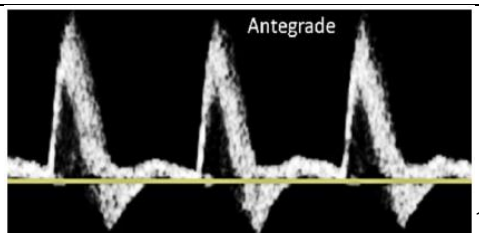
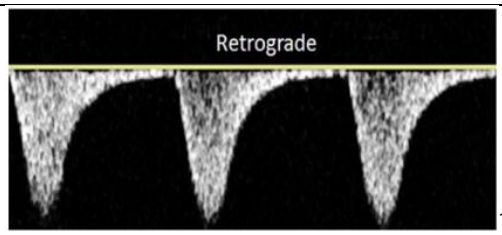
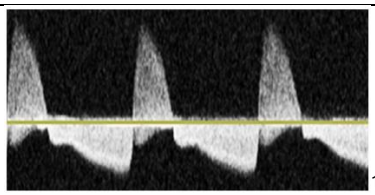
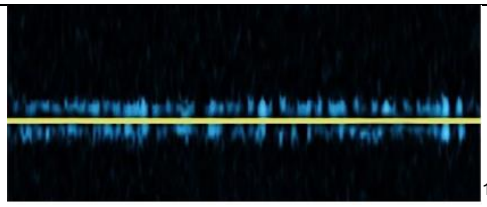
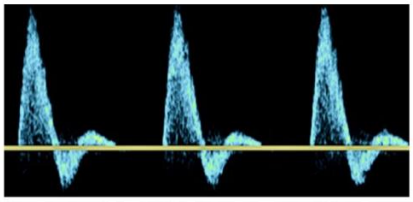
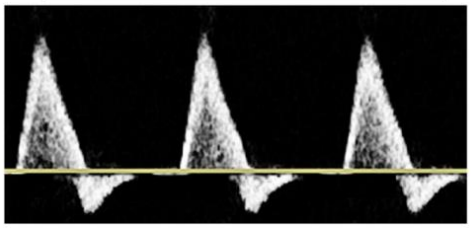
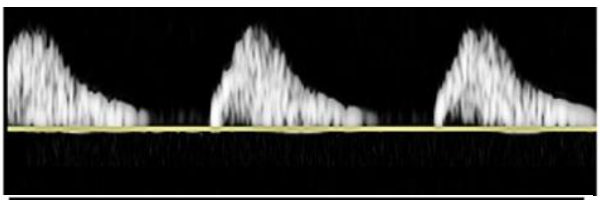
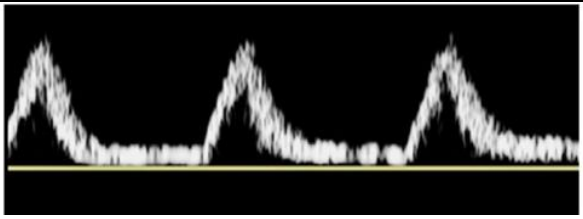
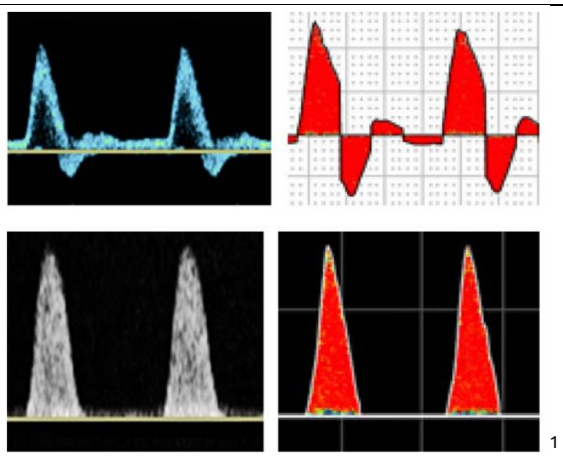
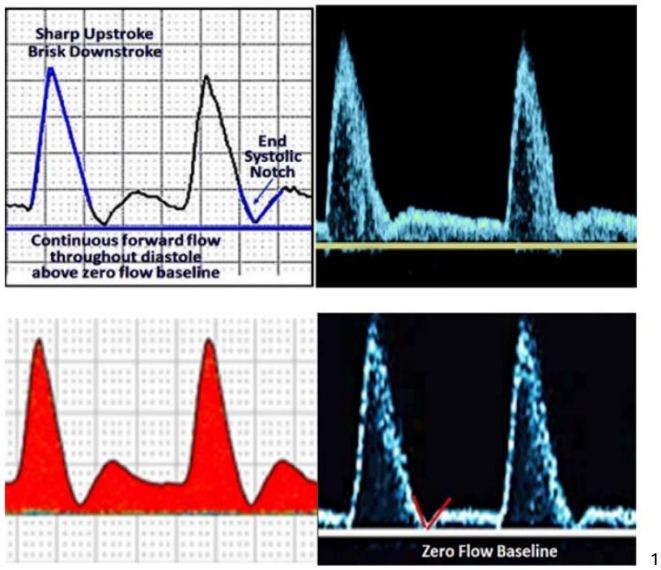
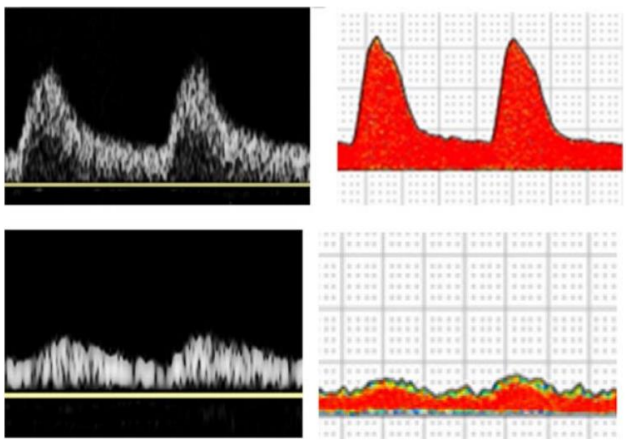
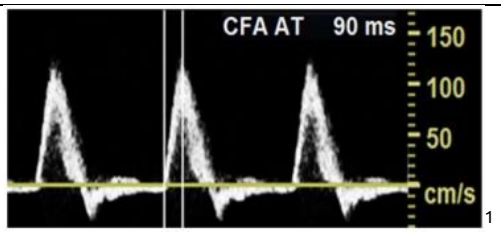
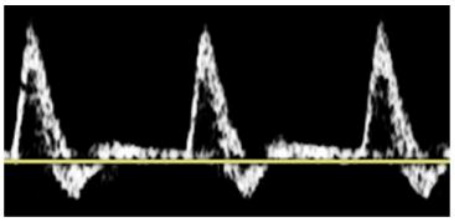
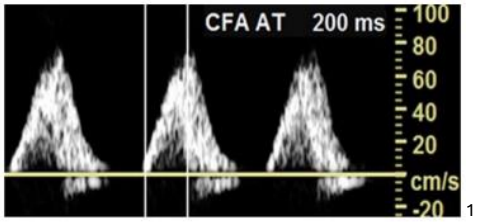
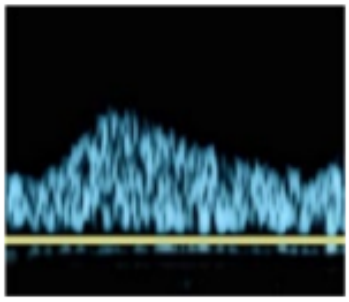
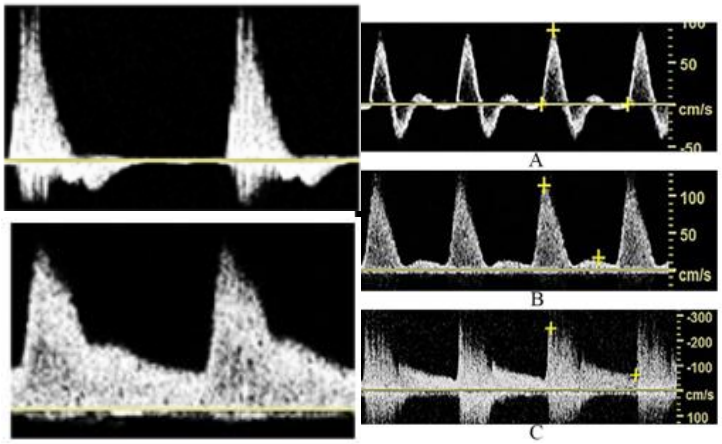
Interpreting Vascular Waveforms

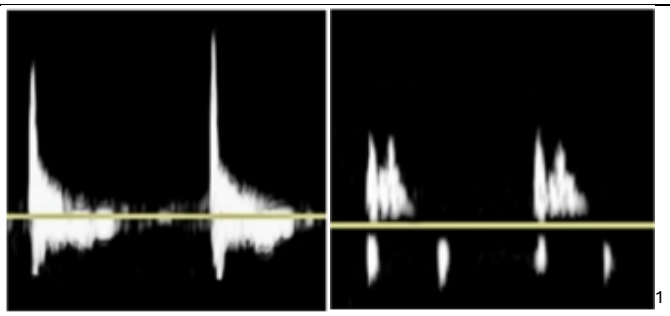
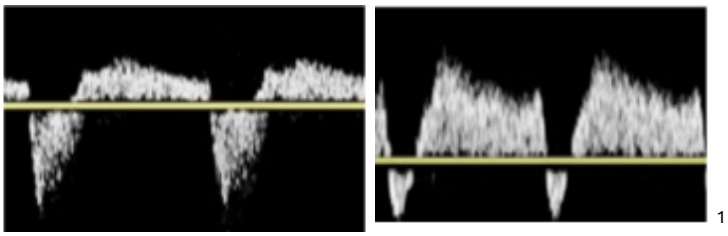
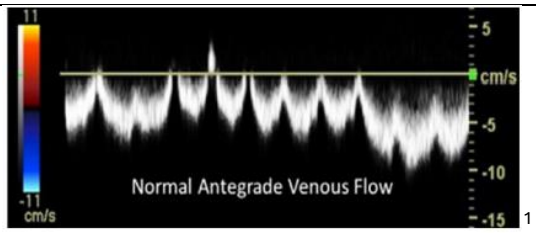
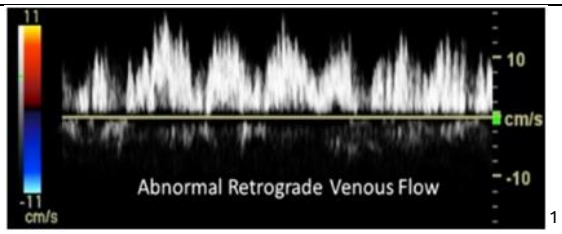
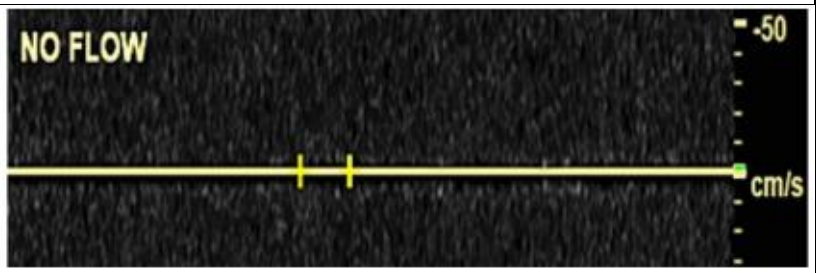
ASA Gold Coast 2026

