Arterial Doppler Waveform Analysis
Understanding Past, Present and Future Components

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Disclosures:

No relevant financial relationships with commercial interests
Arterial waveform principles

It’s not only about the velocities.....

Analysis of waveform morphology is crucial to improve diagnostic accuracy
  • Acceleration / upstroke
  • Systolic peak
  • Deceleration / downstroke
  • Diastolic components

• Identification of flow direction
Arterial waveform principles: Past, Present, Future

**Upstroke, acceleration:** reflects the past, or how the flow arrived (fast or slow)

**Systolic peak:** the present, or fastest flow before deceleration

**Downslope, deceleration and diastolic components:** the future, or what type of vascular beds are being fed
Evaluating extremity waveform components

Triphasic (sharp peak): Normal
**Rapid Acceleration to Deceleration**
RAD

Monophasic (rounded peak): Abnormal
**Slow Acceleration to Deceleration**
SAD
Evaluating waveform components

Always look for symmetry side-to-side

Rapid acceleration, rounding of the systolic peak, slowed deceleration with reduced distal vasomotor tone.

Rapid acceleration and deceleration, sharp peak and normal resting vasomotor tone.
Arterial waveform morphology depends on:

- Cardiac function
- Lumen size at the sample site
- Pressure reducing lesions /obstructions proximal to the sample site
- Distal vasomotor tone at the level of the arterioles in the muscular beds
- Distal obstructions
Arterial Resistance patterns

Normal peripheral resistance at rest
Arterial Resistance patterns

High resistance, closed fist
Arterial Resistance patterns

Low resistance, fist opened
Arterial Resistance patterns

Low resistance, hyperemic
Waveform terminology

**Phasicity**

(Waveform terminology is being evaluated for standardization by SVM & SVU with expected publication in 2019)

Description always relates to changes in direction across the zero baseline or flow all in one direction??

Description relates to changes in speed or direction, number of faster and slower flow components??
Peripheral arterial waveforms

- Arteries feeding skeletal muscle and fasted intestine
  - OR
- Arteries feeding high metabolic demand in the distal tissues
Triphasic
Biphasic
Monophasic
Arterial Stenosis

Velocity increases from pre to peak in areas of significant stenosis (diameter reduction)
Arterial Stenosis

Post-stenotic turbulence is present just distal to hemodynamically significant stenosis (serrated, choppy waveforms with flow reversal under the systolic peak)
Waveform Taskforce Update

Information presented at the SVU Annual Conference
August 2019
By: Esther S.H. Kim, MD, MPH, RPVI
Chair
Waveform Consensus Statement

**SVM members:**
- Esther SH Kim (Chair)
- Aditya Sharma (Co-Chair)
- Gene Zierler
- Guillame Mahe
- Paul Wennberg
- Marie Gerhard-Herman
- Robert Eberhardt
- Rita Shugart

**SVU members:**
- Robert Scissons (Co-Chair)
- Marsha Neumyer
- Steve Knight
- Ann Marie Kupinsky
- David Williams
- JP Hughes
- Tish Poe
- David Dawson
Normal Peripheral Arterial Doppler Waveform

• “Triphasic”
  1. High forward flow during systole
  2. Transient period of flow reversal
  3. Forward flow component

• Physiologic conditions and disease states that alter this pattern are numerous
  • Reactive hyperemia
  • Exercise
  • Arterial Stiffening
  • Proximal high-grade stenosis

• Most can identify the “normal” and “abnormal” as “triphasic” and “monophasic”

Scissons R. JDMS 2008;24:269-276
How would you describe this waveform?

- Triphasic?
- Biphasic?
- Monophasic?
- Multiphasic?
- Abnormal?
- Normal?
- High Resistive?
- Low Resistive?
Characterizing Triphasic, Biphasic, and Monophasic Doppler Waveforms

Should a Simple Task Be So Difficult?

ROBERT SOCISSON, RVT

Doppler waveform analysis is a fundamental part of evaluating peripheral arterial disease. Waveform characteristics are traditionally defined as multiphasic (triphasic, biphasic) and monophasic. The purpose of this investigation is to evaluate whether sonography professionals correctly classify waveforms into these three categories. Thirty Doppler waveforms (15 continuous-wave [CW] and 15 pulsed-wave [PW]) Doppler were obtained from patients with previous noninvasive peripheral arterial evaluations. Participating readers were asked to interpret waveforms as triphasic, biphasic, or monophasic, using standard definitions. "Other" was used to classify waveforms whose morphology could not be determined or accurately classified as triphasic, biphasic, or monophasic. Because multiphasic waveforms with pulsatile flow have been associated with biphasic and monophasic waveform terminology, answer key responses were based on waveform descriptors used by interpreters of the original noninvasive evaluation. There were a total of 97 participants, and of all Doppler waveforms, 75% were correctly identified (75% CW and 71% PW). Participants training or specializing in medical sonography misidentified an average of 27% triphasic, 23% biphasic, or monophasic CW and PW Doppler waveforms more CW than PW waveforms. Because there is considerable variability among sonography professionals and educators in defining and classifying peripheral arterial waveforms, this issue deserves higher priority.

