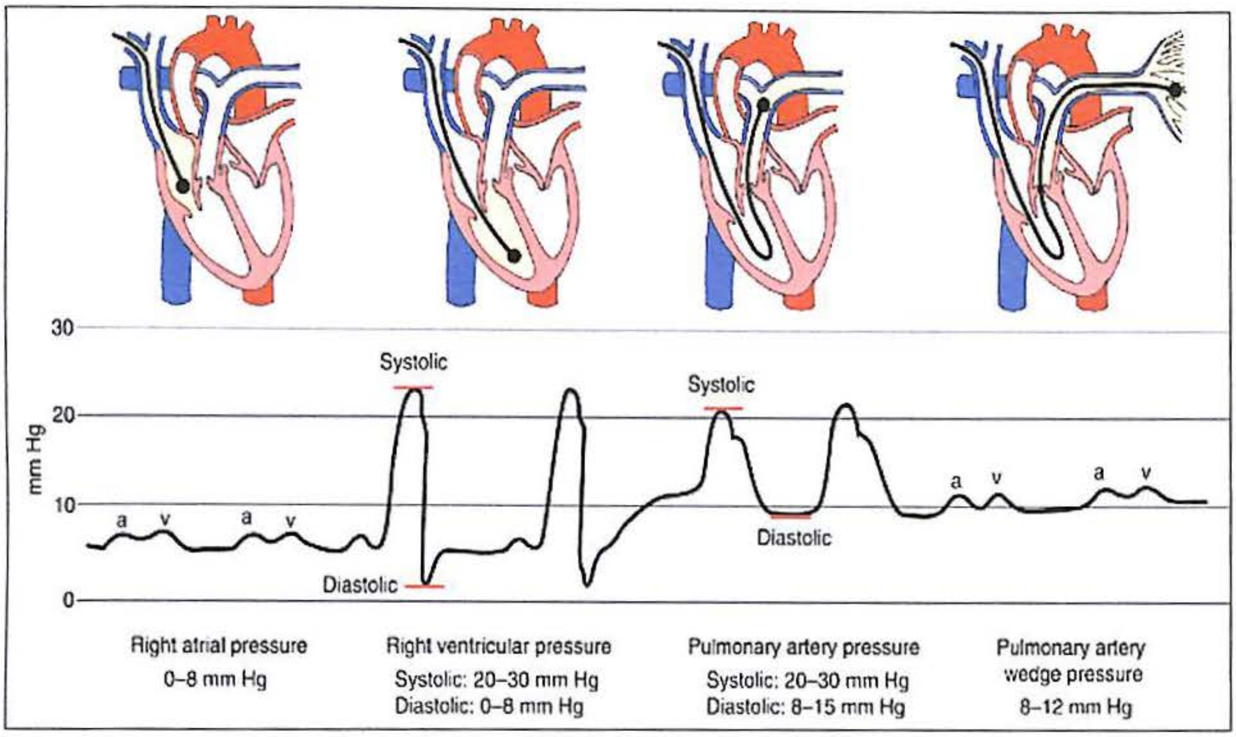

Figure 2.2: Normal values and wave configurations produced by PAC.

Pulmonary artery catheters (PAC) emerged in 1970s and were considered as a gold standard in monitoring patient's volume in intensive care unit. PAC still widely used worldwide until today particularly for patients underwent cardiac surgery or in cardiac intensive care unit. It is estimated that more than 1.2 millions insertions per year (Duke, 2006). However over the last decade, the usage of PAC reduced markedly and sales of PAC in Europe, the United States, and Japan fallen by almost 9% since 2002 – data taken from Edwards LifeSciences, Irvine, CA (Pinsky & Vincent, 2005). This largely due to complications that contributed by PAC insertion. Numerous studies have been done showing that there is no benefit in PAC-associated therapies.

Sandham *et al.*, (2003) compared a goal-directed with standard therapy in an elderly high risk surgical population and found no benefit to PA catheterization. Peters *et al.*, (2003) conducted an observational, retrospective study involving 5-year period data from 1995 to 2000 collected using Acute Physiology, Age and Chronic Health Evaluation (APACHE) score. They found that PAC was used during the first day in 7.7% of ICU admissions with yearly range between 5.7% to 9.1%. 27% of patients without a PAC and 36.7% of patients with PAC died during their hospital stay. They concluded that PAC on the day of admission to medical ICU carries a significant risk factor for hospital death. In fact, tendency for medical community in avoiding PAC presently lead to the introduction of other monitoring devices such as central venous catheter with extended capacity which will be able to derive many of variables that previously can only be acquired by using PAC.

