Doppler Waveform "Bootcamp"

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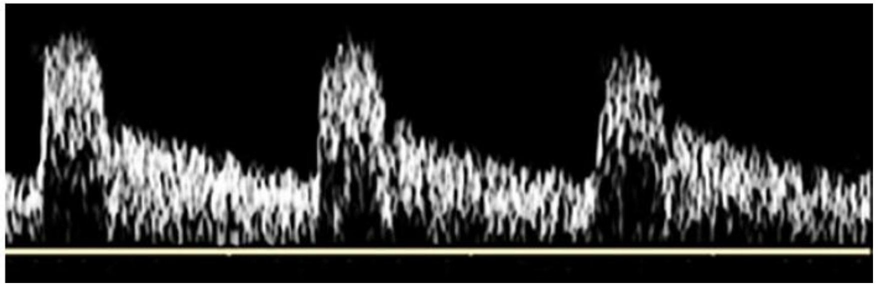
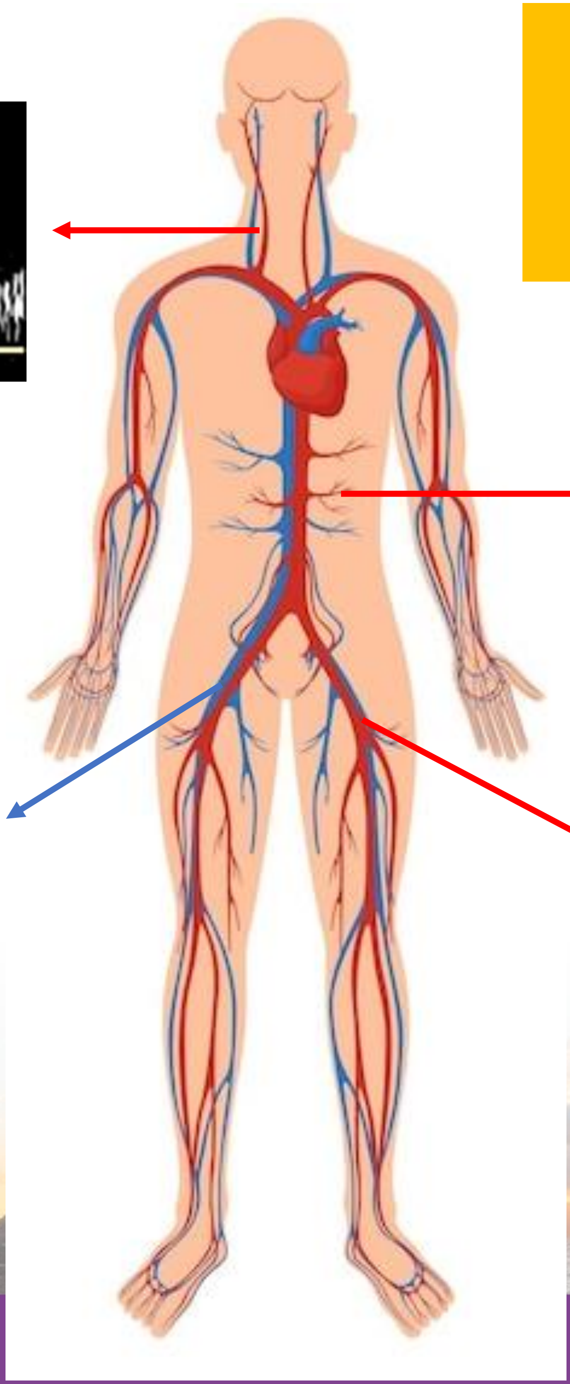
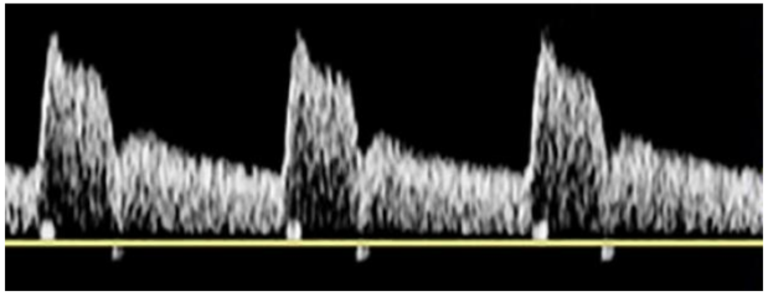
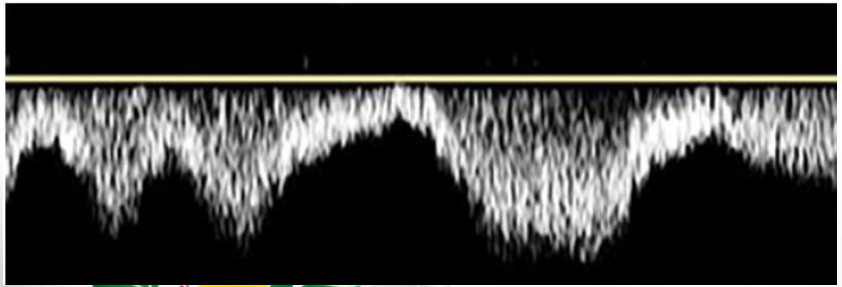
Must know normal to detect abnormal

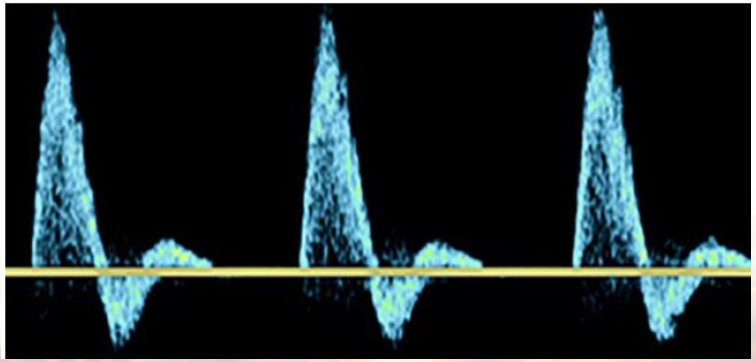


A normal waveform in one bed is abnormal in another bed





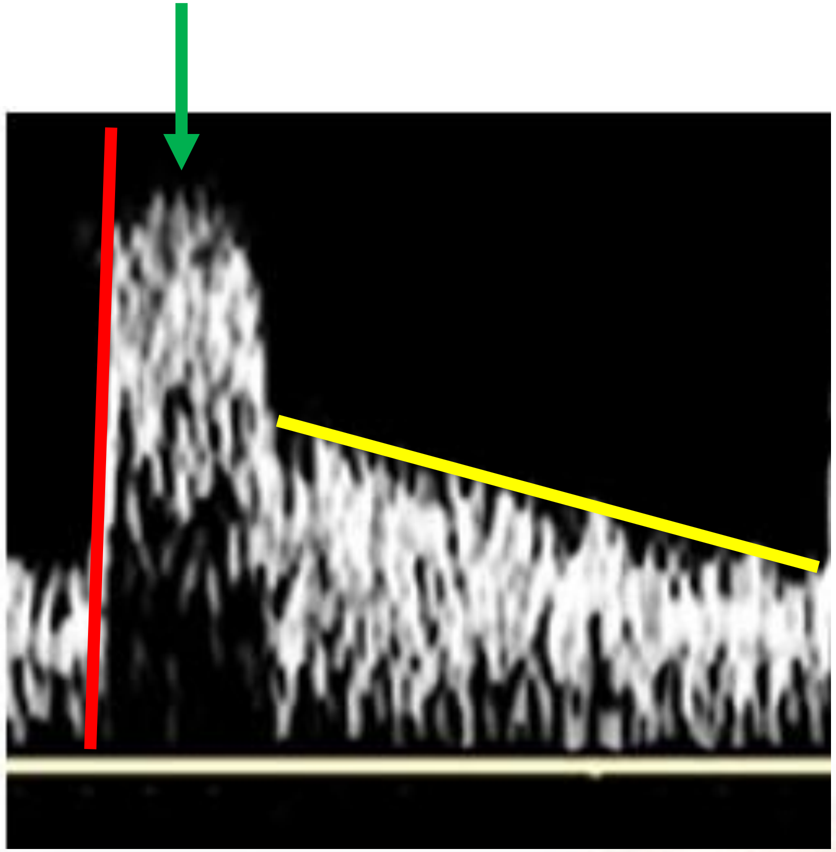




Inflow

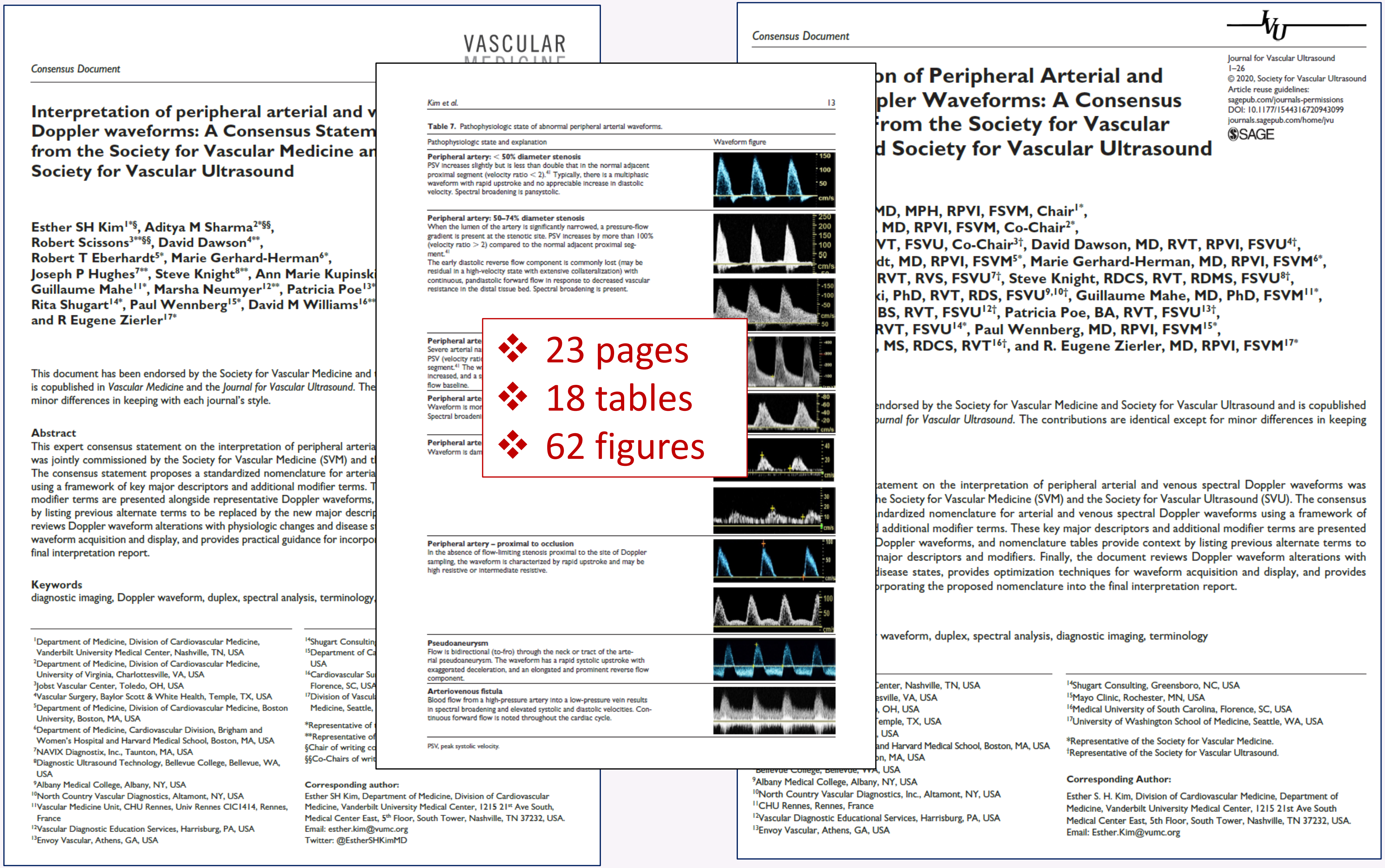
- Upstroke/Acceleration
  - Rapid
  - Prolonged
- How fast did the blood arrive
- *Is there a more proximal problem?*

Systolic Peak



Outflow

- Downstroke/deceleration
- Is there an abnormal impedence or capacitance?
  - Distal occlusion
  - Vasodilation
  - AVF
- *Is there a more distal problem?*


23 pages
18 tables
62 figures
Consensus Document
Interpretation of peripheral arterial and venous Doppler waveforms: A Consensus Statement from the Society for Vascular Medicine and Society for Vascular Ultrasound
Table 7. Pathophysiologic state of abnormal peripheral arterial waveforms.
Journal for Vascular Ultrasound

Standardization in 4 Parts

Part 1: Nomenclature

Purpose: Clarify and standardize key definitions and descriptors that are inherent to the analysis of arterial and venous Doppler waveforms

Part 2: Doppler waveform alterations with physiologic changes and disease states

Purpose: Review Doppler waveform alterations with physiologic changes and disease states

Part 3: Waveform optimization

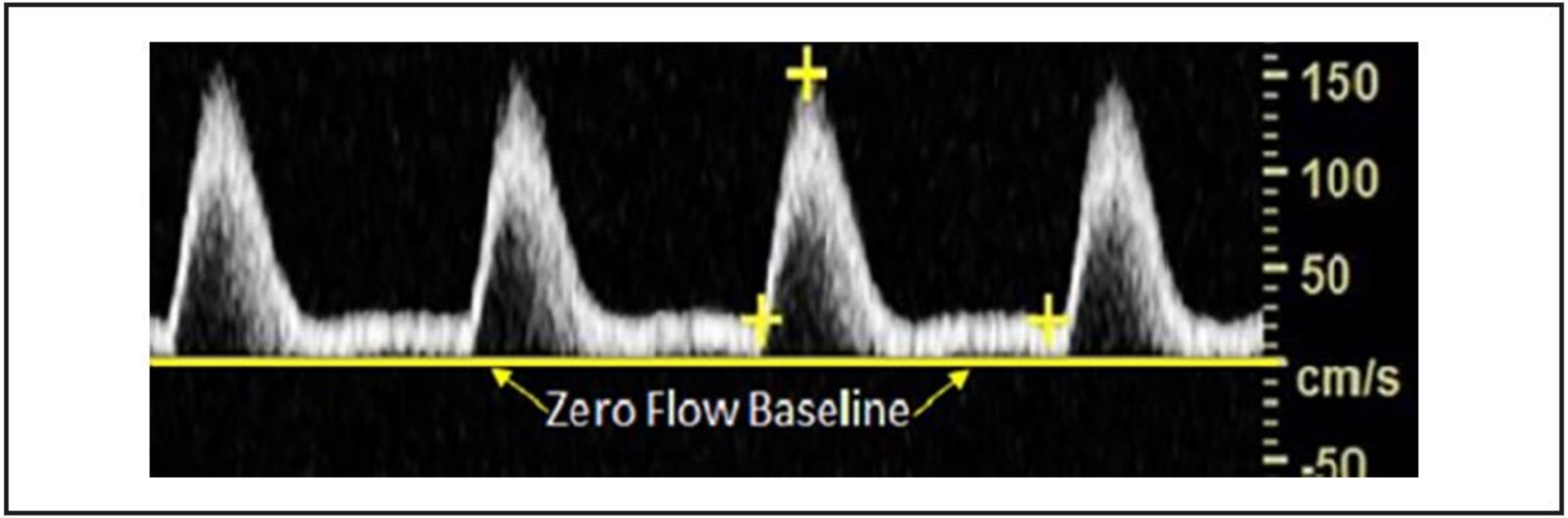
Purpose: Provide Doppler transducer optimization techniques to enhance the quality and presentation of Doppler spectral waveform and color Doppler data

Part 4: Interpretation and reporting

Purpose: Provide interpretation and reporting examples to facilitate use of the recommendations outlined in this consensus document

Four Major Consensus Points

1. The reference baseline for spectral Doppler waveforms will refer to the *zero-flow baseline*



Four Major Consensus Points

2. Arterial spectral Doppler and analog Doppler waveforms should be reported using **key major descriptors**: direction of flow, phasicity, and resistance. **Modifier terms** may be incorporated to provide additional information about waveform appearance.

- Direction of flow

  Antegrade, retrograde, bidirectional, absent

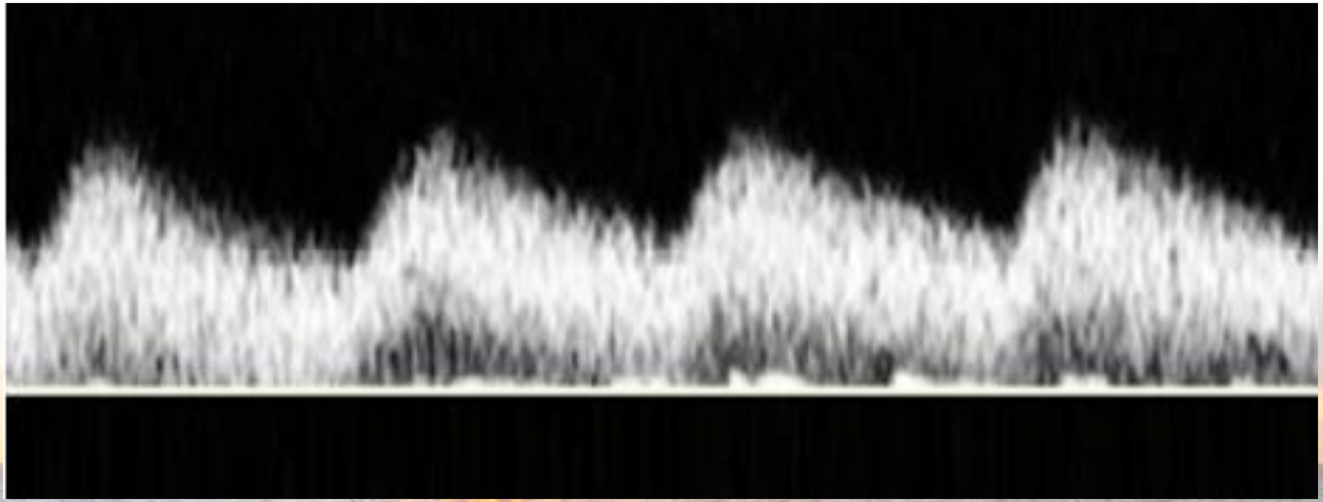
- Phasicity

  Multiphasic, monophasic

- Resistance

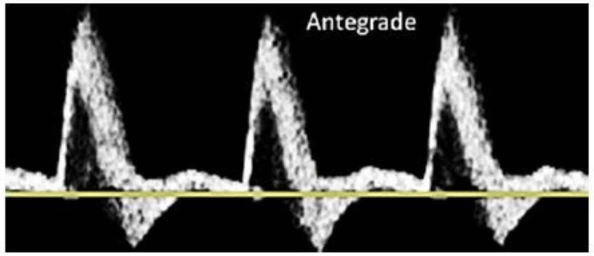
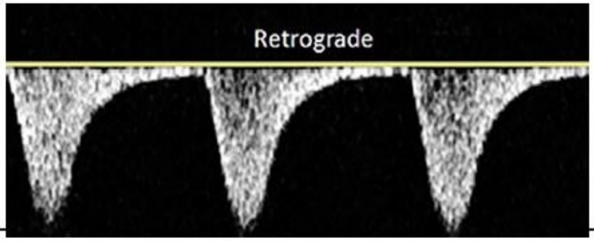
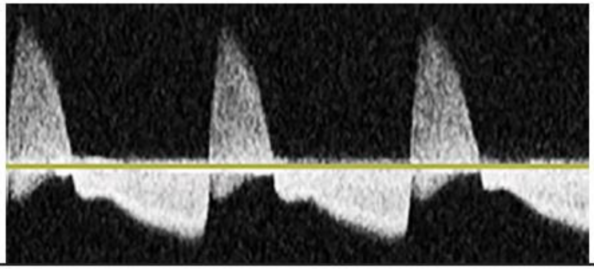
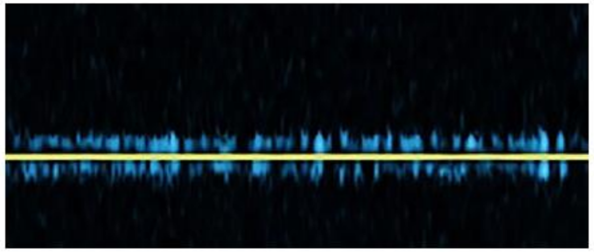
  High, intermediate, low

- Modifier terms



(Antegrade), dampened, low resistive, monophasic waveform with spectral broadening

Major Descriptor – **Direction of Flow**

Major descriptor	Major descriptor terms definitions	Waveform figure
Flow direction	Antegrade *Previous Alternate Term: Forward Flow* Blood flows in the normal direction for the artery being evaluated	
	Retrograde *Previous Alternate Term: Reverse Flow* Blood flows opposite to the normal direction for the artery being evaluated	
	Bidirectional *Previous Alternate Term: To-Fro* Blood flow enters and leaves a contained space via the same orifice.	
	Absent No blood flow is detected with an absent spectral Doppler signal.	

