

## **Instructor's Digital Curriculum Resource-**

### **For Techniques in Noninvasive Vascular Diagnosis-4th edition.**

by Robert J. Daigle, BA, RVT, RVS, FSVU, FSDMS

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## **Chapter 14. Hemodialysis Fistulas and Grafts**

### **Techniques In Noninvasive Vascular Diagnosis-4th edition**

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### **Hemodialysis Access Grafts and Fistula Facts:**

- **Created to sustain patients with end-stage renal failure**
- **Hemodialysis removes waste products from blood**
- **300,000-400,000 patients in USA are dialysis dependent.**
- **Patients are likely to undergo multiple revisions, fistulas or grafts.**

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### **Definitions for this chapter**

- **Anastomosis**
  - Site of attachment of graft to an artery or vein, or site of fistula creation
- **Efferent**
  - conducting outward or away
- **AVF (arterial to venous fistula)**
  - A connection between an artery and a vein (created surgically for hemodialysis access)
- **Autogenous**
  - originating or derived from sources within the same individual

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### **Duplex Exam Purpose**

- **Pre-op exam to assess adequacy of arterial inflow and vein suitability**
- **Post-operatively to assess fistulas / grafts for defects, stenosis or occlusion**
- **Post-op to assess for aneurysm, pseudoaneurysm and abscess**

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### **Indications for Duplex Scan: Signs of possible access failure**

- **Pre-op assessment for vein/artery suitability**
- **Difficult cannulation, or thrombus aspiration**
- **Elevated venous pressure during dialysis**
- **Access recirculation of 12% or greater**
- **Poor dialysis**

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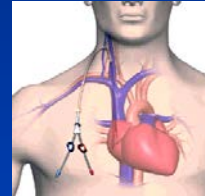
## Indications for Duplex Scan: Signs of possible access failure

- Unexplained urea reduction ratio < 60%
- Shunt collapse
- Distal limb ischemia
- Absence of fistula palpable "thrill"
- Peri-graft fluids or mass

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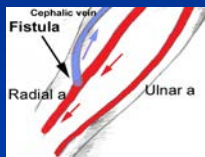
## Types of Access:

- **Central venous catheter**
  - IJV or subclavian vein insertion
  - Temporary-short term solution , or tunneled

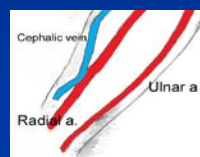


## Native Access Fistulas Brescia-Cimino Fistula

- **Arteriovenous fistulas (AVF)**
  - Usually constructed in the non-dominant arm



End to side anastomosis

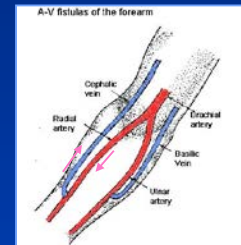


Side to side anastomosis

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## Brescia-Cimino Fistula

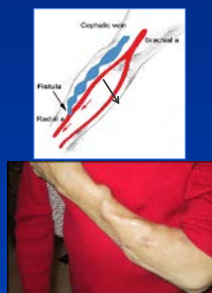
- Radial artery to cephalic vein - most common
- Autogenous
- Known for long term patency
- Low complication rate
- Ulnar a. to basilic v. may also be created, but uncommon.



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## Brescia-Cimino Fistula

- AVF must be allowed to "mature" prior to use, otherwise adequate flow volume may not occur.
- With maturity, becomes "sausage-like".
- Transducer contact sometimes difficult due to superficial location.



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## Other Fistula Sites

- **Brachial artery to cephalic vein**
- **Brachial artery to basilic vein (transposition)**
- **Brachial artery to brachial vein (transposition)**

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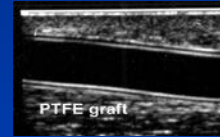
## Access Grafts

- A synthetic tube graft is placed between the artery and vein and used for dialysis puncture.
- Used when veins are inadequate
- Useful when fistulas have failed
- Approx. 50% of patients are not candidates for AVF
- Favored method in the USA, but there is a strong trend towards fistula creation.