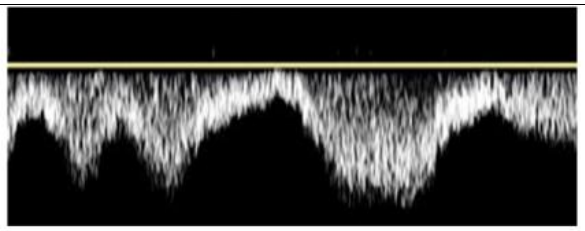
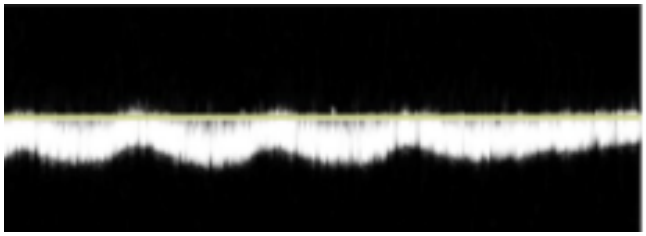
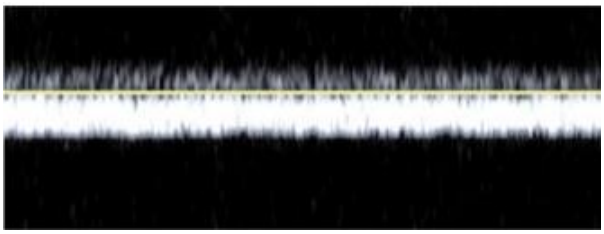
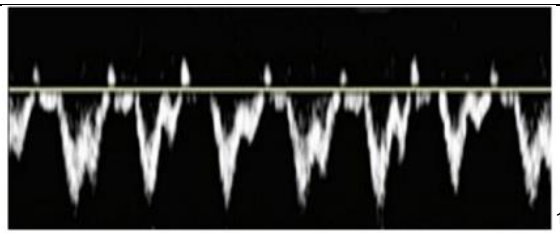
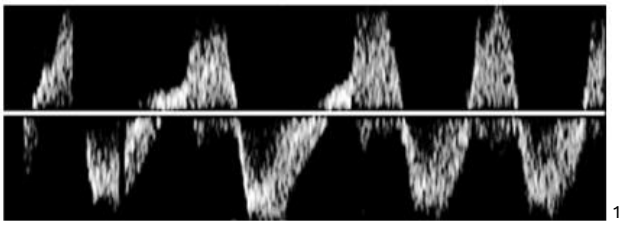
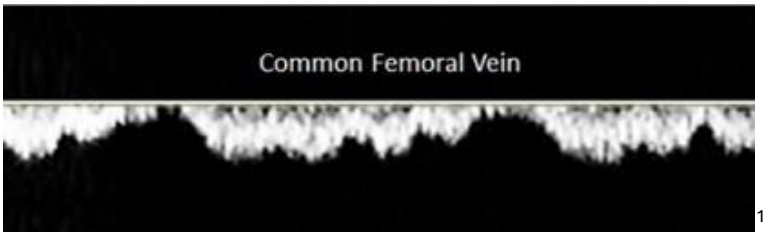
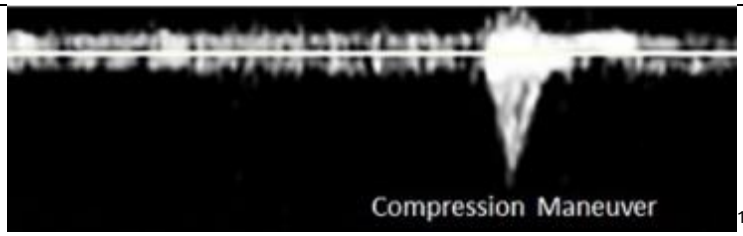
Contents

Key Major Descriptors - Arterial	Waveform direction
Antegrade • *Previous alternate term: forward flow* • Blood flows in the normal direction for the artery being evaluated. [1]	 1
Retrograde • *Previous alternate term: reverse flow* • Blood flows opposite to the normal direction for the artery being evaluated. [1]	 1
Bidirectional • *Previous alternate term: to-fro* • Blood flow enters and leaves a contained space via the same orifice. [1]	 1
Absent • No blood flow is detected with an absent spectral Doppler signal. [1]	 1
	Waveform phasicity
Multiphasic • *Previous alternate terms: triphasic; biphasic* • Waveform crosses the zero-flow baseline and contains both forward and reverse velocity components. [1]	  1
Monophasic • Waveform does not cross the zero-flow baseline throughout any part of the cardiac cycle; blood flows in a single direction. Note: if the waveform does not cross the zero-flow baseline it is considered monophasic. [1]	  1

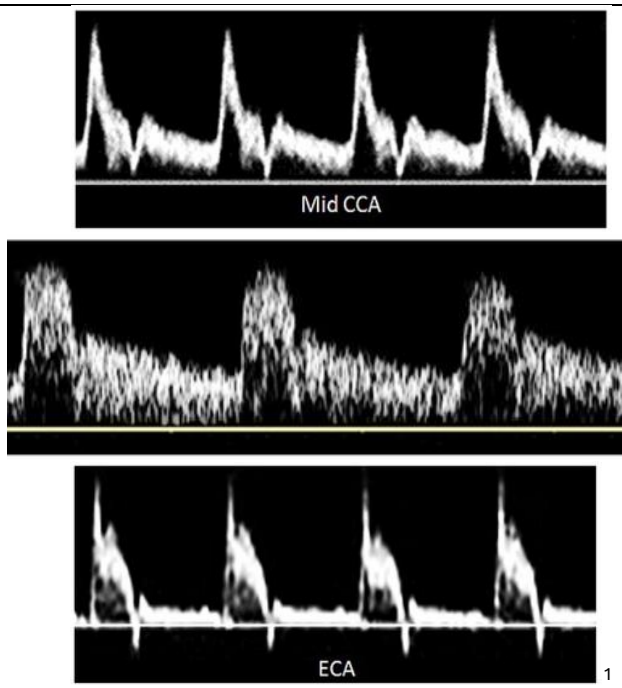
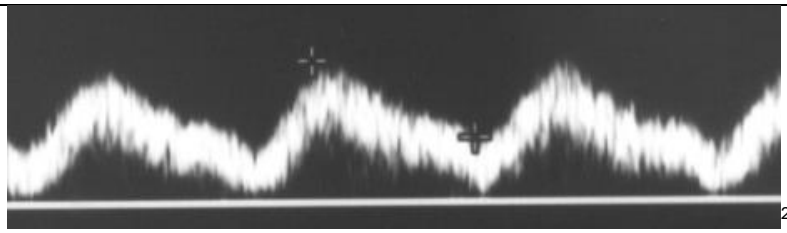
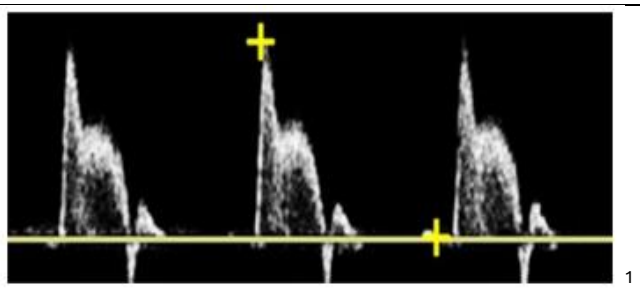
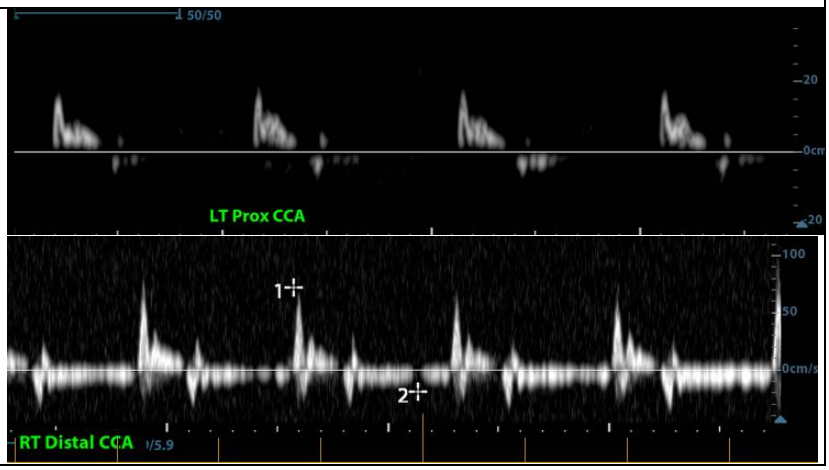
	Waveform resistance
High resistant • Key features: sharp upstroke and brisk downstroke, with or without diastolic flow reversal. [1]	 1
Intermediate resistant • Key features: sharp upstroke, brisk downstroke, visible presence of an end-systolic notch and continuous forward flow throughout diastole that is above the zeroflow 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. [1] • Author's note: although this waveform does not cross the zeroflow baseline simply describing it as 'monophasic' is incomplete and can create confusion.	 1
Low resistant • Key features: a prolonged downstroke in late systole and continuous forward flow throughout diastole. • 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. [1]	 1

