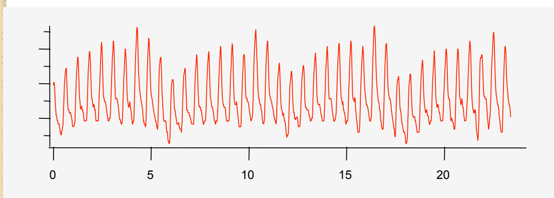
Venous / Arterial Compliance Ratio Calculation

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



STA 2013

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

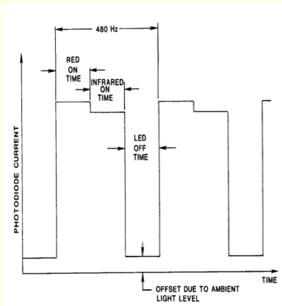
- Fluid status
  - Early success with respiratory-induced variability
  - Fluid infusion vs. Diuretics
- Vasculature tone
  - What do we follow? BP? SVR?
  - Vasoconstrictor vs. Vasodilator
- Cardiac function
  - Adequacy of tissue perfusion on a global and regional level.
  - Blood transfusion & Inotropic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

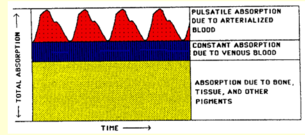
- **Rivers**, E., B. Nguyen, et al. (2001). *"Early goal-directed therapy in the treatment of severe sepsis and septic shock."* N Engl J Med 345(19): 1368-1377.
- **O'Connor, M. F.** – University of Chicago (2009-2011): *Understanding Clinical Hemodynamics* ASA Refresher Course

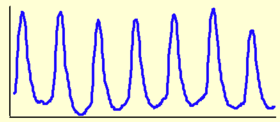
Plethysmograph

How does it work?

Starting Point...





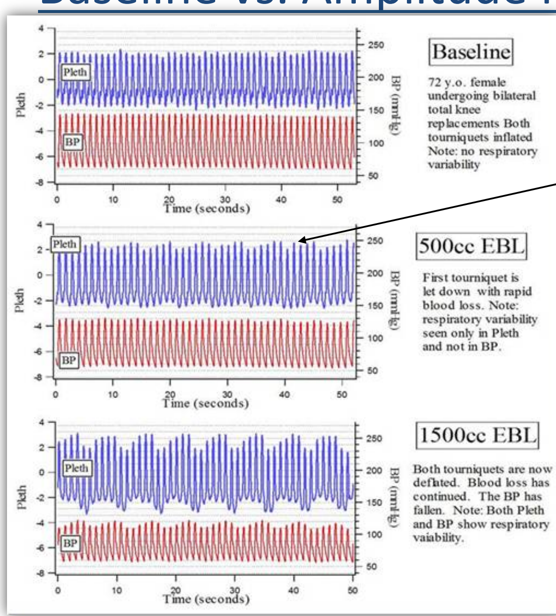


Hertzman, A.B. and C. Spielman, *Observations on the finger volume pulse recorded photoelectrically.* Am J Physiol, 1937. **119**: p. 334-5.

Final Product...

A Volume Signal !

Baseline vs. Amplitude Modulation



Baseline modulation occurs before Amplitude modulation

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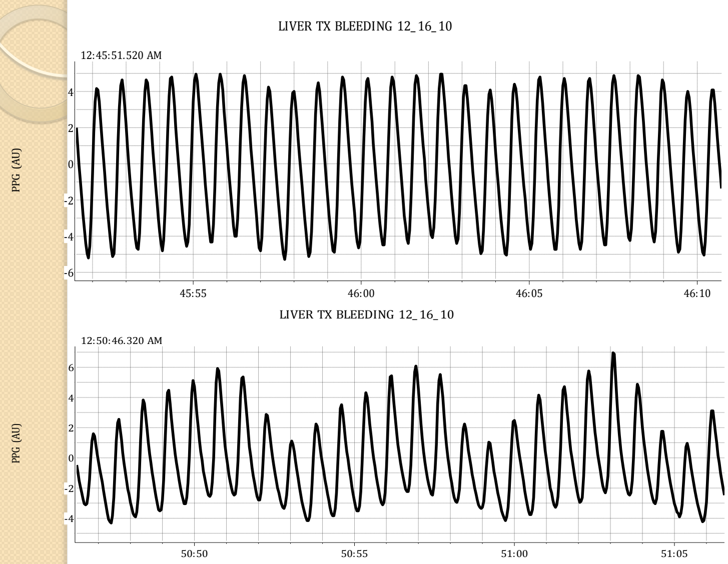
Real World Bleeding

