

Continuous, Noninvasive Blood Pressure Monitoring Boosts Hemodynamic Visibility in the Perioperative Space

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Intraoperative hypotension (IOH), defined as a mean arterial pressure value below 65 mm Hg, is a highly prevalent complication in various clinical settings, which has been shown to affect even healthy patients who are considered at low risk for hemodynamic instability[1]. In the perioperative space, IOH is a modifiable risk factor that can alter the trajectory of postoperative recovery.

Why hemodynamic visibility matters

Detecting blood pressure (BP) fluctuations during and after anesthesia is key to improving the safety of surgical patients. As modern anesthesiology continues its transition from intermittent, episodic checks to continuous, beat-to-beat monitoring, clinicians must be able to rely on instruments that supply accurate, timely data to inform clinical decision-making, according to Joshua A. Bloomstone, MD, MSc, D.ABA, FASA, SSGB, a professor of anesthesiology at the University of Arizona College of Medicine in Phoenix.

"As a former pilot, I often think about the difference between flying under visual flight rules and instrument flight rules," Bloomstone said in an interview. "On a clear day with stable conditions, limited information may be sufficient to accomplish safe flight. However, when visibility deteriorates and conditions become more complex, pilots require more data, more frequently, to maintain situational awareness and safely navigate to their destination. This same principle applies to patients who are having surgery. As a patient's physiology becomes more unstable, more information that describes the foundation of these physiologic perturbations becomes invaluable to proper and timely diagnosis and management."

Prolonged drops in mean arterial pressure have been associated with inadequate organ perfusion, which can result in ischemic damage, multiorgan complications, and increased mortality rates for surgical patients[2,3]. Bloomstone, who has dedicated more than three decades to advancing hemodynamic optimization and transforming clinical practice for anesthesiologists, noted that tracking a patient's hemodynamic changes can mitigate the risk for serious postoperative complications. "Hemodynamic visibility helps anesthesiologists maintain situational awareness relative to a patient's physiologic status, which is particularly important given that anesthesia and surgery rapidly alter the body's normal physiology and often blunt its compensatory mechanisms," he added. "Blood pressure can change rapidly, and significant hypotension may occur before it becomes clinically apparent with standard means of pressure monitoring."

Intermittent cuff measurements might not tell the full story

Noninvasive cuff-based measurements have traditionally been considered the standard method for perioperative BP monitoring[4]. However, research has shown that intermittent cuff measurements can be unreliable during episodes of hemodynamic fluctuation, often misclassifying BP levels by clinically significant margins compared with invasive arterial catheter-based blood pressure measurements[5].

"Imagine driving at night with the caveat that you can only look out the front window every 3 minutes," Bloomstone said. "Intermittent monitoring assesses a continuous physiologic process with periodic snapshots. There is simply no way to capture meaningful blood pressure change, either up or down, when cuff measurements occur intermittently. At best, it puts the anesthesiologist in a reactive position, not a proactive one. We often miss the early signs of vasodilation, hypovolemia, hemorrhage, anesthetic-related cardiovascular depression, not to mention hemodynamic changes due to surgical techniques. Significant hypotension can occur between cuff cycles, and often goes undetected."

Furthermore, Bloomstone noted, the danger of intermittent monitoring lies in its inability to capture the patient's hemodynamic trajectory. "Intermittent monitoring provides snapshots, while continuous monitoring offers a real-time view of evolving patient physiology and pathophysiology," he explained. "Because clinicians can only respond to what they detect, intermittent monitoring may miss meaningful hypotensive episodes between measurements. Improved visibility supports earlier recognition of deterioration, better understanding of physiologic trends, and more timely intervention."

