HD Scanning:
Velocities and Volume Flow

VELOCITY

Non-Invasive Lab Symposium

West Orange, NJ
April 27, 2018

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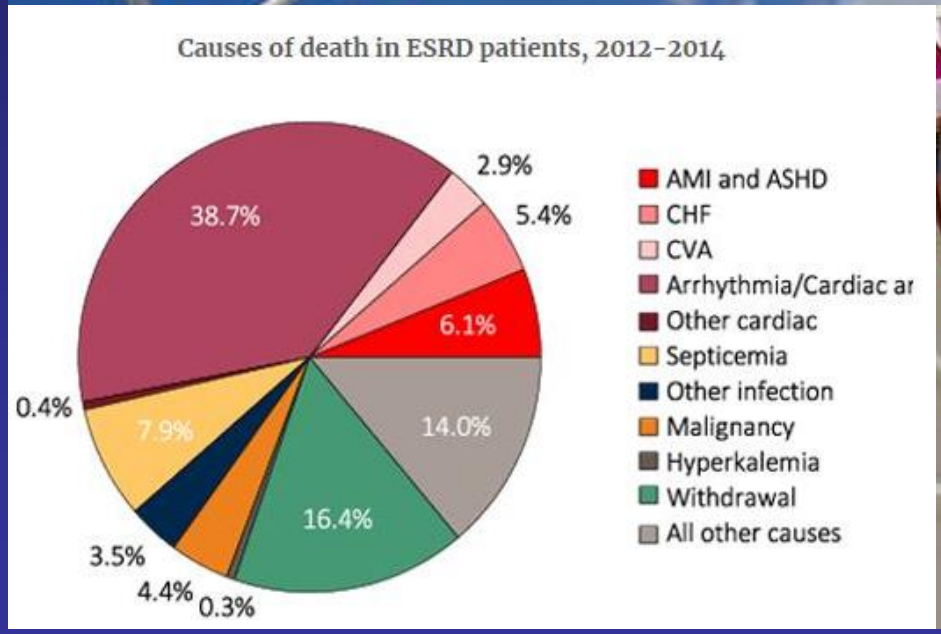
THE CARDIOVASCULAR CARE GROUP

500,000 Americans on dialysis

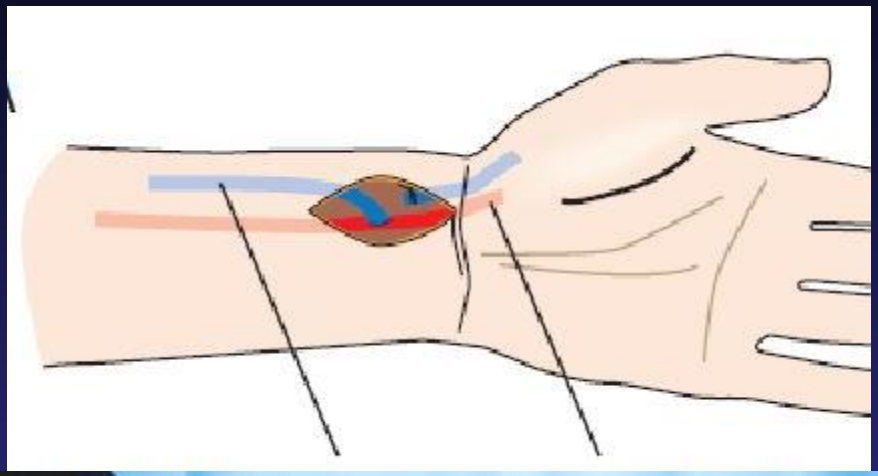
- 20-25% annual mortality
- 65% 5 year mortality