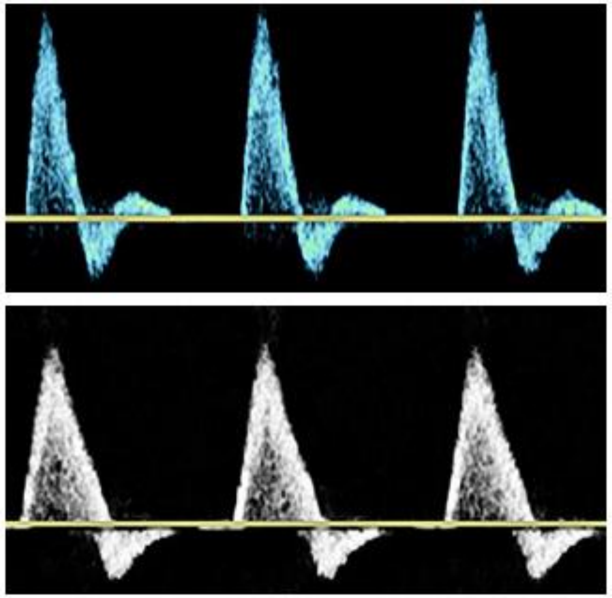
Major Descriptor - **Phasicity**

Waveform figure

Multiphasic

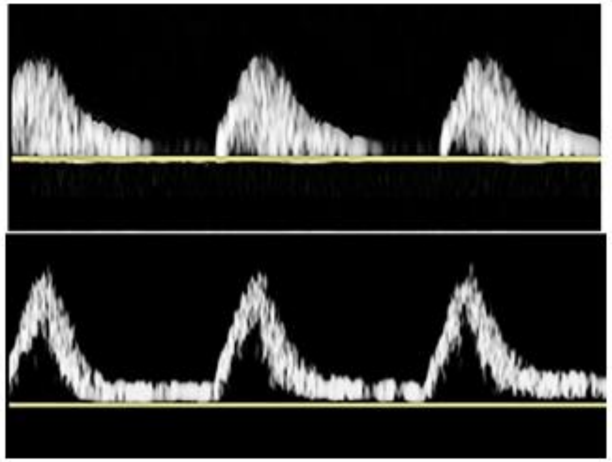
Previous Alternate Terms: Triphasic; Biphasic

Waveform crosses the zero-flow baseline and contains both forward and reverse velocity components



Monophasic

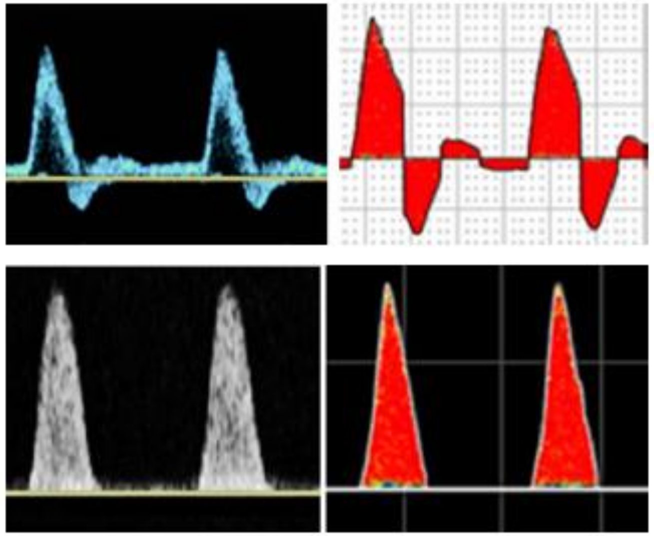
Waveform does not cross the zero-flow baseline throughout any part of the cardiac cycle; blood flows in a single direction



Major Descriptor - **Resistance**

High resistive

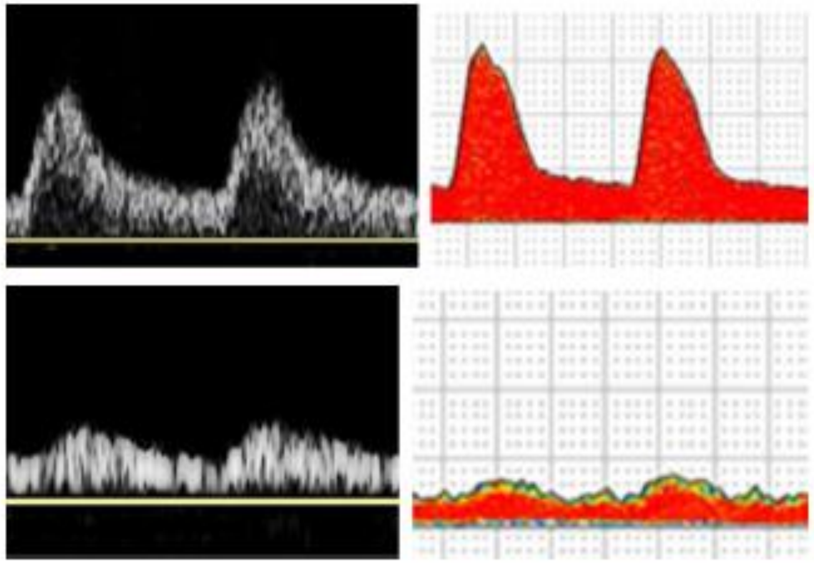
Key features: sharp upstroke and brisk downstroke, with or without diastolic flow reversal.



Low resistive

Key features: a prolonged downstroke in late systole and *continuous forward flow throughout diastole*

Note: Key feature: prolonged diastolic downslope with the presence of pandiastolic flow. In contrast to intermediate resistance, the low-resistive waveform contains a continuous and prolonged diastolic forward flow without the presence of an end systolic notch

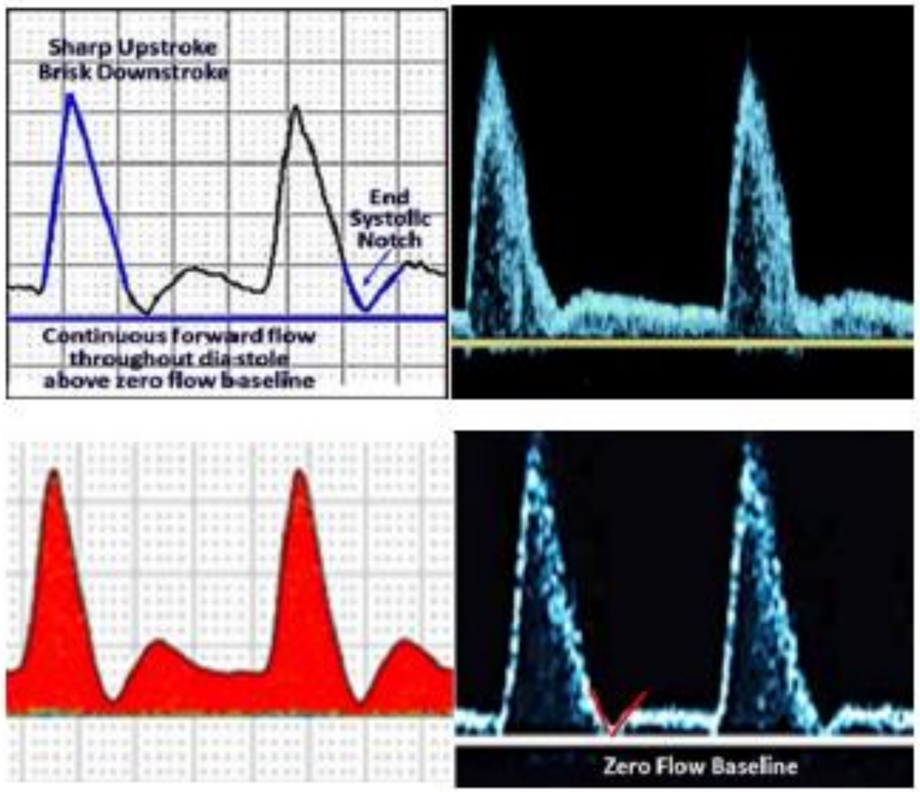


Major Descriptor - **Resistance**

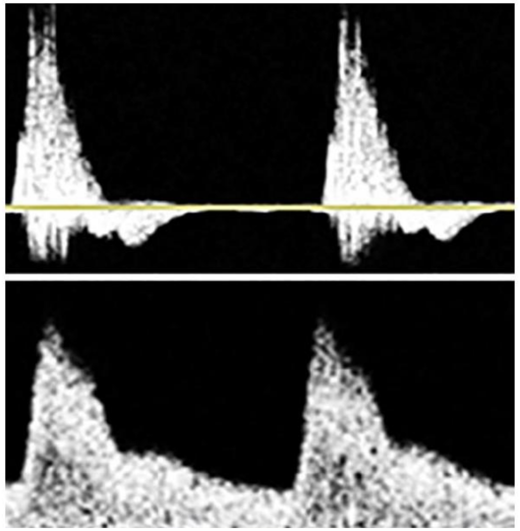
Intermediate resistive

Key features: sharp upstroke, brisk downstroke, visible presence of an end systolic notch and continuous forward flow throughout diastole that is above the zero-flow baseline. In contrast to low resistance, the intermediate resistive waveform contains a rapid deceleration at end systole followed by a diastolic acceleration with continuous forward flow.

The waveform pattern suggests vasodilation and can be the result of exertion (exercise), increased temperature, vasodilator drugs, or a severe arterial obstruction distal to the point of Doppler insonation.[39]



Modifier Terms

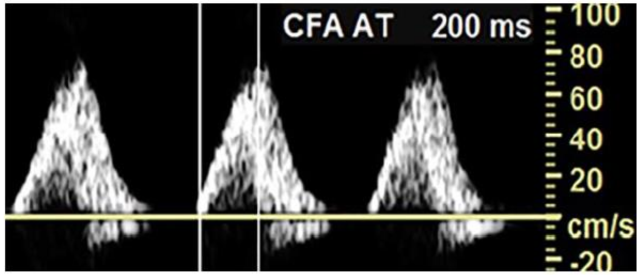


Spectral Broadening

Previous Alternate Terms: Non-Laminar, Turbulent, Disordered, Chaotic

Widening of the velocity band in the spectral waveform; a “filling in” of the clear “window” under the systolic peak.

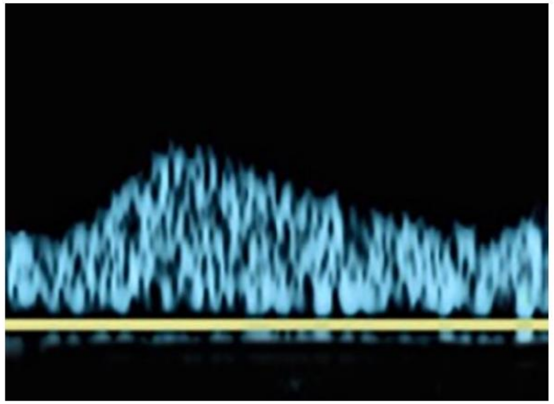
Note: Spectral broadening is commonly seen in turbulent flow but can also be seen in the absence of turbulence



Prolonged upstroke

Previous Alternate Terms: Tardus, Delayed, Damped

Abnormally gradual slope to peak systole. Acceleration time (AT) >140 ms has been used for the lower extremity common femoral artery.[40]



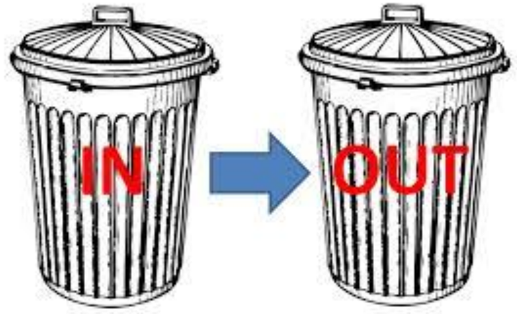
Dampened

Previous Alternate Terms: Parvus et tardus, Attenuated, Blunted

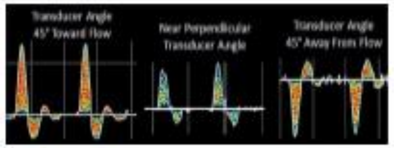
Combined finding of an abnormal upstroke (delayed) and peak (broad), often with decreased velocity

Four Major Consensus Points

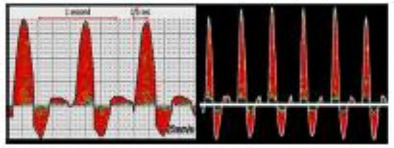
3. Optimization techniques should be used to provide quality Doppler waveforms for accurate interpretation



CW Doppler transducer angulation
The optimal CW Doppler transducer-to-vessel angle of insonation typically lies closer to 45°. Off-axis or perpendicular angles will significantly attenuate the waveform, admit venous artifact from an adjacent vein, or inaccurately display the waveform as reversed flow.

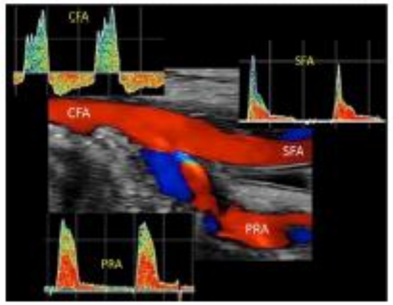


CW Doppler chart recorder speed
Normal peripheral artery systolic waveform acceleration time is approximately 0.20 sec. Modifying the chart recorder speeds to slower than 25 cm/sec can alter the waveform appearance.



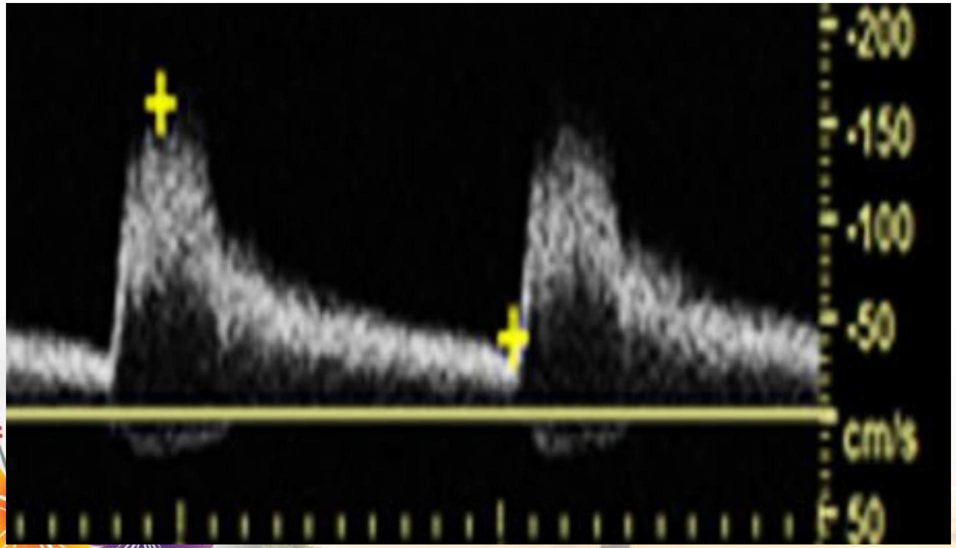
CW Doppler transducer support
Without support, the CW pencil probe becomes less stable, difficult to angulate and subject to motion artifact, particularly when used for evaluation of the posterior tibial and dorsalis pedis arteries. Waveform contour can be altered if the transducer is not properly braced and careful attention given to probe position to prevent off-axis or perpendicular transducer-to-vessel angles of insonation.

CW misidentification of CFA
Variations in anatomy can lead to incorrect identification of the SFA or PRA as the CFA. To avoid this error, shift the transducer medially and laterally; if a second arterial signal is encountered, then the Doppler probe is below the CFA and within the SFA and PRA confluence. The Doppler probe should be positioned more proximally to obtain the correct CFA sample location.



Four Major Consensus Points

4. Waveform descriptors and modifiers, velocity measurements, and image descriptors are test findings, not interpretations. To be clinically useful to the ordering provider, test data, including waveform findings, should be used by the interpreting physician along with exam-specific, validated criteria to determine the final interpretation or conclusion of the vascular study



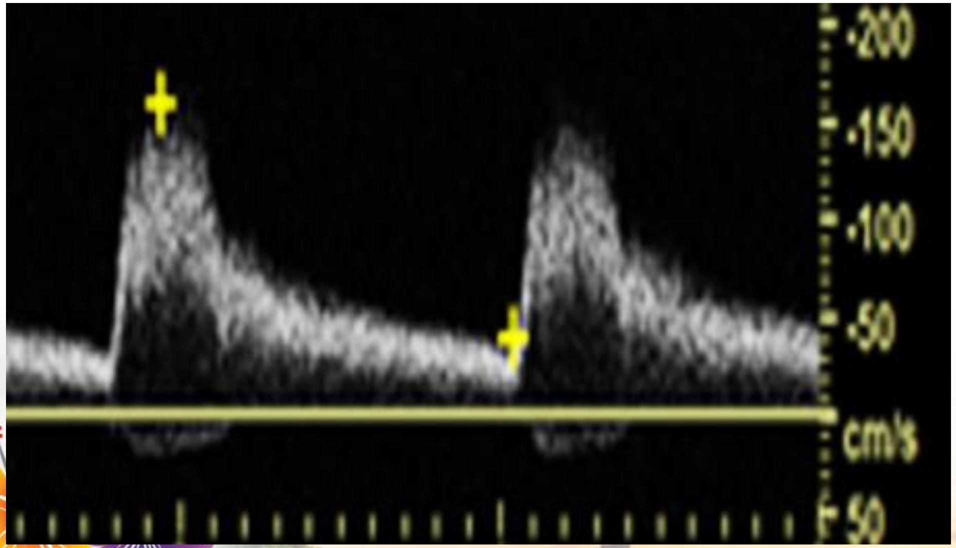
(Antegrade), low resistive, monophasic waveform

Normal or Abnormal?

