Preload Recruitable Stroke Work May Not Be a Valid Index of Cardiac Contractility

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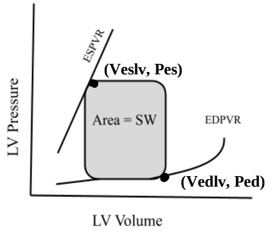
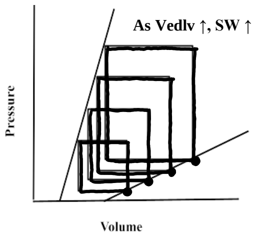
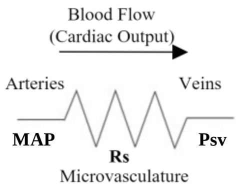
Introduction

Left Ventricle and Systemic Vasculature

- Pressure-volume loop shows changes in the left ventricle's blood pressure and volume during a cardiac cycle, which consists of diastole and systole
- Increasing end-diastolic volume (preload) creates larger loops (stroke work)
- Pumped blood travels from arteries to microvasculature and then veins
- Arterial pressure must overcome venous pressure for blood to flow
- Microvasculature resists blood flow

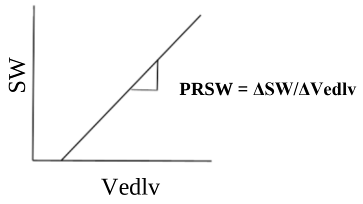






What is PRSW?

- The slope of left ventricular stroke work & end diastolic volume
- Deemed to be a load-independent index of cardiac contractility
- Has been shown to increase with inotropes and remain relatively constant with changes in systemic resistance



Purpose

- To develop an algebraic formula for PRSW in terms of parameters characterizing the critical mechanical properties of the left ventricle and systemic vasculature.

Methods

Assumptions

- End-systolic pressure-volume relationship (ESPVR) is linear
- End-diastolic pressure-volume relationship (EDPVR) is nonlinear
- Pressure-volume loop is approximated by a rectangle
- End-systolic pressure (Pes) is approximated by MAP
- End-diastolic pressure (Ped) is approximated by Ppv
- Ea ≈ (HR)(Rs)
- MAP is either perfectly regulated (1st case) or not (2nd case)
  - Under normal conditions, the baroreflex increases or decreases Rs in order to counter changes to MAP
  - Under extreme conditions, MAP can no longer be maintained and thus, Rs becomes constant

Variables

SW	stroke work	Vedlv	left ventricular end diastolic volume
Vedlv	left ventricular unstressed end-systolic volume	Emaxlv	left ventricular maximum end-systolic elastance
Veslv	left ventricular end systolic volume	Ea	effective arterial elastance
MAP	mean arterial pressure	HR	heart rate
Ppv	pulmonary venous pressure	Rs	systemic resistance
Psv	systemic venous pressure	PRSW	preload recruitable stroke work

Model Equations

(1) $SW = (Vedlv - Veslv)(MAP - Ppv)$

(2) $Ppv = a\, Vedlv^{b}$

(3) $Veslv = \frac{MAP}{Emaxlv} + Voeslv$

(4) $MAP = Psv + (Vedlv - Veslv)(Ea)$

Means of Solving 1st and 2nd Cases

- 1st case: solve eqs. 1-3 for SW, Veslv, Ppv
- 2nd case: solve eqs. 1-4 for SW, Veslv, Ppv, and MAP
- Take the derivative of the SW solutions in terms of Vedlv

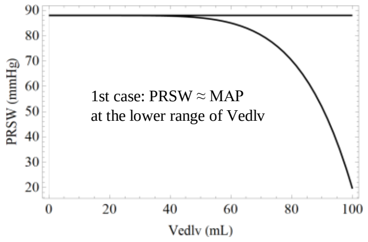
Results

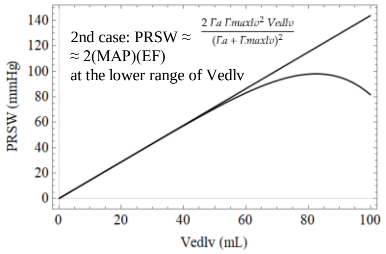
Resultant Equations

1st case: $$PRSW = Psa + \frac{a\, b\, Psa\, Vedlv^{-1+b}}{Emaxlv} - a\, Vedlv^{b} - a\, b\, Vedlv^{b} + a\, b\, Vedlv^{-1+b}\, Voeslv$$

2nd case: $$PRSW = \frac{Emaxlv\left(-a\,(Ea+Emaxlv)\,Vedlv^{b} + Emaxlv\,(Psv + Ea\,(Vedlv - Voeslv))\right)}{(Ea+Emaxlv)^2} - \frac{\left(Ea\,Emaxlv - a\,b\,(Ea+Emaxlv)\,Vedlv^{-1+b}\right)(Psv + Emaxlv\,(-Vedlv + Voeslv))}{(Ea+Emaxlv)^2}$$

Linear Approximations





Discussion

- For case 1, PRSW is mainly determined by MAP at the lower Vedlv range
- For case 2, PRSW is mainly determined by preload, HR, and Rs, in addition to contractility at the lower Vedlv range
- PRSW cannot be treated as only an index of contractility
- 2(MAP)(Ejection Fraction) provides a non-invasive way of determining PRSW, contrasting with traditional vena cava occlusion

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