

Maternal Hemodynamic Monitoring in Obstetric Anesthesia

THE physiologic changes of pregnancy, including an initial gradual increase in cardiac output, followed by the development of increasing aortocaval compression in the third trimester, as well as comorbidities such as preeclampsia, have generated considerable research into maternal hemodynamics. The use of the pulmonary artery catheter allowed a better understanding of the physiology of the healthy parturient¹ and the hemodynamics of preeclampsia, including the effects of epidural analgesia in labor.² Early use of dye dilution techniques gave clinicians insight into the hemodynamic changes during spinal anesthesia for cesarean delivery.³ In sharp contrast with these invasive measures is the use in the current issue of ANESTHESIOLOGY, by Langesæter *et al.*,⁴ of minimally invasive pulse waveform analysis in the assessment of hemodynamic changes during this procedure.

Heart rate and blood pressure are appropriately used as surrogate markers of maternal cardiac output in all routine obstetric anesthesia deliveries, and in most of the clinically valuable obstetric anesthesia research to date. Intraarterial monitoring provides a useful indicator of beat-by-beat changes in unstable patients. During regional anesthesia for cesarean delivery, maintenance of baseline maternal blood pressure, using phenylephrine, has been shown to produce the closest to zero umbilical arterial base deficit, the currently accepted short-term marker of neonatal well-being.⁵ This is despite the fact that phenylephrine, given in doses high enough to produce baroreceptor-mediated decreases in heart rate, probably depresses maternal cardiac output. The effectiveness of phenylephrine may be related to the limited susceptibility of the uterine artery to the vasoconstrictive effects of α agonists in advanced pregnancy.⁵ However, the maximum change in cardiac output has been shown to correlate better with uteroplacental blood flow than with upper arm blood pressure.⁶ The maintenance of blood pressure and maternal cardiac output are therefore both important for maternal safety and comfort and for fetal well-being.

For clinical management and research purposes, there has been an increasing awareness of the potential com-

plications of invasive monitoring. In addition, the importance of the effects of fluid and vasopressor administration on flow, rather than on pressure, is now recognized in the nonobstetric population. In particular, central venous pressure and pulmonary wedge pressure are unlikely to predict the response to fluid administration, and pulse pressure variation and stroke volume variation may be better indicators of fluid resuscitation.⁷ These factors have led to a resurgence of interest in minimally invasive techniques of cardiac output monitoring.

Noninvasive methods of cardiac output measurement used in obstetric anesthesia have provided valuable information on maternal and fetal well-being and hemodynamics in the critical care setting and during regional anesthesia for cesarean delivery. These techniques include transthoracic echocardiography,² transesophageal echocardiography, transesophageal, suprasternal aortic,^{6,8} and uterine artery Doppler ultrasound techniques, and transthoracic and whole body electrical bioimpedance.⁹ All of these methods have disadvantages, including expense, the requirement for user education, movement artifact, and, in the case of bioimpedance techniques, the potential for inaccuracy in terms of absolute cardiac output values in advanced pregnancy and in the presence of increased lung water. None provide beat-by-beat data.

Arterial pulse waveform analysis methods are attractive to the obstetric anesthesiologist in that they provide beat-by-beat assessment of cardiac output and could be used both in critical care monitoring (*e.g.*, in complicated severe preeclampsia) and for research purposes (*e.g.*, effects of fluids, vasopressors, and oxytocic drugs) in the laboring patient or during anesthesia. Of crucial importance in the acceptance of these monitors are the precision and reliability of the employed algorithm in following changes in cardiac output (including in the setting of rapidly changing systemic vascular resistance), and the ability to predict ventricular preload response, through the derivation of fluid responsive parameters. When interpreting published data, usually involving Bland and Altman's recommendation for the use of bias and precision statistics, the reader should bear in mind that in view of the ± 10 - 20% accuracy of thermodilution, limits of agreement of up to $\pm 30\%$ between the new and the accepted technique are generally regarded as acceptable.¹⁰ Currently commercially available methods consist of calibrated devices (LiDCOplus [LiDCO, Cambridge, United Kingdom] and PiCCOplus [Pulsion Medical Systems, Munich, Germany]) and the uncalibrated Vigileo monitor (Edwards Lifesciences, Irvine, CA).¹¹

The PulseCO algorithm used in the LiDCOplus monitor requires only a peripheral arterial and venous line and

This Editorial View accompanies the following article: Langesæter E, Rosseland LA, Stubhaug A: Continuous invasive blood pressure and cardiac output monitoring during cesarean delivery: A randomized, double-blind comparison of low-dose *versus* high-dose spinal anesthesia with intravenous phenylephrine or placebo infusion. ANESTHESIOLOGY 2008; 109:856-63.

