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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

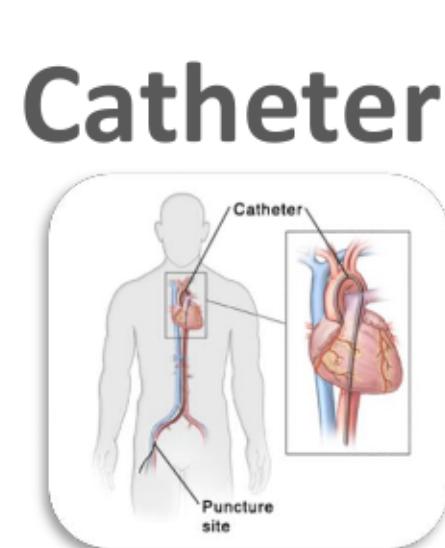
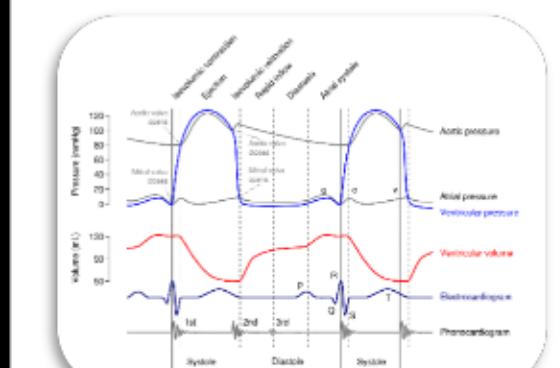
PROBLEM

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

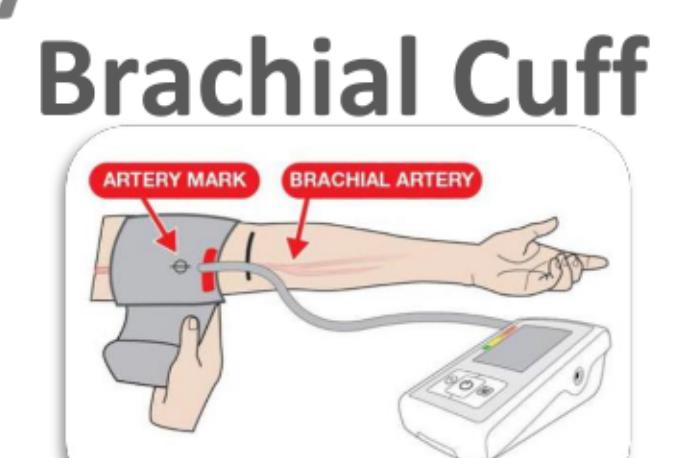
CHALLENGE

Derive central pressure waveform from aortic flow velocity

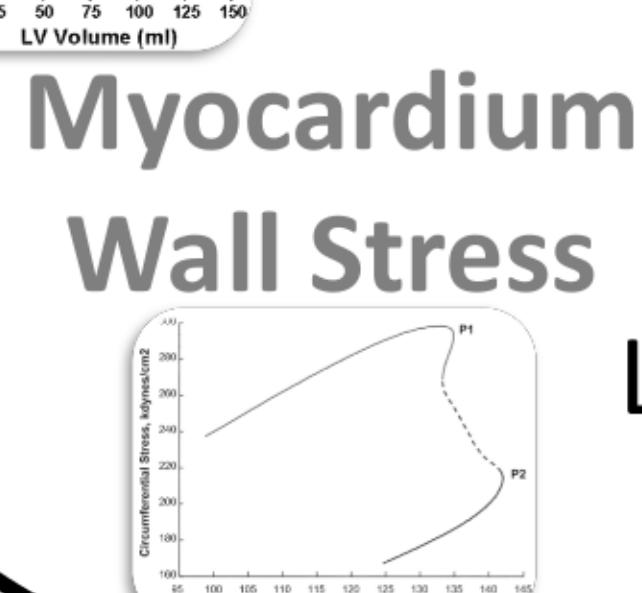
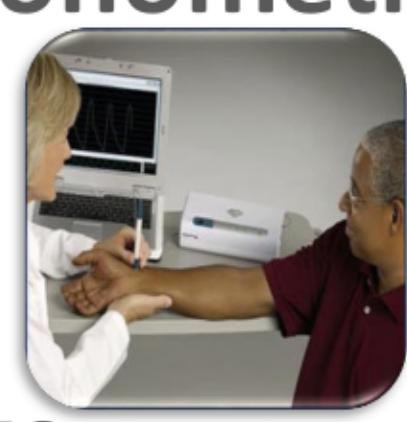
LV Pressure



