From aortic flow to central pressure

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Cardiovascular HEALTHCARE TECHNOLOGY CO-OPERATIVE

Background

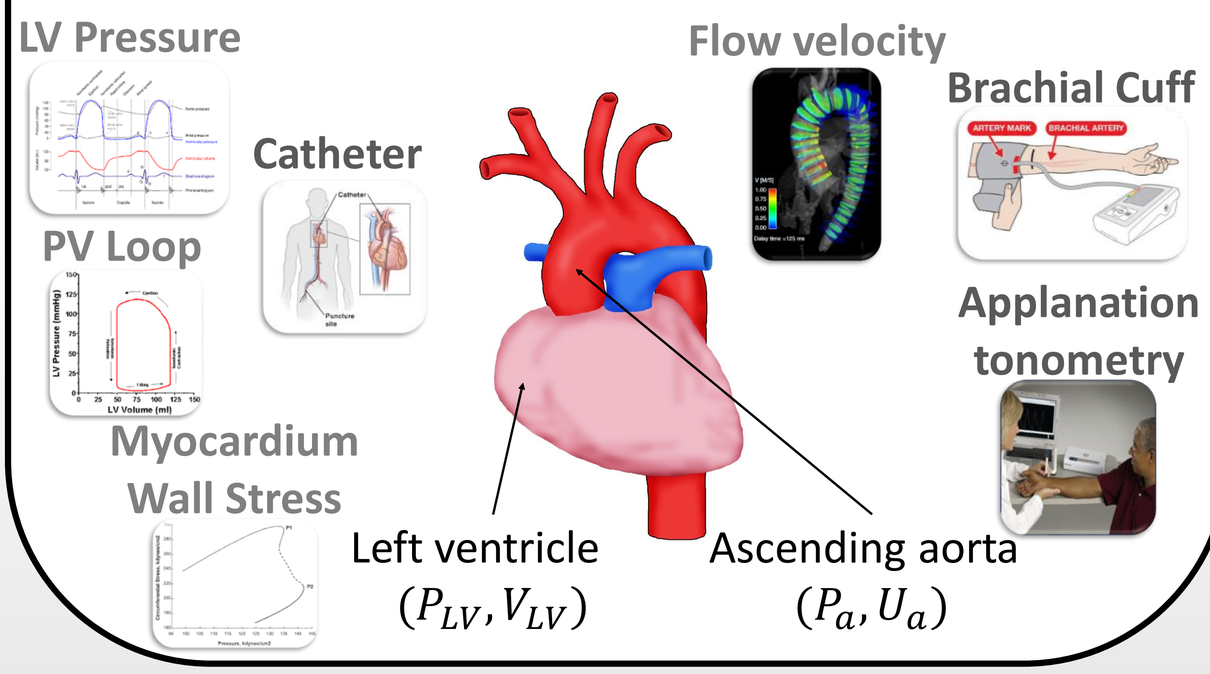
- Cardiovascular disease is the single biggest killer in the world.
- Central aortic pressure is now regarded as the best predictor of cardiovascular event.
- Applanation tonometry is the only technique to estimate aortic pressure throughout the whole cardiac cycle

