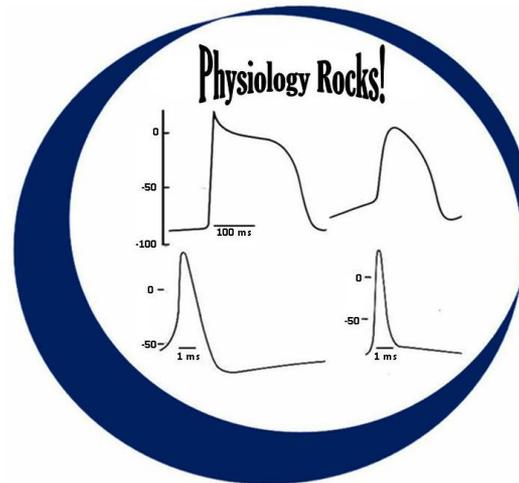


Lecture 12

Arterial Pressures, Pulses and Propagation

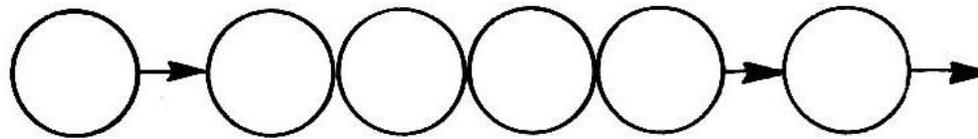
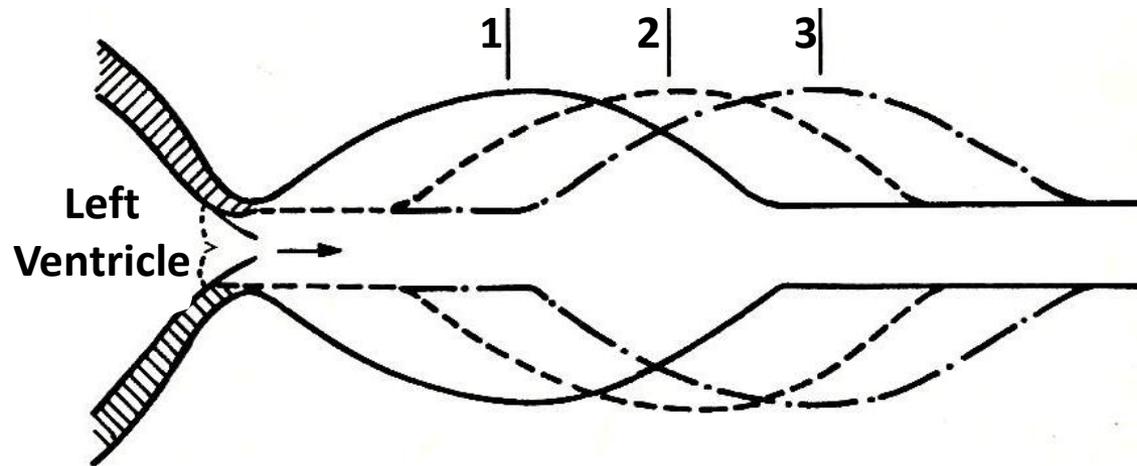


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Topics

- Arterial pulse wave process
- Arterial pulse wave transmission and reflection: Introduction
- Pressure gradient produces pulsatile blood flow
- Pressure vs. pressure gradient features
- Pulse wave interactions
- Pulsatile pressure and flow variations
- Ankle-brachial systolic pressure index (ABI)
- Pulse pressure determinants
- Central pressure concept and augmentation index
- Clinical correlations

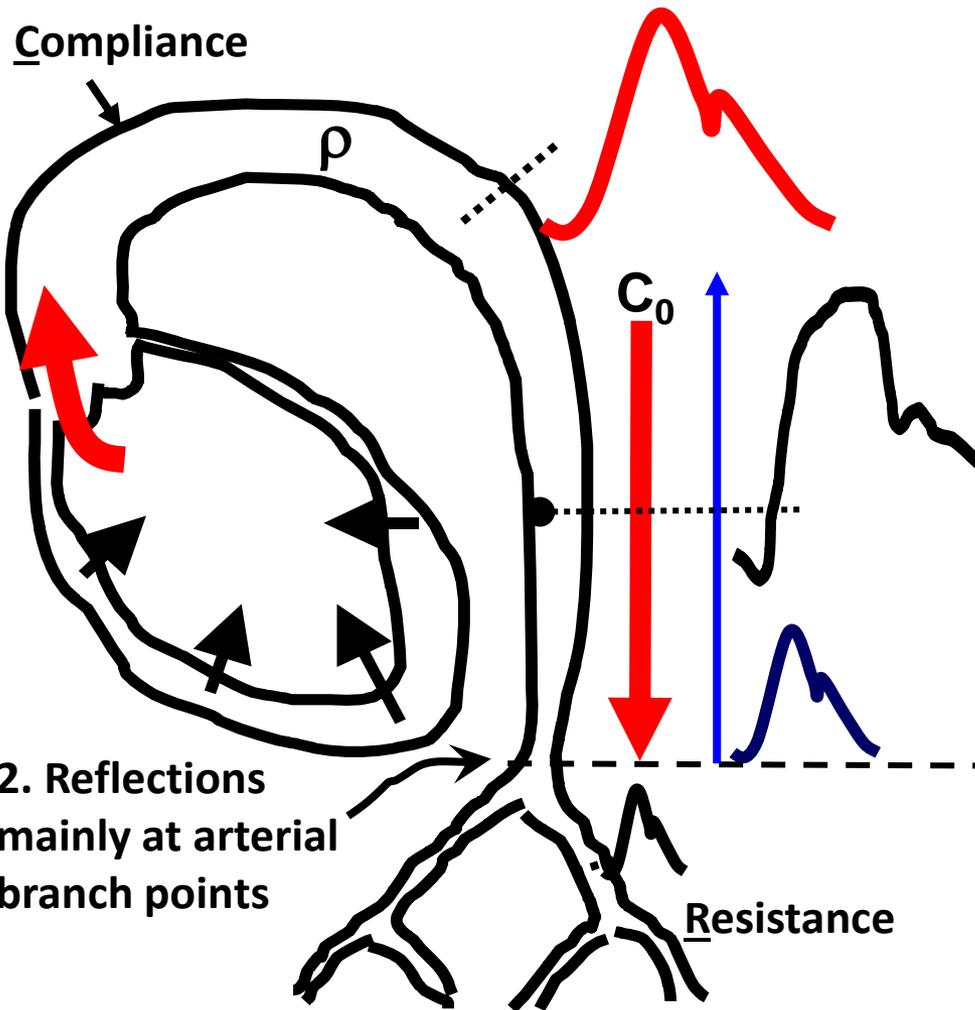
Arterial Pulse Wave Transmission Process



Billiard Balls with Impact Transmission

- Volume ejected initially distends aortic wall at 1 and progresses to site 2 and then to site 3 as a pulse wave
- Wave speed much greater than speed that blood cells themselves move
- Pulse wave speed vs blood velocity concept can be compared to the impact on a billiard ball combination
- The end ball moves off quickly (high speed transmission) but the group hardly moves
- Pulse wave speed is inverse to the square root of the vessel compliance wall in which the wave is travelling

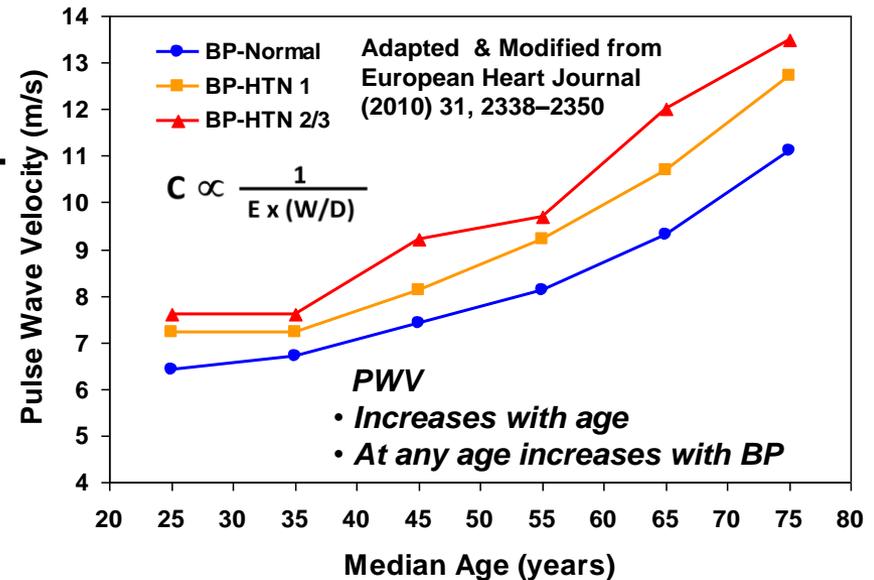
Transmission and Reflection of Pulses



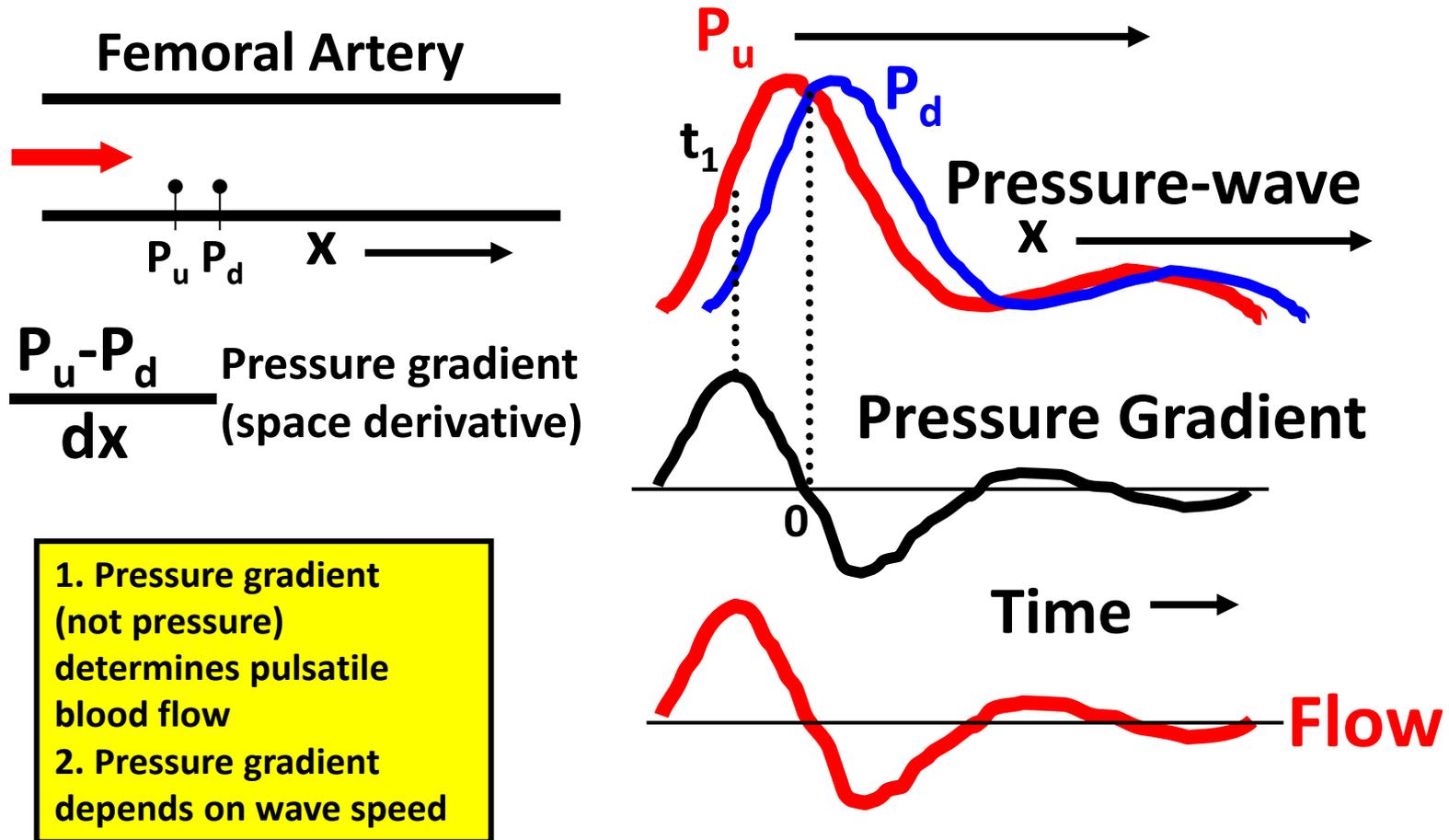
1. Pulse "wave-speed" (C_0) is inverse to Compliance (C)
Stiffer arteries ~ higher speed