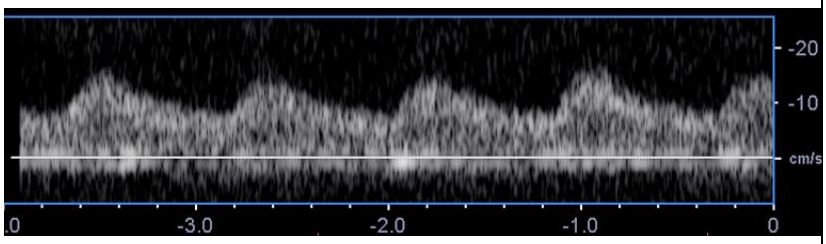
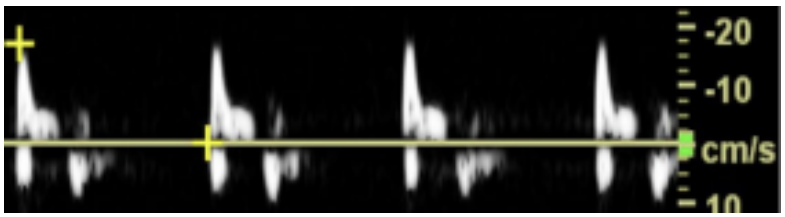
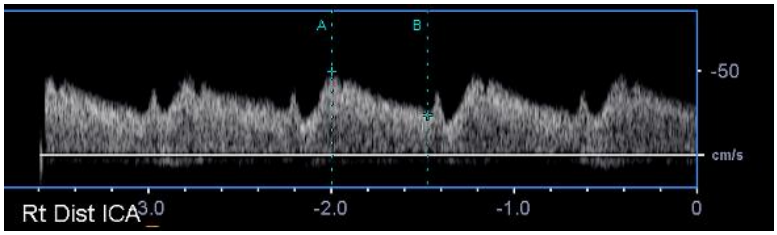
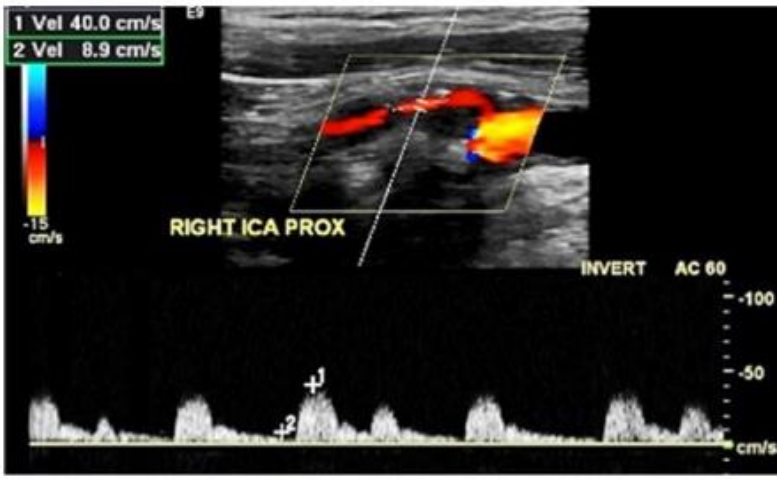
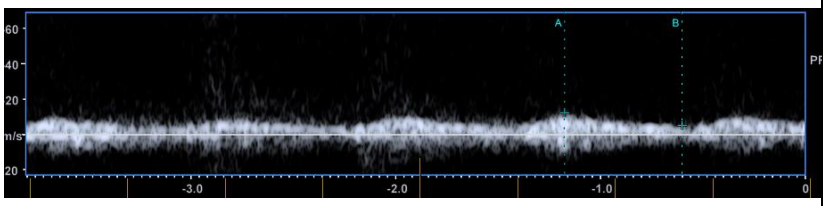
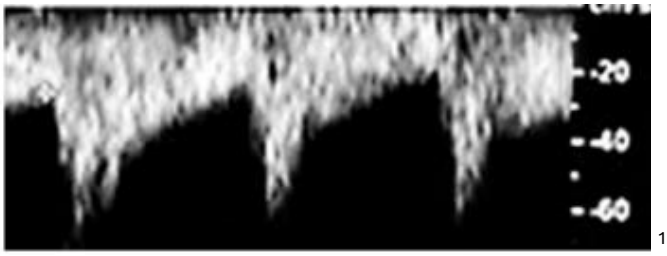
	Waveform characteristics
Rapid upstroke • Nearly vertical slope or steep rise to peak systole. AT < 140 ms has been used for the CFA (measured from start of systole to mid-systole). [1]	 1
Sharp peak • Sharp, single, and well-defined peak, often with maximum velocity, within range of the artery being interrogated. [1]	 1
Prolonged upstroke • *Previous alternate terms: tardus; delayed; damped* (tardus parvus) • Abnormally gradual slope to peak systole. AT > 140 ms has been used for the lower extremity CFA. [1]	 1
Dampened • *Previous alternate terms: parvus et tardus; attenuated; blunted* • Combined finding of an abnormal upstroke (prolonged) and peak (broad), often with decreased velocity. [1]	 1
Spectral broadening • *Previous alternate terms: nonlaminar; 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. [1] • Author's note: there is a significant difference between spectral broadening (B) and turbulent flow with spikes and flow reversal (C). The phrase 'spectral broadening' is not considered specific enough to describe 'C' waveforms. Using the phrase 'turbulent flow' is appropriate for such waveforms. Velocity measurement of turbulent flow in unreliable.	

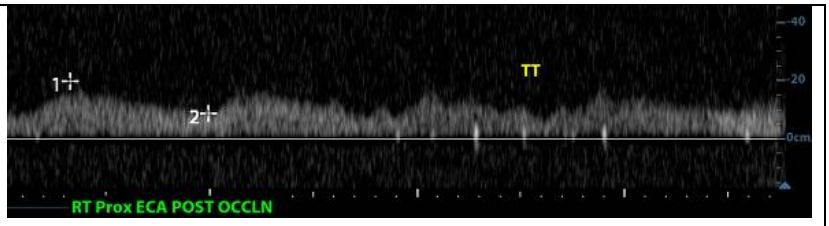
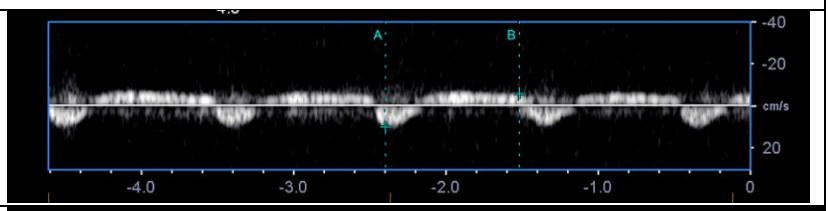
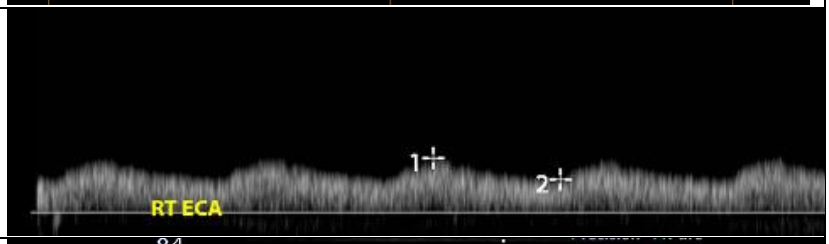
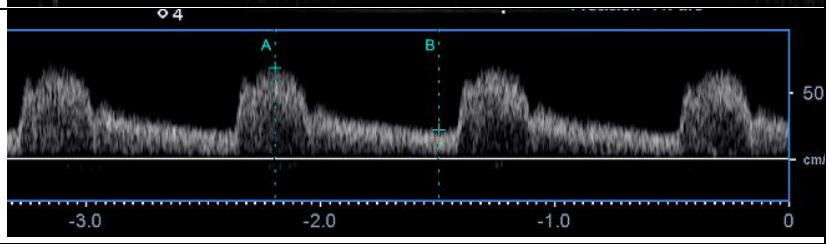
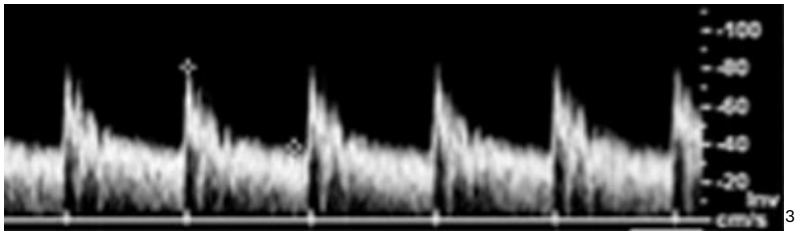
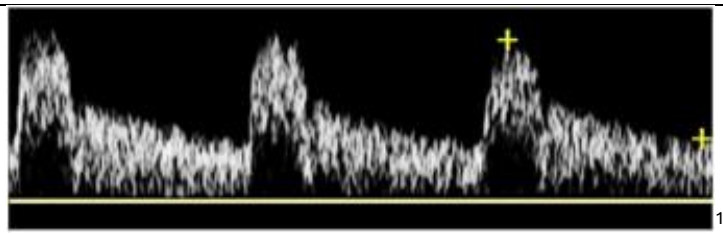
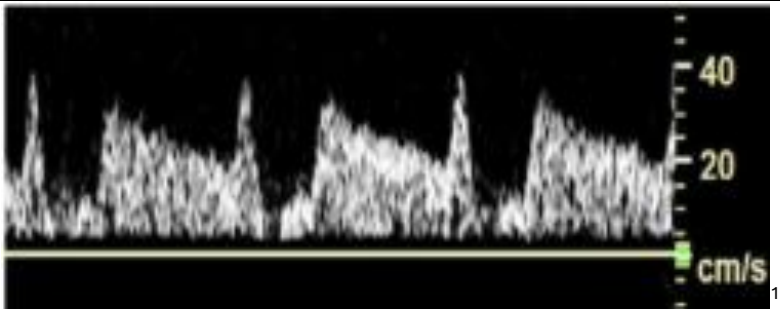
Staccato • A very high-resistance pattern with a short 'spike' of velocity acceleration and deceleration followed by a short and low-amplitude diastolic signal reflecting low antegrade flow. [1] • Author's note: before an occlusion or within a dead-end dissection lumen.	 [1]
Flow reversal (partial or complete) • *Previous alternate terms: pre-steal; competitive flow; oscillating* • Flow that changes direction, not as part of normal diastolic flow reversal, which may be transient (positional) or consistent with each cardiac cycle (systole/diastole). [1] • Author's note: the consensus paper later uses the phrase 'pre-steal' to describe vertebral artery flow reversal during different subclavian steal cases. Please refer to this section of the document for further information.	 [1]
Key Major Descriptors - Venous	**Waveform direction**
Antegrade • *Previous alternate terms: central or forward* • Blood flow in the normal direction for the vein being evaluated. [1]	 [1]
Retrograde • *Previous alternate terms: peripheral or reverse* • Blood flow opposite to the normal direction for the vein being evaluated. [1]	 [1]
Absent • No blood flow is detected with an absent spectral Doppler signal. [1]	 [1]

