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HemoSight™

Clinical Information Leaflet

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Personalized and Continuous Hemodynamic Management

Optimum oxygen delivery as the goal:

The purpose of hemodynamic monitoring is to maintain proper perfusion and oxygen delivery, and to assure oxygen supply-consumption balance by clinical intervention of hemodynamics [1].

Oxygen delivery is realized by blood movement within the circulatory system, and the main monitoring parameter is cardiac output (CO). The decisive elements of cardiac output are cardiac preload, cardiac afterload and myocardial contractility (Figure 1).

Each hemodynamic parameter has its limitation in reflecting physiological changes of the patient. Making decisions based upon the rising or falling value of a single parameter may lead to improper clinical treatment, so there is a need to monitor and analyze multiple parameters and make informed decisions for each patient.

In this sense, it can be stated that a comprehensive and dynamic application of multiple monitoring parameters is key to hemodynamic management [2].

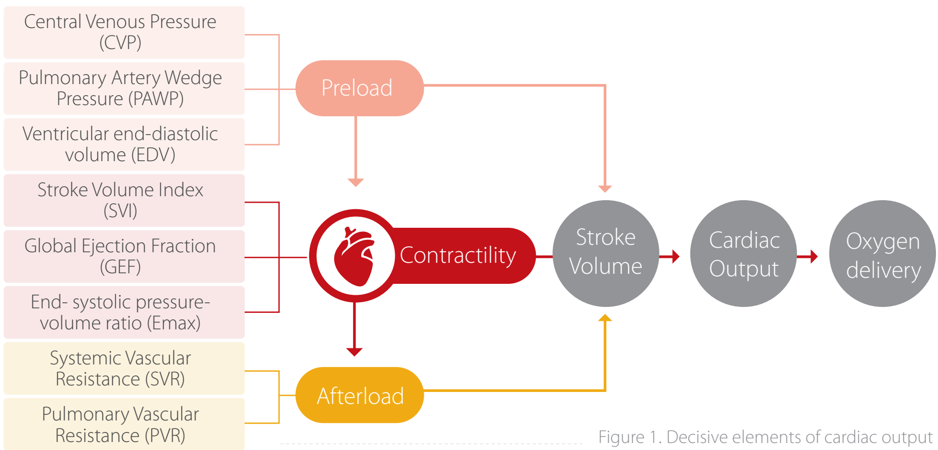


Figure 1. Decisive elements of cardiac output

Personalized continuum of care:

Now we know that mortality within 30 days after surgery is up to 1000 times higher than intraoperative mortality [3,4], and multiple solutions have been proposed to tackle the clinical and economic burden of postoperative complications which leads to death [5]. Among them, one of the most important components is the optimal fluid and hemodynamic management of patients undergoing major surgery. In different stages of hemodynamic therapy, the monitoring method and intensity may differ according to the dynamic status of the patient (Figure 2). This is why personalized hemodynamic management of the patient at every stage of the perioperative process (not only intraoperative) may lead to better outcomes [4,5].

As the technology develops, hemodynamic monitoring is not only useful to reflect patient' s hemodynamic status, but also to find the initial causes and/or disease outcomes by analysing the groups of related hemodynamic parameters that enable practitioners to understand more details of the patient care process [6].Therefore, an adequate management guided by effective and timely hemodynamic monitoring can help reduce the risk of complications and thus potentially improve outcomes along the care pathway for each different patient [6,7].

Patients' diversity, levels of care and hemodynamic monitoring methods:

When it comes to hemodynamic monitoring, there are now many different systems available, and caregivers need to choose among multiple possibilities according to their demands. These systems can be listed in the order of degree of invasiveness, from the highly invasive pulmonary arterial catheter (PAC) to less invasive transpulmonary thermodilution and pulse contour analysis, and completely non-invasive bioimpedance/bioreactance technology.

Decisions of using which method and when to use it are usually based on two main factors: 1. invasiveness of the monitoring procedure and its associated risk; 2. the required accuracy level of the obtained hemodynamic parameters.