$$C_0 \sim \sqrt{\frac{1}{\rho C}}$$

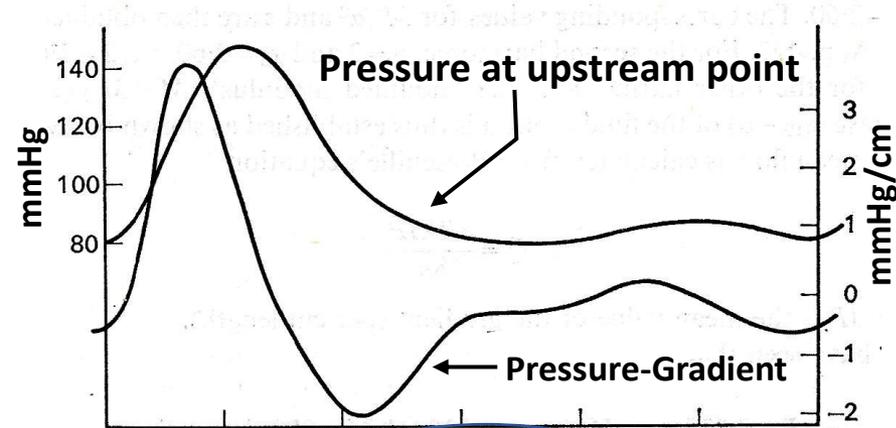
3. Pulse is algebraic sum of forward & backward pulses



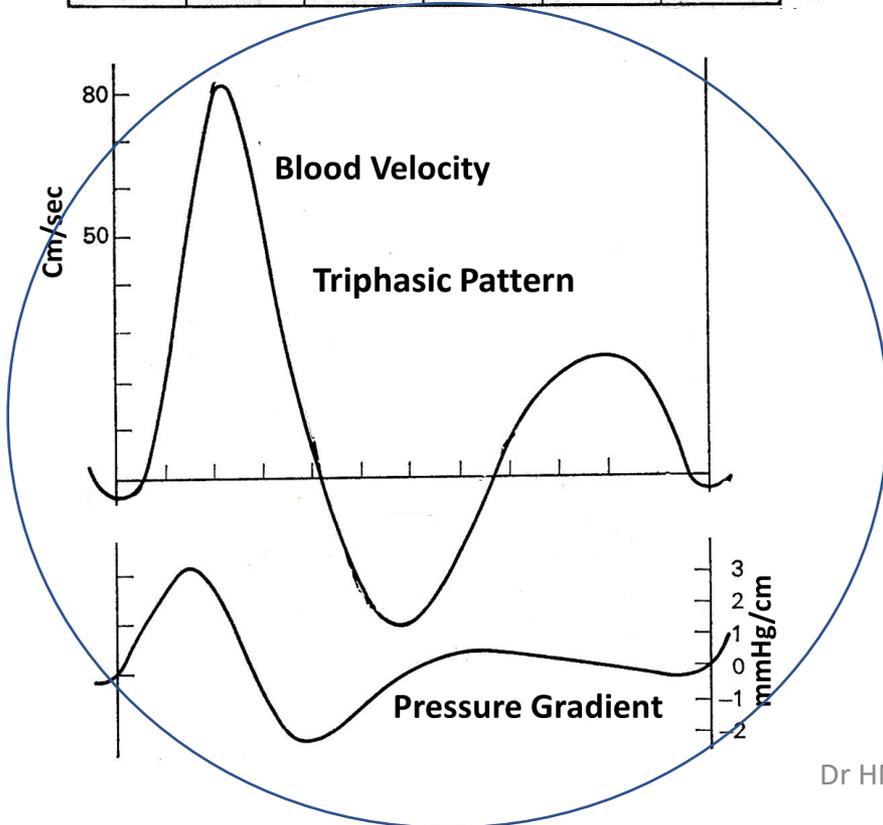
Pressure Gradient Produces Pulsatile Blood Flow



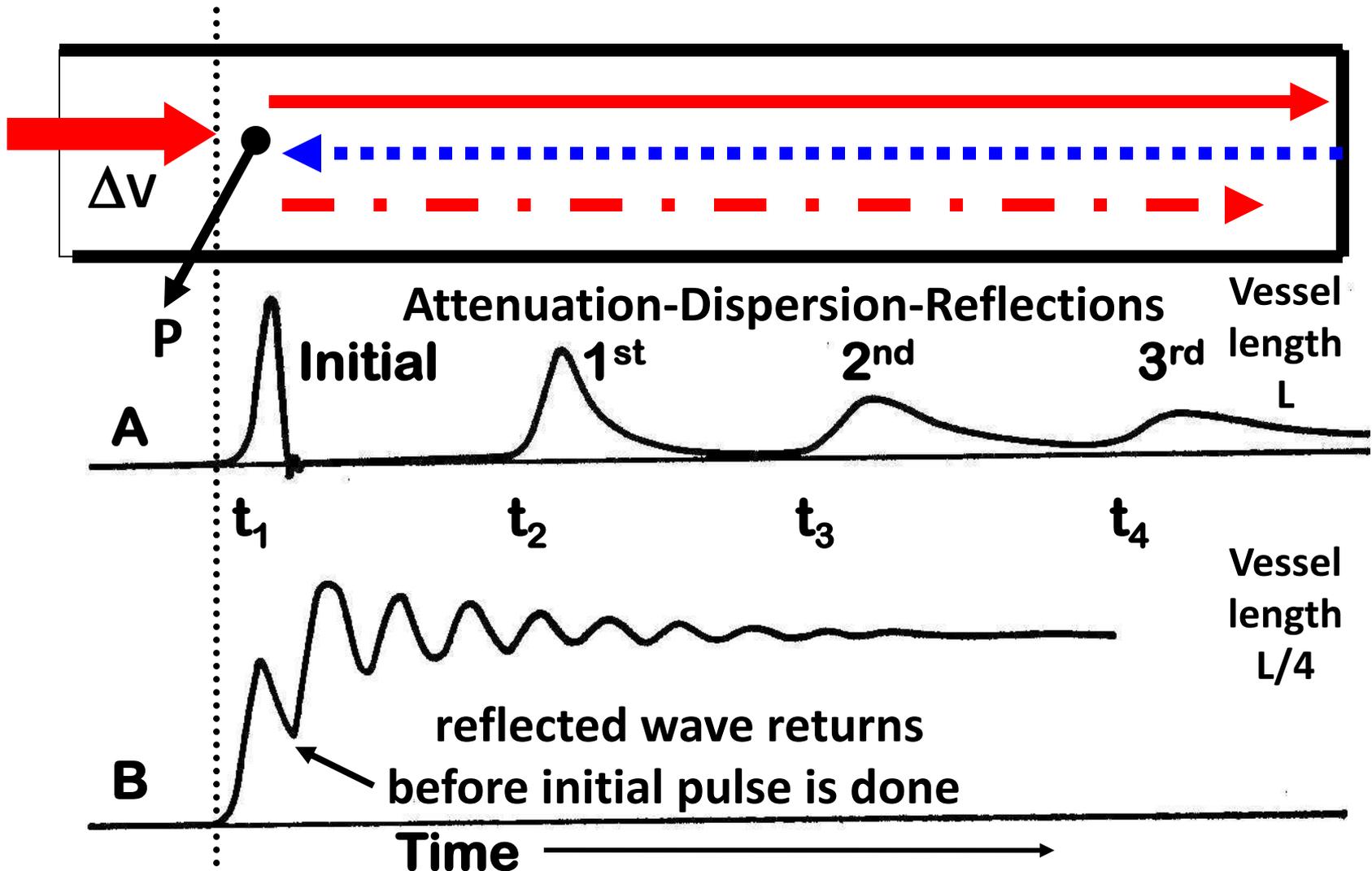
Arterial Pressure vs. Pressure Gradient: Summary



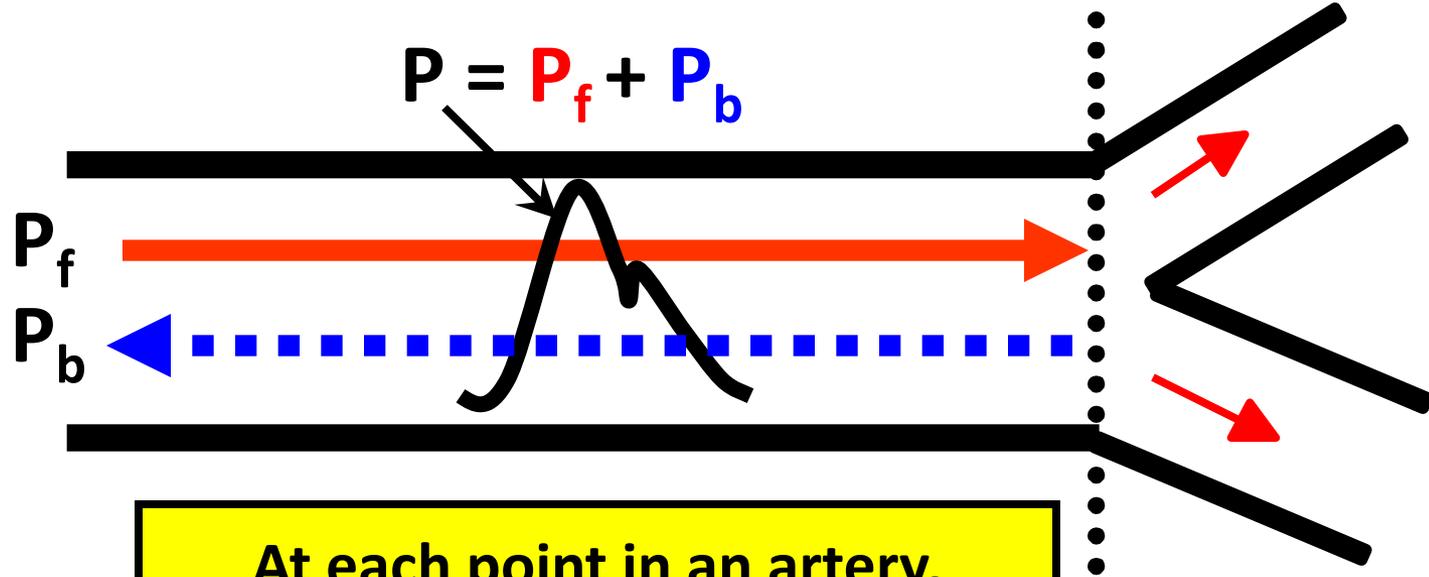
- Pressure is measured in a femoral artery at two sites **separated by 5 cm**
- Pressure difference (upstream – downstream) is calculated and the difference divided by the separation → this is the **pressure-gradient**
- It is pressure-gradient that is the driving force to cause pulsatile blood flow **NOT** the pressure!
- The intensity and pattern of the pulsatile flow depends on the intensity and pattern of the pressure gradient
- Note the similarity of the patterns of blood velocity and pressure gradient