Flow velocity



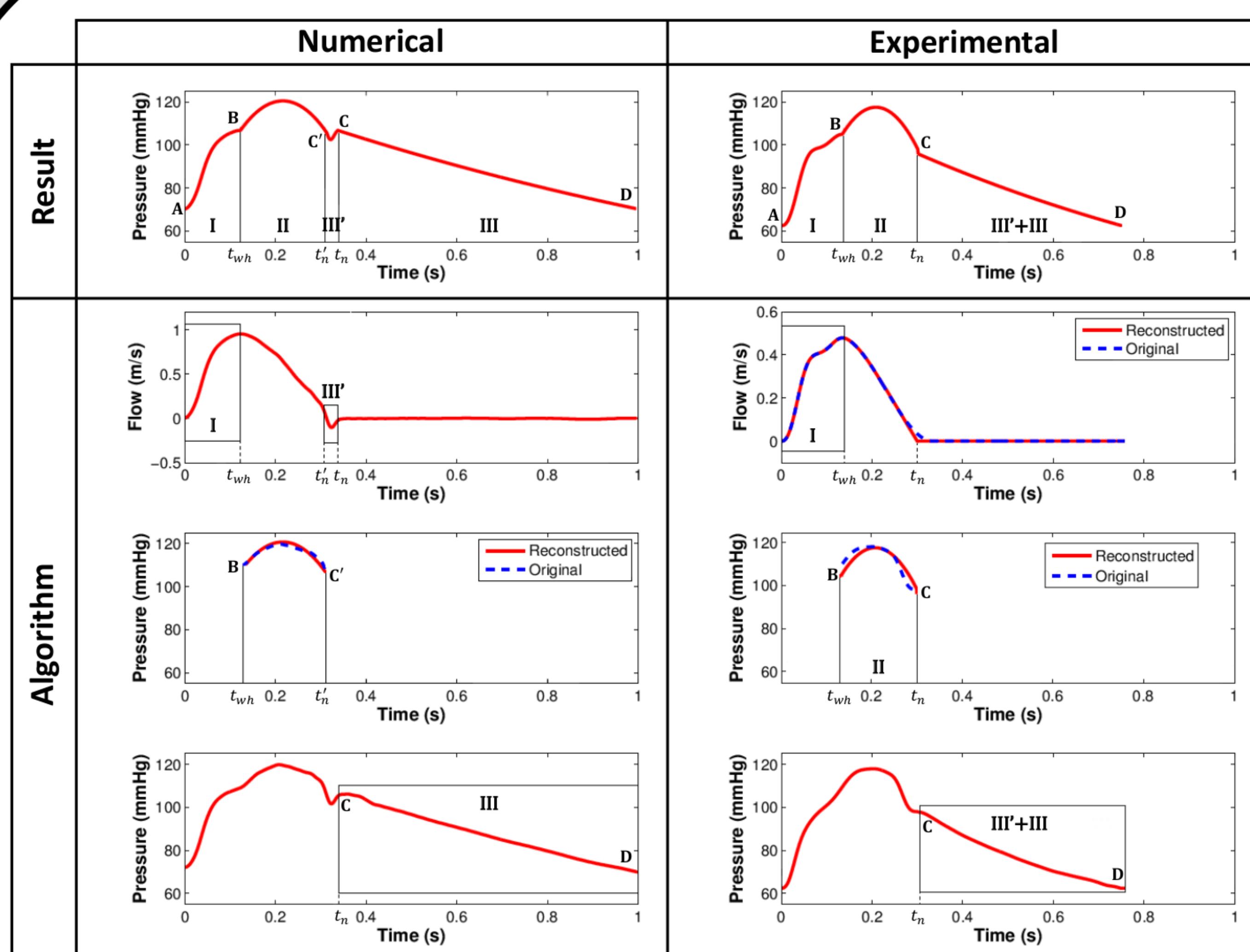
Applanation tonometry



Left ventricle
(P_{LV}, V_{LV})

