ISSN: 2755-0133

Journal of Medical & Clinical Nursing

Review Article

Open Access

Choosing the Best Method for Hemodynamic Monitoring

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ABSTRACT

Optimizing hemodynamics improves patient outcomes in critically ill patients. There are many types of hemodynamic monitoring. When choosing the monitoring type, factors include accuracy, invasiveness, the desired hemodynamic variables, and potential complications. For example, the Pulmonary Artery Catheter is invasive and can be associated with catheter-related complications. Still, the values it provides have been validated and may be more useful when treating patients with heart problems. New minimally invasive and noninvasive hemodynamic monitoring systems, such as the Flo Trac and the ClearSight, deliver functional hemodynamic values that can be used to evaluate the real-time response to fluid administration. Minimally invasive and noninvasive devices' ease of use, availability, and relative lack of patient complications make them appealing. However, they may lack accuracy in some situations.

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Received: November 17, 2021; **Accepted:** November 22, 2021; **Published:** December 23, 2021

Keywords: hemodynamics, stroke volume, cardiac output, systemic vascular resistance, minimally invasive hemodynamic monitoring, noninvasive hemodynamic monitoring, invasive hemodynamic monitoring, pulmonary artery catheters, shock, fluid responsiveness

Choosing the Best Method for Hemodynamic Monitoring

Optimizing hemodynamics in the operating room and intensive care is essential in attaining the best patient outcomes. However, physicians cannot always accurately predict hemodynamic status changes without hemodynamic monitoring, and many physicians change their treatment decisions based on hemodynamic values [1,2]. There are many ways to obtain hemodynamic values. Pulmonary artery catheters (PACs), such as the Swan-Ganz catheter, are the classic method. However, many risks are inherent with the Swan-Ganz catheter, and recent studies have not correlated its use with improved patient outcomes [1]. Additionally, resource-limited settings may not have access to the technology [1]. Due to these risks, limitations, and lack of evidence for their usefulness in improved patient outcomes, there is a need for less-invasive methods for determining hemodynamic parameters. Alternatively, pulse contour analysis is derived using an arterial waveform, obtained using minimally invasive and noninvasive methods. Minimally invasive devices require an arterial line, and noninvasive devices use external cuffs. One of the benefits of these new devices is their ability to continuously monitor dynamic hemodynamic values, which can help determine a patient's immediate response to fluid challenges [2]. Each type of monitoring device has benefits, limitations, and potential risks. Therefore, it is essential to understand the circumstances and for which patients each monitoring device provides accurate and needed information to guide treatment decisions[2].

Hemodynamic Monitoring

Description

The cardiovascular system delivers oxygen to the cells in the body to optimize cellular function [3]. Inadequate tissue oxygenation can lead to organ dysfunction and potentially the patient's death [3]. The goal of treating critically ill patients is to maximize oxygen delivery to bodily organs and tissues. Hemodynamic monitoring provides information about the heart's ability to pump blood, the capacity of the vascular system, and volume in the vascular system [4]. These values can help determine interventions for patients in the operating room during high-risk surgical procedures and critically ill patients in the intensive care unit with shock [3]. Shock is the inadequate perfusion and oxygenation of the tissues [4]. Hemodynamic assessments can help differentiate between shock types, such as cardiogenic, hypovolemic, obstructive, and distributive [4]. Additionally, patients in shock are often hypotensive, and many factors can cause hypotension. Therefore, hemodynamic monitoring helps target interventions, such as giving more fluids, improving cardiac function, or treating vasodilation by giving vasopressors [4]. Hemodynamic monitoring is a tool, and data should match the providers' physical assessment [2].

