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# Monitoring and Preserving Organ Function in Cardiovascular Anesthesia and Critical Care

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## Abstract

Maintaining organ function and closely monitoring vital signs are necessary in heart-lung anesthesia and critical care. Since oxygen and nutrients are provided via the circulatory system to all organs and tissues, any disruption in its functioning may have negative consequences.

A condition of general anesthesia (GA) would be necessary for the patient to undergo several surgical operations. The patient exhibited the key elements of a successful GA: a reversible loss of consciousness with no movement, no awareness, no response to painful stimuli, and no memory of the surgical intervention. Insufficient GA can result in either an extended recovery period and a higher chance of postoperative problems for the patient (from overdosage) or intraoperative consciousness with recall (from patient underdosage). One major reason for insufficient GA is the limited capacity doctors now must assess awareness levels.

**Keywords***:* organ, function, cardiovascular, anesthesia, critical, care.

## Introduction

Heart-lung anesthesia and critical care require close monitoring and maintenance of organ function. All organs and tissues depend on the circulatory system to provide oxygen and nutrients, therefore any impairment in its operation might have detrimental effects [1].

A number of risk factors for unfavorable outcomes in anesthesia patients have been discovered in recent years. Apart from human error, significant morbidity is linked to respiratory and cardiovascular issues. Basic physiological monitoring has been pushed into clinical practice through assessment of problems. Although it has not been demonstrated that monitoring directly influences results, preliminary data indicates that basic cardiorespiratory monitoring lowers the number of major incidents [1].

Preventing hypothermia also lowers morbidity associated with anesthesia. It is essential to take a body temperature, and one easy, efficient way to prevent hypothermia is by active warming. There is mounting evidence that individuals with coronary artery disease, whether confirmed or suspected, should receive perioperative blockers. It is yet unknown if regional or general anesthetic affects perioperative mortality. Neuraxial anesthesia lowers the incidence of respiratory and

cardiovascular problems in high-risk patient groupings [1].

Millions of people get anesthesia on a regular basis each year. It's still debatable how much anesthetic directly causes perioperative morbidity and death. Nonetheless, it is generally acknowledged that improvements in perioperative care, anesthesia, and surgical technique have contributed to a decrease in mortality, at least in industrialized nations. Age, the degree of concurrent illness, the kind and amount of operation, and other factors all affect perioperative mortality. The mortality risk rises significantly after major surgery, especially emergency procedures, and reaches a maximum of around 10% in elderly patients requiring major emergency surgery [1].

Why is it necessary to monitor the depth of general anaesthesia?

A condition of general anesthesia (GA) would be necessary for the patient to undergo several surgical operations. The patient exhibited the key elements of a successful GA: a reversible loss of consciousness with no movement, no awareness, no response to painful stimuli, and no memory of the surgical intervention. Insufficient GA can result in either an extended recovery period and a higher chance of postoperative problems for the patient (from overdosage) or intraoperative consciousness with recall (from patient underdosage). One major reason for insufficient GA is the limited capacity we now have to assess awareness levels [2].

In unselected patients, the rate of awareness decreased from 1-2 percent in the 1980s to around 0.1% currently. However, there is a significantly higher chance of consciousness with some surgical procedures (such heart surgery or cesarean sections) or high risk individuals. Intraoperative awareness can have a variety of outcomes, from a PTSD diagnosis to the lack of long-term aftereffects. Comparatively, between 1990 and 2006, the global anesthesia-related death rate varied from 75 in Thailand to 1 in the USA or Japan per 100,000 anesthetic treatments. Cardiovascular events associated with anesthesia and medication delivery, as well as issues with airway care, were the primary causes of anesthesia-related death [2].

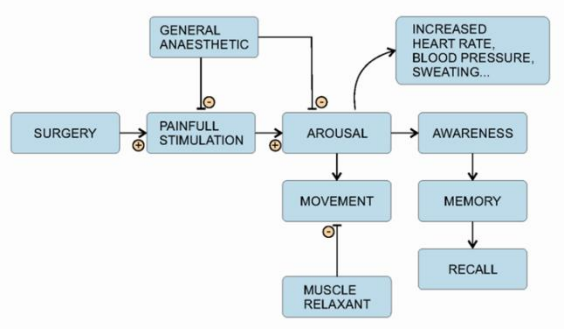


Figure (1) The connection between general anesthesia, surgical stimuli, and consciousness [2].

