Bypass Graft Surveillance

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Disclosures

Non relevant consulting:

- Boston Scientific
- Humacyte

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Objectives

- Normal and abnormal arterial studies
- Understand the reasoning for bypass graft surveillance
- Techniques for scanning bypass grafts
- Understand the time to intervene and identification of at-risk bypass grafts

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Vascular Lab

- Diagnosis
- Intervention
- Surveillance pre and post procedure

Diagnosis: Arterial Insufficiency

- Management determined by:
  - History, symptoms, exam
  - Clinical status of patient
- Tests help map the disease
  - Angiography
  - MRA / CTA
  - Duplex in selected centers

Aorto-iliac Disease

Downstream Evaluation

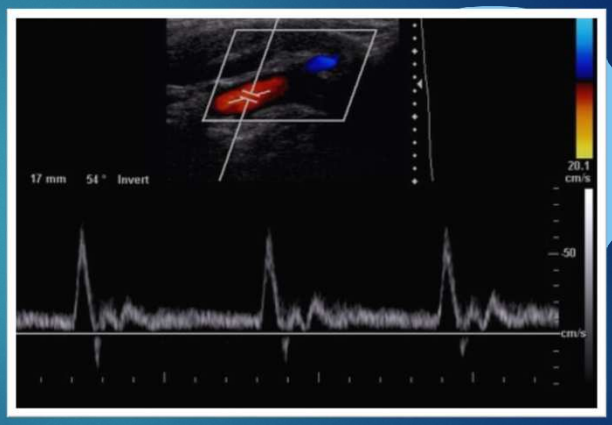
- Monophasic or “disturbed” CFA flow:
  - 38% were abnormal with an aortic lesion
  - 39% were abnormal with a common iliac lesion
  - 69% were abnormal with an external iliac lesions
  - 100% sensitive for occlusions

Lewis et. al., JVT 18(6): 337, 1994

Diagnosis: Peripheral Artery

Normal waveform is multiphasic.

Rapid systolic acceleration followed by transient flow reversal.



Truth about arteries

- Velocities are different for rest and exercise
- Normal velocity varies along and between vessels
- Multiple vessels may be stenotic
- Occlusions are of variable length
- Collaterals may be present

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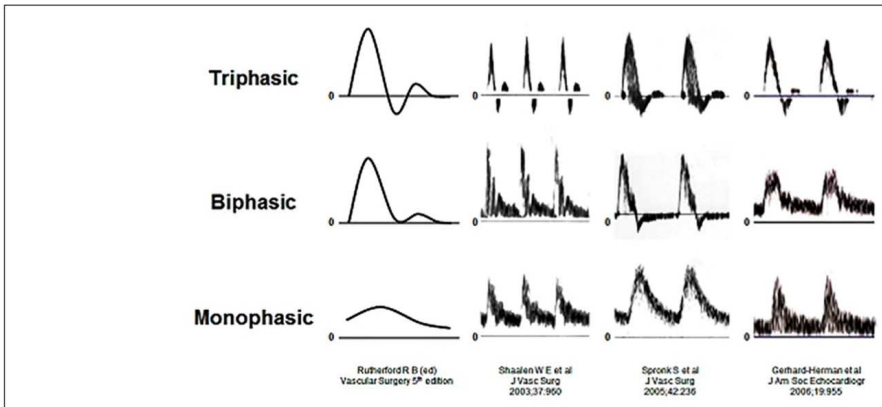

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Table 3. Arterial Waveform Modifier Terms.

Waveform characteristics and definitions	Waveform figure
Rapid upstroke Nearly vertical slope or steep rise to peak systole. Acceleration time (AT) <140 ms has been used for the common femoral artery (measured from start of systole to mid-systole).[46]	
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.[48]	
Sharp peak Sharp, single, and well-defined peak often with maximum velocity within range of the artery being interrogated	
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	
Staccato A very high-resistance pattern with short "spike" of velocity acceleration and deceleration followed by short and low-amplitude diastolic signal reflecting low antegrade flow	
Dampened *Previous Alternate Terms: Parvus et tardus, Attenuated, Blunted* Combined finding of an abnormal upstroke (delayed) and peak (broad), often with decreased velocity	