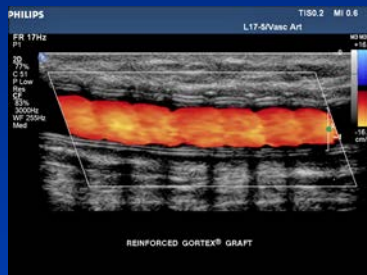
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## Types of Access Grafts

- **Polytetrafluoroethylene (PTFE)**
  - Aka, Teflon
  - Double-wall appearance on US
  - Straight or looped



## Reinforced PTFE Graft



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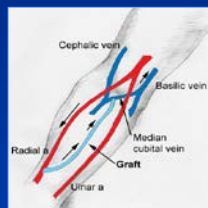
## Types of Access Grafts

- **Polyurethane**
  - **Vectra graft (Thoralon)**
    - Can be used immediately, no maturation time
    - Self-sealing
    - NOTE: impenetrable by ultrasound



## Access Grafts

- The graft may be straight or looped
- If straight, graft courses from a distal artery to a more proximal superficial vein

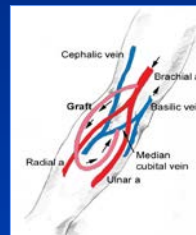


Straight Graft

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## Forearm Loop Graft

provide more length and more puncture locations for dialysis



Forearm loop, brachial a. to median cubital v.



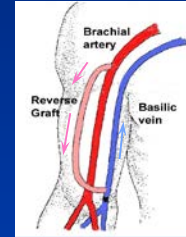
Gore-Tex®

## Other Access Graft Locations

- Brachial artery to basilic vein graft.
- Subclavian artery to jugular vein graft.
- Superficial femoral artery to great saphenous vein loop graft.

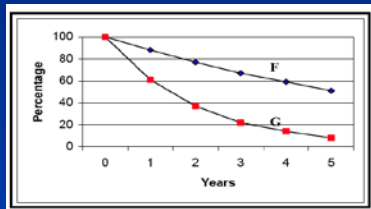
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Brachial artery to  
Basilic vein straight  
graft



**Straight reverse graft,  
brachial a. to basilic vein.**

## AVF vs. Graft Patency Rates



[www.esrdnetwork.org](http://www.esrdnetwork.org)

**F: Fistulae- at 2 yrs. 75%**  
**G: Graft – at 2 yrs. 35%**

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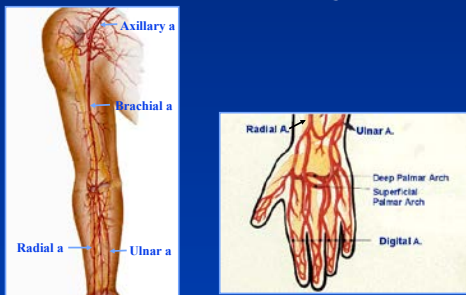
## Pre-operative Vessel Mapping and Autogenous Fistulae

	No-Mapping (n=183)	Mapping (n=172)
Early Failures	36 %	8 %
1 -Yr. Patency	48 %	83 %

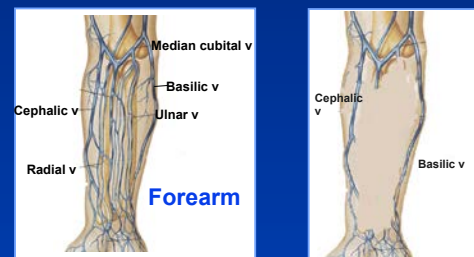
Silva MB, Hobson RW, Pappas PJ et al. A strategy for increasing use of autogenous hemodialysis access procedures: Impact of preoperative noninvasive evaluation. J Vasc Surg. 1998;27:302-307