Key words: waveform, characterization, analysis

Details of the 97 individuals participating in the study are as follows:

- 22 sonography students
- 8 American Registry for Diagnostic Sonography (ARDMS®), Registered Vascular Technologists® (RVT)
- 18 ARDMS® Registered Diagnostic Medical Sonographers® (RDMS)
- 24 multispecialty ARDMS® RVT, RDMS, or Registered Diagnostic Cardiac Sonographers (RDCS®): 6 RVTs with RDCS and 18 RVTs with RDMS
- 25 physicians: doctor of medicine or doctor of osteopathic medicine (11 with RVT).
Triphasic: three phases—forward flow, flow reversal, and a second forward component
Biphasic: two phases—one forward flow and one reverse component
Monophasic: single phase—forward flow with no reverse flow component
Other: waveform considered neither triphasic, biphasic, nor monophasic or a waveform that could not be categorized.

**FIGURE 17.** Multiphasic, common femoral artery pulsed-wave (PW) waveform with no significant inflow disease. Responses: triphasic, 24%; biphasic, 38%; monophasic, 33%; other, 5%.

**FIGURE 3.** Correct continuous-wave (CW) and pulsed-wave (PW) interpretations: years of sonography experience.
PROPOSAL FOR OFFICIAL SVM/SVU CONSENSUS STATEMENT
Society for Vascular Medicine and Society for Vascular Ultrasound
August 3, 2018

**Topic:** Consensus Statement on the Nomenclature for Peripheral Arterial and Venous Doppler Waveforms

**Scope of the Document:** Standardize nomenclature for the interpretation of pulsed and continuous wave Doppler waveforms for peripheral arteries and veins

Planned for co-publication in *Vascular Medicine* and *Journal for Vascular Ultrasound* with simultaneous “Online First” date
What did the panel of experts say?

<table>
<thead>
<tr>
<th>Description</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hyperemic</td>
<td>1</td>
</tr>
<tr>
<td>Biphasic</td>
<td>1</td>
</tr>
<tr>
<td>Multiphasic</td>
<td>2</td>
</tr>
<tr>
<td>Normal</td>
<td>2</td>
</tr>
<tr>
<td>Non-delayed, inflective, low resistant</td>
<td>1</td>
</tr>
<tr>
<td>Low resistive triphasic</td>
<td>3</td>
</tr>
<tr>
<td>Saint-Bonnet N-CF</td>
<td>1</td>
</tr>
<tr>
<td>Monophasic, strongly pulsatile</td>
<td>3</td>
</tr>
<tr>
<td>Normal biphasic</td>
<td>1</td>
</tr>
<tr>
<td>Rapid, multi-speed, hypo-resistant</td>
<td>1</td>
</tr>
<tr>
<td>Hyperemic/low resistance</td>
<td>1</td>
</tr>
</tbody>
</table>

Monophasic described as sharp(1), sharp with notch(1), sharp pulsatile(1)
What did the panel of experts say?

- Biphasic: 9
- Multiphasic: 1
- Normal triphasic: 1
- Normal, non-delayed, inflective: 1
- Normal: 1
- Saint-Bonnet A: 1
- Multiphasic, high resistance: 1
- Delayed, bi-directional, resistant: 1
- Multiphasic/biphasic: 1

Biphasic also described as abnormal (1), high resistive (1)
Venous waveforms are also being addressed

<table>
<thead>
<tr>
<th>Pulsatile</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phasic</td>
<td>1</td>
</tr>
<tr>
<td>Normal</td>
<td>6</td>
</tr>
<tr>
<td>Respirophasic wave form with a, c, v waves reflected</td>
<td>1</td>
</tr>
</tbody>
</table>

Pulsatile was also described as cardiophasic, consistent with chf and normal cardiophasic
First Point of Consensus - KISS

• **Key words:** simplify, nomenclature, applicability to end user (ordering MD), teachability, applicable across acquisition modalities, adaptable to current practice, connect to clinical context

• Describe normal in each vascular bed, then describe abnormal

• Describe versus interpret
Basic Consensus Points

• **Consensus**: A nomenclature system utilizing descriptor and modifier categories will be adopted

• **Consensus**: for arterial beds “multiphasic” will replace “triphasic” and “biphasic”

• **Consensus**: phasicity will be defined in relation to crossing the zero flow baseline

• **Consensus**: aim is to develop “descriptors” of findings, not “interpret” the waveforms.

• It is the responsibility of the interpreting physician to determine which descriptors are “normal” for a particular vascular bed

• *Examples of interpretation, not findings*: normal/abnormal, post-stenotic
In Summary

• There is no “standard” nomenclature to describe spectral Doppler waveforms for the peripheral vasculature

• The SVM and SVU are collaborating to standardize nomenclature for the description of pulsed and continuous Doppler waveforms for peripheral arteries and veins

• Standardization of nomenclature should aim to improve communication amongst clinicians, be teachable to students, experienced sonographers, and physicians, and be quickly adaptable to current practice
Thank you!
Keep those waves rolling!

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