

Carotid Artery Imaging: Ultrasound

Jeffrey W. Olin, DO

Professor of Medicine

Director, Vascular Medicine and Vascular

Diagnostic Laboratory

Mount Sinai School of Medicine

New York, NY

Attenuation

- **A decrease in intensity and amplitude due to wave interaction with the medium**
- **Three wave interactions**
 - **Absorption**
 - **Reflection**
 - **Refraction**

Doppler Equation

$$f_{\text{Dop}} = \frac{2f_0 v}{c} \cos(\theta)$$

- f_{Dop} = Doppler shift frequency
- f_0 = transmit frequency
- v = velocity of target through medium
- c = speed of interrogating beam through medium ($c = 1540$ m/sec for soft tissue)
- $\cos(\theta)$ = mathematical correction for angle effect
- θ = insonification angle (or angle to flow).

Doppler Effect

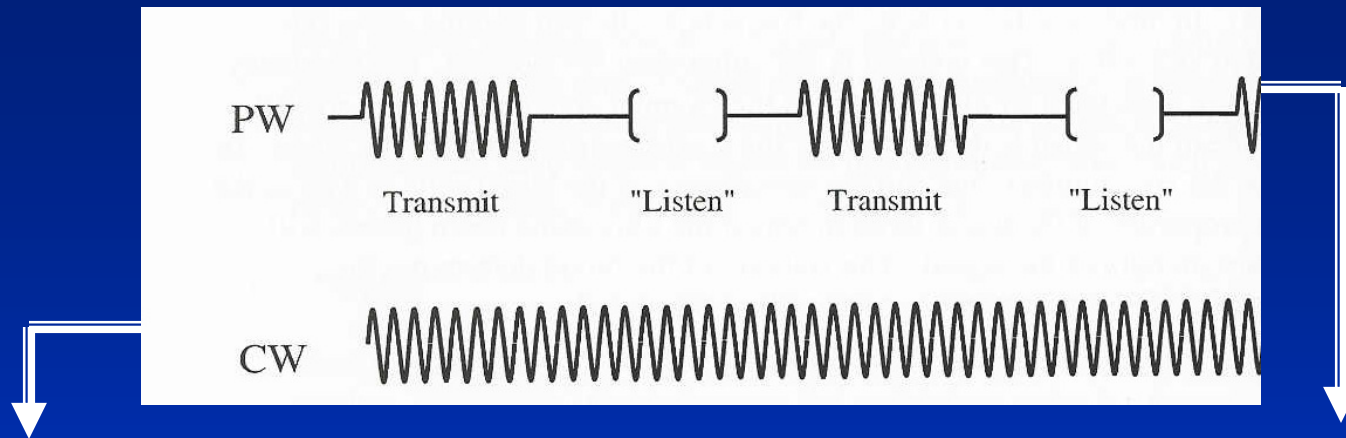
(The Importance of the Cosine)

- **The Doppler shift is related to the cosine of the insonification angle. If this angle is 90° there is no Doppler information:**
 - **$\cos 90^{\circ} = 0$, therefore even if the target is moving you have not detected this movement!!!**
 - **The greatest Doppler shift occurs at an insonification angle of 0° since the $\cos (0^{\circ}) = 1$ or 100%.**

3 Rules of the Doppler Assessment

- **Always place Doppler in center stream and parallel to blood flow**
- **Never exceed an angle of 60°**
- **Sweep the Doppler thru the entire vessel**
 - **Never spot check**

