

## Poor Adoption of Hemodynamic Optimization During Major Surgery: Are We Practicing Substandard Care?

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**H**emodynamic optimization of surgical patients during the perioperative period aims to improve outcomes. This is frequently referred to as goal-directed therapy (GDT), a term that has been used for nearly 30 years to describe methods of optimizing fluid and hemodynamic status. Unfortunately, the term has never been standardized, and therefore can mean different things to different people, causing a significant amount of confusion. It can refer to supramaximal oxygen delivery using a pulmonary artery catheter (PAC),<sup>1</sup> early treatment of sepsis in the emergency department,<sup>2</sup> or perioperative optimization of fluid status,<sup>3</sup> all different goals directing different therapies.

It could be said that we all practice a form of GDT intraoperatively every day, except that our goals are normally related to arterial blood pressure (BP), heart rate, and occasionally central venous pressure (CVP). These are all known to be poor indicators of intravascular volume and cardiac output (CO). In healthy volunteers, heart rate and BP remain relatively unchanged despite a 25% hemorrhage of blood volume.<sup>4</sup> One systematic review showed that CVP is unable to identify which patients need more fluid, and concluded that CVP should no longer be routinely measured in the intensive care unit, operating room, or emergency department.<sup>5</sup> This leads to a key question: Can monitoring of stroke volume (SV) and CO improve our ability to optimize fluid and hemodynamic status?

This issue of *Anesthesia & Analgesia* includes 2 excellent systematic reviews by Hamilton et al.<sup>6</sup> and Gurgel and do Nascimento<sup>7</sup> on hemodynamic optimization of patients undergoing major surgery. The authors avoided the term GDT, and instead described the techniques as “preemptive hemodynamic intervention” and “optimizing tissue perfusion.” It is clear that the reviews examined the same subject, with 26 studies (of 29 and 31, respectively) common to both articles.

Perioperative hemodynamic optimization was first described in the 1980s, when the PAC was used to guide fluid and inotrope administration.<sup>8</sup> This enabled clinicians to augment tissue oxygen delivery to supranormal levels ( $\text{DO}_2 > 600 \text{ mL/min/m}^2$ ) in high-risk surgery patients, the target being based on earlier work by Shoemaker et al.<sup>9</sup> observing survivors after high-risk surgery. As both systematic reviews have shown, oxygen-targeted approaches were generally successful, and when mortality in high-risk surgery was approaching 20%, most studies were able to show a survival benefit.<sup>1,10–12</sup>

Despite these promising results, the technique was not widely adopted. Oxygen-targeted approaches required significant resources, were very labor intensive, and most importantly were reliant on information from the PAC. Catheterization of the right heart began falling out of favor in intensive care units in the 1990s after the publication of several observational studies showing increased mortality.<sup>13</sup> Because early GDT was linked so closely with the use of PACs, it became embroiled in this controversy.

The last 20 years have seen the arrival of a number of minimally invasive CO technologies such as esophageal Doppler, arterial pressure waveform analysis devices providing SV variation (SVV) and pulse pressure variation (PPV), and monitors based on bioimpedance and bioreactance technology.<sup>14</sup> This has enabled clinicians to monitor and optimize SV, SVV, CO, and other hemodynamic variables without the need for a PAC.

These monitors are easy to operate and minimally invasive, so they have gained wider use than PAC optimization in high-risk patients. They are also frequently used in patients undergoing major but not necessarily high-risk surgery, for example, elective abdominal surgery, extensive cancer surgery, hip arthroplasty, or major spinal surgery. Hemodynamic optimization in this patient population can usually be obtained by optimization of preload alone. The change in SV, SVV, or CO in response to a fluid challenge is used to assess volume responsiveness. When a patient is hypovolemic, an IV fluid challenge will typically result in a >10% increase in SV or CO, or a reduction in SVV. This patient has “recruitable” SV and is in a fluid-responsive state. In the perioperative setting, fluid challenges should be considered until the SV no longer increases by 10% and preload has been optimized. SVV and PPV alone have also been shown to be superior to static indices in predicting

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volume responsiveness in controlled mechanically ventilated patients.<sup>15</sup> However, special care should be taken in applying fluid challenges in patients with severely compromised cardiac function. In right heart dysfunction, SVV and PPV may misleadingly suggest volume responsiveness, although further volume may be harmful.<sup>16</sup> Earlier PAC optimization concepts used predetermined supraphysiologic goals, whereas a key difference in the present approach is individualized optimization within each patient's cardiac capacity.