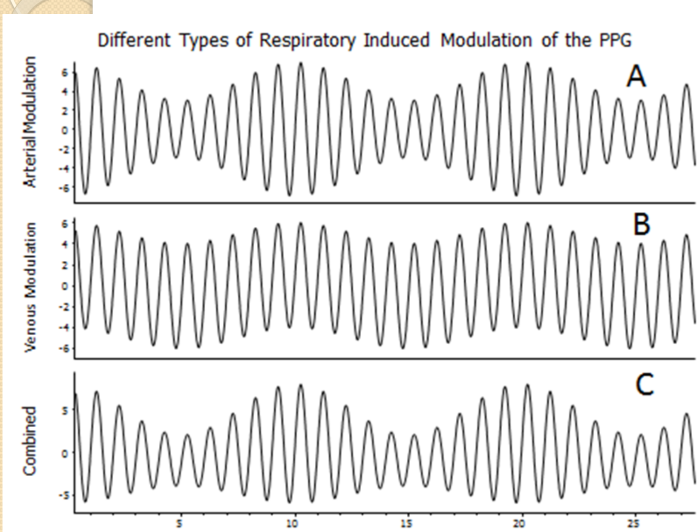


Baseline Modulation Pulse Amplitude remains constant

Baseline and Amplitude Modulating

Aymen Alian – Yale University

Two types of modulation



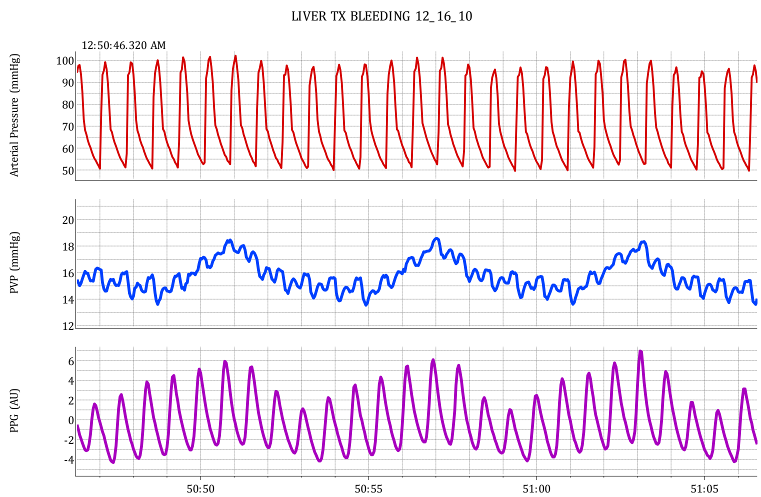
Stroke Volume Variation (ΔPOP) ‘AC Modulation’

Venous Blood Movement ‘DC Modulation’