- ❑ A – Normal
- ❑ B – Abnormal
- ❑ C – Need more information

Four Major Consensus Points

4. Waveform descriptors and modifiers, velocity measurements, and image descriptors are test findings, not interpretations. To be clinically useful to the ordering provider, test data, including waveform findings, should be used by the interpreting physician along with exam-specific, validated criteria to determine the final interpretation or conclusion of the vascular study



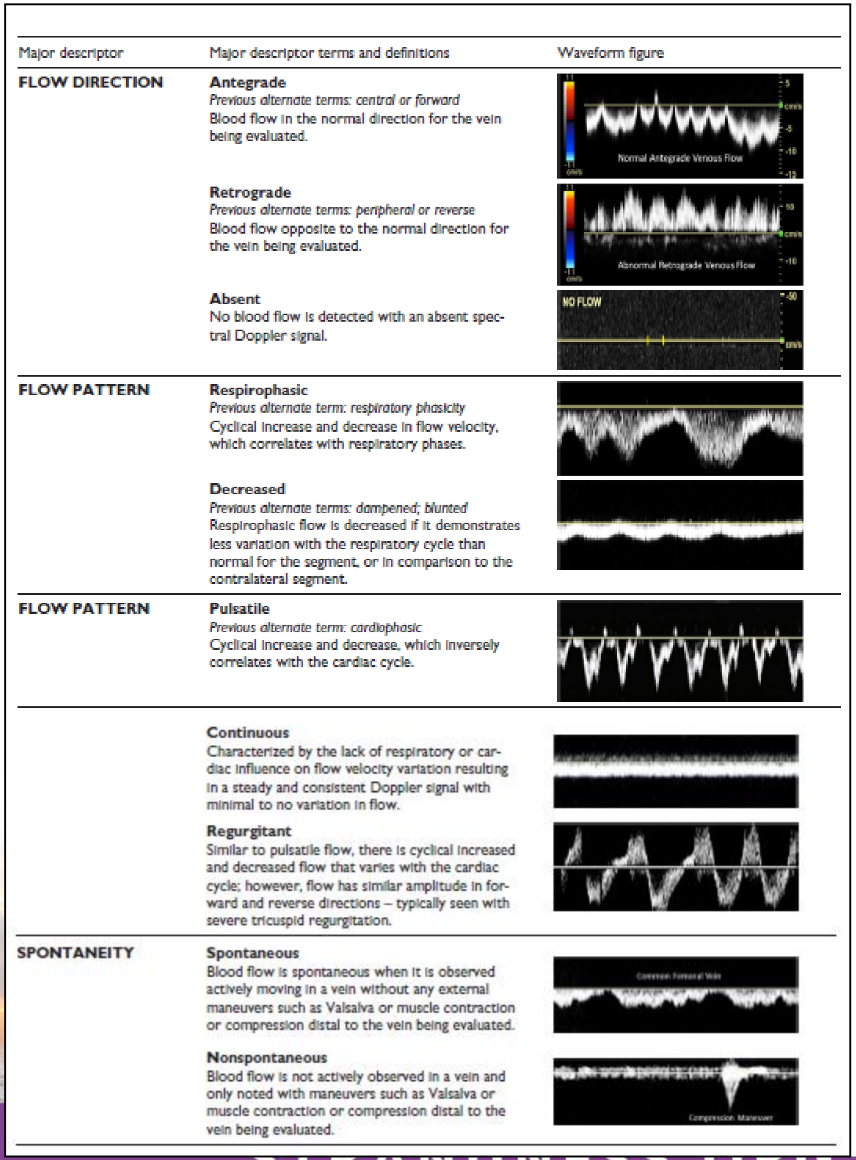
(Antegrade), low resistive, monophasic waveform

Normal or Abnormal?

- ❑ A – Normal
- ❑ B – Abnormal
- ☑ C – Need more information

Venous Key Descriptors and Modifiers

- Flow Direction
  Antegrade, retrograde, absent
- Flow Pattern
  Respirophasic, decreased, pulsatile, continuous, regurgitant
- Spontaneity
  Spontaneous, nonspontaneous
- Other
  Augmentation, reflux, fistula flow



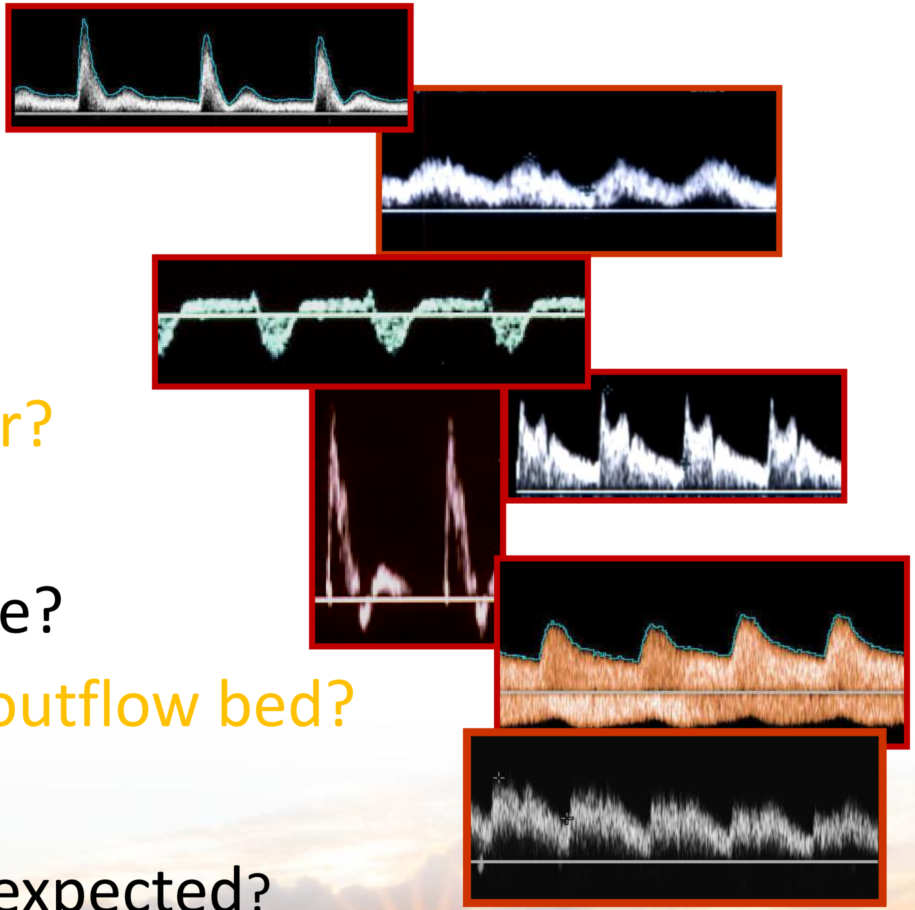
Major descriptor	Major descriptor terms and definitions	Waveform figure
FLOW DIRECTION	**Antegrade** *Previous alternate terms: central or forward* Blood flow in the normal direction for the vein being evaluated.	Normal Antegrade Venous Flow
	Retrograde *Previous alternate terms: peripheral or reverse* Blood flow opposite to the normal direction for the vein being evaluated.	Abnormal Retrograde Venous Flow
	Absent No blood flow is detected with an absent spectral Doppler signal.	NO FLOW
FLOW PATTERN	**Respirophasic** *Previous alternate term: respiratory phasicity* Cyclical increase and decrease in flow velocity, which correlates with respiratory phases.	
	Decreased *Previous alternate terms: dampened; blunted* Respirophasic flow is decreased if it demonstrates less variation with the respiratory cycle than normal for the segment, or in comparison to the contralateral segment.	
FLOW PATTERN	**Pulsatile** *Previous alternate term: cardiophasic* Cyclical increase and decrease, which inversely correlates with the cardiac cycle.	
	Continuous Characterized by the lack of respiratory or cardiac influence on flow velocity variation resulting in a steady and consistent Doppler signal with minimal to no variation in flow.	
	Regurgitant Similar to pulsatile flow, there is cyclical increased and decreased flow that varies with the cardiac cycle; however, flow has similar amplitude in forward and reverse directions – typically seen with severe tricuspid regurgitation.	
SPONTANEITY	**Spontaneous** Blood flow is spontaneous when it is observed actively moving in a vein without any external maneuvers such as Valsalva or muscle contraction or compression distal to the vein being evaluated.	
	Nonspontaneous Blood flow is not actively observed in a vein and only noted with maneuvers such as Valsalva or muscle contraction or compression distal to the vein being evaluated.	

Considerations in Waveform Interpretation

1. Check systolic upstroke
   a) Rapid or delayed?

2. Consider systolic peak
   b) Sharp, blunted, or other?

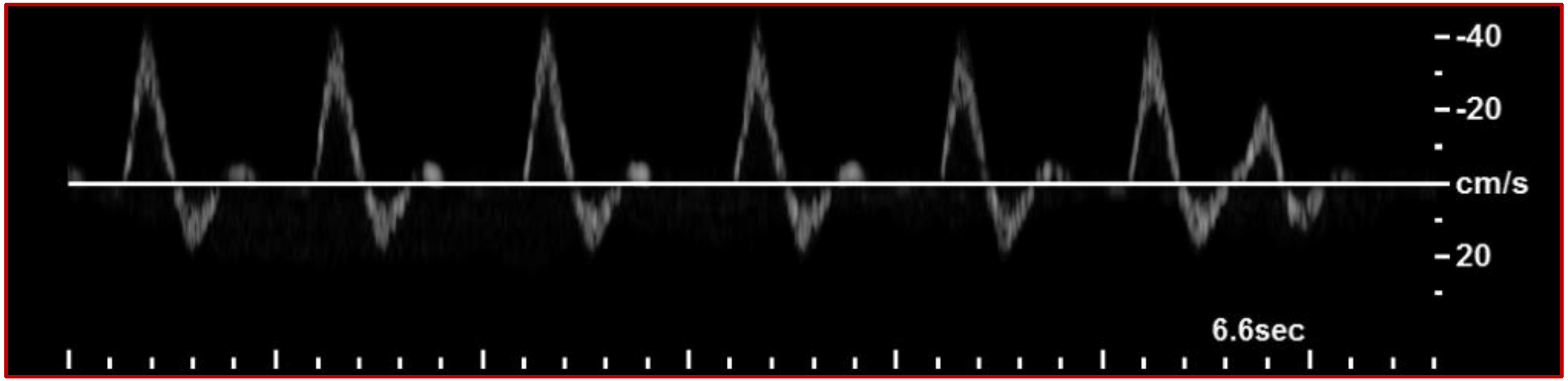
3. Is diastolic flow appropriate?
   d) High or low resistance outflow bed?



5. Are these the findings you expected?

Pattern # 1:

Resting lower limb waveforms from a 40 y.o. following limb trauma



A. Normal; multiphasic

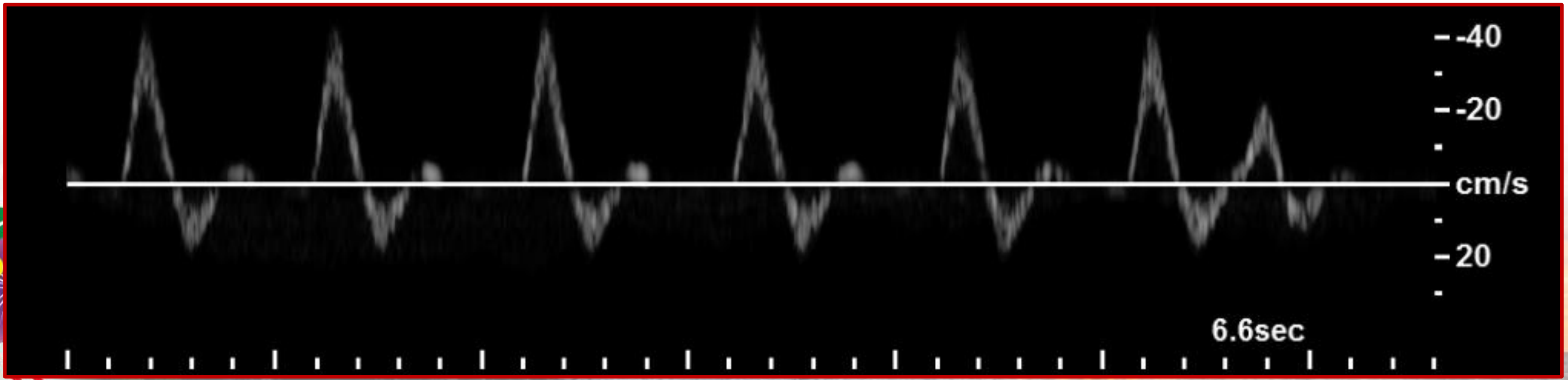
B. Abnormal; obstruction to outflow

C. Normal; monophasic

D. Abnormal; proximal lesion

A. Normal, multiphasic

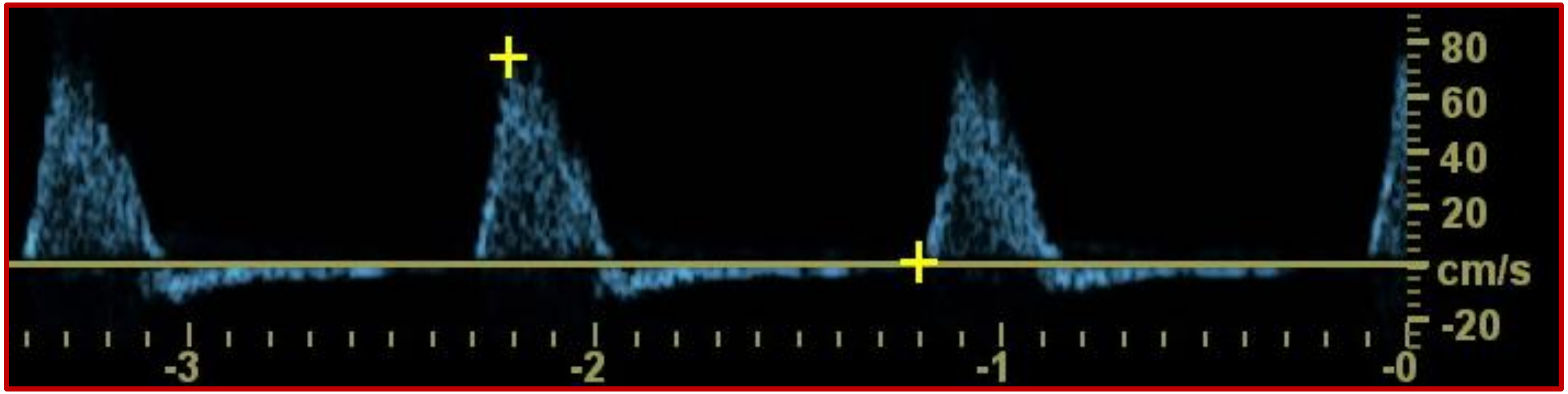
At rest, normal peripheral arteries demonstrate rapid systolic upstroke, rapid systolic deceleration, a reverse early diastolic flow component and, most often, a forward diastolic flow surge



STRANDNESS SYMPOSIUM

Pattern # 2:

Resting lower limb waveforms from an 82 y.o. with complaints of limb pain and swelling



A. Normal; multiphasic

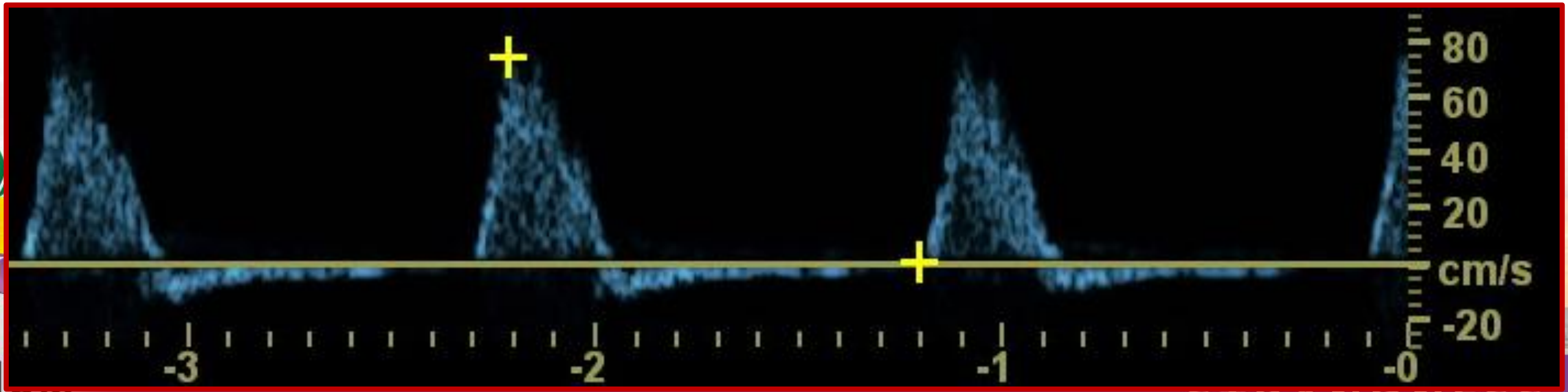
B. Abnormal; obstruction to outflow

C. Normal; monophasic

D. Abnormal; proximal lesion

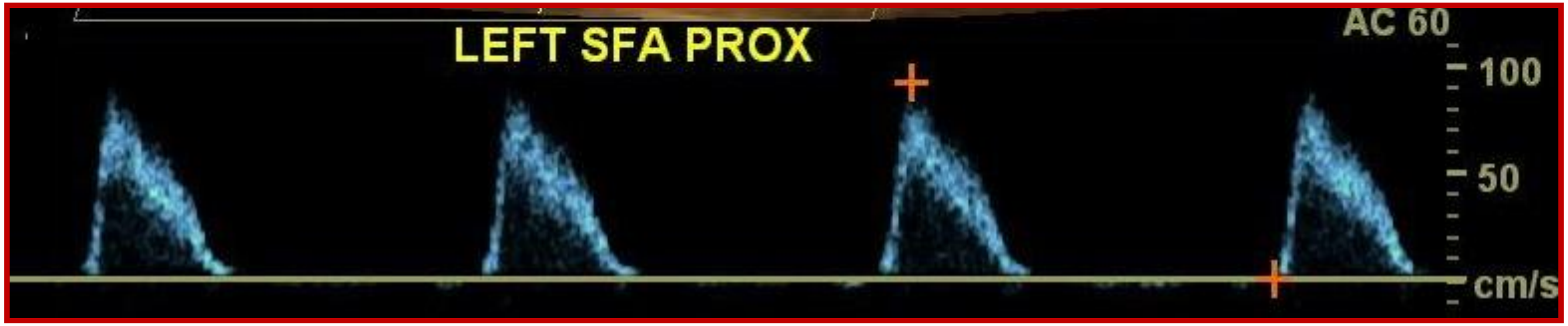
A. Normal; multiphasic

At rest, peripheral arteries may also demonstrate normal characteristics, with the absence of a forward diastolic flow surge. This biphasic waveform suggests reduced arterial compliance (elasticity) in the proximal adjacent segment.



