ADVANCED MODALITIES OF HEMODYNAMICS MONITORING IN INTENSIVE CARE

Essay

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By

Mahmoud Mohammed Abdullah AlMagayda

M.B.B.Ch

Under Supervision of

Prof . Dr . Zakaria Abdulaziz Mostafa

Professor of anesthesiology and intensive care
Faculty of medicine- Ain Shams University

Dr. Mohamed Sidky mahmoud

Ass. Professor of anesthesiology and intensive care
Faculty of medicine- Ain Shams University

Faculty of medicine
Ain Shams University
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DR. Mahmoud Mohammed AlMagayda

CONTENTS

List of abbreviation

Abbreviation	
CBF	cerebral blood flow
CI	Cardiac Index
CO	cardiac output
COPiCCOpulse	Monitoring of the cardiac output by continuous arterial pulse contour
CPB	cardiopulmonary bypass
CPP	Cerebral perfusion pressure
CVD	Cardiovascular diseases
CVP	Central Venous Pressure
DBP	Diastolic blood pressure
e.g.	For example
ECG	Electrocardiography
EDV	End Diastolic Volume
EMD	electromechanical dissociation
et al.	et alii (and others)
etc	Etcetera (and other items)
EV	Electrical velocimetry
GEDV	Global end diastolic volume
IABP	Intra-arterial blood pressure
IBP	Invasive (intra-arterial) blood pressure

ICU	Intensive Care Unit
ITBV	Intra-Thoracic Blood Volume
LIDCO	Lithium indicator dilution calibration system
LV	Left Ventricles
MAP	Mean arterial pressure
MCOT	Mobile Cardiac Outpatient Telemetry
MCT	Mobile cardiovascular telemetry
NIBP	noninvasive blood pressure
PA	Pulmonary Artery
PAC	pulmonary artery catheter
PAOP	pulmonary artery occlusion pressure
PCCO	Pulse contour cardiac output
PPV	Pulse Pressure Variation
ROSC	Return of spontaneous circulation
RV	Right Ventricles
SBP	systolic blood pressure
$ScvO_2$	central venous oxygen saturation
SVV	Stoke Volume Variation
TEB	Thoracic electrical bioimpedance
TOE	Trans-oesophageal echo
TTE	Trans-thoracic echo
VO_2	Oxygen Consumption

INTRODUCTION

Hemodynamic assessment is one of the cornerstones of critical care medicine, as hemodynamic alterations may become life-threatening in minutes. Assuring normal hemodynamic values is therefore mandatory to allow one to buy time for patient healing. The problem arises when we have to define normal hemodynamics in critically ill patients. If we are able to define normal hemodynamics, the target values for therapy will follow ***(Gattinoni et al., 2009)***.

Recently, increased interest in a more proactive use of monitoring technologies has emerged, using the response to the measured variables to a defined stress to unveil the physiological state of the subject. This entire field when applied to the assessment of cardiovascular state is referred to as functional hemodynamic monitoring. Within this context, we can define functional hemodynamic monitoring as the assessment of the dynamic interactions of hemodynamic variables in response to a defined perturbation. Such dynamic responses result in emergent parameters of these commonly reported variables that greatly increase the ability of these measures to define cardiovascular state and predict response to therapy ***(Garcia & Pinsky, 2011)***.

Hemodynamic monitoring may be defined as the collection and interpretation of various parameters that inform determination of: (1) the etiology of a state of hypoperfusion and/or (2) the response of the cardiopulmonary unit to interventions such as fluid therapy, vasoactive drugs, or adjustments in positive pressure ventilation. For many patients, adequate monitoring is achieved by routine vital signs along with collection of data such as input/output, physical examination, and urine electrolytes. In other patients, invasive measurements are made, including use of arterial catheters, central venous catheters (CVC), and right heart catheters (RHC). These catheters provide for continuous transduction of pressure in either the arterial or venous circuit and sampling of blood for determination of oxygen saturation. Simultaneous determination of arterial and mixed venous blood gases also permits determination of oxygen content, oxygen delivery, oxygen consumption, arteriovenous oxygen content difference, and calculation of cardiac output by Fick determination ***(Hall, 2003)***.