Combined Modulations

Adam Shelley - Johns Hopkins

PPG = Arterial + Venous



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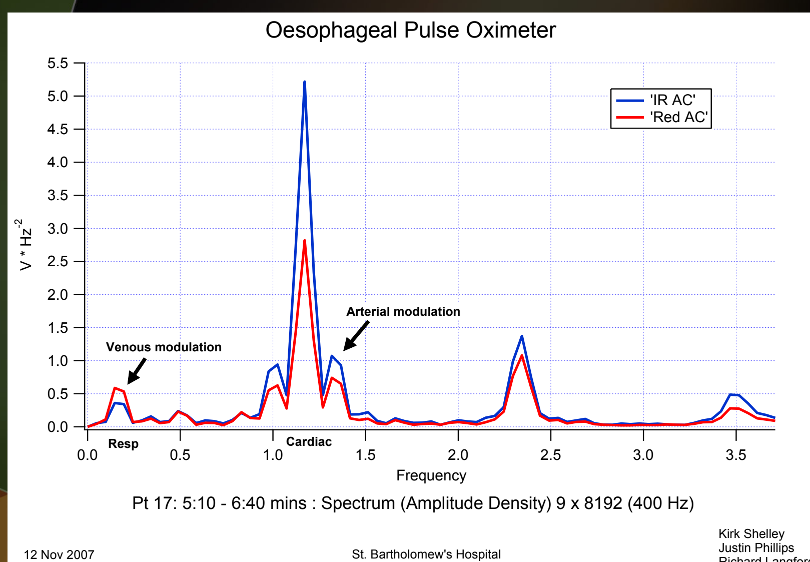
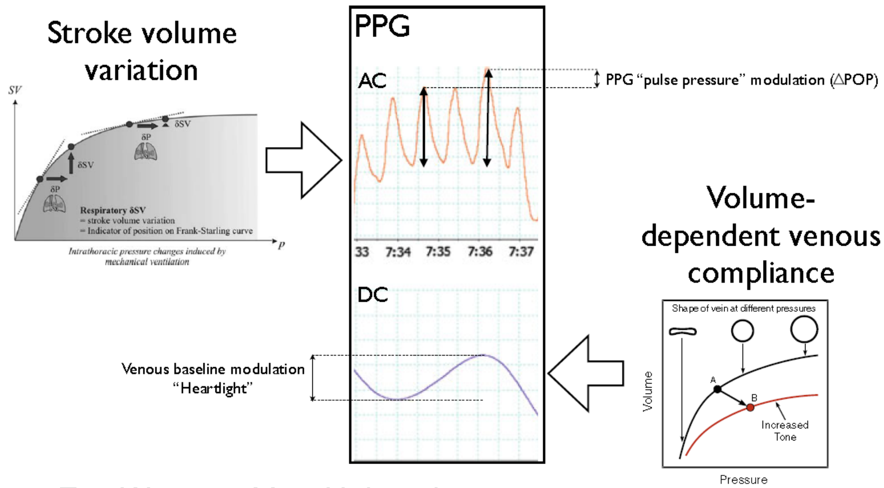
Blood in Motion



City University
London, England

Prof Panayiotis Kyriacou

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

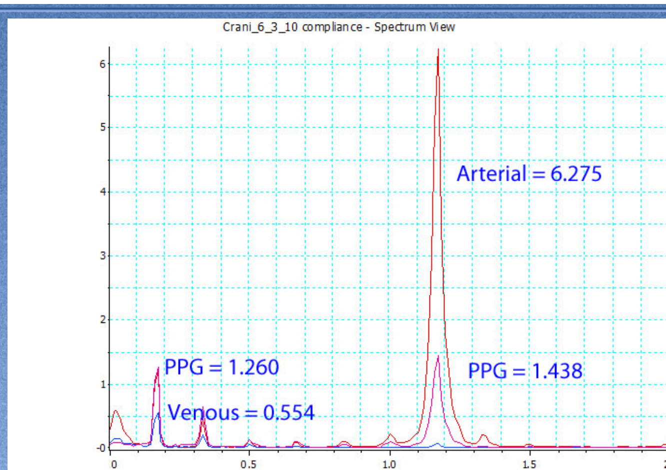


Zac Walton – Yale University

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

$$Compliance\ ratio\ \left(\frac{venous}{arterial}\right) = \frac{PPG\ (resp)}{Venous\ (resp)} \Big/ \frac{PPG\ (cardiac)}{Arterial\ (cardiac)}$$