Multiple Pulse Wave Interactions

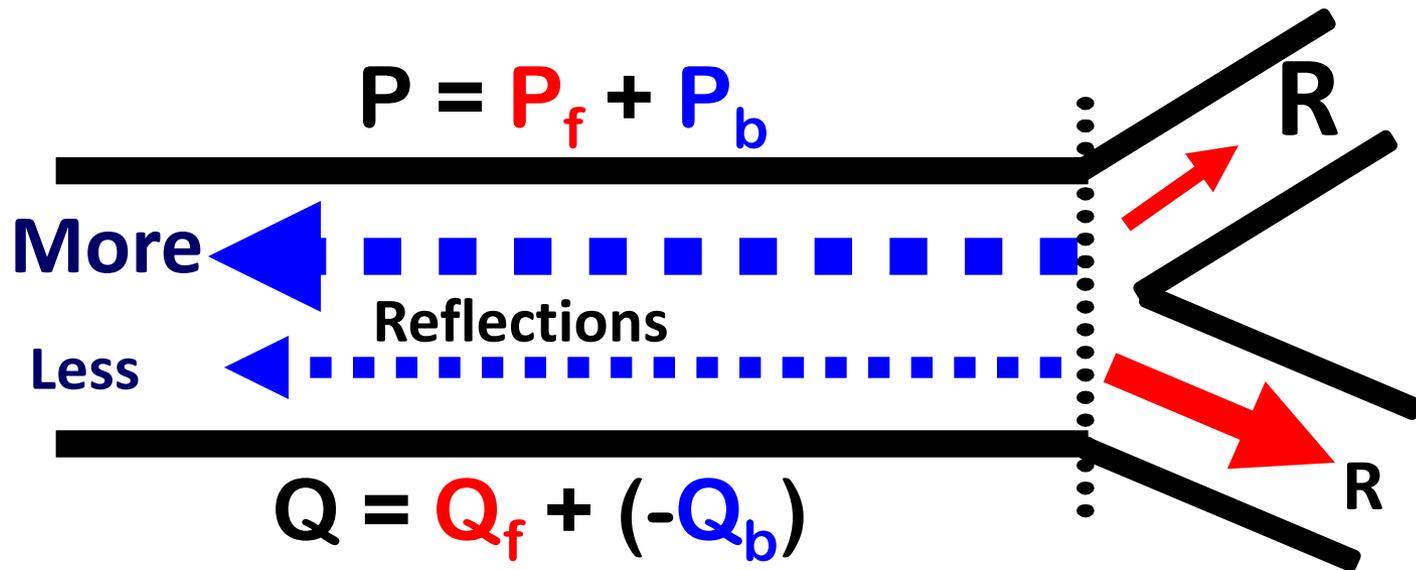


Forward and Backward Arterial Pressure Waves



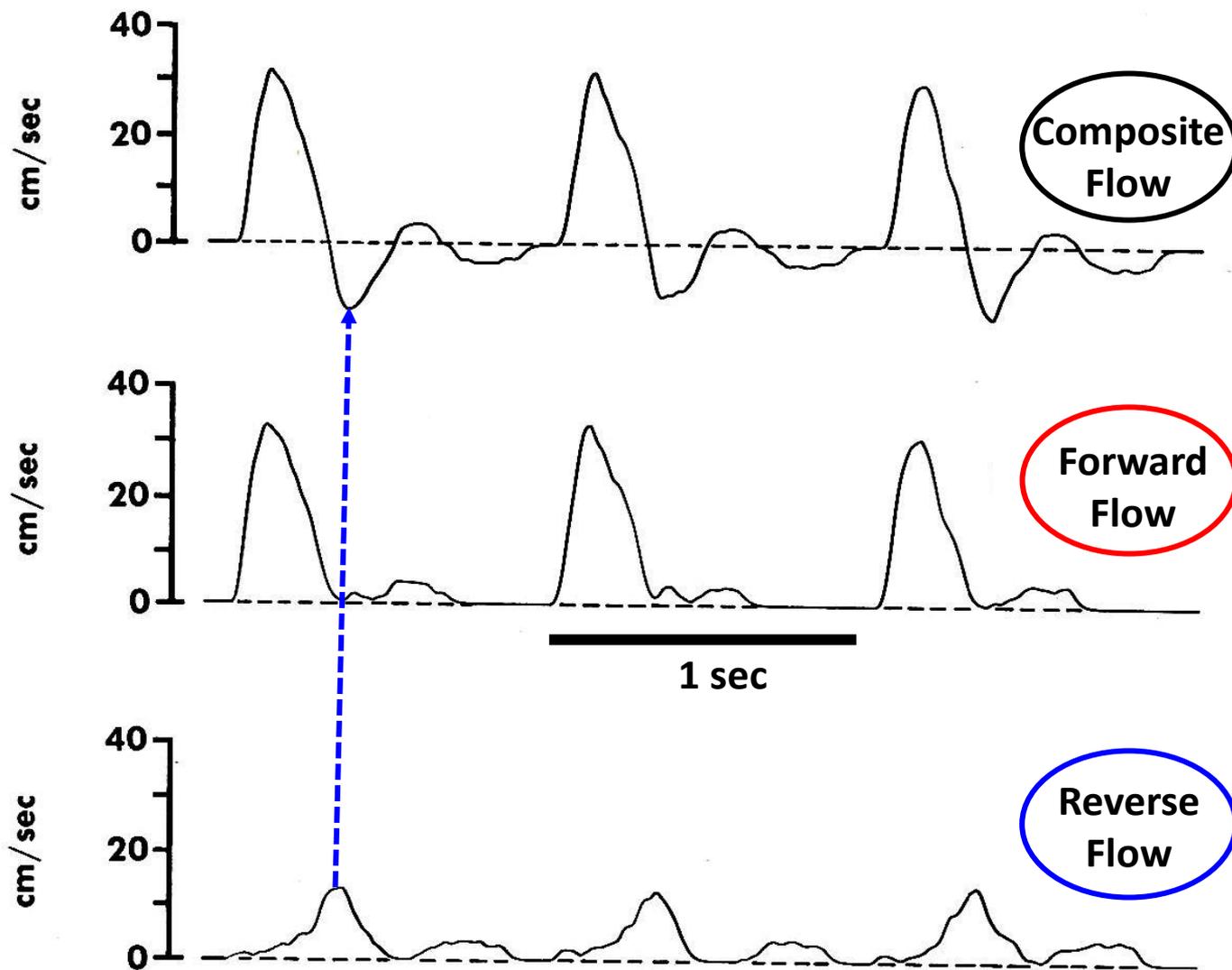
At each point in an artery,
COMPOSITE P & Q pulses
are composed of the sum of
forward & reflected pulses
Reflected P-waves ADD
Reflected Q-waves SUBTRACT

Vascular Resistance Effects on Reflection

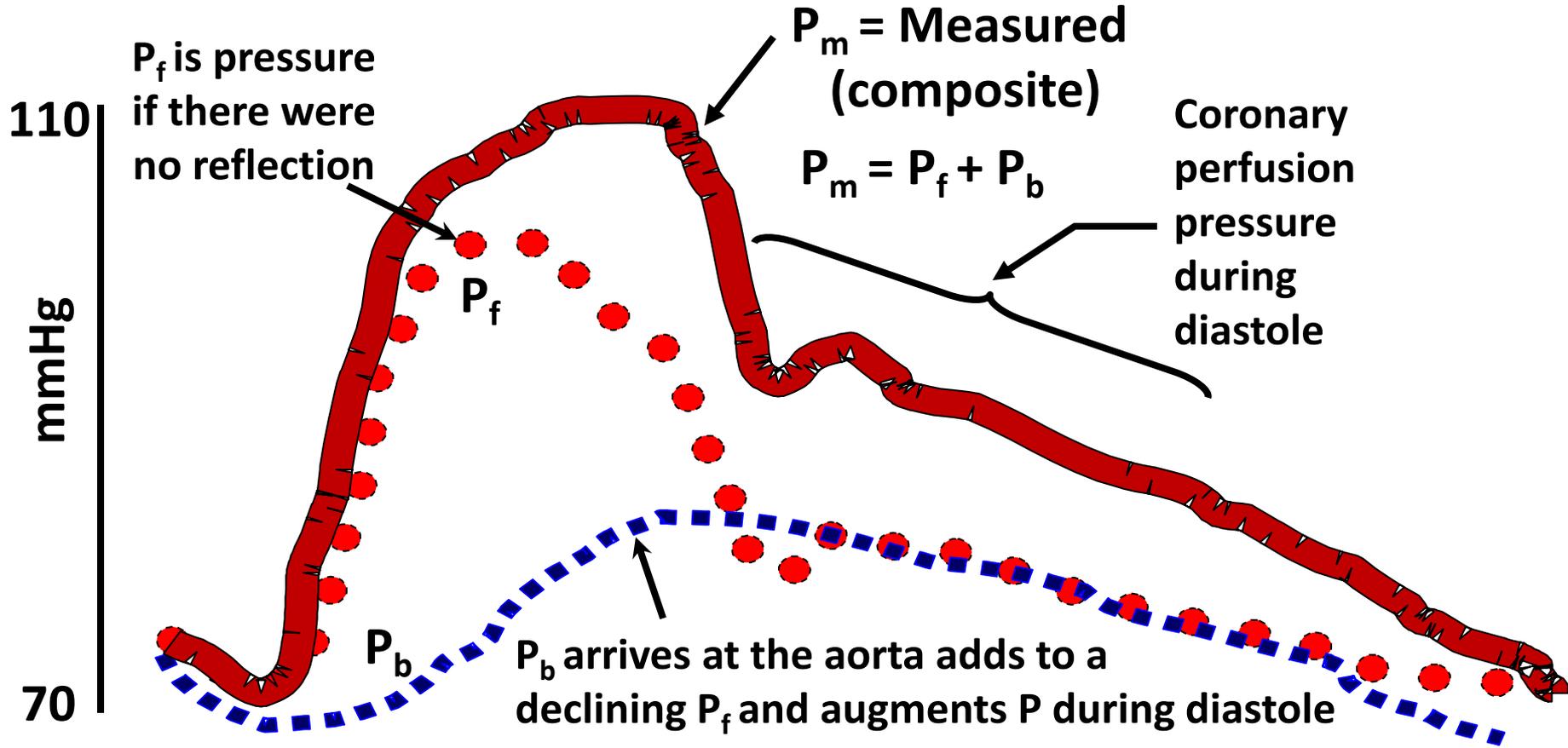


Reflected energy (P & Q) is less if branch pathways lead to vascular beds that have less Resistance. Reflection is greater if these have greater R.