Pattern # 3:

Resting superficial femoral artery waveforms from a 78 y.o. diabetic patient



A. Normal; multiphasic

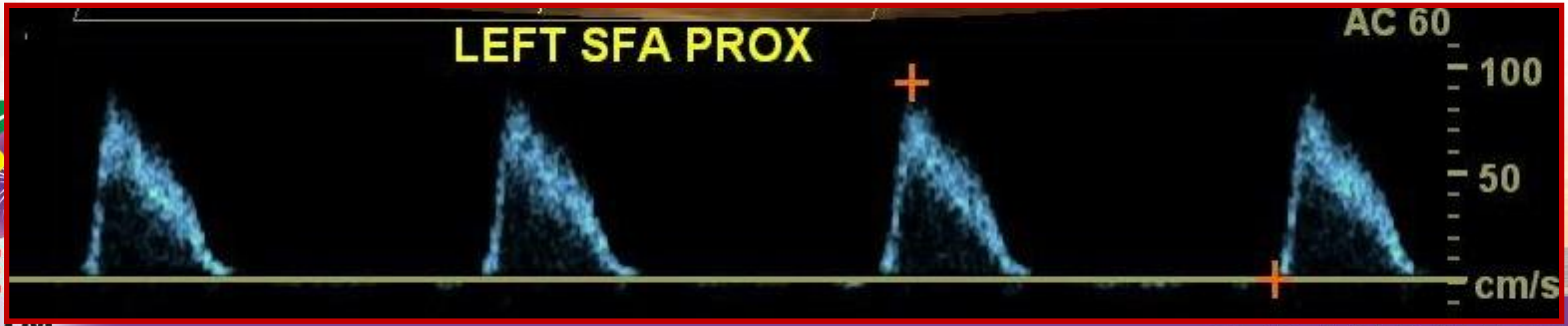
B. Abnormal; obstruction to outflow

C. Normal; monophasic

D. Abnormal; proximal lesion

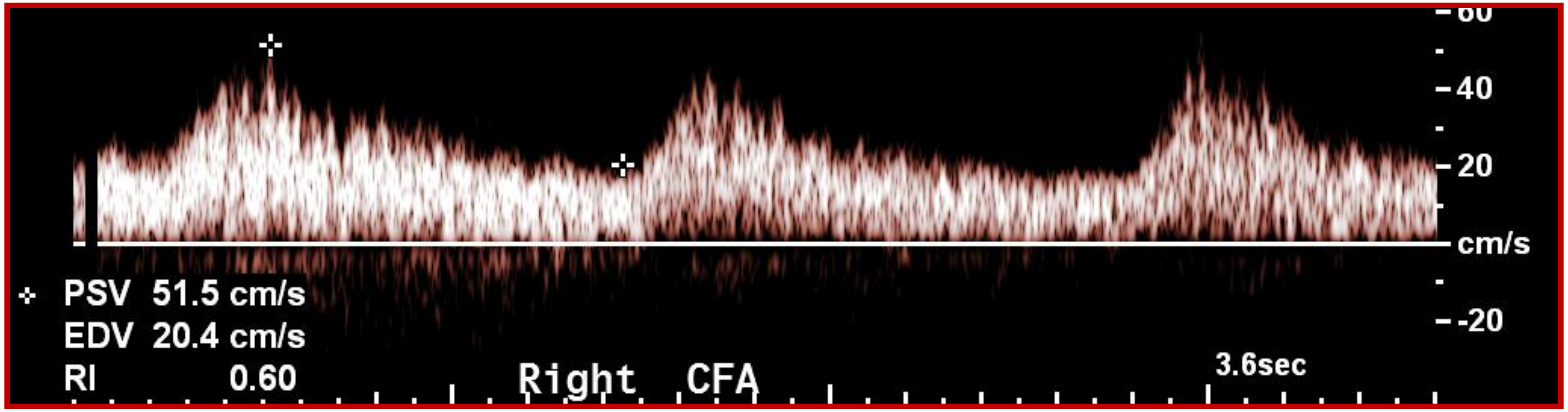
B. Abnormal; obstruction to outflow

Systolic upstroke is rapid, suggesting the absence of proximal flow-limiting disease. There is no early diastolic flow reversal which is consistent with obstruction to outflow. This waveform morphology is often described as “sharp monophasic” and is frequently seen in patients with multilevel calcific lesions.



Pattern # 4:

Resting right common femoral artery waveform from a patient presenting with buttock and thigh claudication



A. Normal; multiphasic

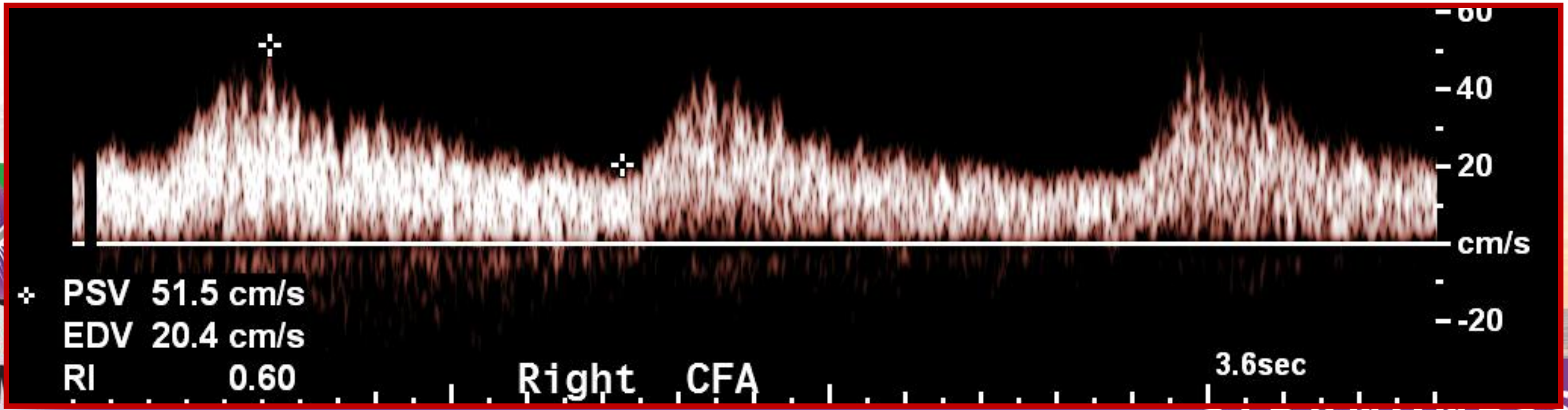
B. Abnormal; obstruction to outflow

C. Normal; monophasic

D. Abnormal; proximal lesion

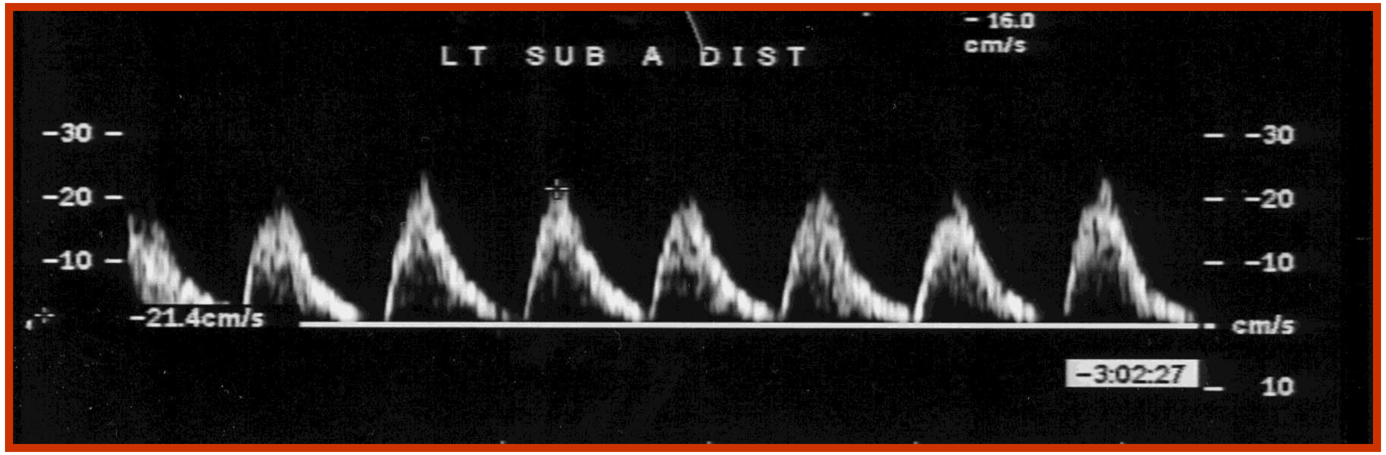
D. Abnormal; proximal lesion

The waveform demonstrates delayed systolic upstroke and forward diastolic flow. These findings are consistent with a flow-reducing lesion (> 50%) proximal to the sample site. The diastolic component reflects the resulting vasodilation distal to the lesion.



Pattern # 5:

The waveforms were obtained from the distal subclavian artery in an arm at rest.



A. Normal; multiphasic

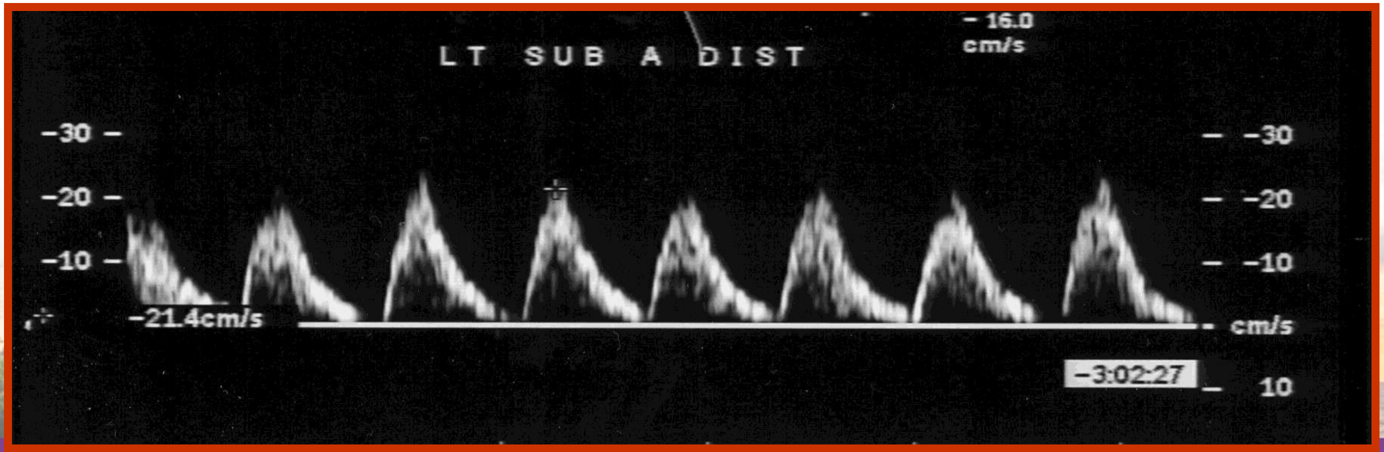
B. Abnormal; obstruction to outflow

C. Normal; monophasic

D. Abnormal; proximal lesion

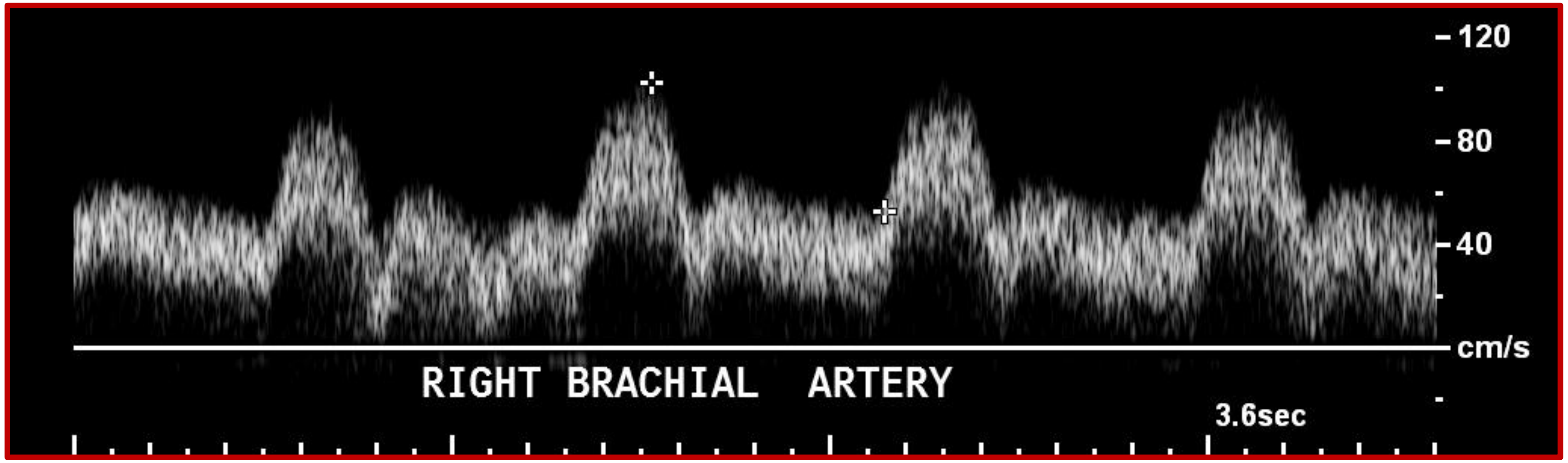
D. Abnormal; proximal lesion

The waveforms illustrate delayed systolic upstroke consistent with a flow-reducing lesion proximal to the recording site.



Pattern # 6:

The waveforms were recorded in the brachial artery from an arm at rest



A. Normal; high resistive

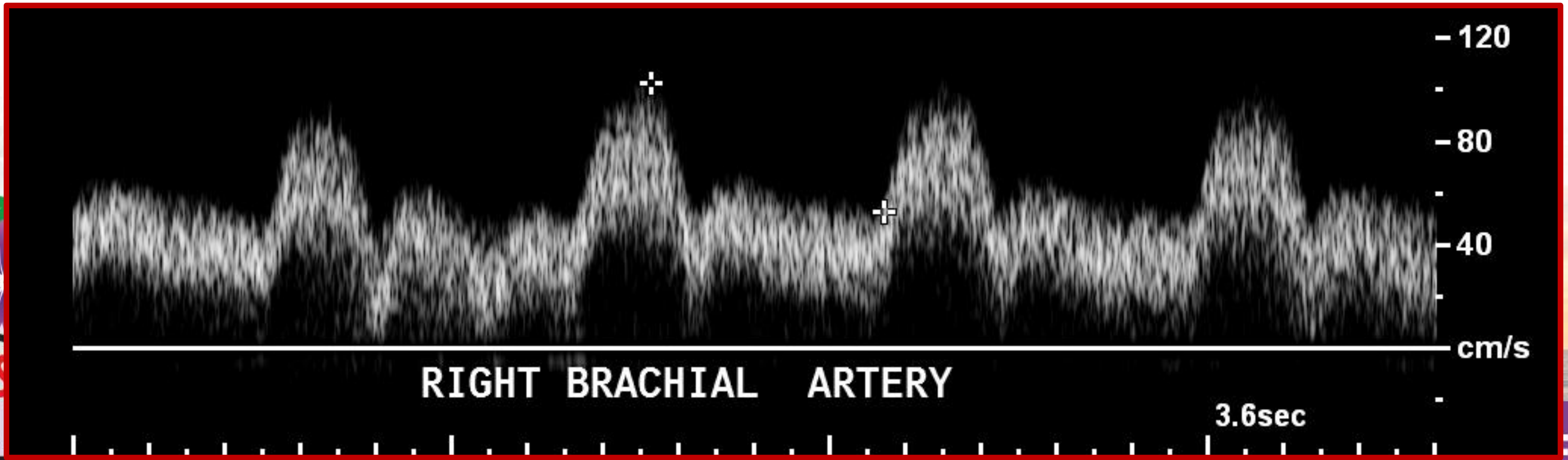
B. Abnormal; distal flow demand

C. Normal; low resistive

D. Abnormal; proximal lesion

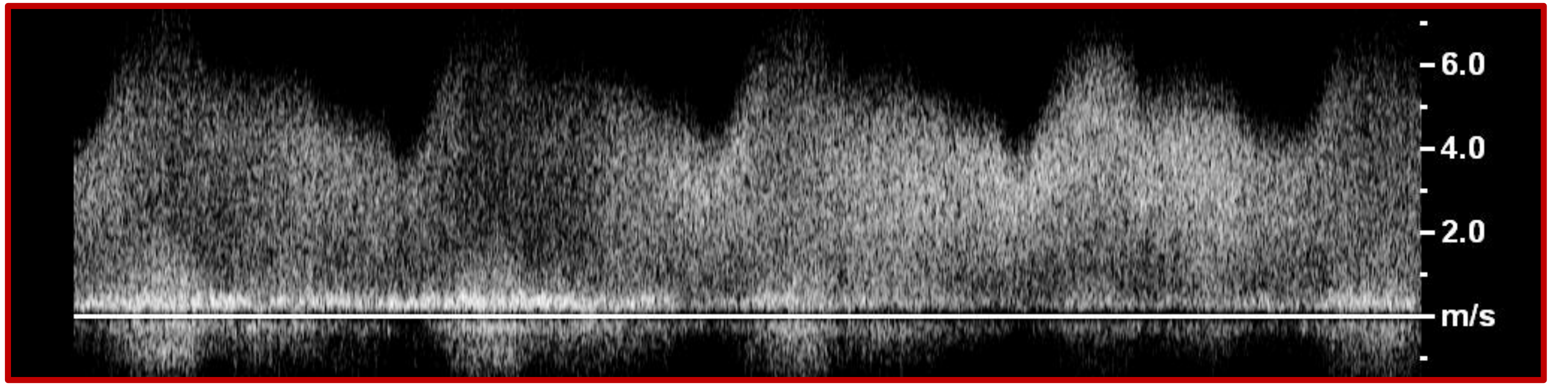
B. Abnormal; distal flow demand

The waveform is abnormal for a resting brachial artery because there is too much diastolic flow; there is a low resistive pattern. A normal resting arterial pattern should be high resistive, multiphasic. This waveform suggests a distal flow demand.



Pattern # 7:

The waveforms were recorded in the distal brachial artery from the patient presented in the previous question (Pattern # 6).



