Venous / Arterial Compliance Ratio Calculation

Kirk H. Shelley, M.D., Ph.D.
Professor of Anesthesiology
Yale University

Conflict of Interest

- Twenty plus year history of research on this and related topics.
- Not a consultant, not in any speaker bureau, nor on any advisor boards. I do not like NDA / CDAs…
- Have applied for patents on this and related technology.
- Scientific founder of a Yale start-up company to help bring new PPG technology to the marketplace.
Clinical Monitoring Essentials

- What do we understand about the physiology?
  - What is our mental model?
- Can we monitor it?
  - Biomedical engineering
- Does it alter therapy?
  - Do we do something with this information?
- Does it change outcomes?
  - Remarkably complex question…

Clinically Actionable Information

- Fluid status
  - Early success with respiratory-induced variability
  - Fluid infusion vs. Diuretics
- Vasculature tone
  - What do we follow? BP? SVR?
  - Vasoconstrictor vs. Vasodilator
- Cardiac function
  - Adequacy of tissue perfusion on a global and regional level.
  - Blood transfusion & Inotropic medications

Real World Bleeding

Baseline and Amplitude Modulating

Baseline Modulation
Pulse Amplitude remains constant

Two types of modulation

Stroke Volume Variation (ΔPOP)
‘AC Modulation’

Venous Blood Movement
‘DC Modulation’

Combined Modulations

Aymen Alian – Yale University

Adam Shelley - Johns Hopkins
PPG = Arterial + Venous

Blood in Motion

Oesophageal Pulse Oximeter

Prof Panayiotis Kyriacou
Potential to have information from both the pre-load and after-load side from the pulse oximeter waveform.

Venous/Arterial Compliance Ratio

- Compliance = volume Δ / pressure Δ
- Photoplethysmograph (PPG) modulation is an uncalibrated measure of blood volume change.
- The arterial line (or just a BP cuff!) and peripheral IV allows one to measure pressure change.
- PPG modulation at the respiratory frequency (0.1 Hz – 0.4 Hz) = change of venous blood volume
- PPG modulation at the cardiac frequency (0.8 Hz – 2.5 Hz) = change of arterial blood volume
\[
\text{Compliance ratio} = \left( \frac{\text{venous}}{\text{arterial}} \right) = \frac{\text{PPG (resp)}}{\text{Venous (resp)}} \div \frac{\text{PPG (cardiac)}}{\text{Arterial (cardiac)}}
\]

9.9 ratio = \(\frac{1.26/0.554}{1.438/6.275}\)

Effect of Phenylephrine

Aymen Alian – Yale University

Yale University School of Medicine
Shoulder Case
Older patient with labile blood pressure

Effect of Phenylephrine on Arterial Compliance

The arterial compliance goes down (vessels get tighter) with phenylephrine.
Effect of Phenylephrine on Venous Compliance

The venous compliance goes up (vessels get looser) with phenylephrine.

Effect of Phenylephrine

So arteries get tighter, veins get looser therefore the vein/arterial compliance ratio goes up with phenylephrine.
Effect of Fluid Boluses

Effect of 300cc Fluid Boluses on Venous Compliance

Venous Compliance drops (veins become tighter) with fluid boluses.
Effect of Fluid Bolus on Arterial Compliance

No significant change in arterial compliance with fluid boluses

Effect of Fluid Boluses

So arteries stay the same, veins get tighter therefore the vein/arterial compliance ratio goes down with fluid boluses.
Why use a ratio?

- Given the fact the PPG is *uncalibrated* the individual arterial and venous compliance measurement can only be followed as a *trend monitor*.
- The venous/arterial compliance ratio allows for the development of a *threshold monitor* with normal values and the potential to guide vasopressor therapy.

Needed to move forward…

- Examples over a wider range of interventions and conditions.
  - Pharmaceutical
    - NTG, Nitroprusside, Vasopressin, Epinephrine, etc…
  - Clinical Conditions
    - Sepsis, CHF, Renal Failure
- ‘Responder vs. Non-Responder’ type Studies
  - Outcome studies that demonstrates that changes in therapy based upon this new measurement.
  - Goal would be improved tissue perfusion
  - What is a marker of that? PI, UO, GI function, venous sats?