9.9 ratio=(1.26/0.554) / (1.438/6.275)

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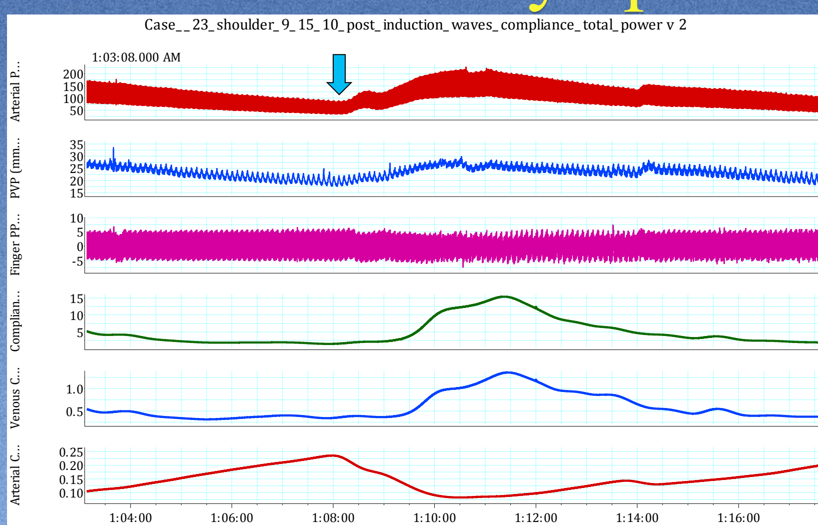
Effect of Phenylephrine



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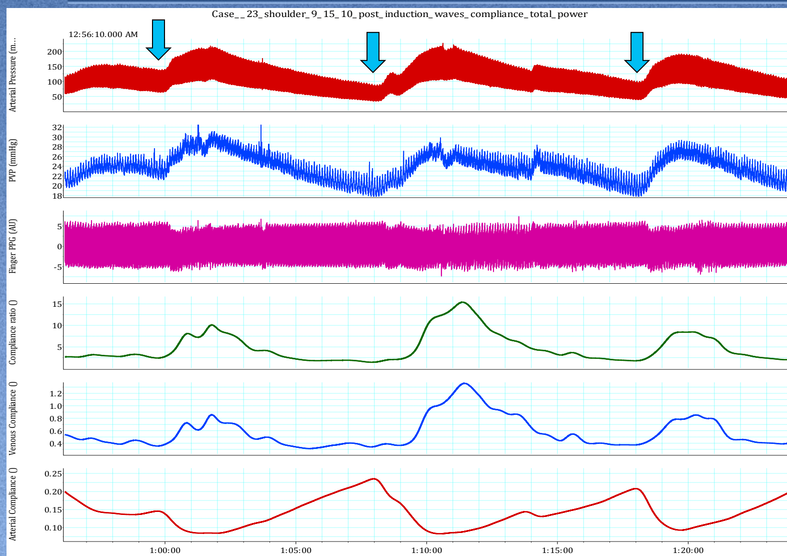
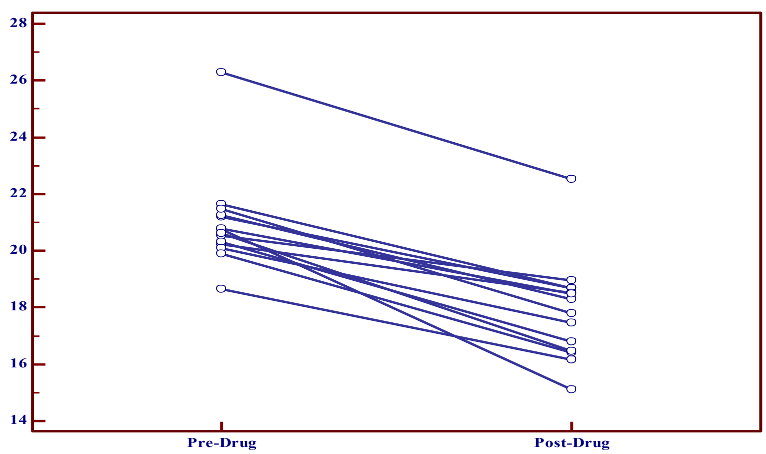
Shoulder Case