A. Normal; high resistive

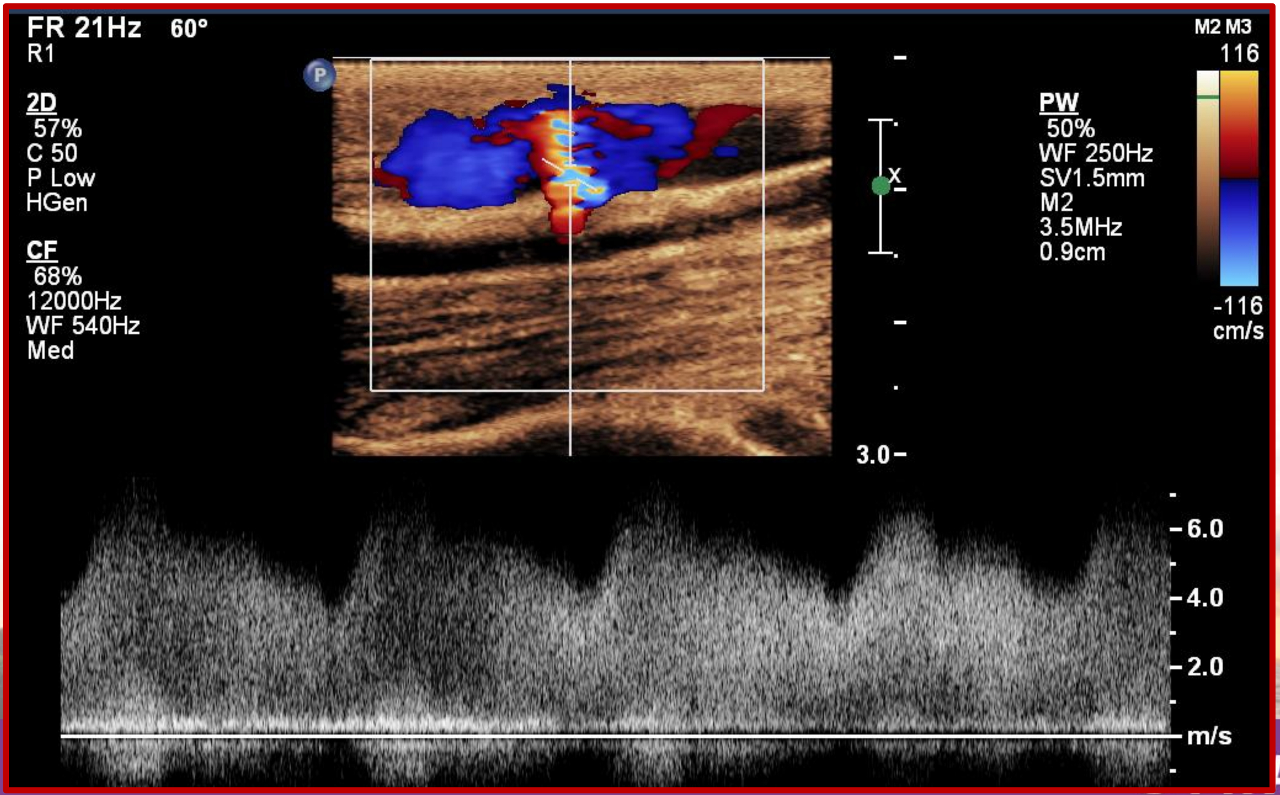
B. Abnormal; pseudoaneurysm flow

C. Normal; low resistive

D. Abnormal; arteriovenous fistula flow

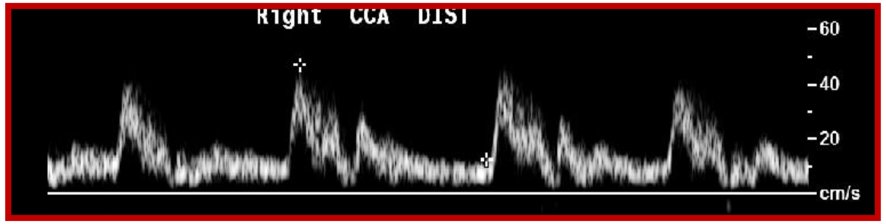
D. Arteriovenous fistula flow pattern

Significant arterial flow is entering the very low resistance brachial vein vs. Continuing distally into the high resistance arteries of the forearm.

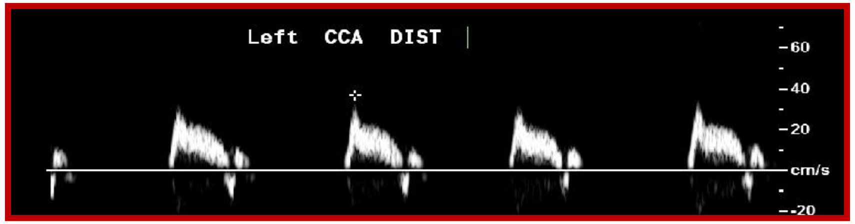


Pattern # 8:

The following waveforms were recorded from the right and left common carotid arteries (CCAs)



RIGHT



LEFT

A. Both sides are abnormal; cardiac dysfunction

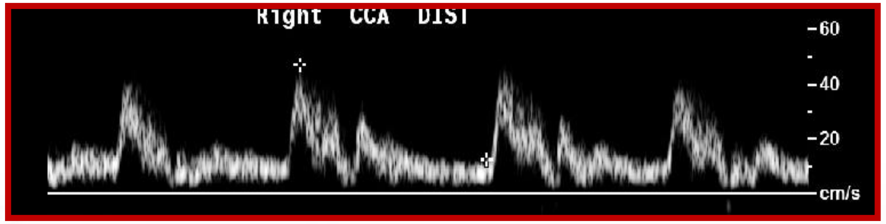
B. Normal right; left suggests ICA obstruction

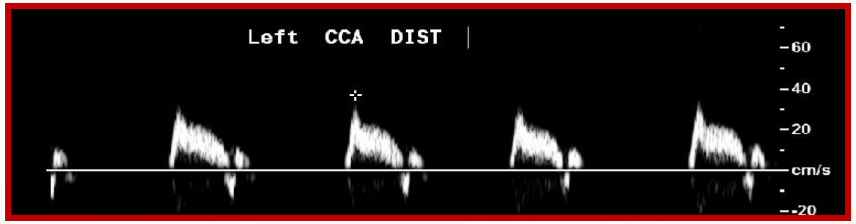
C. Distal right CCA lesion; proximal left CCA lesion

D. Bilateral distal CCA lesions

B. Normal right CCA; left ICA obstruction

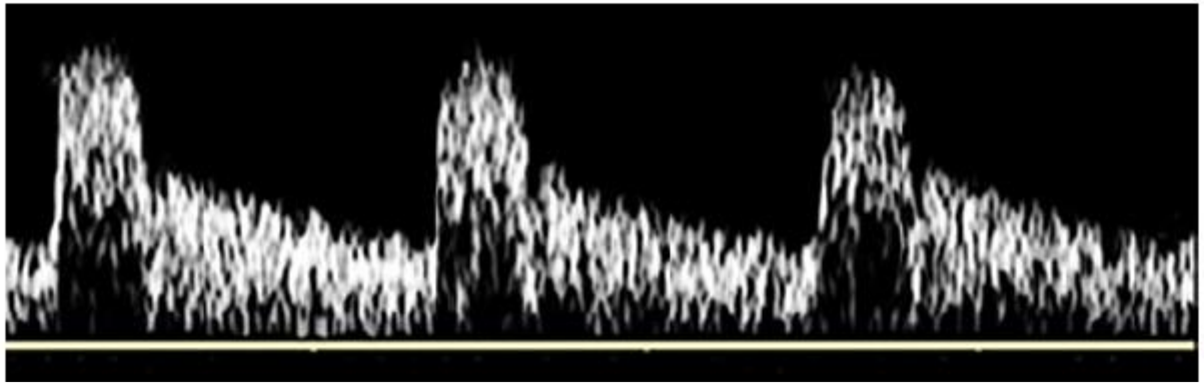
Approximately 80% of the blood flow from the CCA enters the circulation of the ICA and ophthalmic arteries. Therefore the CCA normally has forward diastolic flow (right side). The absence of diastolic flow (left side) suggests critical stenosis or occlusion of the left ICA.





Pattern # 9:

The following waveforms were recorded in the internal carotid artery of a patient with an asymptomatic bruit



A. Normal; low resistive

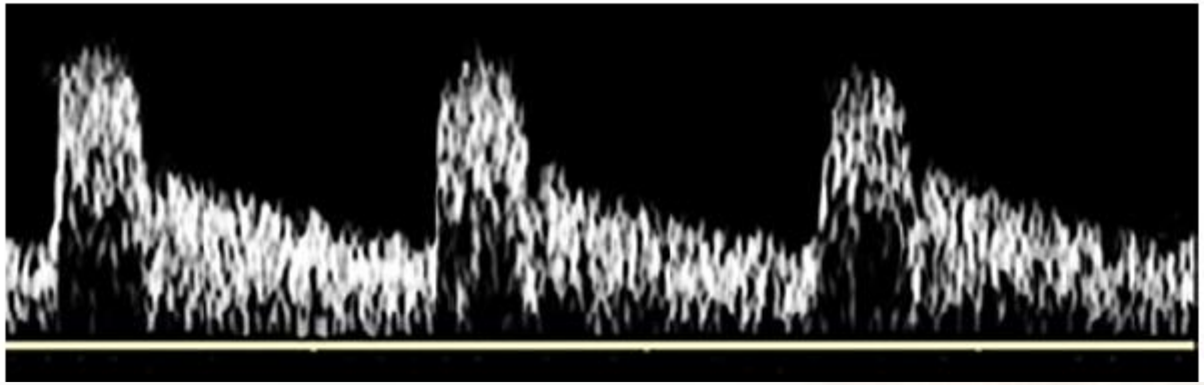
B. Abnormal; distal obstruction

C. Normal; high resistive

D. Abnormal; proximal lesion

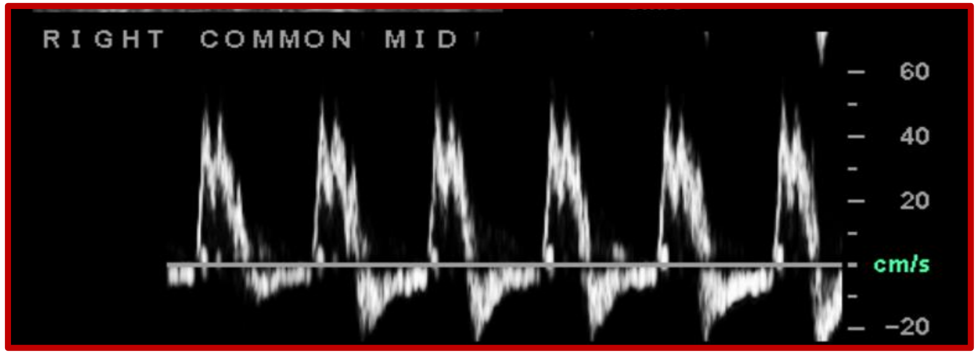
A. Normal; low resistive

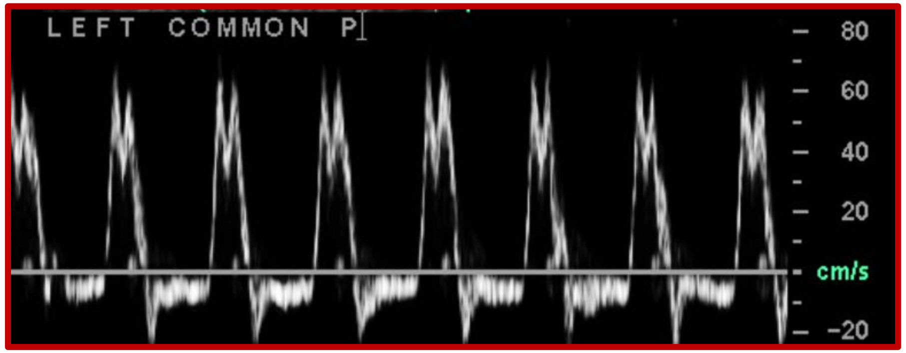
This is a normal internal carotid artery waveform pattern with rapid systolic upstroke, slightly blunted peak and constant forward diastolic flow.



Pattern # 10:

The following waveforms were recorded from the common carotid arteries of a patient returning for a follow-up exam





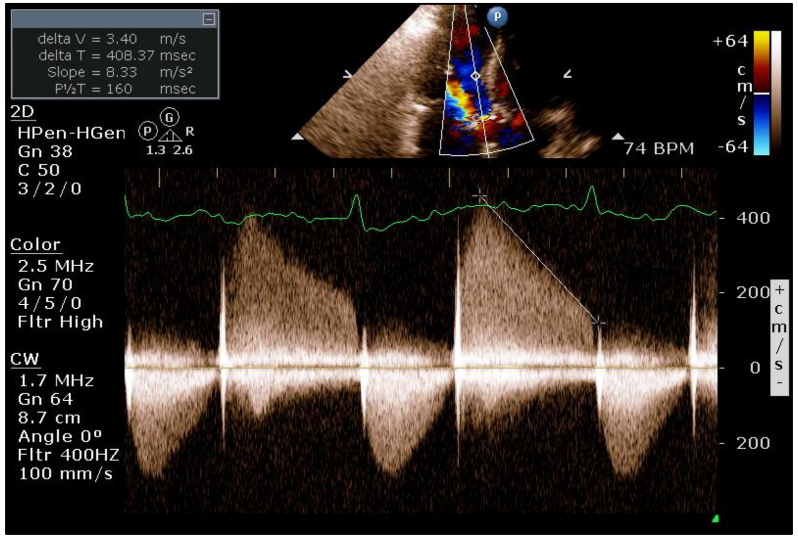
A. Normal CCA flow pattern

B. Bilateral ICA occlusions

C. Proximal CCA stenosis

D. Aortic insufficiency

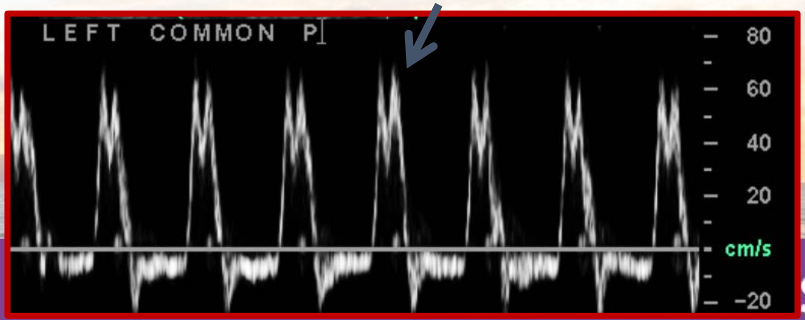
D. Aortic Insufficiency



Aortic insufficiency results in reversed flow throughout diastole and a bisferiens waveform (2 distinct peak separate with the height of the 2nd peak equal to or taller than the height of the first). These findings are classic for aortic insufficiency.

Echo Findings

- s/p AVR bioprosthetic valve
- Severe AI, 3-4+
- T/12 160 msec

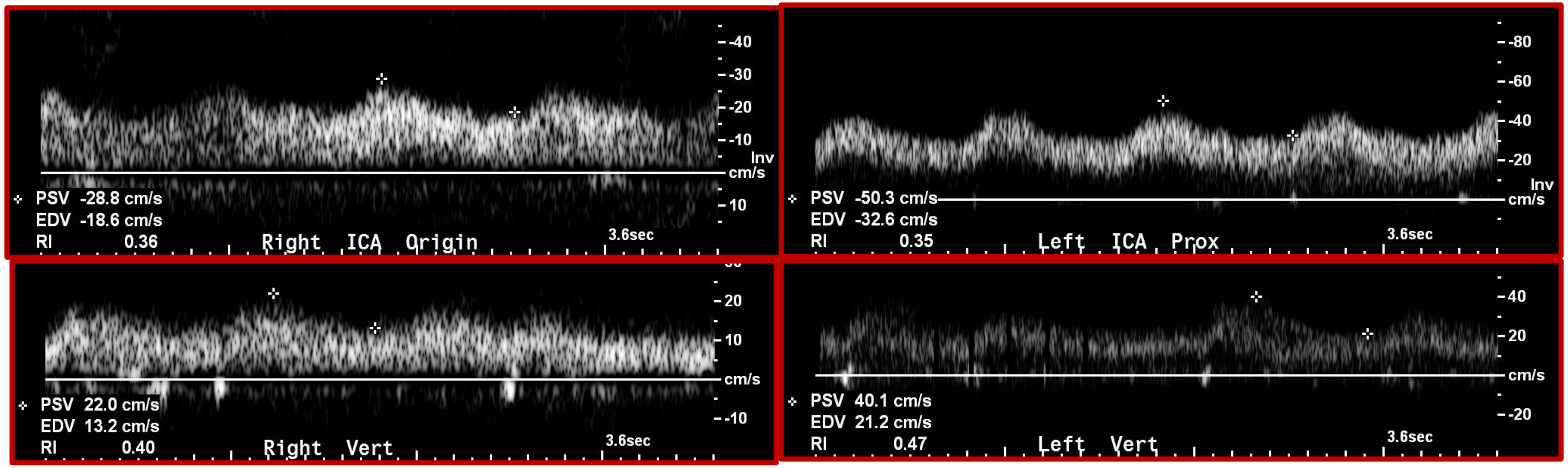


STRANDNESS SYMPOSIUM

S.ORG

Pattern # 11:

The following waveforms were recorded from the internal carotid and vertebral arteries of a patient who presented for a “preop” carotid duplex scan



A. Normal; low resistive

B. Expected; the patient is on cardiac assist

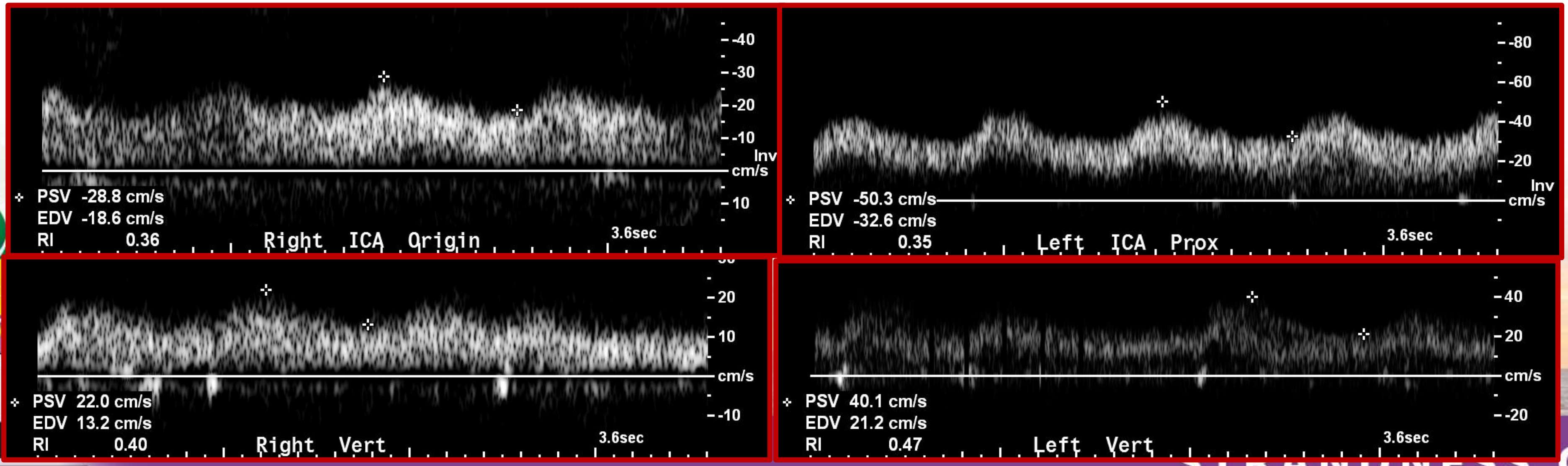
C. Abnormal; proximal obstruction

D. Sonographer error; these are venous waveforms

E. Sonographer error; this is venous flow

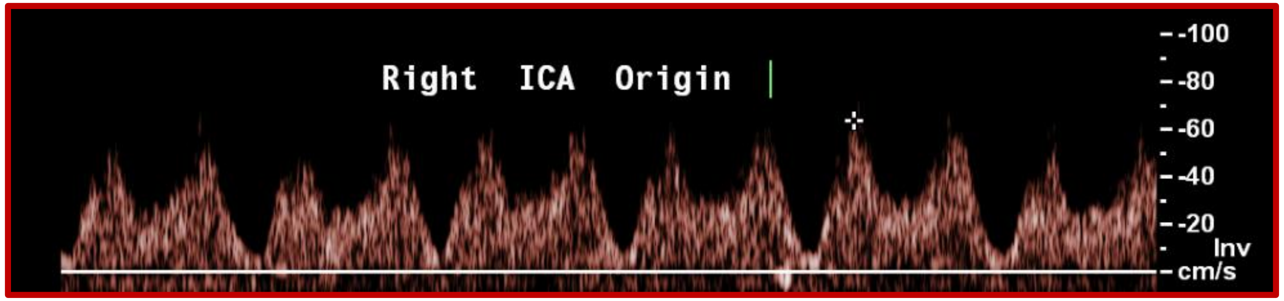
B. Expected; the patient is on cardiac assist

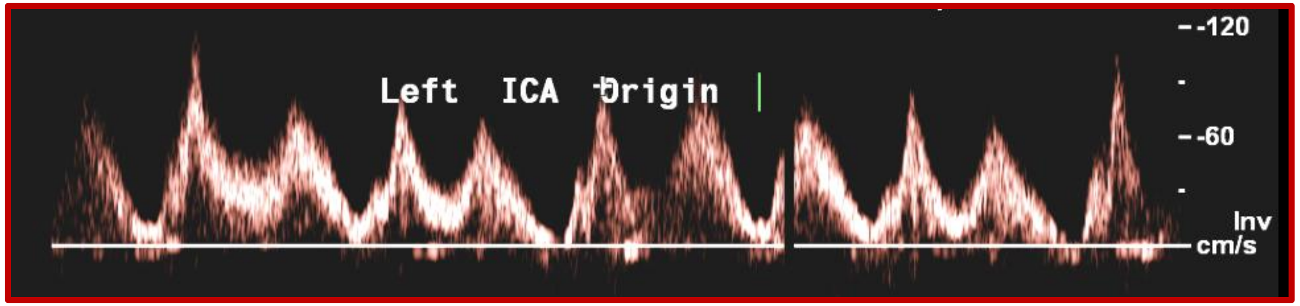
Both the ICA and vertebral arteries are very dampened with low velocity flow. In this case, the patient was supported by ECMO which provides largely continuous circulatory flow. The pattern may also be seen with left ventricular assist devices with very high RPM settings.



