

Commentary

Pulse oximeter as a sensor of fluid responsiveness: do we have our finger on the best solution?

Xavier Monnet¹, Bouchra Lamia¹ and Jean-Louis Teboul²

¹Assistant Professor, Service de Réanimation Médicale, Centre Hospitalier Universitaire de Bicêtre, Assistance Publique – Hôpitaux de Paris, Le Kremlin-Bicêtre, France

²Professor, Service de Réanimation Médicale, Centre Hospitalier Universitaire de Bicêtre, Assistance Publique – Hôpitaux de Paris, Le Kremlin-Bicêtre, France

Corresponding author: Jean-Louis Teboul, jean-louis.teboul@bct.aphp.fr

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Abstract

The pulse oximetry plethysmographic signal resembles the peripheral arterial pressure waveform, and the degree of respiratory variation in the pulse oximetry wave is close to the degree of respiratory arterial pulse pressure variation. Thus, it is tempting to speculate that pulse oximetry can be used to assess preload responsiveness in mechanically ventilated patients. In this commentary we briefly review the complex meaning of the pulse oximetry plethysmographic signal and highlight the advantages, limitations and pitfalls of the pulse oximetry method. Future studies including volume challenge must be performed to test whether the pulse oximetry waveform can really serve as a noninvasive tool for the guidance of fluid therapy in patients receiving mechanical ventilation in intensive care units and in operating rooms.

Introduction

Prediction of volume responsiveness is an important issue in critically ill patients because clinicians must find the best compromise between central blood volume depletion and volume overloading (i.e. two opposing conditions potentially associated with poor outcome). There is now much evidence that dynamic indices based on the heart–lung interaction are useful in the decision-making process regarding volume resuscitation in patients receiving mechanical ventilation with a tidal volume above 8 ml/kg and exhibiting neither inspiratory efforts nor arrhythmias.

It is beyond the scope of this commentary to review in detail the complex physiological background that underlies the use of these dynamic indices, which has been extensively covered in previous review articles [1-3]. Schematically, the influence of positive pressure ventilation on hemodynamics is greater when central blood volume is low than when it is normal or high. In this regard, the larger the respiratory stroke

volume variation, the larger the degree of volume responsiveness should be. Various indirect measures of stroke volume have been proposed to guide fluid therapy using the heart–lung interaction. By virtue of their ability to display values calculated automatically, real-time monitoring devices should make indices of the heart–lung interaction increasingly popular. Respiratory variations in arterial pulse pressure, in ‘pulse contour’ stroke volume and in Doppler aortic blood velocity have been shown to predict volume responsiveness far better than static markers of preload such as cardiac filling pressures or dimensions [4-7].

Until now there has been no ideal tool because the devices that provide these indices either are fairly invasive or they require a lengthy training period before the clinician can acquire sufficient skill. A noninvasive and easy-to-use device that can track changes in stroke volume in order to detect volume responsiveness would be particularly attractive. The pulse oximeter used to monitor arterial blood saturation could be a good candidate because the pulse oximetry plethysmographic (POP) signal resembles the peripheral arterial pressure waveform. Indeed, analysis of the respiratory variation in pulse oximeter waveforms has long been proposed as a technique with which to assess blood volume status in mechanically ventilated patients [8,9]. In some studies [8-10] the degree of respiratory variation in the peak value of the plethysmographic waveform has been correlated with that of systolic arterial pressure.

Respiratory variation in pulse oximetry waveform

In a recent issue of *Critical Care*, Cannesson and coworkers [11] reported a new finding by demonstrating a reasonably

good correlation between respiratory variation in the amplitude of the 'pulse' wave (peak–nadir) calculated from variations in the POP waveform (called Δ POP by the authors) and the respiratory variation in arterial pulse pressure recorded with an arterial catheter. The strength of the study is that it takes into account the variation in the 'pulse' wave rather than that in the peak of the wave. By reflecting the pulsatile changes in absorption of infrared light between the light source and the photo detector of the pulse oximeter, the 'pulse' wave is assumed to be the result of the beat-to-beat changes in stroke volume transmitted to arterial blood. In this respect, Δ POP is potentially a marker of respiratory stroke volume variation. By contrast, the respiratory variation in the peak of the plethysmographic wave – previously proposed for assessing volume status [8,9] – depends not only on local changes in arterial blood volume but also on the slower ventilatory changes in local venous blood volume resulting from the ventilatory changes in venous return that mainly affect the highly compliant venous bed. The two figures presented in the report by Cannesson and coworkers [11] (Figs 1 and 4) clearly illustrate the slow ventilatory variation in the plethysmographic waveform (particularly apparent at the wave 'nadir' level) in addition to the cyclic changes in the 'pulse' wave.