Giving fluids is routine in treating patients in shock who are hemodynamically unstable. Providers give fluids when patients have signs of poor perfusion, such as low urine output, high lactate levels, or hypotension [5]. The goal of fluid administration is to increase preload, which is stretching of the myocardial fibers. This, according to the Frank-Starling law of the heart, will increase the strength of the cardiac contraction [5]. The hope is that increased preload will increase stroke volume (SV), which is the amount of blood pumped by the heart with each beat, and therefore cardiac output (CO) [6]. The definition of fluid responsiveness is a 10-15% increase in SV or CO following the administration of 250-500 milliliters of fluid[6]. Without hemodynamic monitors, providers often use blood pressure (BP) and heart rate (HR) to determine the need for fluids [6]. However, BP and HR do not always change immediately due to fluid administration or blood loss [7]. Unfortunately, not all patients positively respond to fluid administration. Determining when fluid administration will be beneficial is the goal because hypovolemia and fluid overload correlate with poor patient outcomes [6]. The main advantage of hemodynamic monitors is to rapidly determine patients' responses to interventions [8].

Hemodynamic values

The central venous pressure (CVP) provides the right-ventricular end-diastolic pressure, a static measurement of preload [3]. Cardiac output (CO) describes the volume of blood pumped by the heart per minute. The CO is calculated by multiplying the heart's stroke volume (SV) by the heart rate [9]. The CO helps to determine the delivery of oxygen. Pulmonary artery (PA) pressures reflect the pressure needed to perfuse blood through the lungs. These values can help identify pulmonary hypertension. The pulmonary artery occlusion pressure (PAOP) provides an indirect measure of left atrial pressure which can assess left ventricular filling [10]. In addition, the PAOP can give information regarding blood volume status [5]. Calculations based on these numbers can provide information about the patient's systemic vascular resistance (SVR). The SVR refers to the resistance to blood flow by the vasculature [11]. Stroke volume variation (SVV) measures cardiac output changes during positive-pressure ventilation [8].

Static Hemodynamic Values

The classic PAC provides intermittent CO monitoring and static measurements of CVP and PAOP. Static measurements are values that give a glimpse of the assumed relationship between the patient's pressure, volume, and cardiac function at a specific moment in time [5]. However, studies have shown that the CVP and PAOP may not accurately determine fluid responsiveness [12,13]. Additionally, blood pressure, heart rate, and pressure-based parameters, such as CVP and PAOP, may not reflect functional hemodynamic values, and flow may decrease before changes in pressure are noted [13].

Functional Hemodynamic Values

Adequate fluid resuscitation is essential in managing critically ill patients [6]. Knowing if a patient will be responsive to fluids can prevent fluid overload and help monitor the response to fluids [14]. Changes in SV, CO, and SVV help determine the response to fluids [8]. Minimally and noninvasive hemodynamic monitors can assess CO, SV, SVV, and BP. Dynamic preload values such as stroke volume variation (SVV) can help determine fluid responsiveness [2]. The stroke volume variation (SVV) reflects a percentage change in stroke volume during a ventilator cycle due to changes in intrathoracic pressure. A small variation in SVV during the ventilator cycle indicates that a patient may not respond to a fluid bolus. An SVV of greater than 10% means a patient might react positively to fluid administration. Once the SVV drops below 10%, the patient is no longer fluid responsive [3].

Many factors limit the usefulness of the SVV value. First, the patient must be intubated and mechanically ventilated to obtain this value. To be the most accurate, the tidal volume of the ventilator must be over 8ml/kg. Critically ill ICU patients often receive lung-protective ventilation modes with low tidal volumes [8]. With low tidal volumes, there is less intrathoracic pressure change. Therefore, the variation in SV will be small, and the SVV may not accurately determine if the patient will respond to fluids [5]. Additionally, if the patient has heart arrhythmias, an open chest, or breathes spontaneously, the SVV value is inaccurate [5].

Methods of Obtaining Hemodynamics

Pulmonary Artery Catheter

There are many different devices and catheters to obtain hemodynamic values. Invasive methods include the pulmonary artery catheter (PAC) or more commonly known as the Swan-Ganz catheter. A pulmonary artery catheter (PAC) is placed in a central vein through the superior vena cava, into the right atrium, and threaded through the right ventricle into the pulmonary artery[3]. The PAC provides the cardiac output (CO), central venous pressure (CVP), pulmonary artery systolic pressures (PA), and pulmonary artery occlusion pressure (PAOP). Calculations using these values can determine a patient's systemic vascular resistance (SVR) and many oxygen delivery and extraction ratios [8].