Invasive hemodynamic monitoring is not always the answer

Continuous, invasive BP monitoring provides highly accurate data and is considered the gold standard for monitoring patients who are critically ill and those who require precise, rapid beat-to-beat titration of vasoactive agents[5]. Invasive techniques, however, come with a tradeoff between clinical precision and a higher risk for complications, including radial artery occlusion, hematoma, infection at the arterial site, and hemorrhage[6]. "Traditionally, clinicians have relied on either intermittent cuff measurements or invasive arterial lines," Bloomstone remarked. "While arterial lines provide continuous data, they require an invasive procedure and are not necessary for every patient." In less complex cases, continuous, noninvasive monitoring technologies may be the best method for obtaining ongoing hemodynamic information without the risks associated with arterial cannulation.

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Continuous, noninvasive monitoring systems eliminate blind spots

Noninvasive technologies for continuous BP monitoring aim to overcome the limitations of traditional monitoring methods by facilitating ongoing observation while enhancing comfort and accessibility. Unlike cuff-based BP measurements, these systems provide real-time data, enabling clinicians to respond promptly to hemodynamic changes.

"When a patient becomes hypotensive, the question [we ask] is not simply what is the blood pressure, but rather why is the blood pressure low," Bloomstone stressed. "Additional physiologic information may help clinicians differentiate between hypovolemia, vasodilation, reduced cardiac performance, or a combination of factors, allowing for more targeted therapy. In my practice, when continuous blood pressure readings are required but I do not need either measures of acid-base status or oxygenation and ventilation, continuous, noninvasive blood pressure measurement is often a strong option."



The VitaWave™ Plus System, comprising the HemoSphere Stream™ Module, Smart Pressure Controller, and VitaWave™ Plus Finger Cuff, was designed to provide a continuous, beat-to-beat blood pressure arterial waveform to a compatible patient monitor. The arterial waveform data is comparable in morphology and accuracy to data captured with invasive arterial lines.

"The ability of these newer systems to easily integrate into existing monitoring systems means enhanced access for surgical patients whose management may be better served with more information," Bloomstone noted. "The difference between reacting and anticipating is everything in anesthesia. Physiologic instability does not start as a crisis, it generally starts as a pattern - but you have to have the information to see it. Furthermore, continuous information before induction can help to optimize and guide management in patients with physiologically difficult airways. Instead of identifying hypotension after it occurs, continuous monitoring in the right patients can help clinicians to recognize clinically important trends earlier and respond sooner. Indeed, timely physiologic visibility allows for better anesthetic selection and titration, and for the judicious use of fluids, vasopressors, inotropes, and chronotropes, before hypotension becomes prolonged. Our goal is never more interventions, but rather better timed and targeted ones."

Noninvasive monitoring signals potential paradigm shift in perioperative care

The continuous, noninvasive BP monitoring technologies available today represent the culmination of more than 150 years of technological evolution, from early 19th-century vascular theories to modern wearable sensors and machine learning algorithms[7]. "Like pulse oximetry and capnography before it, continuous blood pressure monitoring has the potential to improve how we understand and manage patient physiology," Bloomstone said. "The key benefit is moving from intermittent awareness to continuous situational awareness." While the changes in clinical practice have been incremental, Bloomstone noted that the adoption of continuous, noninvasive BP monitoring systems marks a shift from reactive to proactive perioperative care.

In complex healthcare environments, the widespread adoption of continuous, noninvasive BP monitoring technologies depends on multiple factors, including their ability to fit into existing workflows and operate reliably without adding to the clinical staff's cognitive burden. Moreover, the costs of implementation must be weighed against the evidence of clinical and economic value. "Overall, perioperative care continues to move toward greater physiologic visibility and earlier detection and management of physiologic deterioration," Bloomstone concluded. "Just as aviation has progressively embraced technologies that improve situational awareness in challenging conditions, perioperative medicine continues to move toward monitoring systems that provide us with a more complete understanding of patient physiology. Continuous, noninvasive hemodynamic monitoring appears well aligned with that broader trend and goal. Following the introduction of continuous blood pressure monitoring into my clinical practice, I often marvel at how long 3 minutes is when the equipment is not available."

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