2020 Waveform Criteria JVU

Bypass Graft Surveillance

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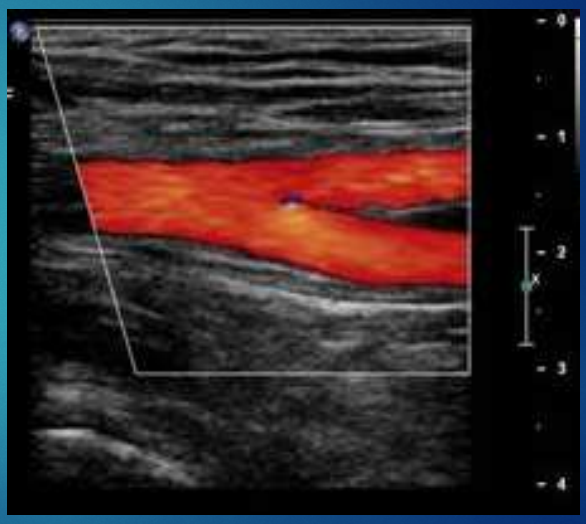
- Autogenous vein is the preferred conduit for open surgical reconstructions in the lower extremity that require bypass grafts.
- When placed in the arterial system, vein grafts can develop stenotic lesions that lead to graft thrombosis and recurrent symptoms of lower extremity ischemia
- Combination of clinical assessment, measurement of ankle-brachial index (ABI), and duplex ultrasound (DUS) scanning has been recommended to identify lesions that threaten graft patency and to facilitate selective interventions to maintain graft function.



Bernoulli and Stenoses

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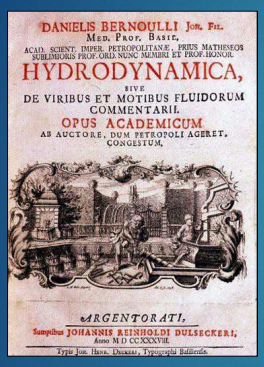
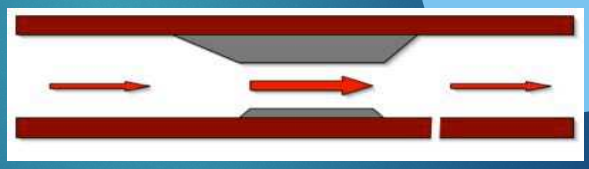


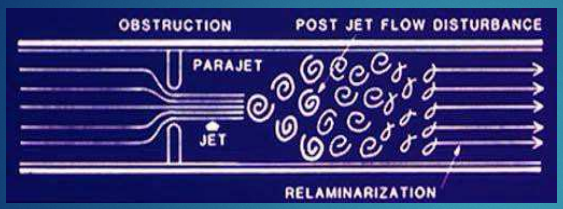
Pre-stenosis	Stenosis	Post-stenosis
High energy	High kinetic energy	Low energy (turbulence)
Normal or low velocity	High velocity	Low velocity



Higher pressure **Lower pressure**

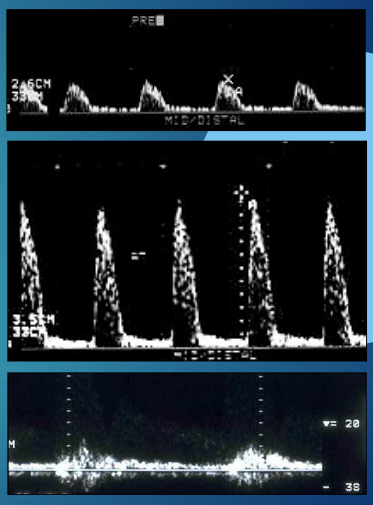
Very low pressure

3 parts of a stenosis



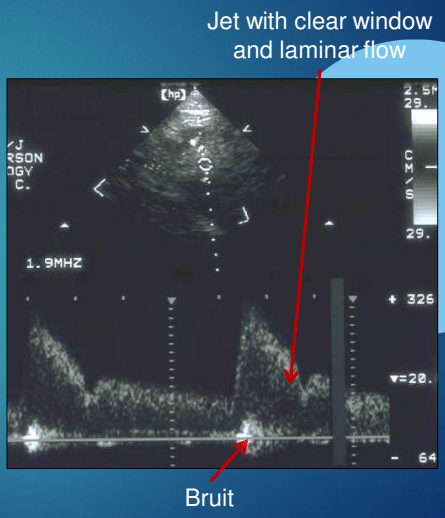
1. Before the stenosis
2. Jet in the stenosis
3. Post-stenotic turbulence