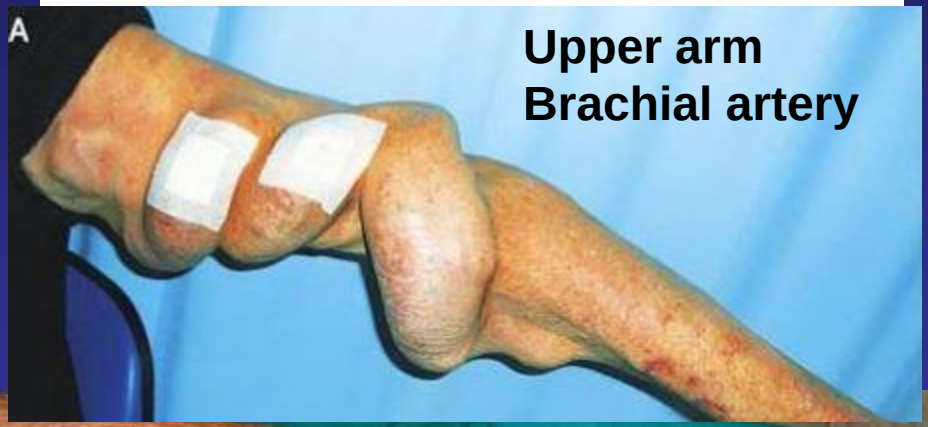
National Kidney Foundation

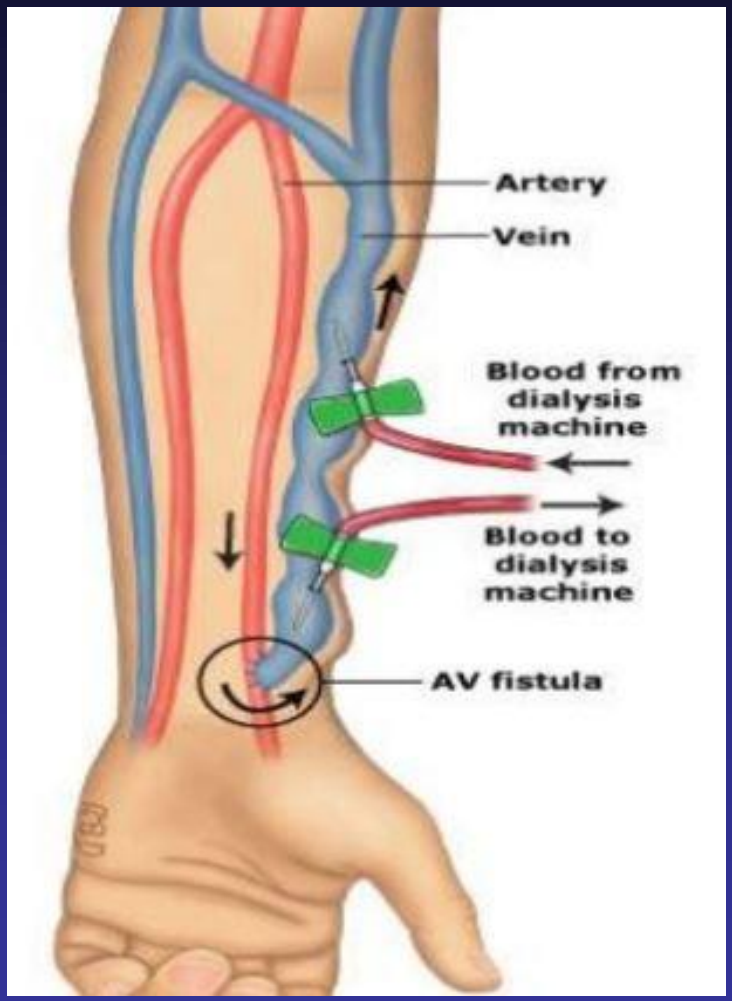
Life line of dialysis patients

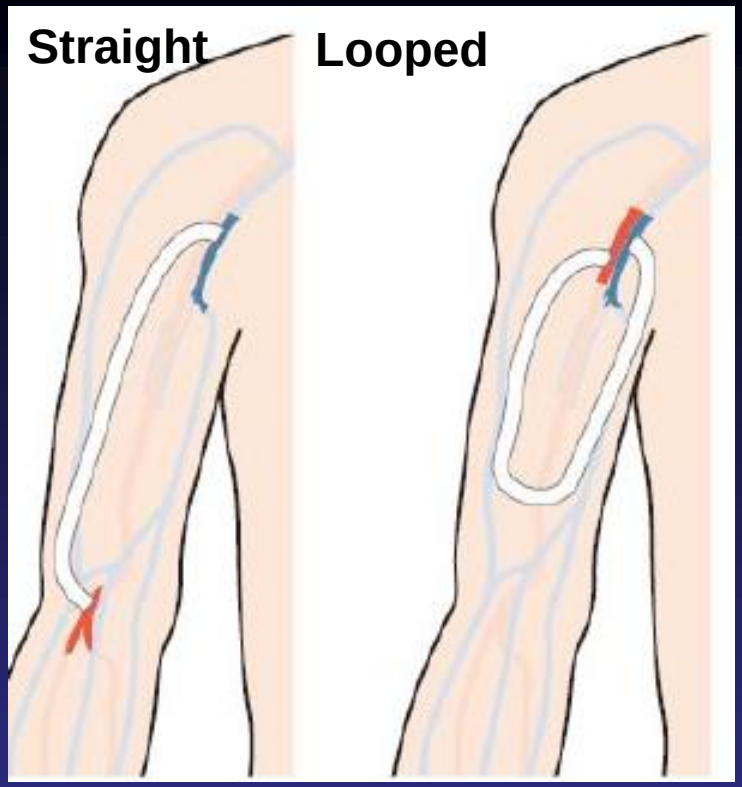


Arterial venous fistula

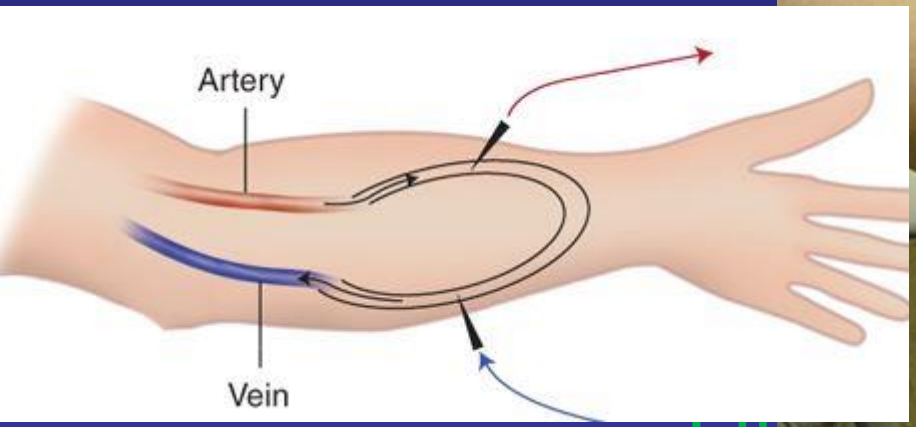




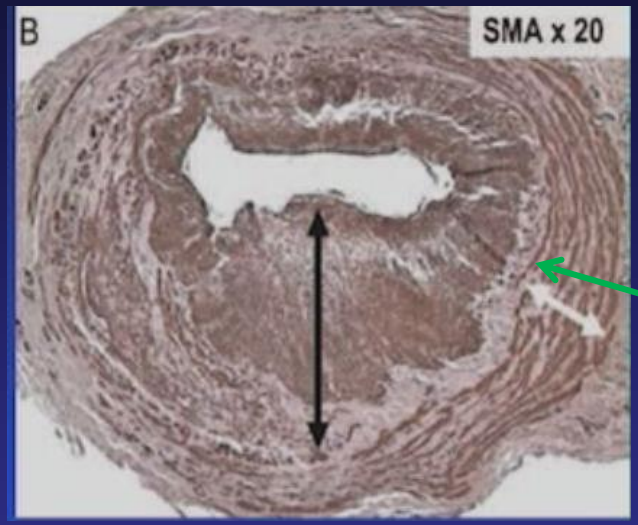




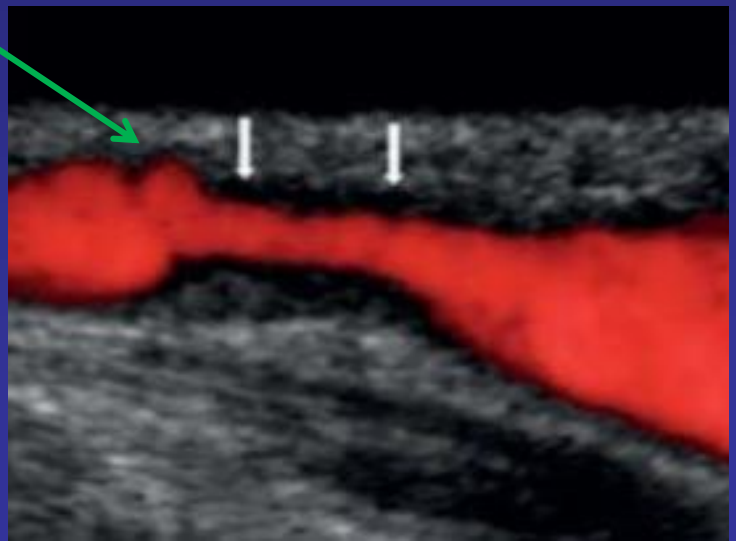
Arterial Venous Grafts



Achille's Heel



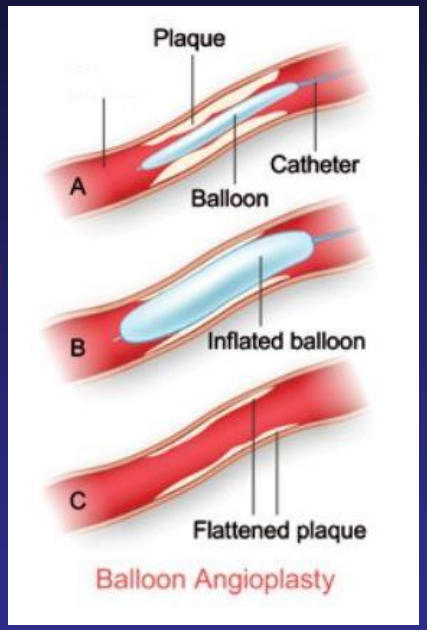
Stenosis → **Thrombosis**



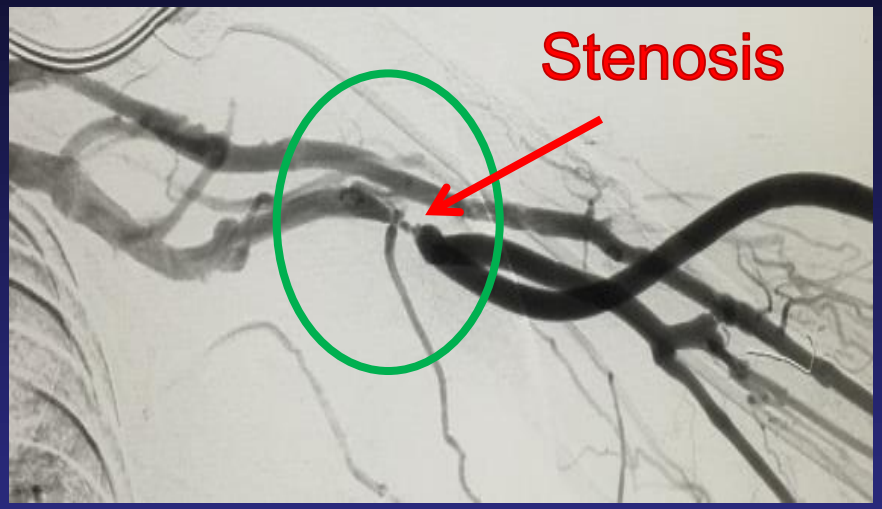
Intervention (to prevent thrombosis)

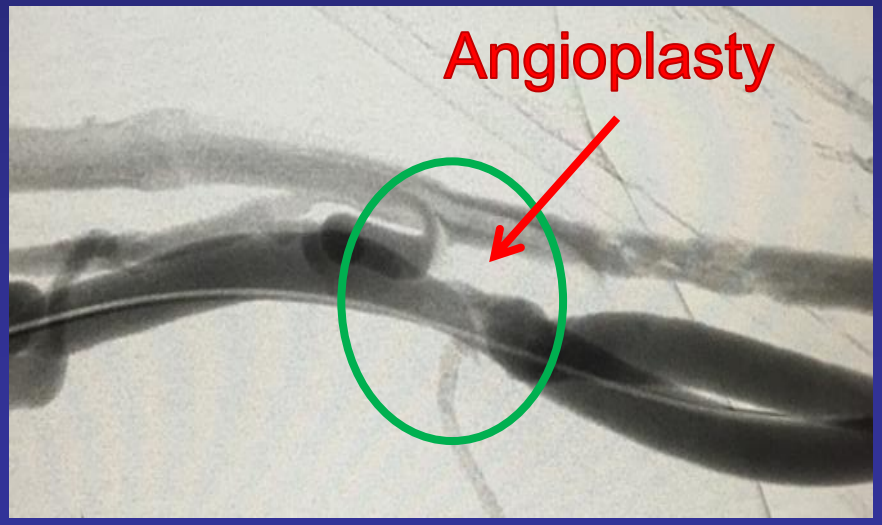
Balloon angioplasty

Plain



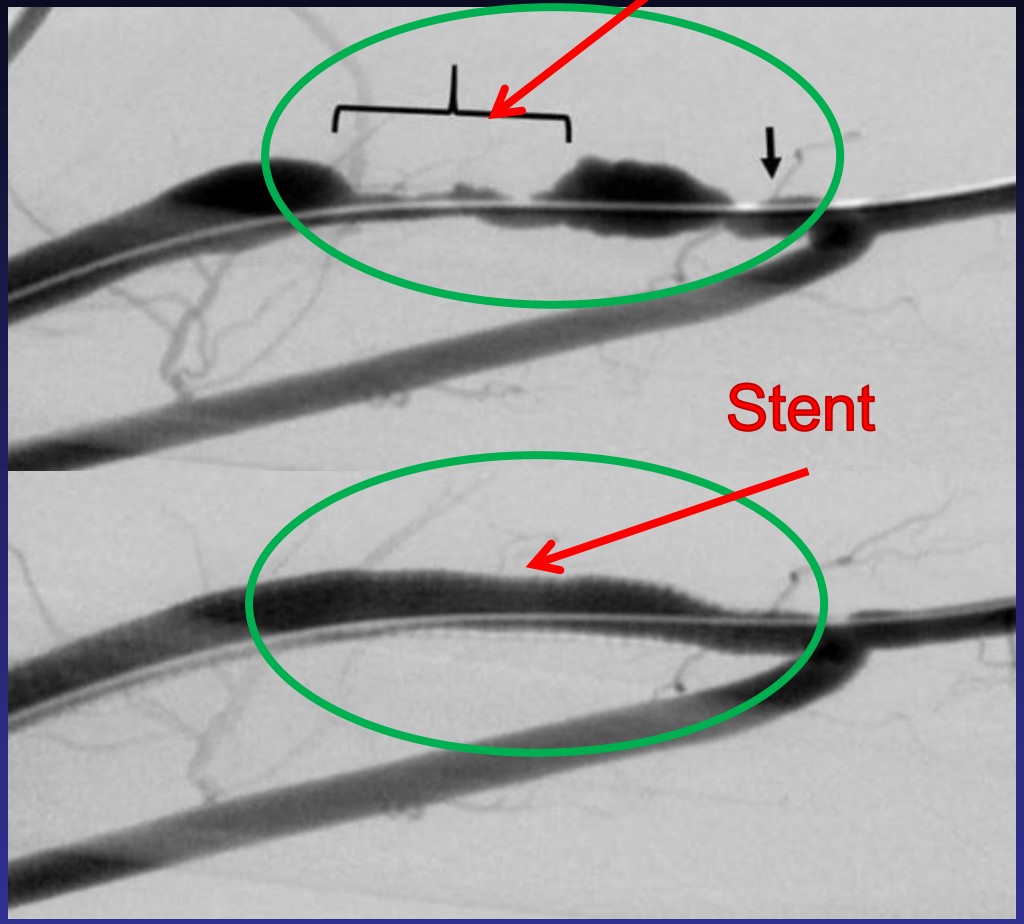
Drug Coated



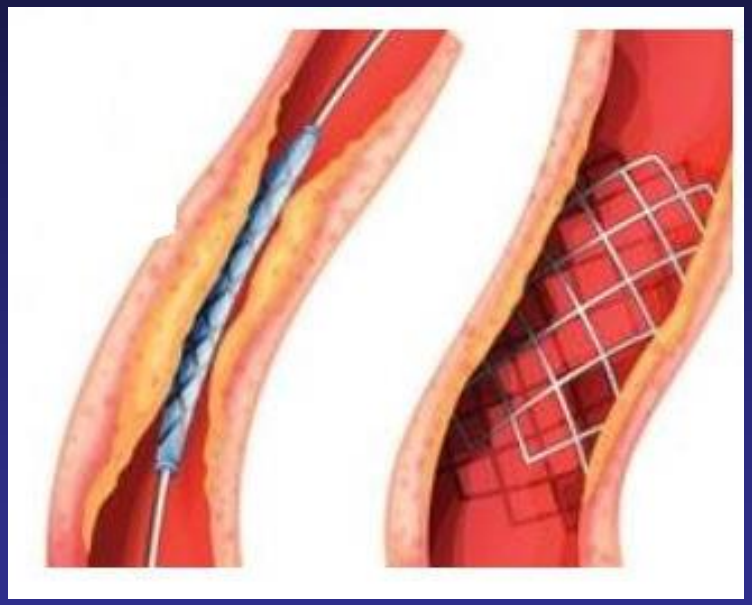


Intervention

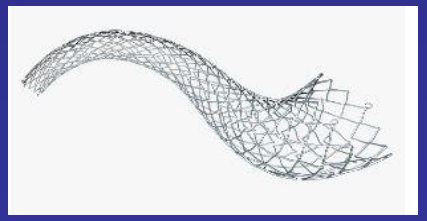
(to prevent thrombosis)



Stenting



Covered



Bare metal

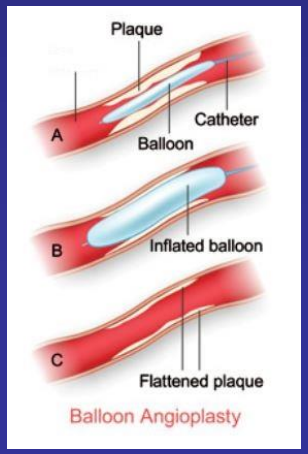
AV access

Lifeline

Achilles heel

Stenosis

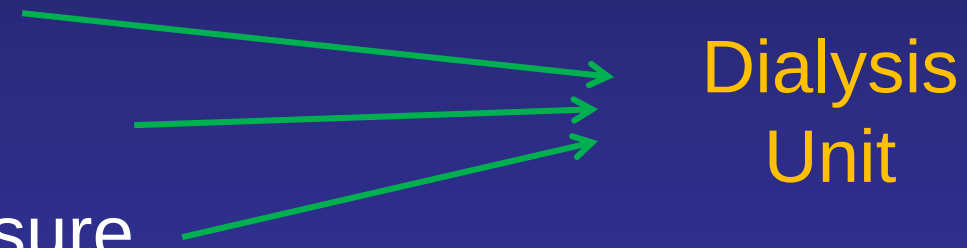
Angioplasty



Surveillance?