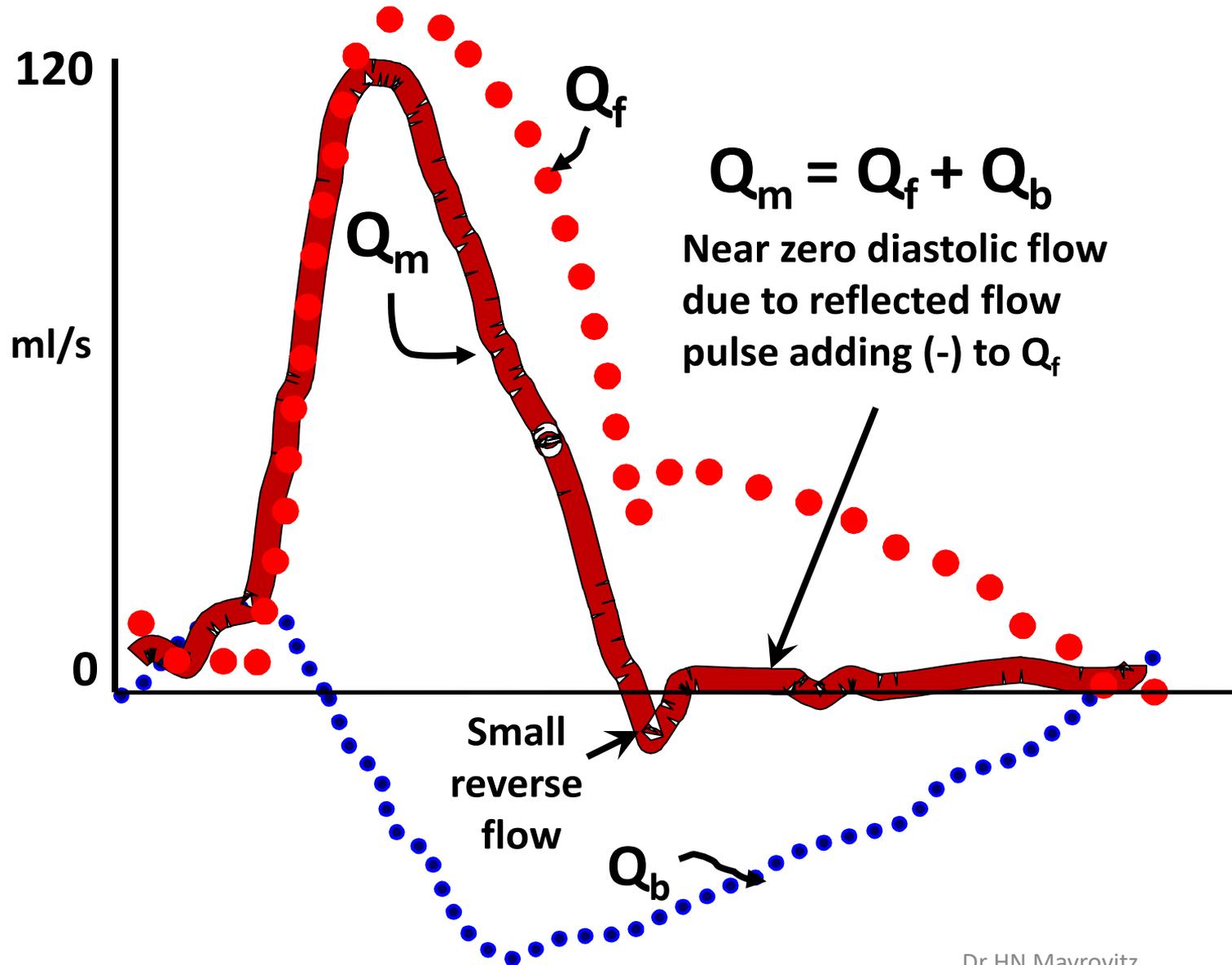
Forming Normal Femoral Arterial Pulsatile Flow



Forming Normal **Ascending Aortic Pressure**

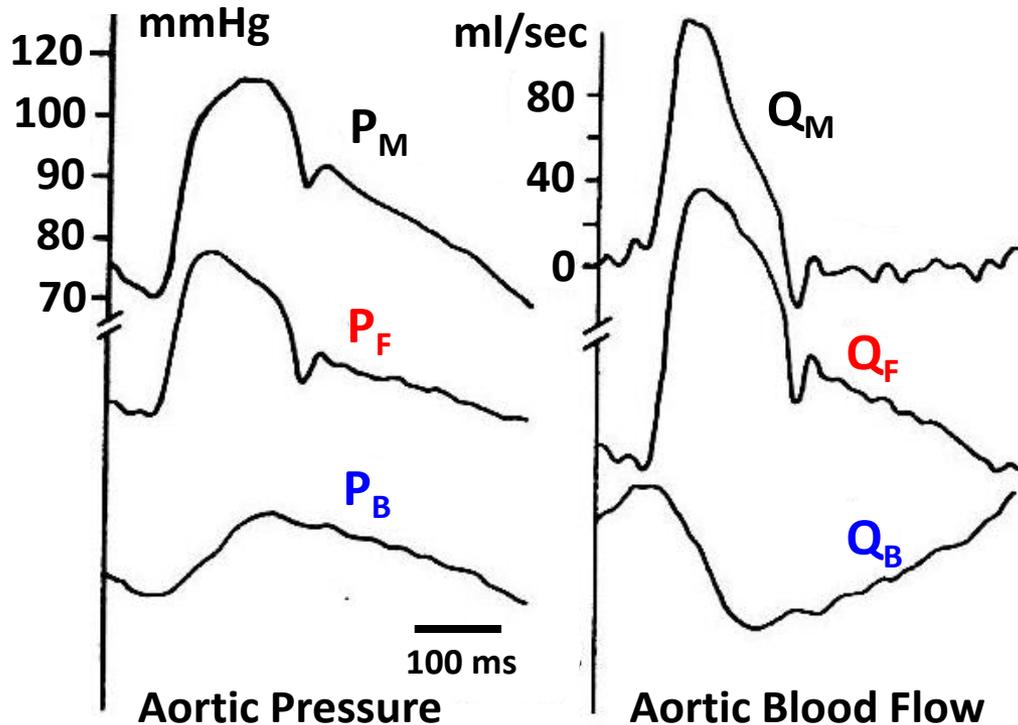


Forming Normal **Ascending Aortic Blood Flow**



Aortic Pressure and Flow Reflections: Summary

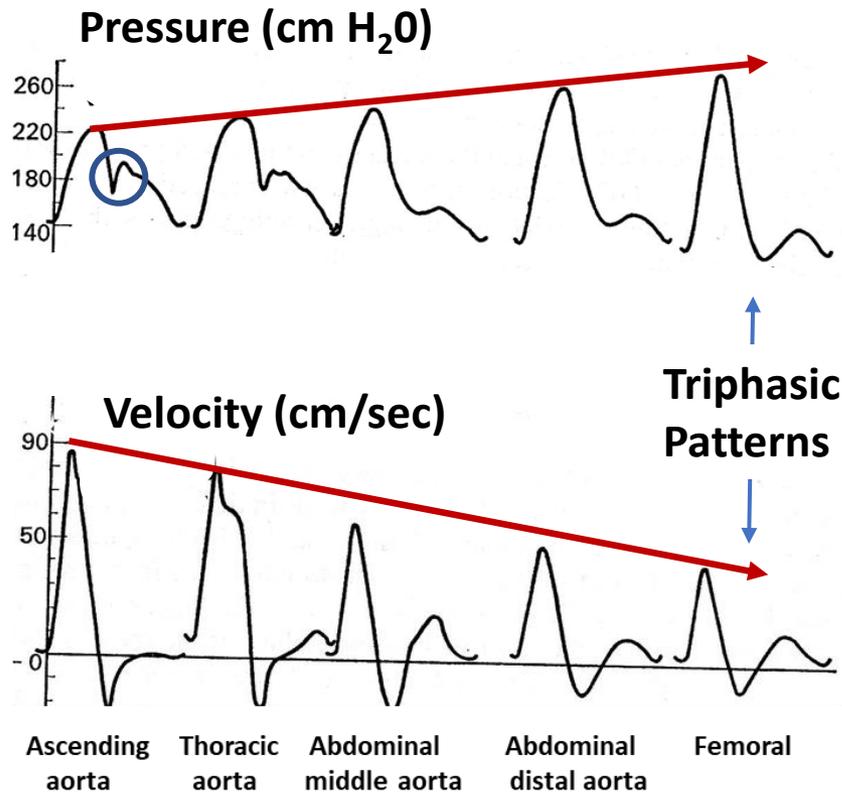
Take Home Points



Subscripts F and B denote forward and backward wave components. Subscript M denotes measured value that depends on both forward and backward waves

- Forward and backward *pressure* waves *add* to form measured (P_M) pressure.
- Backward *flow* wave *subtracts* from the forward wave to form the measured flow (Q_M)
- A greater pulse wave speed causes reflected waves to arrive back to the aortic site earlier causing an elevation in early systolic pressure and a reduction in diastolic pressure
- These effects cause an increase in cardiac afterload and decreased coronary perfusion respectively.
- The effect of earlier flow pulse return is to decrease net measured blood aortic pulse flow

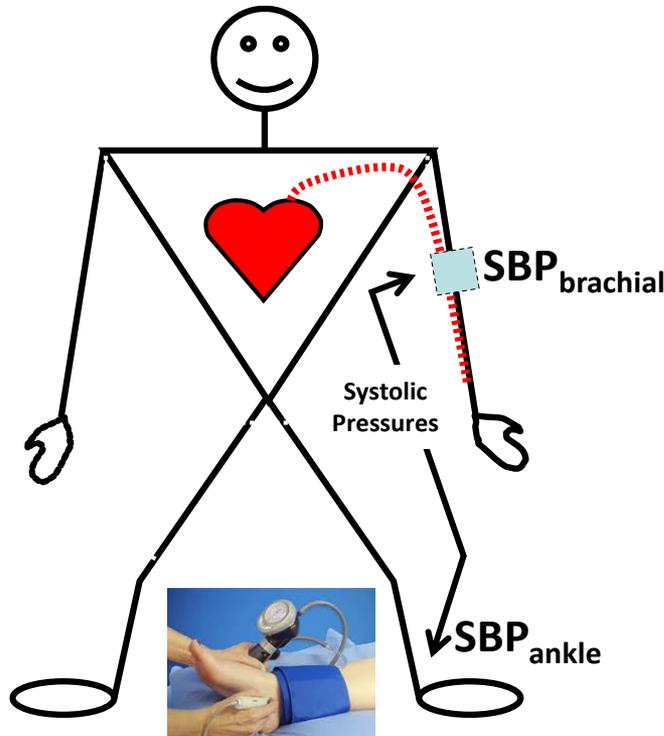
Pulse Pressure Variations with Arterial Position



- Pressure **pulses increase** and **smooths** from aorta toward periphery
- **Factors** involved are due to combined effects of
 - (1) **high frequency filtering** because arterial system acts a low frequency filter
 - (2) **greater transmission speed** of higher frequency components (fast upstroke part) because wall does not expand rapidly enough
 - (3) **wave reflections** due to interactions
- **Peak blood velocity decreases** with distance but the smoothing of the waveforms occurs for the same reasons as the pressure effects
- **Pulse wave velocity increases** in more peripheral arteries due to compliance decrease

Ankle Brachial Systolic BP Index (ABI)