The autonomic nerve system (ANS) regulates vital bodily processes including breathing, circulation, thermoregulation, and hormone production. Additionally, it has a big impact on how people respond to different internal and external events that might change homeostasis. As ANS dysfunction may exacerbate the perioperative course for the surgical patient under anesthesia, increasing morbidity and mortality, it should be considered as an additional risk factor during pre-operative examination. Furthermore, ANS dysfunction can exacerbate the clinical course of critically ill patients hospitalized to intensive care units in instances of trauma, sepsis, neurologic disorders, and cardiovascular diseases, and its presence has a detrimental effect on the result [3].

When it comes to etiology, risk assessment, early prognosis prediction, and therapy approaches, autonomic function evaluation can be helpful in the management of these patients. Anesthesiologists and intensivists should understand how important it is to evaluate ANS function given the importance of the ANS in maintaining systemic homeostasis. Heart rate variability (HRV) measurement provides a simple way to evaluate autonomic function. This inexpensive, non-invasive, and easy-to-use technique reflects the equilibrium of the autonomic nervous system's control over heart rate and provides a means of identifying the

existence of autonomic neuropathy, which can exacerbate a number of disorders [3].

## Literature Review

Anesthetic Preferences for Cardiac Anesthesia

Heart surgery anesthesia is intricate, juggling the fundamental goals of general anesthesia with hemodynamic stability, myocardial function preservation, and organ preservation—often in the particular setting of cardiopulmonary bypass (CPB). To that end, a variety of anesthetics can be employed; nevertheless, an absolute best agent or method has still to be found. First reported in 1974, volatile anesthetic usage during CPB has persisted in popularity because of its possible heart-protective qualities and the desire to stay away from modern long-acting intravenous drugs.

In 1969, high-dose opioid administration during cardiac anesthesia was initially found to be advantageous for patients with little circulatory reserve, and the use of ultra-short-acting opioids, a more recent development, is still prevalent today. Upon the release of propofol in the early 2000s, healthcare professionals have a quick acting intravenous substitute for volatile substances and potent opioids [4].

Research focusing on possible variations in their nonanesthetic effects has attempted to inform practice as intravenous and volatile drugs with comparable anesthetic potency become more readily available. For instance, evidence from a number of modest clinical trials imply that using volatile chemicals preferentially may indicate protection for the heart, kidneys, and brain.In their 2007 guidelines for perioperative treatment, the American College of Cardiologists and the American Heart Association recommended the use of volatile agents during noncardiac surgery due to their potential to prevent postoperative myocardial infarction after cardiac surgery. Furthermore, studies comparing volatile agents to injectable agents have demonstrated a reduction in mortality, length of stay in the intensive care unit (ICU), and time spent on mechanical ventilation. Other clinical investigations, however, have not discovered any distinctions between volatile and intravenous anesthetic regimes in terms of postoperative cardiac damage or death. Most remarkably, a recent multicenter single-blind controlled experiment compared intravenous and volatile anesthetics in 5400 patients undergoing heart surgery and showed no difference in myocardial infarction or 1-year death [4].

When compared to TIVA, general anesthesia with volatile anesthetics was linked to significant improvements in outcome, such as decreased mortality and a lower incidence of pulmonary and other problems, but not in noncardiac surgery [5].

The sedation provider should be informed of any medical conditions or comorbidities that may increase the risk of complications by going over previous medical records and interacting with patients or caregivers. These include severe abnormalities of the organ systems, allergies, obstructive sleep apnea, morbid obesity, a history of sedation, and a history of using mental medications [17].

Drug overdose is the primary cause of most sedation-related issues. 21% of sedation-related claims were connected to respiratory depression, according to an analysis of the American Society of Anesthesiologists' (ASA) Closed Claims database; more than 50% of these claims were found to be "preventable" if proper monitoring and an alarm system had been implemented [18].

Hemodynamic monitoring in intensive care unit

In the intensive care unit (ICU), multiple organ dysfunction syndrome is the primary cause of mortality for patients. This kind of issue puts a tremendous strain on all hospital services, particularly critical care. A significant role in the development and maintenance of multiple organ dysfunction syndrome appears to be played by changes in systemic hemodynamics, organ perfusion, and tissue microcirculation that result in tissue hypoxia, even if the precise pathophysiology of this disease is yet unknown.

"Arterial oxygen content, arterial pressures, blood stream velocity, cardiac work mode, and respiration mode are all incidental and subordinate; they all combine to service the cell," according to Pflueger's 1872 statement [6].

It's still difficult to monitor severely sick ICU patients optimally. The question of whether the patient will benefit from more intensive monitoring is still up for debate. Regretfully, we don't know anything about this field right now. Early identification of hemodynamic catastrophe seems to be critical, and earlier treatment seems to enhance prognosis in this case [6].

