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Review Article

REVIEW ARTICLE

Perioperative goal-directed haemodynamic therapy based on flow parameters: a concept in evolution

L. Meng and P. M. Heerdt*

Department of Anesthesiology, Yale University School of Medicine, 330 Cedar St., PO Box 208051, New Haven, CT 06520, USA

*Corresponding author. E-mail: paul.heerdt@yale.edu

Abstract

Haemodynamic management incorporating direct or surrogate stroke volume monitoring has experienced a rapid evolution, because of emergence of the "goal-directed therapy" concept and technological developments aimed at providing a parameter leading to the goal. Nonetheless, consensus on both definitions of the ideal "goal" and strategies for achieving it remain elusive. For this review, we first consider basic physiological and patient monitoring factors relevant to the concept of "fluid responsiveness", and then focus upon randomized controlled trials and meta-analyses involving goal-directed haemodynamic therapy based on various flow parameters. Finally, we discuss the current status of noninvasive methods for monitoring fluid responsiveness.

Key words: blood pressure; fluid therapy; haemodynamics; monitoring; stroke volume

Management of the interrelated factors that determine blood circulation—"haemodynamics"—remains one of the core tasks in perioperative and critical care settings. Vulnerable to derangement by a wide range of pathophysiological, pharmacological, and mechanical insults, haemodynamic variables need to be reliably monitored in order to be appropriately managed. A monitor typically quantifies and displays a specific variable to facilitate clinical decision making. However, given the spectrum of interrelated physiological processes that fall under the umbrella of haemodynamics, there is no single "haemodynamic monitoring device". As a consequence, we tend to focus on parameters that assess lumped indices such as bp and cardiac output, and use these data to infer adequacy of circulation in terms of organ perfusion and tissue oxygenation.

In 1980, the concept of goal-directed therapy (GDT) in relation to anaesthesia and critical care first appeared in the literature as the central component of a study designed to keep intrapulmonary shunt $\leq$ 15%, by adjusting the PEEP in patients with acute respiratory failure.[1] Eight years later, Shoemaker and colleagues[2] studied the effect of supraphysiologic systemic oxygen delivery on outcome in high-risk surgical patients and found that this haemodynamic goal improved survival. Subsequent work by Mythen and Webb[3] focusing upon intracellular pH of the gastric mucosa as an index of microcirculatory perfusion, found that GDT based upon fluid boluses to optimize central venous pressure (CVP) and stroke volume (SV) in cardiac surgical patients reduced the incidence of mucosal hypoperfusion and improved outcome. Goal-directed fluid management models subsequently began to be incorporated into both the surgical and critical care environments,[4] and have now evolved into the principle of perioperative GDT based on fluid responsiveness. As a result of the rapid expansion of technologies designed to provide the goals for GDT, the body of related literature is now vast and overwhelming.

Whilst direct measurement of SV using minimally invasive techniques has become an accepted tool for guiding fluid administration in high risk patients, there has also been an upscaling trend toward management strategies based upon respiratory variation in arterial pulse pressure (i.e. pulse pressure variation - PPV) or SV (i.e. stroke volume variation - SVV), as the

Editor's key points

- The concept of goal-directed fluid therapy based on fluid responsiveness has received considerable attention in perioperative medicine, but there is limited evidence from randomized trials to support efficacy.
- Future efforts are necessary to refine the specific patient populations that would most benefit, as well as the utility of emerging noninvasive monitoring technologies in guiding therapy.

parameter for directing fluid therapy. This prospect has recently been further advanced by the development of noninvasive technologies. Here, we first briefly review physiological principles relevant to fluid responsiveness as a key concept for perioperative GDT. A summary of randomized controlled trials and meta-analyses related to the application of GDT protocols, based upon data provided by established invasive and minimally invasive methods is then presented. The last section focuses upon current and emerging noninvasive methods that have been used to assess fluid responsiveness in a perioperative setting.