ABI = (Ankle/Brachial) Systolic Pressure



Normal → 1.00 – 1.40

Borderline → 0.90 – 0.99

< 0.90 → Abnormal

0.80 – 0.89 Mild Blockage

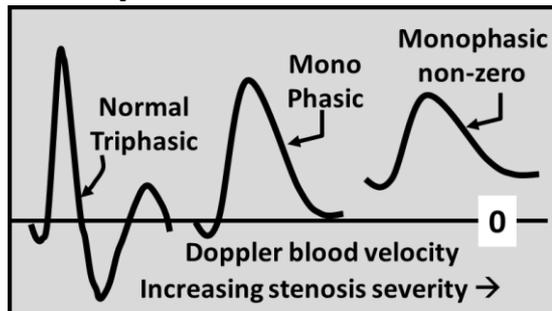
0.50 – 0.79 Moderate Block

< 0.50 Severe Block

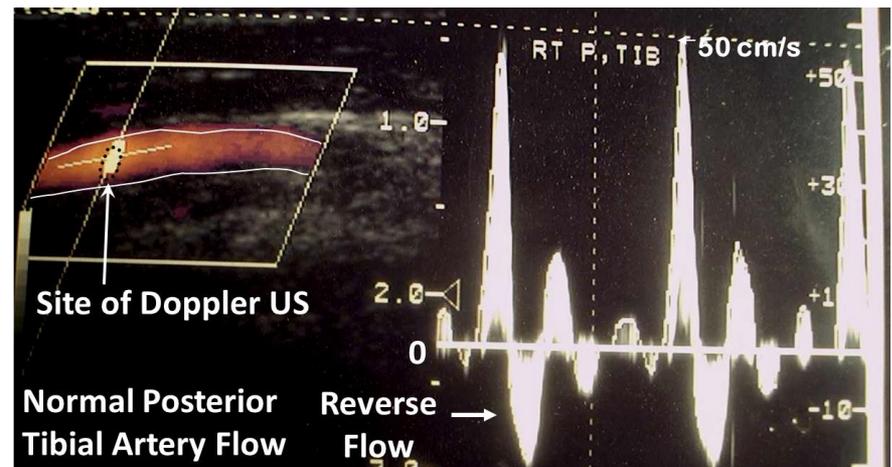
Claudication →

Rest Pain →

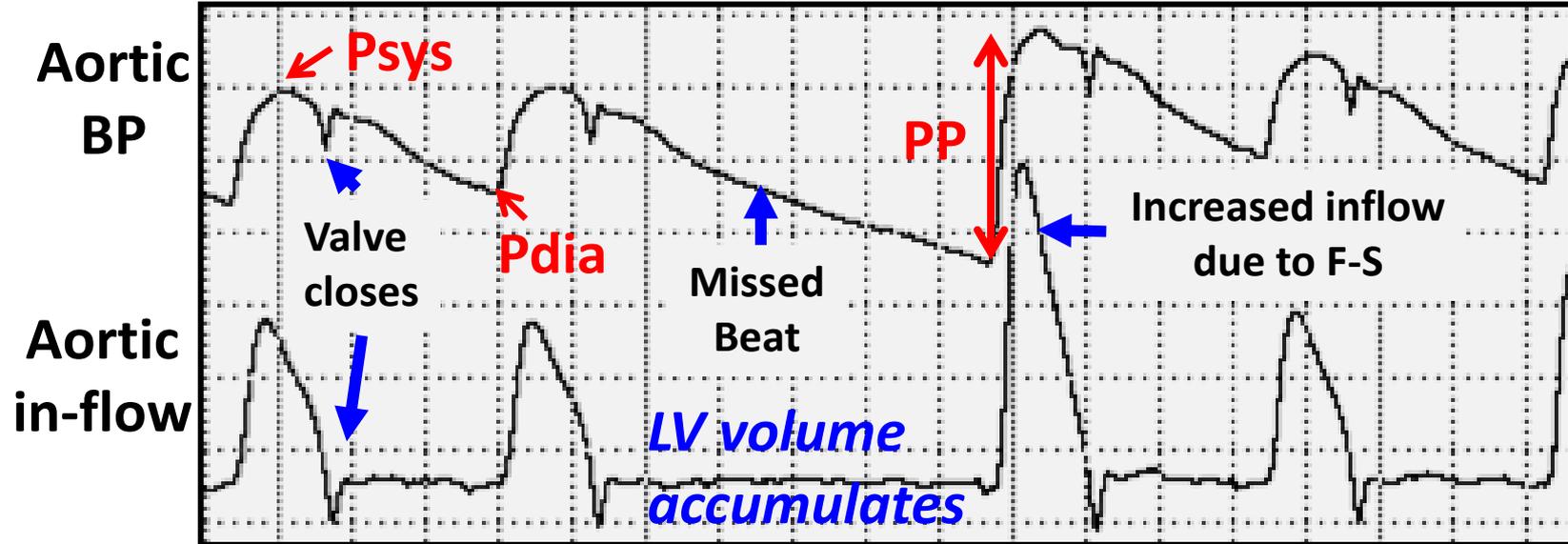
Triphasic pattern lost due to upstream stenosis



Normal Velocity Pulse Pattern is Triphasic



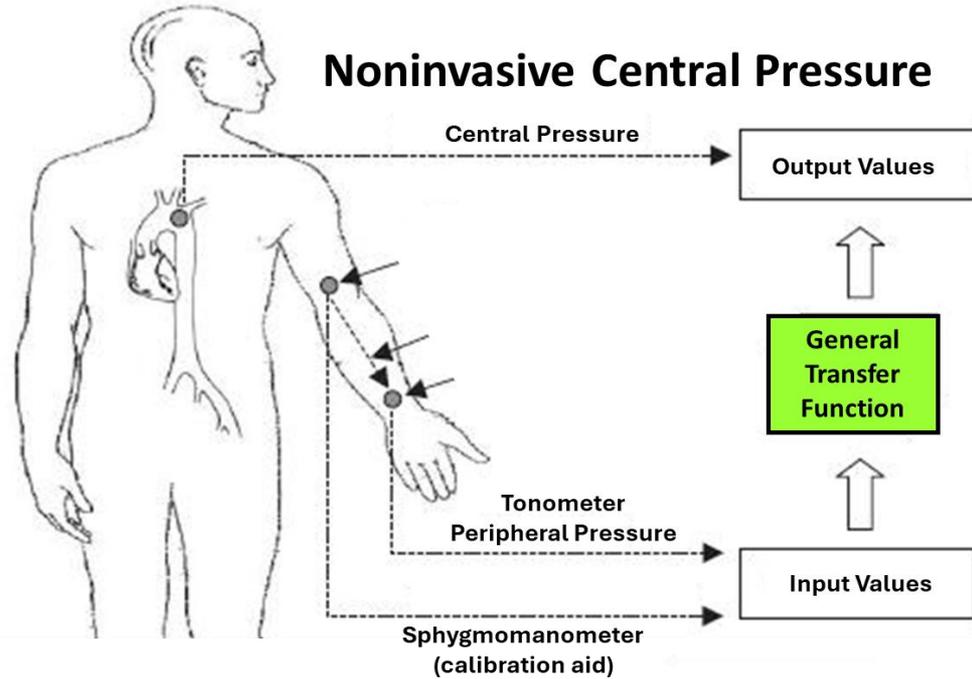
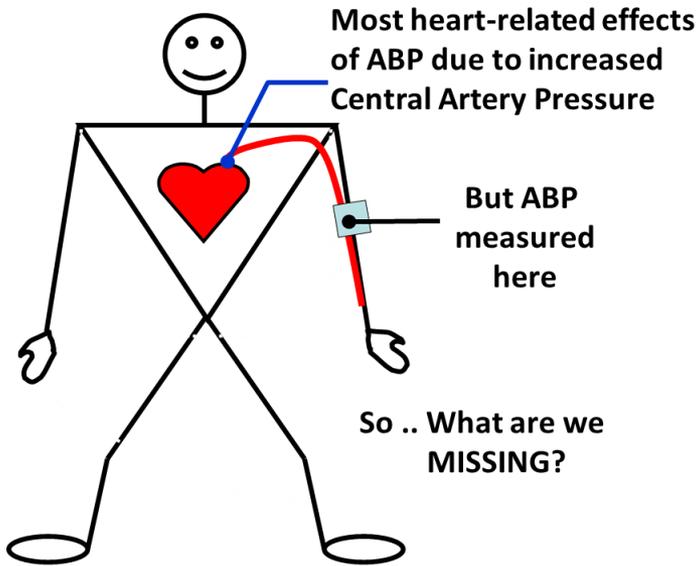
Pulse Pressure Determinants

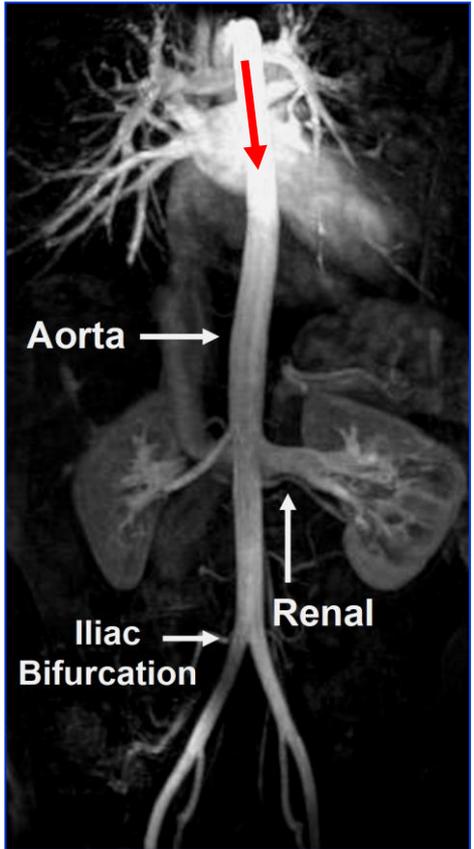
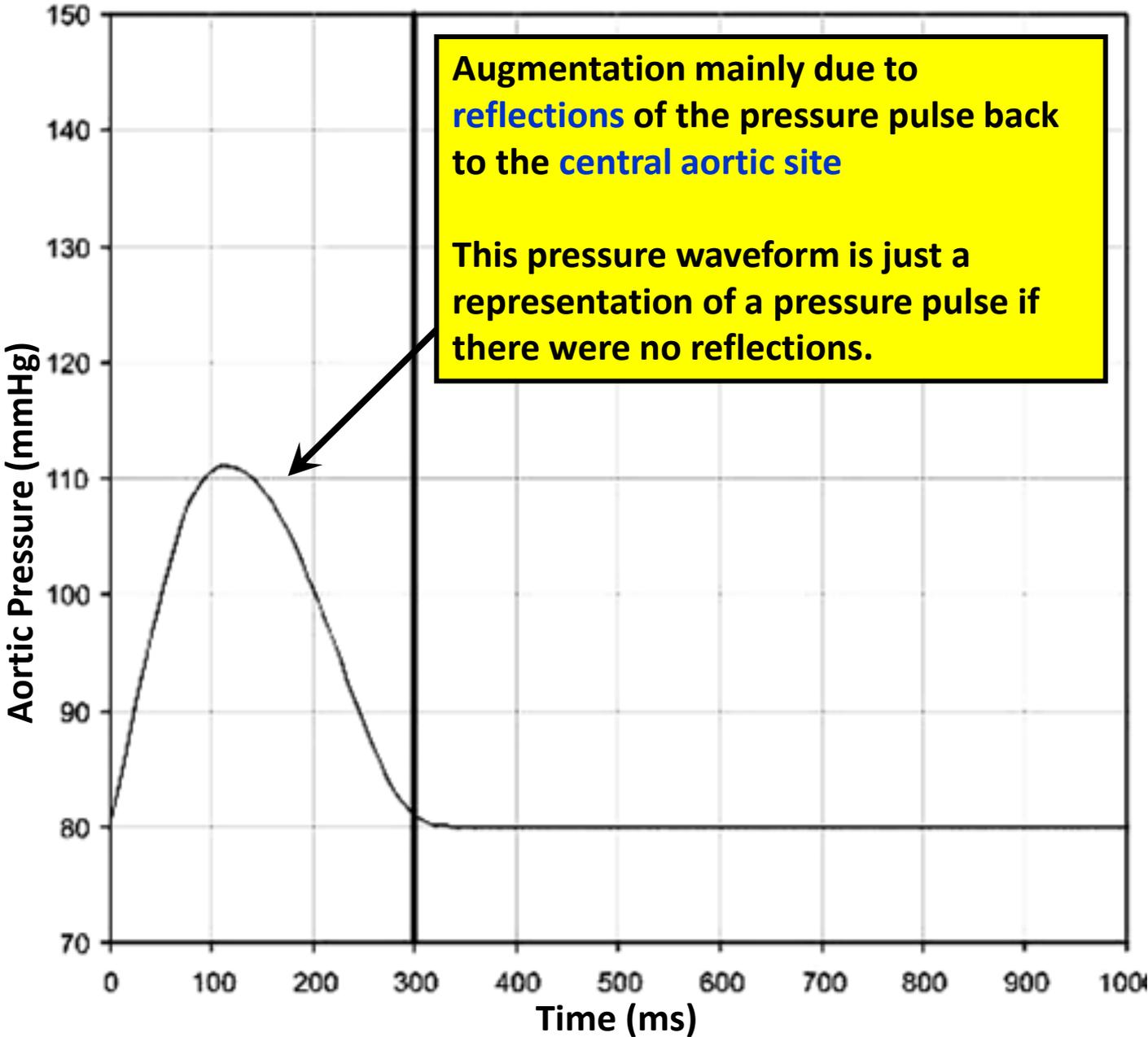