1
2
3



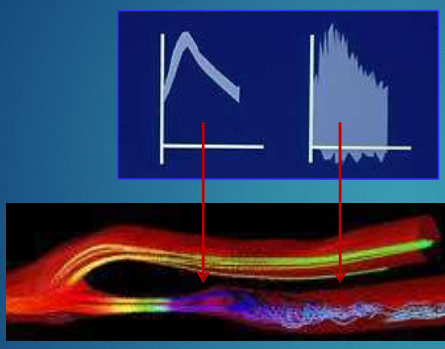
In a stenosis

- Systolic velocity increases first
- Diastolic velocity increases if more severe
- Stenotic jet is laminar



Beyond a stenosis

Velocity decreases and shape changes



Disturbed flow distal to stenosis
Spectral broadening, loss of well-defined spectral edge, forward & reverse flow.

Peak Systolic Velocity Ratio

$PSV_{ratio} = V_r$ (velocity ratio)

PSV_{jet} / $PSV_{proximal\ segment}$

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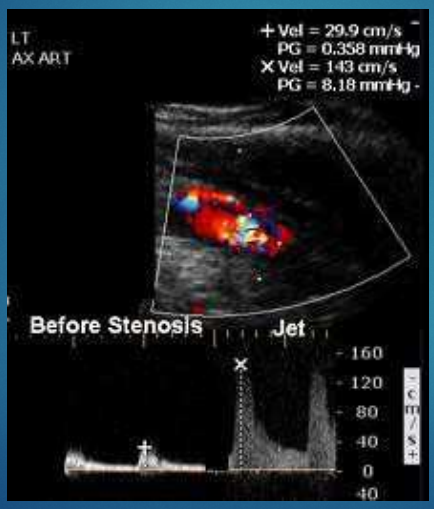
PVS Ratio = 143/30 = 4.8



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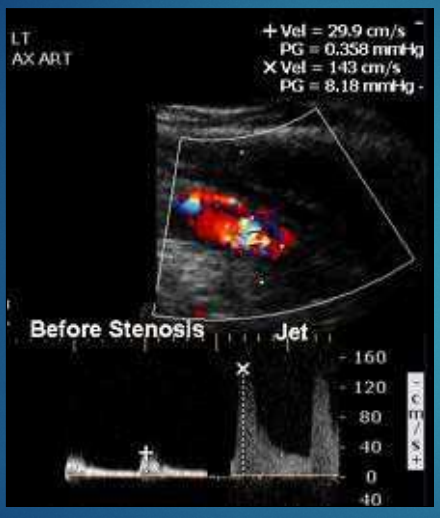
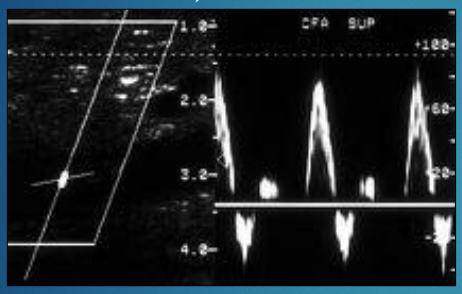
Pre- JET Post-stenosis



