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Editorial II

Less is more . . . using systolic pressure variation to assess hypovolaemia

Systolic arterial pressure decreases during the inspiratory phase of intermittent positive pressure ventilation (IPPV). This cyclical variability in arterial pressure was recognized more than 30 yr ago as being caused by a decrease in venous return as intrathoracic pressure increases during inspiration.[1] The magnitude of the variability was linked to the degree of hypovolaemia by Cohn, Pinkerson and Trismani[2] and later given the term 'positive pressure paradox' by Coyle and colleagues.[3] Perel, Pizov and Cotev[4] subsequently coined the phrase 'systolic pressure variation' and demonstrated, in a controlled study, its direct relationship with acute hypovolaemia.

Systolic pressure variation has not become popular in the UK, despite the fact that it correlates with hypovolaemia more closely than any other measured variable, including central venous pressure, pulmonary artery occlusion or diastolic pressure, pulse pressure, cardiac output or systolic arterial pressure.[4 5] It also compared favourably with arterial pressure and intrathoracic blood volume estimation as an indicator of hypovolaemia in an experimental animal model.[6]

There may be several reasons why systolic pressure variation has not become more widely accepted in Europe. Most published work in this field has been from the USA and Israel: thus British anaesthetists, who perhaps use invasive arterial pressure monitoring less frequently than their North American counterparts, are relatively unfamiliar with the technique. Additionally, manufacturers of monitoring equipment have yet to develop the technology required to facilitate easy, accurate estimation of systolic pressure variation from an arterial pressure trace.

Many different variables affect systolic pressure variation including: lung and chest wall compliance; tidal volume[7] and ventilatory frequency; mode of ventilation; inspiratory–expiratory ratio[8]; use of positive end-expiratory pressure (PEEP)[9]; and the volume status of the patient.[10] In a patient undergoing mechanical ventilation, all ventilation-related variables are relatively constant, thus systolic pressure variation is correlated directly with the degree of hypovolaemia. Although there are also cyclical changes in systolic pressure during spontaneous ventilation, these are not as predictable, perhaps because tidal volumes and chest wall compliance are not as constant as during IPPV.[10]

The baseline for measurement of systolic pressure variation is systolic pressure at end-expiration, which may be estimated during a short period of apnoea. There are then two measurable components: the contribution above the baseline (delta-up: Δup) and the contribution below the baseline (delta-down: Δdown) (Fig. 1). Δdown reflects the normal decrease in venous return during inspiration, which is exacerbated by hypovolaemia and is the major contributor to the total systolic pressure variation.[4] Beaussier and colleagues showed that systolic pressure variation was inversely proportional to stroke volume by measuring the area under the curve when aortic blood flow velocity was plotted against time.[11] Δup reflects augmentation of cardiac output caused by increased left ventricular preload during expiration and usually makes a small contribution to the overall systolic variation. However, it may be significantly increased in left ventricular failure because of the afterload-reducing effect of increased intrathoracic pressure.[12]

The characteristics of systolic pressure variation have recently been defined further. It has been used to detect hypotension secondary to hypovolaemia, even if the patient is also receiving pharmacological vasodilators[13] and may be used to detect hypovolaemia in patients whose lungs are being ventilated mechanically and who are hypotensive because of sepsis.[14] It has even been used as a method of detecting accidental hyperinflation of the chest during IPPV.[15]

Systolic pressure variation may be approximated from most currently available monitors in a ventilated patient undergoing direct arterial pressure measurement. However, accurate measurement is difficult, unless the arterial trace is printed out and measurements made from the printed trace, which is cumbersome. It is easier if more direct measurement is possible. One instrument (Model 90305, SpaceLabs Medical Inc, Redmond, WA, USA) allows the screen to be 'frozen' so that the variation can be measured directly using an on-screen cursor.

For visual estimation of systolic pressure variation, the amplitude of the arterial pressure waveform on screen should be increased to the maximum possible. Additionally, the arterial trace should be slowed from the standard sweep speed of 25 mm s^{-1} to 12.5 mm s^{-1} or even 6.25 mm s^{-1}. This makes systolic pressure variation more apparent by including more respiratory cycles on the display. Additionally, 40 or 50 s of real-time monitoring information is provided which is useful during periods of haemodynamic instability such as aortic unclamping, when the anaesthetist's attention may be directed elsewhere. The normal systolic pressure variation in a patient undergoing mechanical ventilation is 8–10 mm Hg (Δdown component 6–8 mm Hg). Values above this are indicative of hypovolaemia and should be treated according to the response to fluid therapy. Of course, systolic pressure variation may only be measured

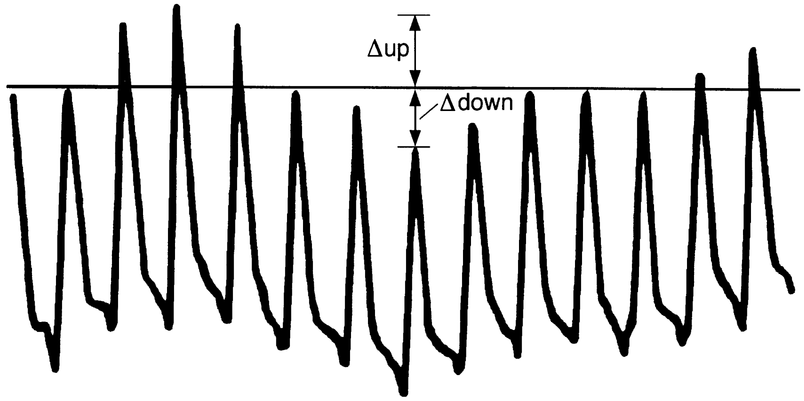

Fig 1 Representation of an arterial pressure trace demonstrating systolic pressure variation during one complete respiratory cycle.

directly if there is invasive arterial pressure measurement. However, changes in the pulse oximetry plethysmographic signal during the respiratory cycle have also been shown to be closely related to the degree of hypovolaemia in clinical studies,[16 17] and it is also possible to measure systolic pressure variation from non-invasive techniques for measuring beat-to-beat arterial pressure such as the Finapres.[18]

Variation in systolic arterial pressure during mechanical ventilation is an under-used monitoring method, which is a very specific and sensitive indicator of hypovolaemia. Developments in monitoring technology should allow easier measurement of systolic pressure variation. There are no extra complications associated with it beyond those of arterial cannulation. Systolic pressure variation should be used more commonly as a monitor of intravascular volume. It may complement, or even replace, other monitors of hypovolaemia.

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