Integrating Duplex Doppler

Traci B. Fox, EdD, RT(R), RDMS, RVT
Department of Medical Imaging & Radiation Sciences
Jefferson College of Health Professions
Tel: 215-503-1325
traci.fox@jefferson.edu

Disclosures

• Royalties from McGraw-Hill and Wolters Kluwer
• Special Thanks to Gail Size (Inside Ultrasound) for her images

• In lieu of an 8 am Doppler talk, I’d like to spend the next hour discussing...

Spoiler Alert
Biggest Lie You Learn in Clinical
• You’ll never use the physics after you graduate:

Basics of Spectral Doppler
• What is “duplex?”

Basics of Spectral Doppler
• Duplex imaging
  • Acquires to 2D image and Doppler separately, not simultaneously

Doppler Terminology
• Duplex imaging
  • Frozen duplex
  • Live duplex

Doppler Angle
• The Doppler angle is the angle between the flow and the beam
  \[ F_D = \frac{2F \cos \theta}{c} \]
Doppler Facts...How Many Do You Know?

- The smaller the Doppler angle, the more accurate the velocities
- We don’t use the angle itself, but the cosine of the angle
- $0^\circ$ is the most accurate angle
- Never use an angle $> 60^\circ$
- Highest shift at $0^\circ$

Doppler Facts...How Many Do You Know?

- The lower (lower/higher) the Doppler angle, the more accurate the velocities
- $0^\circ$ is the most accurate angle
- Never use an angle $> 60^\circ$
- Highest Doppler shift is at $0^\circ$
- The Doppler shift at $90^\circ$ is $0$

PW Spectral Doppler and Aliasing

- How do you fix aliasing? Name FOUR ways
  - Increase the scale/PRF
  - Increase the Doppler angle
  - Decrease the transducer frequency
  - Use continuous wave

PW Spectral Doppler and Aliasing

- Why does aliasing occur?
  - Frequency shift $>\text{Nyquist limit}$
  - You’re not sampling often enough

Aliasing - Another Example

- Temporal aliasing occurs in other areas of life, such as when a wheel or propeller appear to either not spin or spin backwards

Aliasing - The PW Enemy

- What happens if you don’t sample often enough?
  - Sample every 15 sec
  - Sample every 45 sec
Time-Velocity Spectrum (Spectral Analysis)

Spectral Analysis
- Graph of frequency shift (velocity) over time

\[ v = \frac{cF_D}{2f \cos \theta} \]

"Peak" Systolic Velocity

Flow moving at 100 cm/s
- Shift 90° = 0
- Velocity 0 cm/s
- Shift 60° = 0.5
- Velocity 50 cm/s
- Shift 0° = 1.0
- Velocity 100 cm/s

Is this really the highest velocity? Or were these red blood cells just traveling at a lower angle?
Vector Flow

Frequency Shift vs. Velocity
- Why do we have to be 60 degrees or less?
- Degree of error larger at higher angles
  - 60 degree angle: A 5° error in angle, velocity is 15% off
  - 70 degree angle: A 5° error in angle, velocity is 24% off

The Myth of the 60° Angle
Why do we say to use a 60° angle for carotid ultrasound?
- Because that’s what the charts are based on
- Do not force a 60° angle
- 30 – 60° angle ok for ICA

The Myth of the 60° Angle
What angle should you use for carotid ultrasound?
- One that is parallel to the wall
- One that is about 30 - 60°
- One that is consistent with prior exams

The Myth of the 60° Angle
What angle should you use for carotid ultrasound?
- Why not use parallel to flow jet?
- We are imaging a 3D world in 2 dimensions
- Low interoperator reproducibility

What Have We Covered So Far?
- We’re not measuring velocity, but viewing the Doppler frequency shift converted to velocity
- Angle correction needed to display “correct” velocity
- Higher angles result in higher errors
- No, you shouldn’t use 60 degree angle when vessel does this:
How Well Do You Know Your Waveforms?

• What are the three types of flow?

Plug  Laminar  Turbulent

How Well Do You Know Your Waveforms?