Pattern # 12:

The following waveforms were also recorded from the internal carotid arteries of a patient who presented for a “preop” carotid duplex scan

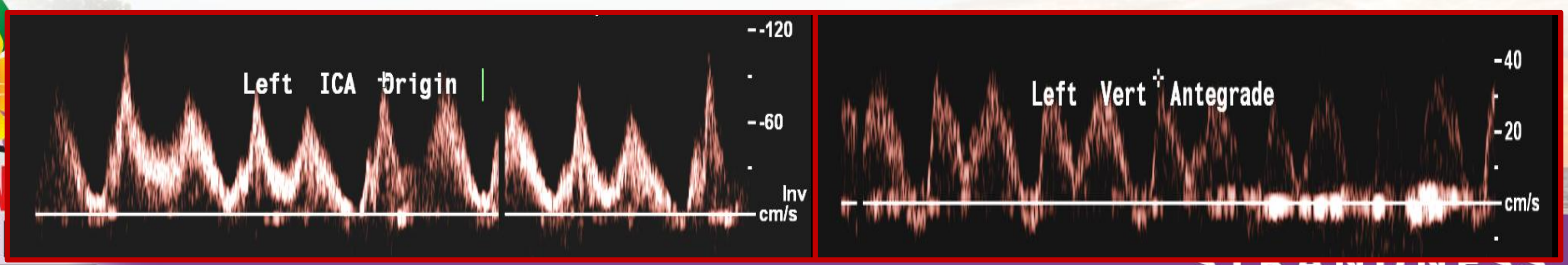




A. Normal; low resistive
B. Expected; the patient is on cardiac assist
C. Abnormal; proximal obstruction
D. Abnormal bilaterally; latent subclavian steal

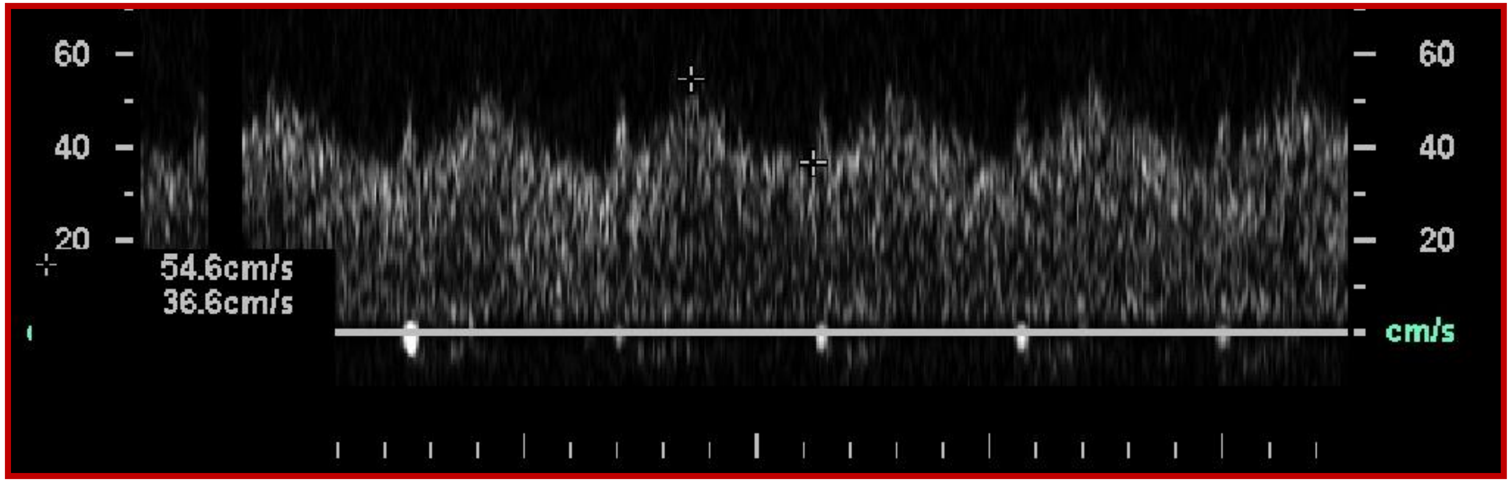
B. Expected; the patient is on cardiac assist

There is an atypical “double hump” morphology of both the ICA and vertebral artery waveforms. Also note very brief flow reversal after the second “hump”. This waveform is classic for an intra-aortic balloon pump inflating 1:1 with every cardiac cycle. Velocity measurements should be made on the 1st (non-augmented) “hump”.



Pattern # 13:

The Doppler spectral waveforms were recorded from the vertebral artery of a patient with non-focal symptoms.



A. Normal; antegrade flow

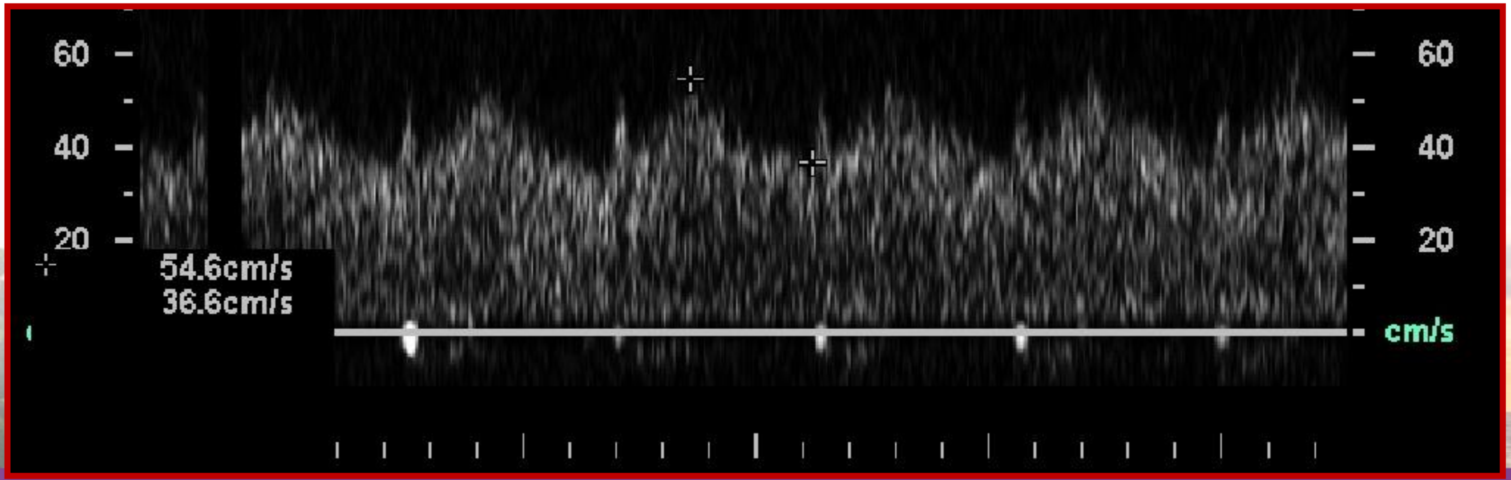
B. Abnormal; retrograde flow

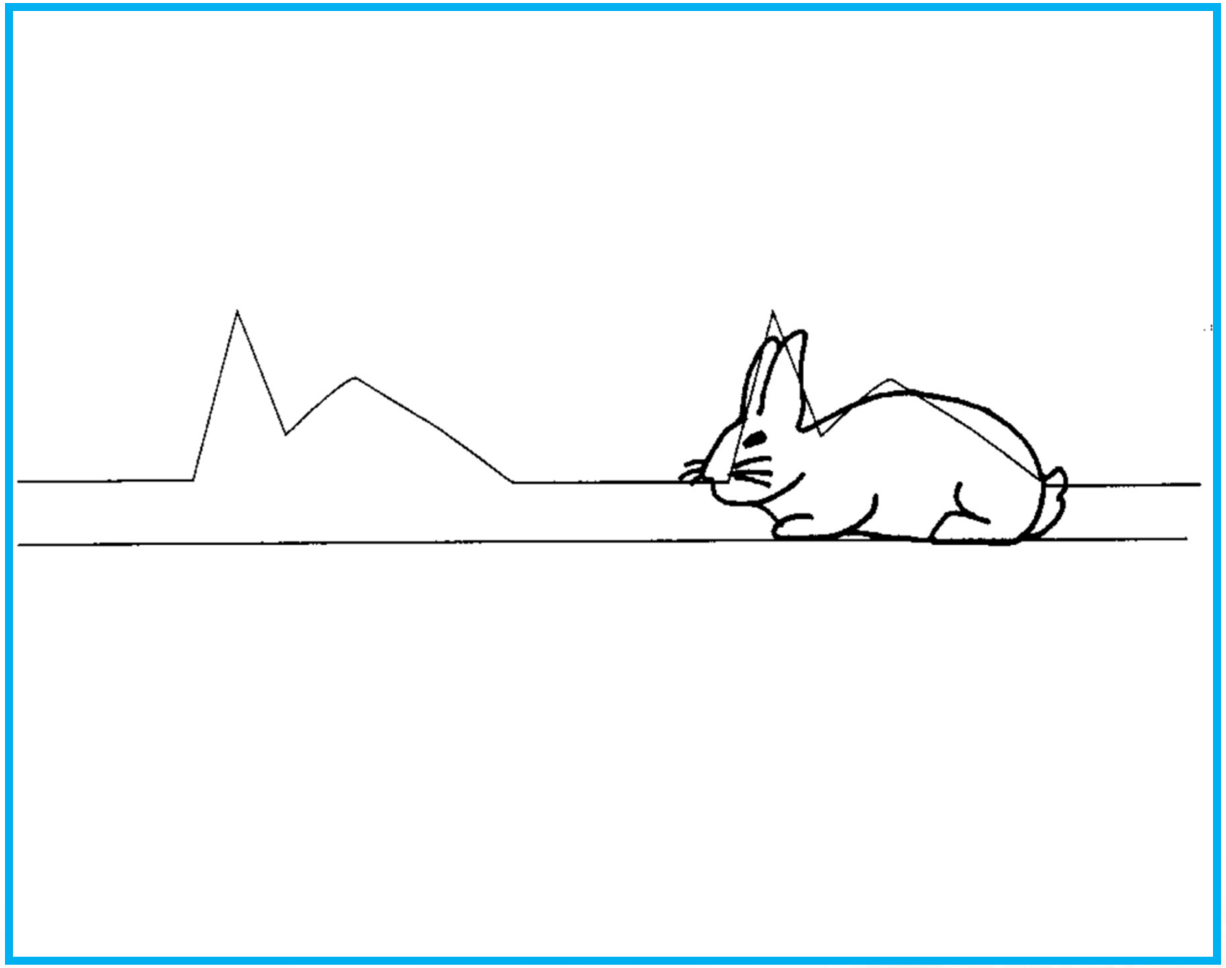
C. Abnormal; vertebral artery stenosis

D. Abnormal; latent subclavian steal

D. Abnormal; subclavian pre-steal

The vertebral artery flow direction is antegrade but the flow pattern is abnormal demonstrating mid-systolic flow deceleration. This has been termed the "bunny rabbit sign" and is associated with a subclavian pre-steal

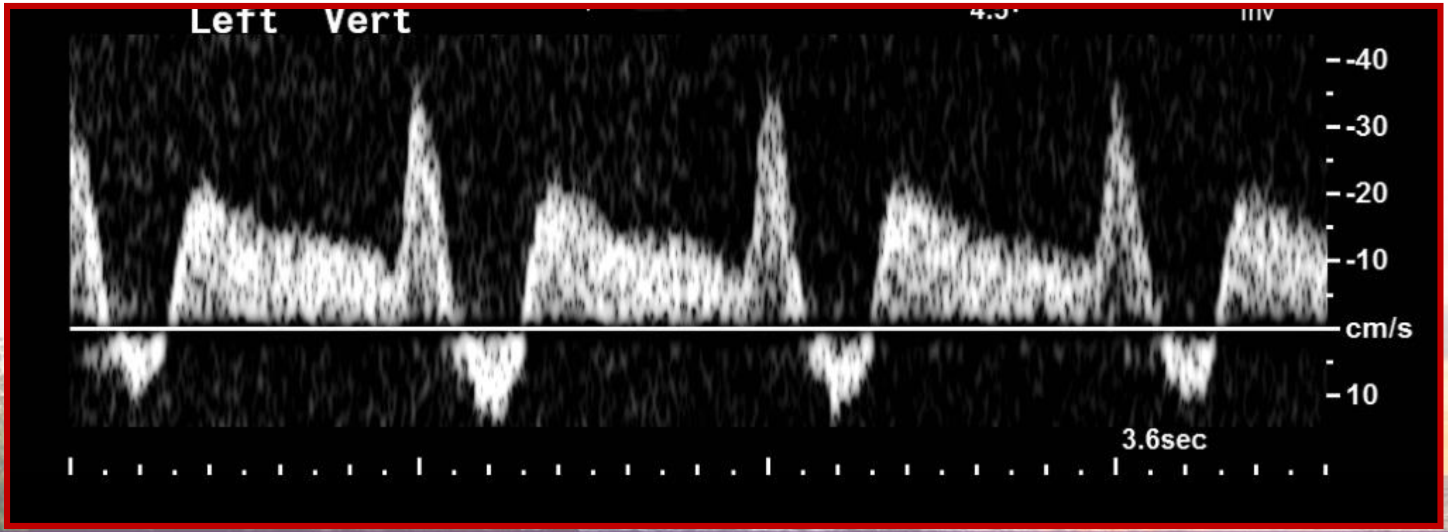




Rohren, E. M. et al. Am. J. Roentgenol. 2003;181:1695-1704

A vertebral artery…

With progression of the subclavian lesion, the vertebral artery waveform may demonstrate early steal morphology (partial steal). Note the brief period of flow reversal.



Pattern # 14:

The following vertebral artery color flow image and waveform display were recorded from a patient with non-focal symptoms.

Left vertebral artery…

A. Normal; antegrade flow

B. Abnormal; complete subclavian steal

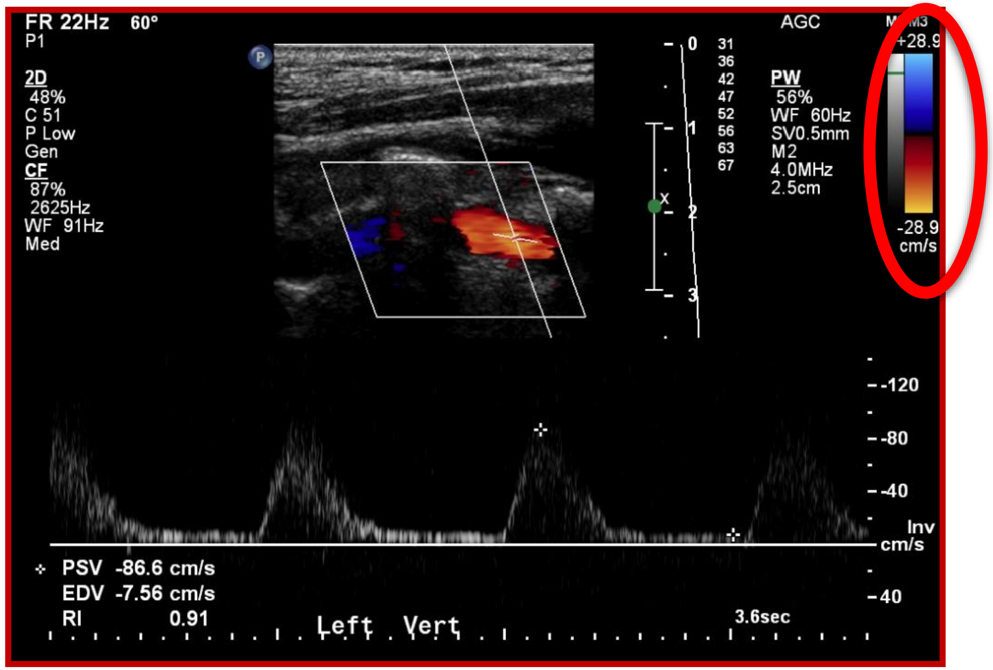
C. Abnormal; vertebral artery stenosis

D. Abnormal; latent subclavian steal

B. Complete subclavian steal

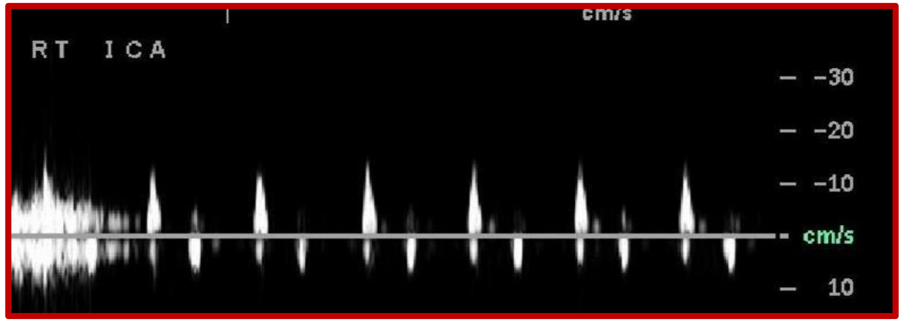
Flow throughout the cardiac cycle is directed toward the arm (shown above the zero baseline)

Retrograde flow is also apparent in the color Doppler image.