Monitoring cardiac function in intensive care

One of the most common organs to fail during a severe illness is the heart, hence accurate assessment and monitoring of cardiac function are crucial in the intensive care unit (ICU).Myocardial function may also be indirectly impacted by other failing organs and the treatments that sustain them. The fact that many illnesses have a greater mortality rate in a low flow condition emphasizes the importance of monitoring heart function. Since clinical flow estimation is rarely reliable, we frequently titrate medications to keep blood pressure within an acceptable range. Although it is crucial to maintain an appropriate perfusion pressure to the organs, equation 1 and figure (2) show that systemic vascular resistance (SVR) and cardiac output (CO) have an impact on blood pressure [7].

Mean blood pressure ≈ cardiac output × systemic vascular resistance (1)

**Table 1** Common measured and calculated haemodynamic variables[20 76]

| Parameter | Formula | Normal range | Units |
|---|---|---|---|
| Cardiac index | CI = CO / body surface area | 3.5–5.5 | l/min/m² |
| Stroke index | SI = CI / heart rate | 30–60 | ml/m² |
| Arterial oxygen content | $CaO_2 = (1.34 \times Hgb \times SaO_2) + (PaO_2 \times 0.03)$ | | ml/l |
| Oxygen delivery | $DO_2 = CI \times CaO_2$ | 570–670 | ml/min/m² |
| Fick principle | $CI = VO_2 / (CaO_2 - CvO_2)$ | 160–180 (infant $VO_2$) | ml/min/m² |
| | | 100–130 (child $VO_2$) | ml/min/m² |
| Oxygen extraction ratio* | $OER = (SaO_2 - SvO_2) / SaO_2$ | 0.24–0.28 | |
| Oxygen excess factor* | $\Omega = SaO_2 / (SaO_2 - SvO_2)$ | 3.6–4.2 | |
| Systemic vascular resistance index | SVRI = 79.9 × (MAP – CVP) / CI | 800–1600 | dyn-s/cm²/m² |
| Left ventricular stroke work index | LVSWI = SI × MAP × 0.0136 | 50–62 (adult) | gm/m² |

$CO$, cardiac output; $CI$, cardiac index; $CVP$, central venous pressure [mmHg]; $CaO_2$, arterial oxygen content; $CvO_2$, mixed venous oxygen content; $DO_2$, oxygen delivery; $Hgb$, haemoglobin concentration [g/l]; $LVSWI$, left ventricular stroke work index; $MAP$, mean arterial pressure [mmHg]; $OER$, oxygen extraction ratio; $PaO_2$, partial pressure of dissolved oxygen; $SaO_2$, arterial oxygen saturation; $SvO_2$, mixed venous oxygen saturation; $SI$, stroke index; $SVRI$, systemic vascular resistance index; $VO_2$, oxygen consumption; $\Omega$, oxygen excess factor.
*The equations given for OER and Ω are only valid if the contribution from dissolved oxygen is minimal. If this is not the case, oxygen content ($CaO_2$, $CvO_2$) must be substituted for saturation ($SaO_2$, $SvO_2$).

Figure (2) common measured and calculated hemodynamic variables [7].

As a result, low CO, low SVR, or both may be the secondary cause of low blood pressure. On the other hand, if SVR is high, normal blood pressure might persist despite decreasing CO. Numerous factors can lead to a low CO, such as insufficient vascular volume, high afterload, poor contractility, diastolic dysfunction, myocardial limitation, valvular stenosis/insufficiency, or cardiac arrhythmia. During the course of a disease, any of these anomalies may coexist and fluctuate, thus a therapy that was suitable at one point in time may become inappropriate when the patient's clinical condition changes.Six Therefore, the assessment of the initial hemodynamic condition, determining the response to therapy, and continuing examination of changes in the hemodynamic state as the illness progresses are all included in the role of cardiac monitoring [7].

Oxygenation monitoring

Assessing end organ oxygenation may be helpful while caring for a critically sick patient. Previous studies have shown that standard monitoring of heart rate, urine output, central venous pressure (CVP), cardiac output (CO), and blood pressure (BP) is inadequate for detecting decreased tissue oxygenation events due to compensatory autonomic processes, such as regional vasoconstriction. This theory implies that in order to identify these compensatory stress states, the microcirculatory status may be assessed, for instance, by noninvasively measuring tissue oxygen saturation (StO2) in combination with a functional hemodynamic monitoring test, such as the vascular occlusion test (VOT). It has been demonstrated that noninvasive StO2 assessment using near infrared spectroscopy (NIRs) is a reliable technique to evaluate the state of microcirculation, particularly in septic and trauma patients. It has been demonstrated that adding a dynamic ischemia challenge, where VOT is used, improves the prediction of StO2 to detect tissue hypoperfusion [8].