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calculates stroke volume by analysis of the arterial blood pressure trace using a pulse power algorithm. This is a three-step process, involving initial transformation (compliance correction) of the arterial pressure into a volume-time waveform, followed by derivation of a nominal stroke volume and beat duration, using autocorrelation, and finally calibration/scaling of the stroke volume with a lithium indicator dilution curve measurement of cardiac output, which is comparable to intrapulmonary thermodilution.¹¹ It is important to note that the PulseCO pulse waveform algorithm described in 2001 used the first harmonic of the blood pressure waveform and related this mathematically to the cardiac output; this bears no relation to the commercially used algorithm.¹² Despite concerns regarding the ability of this method to respond to acute changes in systematic vascular resistance, it is noteworthy that this original algorithm was used successfully to examine the detailed time-based effects of a 5- μ g intravenous dose of epinephrine.¹³

Several publications have shown the ability of the subsequently commercially used pulse power algorithm to trend changes in stroke volume accurately, avoiding the requirement for frequent recalibration.^{14,15} Three studies have demonstrated acceptable agreement¹⁰ between the LiDCOplus-derived cardiac output and lithium dilution,^{15,16} or thermodilution¹⁷ in the setting of systemic vascular resistance changes of up to 200%. Only one published investigation in obstetric anesthesia has examined cardiac output trend changes during spinal anesthesia for cesarean delivery in patients with severe preeclampsia, as well as acute responses to phenylephrine and oxytocin.¹⁸ This study elicited considerable debate,¹⁹ but current knowledge suggests that this monitor is valuable in the setting of acute changes in systematic vascular resistance. Langesæter *et al.*⁴ have used this technology in an attempt to demonstrate the optimal combination of spinal bupivacaine and sufentanil, and phenylephrine infusion, to preserve optimal maternal hemodynamics. In a meticulously conducted blinded study, they were able to show that a small dose of bupivacaine and opioid, in combination with a low-dose phenylephrine infusion, gave the best hemodynamic stability, with minimal maternal symptoms. Spinal anesthesia was associated with a decrease in blood pressure and, interestingly, an increase in cardiac output. Phenylephrine administered slowly intravenously was used to restore systemic vascular resistance and cardiac output toward baseline values. This work suggests that high doses of phenylephrine, inducing hypertension, baroreceptor-mediated bradycardia, and depression of maternal cardiac output, are unnecessary. The study makes a valuable contribution to the fine-tuning of the practice of spinal anesthesia for cesarean delivery and to the understanding of hemodynamic responses to spinal anesthesia.

The LiDCOplus monitor has recently been shown to predict fluid responsiveness in mechanically ventilated

patients by providing reliable measurements of pulse pressure variation and stroke volume variation.⁷ This attribute could be useful in the treatment of patients with complicated severe preeclampsia, in whom pulmonary artery catheterization has a significant complication rate.²

The recently developed PiCCO system uses an algorithm that analyzes the systolic component of the arterial waveform. The calibration method, transpulmonary thermodilution, requires cannulation of a proximal artery and a central vein, which is problematic for obstetric anesthesia research but may be feasible for critical care management. An acute increase in systemic vascular resistance induced by phenylephrine has resulted in increased bias when compared with thermodilution in cardiac surgical patients.²⁰

The Vigileo monitor uses a specialized arterial transducer that is connected to a monitor that samples the pressure recording at a frequency of 100 Hz and analyzes waveform characteristics by a multivariate polynomial equation. Patient demographic characteristics are used to estimate interpatient variability and thereby reduce bias. It does not require calibration, and any artery can be used. There are currently few published comparative data. Moderate accuracy has been shown in comparisons with thermodilution. However, in cardiac surgical patients, the administration of phenylephrine has been shown to increase the cardiac output measurement using the Vigileo monitor when transpulmonary thermodilution showed a decrease in output.²¹ This would suggest that the monitor may not be suitable for the study of rapid hemodynamic changes associated with obstetric anesthesia.

Heart rate and noninvasive blood pressure measurement, as well as communication with the awake patient during regional anesthesia, remain the most important monitors for the obstetric anesthesiologist. Pulmonary artery catheterization has only a limited application in the management of complex cardiac defects or multiple organ failure in the parturient. Less invasive cardiac output monitors will have an important role, both in the hemodynamic management of parturients with comorbidities and in research into the hemodynamics of healthy and critically ill mothers. The prediction of fluid responsiveness using clinical assessment and pulse waveform monitors may prove to be of greater value than the measurement of filling pressures.

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