Ascending aorta
(P_a, U_a)

Method



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

$$P_a(t) = \rho \cdot PWV \cdot U_a(t)$$

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

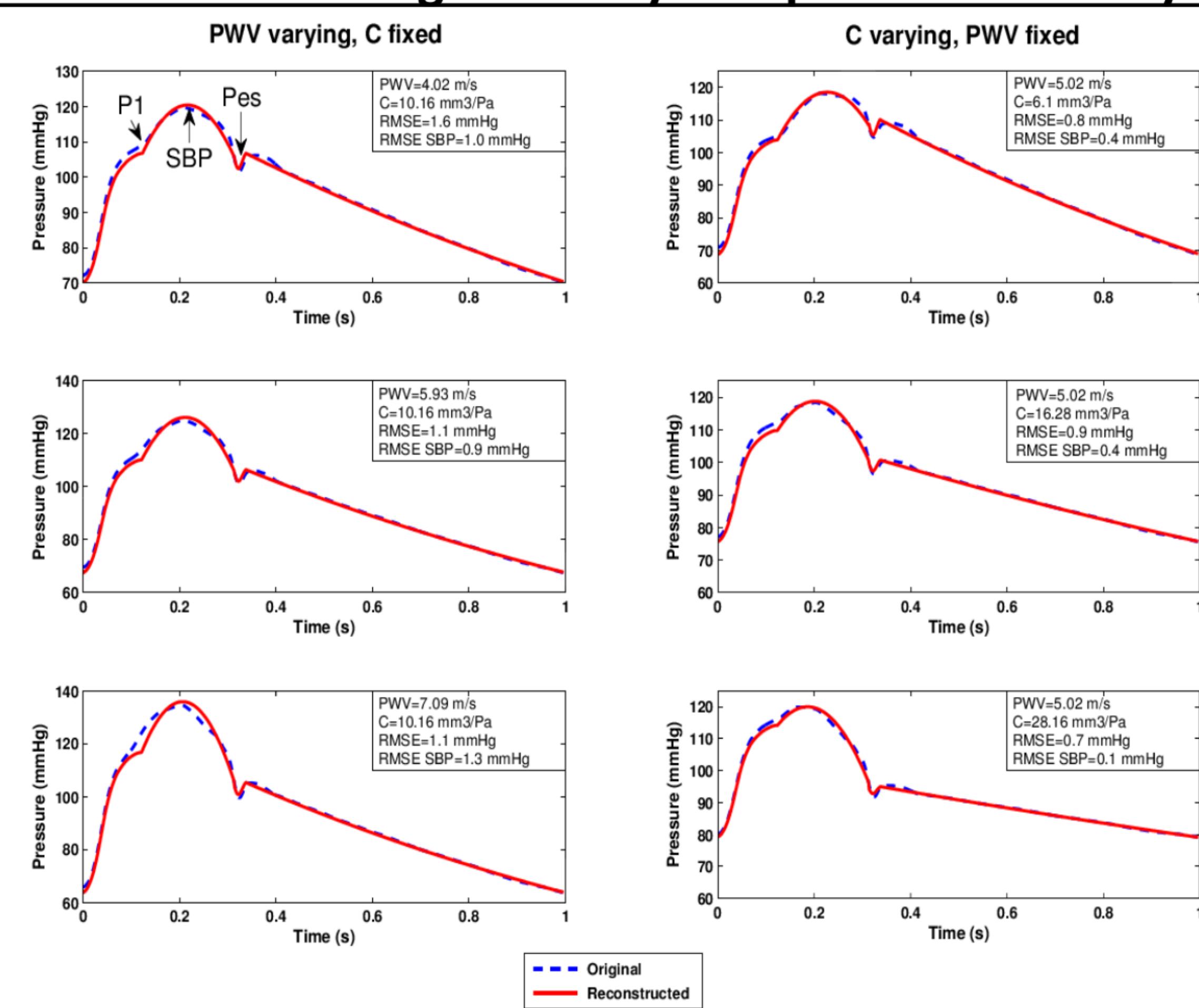
Taken from Water Hammer pressure waveform (Part I) and incorporated at the beginning of diastole

Results

Assumed to be known:

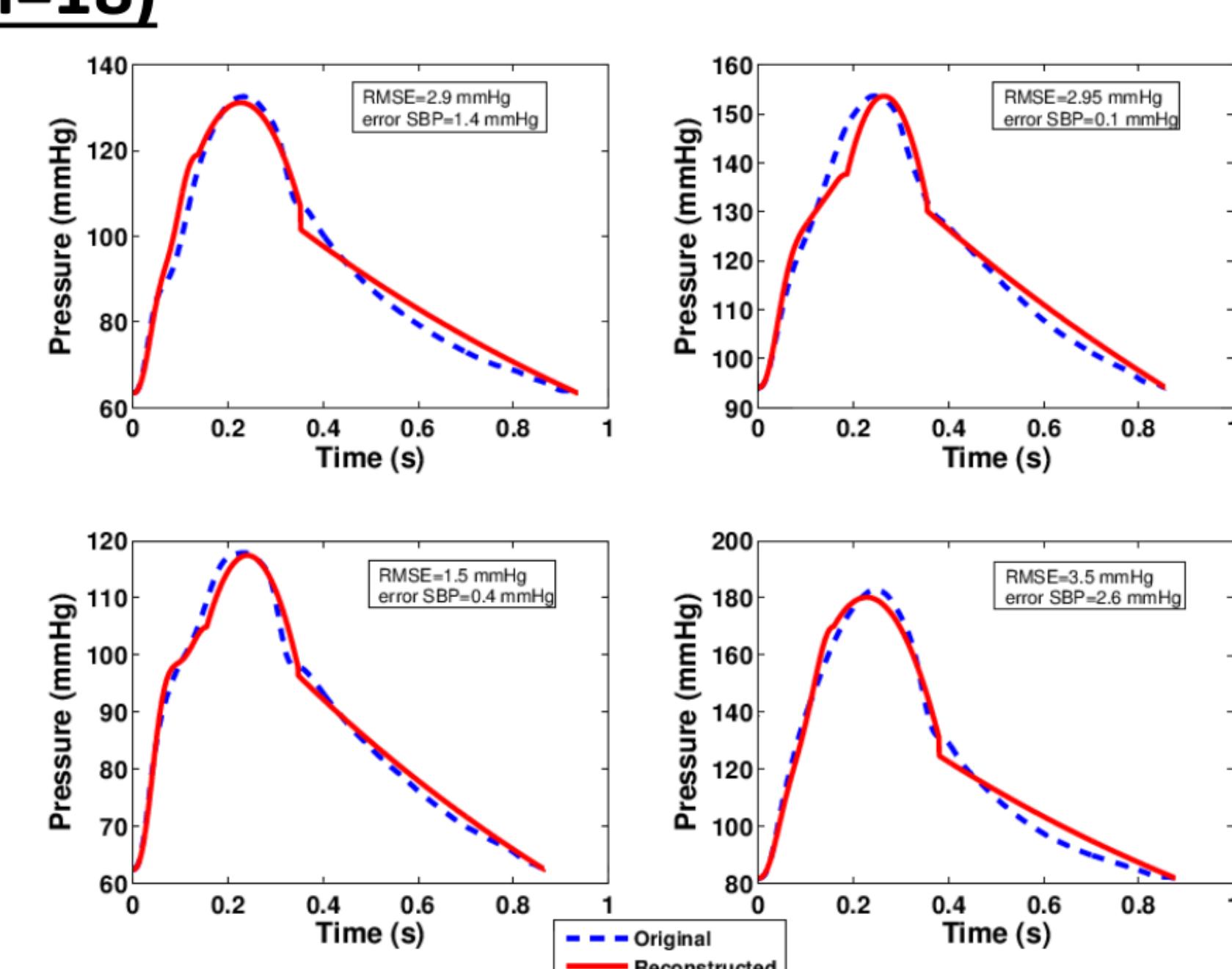
- Pulse Wave Velocity (PWV)
- Diastolic Blood Pressure (DBP)
- Mean Arterial Pressure (MAP)
- Diastolic decay (τ)

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)			
15	3.55-7.09	10.16	1.1±0.2	1.7±2.9	5.7	0.5±0.9	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

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



Waveform	P_1	SBP	P_{es}	Mean RMSE ± SD (mmHg)	
				Mean RMSE ± SD (mmHg)	Mean ± SD (mmHg)
				3.4±1.3	1.9±5.3

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)