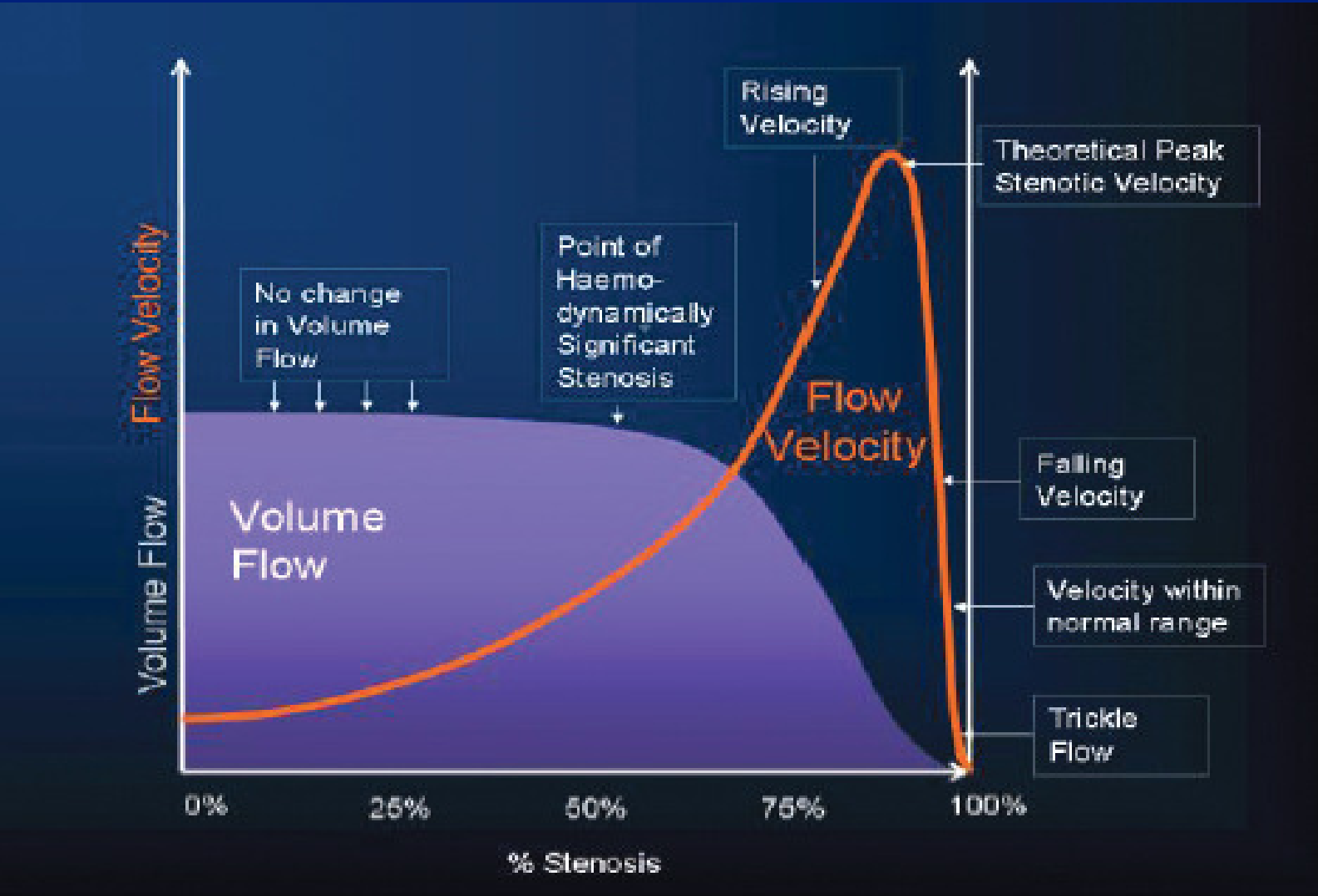
Continuous vs. Pulse Wave Doppler



- **Both transmit and receive are continuous**
 - 1/2 of transducer transmits and 1/2 receives
- **No range resolution**
 - Echos are received from all depths simultaneously
 - No way to tell from where the echos originated
- **Unlimited maximum detectable velocity**
- **Transmit is repeatedly pulsed on and then off**
- **Excellent range resolution**
 - Can distinguish from where the echo comes and at what depth
 - However if the pulse lengthens, range resolution degrades
 - Once you exceed the Nyquist limit ($1/2$ PRF), you no longer have a true representation of the velocity

Conflict between B-mode and Color Duplex Images

- Blood vessel anatomy is best seen when the ultrasound beam is perpendicular to the vessel wall (90°)
- Blood flow cannot be detected with a perpendicular beam (best at 0°)
- Therefore there is a basic conflict that exists between B-mode and flow components of the color duplex images
- Solution:
 - Beam angle chosen that is sufficient to detect flow but not large enough to degrade image
 - Doppler flow angle good enough to get an accurate flow velocity
 - That is where 60° comes from