In order to obtain comprehensive clinical information, a certain level of invasiveness may be considered. On top of that, there is an increasing demand to minimize the risks entailed, so deciding how invasive the monitoring procedure is should be challenging in certain settings (e.g. perioperative). Therefore, it is important to understand the measurement principles and indications of the invasive, minimally invasive, and non-invasive methods available for hemodynamic monitoring, so that the optimal cardiac output monitoring method can be chosen for the individual critically ill or surgical patient [8].

Combining and integrating parameters from various hemodynamic monitoring systems may help improve the understanding of hemodynamic status [9]. For example, a hypotensive patient with a low cardiac output will present different diagnoses, and correct treatment involves consideration of many factors (hypovolemia, decreased contractility or obstruction) and hence require different treatments to a hypotensive patient with a high cardiac output [9].

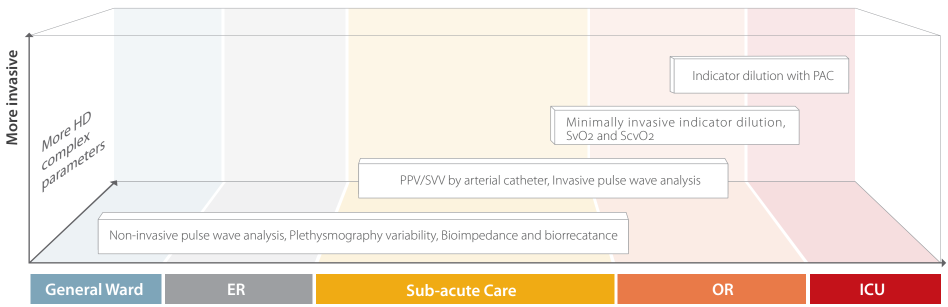


Figure 2. Hemodynamic monitoring techniques within the continuum of care

Comprehensive Hemodynamic Management with HemoSight

HemoSight is a clinical assistive application (CAA) based on the comprehensive hemodynamic monitoring technology. It provides a complete set of clinical assistive tools for hemodynamic management, covering hemodynamic diagnosis, volume therapy tests and treatment follow-up, and all these are sorted by a clear and intuitive interface to enhance clinical workflow.

Hemodynamic diagnosis: Enhanced evaluation with graphic display

In clinical practice, therapy starts with monitoring in order to assess hemodynamic status of the patient. As hemodynamic monitoring technologies are continuously evolving, an increasing number of parameters can be measured. As a result, healthcare professionals acquire a better understanding of patient's hemodynamic status, but on the other hand, a comprehensive analysis of the loads of parameters becomes more and more complicated. Researches showed that human brain could process at most 5 to 7 variables at a time without difficulty [10] and this may be the maximum number of parameters practitioners are able to deal with in hemodynamic monitoring and evaluation.

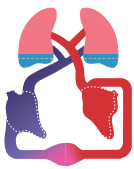
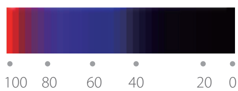
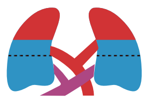


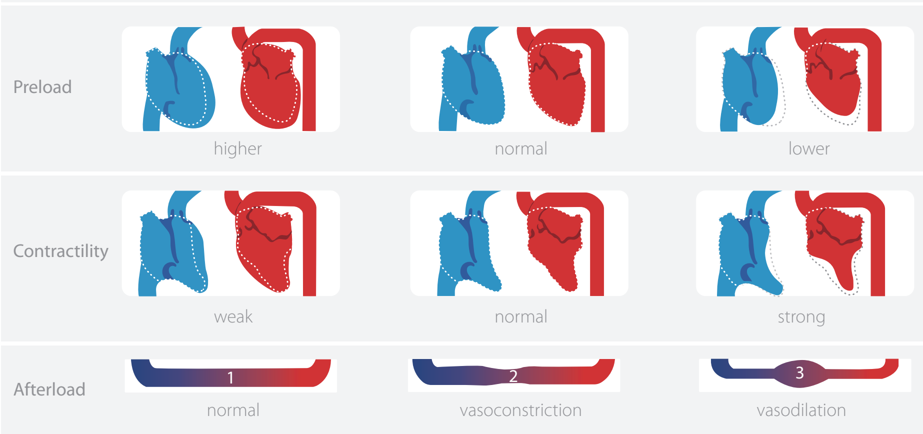
Figure 3. Dynamic graphic display of hemodynamic status



Saturation color scale: the color indicates arterial oxygen saturation.