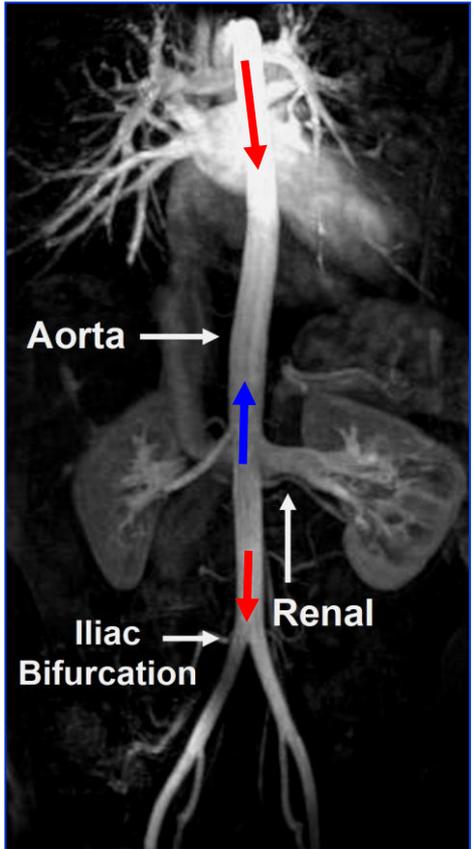
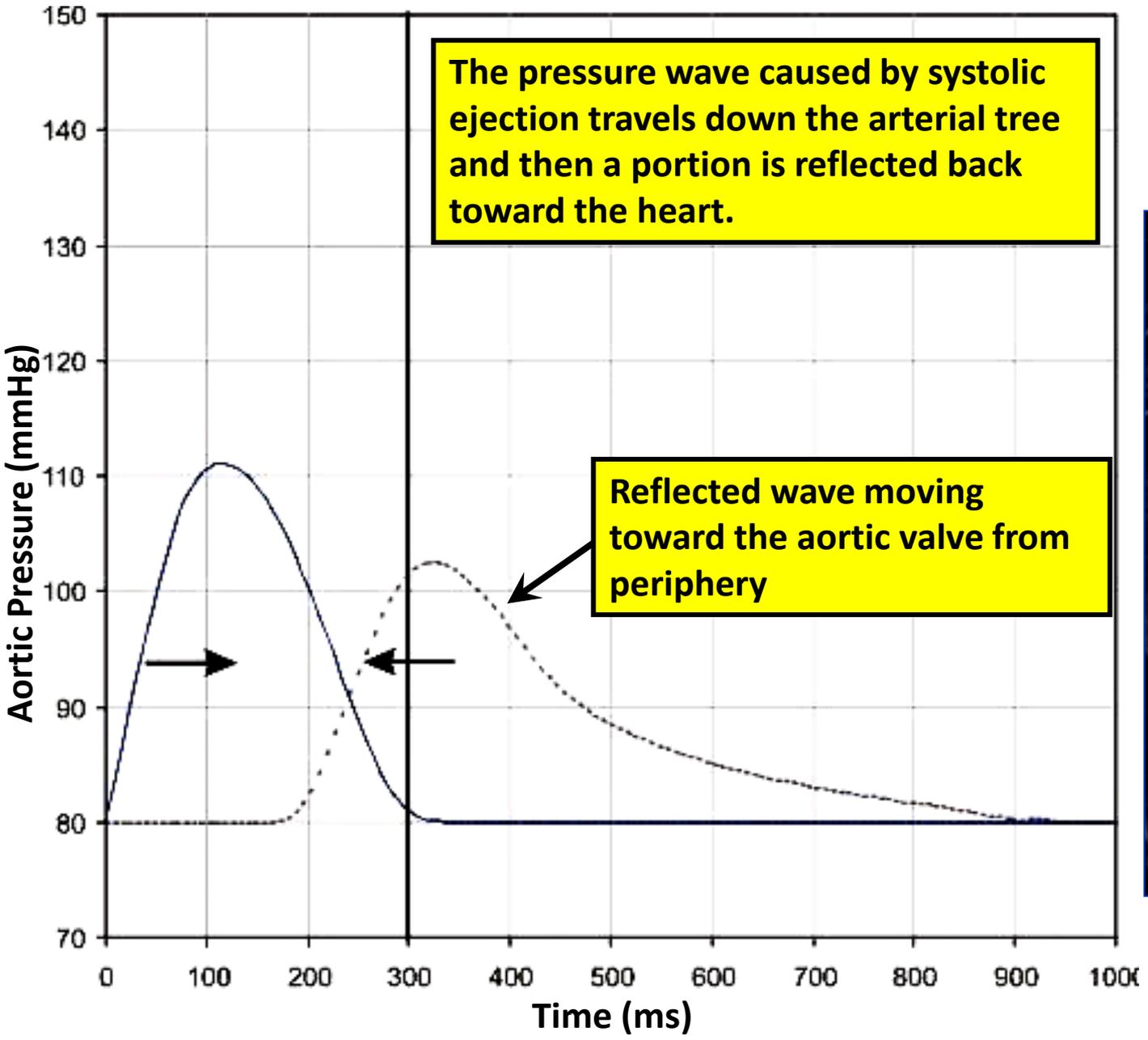
Increase in arterial pulse pressure

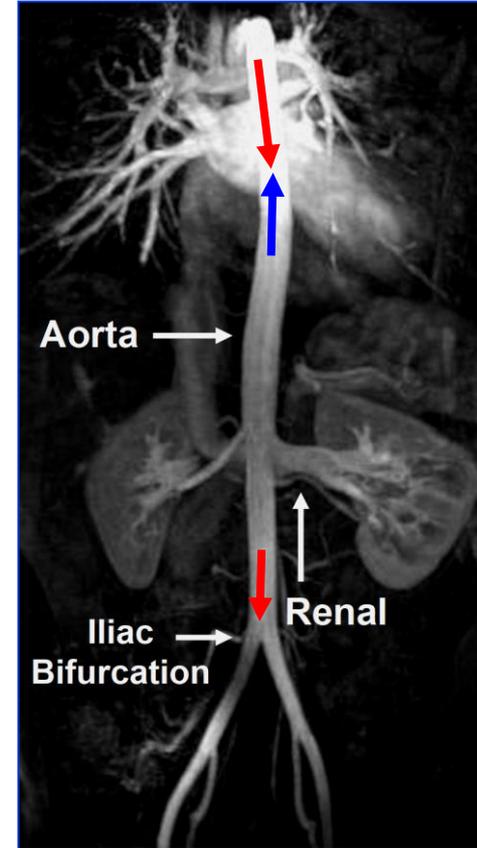
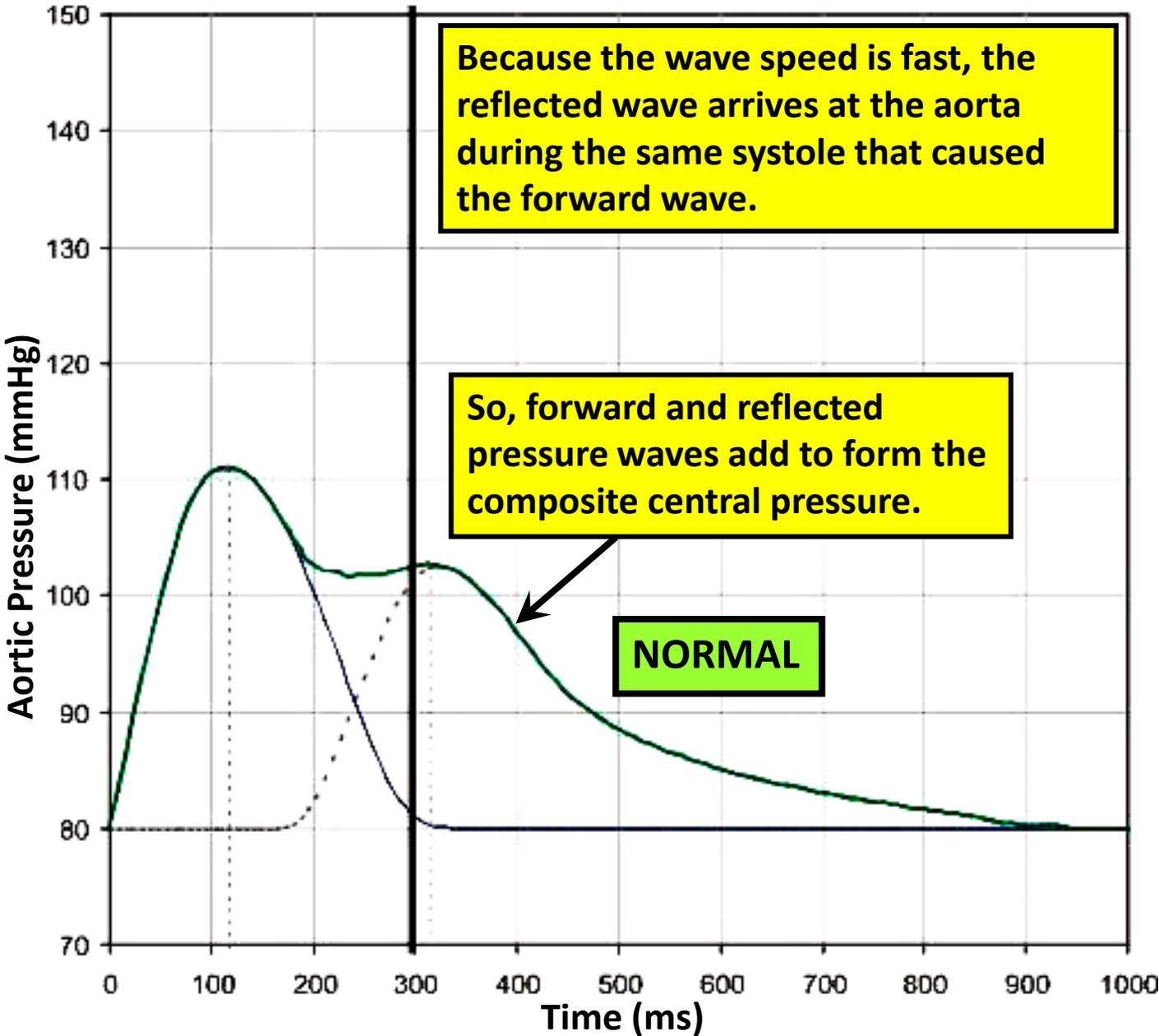
- Increased rate of LV ejection $\rightarrow + dV/dt$
- Increased stroke volume $\rightarrow + SV$
- Decreased aortic compliance $\rightarrow - C$

