Haemodynamic stability requires accurate assessment of fluid status

Introduction

Fluid overload is associated with an increase in ventilator days, ICU stay, PEEP requirements, and transfusions. In addition, it is associated with an increase in intra-abdominal pressure, even in medical patients, which, in turn, is associated with adverse outcomes in the ICU.

Resuscitation requires restoration of DO₂ and VO₂.

\[ \text{DO}_2 = \text{Hb} \times 1.34 \times \text{SAT} \times \text{CO} \]

The measures used to assess fluid status are often not very accurate:

- Initial CVP and PAOP do not correlate with EDV and SV;
- ∆ CVP and PAOP do not correlate with volume infusion;
- However, initial EDV and ∆ EDV do correlate strongly with SV.

As a consequence, pursuing an arbitrary CVP value to guide volume replacement results in unnecessary fluid overload, and does not improve oxygen delivery.

\[ \text{ScvO}_2 \]

In general, \( \text{ScvO}_2 < 70\% \), despite adequate BP, indicates occult hypoperfusion. However, not all studies have confirmed the value of this parameter in sepsis.

\[ P(\text{cv-a})\text{CO}_2 \]

When \( \text{ScvO}_2 \) of 70% is reached, \( P(\text{cv-a})\text{CO}_2 > 6 \text{ mmHg} \) may identify a further group of inadequately resuscitated patients.

Swan-Ganz

The problem with the Swan-Ganz is catheter is that there are no measures of pre-load. Recent studies have demonstrated that PAOP is a poor predictor of preload/volume responsiveness, as PAOP measures LVED pressure, not LVED volume, and pressure is a function of LV compliance. As a consequence, PAOP correlates poorly with CO or SV.

Cardiac ECHO

TEE reliably assesses LV dimensions, but results are conflicting regarding fluid responsiveness. Reuter found TEE to be good but other studies did not. Essentially, static volumes and estimated filling pressures have the same limitations as Swan-Ganz measurements. There is a long learning curve, lack of reproducibility, and the readouts are non-continuous. IVC diameter is an indirect indicator of CVP and, therefore, has the same limitations.

Abbreviations

- BP blood pressure
- BUN blood urea nitrogen
- CABG coronary artery bypass graft surgery
- CO cardiac output
- CRRT continuous renal replacement therapy
- CVP central venous pressure
- DO₂ oxygen delivery
- EDV end-diastolic volume
- Hb haemoglobin concentration
- IBW ideal body weight
- ICU intensive care unit
- IVC inferior vena cava
- LV left ventricle
- LVED left ventricular end-diastolic
- MAP mean arterial pressure
- MV mean flow velocity
- PAC pulmonary artery catheter
- PAOP pulmonary artery occlusion pressure
- P(cv-a)CO₂ central venous-to-arterial carbon dioxide difference
- PEEP positive end-expiratory pressure
- PLR passive leg raising
- PPV pulse pressure variation
- RV right ventricle
- SAT percentage Hb O₂ saturation
- ScvO₂ central venous oxygen saturation
- SV stroke volume
- SVRI systemic vascular resistance index
- SVV stroke volume variation
- TEE transoesophageal echocardiography
- TV tidal volume
- VO₂ oxygen uptake
Oesophageal Doppler

There is a significant learning curve to obtaining adequate signal, however, a meta-analysis demonstrated an 86% correlation between Doppler vs. PAC for CO, and excellent correlation between ∆CO and therapeutic interventions. Respiratory variation in flow velocity with MV is a reliable predictor of fluid responsiveness.

PPV and SVV

The SVV can be reliably assessed using the modified FloTrac® and PICCO® systems. These parameters predict volume responsiveness better than CVP and PAOP post-CABG, intra- and post-operatively, and in septic and ventilated patients.

These measurements are inaccurate with arrhythmias, rapid temperature changes, intra-cardiac shunts, aortic aneurysms, aortic stenosis, pneumonectomy, significant PE and extracorporeal circulation.

SVV/PPV are reliable only when TV ≥ 8 ml/kg. It is suggested that the TV be increased to 8 - 10 ml/kg of IBW prior to and after fluid challenge. They are less reliable during spontaneous breathing. However, when the baseline value is high, a positive fluid response is likely to occur.

Lactate

A value > 4 meq/l and the rate of clearance is associated with a high risk of death. However, lactate clearance lags many hours behind therapeutic intervention and, therefore, is not a surrogate for cardiac output.

Algorithm

1. Screen with ScvO2 (< 70% indicates tissue hypoxia).
3. Assess fluid status: CVP > 10 generally fluid replete, < 10 gives no information.
4. Pulse contour analysis: SVV > 10% administer further fluid bolus and measure cardiac output response (> 15% is a responder).
5. Confirm responsiveness with a transthoracic ECHO ± PLR/ fluid bolus. Also assess LV function, wall motion defects, RV status (pulmonary embolus).
6. If MAP < 65 mmHg, ScvO2< 70%, CI < 2.5, but SVV < 10%
   a. Confirm Hct > 30%, Sat > 90%
   b. No response: calculate SVRI
      - SVRI < 1 000 adrenaline: sepsis/anaphylaxis
      - SVRI > 1 000 dobutamine: myocardial dysfunction
7. Close monitoring of fluid balance is essential. Fluid overload is associated with worse outcome.
8. Stable patients should not be > 500 ml positive per day.
9. Avoid “maintenance” crystalloid; feed early instead.
10. Avoid oedema. If hypotensive and oedematous, initiate inotropes and diurese/dialyse.
11. If oliguric or anuric, initiate CRRT prior to development of fluid overload or arbitrary BUN or creatinine levels are achieved.