Pulse Contour Analysis

Pulse contour analysis uses the arterial waveform from an arterial line or a noninvasive cuff to estimate the cardiac output using different proprietary algorithms and the patient's biometric data [8]. This algorithm can assess beat to beat pulse variability in arterial resistance and compliance to determine hemodynamic values [3]. Many types of devices use pulse contour analysis. Some require an arterial line, such as the Flo Trac. Some devices use a noninvasive cuff around a finger, such as the ClearSight [15]. Some devices require calibration to reference their values to another form of cardiac output monitoring. Others are uncalibrated and use biometric and physiologic data in addition to the arterial waveform and the algorithm to estimate the CO (Saugel et al., 2017). Hemodynamic values obtained from minimally invasive and noninvasive methods include the cardiac output (CO), stroke volume (SV), stroke volume variation (SVV), blood pressure (BP), mean arterial pressure (MAP), and systemic vascular resistance (SVR) [2].

Benefits and Drawbacks of Hemodynamic Measurement Methods

Benefits of PACs

PACs provide additional information that minimally invasive and noninvasive methods do not. PACs can provide mixed venous oxygen saturation (SvO_2), reflecting tissue oxygen extraction, and information related to left and right heart functioning [8]. PACs measure filling pressures, which are more sensitive than cardiac volumes [8]. The filling pressures are the standard for defining pulmonary edema and fluid overload [8]. PACs provide more comprehensive measurements of cardiac functioning and are still valuable in monitoring complex patients [4]. In some studies, heart failure patients show improved outcomes with care using hemodynamic monitoring using a PAC [8].

Drawbacks of PACs

Studies have shown that PACs are not associated with improved patient outcomes and can have complications[3]. Catheter-related complications of PACs include infection, arrhythmias, pneumothorax, air embolism, heart valve damage, thromboembolism, pulmonary ischemia, pulmonary hemorrhage, and perforation of the pulmonary artery[16]. Additionally, proper setup and use are essential in obtaining accurate numbers. The American Society of Anesthesiologists (ASA) recommends using PACs only in institutions where the nursing staff have experience using PACs[3]. The experience of the providers is also important. If providers do not have adequate experience placing PACs or interpreting waveforms, the device may cause patient harm[3]. Additionally, many resource-limited settings cannot utilize PACs because they lack the equipment and technology (De Backer et al., 2018). Also, cardiac monitoring using the classic PAC is not continuous, meaning it may be less likely to detect changes during fluid challenges[8].

Benefits of Minimally Invasive Devices
There are many types of minimally invasive hemodynamic monitoring devices. Benefits of minimally invasive devices include their reduced risk of complications compared to a PAC and their ability to obtain functional hemodynamic indicators in real-time [15,17]. Using an algorithm for pulse wave analysis, these monitors can continuously estimate CO [4]. Also, the values provide a beat-by-beat SV evaluation [4]. Providers can use this rapid response time to determine the effectiveness of the fluid challenge by assessing dynamic values, such as the SVV and changes in CO [4,8]. In addition, studies show these devices provide reliable CO measurements in stable patients when CO is normal or low, and these monitors can track short-term changes in CO in response to fluid administration[8]. Lastly, these systems are easy to set up.