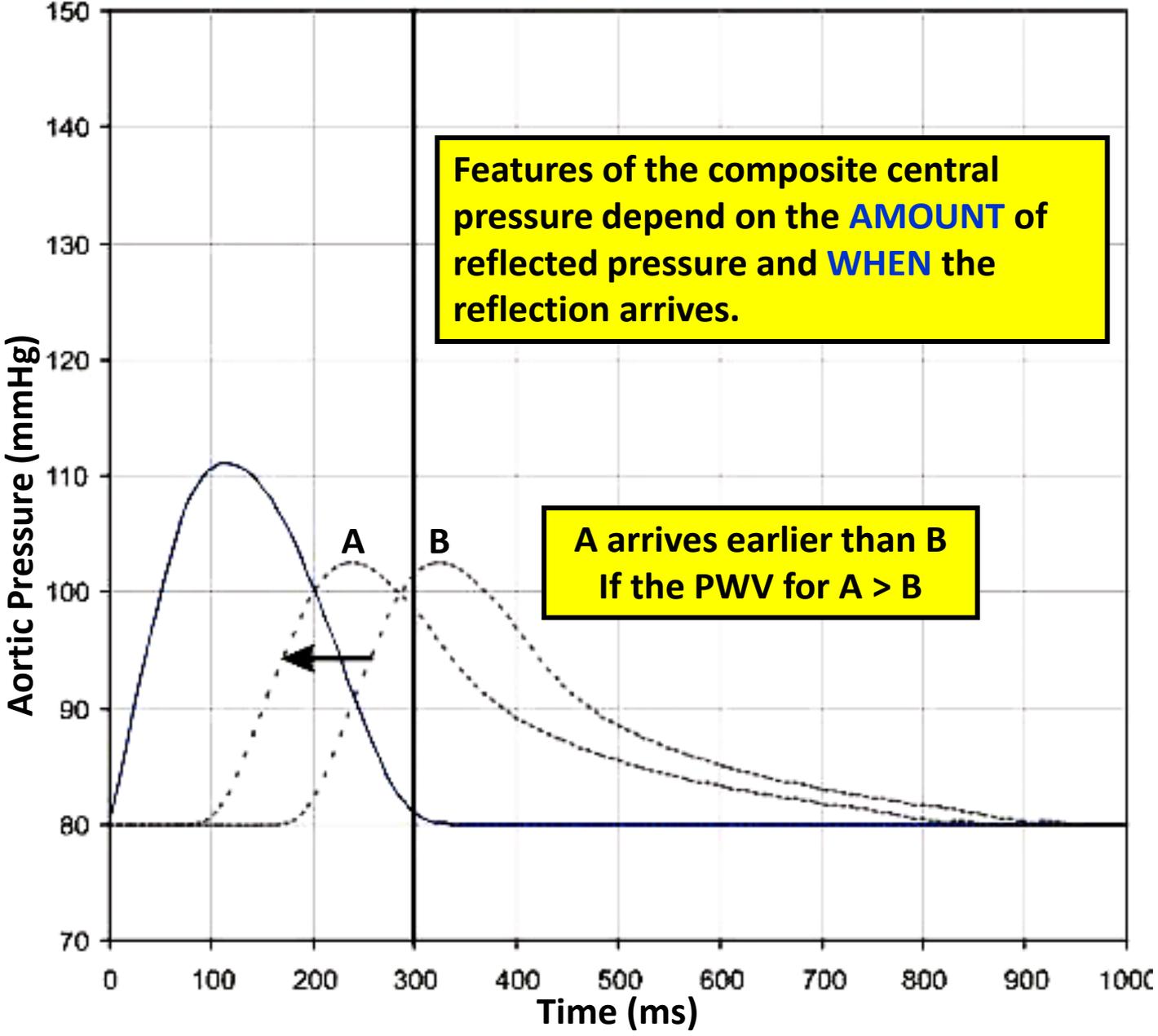
Central Pressure Augmentation via Pulse Reflection







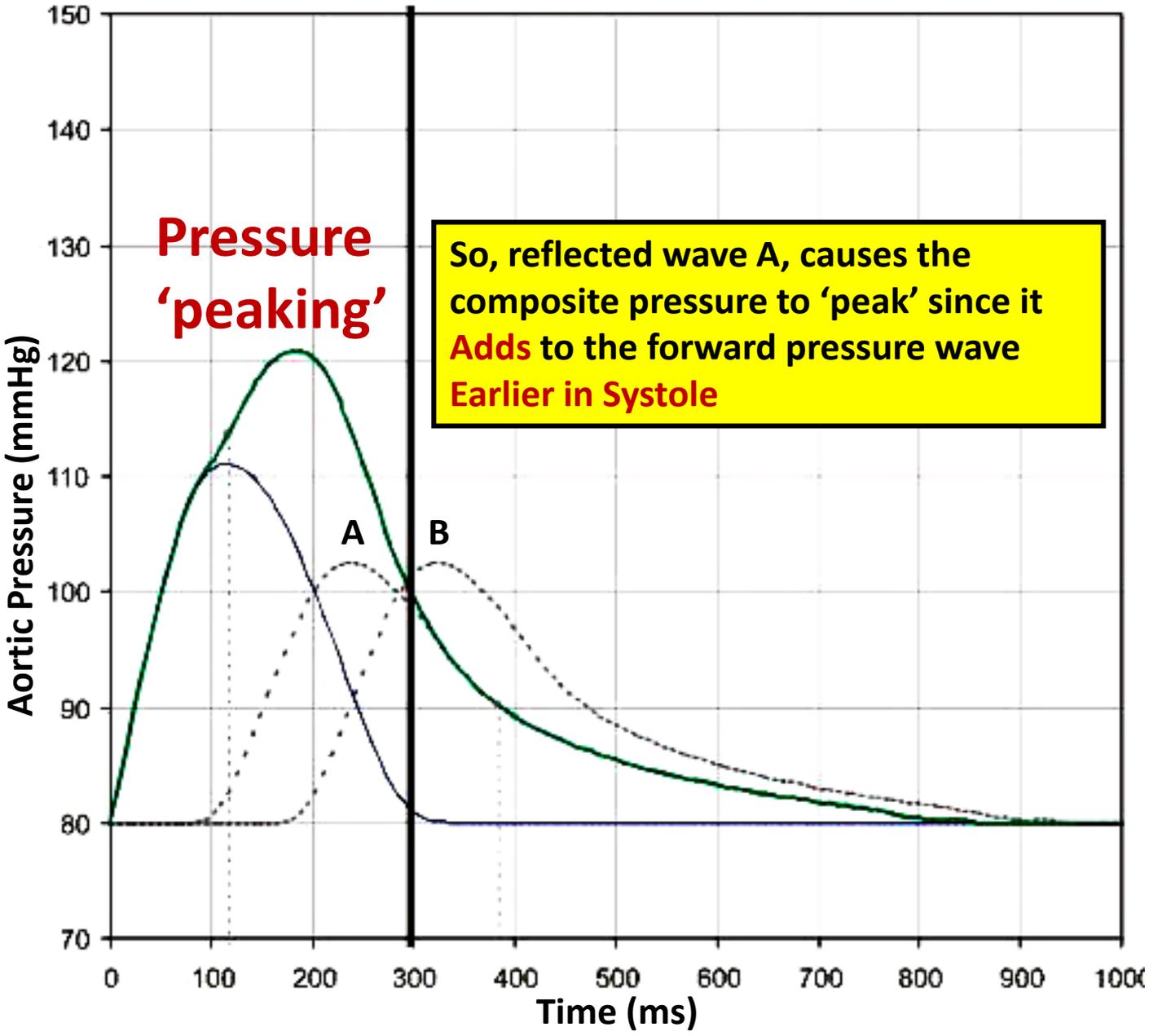




Features of the composite central pressure depend on the **AMOUNT** of reflected pressure and **WHEN** the reflection arrives.

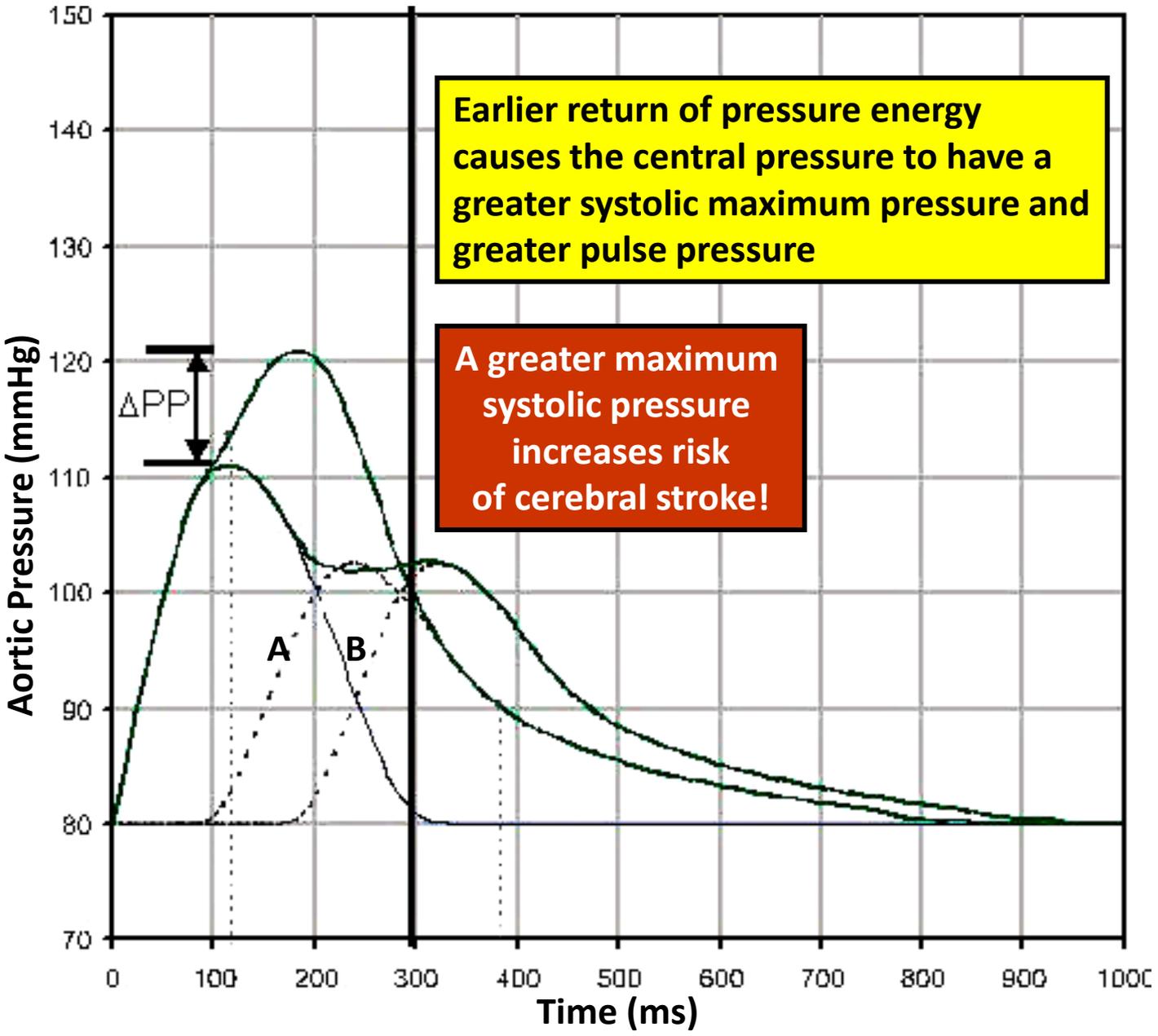
A arrives earlier than B
If the PWV for A > B