PROBLEM

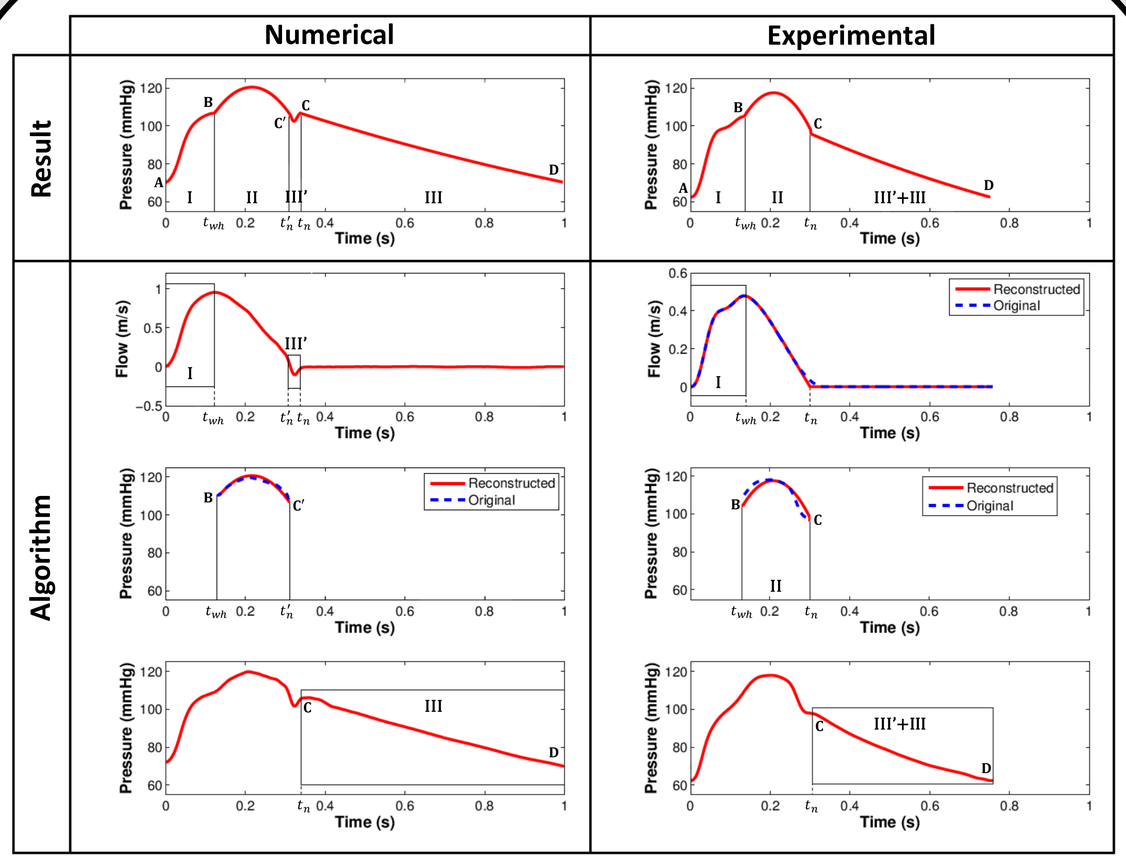
- Not accurate for high-frequency components.
- Not patient specific as uses a generalized transfer function.
- Impossible to couple with an imaging modality

CHALLENGE

Derive central pressure waveform from aortic flow velocity



Method



Part I: Early systole (under the assumption of negligible reflection waves)

Water Hammer equation

$$P_a(t) = \rho \, . PWV \, . U_a(t)$$

Part II: Mid systolic peak

Second-order polynomial approximation

$$P_a(t) = at^2 + bt + c$$

Part III (numerical) or III'+III (experimental): Diastole

Exponential curve with same exponential decay as target pressure

Part III' (numerical): Dicrotic notch

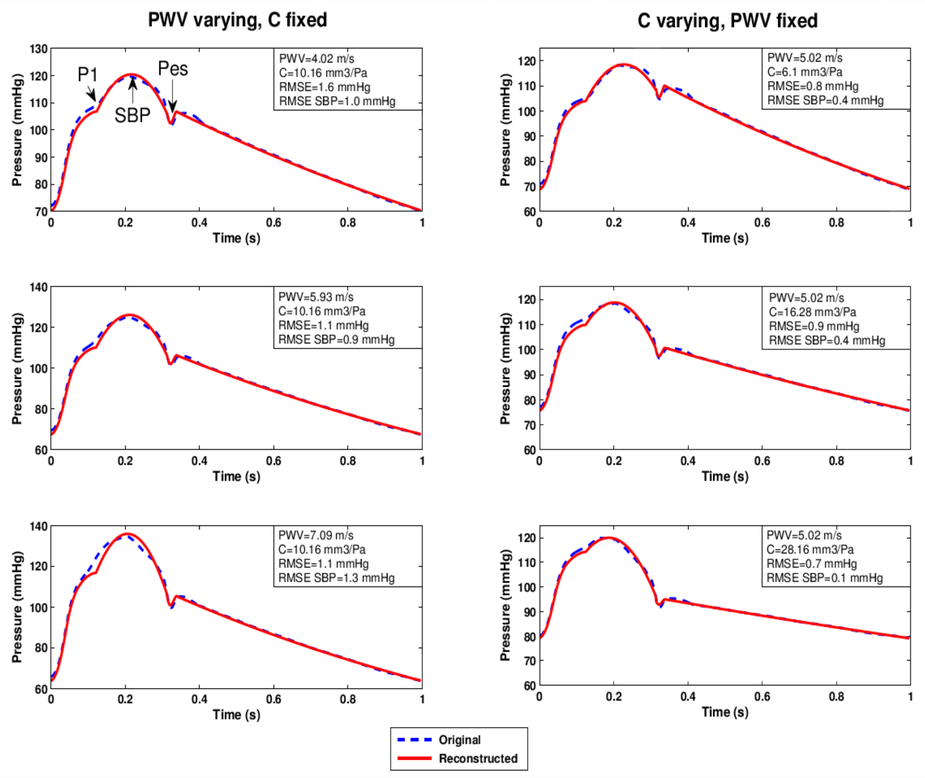
Taken from Water Hammer pressure waveform (Part I) and incorporated at the beginning of diastole