Surveillance

- Clinical Monitoring
  - Bleeding, difficult cannulations, arm swelling, chest wall collateralization, increased pulsatility, decreased thrill
- Surveillance
  - Access flow
  - Recirculation
  - Venous pressure
  - **Ultrasound**



National Kidney Foundation

DOQI™

Kidney Disease Outcomes Quality Initiative

Table 10. Access Flow Protocol Surveillance

Access flow measured by ultrasound dilution, conductance dilution, thermal dilution, Doppler or other technique should be performed monthly. The assessment of flow should be performed during the first 1.5 hr of the treatment to eliminate error caused by decreases in cardiac output or blood pressure related to ultrafiltration/hypotension. The mean value of 2 separate determinations (within 10% of each other) performed at a single treatment should be considered the access flow.

Graft

If access flow is <600 mL/min in a graft, the patient should be referred for fistulogram.
If access flow 1,000 mL/min that has decreased by more than 25% over 4 mo, the patient should be referred for fistulogram.

- Access flow decrease <600cc/min or < 1000cc/min with >25% decrease over 4 month prior
- Increased venous pressure during dialysis
  - >150mmHg or trend of persistent increasing pressure over time

Clinical stenosis

A Meta-analysis of randomized clinical trials assessing hemodialysis access thrombosis based on access flow monitoring: Where do we stand?

Timothy Muchayi, Loay Salman, Leonardo J Tamariz, Arif Asif, Abid Rizvi, Oliver Lenz, Roberto I. Vazquez-Padron, Marwan Tabbara, and Gabriel Contreras

Semin Dial. 2015 March; 28(2):E23-E29.

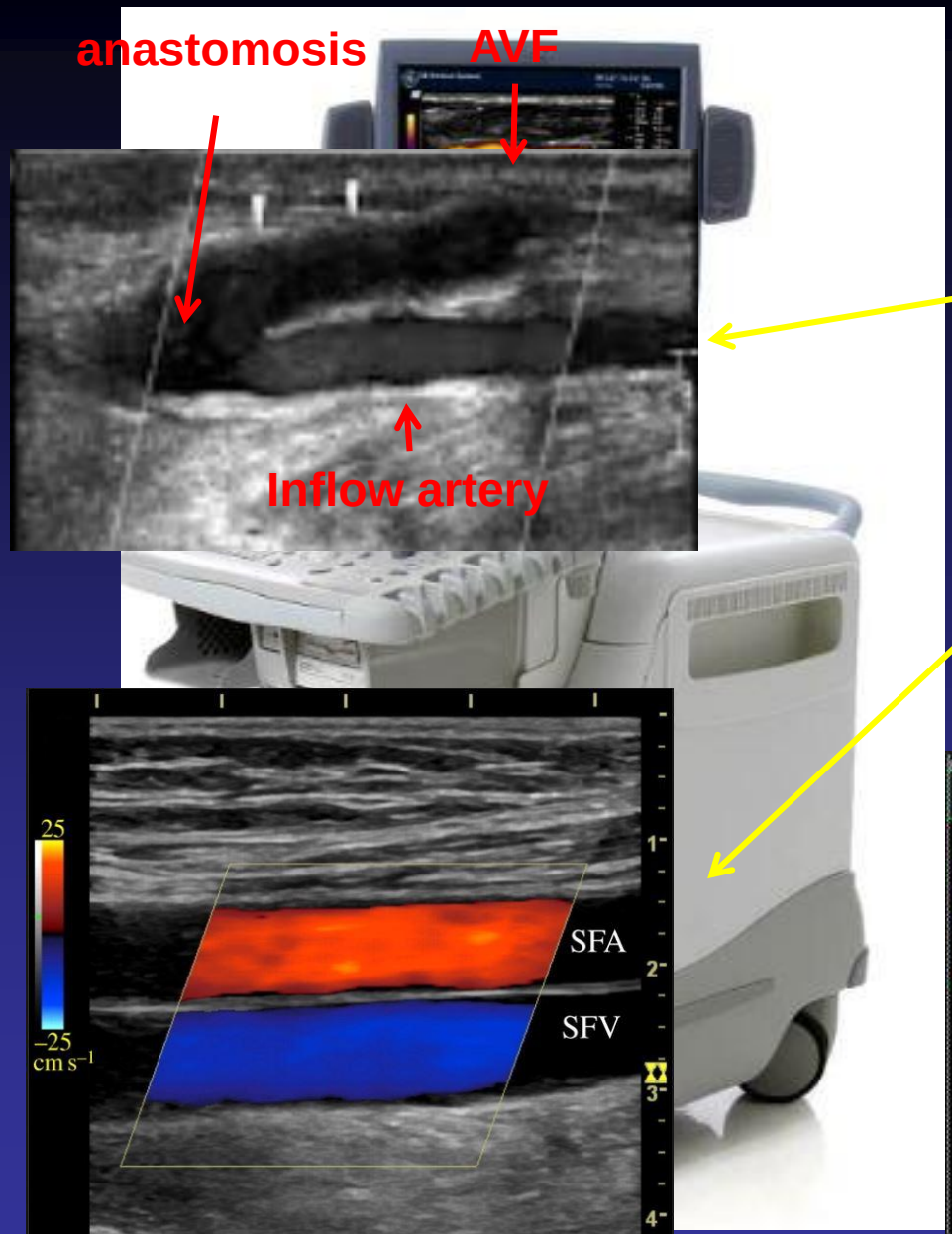
Our results add to the uncertainty of access blood flow monitoring as a surveillance method of hemodialysis accesses.