Pattern # 15:

The following waveforms were recorded in the internal carotid arteries of a patient in the ICU



Yesenko S, et al. JVU 2008; 32:152.

A. Normal; high resistive

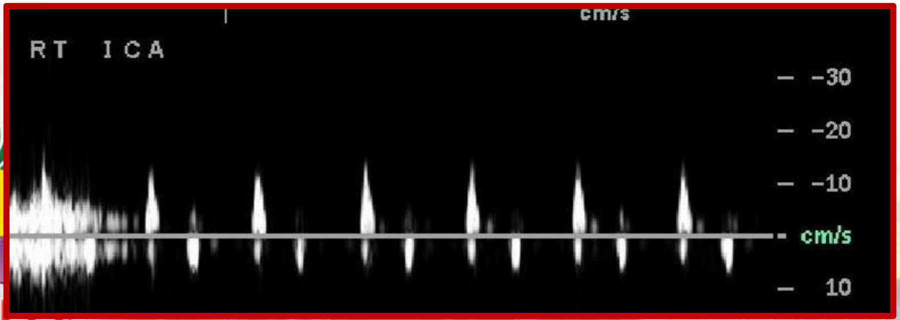
B. Bilateral ICA occlusion

C. Cerebral circulatory arrest

D. Sonographer error; ECA waveforms

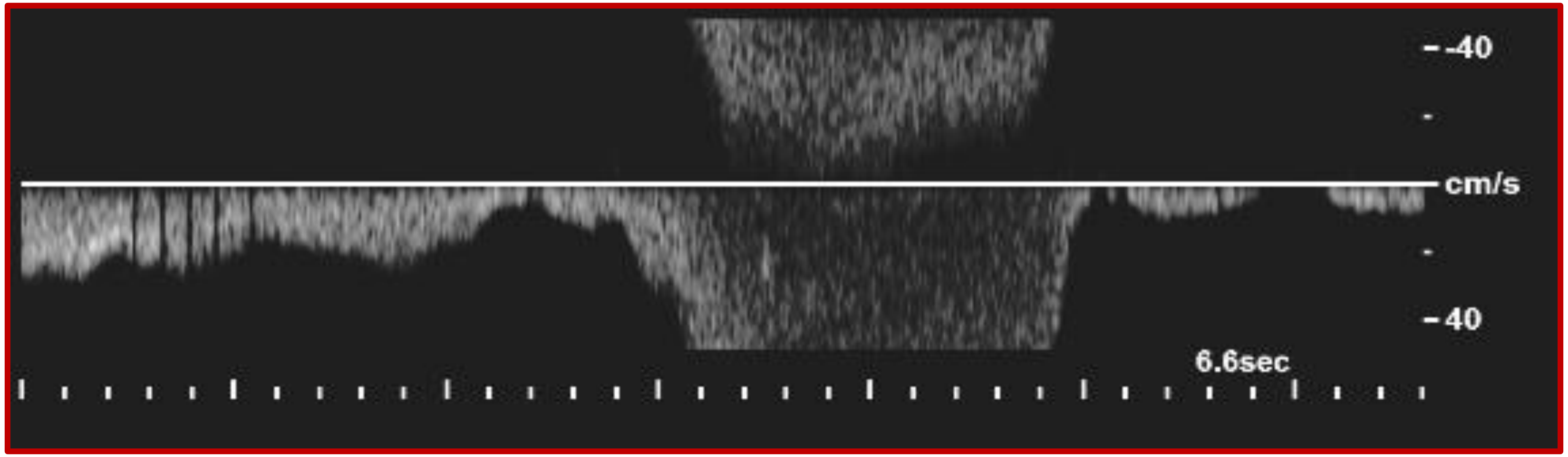
C. Cerebral circulatory arrest

These very abnormal, high resistive, low velocity "spikes" were recorded in the internal carotid and vertebral arteries of a comatose patient after cardiac arrest and are consistent with the waveform recorded intracranially in cases of brain death.



Pattern # 16:

The following waveform pattern was recorded in a lower extremity vein of a patient with a painful, swollen limb.



A. Normal; respirophasic

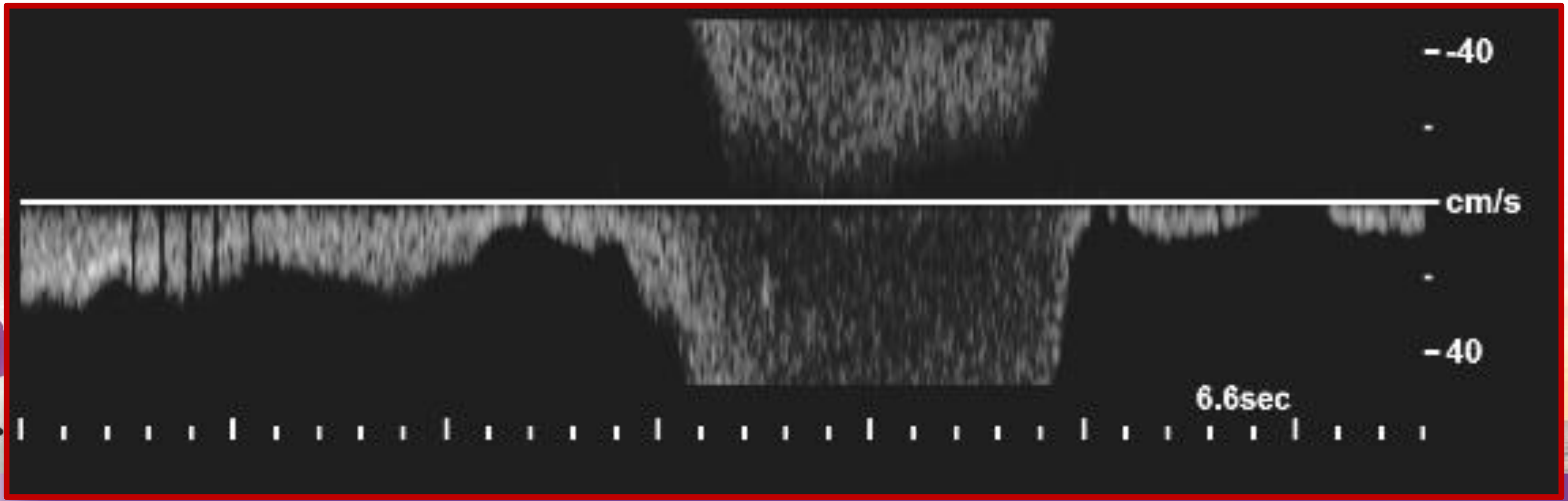
B. Abnormal; non-phasic

C. Abnormal; venous reflux

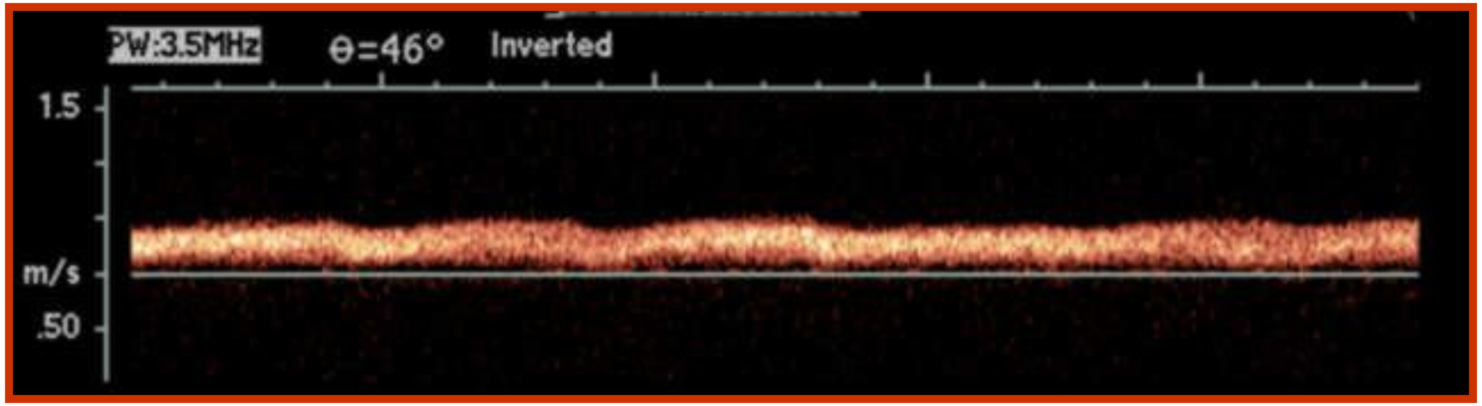
D. Abnormal; aliasing

A. Normal; respirophasic flow

This is a classic, normal waveform demonstrating respirophasic flow and good response to venous augmentation with aliasing on the spectral display.

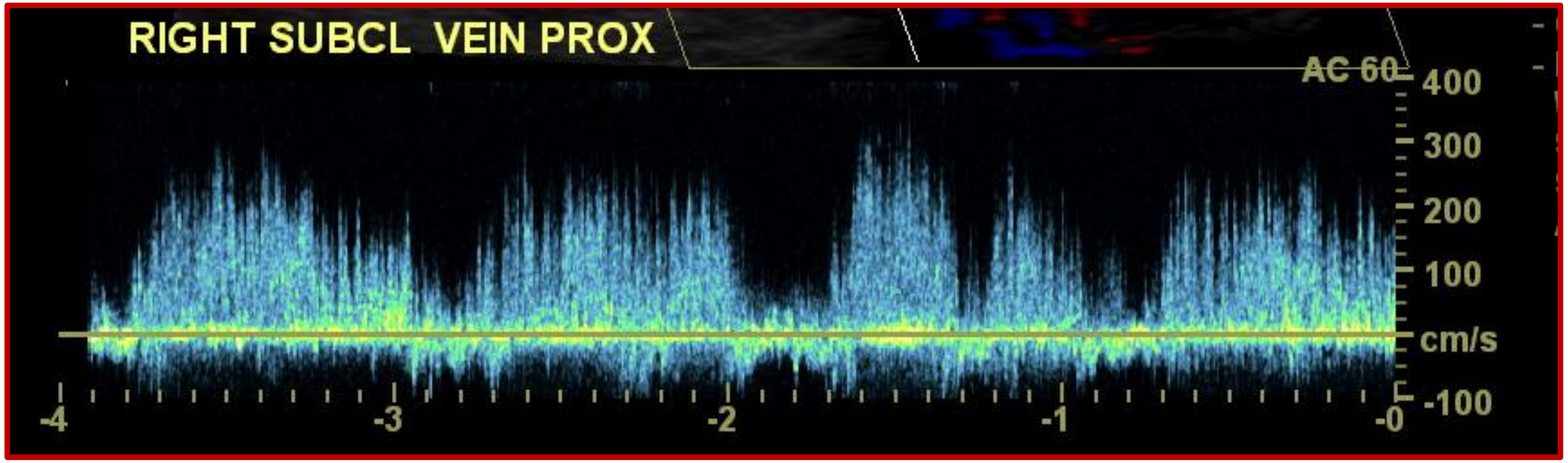


In contrast, this venous flow pattern is continuous and non-phasic. The pattern is consistent with obstruction to venous outflow.



Pattern # 17:

The following waveforms were recorded in a right subclavian vein of a patient who experienced upper extremity and neck trauma.



A. Normal; pulsatile flow pattern

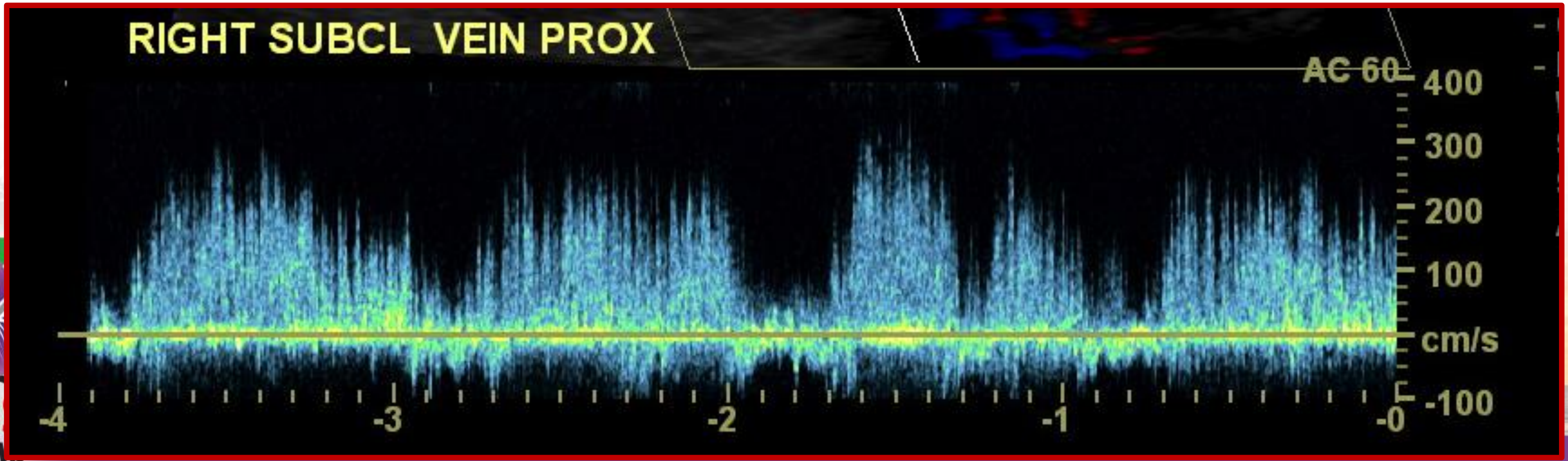
B. Abnormal; possible pseudoaneurysm

C. Abnormal; subclavian vein stenosis

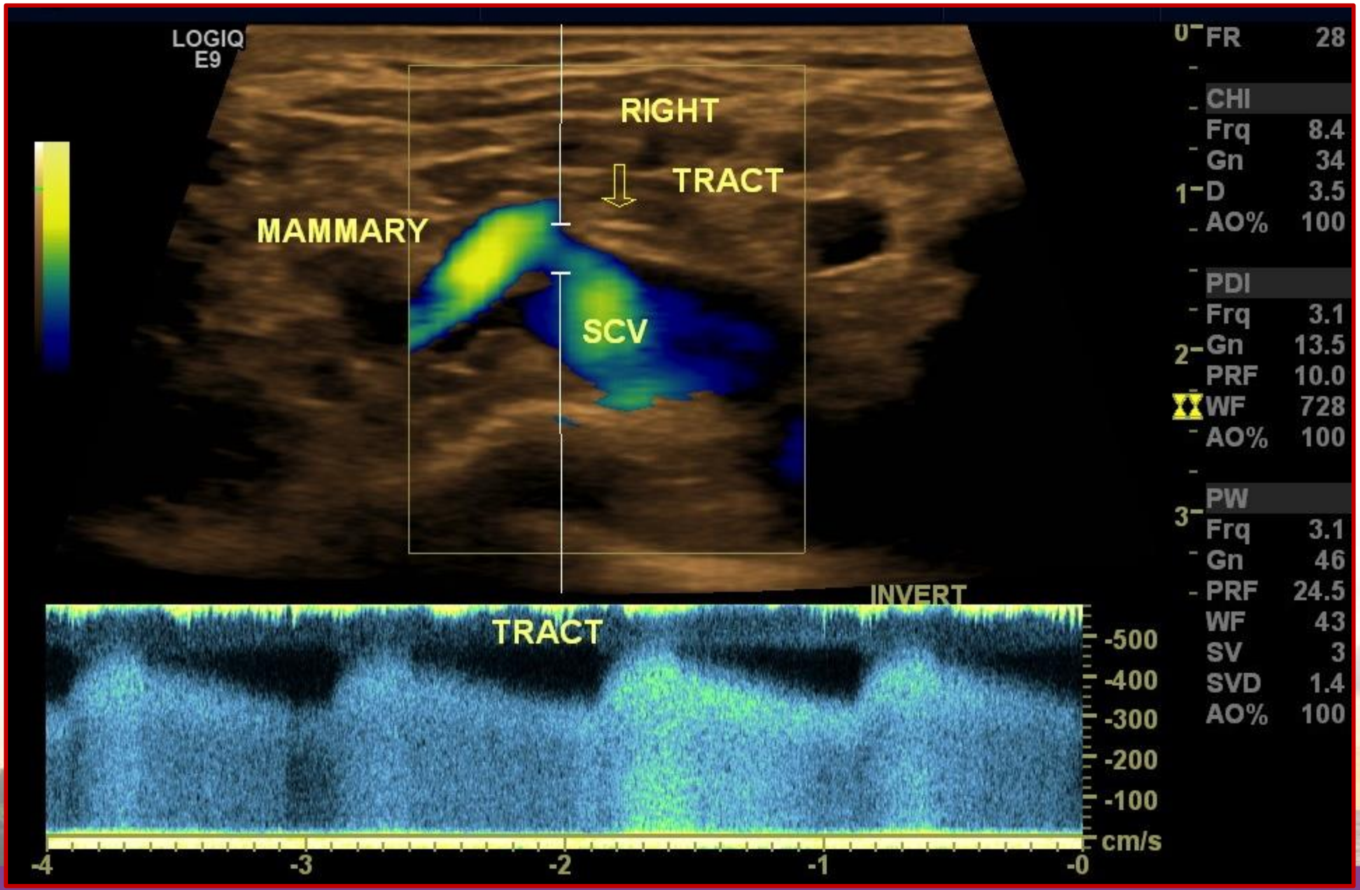
D. Abnormal; possible AV fistula

D. Abnormal; possible AV fistula

This subclavian flow pattern demonstrates unusually pronounced pulsatility, elevated velocity and turbulence. The continuous forward flow suggests a flow demand and the possibility of an arteriovenous fistula.

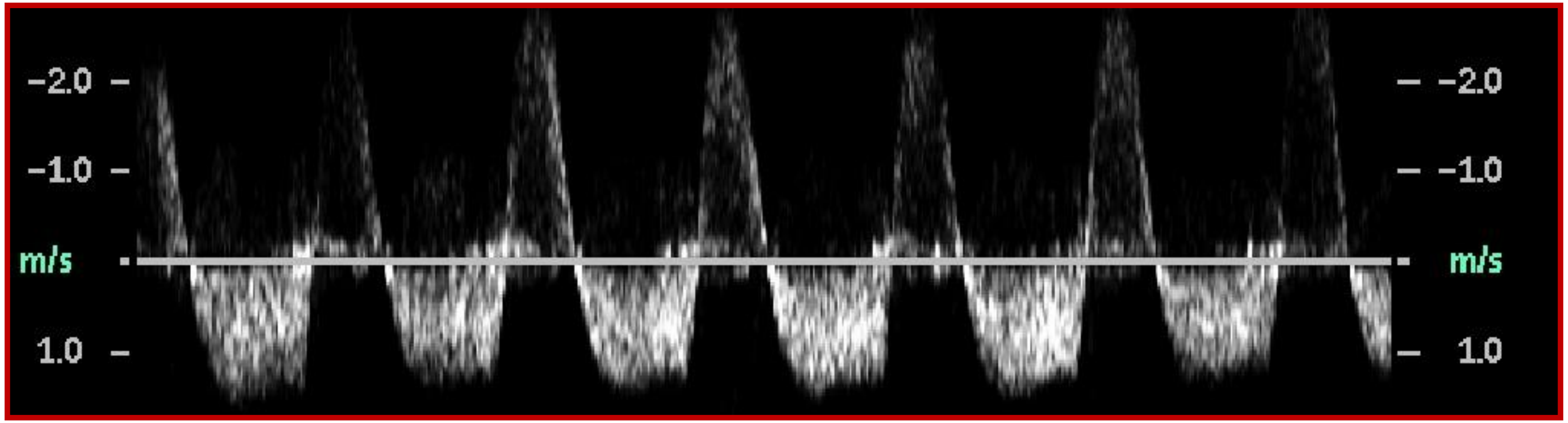


In this case, there was a fistula from an arterial branch of the thyrocervical trunk to the subclavian vein.