Carotid Duplex Ultrasound

- The diagnostic measure of first choice for carotid artery disease
- When performed properly, one can visualize well:
 - The carotid bifurcation
 - The arch vessels
 - The distal internal carotid artery
 - The proximal vertebral artery
 - The subclavian arteries

Drawbacks of Carotid Ultrasound

- **Its very operator dependent**
- **Not the best test for arch vessel disease**
- **Does not show the interventionalist the anatomy well enough to plan intervention in a difficult patient**
- **Poor for posterior circulation and intracranial disease**

Accuracy of Duplex Ultrasound of the Carotid Arteries

- **Carotid duplex ultrasound has a 97% accuracy when compared to angiography.**
- **Highly accurate in identifying carotid artery occlusions with a positive predictive value of 92.5%.**

*Olin JW et al. Atherosclerotic Vascular Disease
Conference: Writing*

Group IV: Imaging. Circulation 2004;109:2626-2633.

Categories of Internal Carotid Artery Stenosis by Duplex Ultrasound

<i>Percent Stenosis</i>	<i>PSV</i>	<i>EDV</i>	<i>Spectral Broadening</i>
<i>0-19%</i>	<105	...	Absent
<i>20-39%</i>	<105	...	Present
<i>40-59%</i>	105-149	...	Present
<i>60-79%</i>	150-240	...	Present
<i>80-99%</i>	>240	≥135	Present
<i>Occluded</i>	No DS	No DS	No DS

Categories of Internal Carotid Artery Stenosis by Duplex Ultrasound (*Strandness Criteria*)

<i>Percent Stenosis</i>	<i>PSV</i>	<i>EDV</i>	<i>Spectral Broadening</i>
<i>0-15%</i>	<125	...	Absent
<i>16-49%</i>	<125	...	Present
<i>50-79%</i>	>125	<140	Present
<i>80-99%</i>	...	> 140	Present
<i>Occluded</i>	No DS	No DS	No DS

Consensus Panel Criteria for Carotid Stenosis

TABLE 3
Consensus Panel Gray-Scale and Doppler US Criteria for Diagnosis
of ICA Stenosis

Degree of Stenosis (%)	Primary Parameters		Additional Parameters	
	ICA PSV (cm/sec)	Plaque Estimate (%)*	ICA/CCA PSV Ratio	ICA EDV (cm/sec)
Normal	<125	None	<2.0	<40
<50	<125	<50	<2.0	<40
50–69	125–230	≥50	2.0–4.0	40–100
≥70 but less than near occlusion	>230	≥50	>4.0	>100
Near occlusion	High, low, or undetectable	Visible	Variable	Variable
Total occlusion	Undetectable	Visible, no detectable lumen	Not applicable	Not applicable

* Plaque estimate (diameter reduction) with gray-scale and color Doppler US.

Grant EG et al. Radiology 2003;229:340-346.

Pitfalls of Carotid Duplex Imaging

- Multiple Doppler angles
- Misidentification of a pulsatile vein for the internal carotid artery
- **Tortuous vessels**
- Failure to survey the distal internal carotid artery
- Failure to interrogate the common carotid or innominate arteries
- Near total occlusion
- Calcification
- Spot Doppler assessment
- External carotid artery with significant lesion

Interpretation Errors

- Using published criteria without internal validation
- Effect of cardiac output
- Effect of intracranial ICA occlusion
- Tandem lesions
- Contralateral disease
- Extensive disease in a large vessel
- Systolic deceleration
- Innominate stenosis
- Cardiac arrhythmias
- Effect of patch angioplasties
- **Using visual means for determining degree of stenosis**

4 Significant Errors of Carotid Ultrasound Scanning

- **Misidentification of external and internal carotid artery**
- **Failure to interrogate the common carotid or innominate arteries**
- **Failure to survey the distal internal carotid a**
- **Spot Doppler assessment**

Surveillance After Carotid Stenting

- **Soon after stent procedure to establish a baseline**
- **3 months**
- **6 months and every 6 months thereafter for at least 24 months**
- **Then yearly**