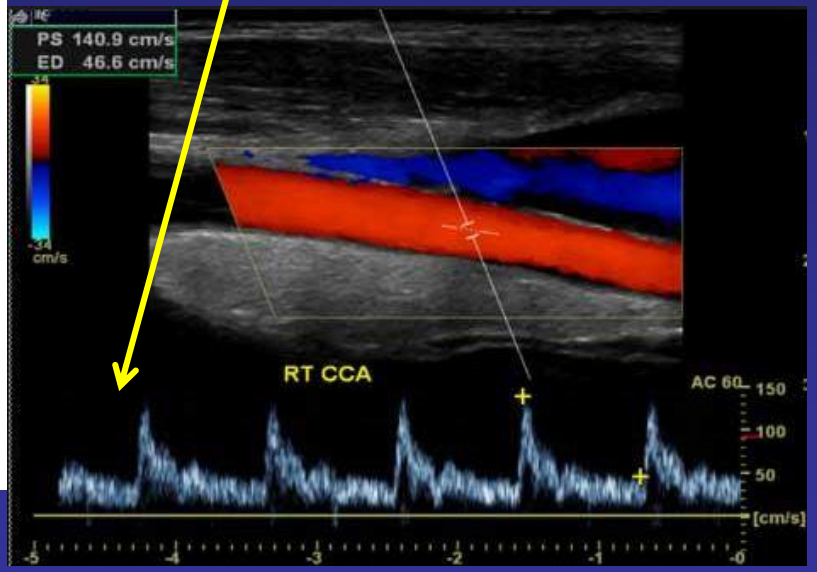
Ultrasound

B mode

Color Doppler

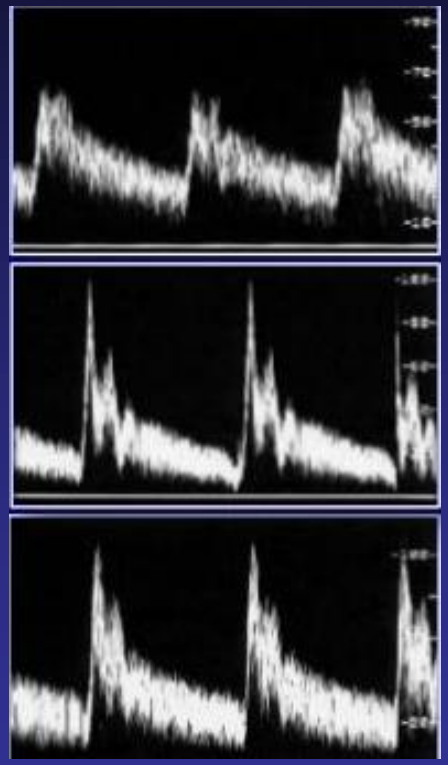
Spectral Doppler





Ultrasound - Carotid Circulation

Normal Doppler Spectra

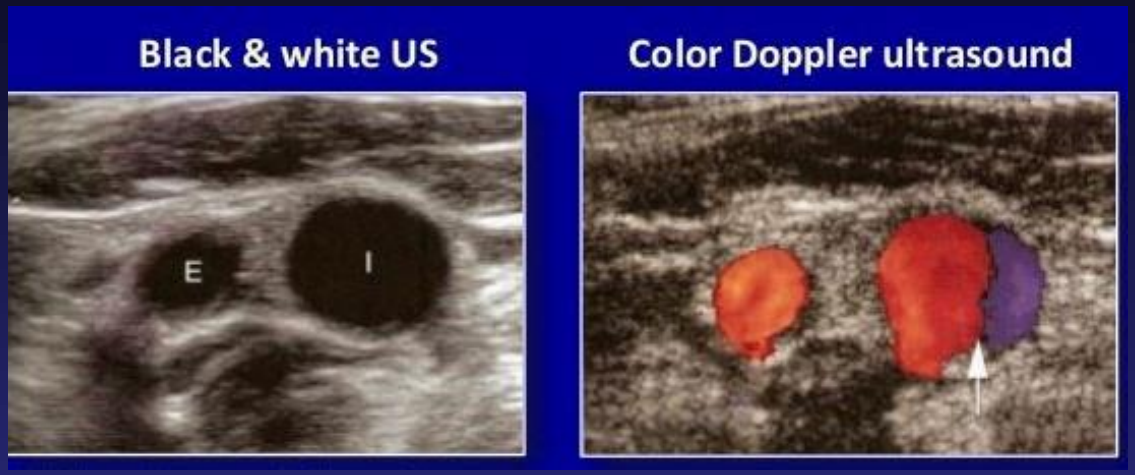


ICA

ECA

CCA

Zwiebel WL et al. 2000

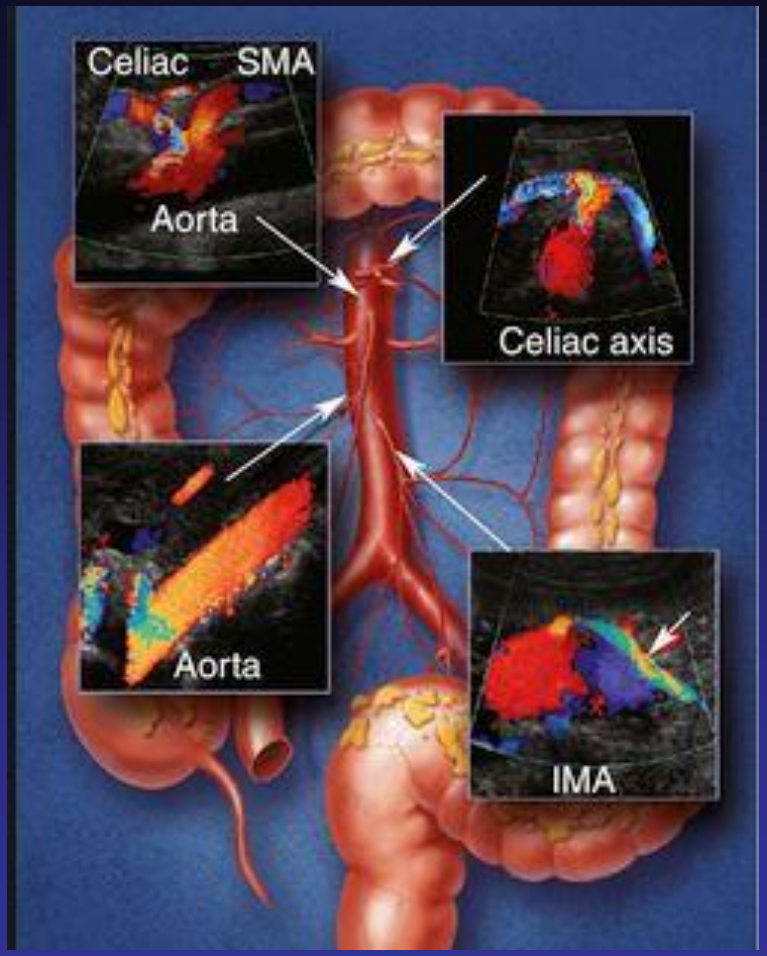


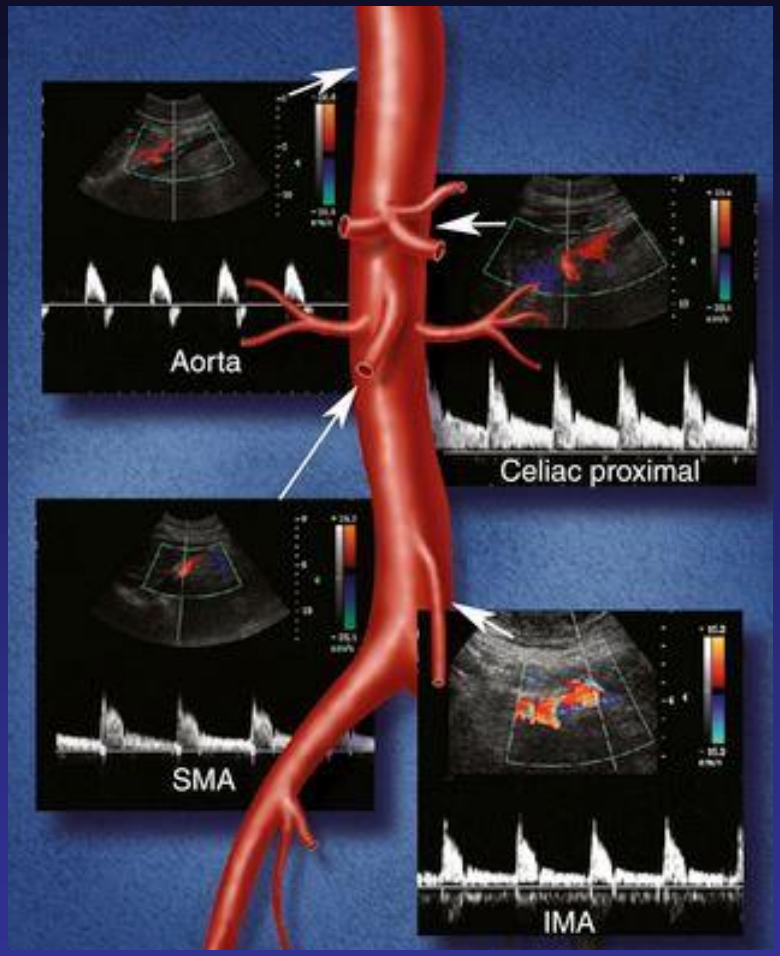
Thrush A. Harshorne et al. 2005

SRU Carotid Consensus Conference

	ICA PSV	Stenosis	ICA/CCA	ICA EDV
Normal	< 125	None	< 2.0	< 40
< 50%	< 125	< 50%	< 2.0	< 40
50 - 69%	125 - 230	≥ 50%	2.0 - 4.0	40 - 100
≥ 70 to Near Occlusion	> 230	≥ 50%	> 4.0	> 100

