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Goal-Directed Therapy and Hemodynamic Optimization in the Critical Care Setting: Practical Applications and Benefits

I. Introduction
In the operating room and in the intensive care units, the optimization of patient’s hemodynamics is key to improving morbidity and mortality. Evidence suggests that either too little or too much fluid administration during the perioperative period can worsen tissue perfusion and oxygenation leading to organ dysfunction. Further, this impairment may not be reliably revealed by alterations in conventional hemodynamic indices such as heart rate, urine output, central venous pressure or blood pressure. Numerous investigative studies in a spectrum of patient populations (sepsis, cardiovascular surgery, trauma, and other critical illnesses) have challenged the notion that these indicators accurately predict volume status.1-7 Goal directed therapy (GDT) is the concept of using indices of continuous blood flow and/or tissue oxygen saturation to optimize end organ function. By using the flow related parameters such as stroke volume (SV), cardiac output (CO), and markers of fluid responsiveness such as stroke volume variation (SVV), pleth variability index (PVI), and corrected aortic flow time (Ftc), one is able to precisely infer where the patient is on their Frank Starling relationship, and thus, optimize oxygen delivery. Similarly, by using markers of tissue oxygenation/extraction, such as central venous saturation (ScVO2) and somatic tissue oxygenation (StO2), one is able to provide GDT therapy to improve end organ oxygenation. The body of evidence in favor of GDT continues to grow; therefore, GDT is rapidly becoming the standard of care in the ICU, emergency department, and in the operating rooms.

II. Goal-Directed Therapy in the Intensive Care Unit and in the Emergency Department
Shoemaker et al. were one of the first to show that in the critically ill patient, one should treat by physiologic criteria, and administration of therapy should be monitored to attain optimal physiologic goals.8 These concepts have been advanced by the landmark study by Rivers et al. that showed improved patient outcome using early goal directed therapy based on a protocol maintaining ScVO2 >70 % during treatment of severe sepsis and septic shock.9 Pearse et al. showed that it is possible to bridge intraoperative GDT to the ICU, and by maximizing patients oxygen delivery index, post-operative complications and duration of postoperative hospital stay can be decreased.10

With regards to this, Emergency physicians (EPs) serve a key role in recognition of early disease presentation and the implementation of GDT therapy. During the past few years, several randomized, controlled trials in patients with severe sepsis and septic shock have demonstrated significant reductions in mortality rates with the institution of GDT therapies.9,11
While these have shown the importance of hemodynamic flow guided indices there are still many areas of clinical practice that need to be further developed. These include the more widespread use of SV optimization algorithms in the intensive care and emergency departments.

III. GDT in the Perioperative Period
The use of flow-related indices to guide intraoperative goal-directed fluid therapy has appeal since these parameters provide a numeric representation of the patient’s volume status, which can frequently be difficult to ascertain using standard hemodynamic monitors, urine output or even CVP. Gan et al. in 2002 reported earlier return of bowel function, lower incidence of postoperative nausea and vomiting, and decrease in length of hospital stay in patients whose stroke volume was optimized using an esophageal Doppler. Intraoperative GDT has also reported to improve outcomes following surgery in high-risk patients, decreasing both morbidity and length of hospital stay. Previously published studies have shown decreased complications and hospital length of stay in high-risk patients undergoing major abdominal surgery with SVV guided GDT therapy. In addition, similar results have been shown in non-high risk surgical patients undergoing elective total hip arthroplasty and major abdominal surgery. These studies support that the use of flow guided parameters can aid in continuous maintenance of a euvolemic state by indicating the appropriate timing of fluid administration.

IV. Fluid Administration
Optimal fluid administration in the critically ill patient is important because prior reports indicate that both hypo- and hypervolemia may deleteriously affect perioperative organ function. High volume perioperative fluid therapy has shown to have deleterious effects on cardiac and pulmonary function, recovery of gastrointestinal motility (postoperative ileus), tissue oxygenation, wound healing and coagulation. On the other hand, one of the major concerns with intraoperative fluid restriction is unrecognized hypovolemia resulting in organ dysfunction, particularly postoperative acute renal failure. Given these considerations, the primary resuscitation goal in the critical patient is to restore tissue perfusion / cellular oxygenation, and maintain end-organ function through volume resuscitation. The optimal resuscitation fluid, however, remains a subject of debate.

The decision, whether to use crystalloid versus colloid as the primary resuscitation fluid in the critically ill remains contentious. Two previous meta-analyses of the numerous prospective, clinical trials in this area suggested that colloid resuscitation may be associated with increased patient mortality. A large multicenter, randomized, double-blind trial, however, documented the safety of colloid- based resuscitation using albumin, but failed to demonstrate either an economic or survival benefit to such therapy. The SAFE study authors subsequently performed a post hoc analysis of their data to confirm the suggestion that albumin is associated with a higher mortality rate in patients with traumatic brain injury (TBI). These studies do not refute the fact that: 1) colloids remain intravascular longer than crystalloids, 2) colloids expand plasma volume to a greater extent, and 3) crystalloids are more likely to cause edema formation.

