Recent Updates: Invasive and Non-Invasive Cardiac Output Monitoring in Critically Ill Septic Patients

Essay

Submitted for Partial Fulfillment of Master Degree
in General Intensive Care

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2017

Abstract

Background: Derangements in the circulation are a common feature of sepsis, trauma, major surgery and other critical illnesses. Detailed evaluation of the circulation is therefore is essential aspect of the clinical management of such patients. Thus the use of cardiac output monitoring technology is increasingly important in evaluating those patients. Sepsis occurs in 1-2% of all hospitalizations and accounts for as much as 25% of ICU bed utilization. Due to it rarely being reported as a primary diagnosis the incidence, mortality, and morbidity rates of sepsis are likely underestimated and It is the second-leading cause of death in non-coronary intensive care unit (ICU) patients, and the tenth-most-common cause of death overall

Aims: The aim of the study is to provide a systemic update of the currently available and most commonly used cardiac output monitoring devices and their integration in management of critically ill septic patients.

Conclusion: Derangements in the circulation are a common feature of sepsis, trauma, major surgery and other critical illnesses. One of the most important thing which affect outcome of the patient with sepsis is clinical monitoring with frequent reassessments. Patient monitoring in severe sepsis is implemented during resuscitation and should not delay initiation of resuscitation; however, hemodynamic monitoring provides for appropriate goals for directed therapy and should completed as soon as is feasibly possible.

Keywords: Recent Updates, Invasive and Non-Invasive, Cardiac Output, Ill Patients

بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا
إلا ما علمتنا إنك أنت
العليم الحكيم

صدق الله العظيم

سورة البقرة الآية: ٣٢

ACKNOWLEDGEMENT

First of all, thanks to **Allah** whose magnificent help was the main factor in completing this work.

No words can express my deep sincere feelings Towards **Prof. Dr. Mohamed Sidky Mahmoud,** Professor of Anesthesia and Intensive Care, Faculty of Medicine-Ain Shams University for his continuous encouragement, guidance and support he gave me throughout the whole work. It has been a great honor for me to work under his generous supervision.

I would like to express my deepest appreciation, respect and thanks to **Dr. Hany Victor Zaki,** Lecturer of Anesthesia and Intensive Care, Faculty of Medicine-Ain Shams University, for his continuous guide in all aspects of life beside his great science, knowledge and information.

I would like to express my deepest appreciation, respect and thanks to **Dr. Rania Hassan Abdel Hafiez,** Lecturer of Anesthesia and Intensive Care, Faculty of Medicine-Ain Shams University, for her continuous guide in all aspects of life beside her great science, knowledge and information.

Last but not least, sincere gratitude to ***My Family*** for their continuous encouragement and spiritual support.

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List of Abbreviations

AdRs	: Adrenoreceptors
ALI	: Acute lung injury
ANP	: Atrial natriuretic protein
ARDS	: Acute respiratory distress syndrome
AT1	: Angiotensin 1
AT2	: Angiotensin 2
ATP	: Adenosine triphosphate
BNP	: B-type natriuretic peptide
Ca^{2+}	: Calcium
CABG	: Coronary artery bypass grafting
Cl^{-}	: Chloride
CO	: Cardiac output
CORTICUS	: Corticosteroid Therapy of Septic Shock
CPB	: Cardio-pulmonary bypass
CVP	: Central venous pressure
ECC	: Excitation-contraction coupling
EF	:Ejection fraction
EVLW	: Extra vascular lung water

ESICM	:European Society of Intensive Care Medicine
GPCRs	: G-proteins coupled receptors
H_2	: Histamine 2
HCN	: Hyperpolarisation-activated cyclic nucleotide-gated
iCa_2+	: Intracellular Ca^{2+}
ICU	: Intensive Care Unit
K+	: Potassium
LiCl	: Lithium chloride
LiD CO	: Lithium dilution technique cardiac output
LV	: Left ventricular
MAP	: Mean arterial pressure
MRSA	: Methicillin-Resistant Staphylococcus Aureus
Na+	: Sodium
NIPPV	: Noninvasive positive pressure ventilation
ODM	: Oesophageal Doppler monitoring
PAC	: Pulmonary artery catheter
PAOP	: Pulmonary artery occlusion pressure
PARs	: Protease-activated receptors
PiCCO	: Pulse Contour Continuous Cardiac Output