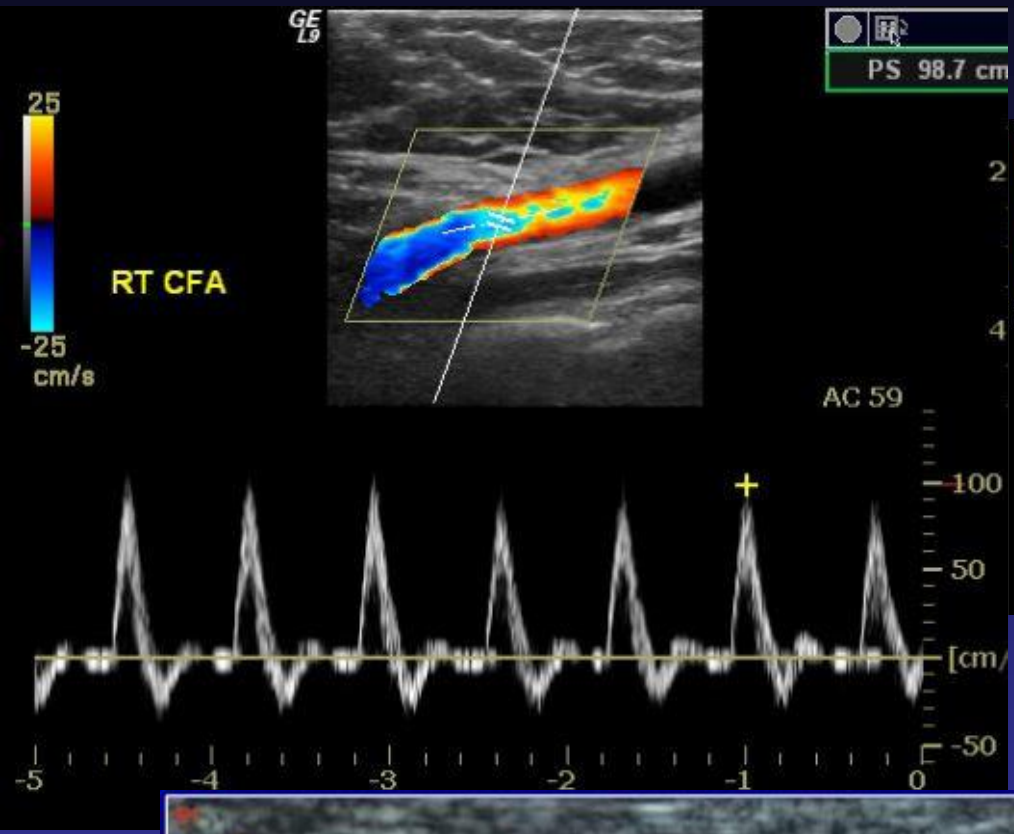
Ultrasound – Mesenteric circulation

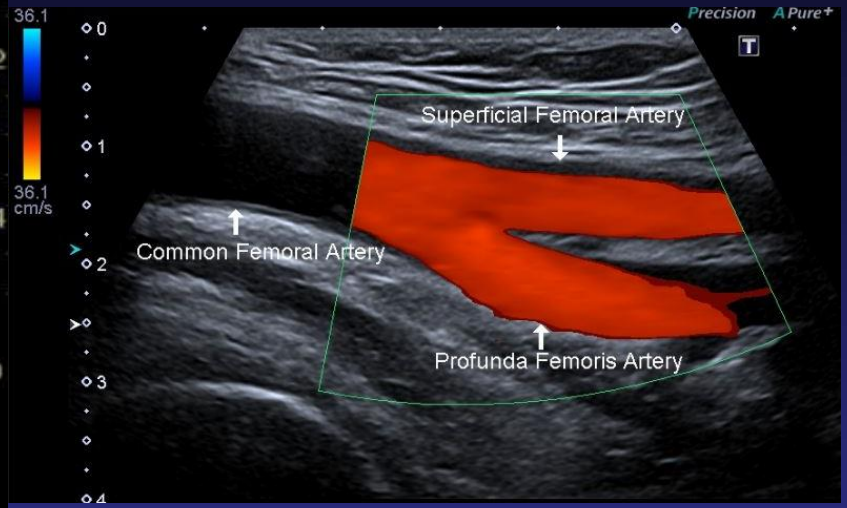


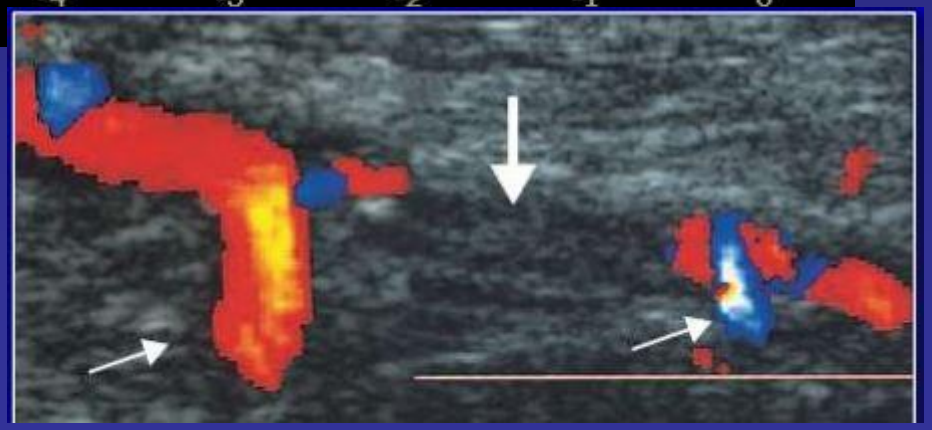


SMA: PSV > 275cm/s → 70% stenosis
Celiac: PSV > 250cm/s → 70% stenosis

Ultrasound – peripheral circulation

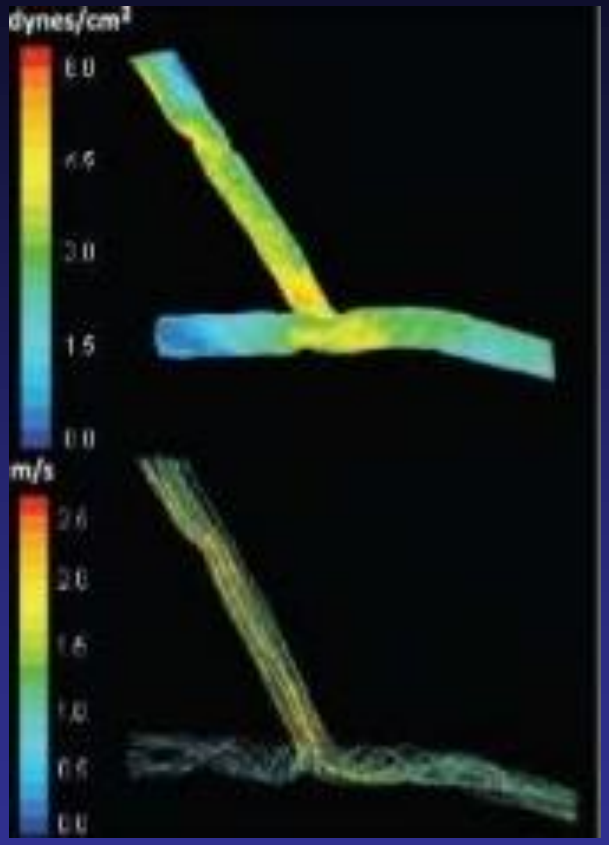






2011 ACC/AHA guidelines for management of PVD – ultrasound is useful in diagnosing location and severity of stenoses.

Ultrasound – Dialysis Circuit



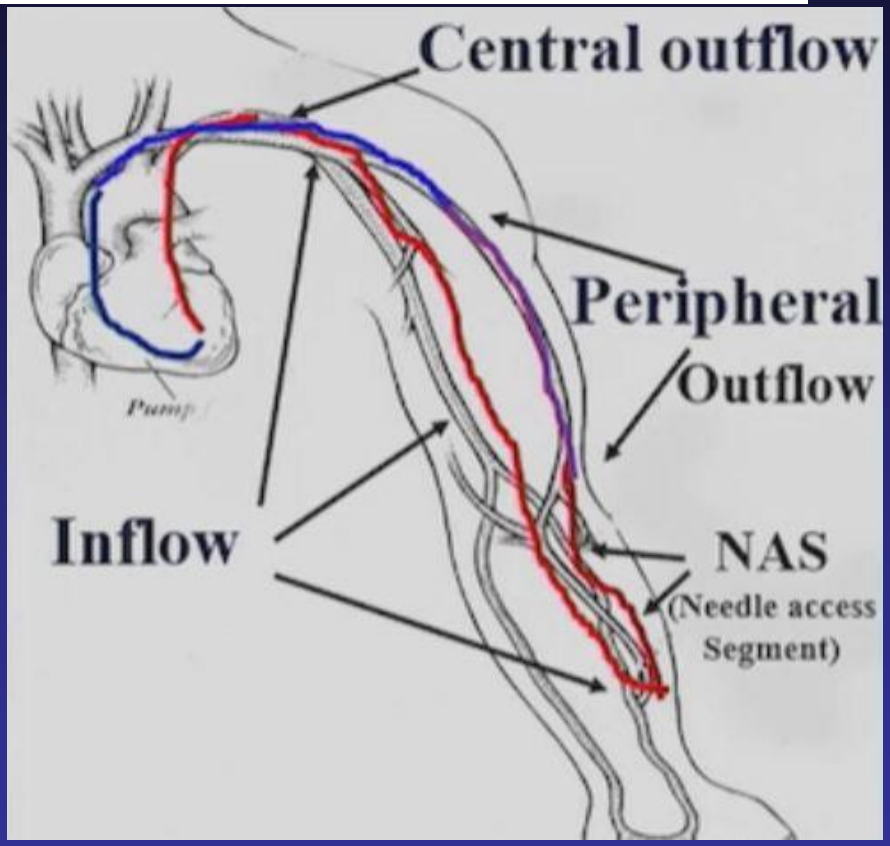
- Tortuosity
- Aneurysms/pseudoaneurysm
- Angulation of anastomosis
- Compliance of vein/grafts different from arteries
- Diameter of vein varies along its length

IAC
INTERSOCIETAL ACCREDITATION COMMISSION

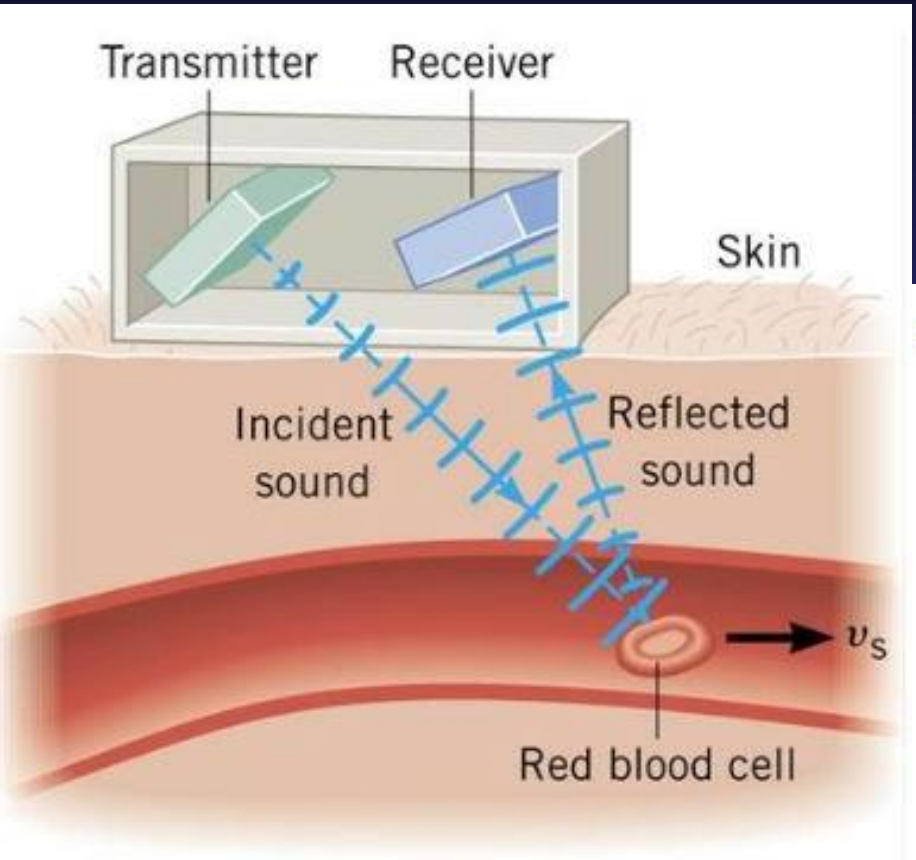
VASCULAR TESTING

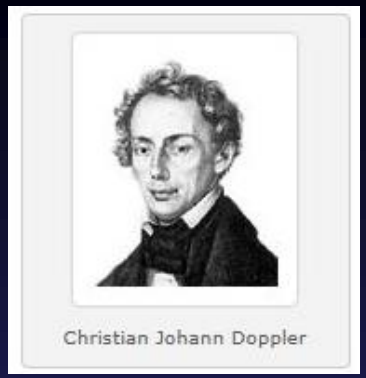
Improving health care through accreditation®

- **Grayscale/color doppler**
  - inflow
  - anastomosis
  - outflow
  - +/- subclavian vein
- **Spectral waveforms and velocity**
  - Inflow
  - Anastomosis
  - proximal
  - outflow (beyond anastomosis
  - subclavian vein
- Blood **flow volume** from at least one site.
- Abnormalities require additional images, waveforms, velocity measurements.



Velocity





Christian Johann Doppler

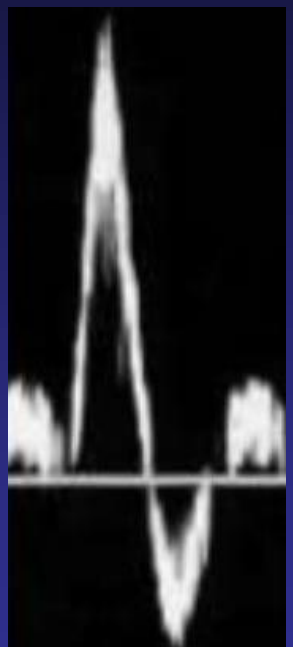
- Velocity is given by Doppler equation..

$$V = c f_d / 2 f_o \cos \theta$$

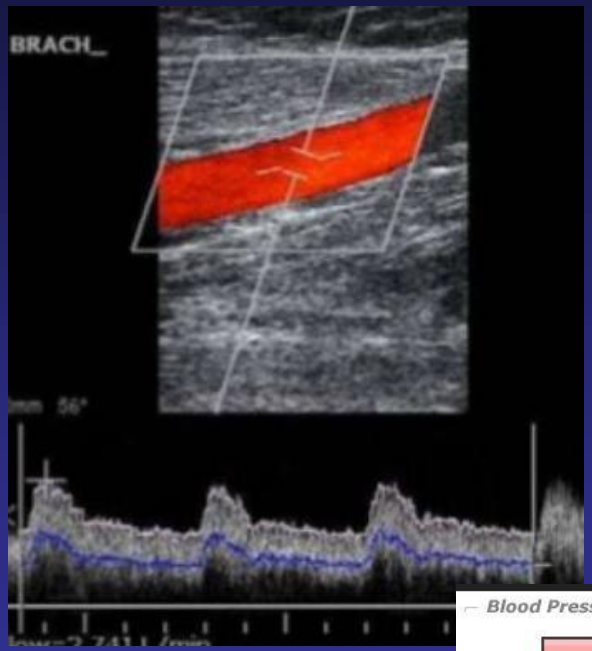
  - V – target velocity
  - C – speed of sound in tissue
  - f_d –frequency shift
  - f_o –frequency of emitted U/S
  - θ - angle between U/S beam & direction of target velocity(received beam , not the emitted)

Inflow artery

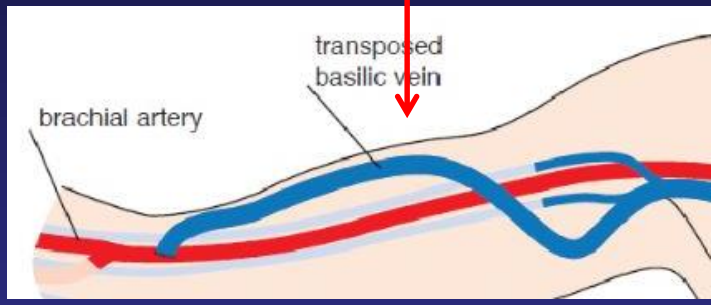
Normal brachial artery:
- Triphasic
- High resistance

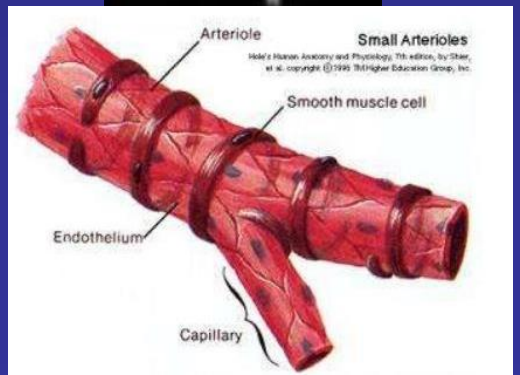


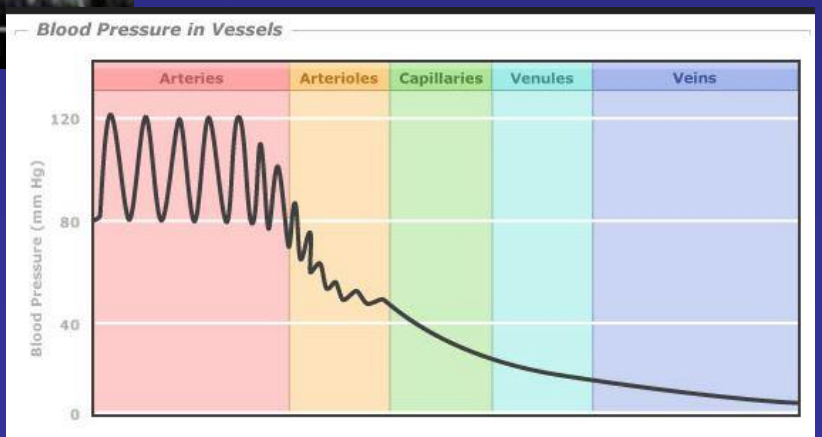
Brachial artery – after access creation
- Monophasic flow
- Large diastolic component