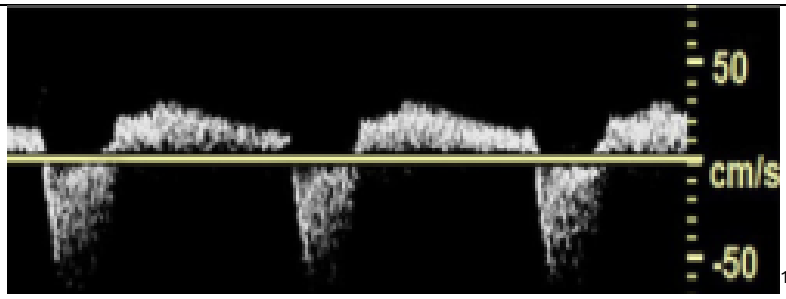
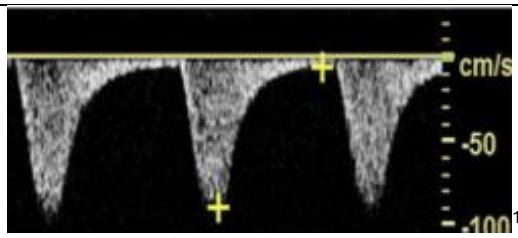
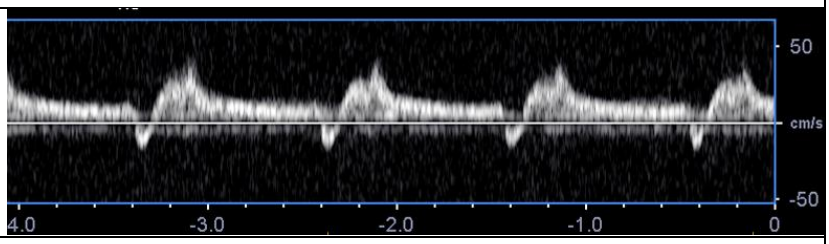
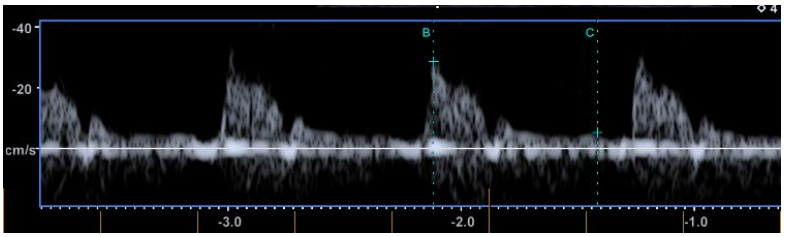
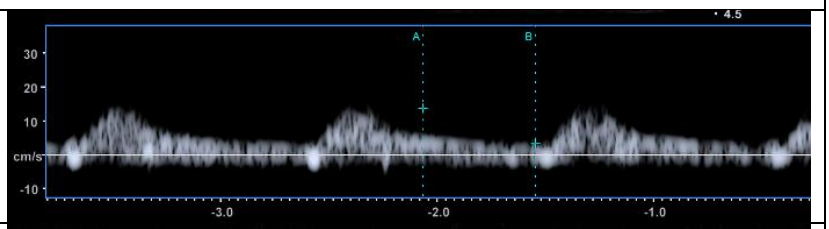
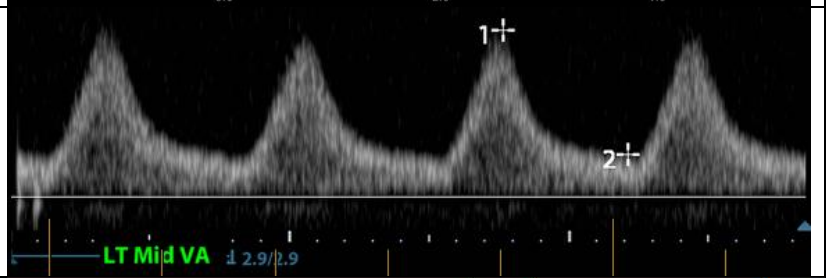
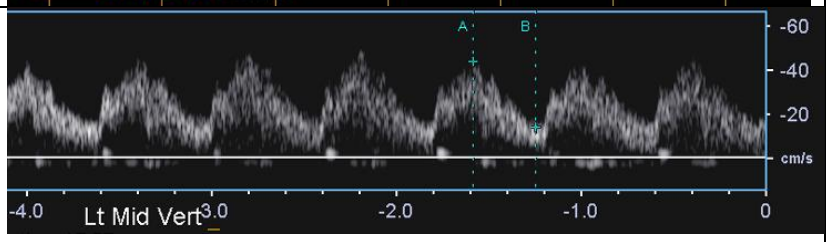
	Waveform pattern
Respirophasic • *Previous alternate term: respiratory phasicity* • Cyclical increase and decrease in flow velocity, which correlates with respiratory phases. [1]	 1
Decreased (phasicity) • *Previous alternate terms: dampened; blunted* • Respirophasic flow is decreased if it demonstrates less variation with the respiratory cycle than normal for the segment, or in comparison to the contralateral segment. [1]	 1
Continuous • Characterised 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. [1] • Author's note: typically occurs with a more proximal obstruction.	 1
Pulsatile • *Previous alternate term: cardiophasic* • Cyclical increase and decrease, which inversely correlates with the cardiac cycle. [1]	 1
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. [1]	 1
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. [1]	 1
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. [1]	 1

Normal vs Abnormal waveforms – region specific

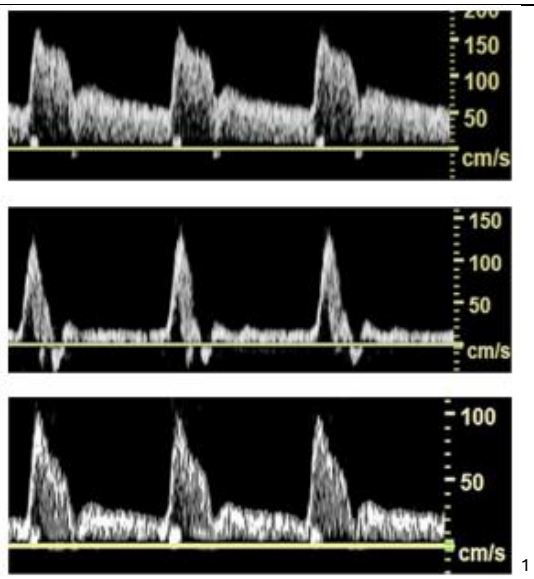
Arterial – Carotid	Normal
Normal • CCA: *minimal or no reverse flow and relatively high diastolic flow* • ICA: *forward flow throughout the cardiac cycle and relatively high diastolic flow velocities* • ECA: *presence of a reverse flow phase in late systole or early diastole and a multiphasic flow pattern*[1] • Authors note: higher resistant flow.	 1
Common Carotid Artery	**Abnormal**
Prolonged upstroke • Prolonged upstroke, decreased peak systolic velocities, and a dampened peak are all typical features produced by a proximal obstructive lesion. • Will also be present in ICA and ECA [1]	 2
Ipsilateral ICA occlusion • The CCA waveform demonstrates an atypical high-resistive pattern with a small reverse flow phase in late systole and absent diastolic flow. In the setting of an ipsilateral ICA occlusion, the CCA waveform resembles that of the ECA. Rapid upstroke indicates normal inflow [1]	 1
Staccato • Small, blunt percussive waveforms with little or no diastolic flow (also called "knocking" or "stump-thump" waveforms) • Occur proximal to a complete or nearly complete vascular occlusion • This appearance can also be a sign of dissection and should prompt a search for an intimal flap [2]	

