Best Practice & Research Clinical Anaesthesiology 28 (2014) 407–418

Contents lists available at ScienceDirect

Best Practice & Research Clinical Anaesthesiology

journal homepage: www.elsevier.com/locate/bean

8

Respiratory variation and cardiopulmonary interactions

Russell S. Roberson, MD, Assistant Professor *

Department of Anesthesiology and Pain Management, University of Texas Southwestern Medical Center at Dallas, 5909 Harry Hines Blvd, Dallas, TX 75390-9202, USA

Keywords:
stroke volume variation
pulse pressure variation
pulse contour analysis
acute respiratory distress syndrome
dynamic preload assessment
fluid therapy
fluid responsiveness
hypovolaemia

It is often unclear whether or not a patient's stroke volume will increase following a fluid bolus. Volume responsiveness is defined by an increase in stroke volume following a fluid bolus. For patients being mechanically ventilated, the cardiopulmonary interactions associated with positive pressure ventilation create pulse pressure and stroke volume variation in the arterial pressure waveform that can be used to assess fluid responsiveness, so-called dynamic preload assessment. However, lung-protective ventilation is increasingly being used to avoid the adverse outcomes of higher tidal volume ventilation, and pulse pressure and stroke volume variation do not effectively predict volume responsiveness in the setting of lung-protective ventilation without using special techniques. Dynamic preload assessment is more effective at determining whether a patient will be fluid responsive than static measures of preload, but further studies are needed to more conclusively show that outcomes are improved with this approach to fluid management.

A frequent dilemma when caring for patients in the operating room and intensive care unit (ICU) is whether a patient's haemodynamics can be improved with fluid therapy. Historically, static measures of preload (cardiac filling pressures and left ventricular (LV) end-diastolic area) have been used to guide this decision, but it is has become increasingly clear that dynamic preload assessment can more successfully answer the question of whether a patient will be fluid responsive and that static assessments

* Tel.: +1 214 645 1060; Fax: +1 214 645 1061.
E-mail address: russell.roberson@utsouthwestern.edu.

http://dx.doi.org/10.1016/j.bpa.2014.09.001

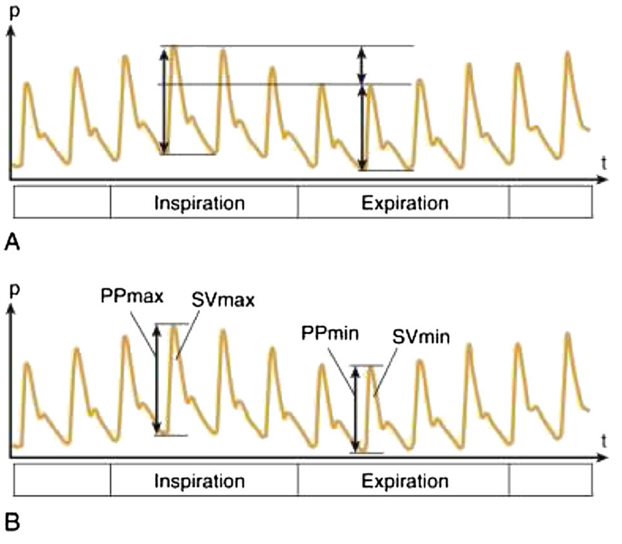

Fig. 1. (Adapted from Figure 88-1 in Miller's Anaesthesia) [83]. A, Qualitative example of pulse pressure variation (PPV) resulting from positive-pressure ventilation in a hypovolemic patient. Both the systolic and diastolic pressure drop with mechanical inspiration, but the decrease in the systolic pressure is greater than the drop in the diastolic pressure due to the decrease in preload. *p*, pressure; *t*, time. B, Quantitative assessment of PPV and stroke volume (SVV) using pulse contour analysis; *p*, pressure; *t*, time.

of fluid responsiveness are often misleading [1]. Fluid responsiveness is simply an increase in stroke volume (SV) in response to a fluid bolus, often defined as an increase in SV > 10% [2].

Physiology behind systemic arterial respiratory variation

With controlled positive pressure ventilation, inspiration increases intrathoracic pressure impeding venous return to the heart, thereby reducing SV and systolic and diastolic pressure in subsequent cardiac cycles. These changes in blood pressure (BP) in mechanically ventilated patients can be quantified by a variety of methods and used to assess fluid responsiveness, so-called dynamic preload assessment.

During inspiration with controlled ventilation, there are four cardiopulmonary interactions leading to alterations in BP. First, positive pressure during inspiration decreases vena cava blood flow (venous return), thereby sequentially decreasing right ventricular (RV) preload, RV ejection, pulmonary artery (PA) blood flow, and LV preload and ejection. Second, RV afterload increases during inspiration impeding RV ejection; third, LV preload increases during inspiration because the increased lung volume pushes blood through the pulmonary vasculature into the left atrium (LA); and, fourth, LV afterload decreases due to increased intrathoracic pressure. Because of the relatively long transient time of pulmonary blood flow, the inspiratory decrease in RV filling and ejection only impairs LV filling and ejection a few seconds later [3], which is typically during the expiratory period, even though the increased intrathoracic pressure during inspiration sets these changes in motion. These alterations in arterial BP due to mechanical ventilation can be quantified as systolic pressure variation (SPV) and used to assess fluid responsiveness.

Pulse pressure variation (PPV) and stroke volume variation (SVV) are two other commonly used methods of pulse contour analysis to assess fluid responsiveness in mechanically ventilated patients. PPV, SVV and SPV increase with progressive hypovolaemia and decrease with volume loading. There are a variety of commercially available devices (see the next section 'Devices For Predicting Fluid Responsiveness') that provide automated calculations of these parameters from the arterial trace. Dynamic preload assessment using PPV or SVV is only reliable in sedated patients on controlled