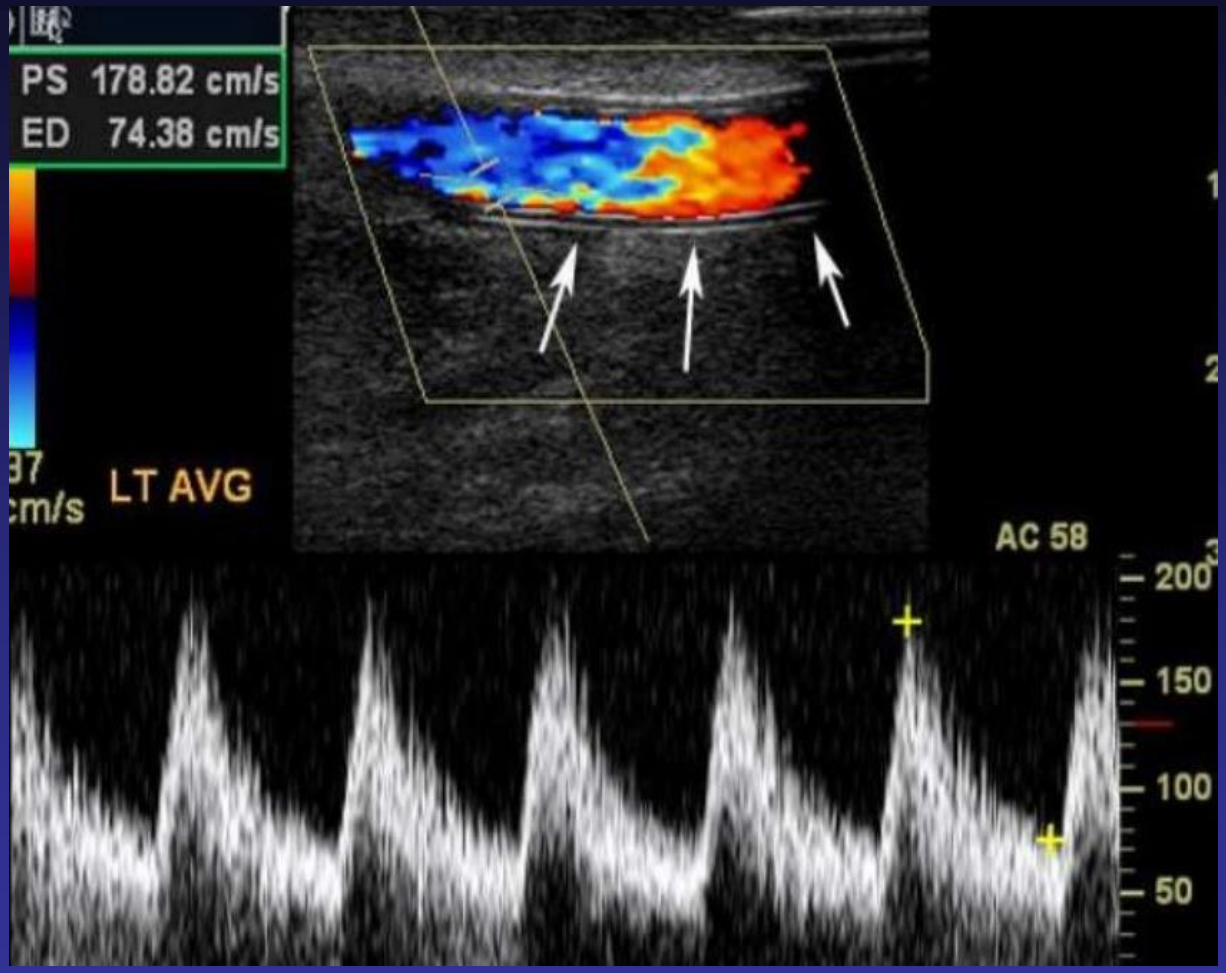
Low resistance venous outflow (AV access)





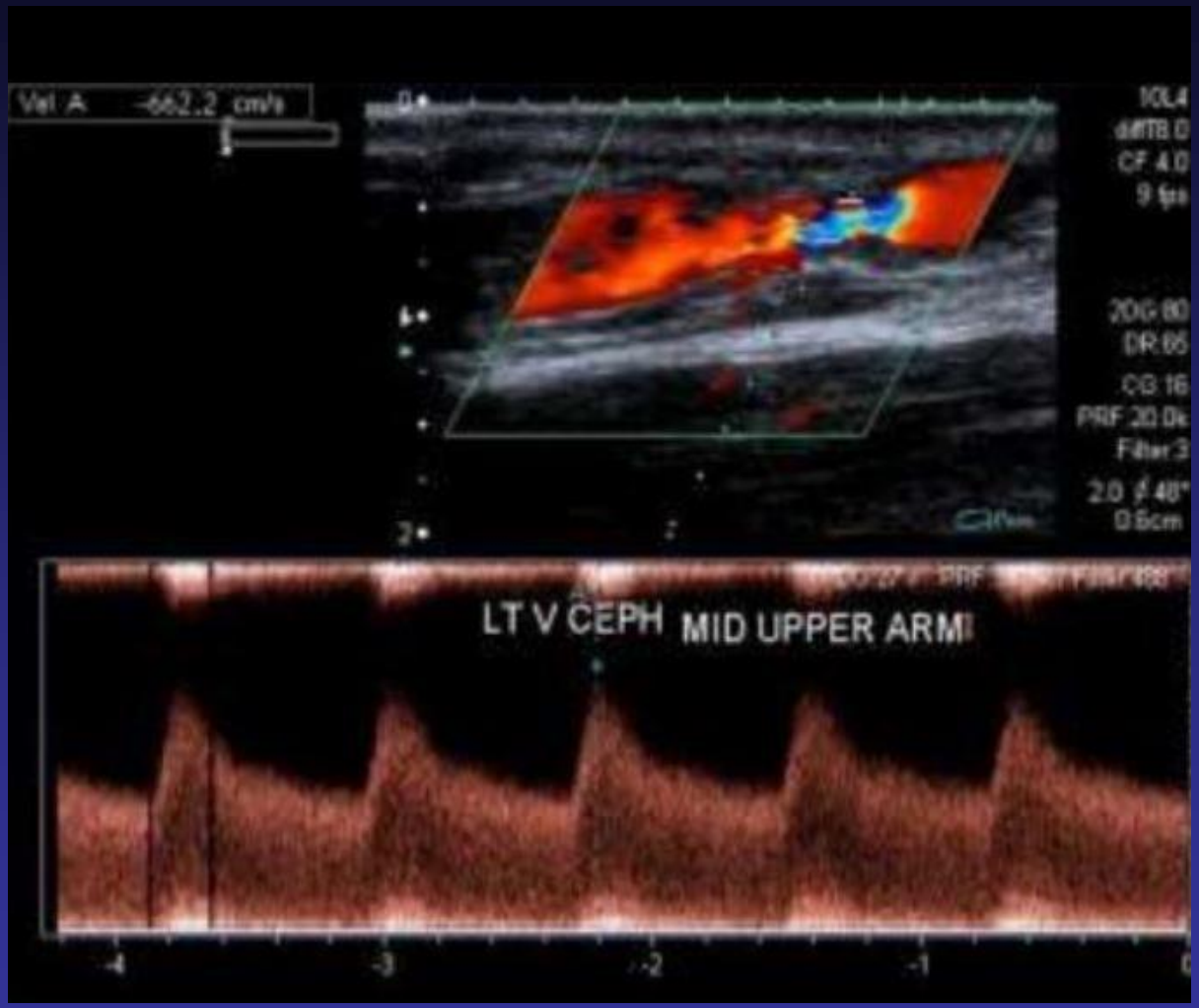


Normal Velocity



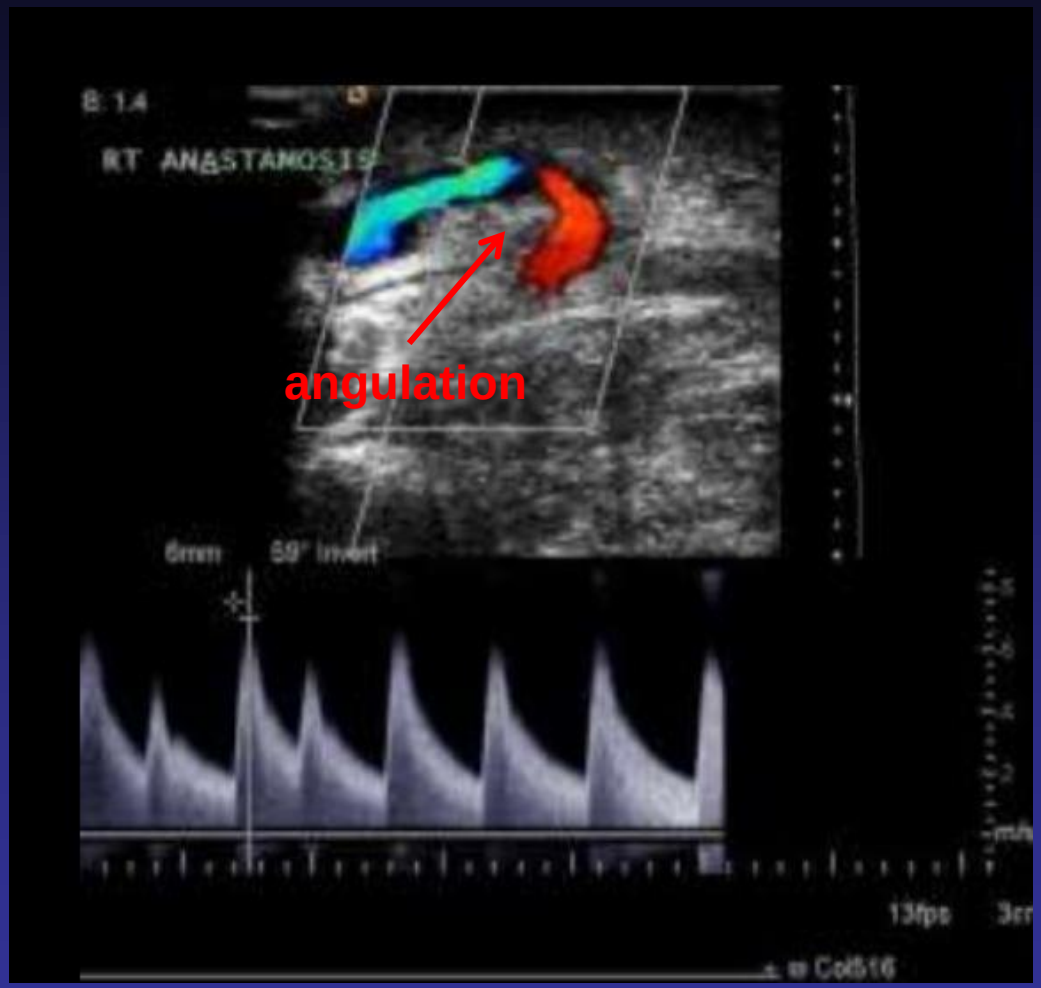
100-300cm/s

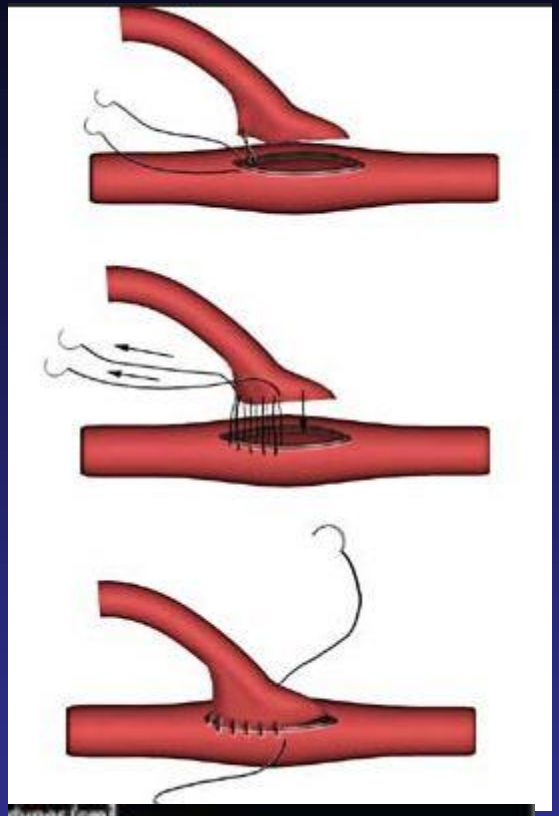
Stenosis in AVF

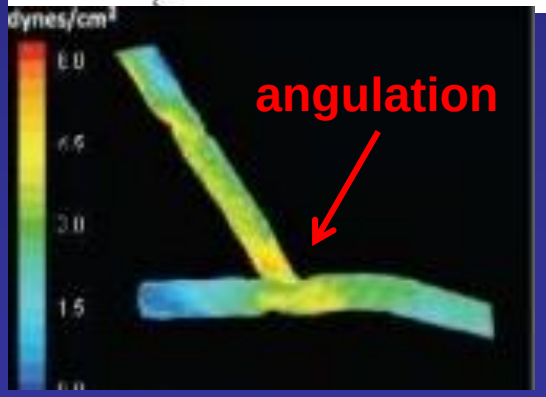


PSV > 400-500 cm/s suggest > 50% stenosis

Stenosis at anastomosis







PSV > 600 cm/s suggest stenosis?