V. Protocols for Goal-Directed Therapy
Many protocols have been proposed for Goal-Directed Therapy in the critical care setting. While they are relatively clear for the management of the septic patient in the emergency department and in the intensive care unit (i.e. the Rivers protocol is the most widely accepted), the range of protocols available for the perioperative setting is much wider and depends mainly on the patient’s vascular access and the availability of the monitors.
Goal-Directed Therapy Protocols in the Intensive Care Unit and the Emergency Department

In the intensive care unit and in the emergency department, the Rivers protocol for the management of the septic patient has been widely accepted. (Figure 1) This protocol is presented here as Figure 1. This protocol relies on the early optimization of mean arterial pressure, central venous pressure, and ScvO2. The interventions used in this protocol are volume expansion in order to keep central venous pressure between 8 and 12 mmHg, vasopressors to maintain mean arterial pressure between 65 and 90 mmHg, and transfusion and/or inotropes to keep ScvO2 more than 70%. The implementation of this protocol within 6 hours following the diagnosis of sepsis has been shown to decrease mortality in this setting.9

Figure 1 - Rivers protocol for the management of the septic patient.
Goal-Directed Therapy Protocol in the Operating Room

The first step in the operating room is to identify the patient’s risk and then to define the vascular access. (Figure 2) Then, based on the vascular access, the monitoring approach is chosen and the hemodynamic optimization protocol is applied. Figure 2 is a suggestion for the choice of the hemodynamic monitoring system based on patient’s risk and vascular access.

![Figure 2 - Proposed Algorithm for Hemodynamic Monitoring in the Perioperative Period.](image)

- **ΔPOP**: Respiratory variations in the SpO2 waveform
- **PVI**: Pleth Variability Index
- **A-line**: Arterial Line
- **SVV**: Stroke Volume Variation
- **PPV**: Pulse Pressure Variation
- **PAC**: Pulmonary Artery Catheter
- **TEE**: Transesophageal Echocardiography
Protocol for Moderate Risk Surgery

Patients ASA 2 or 3, with expected blood loss less than 1,500 ml.
Surgeries: abdominal, peripheral angiography, head and neck, major orthopedic surgery, kidney transplantation, urology.

Vascular Access: one or two peripheral IV.

Monitoring: standard ASA monitors +/- respiratory variations in the plethysmographic waveform (Pleth Variability Index) if the conditions of applications are met (sinus rhythm, general anesthesia with mechanical ventilation, tidal volume > 7 ml/kg).

If a non-invasive cardiac output monitor is used, the NICE protocol can be applied (see Figure 4). The goal is to titrate fluid administration in order to maximize stroke volume.

Protocol for Low Risk Surgery

Patients ASA 1 or 2, with expected blood loss less than 500 ml.
Surgeries: breast, stomatology, ophthalmology, gynecology, endocrinology (except pheochromocytoma and carcinoid tumor), plastic surgery, minor orthopedic surgery, minor urology surgery.

Vascular Access: one or two peripheral IV.

Monitoring: standard ASA monitors +/- respiratory variations in the plethysmographic waveform (Pleth Variability Index) if the conditions of applications are met (sinus rhythm, general anesthesia with mechanical ventilation, tidal volume > 7 ml/kg).

The protocol for fluid administration is shown in Figure 3. The goal is to use a baseline crystalloid administration of 3 to 5 ml/kg/h and to titrate volume expansion based on PVI.26

Protocol for Moderate Risk Surgery in a Patient Who is Not Equipped with an Arterial Line:

Patients ASA 2 or 3, with expected blood loss less than 1,500 ml.
Surgeries: abdominal, peripheral angiography, head and neck, major orthopedic surgery, kidney transplantation, urology.

Vascular Access: one or two peripheral IV.

Monitoring: standard ASA monitors +/- respiratory variations in the plethysmographic waveform (Pleth Variability Index) if the conditions of applications are met (sinus rhythm, general anesthesia with mechanical ventilation, tidal volume > 7 ml/kg) and / or non invasive cardiac output monitoring.

If a non-invasive cardiac output monitor is used, the NICE protocol can be applied (see Figure 4). The goal is to titrate fluid administration in order to maximize stroke volume.
Protocol for Moderate Risk Surgery in a Patient Equipped with an Arterial Line

Monitoring: standard ASA monitors +/- stroke volume variation or pulse pressure variation (sinus rhythm, general anesthesia with mechanical ventilation, tidal volume > 7 ml/kg) and/or cardiac output monitoring based on arterial pressure waveform monitoring (pulse contour analysis or pulse power analysis) or non invasive cardiac output monitor (esophageal Doppler or bioreactance).

In this case, stroke volume can be optimized using the NICE protocol released in March 2011 by the National Health Service in the UK (see figure 4) or in conjunction with SVV or PPV monitoring (see figure 5). If only pulse pressure variation is monitored, a PPV minimization protocol aiming at keeping PPV below 13 % can be used (Figure 5).

In all cases, standard hemodynamic management for arterial pressure, urine output and heart rate must be respected.

Figure 5 - Goal Directed Therapy protocol based on PPV/SVV and stroke volume monitoring

Figure 6. Goal-Directed Therapy protocol based on PPV/SVV alone (adapted from Ramsingh et al.)
Conclusion

We believe that GDT is a powerful clinical approach for managing critically ill patients. Evidence supporting the role of GDT in improving patient outcomes is becoming well-established. Further implementation of protocols of GDT will likely provide consolidation and streamlining of care for the patients by minimizing variability in clinical practice. This also has potential for improving resource utilization while implementing evidenced-based medicine.

References


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