• So...laminar flow is what normal blood flow looks like, right?

How a Stenosis Affects Flow

Pre-stenotic turbulence

At stenosis/jet

Poststenotic turbulence

How Well Do You Know Your Waveforms?

• Spectral broadening...why?
  • Pathology, turbulence (nl vs. abnl), tortuosity, spectral gain ↑, CW

Spectral Analysis

Keep the cursor in the center of the vessel (fastest flow) for clear window

Cursor towards the edge (boundary layer) or gate to wide open results in broadening (no window)
“Pretty” vs. “Search & Destroy”

- Normal vessel
  - Go with pretty, laminar flow pattern
  - Small gate, optimized gain
- Any suspected pathology, including stenosis, near-occlusion
  - Search and destroy mode (i.e., max sensitivity)

Appropriate Scale for Low/No Flow

- High sensitivity setting...searching for flow
  - Low scale
  - Increase gain (but not too much)
  - Lowest wall filter
  - Open gate wide

Gate Size

- Gate placed in vessel full of plaque
  - Plaque can be anechoic (i.e., invisible)
  - Gate is too narrow... does not detect flow

Gate Size

- Gate placed in vessel full of plaque
  - Open gate to “search” for flow
  - Effectively turns PW gate in sort-of a CW probe (i.e., large sample volume)
  - With large gate you’ll find the flow

Where to Measure in Blood Vessel With Stenosis

The “Three Musketeers”

  Before stenosis • At stenosis • After stenosis

Walk the cursor through. Open gate to capture ALL velocities

Phasicity

Phasicity relates to the bed being fed by the vessel and not to the vessel itself.
Phasicity

- Phasicity relates to the bed being fed by the vessel and not to the vessel itself
  - i.e., the DISTAL bed

Spectral Doppler and Phasicity

- What is the distal bed doing?
  - Is this waveform normal?
    - In a resting leg?
    - In an ICA?

Phasicity

- Monophasic flow always abnormal in (resting) lower extremity arteries
- Persistently dilated downstream vessels due to disease

What the heck is this?

- Vertebral a.
- Occult steal
  - Reversed late systolic flow after exercise

How to Start a Riot at an Ultrasound Conference...

- What type of waveform is this?
  - Monophasic? Biphasic? Low resistance? High resistance?

How to Start a Riot at an Ultrasound Conference...

- What about this? Monophasic means low-resistance, right?
What Does the Research Say?

• Everyone agrees this is triphasic (multiphasic)

• So is this high resistance or low resistance?
  • Better question: Is it normal?

What Does the Research Say?

• Everyone agrees this is monophasic

<table>
<thead>
<tr>
<th>Table 1: Distribution of Survey Responses to Direct Yes/No Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yes</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1. Should all arterial waveforms display a well-delimited zero-flow baseline?</td>
</tr>
<tr>
<td>2. Should all “trihphasic” waveforms exhibit diastolic flow reversal?</td>
</tr>
<tr>
<td>3. Do all “trihphasic” waveforms exhibit diastolic flow reversal?</td>
</tr>
<tr>
<td>4. Can the term “trihphasic” be used to describe both normal and abnormal arterial Doppler waveforms?</td>
</tr>
<tr>
<td>5. Should the term “monophasic” be used to define waveforms found distal to a flow-limiting peripheral arterial obstruction?</td>
</tr>
<tr>
<td>6. Is a monophasic arterial Doppler waveform found only distal to a flow-limiting arterial obstruction?</td>
</tr>
</tbody>
</table>

NA, not applicable.

Note: Spectral Doppler of Aorta

Aorta waveform will change depending on location (supra- or infrarenal).
What Waveform is This?

Post-stenotic turbulence (PST)

What Waveform is This?

Right Proximal CCA
Severe CHF

What Waveform is This?

Tardus Parvus
• Signifies significant disease proximal to point of sampling
• Tardus parvus

• Delayed upstroke (acceleration) from proximal obstruction

What Waveform is This?

Turbulence right CCA means brachiocephalic a. or prox CCA stenosis
(If left CCA, means prox left CCA stenosis)

Know your anatomy!