Liquid level indicates extravascular lung water (EVLW)



A good graphic display helps practitioners obtain information more efficiently and effectively from multiple hemodynamic parameters, thus improving the efficiency and the accuracy of decision making [10,11,12,13,14]. To study how numeric/graphic display affects the ability of anaesthesiologists to perform a diagnosis, Blike GT et al. carried out an experiment, in which data sets consisting of heart rate, systemic arterial blood pressure, pulmonary arterial blood pressure, central venous pressure, and cardiac output were generated and displayed in numeric format and graphic format respectively for subjects to diagnose whether the patients were in shock and the aetiology of the shock [15]. Eleven anaesthesiologists participated in this study and they completed a total of 3060 diagnostic decisions. The test results showed that compared with numeric display, graphic display improved accuracy of diagnosis (shock recognition by 1.4% and aetiology determination by 4.1%, $p < 0.001$) as well as the speed of diagnosis(no-shock recognition by 1.0 seconds, and shock aetiology determination by 1.4 seconds). Also, as Gorges and Staggers summarized in their 2008 review, eighteen studies showed graphic display made practitioners faster in detecting an adverse event; thirteen studies proved graphic display increased the accuracy of clinical diagnosis; and three researches proved graphic display reduced mental workload of practitioners [16].

HemoSight provides not only grouped numeric display of hemodynamic parameters, but also dynamic graphic display, so as to facilitate a faster detection of changes in physiologic variables, a more accurate diagnosis and a decreased mental workload [16,17].

Volume therapy tests: Goal directed therapy with a wider vision

Hemodynamic monitoring alone can reflect hemodynamic status of the patient and provide targets for hemodynamic therapy, but it cannot provide guidance or feedback towards treatment strategy. Therefore, sometimes such monitoring techniques, PAC for example, fail to justify its benefits on patient's outcome [6,18,19]. Hemodynamic therapy should be tissue-perfusion-oriented and optimize cardiac output and oxygen delivery based on functional assessment of each individual's fluid responsiveness [20].

"Surviving Sepsis Campaign(SSC): International Guidelines for Management of Severe Sepsis and Septic Shock 2012" stated that early resuscitation strategies could help improve organ function and reduce mortality rate of patients with septic shock [21,22]. Accurate fluid resuscitation can increase effective circulating blood volume and improve tissue perfusion, thus improving organ function. Improper fluid resuscitation, however, may cause pulmonary and other organ oedema, respiratory failure, prolonged mechanical ventilation, affect oxygen supply, and increase mortality rate in the end [23].

Studies found that only about 50% critical patients respond to fluid resuscitation [24], and for patients not responding to fluid resuscitation, volume expansion therapy will aggravate oedema and hypoxia, worsening prognosis. Therefore, it is of great clinical value to predict volume responsiveness, so as to keep the balance between potential benefits of volume expansion and risk of aggravating lung and tissue oedema [25].

Common indexes and methods to determine volume responsiveness include: static preload indexes, such as central venous pressure (CVP), pulmonary artery wedge pressure (PAWP) and ventricular end-diastolic volume; dynamic preload indexes, such as pulse pressure variation (PPV), stroke volume variation (SVV), and volume responsiveness tests such as RFL (Rapid Fluid Loading) Test and PLR (Passive Leg Raising) Test.

Static preload indexes are actual reflection of cardiac preload. It had been believed that low preload predicts favourable volume responsiveness, while high preload predicts poor volume responsiveness. However, clinical studies have revealed that this traditional use is not reliable [25], because they are interfered by many other factors such as thoracic, pericardial, and abdominal pressures [26]. They reflect volume load status instead of volume responsiveness [27,28,29]. As an index of cardiac volume load status, static preload could be used as safety threshold value with the value individually determined [26].