Similar to this, as aberrant blood flow to the splanchnic circulation is linked to a number of morbidities, including multiple organ failure that can be fatal, the capacity to continually

monitor oxygen supply to organs supplied by this circulation may also be crucial. Serum lactate levels and mixed venous saturation (SvO2) are examples of measures of global oxygen supply and demand, but they may not be a good indicator of localized tissue viability and splanchnic oxygen delivery. It is possible to hypothesize that treating the underlying physiological condition would enable treatment of reduced splanchnic circulation before other systemic measurements (SvO2, lactate, HR, UOP, BP, and CVP) are impacted. This would be accomplished by measuring oxygen supply to an organ system that is supplied by the splanchnic circulation. Visible light spectroscopy (VLS) using an oesophageal probe T-STAT 303 (Spectres Corporation, Portola Valley, CA, USA) has shown promising preliminary evidence about its capacity to identify ischemia to the splanchnic bed [8].

Perfusion monitoring

It is impossible to separate oxygenation from perfusion. In fact, all circulations have low flow and lower TO2 relative to VO2, which results in decreased ScvO2, when global perfusion is reduced because of decreasing CO. Despite the fact that ScvO2-guided treatment decreased septic shock mortality, multiorgan failure with hypoperfusion still contributed to 30% of deaths. This disparity is most likely caused by ScvO2's incapacity to investigate microcirculatory or locoregional perfusion. In fact, tissue surrounding nonperfused capillaries will experience hypoxia as a result of perfusion heterogeneity, such as that seen in septic shock. Because capillaries that are still perfused will get extra shunted flow from nonperfused capillaries, the resulting net venous capillary oxygen saturation will be a combination of highly saturated from open capillaries and low saturations from closed capillaries, with a normal net ScvO2. This is because the amount of oxygen consumed by the environment doesn't vary (Figure 3) [8].

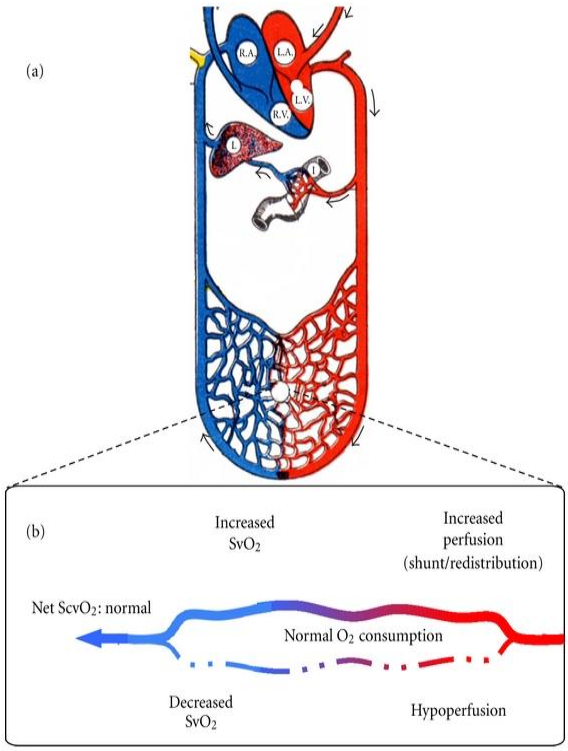


Figure (3) oxygenation and perfusion relationship [8].

During sedation, the most common adverse event is respiratory depression caused by an overdose of sedatives [9].

Pulse oximetry should be used to check for hypoxemia or desaturation in any patient receiving procedural sedation [10]. Since pulse oximetry gauges arterial oxygen saturation, it may take longer to identify individuals with impaired respiratory function, particularly if they are getting extra oxygen. Pulse oximetry is not as good as measuring exhaled carbon dioxide tension for the early identification of hypoventilation [11].

Neurological monitoring

Although electroencephalography (EEG) was used in some of the initial cardiopulmonary bypass treatments and is a tool that assesses cerebrocortical neuronal electrical activity, it is not widely used in practice today. Transcranial Doppler (TCD) ultrasonography can be used to constantly and noninvasively examine the impact of intracranial hemodynamics on reported EEG changes. TCD offers vascular resistance or abrupt changes in blood flow

indications in addition to emboli identification. Regional cerebral venous oxygen saturation (rCVOS) can also be used to track the metabolic state of cortical neurons by noninvasive transcranial near-infrared spectroscopy. Over a broad variety of temperatures, perfusion pressures, and anesthetic states, the percentage rCVOS often stays astonishingly steady. A significant imbalance between the supply and consumption of oxygen is indicated by a noticeable shift in either direction. Since rCVOS measurement does not need pulsatile or other blood flow, it is the only monitoring option available during circulatory arrest. These technologies enable prompt identification and remediation of potentially dangerous circumstances by describing the dynamic interaction between brain hemodynamics, metabolism, and electrogenesis [12].