Integration of arterial pressure and flow

Fundamentally, mean arterial pressure (MAP) is the product of cardiac output and the resistance presented by the entire vascular bed, and changes little from the central aorta to peripheral arteries. In turn, total arterial resistance is the sum of myriad parallel circuits, each with a local resistance controlled in an organ-specific manner. Under normal circumstances, homeostatic mechanisms are remarkably efficient for matching MAP with organ perfusion to meet metabolic needs over a range of physiological conditions. However, the flow regulatory capacities of different organs in the face of a changing bp are not equivalent. The lower limit (i.e. the perfusion pressure below which the organ perfusion becomes inadequate because of the exhausted vasodilatory capacity) varies among different organs. For example, the lower limit of the human kidney is about 70–80 mm Hg,[5 6] of the brain about 60-65 mm Hg,[7] and of the coronary circulation about 50-55 mm Hg.[8] It is important to emphasize that the lower and upper limits of pressure autoregulation are not specific numbers, but a range of distribution in the population, that can vary widely depending on physical status, disease, physiological stress and drugs.[9 10] Furthermore, at the microcirculation level, tissue perfusion is also influenced by the "outflow" venous pressure. Therefore, without consideration of total and regional arterial resistances, organ-specific pressure autoregulation, and the potential for tissue oedema and venous congestion, assuming a "good" flow based on a "good" pressure can be misleading. The advent of technologies for continuous bedside monitoring of cardiac output and tissue oxygenation has made it possible for clinicians to visually appreciate the potential for a disconnect between bp, blood flow, and tissue oxygenation (Fig. 1). These observations support the concept behind SV monitoring in high-risk patients, or during high-risk surgeries where SV and cardiac output are prone to derangement, as the pressure/flow relationship can be inconsistent, especially at the end-organ level. However, as with all monitoring, SV measurement is simply a number unless linked to an outcome and an intervention strategy designed to affect that outcome. A fundamental assumption is that increasing systemic blood flow and oxygen delivery will produce a parallel increase in oxygen delivery to critical organs. Nonetheless, even if cardiac output and MAP are measured with great accuracy, the current ability to clinically monitor the relationship between systemic arterial pressure and local blood flow, oxygen delivery, and oxygen uptake in specific organ beds remains limited.

The evolution of flow monitoring technology

Pulmonary artery catheter

After introduction into clinical practice in the early 1970's, the flow-directed pulmonary artery catheter (PAC) became widely used in surgery and critical care, largely based upon the perceived ability to provide an integrated assessment of biventricular preload and stroke volume. Clinical experience and randomized controlled trials (RCTs) initially supported perioperative PAC use,[2 11–15] and bolus thermodilution emerged as the clinical standard for cardiac output measurement.[16] However, some outcome studies were negative,[17 18] and once the body of available literature achieved a quantity and quality sufficient for meta-analyses, widespread clinical utility – and even safety – of PAC use was questioned.[19–21]

Minimally and noninvasive flow technologies

Although intraoperative oesophageal Doppler monitoring (ODM) of SV and cardiac output has been widely used for more than 20 yr, more recently there has been rapid development and marketing of other minimally and noninvasive devices designed to measure cardiac output, without the risk associated with PAC insertion. Multiple reviews have recently been published describing technical aspects of existing technologies along with clinical application,[22–24] and more devices are in development. An important feature of many new methods is the ability, such as ODM, to continuously measure SV, a major improvement over bolus thermodilution that provides only intermittent measurement of cardiac output from which SV is derived. From an application standpoint, the greatest utility would seem to lie in a device that is noninvasive, accurate, universally applicable, and completely reliable. At present, such a device does not exist.

Flow monitoring and fluid responsiveness

Some postoperative complications are often empirically attributed to fluid administration – too much or too little. Recent analysis by Thacker and colleagues[25] of a large database containing information from ∼ 6 million hospital discharges/yr in the USA supports this contention, leading these authors to advocate for wider application of patient-centred care pathways that incorporate protocols for intraoperative fluid management. In this context, the ability to determine which patients do/do not respond favourably to a fluid bolus in terms of increasing SV has considerable value, both in terms of optimizing organ perfusion for "responders" and avoiding potentially deleterious effects in "non-responders".

When considering clinical assessment of fluid responsiveness, three interrelated elements take prominence: regulation of venous return, the Frank-Staring relationship, and the incidence of non-responders.