Hemodynamic monitoring is a cornerstone of care for the hemodynamically unstable patient, but it requires a manifold approach and its use is both context and disease specific. One of the primary goals of hemodynamic monitoring is to alert the health care team to impending cardiovascular crisis before organ injury ensues; it is routinely used in this manner in the operating room during high-risk surgery. Another goal of hemodynamic monitoring is to obtain information specific to the disease processes, which may facilitate diagnosis and treatment and allow one to monitor the response to therapy ***(Gattinoni et al., 2009)***.

The effectiveness of hemodynamic monitoring depends both on available technology and on our ability to diagnose and effectively treat the disease processes for which it is used. The utility of hemodynamic monitoring has evolved as it has merged with information technology and as our understanding of disease pathophysiology has improved. Within this context, hemodynamic monitoring represents a functional tool that may be used to derive estimates of performance and physiological reserve that may in turn direct treatment. However, no monitoring device can improve patient-centered outcomes useless it is coupled to a treatment that improves outcome. Thus, hemodynamic monitoring must be considered within the context of proven medical therapies, success of which is dependent on the clinical condition, pathophysiological state and ability to reverse the identified disease process ***(Gattinoni et al., 2009)***.

Hemodynamic monitoring is a diagnostic tool. Because hemodynamic monitoring often requires invasive procedures, it can be associated with an increased incidence of untoward events. Like any diagnostic tool, its ability to improve outcome will be primarily related to the survival benefit enjoyed by specific therapies that can only be given without complications based on their use. Presently, few specific treatment plans fit into this category. The diagnostic accuracy of preload responsiveness is markedly improved by the use of arterial pulse pressure or stroke volume variation, neither of which requires pulmonary arterial catheterization. The field of hemodynamic monitoring is rapidly evolving and will probably continue to evolve at this rapid pace over the next 5 to 10 years as new technologies, information management systems, and our understanding of the pathophysiology of critical illness progresses ***(Pinsky and Payen, 2005)***.

AIM OF THE ESSAY

- **Aim:**

Reviewing of hemodynamic disorders in intensive care units and the new methods of hemodynamic monitoring

Chapter I

Physiological background

Physiological background

The heart is the driver of the circulatory system generating cardiac output (CO) by rhythmically contracting and relaxing. This creates changes in regional pressures, and, combined with a complex valvular system in the heart and the veins, ensures that the blood moves around the circulatory system in one direction **(Abbas & Hill, 2008)**. The “beating” of the heart generates pulsatile blood flow which is conducted into the arteries, across the micro-circulation and eventually, back via the venous system to the heart **(Costa et al., 2008).**

The aorta, the main artery, leaves the left heart and proceeds to divide into smaller and smaller arteries until they become arterioles, and eventually capillaries, where oxygen transfer occurs **(Lelyveld et al., 2008).** The capillaries connect to venules, into which the deoxygenated blood passes from the cells back into the blood, and the blood then travels back through the network of veins to the right heart **(Marque et al., 2009).**

The micro-circulation - the arterioles, capillaries, and venules constitutes most of the area of the vascular system and is the site of the transfer of O_2, glucose, and enzyme substrates into the cells **(Shah et al., 2005).**

The venous system returns the de-oxygenated blood to the right heart where it is pumped into the lungs to become oxygenated and CO_2 and other gaseous wastes exchanged and expelled during breathing. Blood then returns to the left side of the heart where it begins the process again. Clearly the heart, vessels and lungs are all actively involved in maintaining healthy cells and organs, and all influence hemodynamics **(Squara et al., 2009).**