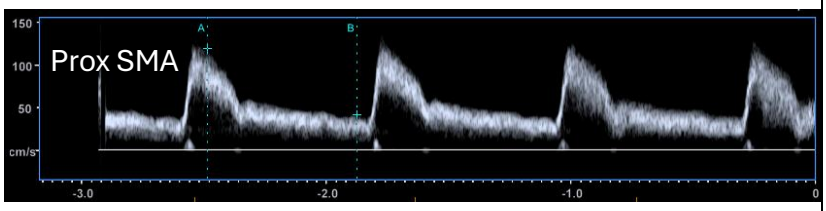
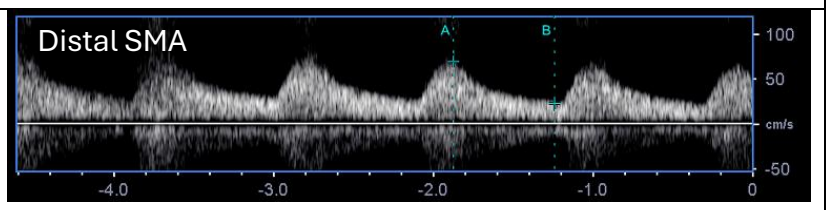
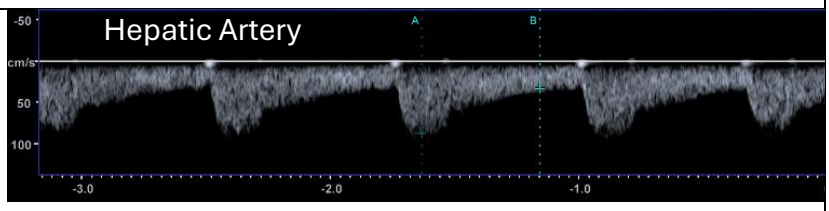
Internal Carotid Artery	Abnormal
Dampened flow – proximal disease • Decreased peak systolic velocities • Dampened peak • Prolonged upstroke • Typical features produced by a proximal obstructive lesion. [1]	
Staccato - distal occlusion • Rapid deceleration with low velocity or absent flow throughout diastole[1]	 1
Mid-systolic flow deceleration • Secondary to severe proximal stenosis (Innominate stent stenosis in this case)	
Near occlusion – string sign • Large plaque/tight stenosis • Jet may not be present • Low velocity flow [1]	 1 
External Carotid Artery	**Abnormal**
Retrograde flow – CCA occlusion • Retrograde flow direction • The relatively high diastolic flow is characteristic of flow to a low-resistive vascular bed. • This pattern can be described as 'internalized' because the waveform resembles that of a typical ICA. [1]	 1

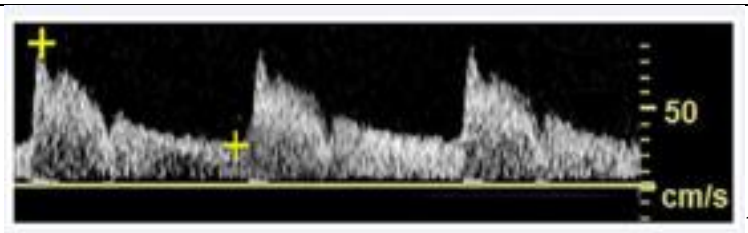
Dampened flow - proximal occlusion • Delayed systolic acceleration indicates abnormal inflow through a collateral bed. • Temporal tap positive response*	
Bidirectional flow • CCA occlusion, with severe ICA stenosis or occlusion • Low velocities in both directions.	
Low resistant – dampened • Delayed systolic acceleration indicates abnormal inflow through a collateral bed.	
Low resistant - internalisation • High diastolic flow • Ipsilateral ICA occluded/high grade stenosis • 'Internalisation' due to collateral flow, often via the ophthalmic bed. [1]	
Low resistant flow - AVF • Grossly high diastolic flow secondary to cavernous sinus dural arteriovenous fistula [3] Helpful support • CCA marked increased diastolic flow, normal ICA resistance • IJV fistula flow	 3
Arterial – Vertebral	**Normal**
• Forward flow • Relatively high diastolic flow • Similar to ICA[1]	 1
Vertebral Artery	**Abnormal**
Vertebral artery pre-steal • Early in the development of a subclavian steal (syndrome), a mid-systolic velocity deceleration is noted in the vertebral artery waveform. This feature becomes more prominent as the subclavian artery stenosis progresses and eventually results in a period of reverse flow (see *partial steal* below). [1] • Best practice to describe the waveform ie. mid-systolic retraction	 1

Vertebral artery steal (partial) • Alternating forward and reverse flow direction are noted during each cardiac cycle, indicating a partial or 'incomplete' steal. The extent of steal (partial or complete) depends primarily on pressure gradients produced by the innominate or subclavian artery lesion. [1] • Best practice to describe the waveform ie. mid-systolic flow reversal, systolic flow reversal etc	 [1]
Vertebral artery steal (complete) • This vertebral artery waveform shows a complete steal with reverse flow direction throughout the cardiac cycle. [1]	 [1]
Early systolic retraction • Brief retraction in early systole • May become less apparent in mid neck above collateral communications • Often due to proximal occlusion	
High resistant • Lower diastolic flow • Often lower overall velocities • May be caused by hypoplasia or distal disease • A bilateral presence raises concerns about significant distal posterior circulation obstruction or hypoplasia	
Dampened • Delayed upstroke • Broad peak • Decreased velocities • Indicates more proximal disease	
Compensatory (normal) flow • Higher velocities/volume flow • Broad waveform • Due to high demand ie contralateral VA reversed flow/occlusion, significant bilateral ICA disease/occlusion etc	
Compensatory dampened flow • Higher volume flow • Very broad peak, including diastole • Due to high demand whilst proximal disease present ie contralateral VA reversed flow, ipsilateral subclavian stenosis	

Abdominal arteries

Mesenteric Arteries	Normal waveforms
• Normal coeliac (fasting or postprandial) The liver and spleen have high metabolic demands, which are met by constant forward flow throughout systole and diastole. The normal celiac artery Doppler waveform is antegrade, low resistive, and monophasic. • Normal SMA (fasting) Waveform is antegrade, high resistive, and multiphasic, with early diastolic flow reversal often apparent. • Normal SMA (postprandial) Velocity increases in both systole and diastole. Flow direction remains antegrade, but waveform becomes low resistive and monophasic. [1]	 1

Mesenteric Arteries	Abnormal waveforms
Compensatory flow • Higher volume flow • Likely present in: • Occlusion/tight stenosis of another vessel (Coeliac Trunk)	
Monophasic and dampened flow • Low resistant • Prolonged upstoke • Secondary to significant proximal disease	
Retrograde flow • Low resistant, reverse flow • Secondary to tight stenosis or occlusion • Continuous or transient with respiration	

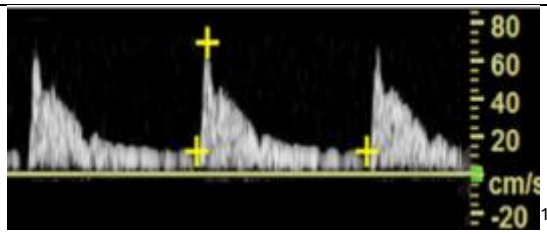
Renal arteries	Normal waveforms
Normal • Flow in the normal main and/or accessory renal artery is antegrade, low resistive, and monophasic. [1]	 1

Renal arteries

Higher resistance waveform

- Intrinsic renal parenchymal dysfunction
- Decreasing diastolic flow, high resistant
- Mono or multiphasic
- RI >0.7
- Suggesting medical renal disease [1]

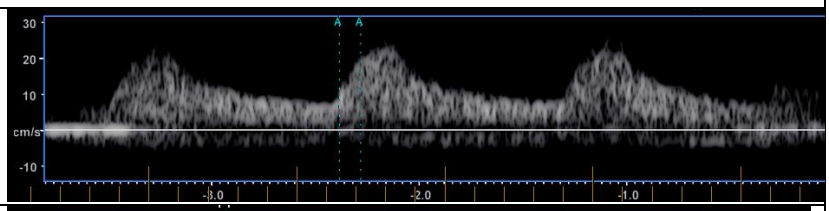
Abnormal waveforms



[1]

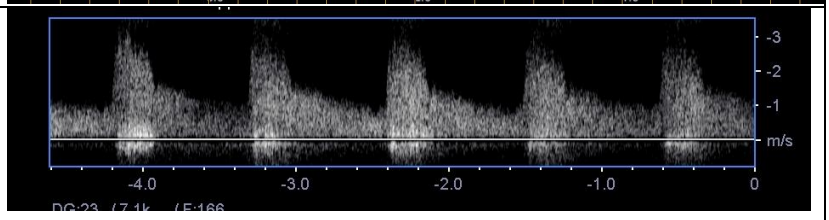
Prolonged upstroke
Delayed acceleration time

- Low resistant, dampened, monophasic
- AT >0.07-0.1 seconds



Flow derangement - FMD

- Focal disruption in flow order
- Often coupled with increased velocities in the presence of vessel stenosis/dilatations.

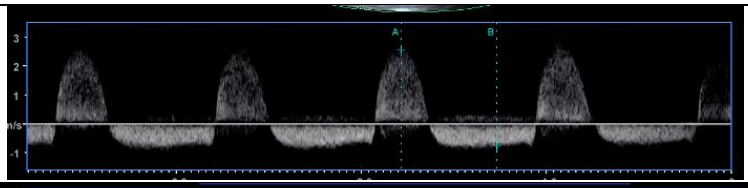


Aneurysm sac

Bi-directional flow

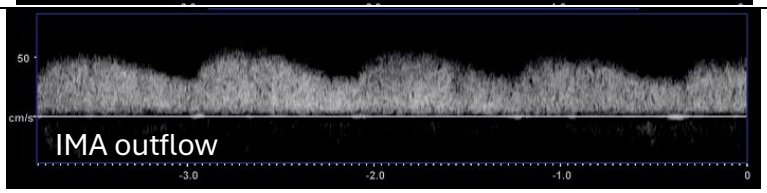
- Alternating flow direction

Endoleak



Uni-directional flow

- Low resistant, uni-directional flow
- Multiple endoleak sources present
- (IMA is acting as an outflow source in this case)

