What is not revealed by a simple arm blood pressure measurement?

Affects of Pressure Pulse Reflections on Central (Aortic) Pressure

Dr. HN Mayrovitz
Most negative heart-related effects of elevated blood pressure are due to increased ‘central’ aortic pressure.

But BP is measured here!

So, what are we missing?
These are the composite Pressures measured at various arterial sites.

So why do shapes and values at peripheral sites differ from the central aortic site?
Inertia

Compliance

Blood Filled

Vessel Wall

Resistance

Pulse “wave-speed” inverse to Compliance

Stiffer arteries ~ higher speed

$S_0^2 \sim \frac{1}{\rho C}$
Reflection of Pulses

1. Pulse “wave-speed” ($S_0$) is inverse to Compliance ($C$)
   Stiffer arteries ~ higher speed

\[ S_0^2 \sim \frac{1}{C} \]
1. Pulse “wave-speed” ($S_0$) is inverse to Compliance ($C$)

Stiffer arteries ~ higher speed

$$s_0^2 \sim \frac{1}{C}$$

2. Reflection sites mainly at arterial branches
1. Pulse “wave-speed” \( (S_0) \) is inverse to Compliance (C)

Stiffer arteries \( \sim \) higher speed

\[
s_0^2 \sim \frac{1}{C}
\]

2. Reflection sites mainly at arterial branches

3. Pulse at any point in artery is algebraic sum of forward transmitted pulses and reflected backward pulses

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Normal Ascending Aortic Pressure

\[ P_m = \text{Measured (composite)} \]
\[ P_m = P_f + P_b \]

- \( P_f \) is pressure if there were no reflection
- \( P_b \) arrives at the aorta it adds to a declining forward P-wave

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So What?
Earlier Reflection Arrival

- Systolic Peaking
- Increased Ventricular Systolic Loading
- Reduced Diastolic Pressure

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Review
Fundamental Process
Effect mainly due to reflections of the pressure pulse back to the central aortic site.

This pressure waveform is a representation of what the pressure pulse would look like if there were no reflections.

Realistic aortic pressure waveform.
The pressure wave caused by systolic ejection travels down the arterial tree and then a portion is reflected back toward the heart.

Reflected wave moving toward the aortic valve from periphery
Because the wave speed is fast, the reflected wave arrives at the aorta during the same systole that caused the forward wave.

So, forward and reflected pressure waves add to form the composite central pressure.
Features of the composite central pressure depend on the AMOUNT of reflected pressure and WHEN the reflection arrives.

A arrives earlier than B

Artery ‘stiffening’

Decreased Compliance

Increased wave speed

Earlier return of reflected pressure
So, reflected wave A, causes the composite pressure to ‘peak’ since it **adds** to the forward pressure wave **Earlier in Systole**
Earlier return of pressure energy causes the central pressure to have a greater systolic maximum pressure and greater pulse pressure.

A greater maximum systolic pressure increases risk of cerebral stroke!
Earlier pressure return causes **Increased ‘Load’** on the left ventricle (LVL) during systole. This ‘load’ is related to the area under the pressure-time curve.

Greater LVL increases risk of left ventricular hypertrophy and its many complications!
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 an ischemic event!
So – Standard BP by sphygmomanometry, though important and clinically useful only tells PART of the story

• Stiffening of arteries is a more-or-less general feature of the aging process

• There is a major push to be able to reliably and noninvasively assess *Aortic Central Pressure*

• More accurate risk assessment?
Noninvasive Central Pressure

General Transfer Function

Calibration

Tonometer pressures

Pulse pressure

Time (sec)
Noninvasive Central Pressure

Central pressures → Output values

Tonometer → GTF → Input values

Sphygmomanometer

Calibration

Validation Issues

General Transfer Function

Pulse pressure

Tonometer pressures

Time (sec)
Marey EJ. Physiologie Medicale de la Circulation du Sang. Paris, France: Adrien Delahaye; 1863
Actual Example of Principle
Son and Dad: Same Brachial Systolic Pressure

Son and Dad: Same Brachial Systolic Pressure

Son 36yo
Dad 68yo

Radial Artery
Systolic same for Son and Dad

Aorta
Son 36yo
Dad 68yo
Aortic Systolic 17 mmHg more for Dad

Actual Example of “Treatment” Effect
68 year old male

Radial Artery

Aorta

Baseline
Baseline

Radial Artery

68 year old male

Small \( \Delta \) due to med

2 hrs after ACEI (Ramipril 10 mg)

VSM relaxation – Artery Relaxation and Arteriole Vasodilation

Increases C
Reduces \( S_0 \)

Aorta

Big \( \Delta \) due to med

Reduces Reflection
Summary of Major Aspects

- Systolic Peaking (stroke risk)
- Increased ventricular systolic afterload (LVH risk)
- Normal Composite (P_m)
- Reduced diastolic Pressure (Ischemic risk)
- Earlier Reflection
- Normal Reflection (P_b)
Conclusions

• Standard BP good but misses stuff that effects heart

• Reasons have to do with pressure wave interactions that are most directly influenced by:
  A. Pulse wave speed (Artery compliance)
  B. Reflection amplitudes (Vasoconstriction state)
  Both tend to increase with hypertension and aging

• Prediction:
  New office BP assessment devices within 4 years??

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"That's all folks!"