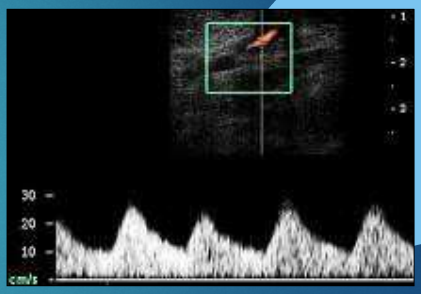
Pre- and post-stenosis

Normal, no stenosis



Multiphasic

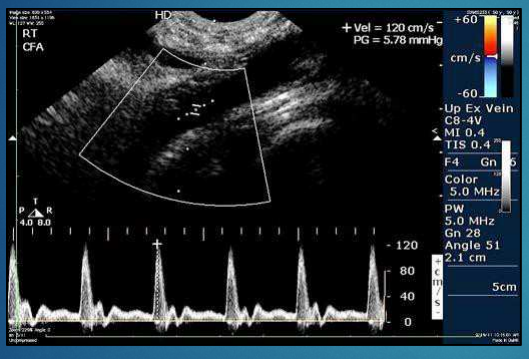
Distal to stenosis

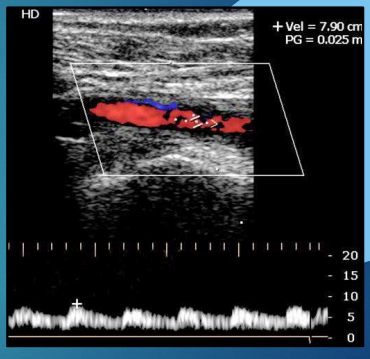


Monophasic

Tardus Parvus

Weak and delayed





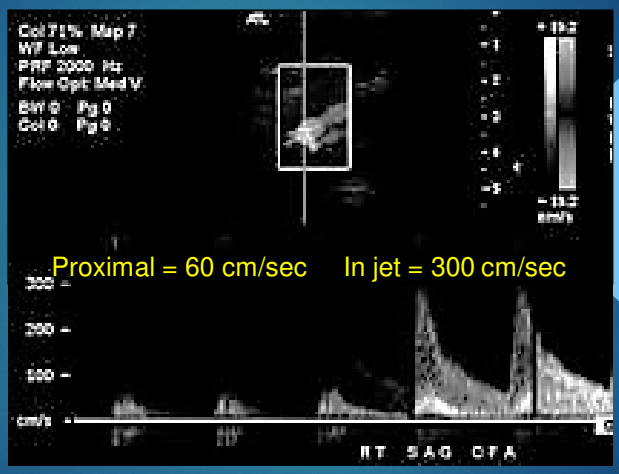
Arterial Stenosis Criteria

Stenosis	PSV	EDV	PSV ratio	Post-Stenosis
None				
1-19	< 150	< 40	< 1.5	Triphasic
20-49	150-200	< 40	1.5-2	Triphasic
50-75	200-300	< 90	2-3.9	Turbulence distal, monophasic
> 75	> 300	> 90	> 4	Turbulence distal, monophasic Dampened, low PSV downstream
Occlusion	none			Look for reconstitution

Study Technique

- Color duplex is required
  - Involved study over long segments
  - Color to localize disease and occlusion
    - Color change, narrowing, aliasing
  - Spectral Doppler for quantification
- Gray scale
  - Turn off color at suspected stenosis
  - Record character of plaque

"Walk Through" Stenosis



Occlusion

- Pre-Occlusive "thump" – proximal waveform changes
- No color filling
- Doppler silent
- Intraluminal echos
- Collaterals?
- Post occlusion changes
- Spectral sample may miss a high-grade stenosis
  - Color/power mode can help find lumen
  - Color/power less sensitive so use all modalities

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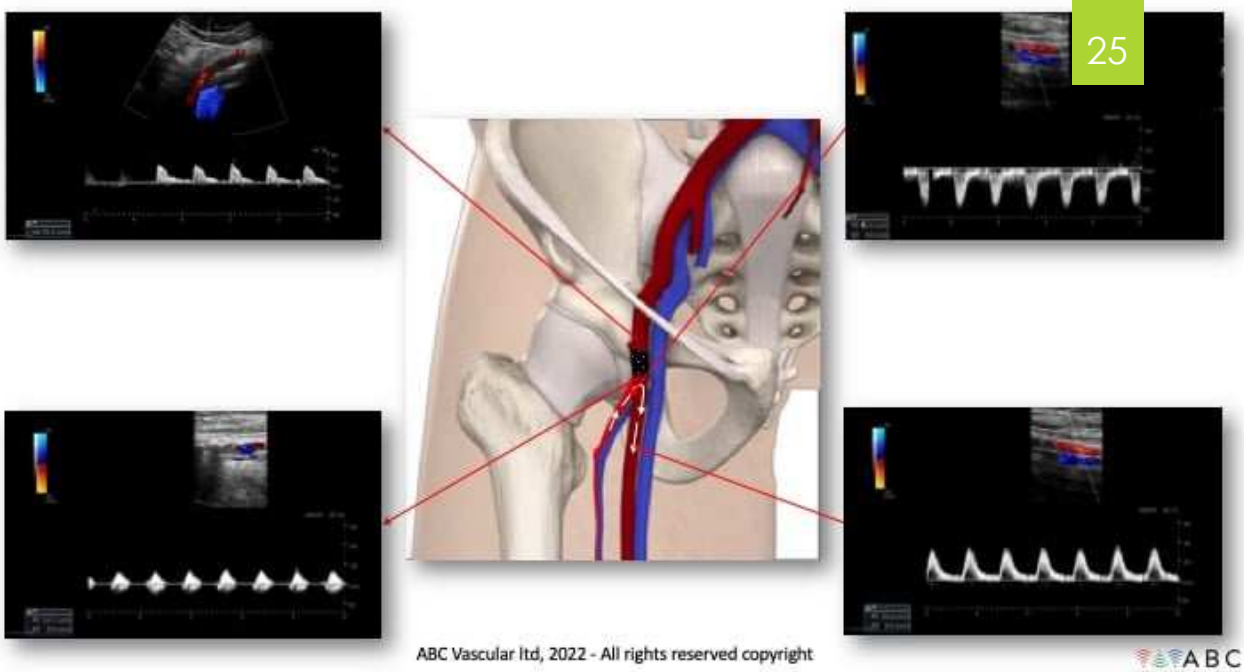