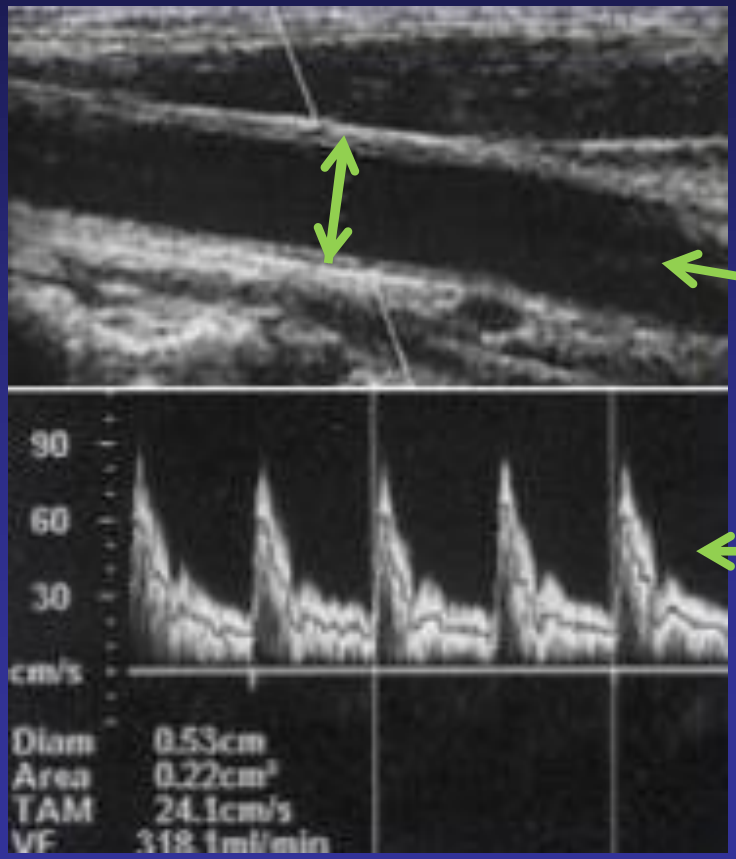
Occlusion of AVF

Triphasic brachial artery waveform in association with an occluded brachiocephalic fistula

Occlusion of brachiocephalic fistula. Thrombus within the vein

Volume Flow

Volume (cc/min) = Area (cm2) x Velocity (cm/s)

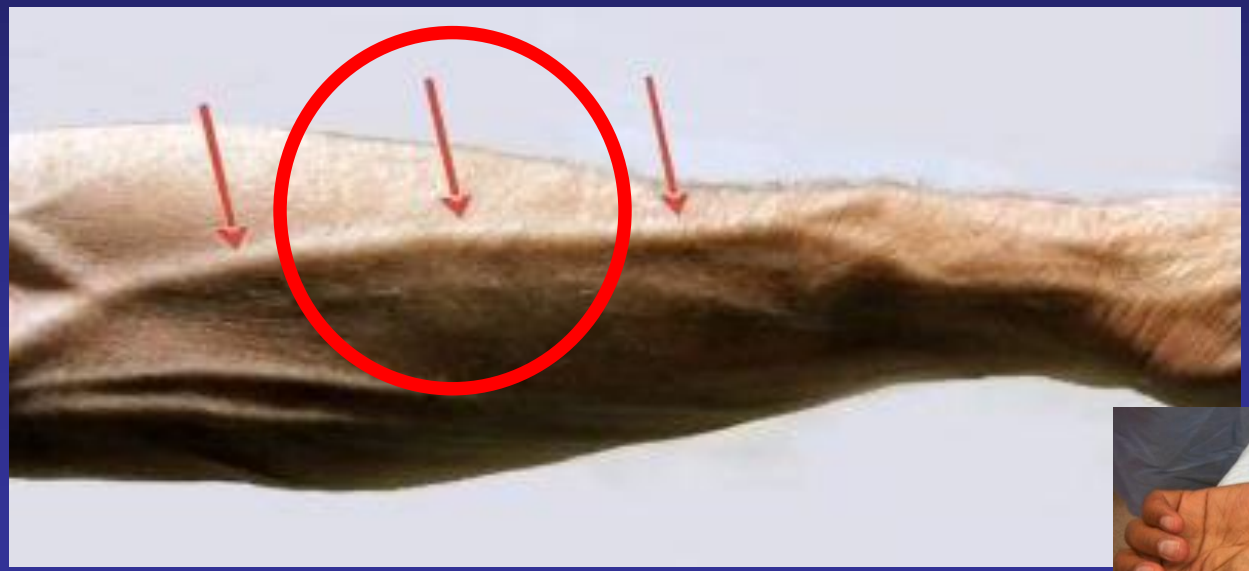


Diameter (longitudinal)

velocity

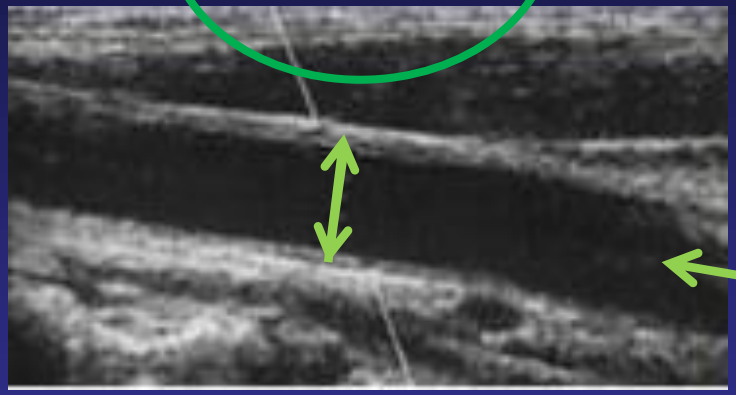
Volume flow

- Straight segment
- 5cm away from anastomosis/stenoses/major abnormalities
- Some recommend measuring at brachial artery



Volume Flow

Volume $_{(cc/min)}$ = Area $_{(cm2)}$ x Velocity $_{(cm/s)}$ x 60

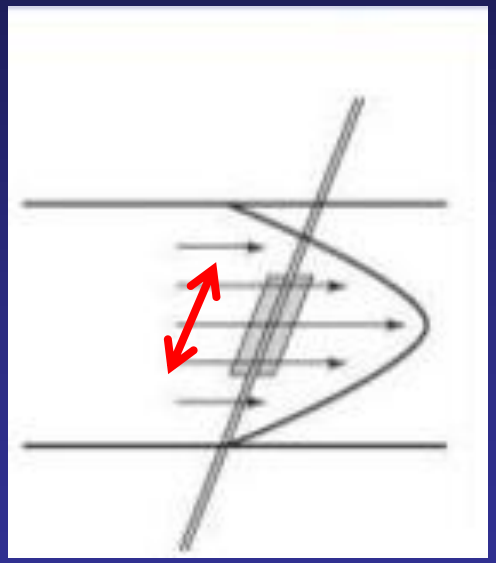


Diameter
(longitudinal)

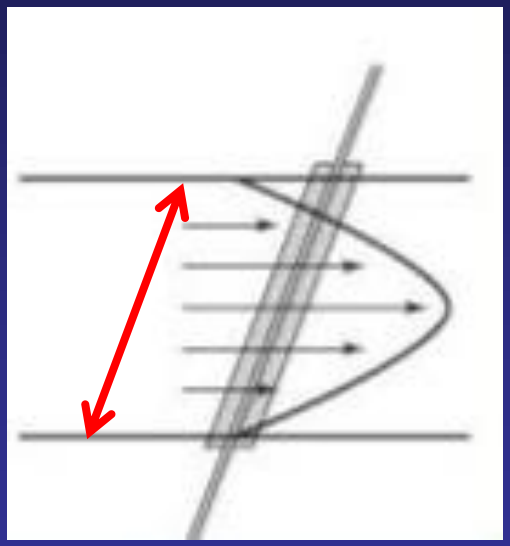
- Longitudinal view
- Systole
- Measure in non-aneurysmal area

Volume Flow

Volume (cc/min) = Area (cm2) x Velocity (cm/s) x 60



Sample volume needs to include the whole diameter of the vessel and not just the middle

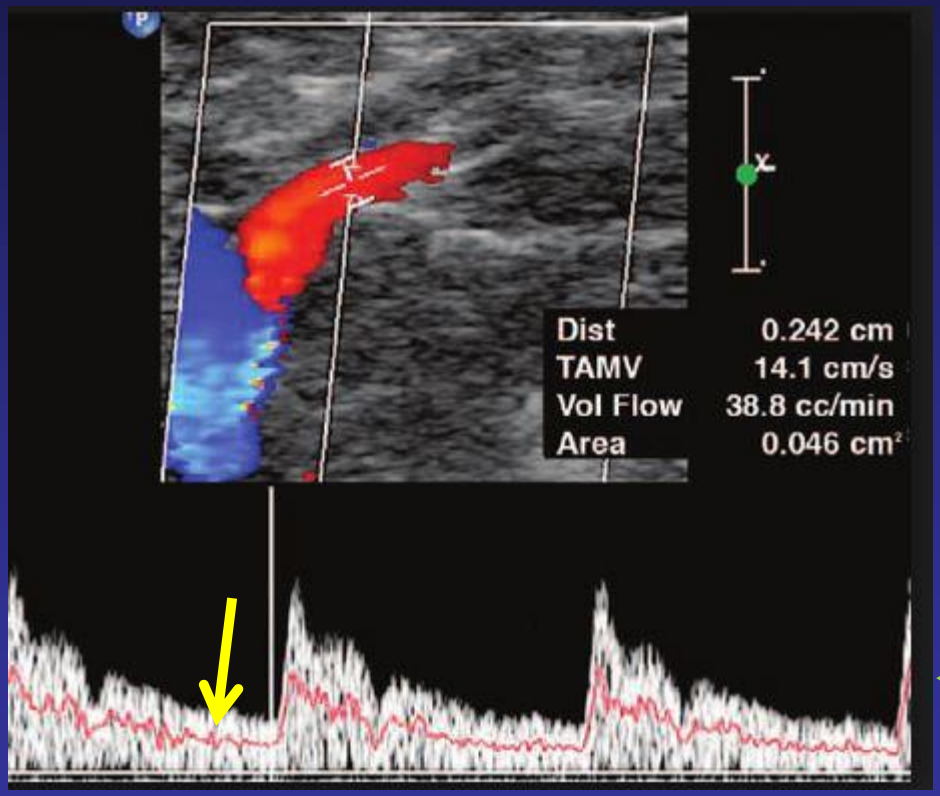


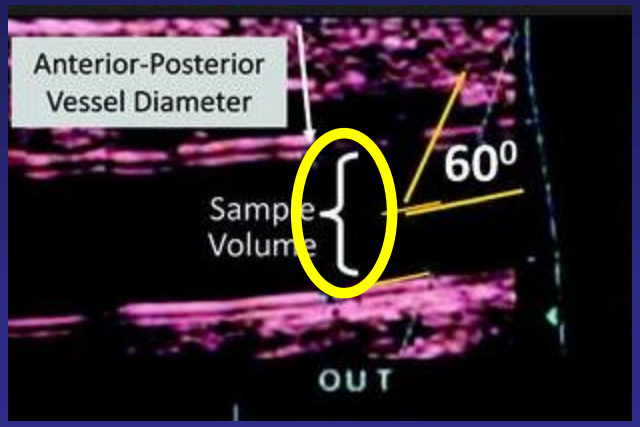
Parabolic flow

- rbcs in the middle of the vessel travel faster
- rbcs in at the periphery of the vessel travels slower

Volume Flow

Volume (cc/min) = Area (cm2) x Velocity (cm/s) x 60





velocity

Mean velocity throughout the blood vessel average over a few cycles.