Despite what many believe to be conflicting bodies of evidence, volume optimization is in fact complementary to a "restrictive" fluid approach, particularly with regard to crystalloids.<sup>17</sup> Our use of crystalloids has been greatly exaggerated over the last 50 years. An excellent review claimed that the so-called third space does not exist, and that intraoperative evaporative losses are probably no more than 100 mL/h.<sup>18</sup> Hence, a background infusion of balanced crystalloid (e.g., lactated Ringer solution) of 1 to 2 mL/kg/h for maintenance requirements can be combined with colloid boluses of 250 mL for volume optimization.

A number of studies have demonstrated that perioperative volume optimization is beneficial, and that it results in improved outcomes with lower complication rates and shorter hospital lengths of stay. Admittedly, most are single-center trials.<sup>19</sup> In modern major elective surgery, mortality is much less than previous optimization of high-risk patients with the PAC; therefore, these small studies are underpowered to detect a mortality difference.

So the pertinent question remains: Why is modern hemodynamic optimization not performed routinely for high-risk surgery? One possible factor is that anesthesiologists like to see immediate results. Benefits from optimization will not be obvious during the intraoperative and early postoperative periods. Lack of user-friendly equipment and skepticism with regard to the concept may also have a role. Furthermore, the absence of large-scale randomized controlled trials is almost certainly a significant factor. Systematic reviews, despite their inherent limitations, are therefore a valuable way of analyzing the literature.

The 2 systematic reviews published in *Anesthesia & Analgesia* this month are the largest yet published on hemodynamic optimization in major surgery. Hamilton et al.<sup>6</sup> specifically investigated hemodynamic intervention, and showed a significant reduction in complications with modern minimally invasive devices that are comparable with PAC optimization. This is an important finding, because the growing availability of minimally invasive devices is the future of perioperative optimization.

Gurgel and do Nascimento<sup>7</sup> focus more on tissue perfusion, and include negative studies such as one by Takala et al.,<sup>20</sup> which added an intervention in the study group (in this case dopexamine) without a clear optimization goal. Although this reduces the significance of their overall results, nevertheless they again showed a clear benefit with optimization. The lack of a reliable marker of tissue perfusion is highlighted, with lactate and central venous oxygen saturation the best available. Monitoring "adequacy" of tissue perfusion remains controversial, but until such time as the ideal tissue perfusion monitor is available, our present focus should remain on optimization of CO and DO<sub>2</sub>.

So what does the future hold? Interest in perioperative hemodynamic optimization continues to grow. It is easy to accomplish for all major surgery, makes physiologic sense, and has a growing evidence base. A reduction in complication rates and shorter hospital stays have been widely demonstrated across surgical types. There is emerging evidence that optimization during the perioperative period may be associated with a long-term (15 years) survival benefit in high-risk patients.<sup>21</sup> Furthermore, Enhanced Recovery After Surgery programs are currently driving increased interest in hemodynamic optimization.<sup>22</sup> This is common practice in our hospital for selected procedures.

There are effectively 2 main groups of patients in which the clinician should carefully consider monitoring and optimization. First, we believe that a minimally invasive CO monitor should be considered in all major surgery to optimize preload. If CO and/or BP are still inadequate after volume optimization, the physiologic variables should guide the addition of an inotrope or vasopressor. This should be individualized to meet the patient's needs, and is currently based on measurements of CO and DO<sub>2</sub>, with the future hope of advanced monitoring of tissue perfusion.

The second group of patients is those at increased risk of significant perioperative morbidity and mortality. Should we aim for supraphysiologic targets or not? These meta-analyses make a strong point for aiming "high," especially in the sickest of this second group of perioperative patients. Although the target DO<sub>2</sub> of 600 mL/min/m<sup>2</sup> suggested by Shoemaker et al.<sup>8</sup> could still be ideal, it seems prudent to individualize each patient's target based on their specific physiologic profile. Our challenge: Do we believe that supramaximal targets are necessary in these patients, are we brave enough to implement them, and what will we use to accomplish these goals?

As the population ages, the number of patients requiring major noncardiac surgery is only going to increase. Hemodynamic optimization using a variety of invasive and minimally invasive technologies may be a key step in improving short-, intermediate-, and long-term outcomes in these patients. ■■

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