Drawbacks of Minimally Invasive Devices
There are drawbacks to minimally invasive hemodynamic monitoring devices. Minimally invasive devices, for example, the Flo Trac, use an arterial line to obtain an arterial waveform [4]. Potential complications from the arterial line include hematoma, nerve injury, and pseudoaneurysm [15]. In addition, the accuracy of the values depends upon the quality of the arterial waveform, and rapid changes in the patient's SVR may make the readings unreliable [4]. Additionally, they may be less accurate in patients with left ventricle (LV) dysfunction, and the dynamic preload indicators can be affected by vasopressor use [2,15]. These values may also become unreliable during hemodynamic instability. Ganter et al. (2016) did not find uncalibrated pulse contour analysis to be accurate in determining trends in CO in patients with septic shock [9]. Therefore, providers need to use caution when using CO measurements from pulse contour analysis devices in hemodynamically unstable patients with rapid changes in vascular tone [2]. However, measurements may be accurate for hemodynamically stable patients.

Other drawbacks include operator error, such as variations in the arterial pressure transducer positioning. Changes in positioning can result in inaccurate values when using pulse contour analysis derived values [16,2]. There are additional limitations in accuracy when determining CO values in obese patients, patients undergoing liver transplants, patients with low CO, and during surgeries that require the clamping and unclamping of major arteries [17]. Lastly, these devices do not provide the same information that a PAC can obtain [18].

Benefits of Noninvasive Hemodynamic Monitoring Devices
The ClearSight system is an example of a noninvasive hemodynamic monitoring device. It uses a finger cuff that rapidly inflates and deflates to obtain an arterial waveform from finger arteries [1]. These devices use the pulse contour analysis method to estimate CO and hemodynamic values [15]. Like the minimally invasive monitor, the noninvasive monitor offers beat-to-beat continuous CO monitoring, thus providing information about a patient's response to fluid administration [4]. The ability to measure BP and CO is relatively accurate in patients with a normal SVR [15]. In addition, this system can determine the SVV [12,2]. A study by assessed the ability of the ClearSight to determine fluid responsiveness during anesthesia and found the ClearSight was able to predict a 10% increase in SV utilizing the SVV value reasonably accurately [2]. These monitors are easy to set up and have relatively no complications [17].

Drawbacks of Noninvasive Hemodynamic Monitoring Devices
Like the minimally invasive device, the noninvasive device may be affected by an altered SVR state [15]. Mukai et al investigated the effectiveness of the ClearSight after vasopressor administration [15]. The results indicated that the ClearSight is accurate for trending BP after vasopressor administration. Unfortunately, its ability to track changes in CO measurements after vasopressor administration was poor [15]. There have been conflicting studies about the noninvasive methods to accurately detect changes in CO after fluid administration. Studies by Bubenek-Turconi et al determined that the ClearSight accurately detects CO changes after fluid administration [15]. In contrast, Monnet et al found poor reliability. Lastly, edema of the fingers may affect limit its use [1].

Conclusion
Maximizing patients' hemodynamic stability improves outcomes. Ensuring that providers base interventions on sound data is essential. Over-treating patients based on inaccurate data can cause poor outcomes [2]. To determine which method of hemodynamic monitoring is best for the patient depends on many factors. Pertinent factors include the device's risks, accuracy, patient characteristics, and type of hemodynamic variables desired[9]. Minimally invasive and noninvasive hemodynamic monitoring devices do not provide all of the information provided by the PAC [8]. Patients with complex heart problems may still benefit from monitoring with the PAC [8].

The main advantages of minimally invasive and noninvasive monitors are their ability to provide continuous evaluation of functional hemodynamic values, which can help determine immediate changes in CO in response to interventions, and their ease of use [7,8]. Drawbacks include their potential inaccuracy for critically ill patients with left ventricular dysfunction, hemodynamic instability, vasopressor use and altered systemic vascular resistance [1,2,4,15]. All hemodynamic values are a tool to help the provider make decisions, and data needs to match the providers' physical assessment [2]. The provider must be aware of the pros and cons of each hemodynamic monitoring system and which patient conditions may cause inaccurate readings [15]. These less invasive methods may be an alternative for patients in whom invasive methods are contradicted, such as in patients with a coagulopathy and in situations where more invasive methods are not available [8,17]. These devices may also be valuable for patients who are more stable and undergoing elective procedures [17]. Minimally invasive and noninvasive devices' ease of use, availability, and relative lack of patient complications make them appealing. Further research is still needed to determine their accuracy and for which patients and which specific situations they can be helpful [1-18].