Volume Flow

A-V access for hemodialysis	Flow volume (mL/min)
Normal value	
Forearm fistula	600 – 800
Upper arm fistula	900 – 1200
Mature fistula	≥ 500
High risk of occlusion	
AVF	< 300
Graft	< 650

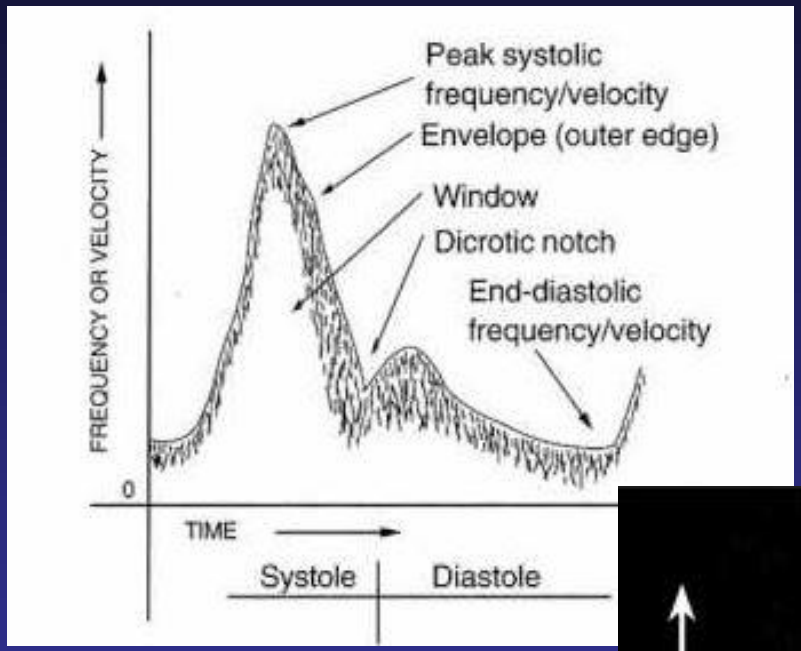
Schäberle W. Ultrasonography in vascular diagnosis.

Conclusion

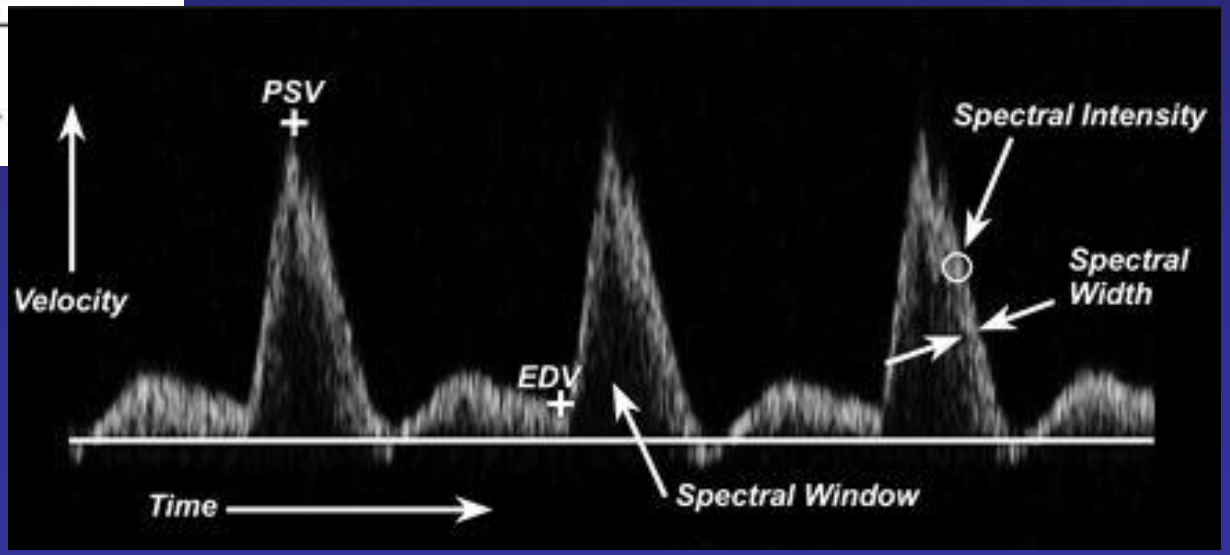
- Ultrasound can be very important in the surveillance of dialysis access.
- When used accurately, can identify stenoses.
- Need to better understand and come up with appropriate criteria to indicate stenosis.
- Probably cannot be used in isolation and clinical monitoring is important.

Thank You

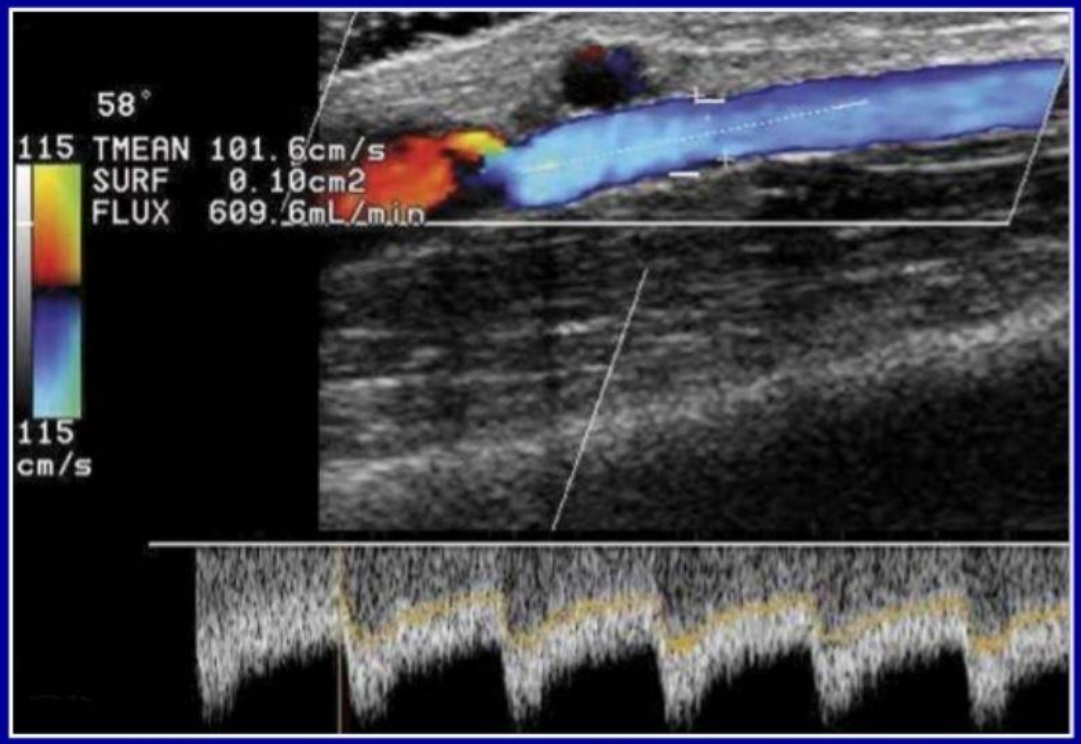
Peak systolic velocities



Normal duplex of peripheral arteries. High resistance waveforms. High resistance flow leading to triphasic waveforms.



Measurement of flow volume /Feeding artery



Diameter perpendicular to axis

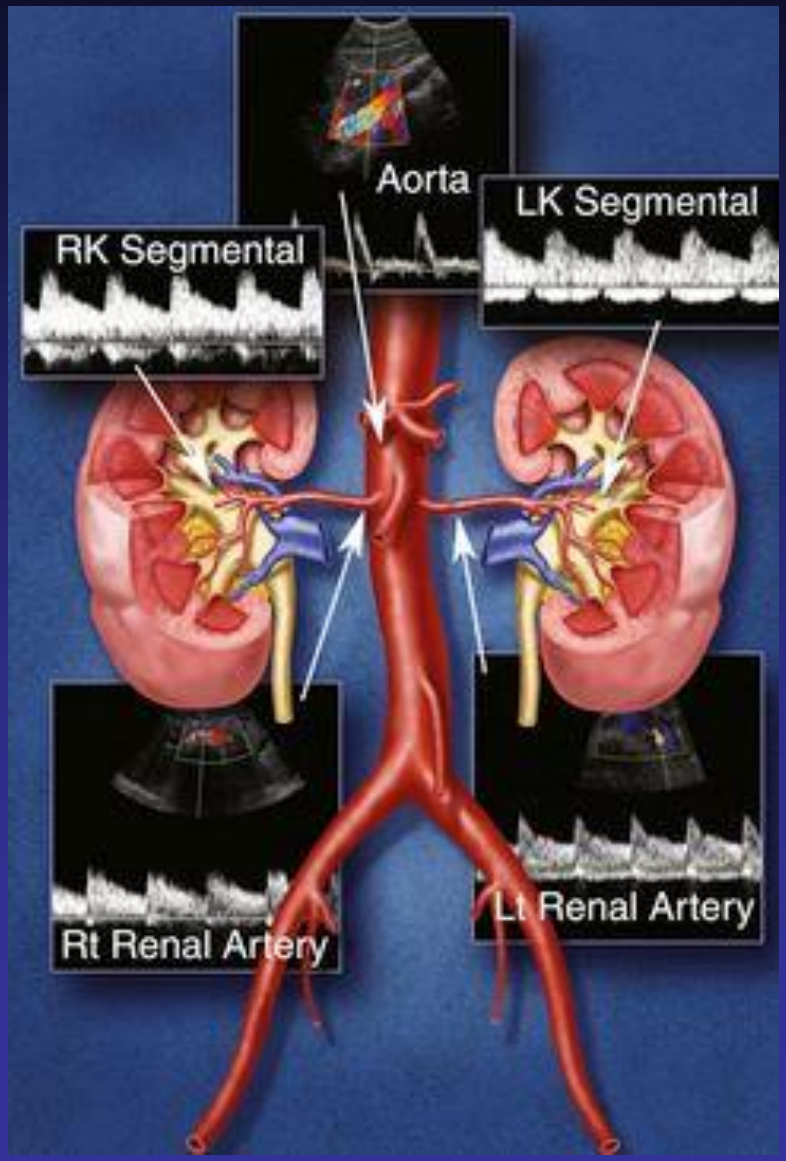
Sample volume across width of vessel

Sample volume in same site of diameter measurement

Correct estimation of angle

TAMV: 3 – 5 cardiac cycles

Ultrasound – Renal Circulation



Renal guidelines as listed.