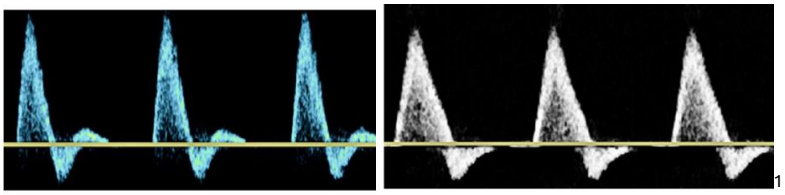


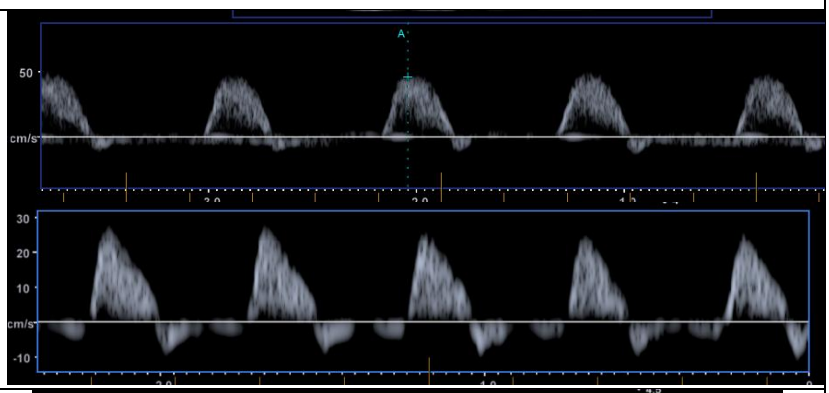
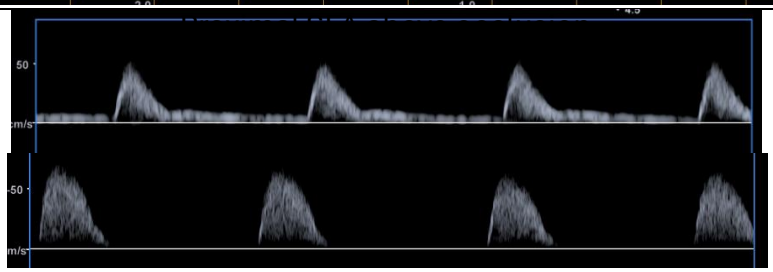
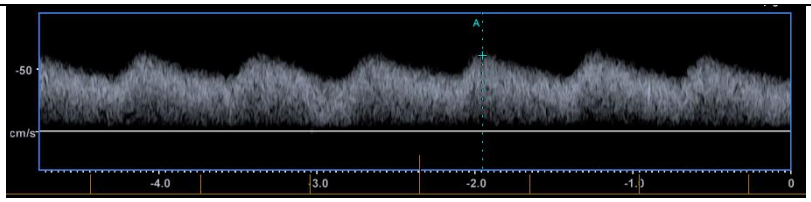
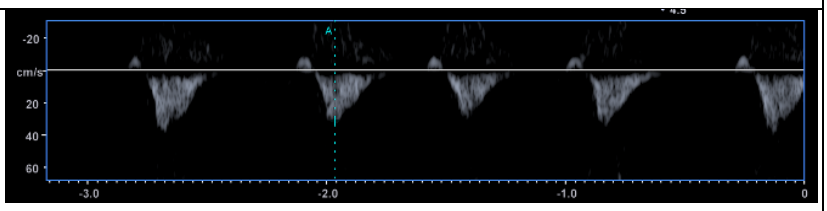
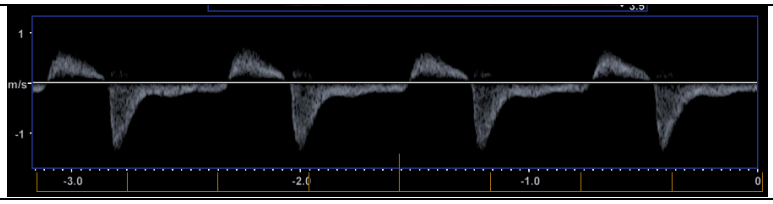
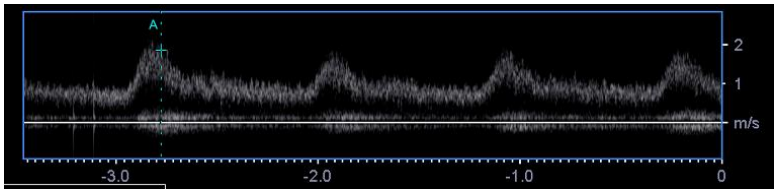
Arterial - Extremities

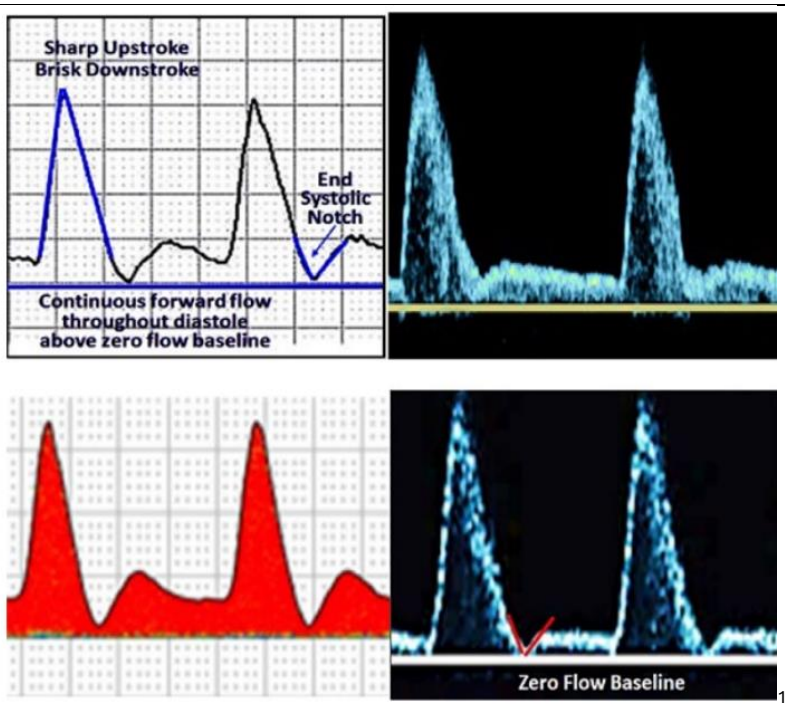
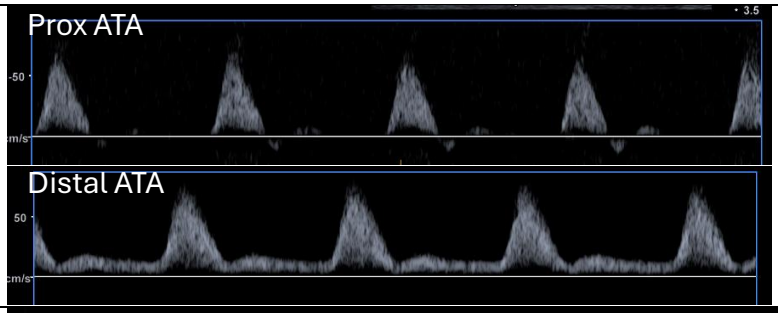
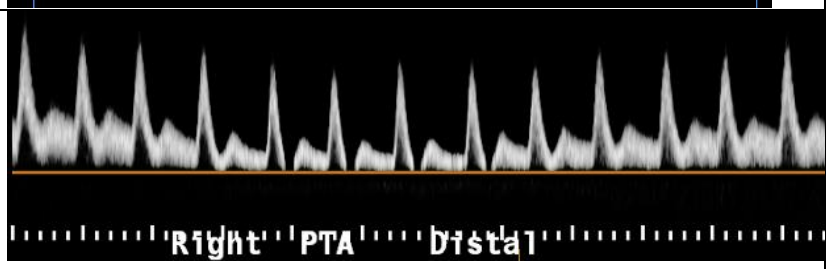
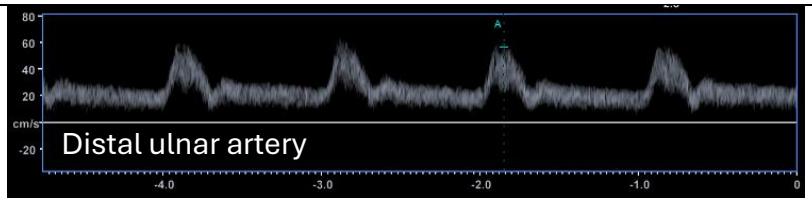
Multiphasic

- *Previous alternate terms: triphasic; biphasic*
- Waveform crosses the zero-flow baseline and contains both forward and reverse velocity components. [1]

Normal


[1]

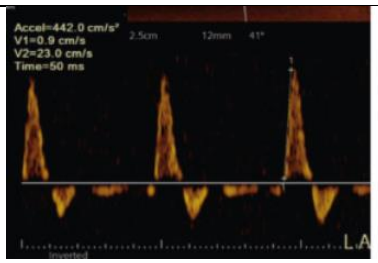
Arterial - Extremities	Abnormal
Abnormal Multiphasic • Waveform crosses the zero-flow baseline and contains both forward and reverse velocity components. • Abnormal dampened components, including rounded/extended peak, broad body and low velocity.	
Monophasic – above disease • Sharp upstroke • Waveform does not cross the zero-flow baseline throughout any part of the cardiac cycle [1] • May have diastolic antegrade flow, or no diastolic flow	
Monophasic – below disease • Dampened waveform shape. • Waveform does not cross the zero-flow baseline throughout any part of the cardiac cycle • Typically has antegrade diastolic flow	
Retrograde flow • Reverse flow direction • Secondary to significant proximal stenosis or occlusion, vessel fed by a collateral pathway	
Early diastolic kick-back • Retrograde flow post systole • Pre-stenosis kick-back	
Fistula flow • Blood flow from a high-pressure artery into a low-pressure vein results in spectral broadening and elevated systolic and diastolic velocities. Continuous forward flow is noted throughout the cardiac cycle. [1] • Disturbed flow often present. • Occurs proximal to the AV communication.	

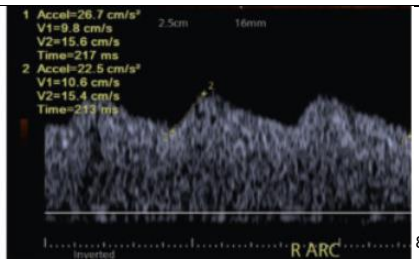
Intermediate resistance • Key features: sharp upstroke, brisk downstroke, visible presence of an end-systolic notch and continuous forward flow throughout diastole that is above the zeroflow baseline. In contrast to low resistance, the intermediate resistive waveform contains a rapid deceleration at 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.[1]	
Intermediate resistance – above occlusion • Rapid deceleration at end systole followed by a diastolic acceleration with continuous forward flow. • More pronounced closer to the occlusion.	
Intermediate resistance – autonomic • Transient change between high-resistant multiphasic and intermediate resistance flow. • Typically due to sympathetic-mediated vasodilation/constriction. • Occurs over a matter of seconds. • More common in younger patients.	
Intermediate resistance – compensatory • Intermediate – low resistance flow • Increased volume flow due to increased demands from that vessel ie secondary to occlusion of the radial artery in this case.	