What Waveform is This?

Tardus parvus proximal right CCA - indicates more proximal obstruction

NEED TO KNOW ANATOMY
Either origin of CCA or brachiocephalic a.

When you see tardus parvus in a vessel, ask yourself, what did I miss?
Venous Waveforms

• What are the characteristics of normal venous waveforms in the lower extremities?
  - Respiratory phasicity: Non-pulsatile
  - Not continuous: Spontaneous?
  - Augmentation?

Venous Waveforms

Upper extremities:
  - Blood flow returns to heart on deep inspiration
Lower extremities:
  - Blood flow is returns to heart on exhalation

Venous Waveforms

Central upper extremity and central venous waveforms more likely to transmit cardiac pulsations related to right heart

Venous Waveforms

Normal hepatic veins during respiration

Normal distal IVC

Breathing and Central Venous Waveforms

Traci Fox 2019
Venous Waveforms

• Rouleaux flow: DVT precursor or harmless finding?
  • Usually inconsequential
  • Could be positional, other hemodynamic factors
  • Can be seen in presence of more central obstruction

Abnormal Venous Waveforms

• Continuous venous waveform from increased resistance in liver

Abnormal Venous Waveforms

• Turbulence from intrinsic thrombus

Measuring Velocities in Veins

• Do you have validated criteria?
• How will the information change the management of the patient?
• Ergonomics issue

Q1

• At the point of a stenosis, what happens to the velocity?

It increases
Q2
- When you see the image below, the disease is most likely proximal to the point of sampling.

Q3
- You see color in the tissue adjacent to an artery. Does that mean “there’s a bleeder?”

Q4
- True or False: this waveform is abnormal. You don’t know what vessel it is! Okay for ICA, not okay for resting LE.

Q5
- This waveform implies...
Q6
• What happens to the pressure at the point of a stenosis?

Velocity goes up, pressure goes down

Q6
• What happens to the pressure at the point of a stenosis?

Image from Kupinski, A., The Vascular System (Diagnostic Medical Sonography Series), 2d ed. Wolters Kluwer

Q7 What is Causing This Waveform?

“Water Hammer” Pulse
• Aortic insufficiency/regurgitation causes sharp upstroke and sharp downstroke
• This waveform has reversal of flow due to severe regurgitation

Image courtesy of Gail P. Size, BS, RPhS, RVS, RVT, FSVU, President, Inside Ultrasound, Inc.

Q8 What is Causing this Waveform?

Right-Sided Heart Failure
• CFV with pulsatile flow
• Caused by elevated right-side heart failure

Image courtesy of Gail P. Size, BS, RPhS, RVS, RVT, FSVU, President, Inside Ultrasound, Inc.
Q9 What is Causing These Waveforms?

A. [Waveform Image]
B. [Waveform Image]

A. IABP & B. LVAD
- A. Intraaortic balloon pump (IABP)
- B. Continuous flow left ventricular assist device (LVAD)
- Will not get accurate velocities - be sure to mention in report

Q10 What is Causing This Waveform?

Hint: It's bilateral

Severe Congestive Heart Failure
- Tardus parvus waveform implies proximal disease
- However, bilateral tardus parvus implies cardiac origin
- This patient had aortic stenosis

Q11 What is Causing This Waveform?

Hint: It's the CFV

Central Venous Obstruction
- Continuous flow that looks pulsatile because of the very low scale setting
- Cause was a large cystic mass
- Other causes: pregnancy, very full urinary bladder, intrinsic thrombus, other cause of extrinsic compression of IVC or CIV/EIV.
Q12. What is Causing This Waveform?

Hint: It’s the RIGHT subclavian v.

It’s Normal!

(Don’t matter that it’s the right side. Venous anatomy is bilateral in the UE.

Bazinga!

Summary

• Knowledge of hemodynamics, Doppler settings and anatomy are important to understanding waveforms
• Waveforms are important for knowing normal vs. disease

Shameless Self Promotion Slide

Thank you

Go with the flow.