Definition of Hemodynamic monitoring

Hemodynamics, by definition, is the study of the motion of blood through the body. In simple clinical application this may include the assessment of a patient's heart rate, pulse quality, blood pressure, capillary refill, skin color, skin temperature, and other parameters (**Tsutsui et al., 2009).**

In more practical words **Dellinger et al., 2008** said that hemodynamics is an important part of cardiovascular physiology dealing with the forces the pump (the heart) has to develop to circulate blood through the cardiovascular system. Adequate blood circulation (blood flow) is a necessary condition for adequate supply of oxygen to all tissues, which in return is synonymous with cardiovascular health, survival of surgical patients' longevity and quality of life. To an outside observer (a physician or a nurse) these hemodynamic forces demonstrate themselves as blood pressure and blood flow paired values at different nodes of the cardiovascular system.

Assessment and monitoring of hemodynamics is a cornerstone in critically ill patients as hemodynamic alteration may become life-threatening in a few minutes. Defining normal values in critically ill patients is not easy, because 'normality' is usually referred to healthy subjects at rest **(Raval et al., 2008).**

Defining "adequate" hemodynamics is easier, which embeds whatever pressure and flow set is sufficient to maintain the aerobic metabolism. Accordingly, the alteration of three independent variables - heart (contractility and rate), vascular tone and intravascular volume - may lead to under-filling of the arterial tree, associated with reduced (as during myocardial infarction or hemorrhage) or expanded (sepsis or cirrhosis) plasma volume **(Keren et al., 2007).**

The factors influencing hemodynamics are complex and extensive but include CO, circulating fluid volume, respiration, vascular diameter and resistance, and blood viscosity. Each of these may in turn be influenced by physiological factors, such as diet, exercise, disease, drugs or alcohol, obesity and excess weight **(Wakeling et al., 2005).**

Our understanding of hemodynamics depends on measuring the blood flow at different points in the circulation. A basic approach to understanding hemodynamics is by “feeling the pulse”. This gives simple information regarding the strength of the circulation via the systolic stroke and the heart rate, both important components of the circulation which may be altered in disease **(Reinhart et al., 2004).**

The blood pressure can be simply measured using a plethysmograph or cuff connected to a pressure sensor (mercury or aneroid manometer). This is the most common clinical measure of circulation and provides a peak systolic pressure and a diastolic pressure, often quoted as a normal 115/75 **(Ospina et al., 2008).**

Since the blood flow and blood pressure controls are performed by the cardiovascular system on the basic clock of the system (i.e., the heartbeat) and not on a per-minute basis, the new concepts of "per-beat hemodynamics" have been introduced and propagated by the International Hemodynamic Society **(Squara et al., 2007).**

<u>Hemodynamic Values</u>

The normal range of the hemodynamic parameters varies by facility. Nurses need to follow the parameters set by their hospitals. It is also important to ask the physicians what they consider normal ranges for the individual patient and when they would like to be notified (**Hanley & Belfus 2009).** The nurse should always set patient alarms so that she is immediately aware of any deviation from normal for her patient. The following definitions and values represent a standard range of hemodynamic parameters **(Stoker, 2004).**

The main variables of hemodynamics as classified by **(Boyd et al 2010)** into **static and dynamic** indices.

Static indices as (**Lafanechere et al 2006**) mentioned are:

- **Right atrial pressure** (also known as central venous pressure): describes the pressure of blood in the thoracic vena cava, near the right atrium of the heart. CVP reflects the amount of blood returning to the heart and the ability of the heart to pump the blood into the arterial system.
- **Pulmonary artery occlusion pressure:** is the pressure measured by wedging a pulmonary catheter with an inflated balloon into a small pulmonary arterial branch. Because of the large compliance of the pulmonary circulation, it provides an indirect measure of the left atrial pressure **(Antonelli et al 2006).**
- **Right/left ventricular end diastolic volume:** is the volume of blood in the right and/or left ventricle at end load or filling in (diastole). Because greater End Diastolic Volume (EDVs) cause greater distention of the ventricle, EDV is often used synonymously with preload, which refers