Pattern # 18:

The following waveforms were recorded during an abdominal duplex exam in a patient who had undergone abdominal aortic surgery



A. Normal distal aortic waveform

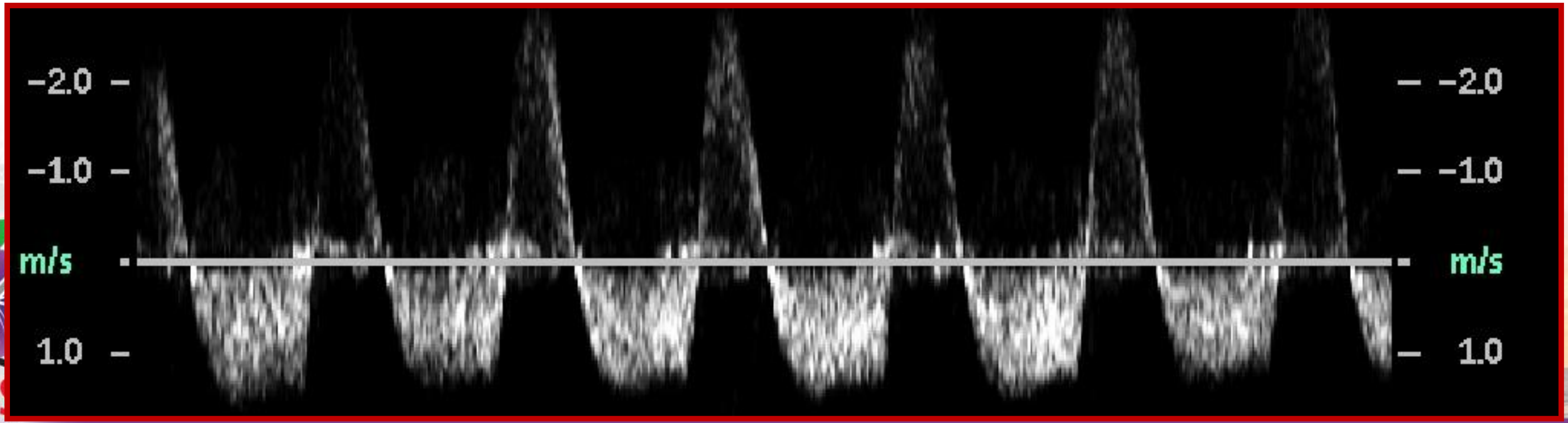
B. Type II aortic endoleak

C. Normal superior mesenteric artery waveform

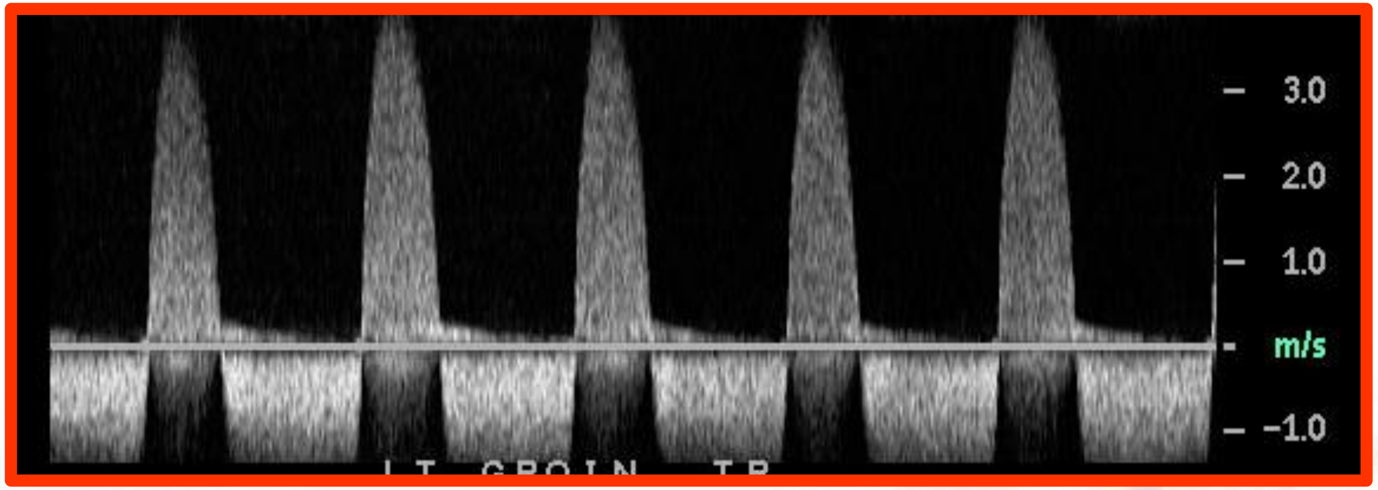
D. Arterial pseudoaneurysm

B. Type II aortic endoleak

This bi-directional to-fro waveform pattern is similar to the pattern associated with an arterial pseudoaneurysm. It is also the classic Doppler signature of a Type II endoleak with flow into and out of the residual aneurysm sac from an arterial branch (usually from the IMA or lumbar artery)

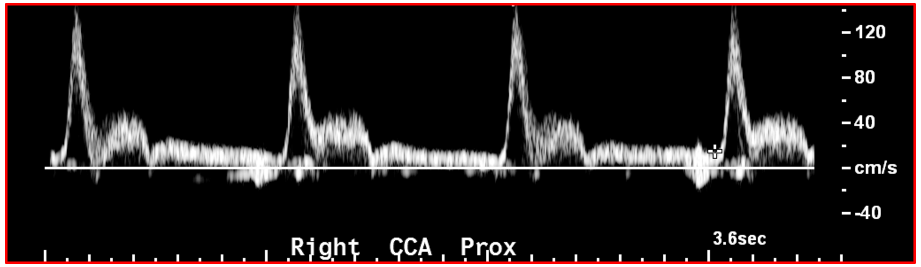


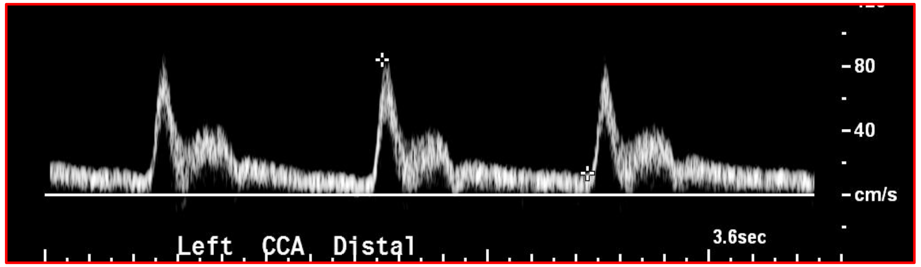
The classic “to-fro” flow pattern found in the neck of an arterial pseudoaneurysm



Pattern # 19

These waveforms were recorded in the carotid arteries of a patient who was pre-operative for a cardiac surgery.





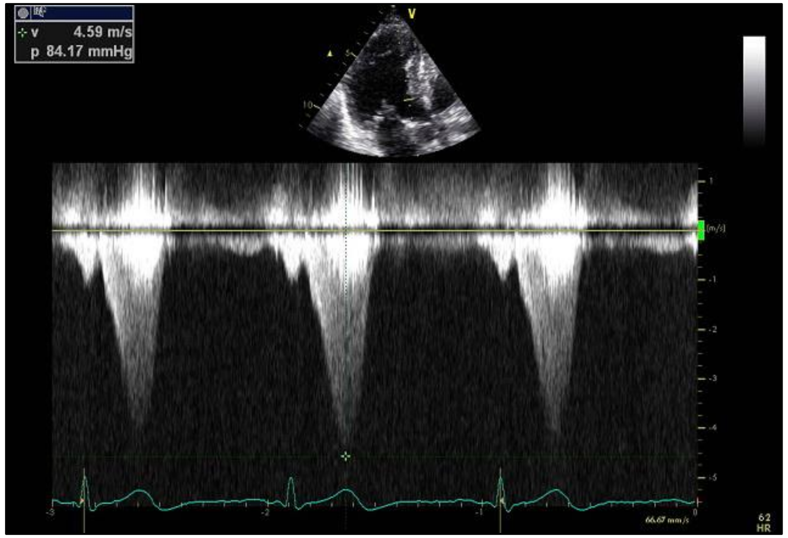
A. Aortic insufficiency

B. Aortic stenosis

C. Hypertrophic cardiomyopathy

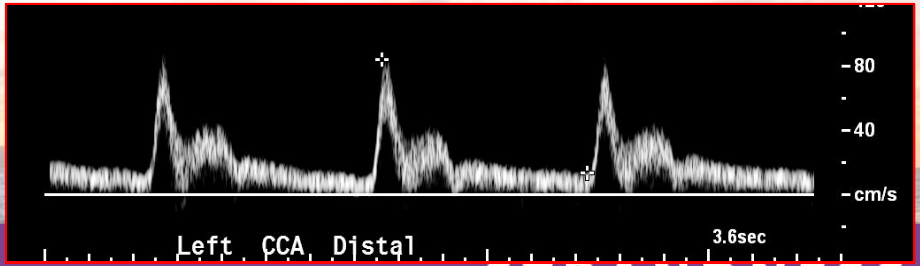
D. Severe heart failure

C. Hypertrophic Obstructive Cardiomyopathy



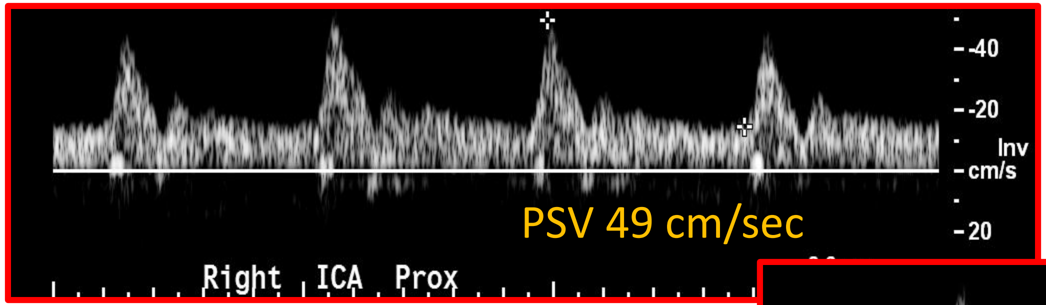
- Severe anterior leaflet SAM with septal contact at rest
- LVOT gradient 90 mmHg

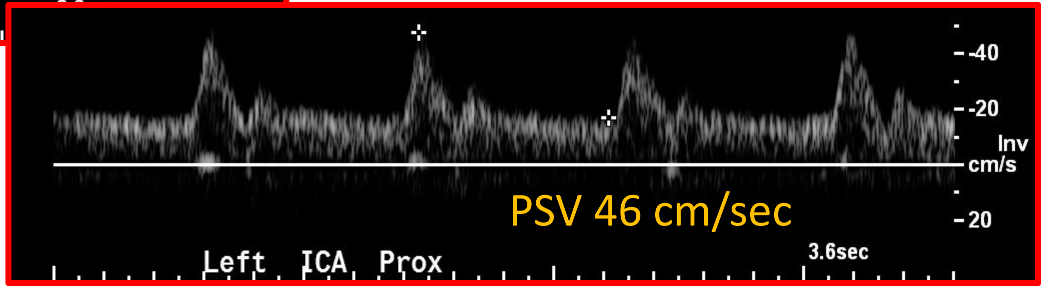
Hypertrophic obstructive cardiomyopathy results in Doppler waveforms with exaggerated, rapid upstroke followed by rapid decent. They have a classic systolic “spike and dome” appearance.



Pattern # 20

54 year old man with SOB and edema; pre-operative carotid ultrasound prior to cardiac surgery





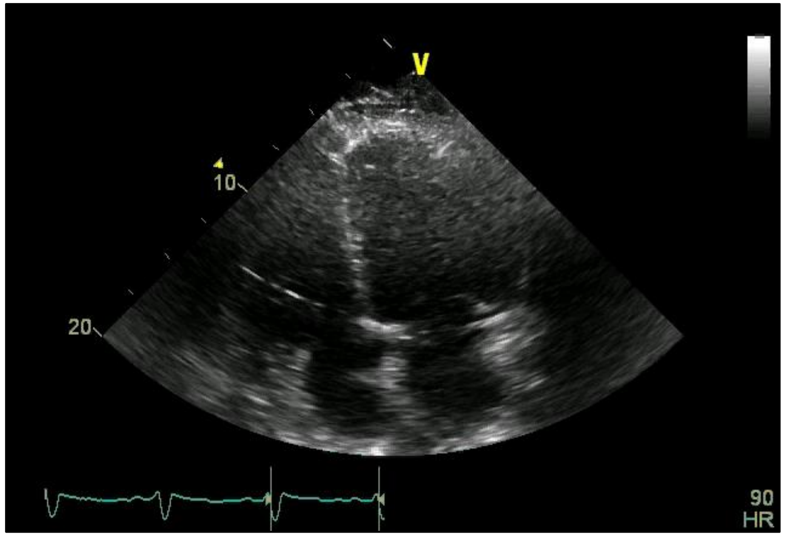
A. Aortic insufficiency

B. Aortic stenosis

C. Hypertrophic cardiomyopathy

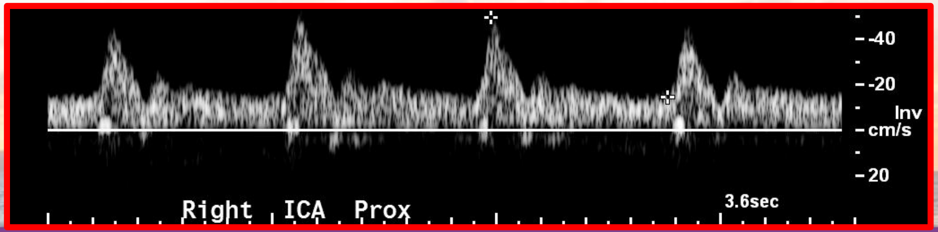
D. Severe heart failure

D. Severe Heart Failure



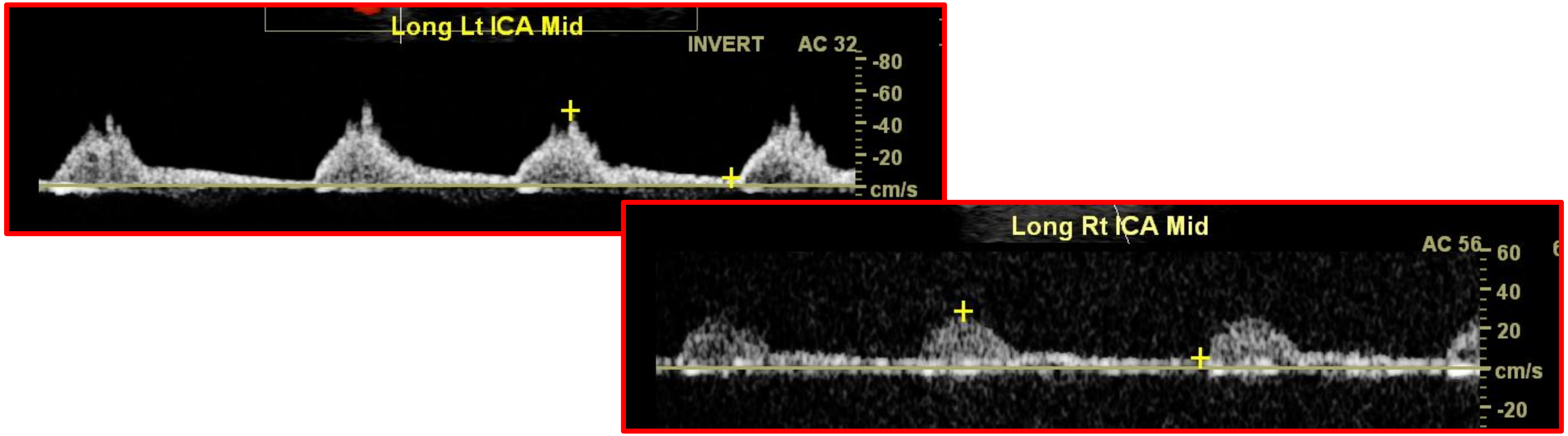
- Severely dilated LV
- EF 15 ± 5%
- *Pre-LVAD evaluation*

Low cardiac output (severe heart failure) results in a preserved upstroke (not tardus) but with unusually low peak systolic velocity. Caution must be used when applying carotid velocity criteria for assessment of ICA stenosis in patients with low output heart failure.



Pattern # 21

These waveforms are from the internal carotid arteries of an 83 year old man referred for ultrasound after presenting with syncope



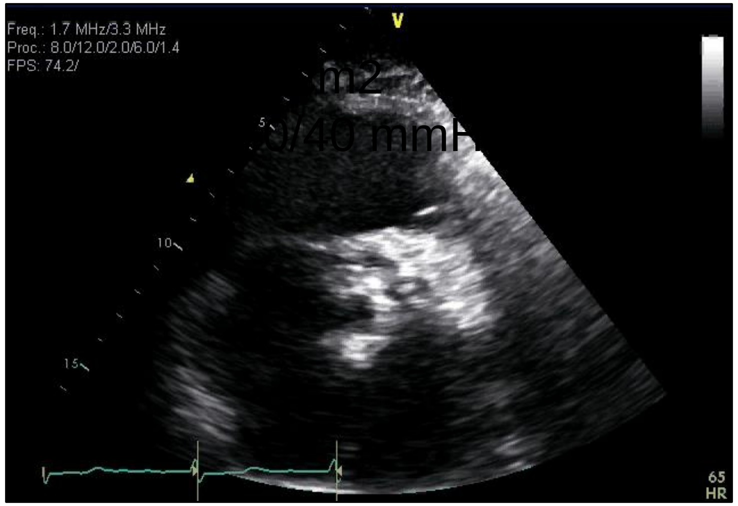
A. Aortic insufficiency

B. Aortic stenosis

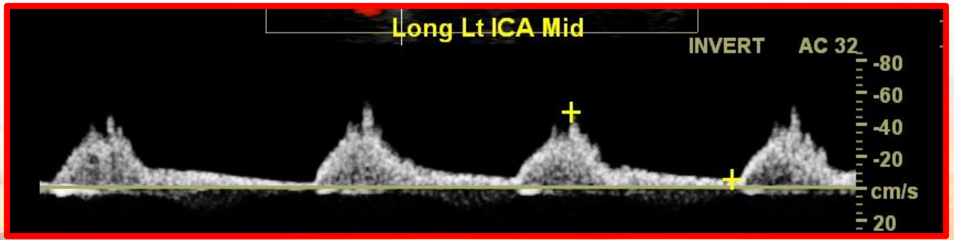
C. Hypertrophic cardiomyopathy

D. Severe heart failure

B. Aortic Stenosis



Aortic stenosis results in delayed systolic upstroke (prolonged acceleration time), rounded waveform appearance ➔ *dampened* waveform



Great Job!