Limitations of pulse oximetry waveform interpretation

The following weaknesses may limit the extent of the conclusions that may be drawn from the study [11]: no volume challenge was performed and Bland–Altman analysis revealed unsatisfactory agreement between Δ POP and pulse pressure variation. Thus, utility of Δ POP in detecting fluid responsiveness was not demonstrated.

Furthermore, numerous limitations and pitfalls related to the pulse oximetry method must be highlighted. For technical reasons, the pulse oximetry signal may be of poor quality in the presence of motion, hypothermia or arterial vasoconstriction, although the new generation of pulse oximeters allows one to optimize the recorded signal-to-noise ratio and thus improve the quality of the displayed signal [12]. In this regard, the proprietary software included with pulse oximeter monitors generate plethysmographic signals that are substantially filtered, amplified and smoothed before they are displayed. Any significant signal processing makes the theoretical proportionality between respiratory variation in left ventricular stroke volume and indices such as Δ POP highly questionable. This may occur under conditions of low peripheral perfusion, in which amplification of the signal-to-noise ratio is maximized. In an attempt to limit the potential influence of the signal processing on the displayed waveform, the automatic gain incorporated into the pulse oximeter was disengaged in the study conducted by Cannesson and coworkers [11]. This allowed the investigators to maintain a constant gain throughout the study, rendering quantitative analysis of the waveform easier.

Conclusion

Additional studies – including volume challenge – are mandatory if we are to determine whether respiratory variation in pulse oximetry really can predict volume responsiveness in mechanically ventilated patients without arrhythmias or inspiratory effort. In such studies it would be important to seek a threshold value of Δ POP that permits acceptable prediction and to investigate whether this value differs between pulse oximeter models, because their signal processing software may differ. Finally, it would be important to determine the extent to which Δ POP is able to decrease in parallel with the increase in cardiac output that occurs after volume loading. Achievement of these objectives is mandatory before oximetry waveform variation can be recommended as a guide to fluid therapy in mechanically ventilated patients in intensive care units and operating rooms, in the same way that arterial pulse pressure variation and other heart–lung interaction indices are currently used [1,13].

Competing interests

Professor JL Teboul is a member of the Medical Advisory Board of Pulsion Medical System (Germany). Drs X Monnet and B Lamia have no competing interests.

References

1. Bendjelid K, Romand JA: **Fluid responsiveness in mechanically ventilated patients: a review of indices used in intensive care.** *Intensive Care Med* 2003, **29**:352-360.
2. Michard F, Teboul JL: **Using heart-lung interactions to assess fluid responsiveness during mechanical ventilation.** *Crit Care* 2000, **4**:282-289.
3. Pinsky MR: **Assessment of indices of preload and volume responsiveness.** *Curr Opin Crit Care* 2005, **11**:235-239.
4. Michard F, Boussat S, Chemla D, Anguel N, Mercat A, Lecarpentier Y, Richard C, Pinsky MR, Teboul JL: **Relation between respiratory changes in arterial pulse pressure and fluid responsiveness in septic patients with acute circulatory failure.** *Am J Respir Crit Care Med* 2000, **162**:134-138.
5. Kramer A, Zygun D, Hawes H, Easton P, Ferland A: **Pulse pressure variation predicts fluid responsiveness following coronary artery bypass surgery.** *Chest* 2004, **126**:1563-1568.
6. Feissel M, Michard F, Faller JP, Teboul JL: **The respiratory variation in inferior vena cava diameter as a guide to fluid therapy.** *Intensive Care Med* 2004, **30**:1834-1837.
7. Hofer CK, Müller SM, Furrer L, Klaghofer R, Genoni M, Zollinger A: **Stroke volume and pulse pressure variation for prediction of fluid responsiveness in patients undergoing off-pump coronary artery bypass grafting.** *Chest* 2005, **128**:848-854.
8. Partridge BL: **Use of pulse oximetry as a noninvasive indicator of intravascular volume status.** *J Clin Monit* 1987, **3**:263-268.
9. Shamir M, Eidelman LA, Floman Y, Kaplan L, Pizov R: **Pulse oximetry plethysmographic waveform during changes in blood volume.** *Br J Anaesth* 1999, **82**:178-181.
10. Murray WB, Foster PA: **The peripheral pulse wave: information overlooked.** *J Clin Monit* 1996, **12**:365-377.
11. Cannesson M, Besnard C, Durand P, Bohé J, Jacques D: **Relation between respiratory variations in pulse oximetry plethysmographic waveform amplitude and arterial pulse pressure in ventilated patients.** *Crit Care* 2005, **9**:R562-R568.
12. Jubran A: **Pulse oximetry.** *Intensive Care Med* 2004, **30**:2017-2020.
13. Michard F, Teboul JL: **Predicting fluid responsiveness in ICU patients: a critical analysis of the evidence.** *Chest* 2002, **121**:2000-2008.