Waveforms of the foot

Pedal acceleration time

- Acceleration time measured over slope from the onset to peak systole
- Class 1: 20-120 msec
- Class 2: 121-180 msec
- Class 3: 181-224 msec
- Class 4: >225 msec [8]





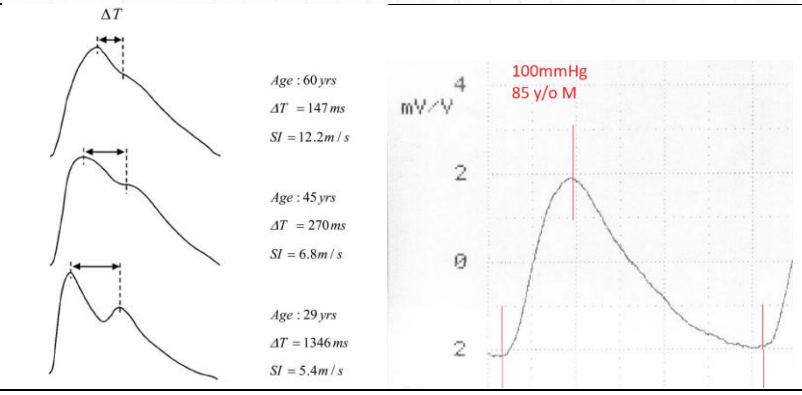
[8]

Photoplethysmography - normal

- Sharp upstroke, short crest, extended downslope/falling edge, dicrotic notch (age dependent).

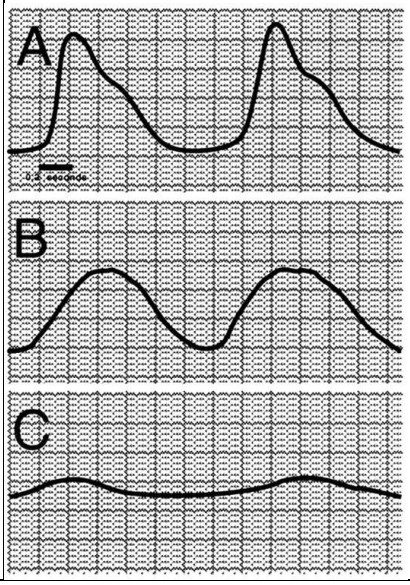
Photoplethysmography – dicrotic notch

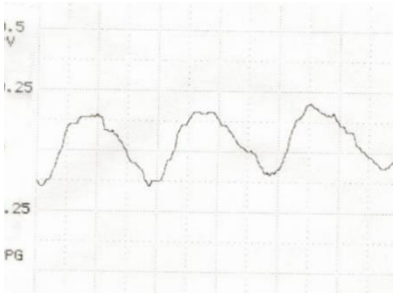
- The time delay between the systolic and diastolic peaks decreases with age because of increased large artery stiffness and increased pulse wave velocity of pressure waves in the aorta and large arteries. [9]

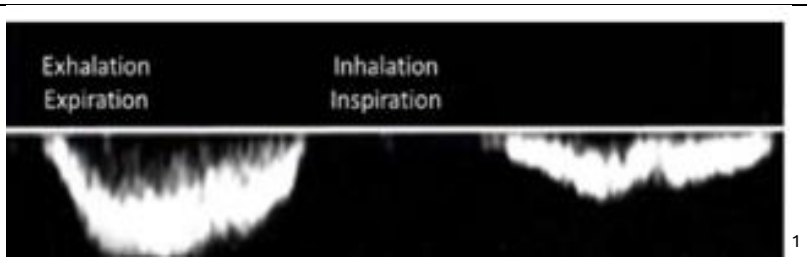
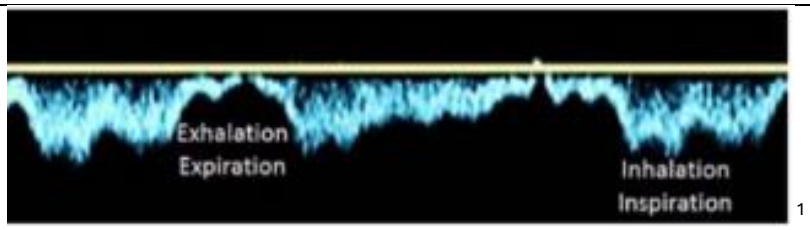
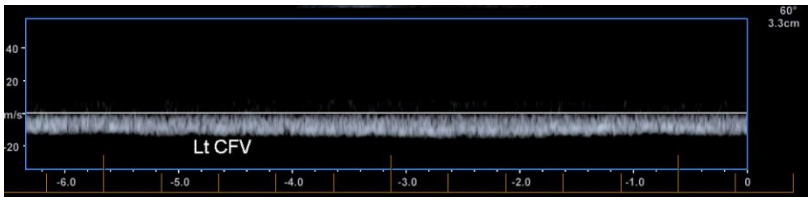
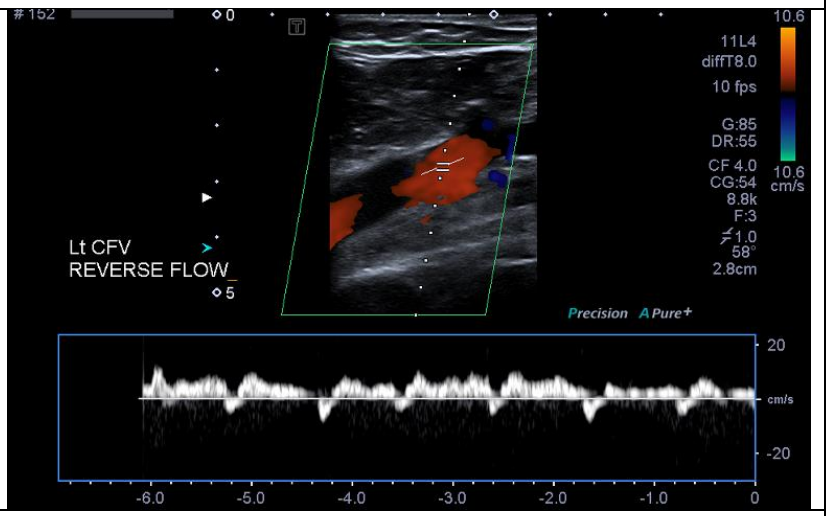
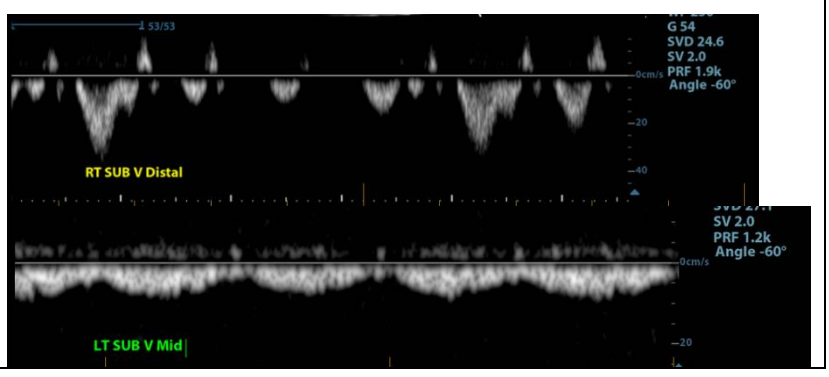


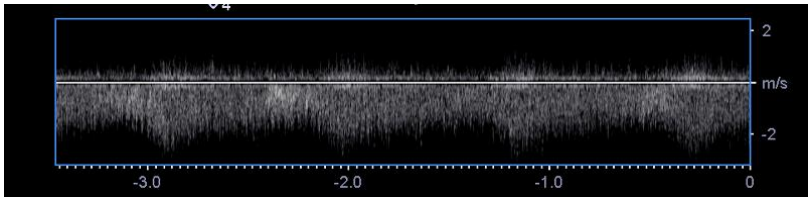
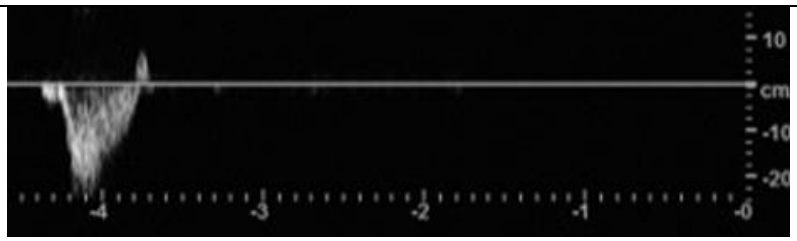
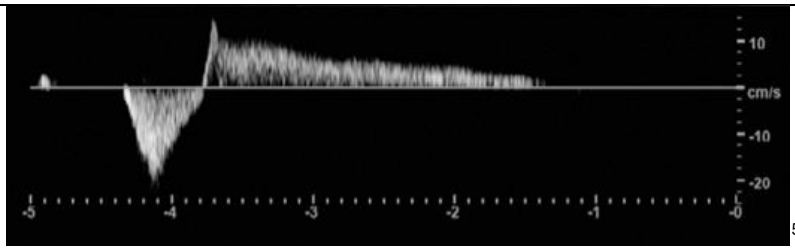
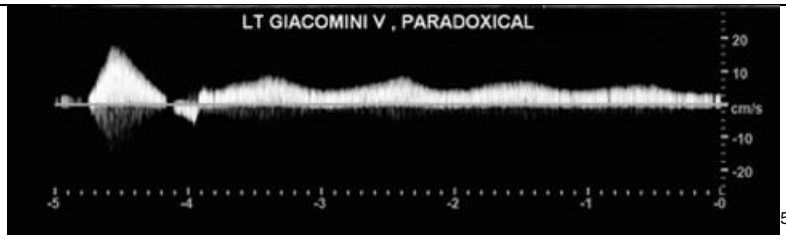
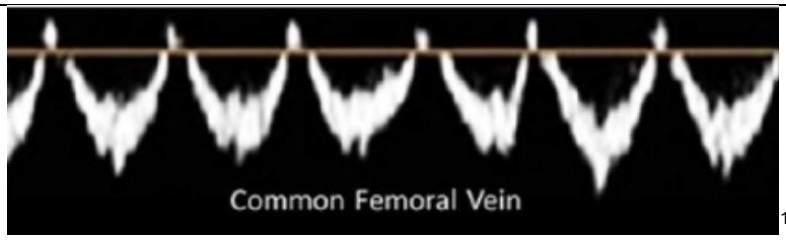
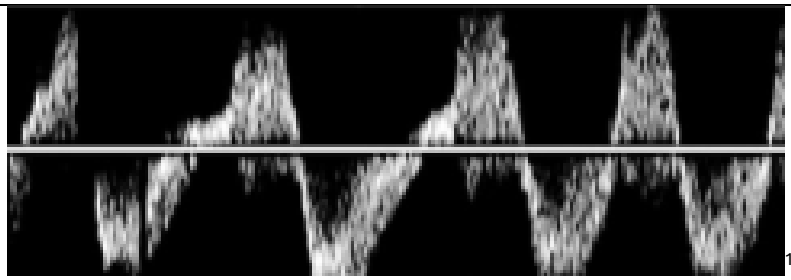
Photoplethysmography – abnormal