Older patient with labile blood pressure

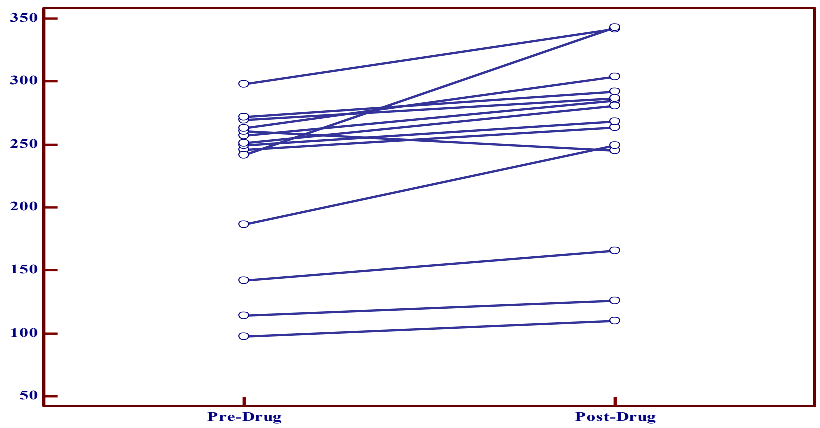


Effect of Phenylephrine on Arterial Compliance



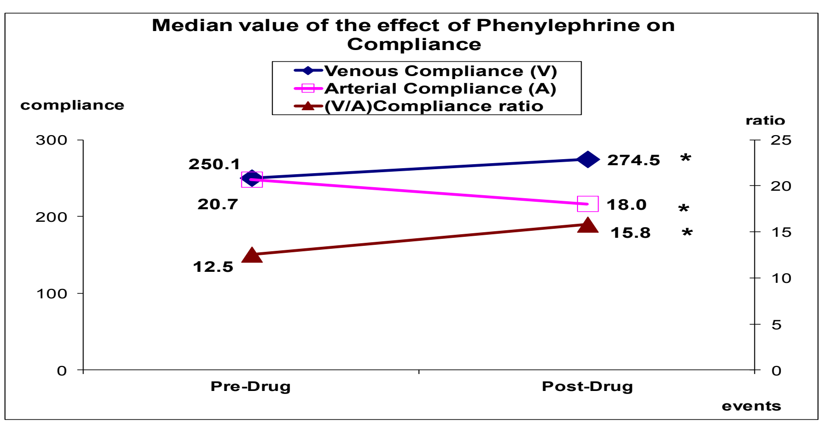
The arterial compliance goes down (vessels get tighter) with phenylephrine.

Effect of Phenylephrine on Venous Compliance



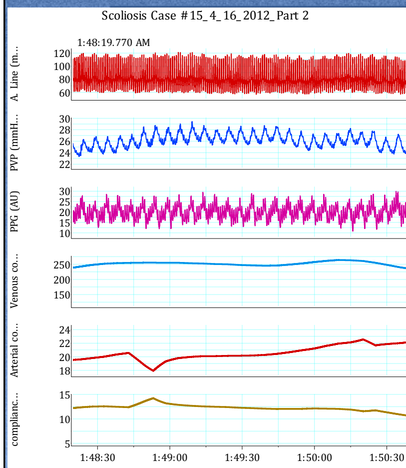
The venous compliance goes up (vessels get looser) with phenylephrine.

