# Noninvasive Hemodynamic Monitoring

## *No High Heels on the Farm; No Clogs to the Opera*

IN this issue of ANESTHESIOLOGY, Hengy *et al.*[1] demonstrated a poor relationship and a poor agreement between the noninvasive respiratory variations in the plethysmographic waveform amplitude (ΔPOP) and the invasive respiratory variations in pulse pressure (PPV) in patients undergoing high-risk surgery.

To begin, one must ask why the anesthesiology community even needs noninvasive hemodynamic monitors. The most intuitive answer is that anesthesiologists need noninvasive monitors to "replace invasive ones and get rid of the complications related to vessel cannulation."[2] This is probably why mini invasive cardiac output monitors are so popular these days; they may replace highly invasive monitors such as the Swan Ganz catheter. Consequently, one may envision that, in the future, noninvasive monitors will completely replace invasive approaches. Following this logic, some may even think that hemodynamic information derived from the plethysmographic waveform may replace the Swan Ganz. However, noninvasive technologies are not there yet, and when used in high-risk settings, these noninvasive technologies may prove to be unreliable in the early stages of their development as is the case with mini- and noninvasive cardiac output monitors.[3] However, a more relevant answer to the opening question is that we need noninvasive monitors in order to obtain critical information in patients for whom the risks associated with an invasive monitor outweigh its expected benefits.

***"… choosing the most appropriate hemodynamic monitor is context dependent ('no high-heels on the farm; no clogs to the opera')."***

During the past 10 yr, besides the development of new mini- or noninvasive cardiac output monitors,[4] a significant part of the perioperative hemodynamic research has been dedicated to the so-called functional hemodynamic parameters such as PPV[5] and ΔPOP.[6] These parameters have been shown to be accurate predictors of fluid responsiveness and capable of guiding fluid management during surgery with a potential positive impact on postoperative outcome.[7,8] One is invasive PPV, whereas the other one is completely noninvasive ΔPOP. Consequently, here again, the question related to the potential of noninvasive monitoring *versus* the invasive one has been raised.

In the study published this month by Hengy *et al.*,[1] the authors compared PPV and ΔPOP in patients undergoing major high-risk abdominal surgery. Patients included in this study were referred for surgeries, including liver resection, liver transplantation, esophagectomy, and duodenopancreatectomy. Not surprisingly, the authors found that during these surgeries, the relationship between PPV and ΔPOP was weak. However, one may ask whether any anesthesiologist envisions using ΔPOP as the only variable for hemodynamic management and fluid optimization in patients undergoing liver transplantation, liver resection, or high-risk pancreatic surgery. Is it the purpose of ΔPOP to replace PPV (and thus, arterial line placement) in this setting? It is more likely that anesthesiologists will still, and for a long time, rely on invasive and robust hemodynamic parameters in this patient population. Moreover, it is well documented that changes in vasomotor tone, vasopressor administrations, and other conditions such as hypothermia have an impact on the plethysmographic waveform.[9,10] Consequently, such a subtle hemodynamic parameter as ΔPOP will probably not replace the arterial line in the near future. This is probably the main message carried by the Hengy *et al.*[1] study; choosing the most appropriate hemodynamic

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monitor is context dependent ("no high heels on the farm; no clogs to the opera"). During high-risk surgery, invasive and more robust signals should still be preferred. However, there is no justification in using invasive lines in patients who are at lower risks. As recently demonstrated by Hood *et al.*,[11] a noninvasive parameter such as ΔPOP still has significant clinical potential in this less challenging and more standardized situation.

Hengy *et al.*[1] clearly demonstrated that ΔPOP and PPV were not interchangeable during high-risk surgery, meaning that the observed values of ΔPOP should not be interpreted as surrogate values of PPV corrected for the observed mean bias (mean difference between ΔPOP and PPV was 5.2% in this study) in this setting. Nevertheless, they also showed that the relationship between ΔPOP and PPV included not only a constant term (the mean bias) but also a linear relationship (the higher the absolute values are the higher the difference between the two measures is). Consequently, this study demonstrates that we need to better define how we should interpret ΔPOP. This probably requires that we start from the beginning with ΔPOP values to define the details of its potential for the prediction of the fluid responsiveness and not from the values of another predictor of fluid responsiveness, such as PPV.

Finally, one has to remember that even if the plethysmographic and the arterial pressure waveforms look similar, they are actually dramatically different. The arterial pressure waveform is a pretty straightforward signal, relatively easy to record and to analyze. The plethysmographic waveform is highly processed and contains many different pieces of information (stroke volume, vasomotor tone, venous signal).[12] According to Hengy *et al.,* this may explain the poor agreement between PPV and ΔPOP in this study. However, a rich signal does not mean that it cannot be interpreted. As a matter of fact, when looking again at the article by Hengy *et al.* it seems that the ΔPOP signal is much noisier than the PPV signal and it looks like a more sophisticated processing of the trend (filtering and smoothing) could eventually make the signal more relevant. This emphasizes the importance of using more advanced signal-processing algorithms when analyzing the plethysmographic waveform than when studying the arterial pressure signal.[13] For this situation, the article by Hengy *et al.*[1] should be considered as encouraging; in this study, no engineering was used for the analysis of the plethysmographic waveform, but only a relatively simple algorithm developed on Excel (Microsoft, Redmond, WA). This may also explain why other groups have found good predictive value for ΔPOP in the perioperative setting and also why more sophisticated analyses of the plethysmographic waveform have been shown to be able to guide fluid resuscitation during surgery with positive impact on postoperative outcome.[7]

There is no doubt that the future of perioperative monitoring is noninvasive. However, as anything in medicine, the choice of a treatment or of a technology is context dependent. On the one hand, using a noninvasive technique in a more challenging setting can lead to inappropriate clinical conclusions. On the other hand, it is unacceptable to expand the indications for invasive monitoring when their risks outweigh their benefits. This has been nicely demonstrated in the study by Hengy *et al.*; at this stage, hemodynamic monitoring in very high-risk surgery patients such as those included in this study (liver transplantation, esophageal surgery) must not rely only on the analysis of the plethysmographic waveform. Although, there is no evidence of the interchangeability of ΔPOP with PPV in lower-risk surgery, the ability of ΔPOP to predict fluid responsiveness in this setting has been clearly demonstrated.[11,14] And it is precisely what we expect from such a device: to predict fluid responsiveness. In contrast, the ability of ΔPOP to predict fluid responsiveness in high-risk surgery has not been demonstrated, and Hengy *et al.* provide us a clear demonstration of the discrepancy between ΔPOP and PPV in major digestive surgeries.

Consequently, this monitoring should be reserved for low- or moderate-risk patients for whom it is accurate and for whom no other monitor is available. We should always keep this in mind when choosing the most appropriate hemodynamic monitor for our patients.

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