There are few complications related to PAC insertion that worth to mention. The most common complication that occurs during flotation of PAC is the development of cardiac arrhythmias (Coulter & Wiedemann, 1999). The incidence of cardiac arrhythmias are high ranging from 17% to 78% (Thomson, 1979) but later study shows lower incidence, approximately 60% to 70% (Sprung, 1982). Most common arrhythmia is premature ventricular contractions that occur up to 68% (Shah, 1984), whereas ventricular tachycardias occur in 33% of insertions (Sprung, 1981). Catheter related infection also common in PAC insertion. The best estimate of PAC-related colonization is 5.9% to 29.1% and PAC-related bacteremia is 0.4% - 4.6% (Mermel & Maki, 1994). PAC usually inserted via internal jugular vein. Therefore, the incidence of carotid artery puncture can be happen with reported incidence up to 10% (Denys & Uretsky, 1991). Insertion via internal jugular vein also can be complicated with pneumothorax. The incidence of pneumothorax however based on site of insertion and degree of operator experience (Bernard & Stahl, 1971). Venous air embolism also can be happen particularly if patients in upright position, hypovolemic, or during deep inspiration (Peters, 1988) but the incidence is very low (Feliciano, 1979). Mechanical complications include knotting and misplacement. In one study involving 217 cardiac surgery patients Wilson *et al,*. (1984) found the distal tip of the PAC residing in the right main PA in 191 (88%) of the patients. A prospective study by Kaiser *et al,*. (1981) found 19% of internal jugular vein and 16% of subclavian vein cannulation were misplaced. There are other complications that could be more serious than above mention complications. These include cardiac perforation and pulmonary artery rupture. However, pulmonary artery rupture itself is very rare, with incidence of 0.034% (Kearney & Shabbot, 1995).

Pulmonary Artery Consensus Conference Statement 1997 which was partly supported by society of Critical Care Medicine clearly indicated that the strength of evidence demonstrating a benefit was not substantial and in fact, there was evidence that PAC can be detrimental (Duke, 2006). In this Pulmonary Artery Conference Consensus Statement, vital questions related to the PAC were identified and the grade given for the response. The grading of responses to questions and levels of evidence are as below:

Grading of Response to Questions

A – Supported by at least two level I investigations

B – Supported by only one level I investigation

C – Supported by level II investigations only

D – Supported by at least one level III investigation

E – Supported by level IV or level V evidence

Levels of Evidence

Level I – Large, randomized trials with clear cut results; low risk of false positive error or false-negative error.

Level II – Small, randomized trials with uncertain results; moderate to high risk of false positive error or false-negative error.

Level III – Nonrandomized, contemporaneous controls.

Level IV – Nonrandomized, historical controls and expert opinion.

Level V – Case series, uncontrolled studies, and expert opinion.

Based on this consensus, there were only few diseases where PAC improves patient outcomes. These include myocardial infarction (MI) with hypotension, MI with mechanical complication, MI with right ventricular infarction, high risk aortic surgery, trauma and critically ill pediatric patients. But all of these diseases was even put a grade of E. However, in patients underwent peripheral vascular surgery, PAC reduced complications (with grade D) but uncertain in reducing morbidity.

However, Pinsky & Vincent (2005) believed PAC still significant in management of patient and affect outcomes and overall costs. They cited few reasons why use of PAC declining in usage:

i. Placement of PAC increase risk to patients,
ii. The ability to measure similar variables via central venous catheterization, echocardiography or other less invasive technique,
iii. Increased cost,
iv. Misuse of the PAC-derived variables by their inaccurate measurement,
v. Incorrect interpretation and application of the PAC-derived data to clinical care and
vi. Lack of proven benefit of PAC use in the overall management of patients.

However, they also cited few reasons why PAC still has a role:

i. The risks are mainly due to insertion of central catheter not a pulmonary artery catheter,
ii. Continuous monitoring of left ventricular filling pressures, pulmonary vascular pressure, and mixed venous oxygen saturation is a unique feature,
iii. Additional costs are minimal relative to the cost of intensive care,
iv. Measurement errors require ongoing programmatic educational efforts,
v. Pulmonary artery catheter-derived data need to be used within the context of a defined treatment protocol and
vi. No monitoring device will improved patient-centered outcomes unless coupled with a treatment.