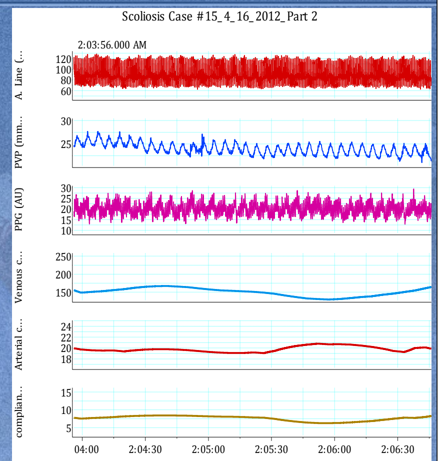
Effect of Phenylephrine



So arteries get tighter, veins get looser therefore the vein/arterial compliance ratio goes up with phenylephrine

Effect of Fluid Boluses





Before fluid bolus

After fluid bolus

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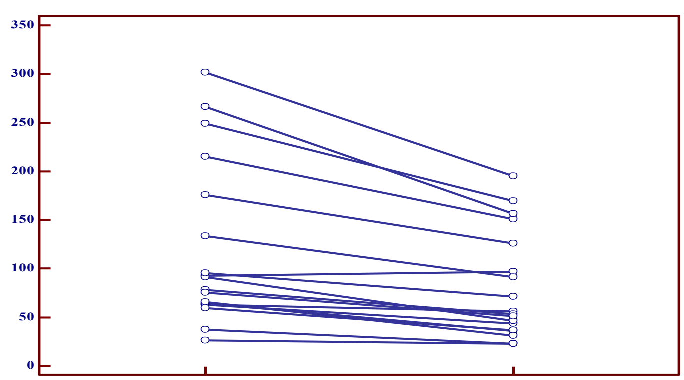
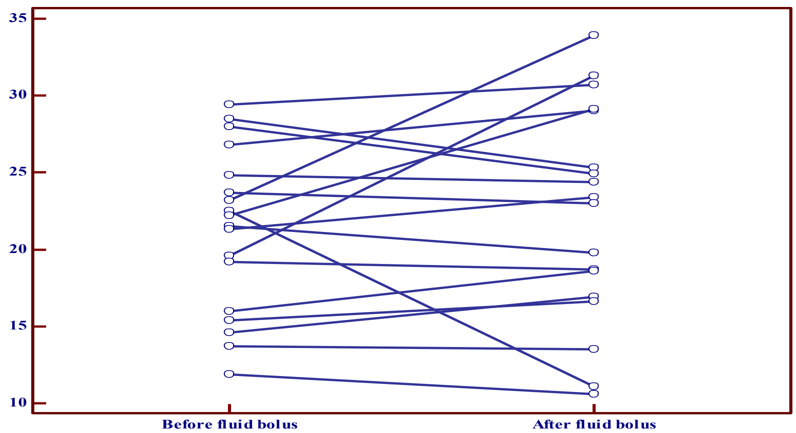
Effect of 300cc Fluid Boluses on Venous Compliance



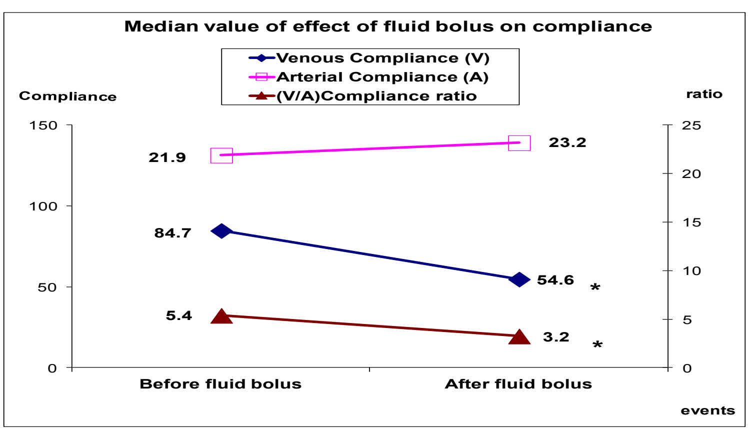
Venous Compliance drops (veins become tighter) with fluid boluses.

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 ?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