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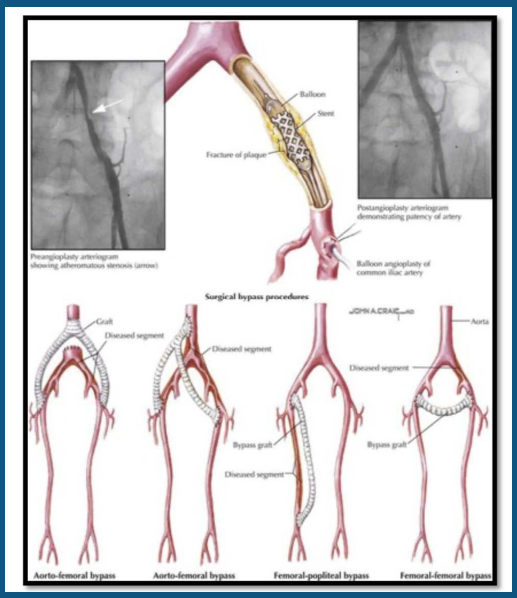

Bypass Graft Interrogation

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- Need to know the type of graft / procedure performed
- Autologous vein is the most durable conduit for bypass
- No special preparation is required for a graft surveillance examination.
  - Complete duplex scan of the graft and the inflow and outflow arteries.
  - Ankle and arm blood pressures will be measured using inflatable cuffs and an ultrasound Doppler flow detector.
  - A complete study usually takes 30 to 90 minutes.
- Vein bypass grafts are evaluated at three-month intervals for the first year after surgery. Surveillance studies are done every six months in the second year, then annually thereafter. Shorter interval surveillance may be recommended if an irregularity is found

Bypass Protocol

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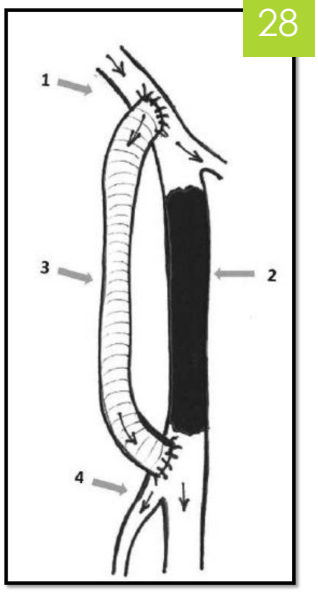
- Inflow arterial flow
- Proximal anastomosis
- Proximal, Mid, Distal Graft
- Distal Anastomosis
- Outflow



Bypass graft evaluation

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- Stenosis / occlusion
  - Involving graft or atherosclerosis in nearby native arteries
- Retained valve cusps
- A-V fistula in vein graft
- Perigraft collections

Graft failure

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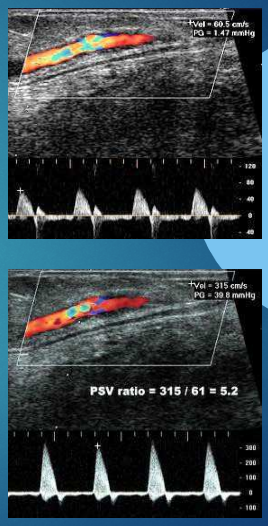
- Immediate failure usually technical
- 4-10% fail in first several days
- 12% fail in first year, then 2-4% per year
  - Myointimal hyperplasia within 2 years
  - Recurrent disease in adjacent vessels after 2 years
- 11-33% of saphenous vein grafts develop lesions, 75% within the first year
- Aneurysmal degeneration