Coagulation Monitoring

Perioperative blood coagulation monitoring is crucial for understanding the causes of hemorrhage, predicting the risk of bleeding during following anesthesia or surgical procedures, and guiding hemostatic treatment. Point-of-care (POC) coagulation monitoring devices that assess the viscoelastic properties of whole blood, such as thromboelastographic, rotating thermoelectrometry, and Sonoclot analysis, can potentially address the limitations of routine coagulation tests in the perioperative setting. These methods have the benefit of being able to quantify the clotting process with minimum delays, beginning with fibrin production and continuing through clot retraction and fibrinolysis at the bedside [13].

Additionally, whole blood testing is used to evaluate the coagulation state of patients. This allows the plasmatic coagulation system to interact with red blood cells and platelets, supplying valuable extra data on platelet function. In clinical practice, viscoelastic POC coagulation devices are being utilized more and more, particularly in the treatment of patients having liver and heart surgery. Additionally, they offer valuable data in a wide range of therapeutic situations, such as severe bleeding, evaluating hypo- and hypercoagulable states, directing pro- and anticoagulant treatments, and identifying surgical bleeding. When the findings of the viscoelastic test are normal, the surgical etiology of bleeding must be taken into account. In conclusion, pro- and anticoagulant treatments may be guided by viscoelastic POC coagulation devices, which may also assist in determining the source of bleeding. Standardized protocols for blood collecting and handling, stringent quality controls, and qualified staff are necessary to guarantee the highest levels of accuracy and performance [13].

Glycemic monitoring

Patients who are critically sick frequently have elevated insulin resistance and hyperglycemia brought on by stress. It has a substantial correlation with higher mortality. Other adverse clinical outcomes, including as infection, sepsis and septic shock, myocardial infarction, polyneuropathy, and multi-organ failure, are also linked to higher rates of hyperglycemia [14].

Glycemic variability, hyperglycemia, and hypoglycemia are all independently linked to the morbidity and death of critically sick patients. The prognosis of critically sick patients may be improved by a strategy aimed at normoglycemia, or "tight glycemic control," however there have been mixed findings from randomized controlled studies of this approach. The advantage of this strategy may be outweighed by the increased risk of hypoglycemia that comes with strict glycemic control. Notably, less stringent glucose control regimes may not always eliminate the risk of hypoglycemia. Therefore, there is ongoing discussion over the ideal blood glucose management goals for critically sick patients. It should be understood that blood glucose management is a complicated intervention with several important components that might impact its efficacy and safety. Blood glucose control's effectiveness and safety in particular still need to be improved [15].

Drug monitoring

During their career, an anesthesiologist may inject up to 500,000 distinct medications. It is

conceivable that an unintended mistake may occur. Patients under anesthesia who have variable physiological reserves would not exhibit or communicate any symptoms, such as hypotension, bronchospasm, arrhythmias, or cardiac arrest, that an awake patient would. Such a mistake might result in permanent harm. Patients trust that our training is sufficient, our judgment is unaffected, and our competence is recognized when they give their consent for anesthesia. This is the duty that we are liable for [16].

During the first few days following surgery, inadvertent core hypothermia is frequently discovered [19]. According to a number of studies, even having a temperature that is 1–3°C below normal during the preoperative period is linked to a number of physiological abnormalities that might have negative consequences [20].

## Conclusion

The critical care of patients undergoing heart surgery is a dynamic and intricate task. Important elements include proper inotropic support, enough fluid resuscitation, rewarming care, and ventilator control. Experienced staff, a well-organized transfer between the ICU and operating room teams, and suitable transfusion techniques all contribute to improved patient safety. An increasing body of research indicates that no one monitoring tool can enhance patient outcomes in the operating room or critical care unit. Pulse oximetry, ECG, capnography, and blood pressure monitoring together can detect the majority of cardiovascular issues related to anesthesia. Finding the standards for using enhanced surveillance in these individuals will need further investigation, though. Advanced monitoring techniques, including transesophageal echocardiography, lithium dilution, Swan-Ganz catheter, and trans cardiopulmonary indicator dilution, may enhance safety and results for specific patient populations.

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