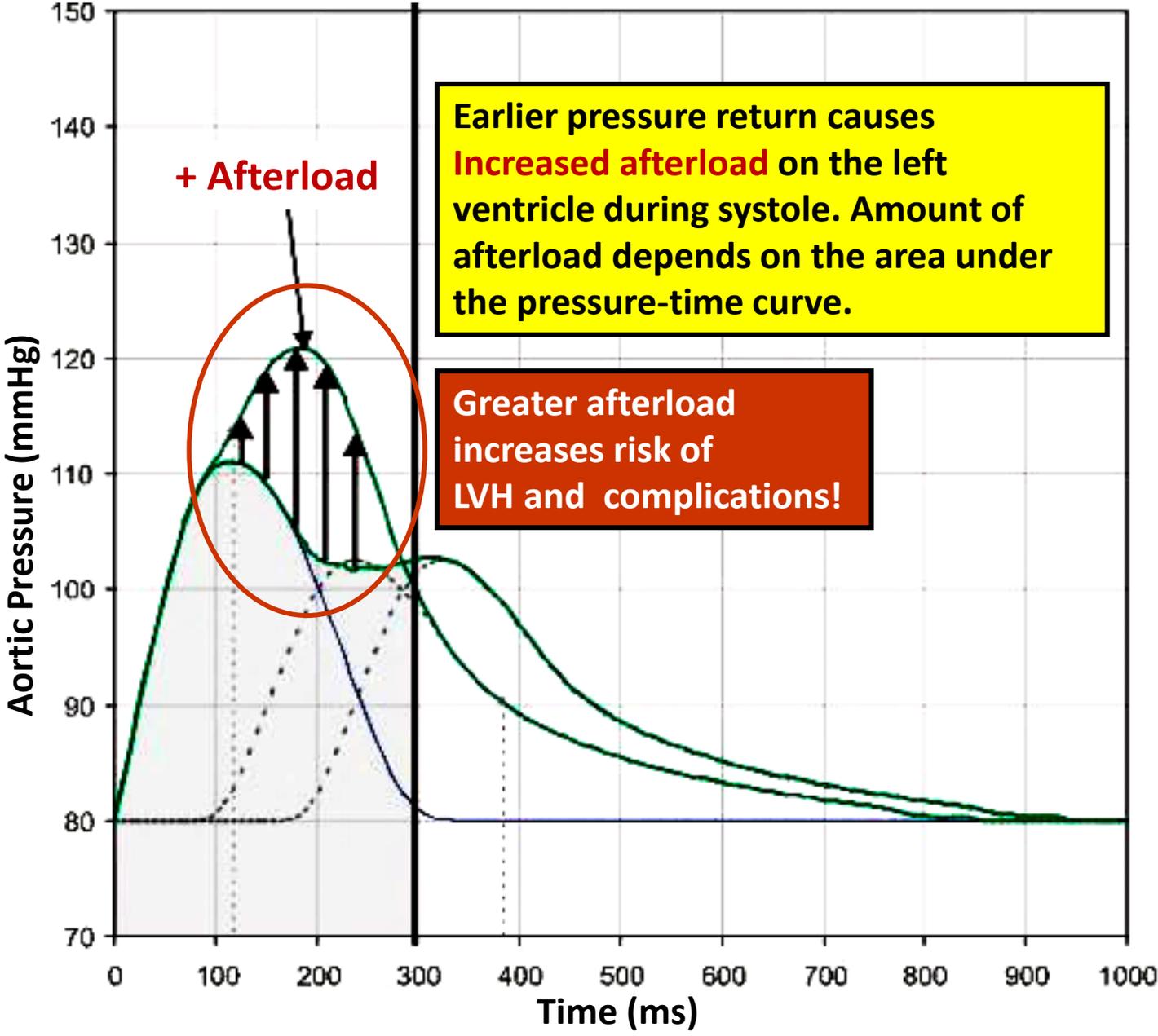
Age related issues
 ↓
 - compliance
 ↓
 + wave speed
 ↓
 reflected wave earlier return

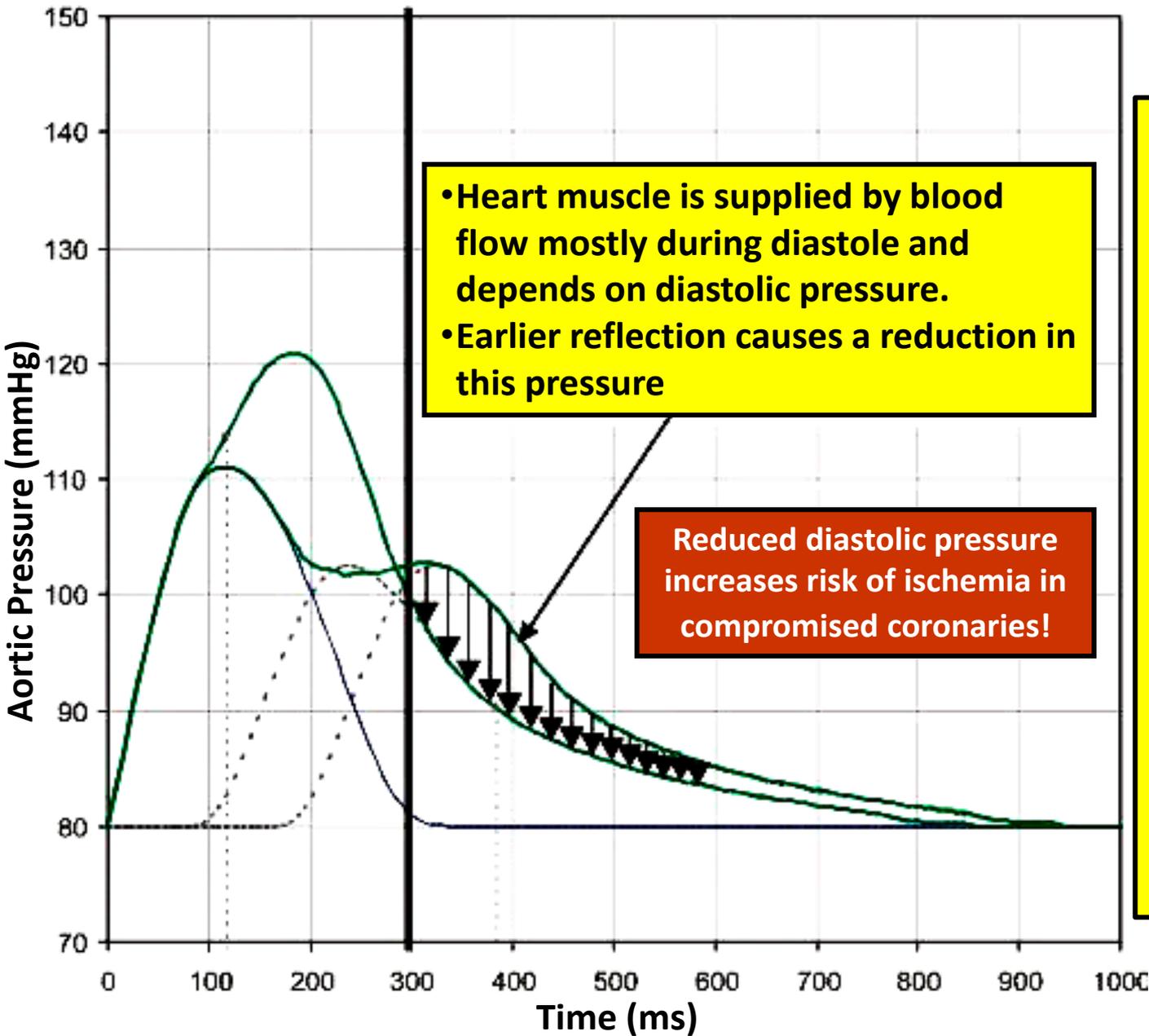


So, reflected wave A, causes the composite pressure to 'peak' since it Adds to the forward pressure wave Earlier in Systole

Pressure 'peaking'







- Heart muscle is supplied by blood flow mostly during diastole and depends on diastolic pressure.
- Earlier reflection causes a reduction in this pressure

Reduced diastolic pressure increases risk of ischemia in compromised coronaries!

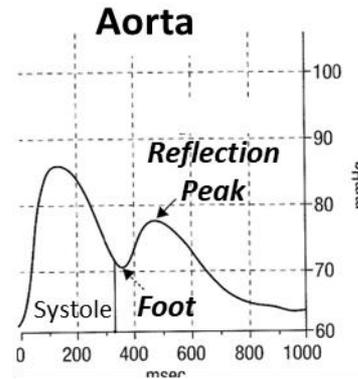
SUMMARY

- Earlier return of reflected wave causes augmentation of aortic pressure
- This occurs if wave speed increases
- Low arterial compliance is a major factor
- Effect increases central BP that causes increased afterload and reduces aortic diastolic coronary perfusion pressure
- Complications include stroke risk and LVH

Central Pressure Augmentation Examples: AGE

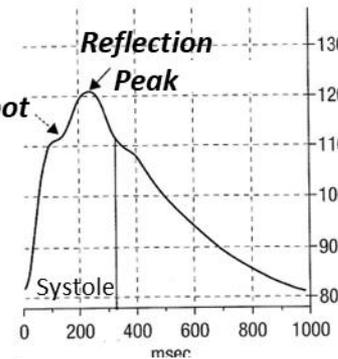
Healthy
Males
of
different
ages

19 yrs.



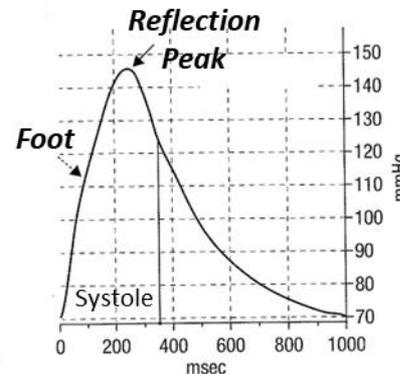
- Reflection in diastole only
- Contributes to coronary perfusion
- No augmentation of systolic pressure
- Does not increase systolic afterload

42 yrs.



- Reflection in mid-systole
- Augments systolic pressure
- Increases systolic afterload
- AI = 25%

83 yrs.



- Reflection in early-systole
- Greatly augments systolic pressure
- Large increase in systolic afterload
- AI = 46%

Foot = start of upstroke of the reflected pressure wave

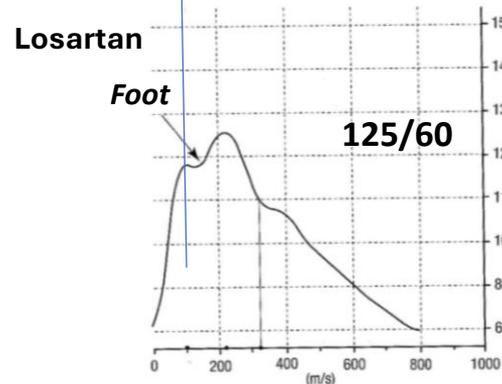
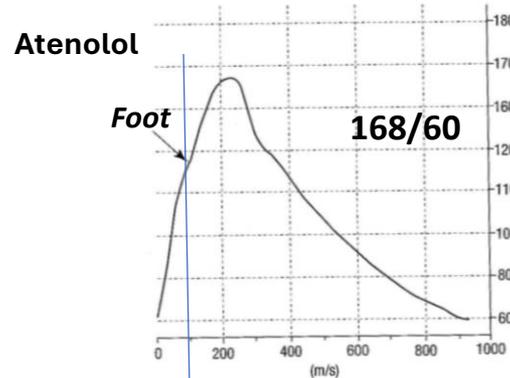
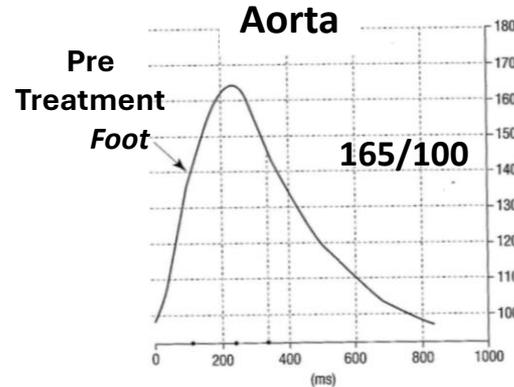
Central Pressure Augmentation: *Which Drug to use?*

Patient with hypertension treated with two different Medicines

Both drugs had about the same Effect on brachial artery systolic, diastolic and pulse pressure!

Atenolol (β -blocker)

Losartan (Angiotensin Receptor Blocker (ARB))



How did drug effects on central systolic pressure compare?

Losartan more reduction in systolic

What accounts for the BP reduction associated with Losartan?

Reduced AI due to later reflection

Foot = start of upstroke of the reflected pressure wave

End CV Physiology Lecture 12