Dynamic preload indexes assess volume status and predict volume responsiveness through cardiopulmonary interaction mechanism. A large number of studies have proved that dynamic preload indexes are superior to static preload indexes in predicting volume responsiveness in terms of sensitivity and specificity [30,31]. Dynamic preload indexes can be monitored continuously, to assess the real-time volume responsiveness of the patient. However, the clinical application of these indexes is greatly limited. They are only applicable to mechanically ventilated patients without spontaneous respiration or arrhythmia, whose tidal volume exceeds 8ml/kg.

In volume responsiveness tests, practitioners increase volume of the patient experimentally and observe patient' s cardiac output indexes to determine patient' s volume responsiveness. Two techniques are widely available, easy to perform and physiologically based, the PLR (Passive Leg Raising) maneuver and RFL (Rapid Fluid Loading) [32,33].

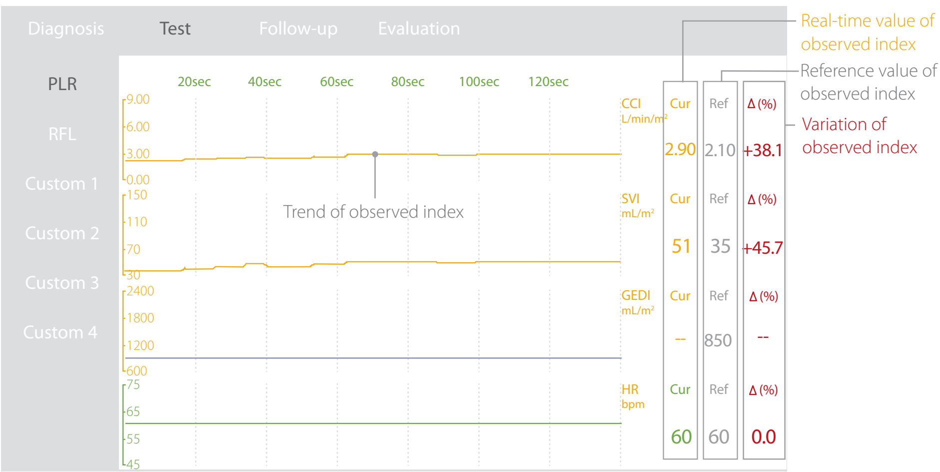


Figure 4. Hemodynamic test tool.

In RFL Test, patient' s volume is increased through experimental fluid resuscitation. In PLR Test, patients' legs are raised, and this leads to transferring a volume of around 300 ml of venous blood from the lower body toward the right heart, thus mimics a fluid challenge [34]. This method has the advantages of reversing its effects rapidly and remains reliable in conditions in which indices of fluid responsiveness that are based on the respiratory variations of stroke volume cannot be used [35], like spontaneous breathing, arrhythmias, low tidal volume ventilation, and low lung compliance. Of note, the technique of cardiac output during PLR must detect short-term and transient changes as PLR effects may vanish very soon; also, cardiac output must be measured not only before and during PLR but also after PLR in order to check the baseline; last but not the least, adrenergic stimulations, such as pain, cough, discomfort and awakening, should be avoided to ensure the correct interpretation of cardiac output changes [35]. To follow the above rules more easily, during the whole procedure of PLR, it is necessary to closely monitor and real-time document the changes of relevant physiologic indexes.

Each of these indexes and methods for volume responsiveness prediction has its advantages and disadvantages. Healthcare professionals should select a proper one for each specific patient in clinical applications.

Hemodynamic test tools (Figure 4) provides dynamic trends of selected indexes in the test process and displays real-time values, reference values and variation (percentage) of selected indexes, enabling more accurate estimation of the patient' s volume responsiveness.

Moreover, as a platform tool, HemoSight provides a user customized test apart from RFL (Rapid Fluid Loading) Test and PLR (Passive Leg Raising) Test. Practitioners can select parameters to be observed and define the test duration.

Treatment Follow Up:
Meaningful Tools to Manage Patients' Evolution

The Frank-Starling law:

The stroke volume (SV) increases when the end diastolic volume (EDV) increases, so the CO can be raised by increasing the preload (administering fluids). This relationship works up to a point when the myocardial tissue cannot stretch anymore, so increasing EDV won't correlate to a higher SV and the patient is at risk of fluid overload while SV starts decreasing (Figure 5) [36].