Results

Assumed to be known:

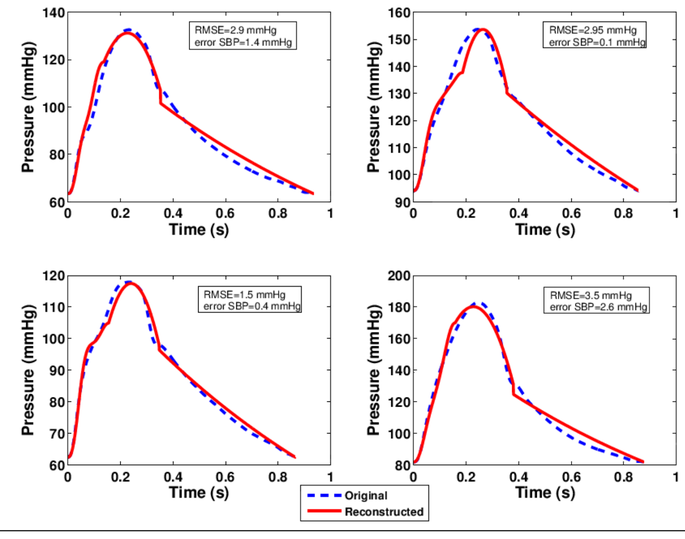
- Pulse Wave Velocity (PWV)
- Diastolic Blood Pressure (DBP)
- Mean Arterial Pressure (MAP)
- Diastolic decay (τ)

Numerical results for a generically-computed one-artery model:



Number of datasets	PWV (m/s)	Compliance C (mm³/Pa)	Waveform	P_1		SBP		P_{es}	
			Mean RMSE ±SD (mmHg)	Mean±SD (mmHg)	Max (mmHg)	Mean±SD (mmHg)	Max (mmHg)	Mean±SD (mmHg)	Max (mmHg)
15	3.55-7.09	10.16	1.1±0.2	1.7±2.9	5.7	0.5±0.9	1.8	1.7±0.1	1.8
12	5.02	6.10-28.16	0.9±0.1	0.3±1.1	2.4	0.3±0.3	0.5	1.4±0.4	2.1

Experimental results with a dual pressure/Doppler flow transducer (n=18)



Waveform	P_1		SBP		P_{es}	
Mean RMSE ±SD (mmHg)	Mean±SD (mmHg)	Max (mmHg)	Mean±SD (mmHg)	Max (mmHg)	Mean±SD (mmHg)	Max (mmHg)
3.4±1.3	1.9±5.3	14	1.4±2.0	5.2	0.9±3.4	6.9

Implications

- First derivation of central pressure based on phenomenon occurring directly in the ascending aorta
- Potential to derive left ventricular pressure noninvasively
- Possibility to partition pulsatile component of aortic pressure into:
  - Those arising as a result of aortic stiffening (PWV)
  - Those arising as a result of altered ventricular dynamics (U_a)

Vennin et al. "Noninvasive calculation of the aortic blood pressure waveform from the flow velocity waveform: a proof of concept." *American Journal of Physiology-Heart and Circulatory Physiology* 309.5 (2015): H969-H976.