Beyond Peak Velocities: Waveform Interpretation in Carotid Doppler Studies

Mark Kliewer, MD
University of Wisconsin:
Leslie Scoutt, MD
Yale University

Carotid Waveforms

- Doppler samples used primarily to quantitate velocity elevations at stenoses
- Clues to disease also contained in the shape and contour of the waveform itself
- Aberrations of waveform morphology can signal regional disease, remote CV disease, and iatrogenic conditions

Carotid Waveforms

- Normal
- Waveform Changes
  - In Systole
  - In Diastole
  - Throughout the cardiac cycle

Normal

- Characteristic spectral waveforms of the common, external, internal carotid arteries and the vertebral artery
- These waveform appearances reflect the character of the vascular bed supplied by each vessel
Carotid Waveforms

- Normal
- Waveform Changes
  - In Systole (5)
  - In Diastole
  - Throughout the cardiac cycle

Tardus Parvus

- *pulsus parvus*: diminished peak systolic velocity
- *pulsus tardus*: prolonged systolic acceleration, delayed systolic upstroke, rounded systolic peak
- Distal to a high-grade stenosis, occurring anywhere from the aortic valve to the carotid arteries

- Severe Aortic Stenosis
Pulsus Bisferiens

- Two prominent systolic peaks with an interposed midsystolic retraction
- Latin for “beat twice”
- AR and hypertrophic obstructive cardiomyopathy
- Mid-systolic flow deceleration caused by either:
  - the regurgitant valve and a reflected tidal wave,
  - the rapid ejection of a large blood volume creates a Venturi effect in the aorta

Pulsus Alternans

- Alternating peak systolic heights with a regular cardiac rhythm
- Intrinsic myocardial disease (ischemia, cardiomyopathy, valvular disease)
- Metabolic disease (hypocalcemia)
- Impairment of venous return (IVC compression or obstruction)
The Vertebral Bunny

- One of a spectrum of waveform changes with varying degrees of subclavian steal
- Provocative maneuvers can convert a pre-steal waveform to a complete steal
- The Venturi effect: a high-velocity jet across the vertebral artery origin during systole causes a transient pressure drop and concomitant flow deceleration

The Venturi Effect
The Right Carotid Bunny

- A waveform like the pre-steal waveforms of the vertebral arteries
- Brachiocephalic artery stenosis causes:
  - a jet across the origin of the right CCA,
  - a transient pressure drop at peak systole,
  - and the mid-systolic retraction

The Right Carotid Bunny

- Brachiocephalic artery stenosis causes: a jet across the origin of the right CCA, a transient pressure drop at peak systole, and the mid-systolic retraction

Stenosis of Innominate Artery

Carotid Waveforms

- Normal
- Waveform Changes
  - In Systole
  - In Diastole (5)
  - Throughout the cardiac cycle
Internalization of ECA

- Low-resistance ECA waveform simulates an ICA waveform
- Due to ICA occlusion with development of low-resistance collaterals between the external and internal circulations usually through the ophthalmic bed

Reconstituted ICA flow from ECA

- Blood flow moves retrograde down the ECA to the carotid bulb and then antegrade in the ICA
- ECA and ICA have low resistance waveforms with diminished systolic amplitude
- Filtering out of the higher frequency velocities by the collateral network supplying the ECA
Water Hammer Pulse

- Free aortic regurgitation
- Waveforms mirror the physical exam: rapidly rising pulse collapses suddenly in late systole
- Sharp systolic peak, a precipitous deceleration of flow in late systole, and sustained flow reversal through diastole

Aortic Regurgitation

Severe Aortic Regurgitation

Historical Speculation

To and Fro Flow

- In the neck of pseudoaneurysms, blood flows toward the pseudoaneurysm in systole and returns to the parent artery in diastole
- Alternating currents can be reflected into the lumen of an artery
- A consequence of trauma, surgery, or misplaced central venous lines
Shunt Vascularity

- High flow and low resistance waveforms with nearly uninterrupted forward flow
- Vascular shunting due to arteriovenous communication
- Concomitant pulsatility of venous waveforms
- A “soft-tissue bruit” with color speckling marking the site of the fistula

Carotid Waveforms

- Normal
- Waveform Changes
  - In Systole
  - In Diastole
  - Throughout the cardiac cycle (4)
Pulsus Paradoxus

- Seen in asthma, cardiac tamponade, deep breathing, obstructive airway disease
- The exaggerated fall in systolic blood pressure with inspiration
- The negative pressure of inspiration causes blood to pool in the lungs, and decrease cardiac output.

Pulsus Paradoxus

- Aortic - and carotid - flow velocities decreases with inspiration
- Experimentally demonstrated with labored breathing through airway resistors
- May be useful as an objective index of the airway resistance elevation

Knocking Waveforms

- Small, blunt percussive waves with little or no diastolic flow
- Sampling immediately proximal to a vascular occlusion
- Dissections: high resistance waveforms over long segment of ICA, conspicuously little plaque
- Worsens as approach obstructing lesion

**Bilateral Knocking Waveforms**

- Increased intracranial pressure
Swirling, Bidirectional Flow

- Flow reversal within a carotid artery segment raises possibility of tandem stenoses
- The abnormal hemodynamic pattern of one lesion can overlap that of a second, and produce bizarre waveforms and eddy currents

Transmitted Percussion Waves

- Small, regular percussion waves are seen when the examiner performs a temporal tap maneuver to identify the ECA
- The reflected pulsations are propagated along the vessel in both directions
- The distortion can be evident in the ICA as well
- Interrogate both carotid vessels: taps in the true ECA tend to be sharper, better defined, and higher amplitude
Cyclical Flow Perturbations

- **Intra-aortic Balloon Pump**
  - 2 peaks of forward flow in systole due to LV contraction and balloon inflation
  - 1 inverted peak of flow reversal, due to deflation of the balloon
  - 1-2-back: tango, jitterbug

Intra-Aortic Balloon Pump

- Deflation of balloon causes reversed flow at the end of diastole

Minimally Pulsatile Flow

**Left Ventricular Assist Device**

- Pump between the LV and the either ascending or descending Aorta
- Bridge to transplant; temp or permanent cv support
- Can be pulsatile or non-pulsatile

Left Ventricular Assist Device

- Waveform either monophasic or biphasic with abundant diastolic flow