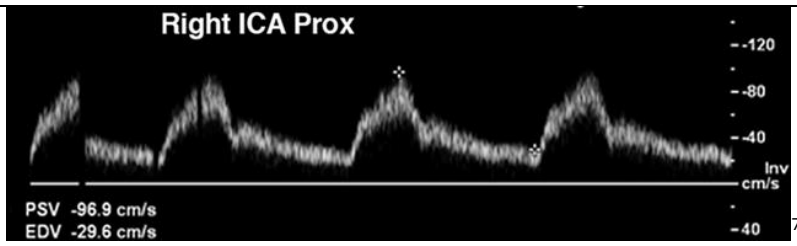
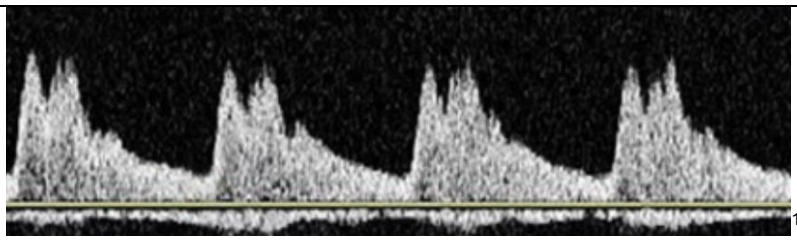
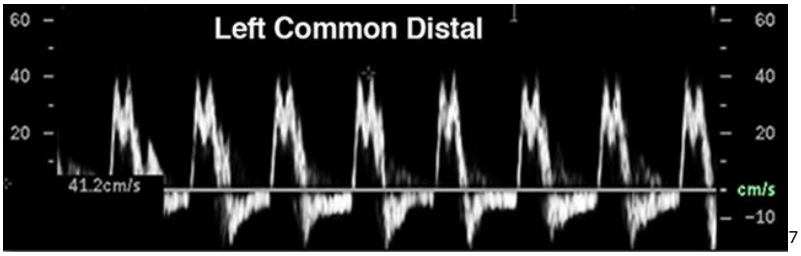
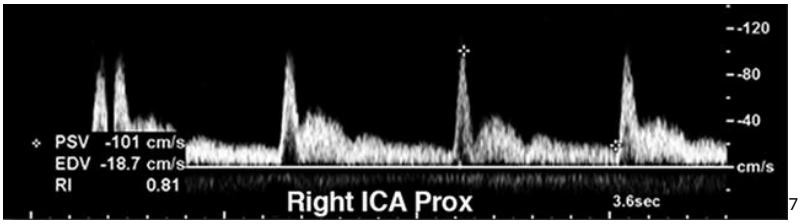
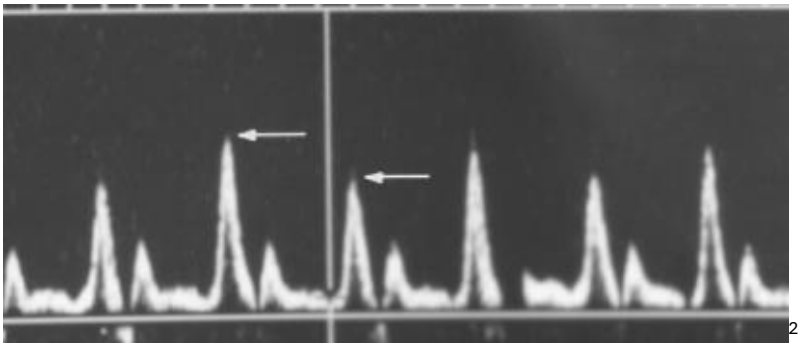
- Waveform A is normal, having a sharp upstroke, short crest and dicrotic notch.
- A prolonged rise-time (crest-time%) and waveform flattening (B and C) is associated with digital artery obstruction. [4]

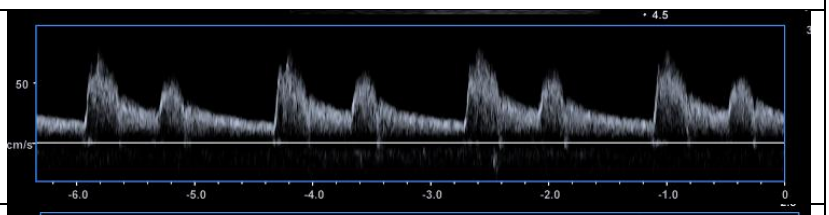
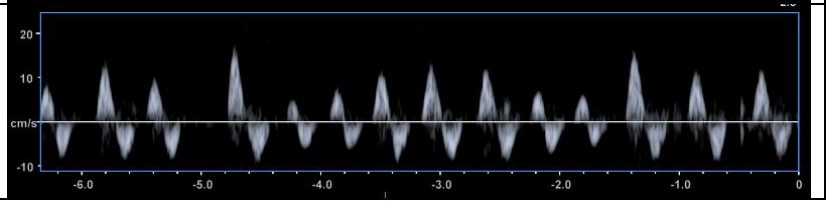




Venous – Extremities	Normal respirophasic
Lower extremity • Antegrade flow decreases with inspiration due to higher intra-abdominal pressure and increases with expiration due to decreased intra-abdominal pressure. [1]	 1
Upper extremity • Antegrade flow increases with inspiration due to negative intrathoracic pressure and decreases with expiration due to increased intrathoracic pressure. [1]	 1
Venous – Extremities	**Abnormal**
Continuous • A steady and unwavering waveform identifies a more central obstruction - either intrinsic (fully or partially occluding thrombus or stenosis) or from extrinsic compression. • The increased venous pressure at the Doppler sample level obviates (eliminates) the influence of respiratory and cardiac factors on the waveform. [1]	
Reverse flow • Retrograde venous flow secondary to a more proximal obstruction. • There is reverse flow in a segment until it reaches a lower resistance outflow vessel/pathway.	
Decreased respirophasicity • *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. [1]	

Fistula flow • *Previous alternate terms: arterialized; fistulous* • Venous flow proximal to an arteriovenous fistula becomes pulsatile due to direct communication with an artery; sharp peaks often appearing pulsatile with spectral broadening. [1]	
	Extremity reflux
Normal • No prolonged reverse flow • Brief blip of reverse flow as the valves close	 5
Reflux • > 1 second of reversed flow in the femoropopliteal segments • > 0.5 seconds of reversed flow in superficial, calf deep and deep (profunda) femoral veins. • > 0.5 seconds for perforating veins. [5]	 5
Paradoxical reflux • Reflux presents as a continuation of prolonged antegrade flow after augmentation. • Siphon effect as blood is drawn up a segment prior to communicating with a large refluxing vein.	 5
Cardiac effects on waveforms	**Abnormal venous flow**
Lower extremity – Pulsatile • Seen with elevated central venous pressure from heart failure, tricuspid valve regurgitation, pulmonary hypertension, and elevated right heart pressures or dysfunction (e.g congestive cardiac diseases). [1]	 1
Lower extremity - 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. [1]	 1

	Abnormal arterial flow
Aortic valve stenosis (severe) • Doppler waveforms demonstrate a delayed systolic upstroke (prolonged acceleration time) with decreased amplitude and rounded waveform appearance. [7]	 7
Severe aortic insufficiency/regurgitation • Doppler waveforms demonstrate an exaggerated, rapid upstroke. There are 2 distinct systolic peaks separated by a dicrotic notch with the height of the second peak equal to or taller than the height of the first (bisferious waveform). • Pan-diastolic flow reversal is present in the lower case. • The presence of a bisferious waveform in the carotid arteries has been shown to be more sensitive for detection of aortic insufficiency than diastolic flow reversal, but the latter is likely a more specific sign. [7]	 1  7
Hypertrophic cardiomyopathy • Doppler waveforms demonstrate an exaggerated, rapid upstroke followed by rapid descent. • There is an increased peak systolic velocity which is followed by systolic cleft and dome. • There is decreased flow throughout diastole with an abnormally high-resistive waveform morphology. • The spike-and-dome pattern of ventricular outflow obstruction is a classic finding of hypertrophic cardiomyopathy and can be seen in both the aorta and the carotid arteries. [7]	 7
Pulsus Alternans • Alternating peak systolic heights with a regular cardiac rhythm. • Intrinsic myocardial disease (ischemia, cardiomyopathy, or valvular heart disease), metabolic disease (hypocalcemia), or impairment of venous return (inferior vena cava compression or obstruction) can produce this waveform. • The sensitivity of the finding is unknown. [2]	 2

	Cardiac arrythmias
Regularly irregular • Repeating, predictable pattern of cardiac inconsistency. [6]	
Irregularly irregular • No discernible pattern in cardiac inconsistency. [6]	

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