Graft exam technique

- Look for high peak systolic velocity or jet
- PSV jet / PSV in proximal segment
  - PSV > 300 cm/sec or ratio > 3.5 prone to fail
- Average PSV from 3-4 sites along graft
- Low-flow graft at high risk of thrombosis (<45 cm/sec)
- Character of runoff flow (multi- or monophasic)
- Cannot compare native vessels to graft



Stents/Grafts are <u>not</u> OEM

(original equipment manufacturer)

- Tubular strut for a living vessel, but……
  - <u>Not</u> alive
  - <u>Not</u> normally-compliant, expansile, or pliable
  - <u>Limited warranty</u>
    - (40% 1-year stenosis)
    - 87% assisted primary patency in 2 years
    - 94% secondary patency in 2 years
  - <u>No</u> refund, <u>no</u> return, original owner only

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Interrogation techniques – SFA

- Peak systolic velocity (PSV) measured in disease-free segment 3 cm proximal to stent (or nearest normal)

$$PSV_{ratio} = \frac{\text{Max stent velocity}}{\text{disease-free SFA}}$$

Baril DT et al. J Vasc Surg 2009;49:133-139

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SFA Stent Evaluation

- Up to 60% stenosis
  - Normal PSV and ratio
  - Decrease in ABI < 0.15
- Greater than 50% stenosis
  - PSV ≥ 190 (88% sens, 95% spec)
  - Ratio ≥ 1.5 (93% sens, 89% spec)
- Greater than 80% stenosis
  - PSV ≥ 275 and Ratio ≥ 3.5 (74% sens, 94% spec)

Velocity Criteria (Ratio)

<50% diameter reduction	< 2:1
50-75% diameter reduction	2:1
>75% diameter reduction	3:1
Occlusion	No flow

Bypass Criteria

- Apply velocity ratio
- Mean graft velocities < 45 cm/sec indicates impending graft failure
- Most graft failure is due to inflow / ouflow stenosis

Category	Peak systolic velocity (PSV) (cm/sec)	Velocity Ratio	Average velocity within graft (cm/sec)	Change in ABI compared to previous Evaluation
High risk	>300	>3.5	<45	>0.15
Intermediate risk	180-300	>2.0	>45	<0.15
Low risk	<180	<2.0	>45	<0.15

Armstrong and Bandyk in Rutherford's Vascular Surgery 7th edition. Cronenwett and Johnston eds. 2010.Vol 1. Pages 235-255.

Surveillance

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- Primary goal is graft patency
- New or changes in limb ischemia symptoms
- Measurement of ankle or toe systolic pressure
- Duplex ultrasound imaging of the bypass graft
- The testing frequency should be individualized to the patient, type of arterial bypass, and duplex scan findings.
- Graft surveillance should focus on the identification and repair of critical stenosis (peak systolic velocity exceeding 300 cm/s, and peak systolic velocity ratio across the stenosis exceeding 3.5) correlating with more than 70% diameter-reducing stenosis. A graft surveillance program should result in a graft failure rate of less than 3% per year.

Graft Surveillance

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- Low graft flow was a more common mode of prosthetic bypass failure than development of duplex scan-detected stenotic lesions during follow-up.
- Early duplex scanning may be more important for characterizing midgraft velocity and related thrombotic potential and selecting patients for chronic anticoagulation.
- May consider anticoagulation in high risk grafts.

Conclusions

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- DUS can be used to help predict bypass graft patency and identify at risk findings for potential failure.
- Because of its noninvasive nature and low cost, vascular specialists may incorporate DUS as they individualize the follow-up of lower extremity bypass grafts.
- Decision making should be based on patient factors and preferences, physiologic tests, other imaging modalities and physical exam.
- DUS may be considered to be utilized at time of intervention to determine resolution concerned findings.
- Quality measures including comparative studies must be be used for validation

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Graft/ bypass failure can be predicted and avoided by identifying ultrasound criteria such as:

A. Bypass graft dilatation by more than 25%

B. Velocity < 45 cm/sec

C. Velocity >150 cm/sec

D. Intraluminal calcium deposition

E. Remaining valve leaflets

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Thank you