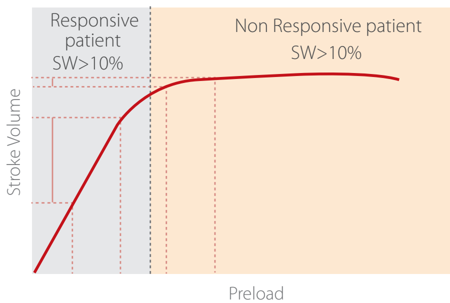


Figure 5. Frank-Starling Curve

The right amount of fluid:

Inappropriate fluid management is a significant cause of patient morbidity and mortality and may result from either too much or too little volume [21,22,23].

The goal of volume resuscitation is to prevent or restore impaired circulatory function from secondary harm to ineffective vascular volume.

- Fluid overload show complications that usually arise in the context of pre-existing cardiorespiratory diseases and severe acute illness.
- Insufficient fluid administration is usually identified by signs and symptoms of inadequate circulation and decreased organ perfusion.

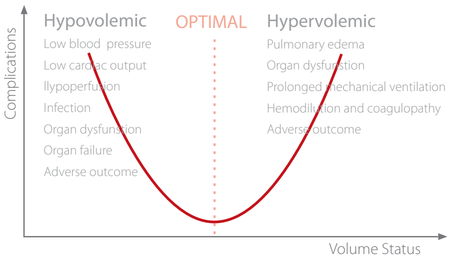


Figure 6. Fluid Optimization

Hemodynamic therapy follow up:

HemoSight keeps track of patient' s preload indexes, cardiac output and extravascular lung water (EVLW) indexes, providing real-time feedback of patient's hemodynamic changes during fluid resuscitation process and helping healthcare professionals better control the treatment process and optimize the hemodynamic therapy.

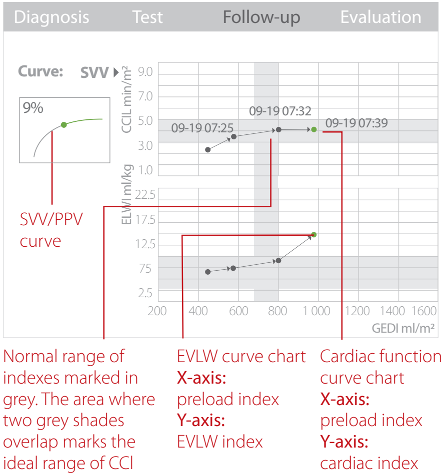


Figure 7. Hemodynamic therapy follow up

SVV/PPV curve indicates the patients' real-time volume responsiveness, helping practitioners keep track of the patients' preload status and determining the goal of fluid resuscitation. It can also remind practitioners when they may need to adjust the treatment strategy, for example, adopting medication treatment other than fluid therapy to improve patient' s unsteady hemodynamic status.

- When a patient' s SVV/PPV is less than 10% and in the green section of the curve, his or her cardiac output is on the platform of Frank-Staring curve and the patient would not respond to fluid resuscitation.
- When a patient' s SVV/PPV is more than 10% and not in the green section of the curve, his or her cardiac output is on the slope of Frank-Staring curve and the patient would respond to fluid resuscitation.

The cardiac function curve chart records how patient's cardiac function alters in the treatment process. Cardiac function of different time points are marked with dots and connected with arrows in chronological order.

Patient’s EVLW line chart is also displayed in follow-up tool. It indicates patient’s real-time extravascular lung water level, helping practitioners keep track of the influence of increased volume load and avoid lung injury of patients.

In addition, visualization of target zones will help clinicians to chase one or more targets [17], and has the potential to improve the compliance when goal-directed strategies are followed.

Mindray’s clinical assistance application tool, HemoSight, helps healthcare professionals to enhance hemodynamic monitoring and management. A comprehensive analysis of multiple hemodynamic parameters and their relationship presented on a simple and intuitive graphic display can optimize clinical workflow. This tool is designed for healthcare professionals to quickly assess a patient’s hemodynamic status and support diagnosis and therapy decision more efficiently with ease.

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