References
1. Teboul J L, Saugel B, Cecconi M, DeBacker D, Hofer C K (2016) Less invasive hemodynamic monitoring in critically ill patients. Intensive Care Medicine 42: 1350-1359.
2. Saugel B, Bendjelid K, Critchley L A, Rex S, Scheeren T W (2017) Journal of Clinical Monitoring and Computing 2016 end of year summary: Cardiovascular and hemodynamic monitoring. Journal of Clinical Monitoring and Computing, 31: 5-17.
3. Muller J C, Kennard J W, Browne J S, Fecher A M, Hayward TZ (2012) Hemodynamic monitoring in the intensive care unit. Nutrition in Clinical Practice 27: 340-351.
4. Vincent J L, Joosten A, Saugel B (2021) Hemodynamic monitoring and support. Critical Care Medicine 49: 1638-1650.
5. Bridges E (2013) Using functional hemodynamic indicators to guide fluid therapy. AJN, American Journal of Nursing

113: 42-50.
6. Rogers C, Zieleskiewicz L, Demattei C, Lakhal K, Piton G etal. (2019) Time course of fluid responsiveness in sepsis: The fluid challenge revisiting (FCREV) study. Critical Care 23: 179-179.
7. Truijen J, Van Lieshout JJ, Wesselink W A, Westerhof B E (2012) Noninvasive continuous hemodynamic monitoring. Journal of Clinical Monitoring & Computing 26: 267-278.
8. De Backer, D, Bakker, J, Cecconi M, Hajjar L, Liu D W etal. (2018) Alternatives to the Swan-Ganz catheter. Intensive Care Medicine 44: 730-741.
9. Saugel B, Vincent J L (2018) Cardiac output monitoring: How to choose the optimal method for the individual patient. Current Opinion in Critical Care 24: 165-172.
10. Nagy A I, Venkateshvaran A, Dash PK, Barooah B, Merkely B etal. (2014) The pulmonary capillary wedge pressure accurately reflects both normal and elevated left atrial pressure. American Heart Journal 167: 876-883.
11. Ishihara H, Tsutsui M (2014) Impact of changes in systemic vascular resistance on a novel non-invasive continuous cardiac output measurement system based on pulse wave transit time: A report of two cases. Journal of Clinical Monitoring and Computing 28: 423-427.
12. Hoffer CK, Cannesson M (2011) Monitoring fluid responsiveness. Acta Anaesthesiologica Taiwanica 49: 59-65.
13. Johnson A, Mohajer-Esfahani M (2014) Exploring hemodynamics. Critical Care Nursing Clinics of North America 26: 357-375.
14. Pinsky M R (2015) Understanding preload reserve using functional hemodynamic monitoring. Intensive Care Medicine 41:1480-1482.
15. Mukai A, Suehiro K, Kimura A, Tanaka K, Yamada T etal. (2021) Effect of systemic vascular resistance on the reliability of noninvasive hemodynamic monitoring in cardiac surgery. Journal of Cardiothoracic and Vascular Anesthesia 35: 1782-1791.
16. Rudziński P N, Henzel J, Dzielińska Z, Lubiszewska B M, Michalowska I etal (2016) Pulmonary artery rupture as a complication of Swan-Ganz catheter application. Diagnosis and endovascular treatment: A single center's experience. Advances in Interventional Cardiology, 2, 135-139.
17. Pour-Ghaz I, Manolukas T, Foray N, Raja J, Rawal A etal. (2019) Accuracy of non-invasive and minimally invasive hemodynamic monitoring: Where do we stand? Annals of Translational Medicine 7: 421-421.
18. De Backer D, Hajjar LA, Pinsky M R (2018) Is there still a place for the Swan-Ganz catheter? We are not sure. Intensive Care Medicine 44 : 960-962.

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