PPIs : Proton pump inhibitors

PPV : Arterial pulse pressure

PRAM : Pressure recording analytical method

PSA : Pulsatile systolic area

qSOFA : Quick SOFA

RV : Right ventricle

RyRs : Ryanodine receptors

SAFE : Saline versus Albumin Fluid Evaluation

SAN **:** Sainoatrial node

SERCA : Sarcoplasmic/ endoplasmic reticulum Ca_2+-ATPase

SIRS : Systemic inflammatory response syndrome

SOFA : Sequential organ failure assessment

SR : Sarcoplasmic reticulum

SSC : Survival sepsis campaign

SV : Stroke volume

SvO_2 : Venous oxygen saturation

TnC : Troponin C

TOE : Trans-esophageal echocardiography

VET : Ventricular ejection time

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Introduction

Derangements in the circulation is a common feature of sepsis, trauma, major surgery and other critical illnesses. Detailed evaluation of the circulation is therefore essential aspect of the clinical management of such patients. Thus the use of cardiac output monitoring technology is increasingly important in evaluating those patients. Understanding of the physiological principles applied by such technology is essential for safe and effective use in clinical practice ***(Jhanji et al., 2005).***

Sepsis causes millions of deaths globally each year and is the most common cause of death in people who have been hospitalized ***(Tracey et al., 2014).*** The worldwide incidence of sepsis is estimated to be 18 million cases per year. In the United States sepsis affects approximately 3 in 1,000 people, and severe sepsis contributes to more than 200,000 deaths per year ***(Munford et al., 2011).***

Sepsis occurs in 1-2% of all hospitalizations and accounts for as much as 25% of ICU bed utilization. Due to it rarely being reported as a primary diagnosis the incidence, mortality, and morbidity rates of sepsis are likely underestimated and It is the second-leading cause of death in non-coronary intensive care unit (ICU) patients, and the tenth-most-common cause of death overall ***(Martin et al., 2003)***.

Cardiac output monitoring in critically ill patients is becoming a standard practice in order to ensure tissue oxygenation and has traditionally accomplished using the pulmonary artery catheter (PAC) ***(Connors et al., 1996).***

Recently, the value of PAC has been questioned with some suggestion that its use might not only be unnecessary but also potentially harmful. This notion, together with the availability of new less invasive cardiac output measuring devices, has markedly decreased the widespread use of the PAC ***(Harvey et al., 2016).***

Some of these less invasive devices track stroke volume (SV) continuously and provide dynamic indices of fluids responsiveness, others assessment of volumetric preload variables and some also provide continuous measurement of central venous saturation via the use of proprietary catheters that are attached to the same monitor. All these variables, together with the cardiac output, may result in improvement of hemodynamic management of the critically ill patient. Therefore, the concept of hemodynamic optimization is increasingly recognized as a cornerstone in the management of critically ill patients ***(Lees et al., 2009).***

Aim of the Work

The aim of the study is to provide a systemic update of the currently available and most commonly used cardiac output monitoring devices and their integration in management of critically ill septic patients.

Physiology of Cardiac Output

Cardiac Work:

The work of the heart can be divided into external and internal work. External work is expended to eject blood under pressure, whereas internal work is expended within the ventricle to change the shape of the heart and to prepare it for ejection. Internal work contributes to inefficiency in the performance of the heart. External work, or stroke work, is a product of the stroke volume (SV) and pressure (P) developed during ejection of the SV

$$\text{Stroke work} = \text{SV} \times \text{P or } (\text{LVEDV} - \text{LVESV}) \times \text{P}$$

(Katz, 2011)

The external work and internal work of the ventricle both consume O_2. The clinical significance of internal work is illustrated in the case of a poorly drained LV during cardiopulmonary bypass. Although external work is provided by the roller pump during bypass, myocardial ischemia can still occur because poor drainage of the LV creates tension on the left ventricular wall and increases internal work. The efficiency of cardiac contraction is estimated by the following formula

$$\text{Cardiac efficiency} = \text{External work/Energy equivalent of } O_2 \text{ consumption}$$

(LeWinter and Osol, 2011).