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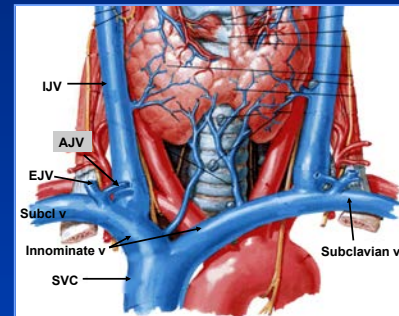
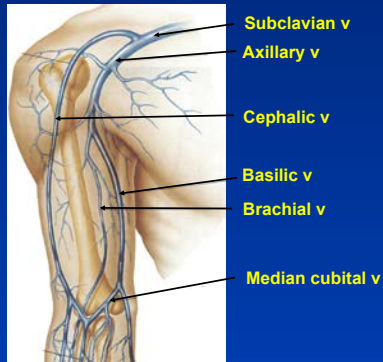
## Arterial/Venous Anatomy Review



## Forearm Venous Anatomy



## Venous Anatomy-arm



## Pre – Operative Assessment

- Adequate arterial inflow (no subclavian stenosis)
- Patent palmar arch
- Arterial lumen diameter  $\geq 2.0$  mm at point of anastomosis

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## Post –Op Assessment

- Graft thrombosis - stenosis
- Flow volume
- Arterial steal
- Venous outflow
- Peri-graft mass

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## Pre-op Exam: Arterial

- Measure bilateral arm systolic pressures
- Image brachial, radial, and ulnar arteries
- Look for stenosis, sclerosis, occlusion, anomalous anatomy



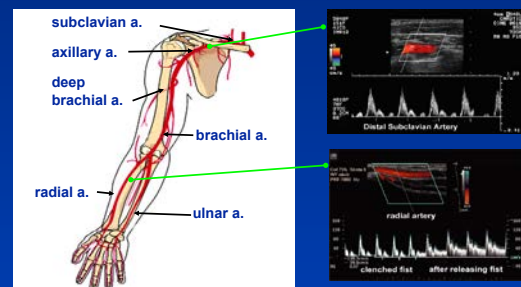
Radial artery occlusion.



Calcified plaque in RA

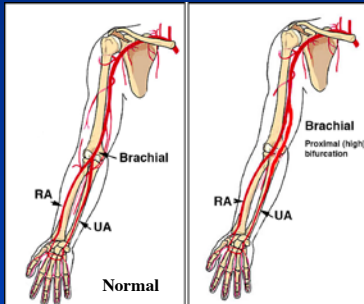
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## Upper Arterial Anatomy



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## Note Any Anatomic Variations



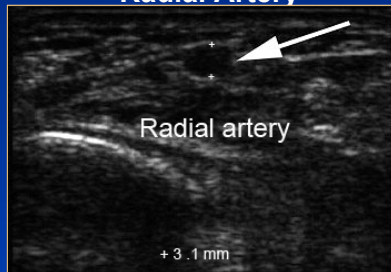
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## Arterial "Suitability"

- In transverse plane measure the inside diameter of the distal radial artery.
- Suitable radial arterial diameter  $\geq 2.0$  mm.
- PSV  $\geq 50$  cm/sec.
- Note calcified artery segments, record location.
- Is the palmar arch patent?

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## Measure Diameter of Distal Radial Artery



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## Arterial Evaluation - Normal Exam Summary

- Less than a 20 mmHg pressure gradient between arms (brachial arteries)
- Arterial lumen diameter  $\geq 2$  mm
- Absence of radial artery stenosis
- Patent palmar arch
- Distal RA PSV  $\geq 50$  cm/sec

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## Pre-op Assessment

- **Palmar arch patency**



See chapter 12 or 13 for details of methods

## Venous Requirements for AVF and Grafts

- **Venous luminal diameter (with or without arm tourniquet)**
  - $\geq 2.5$  mm for fistula \*
  - $\geq 4.0$  mm for graft \*
- **Absence of stenosis or thrombosis**
- **Patent deep veins in upper arm and central veins**

A strategy for increasing use of autogenous hemodialysis access procedures...  
Silva MB, Hobson RW, et al. J Vasc Surg 1998;27:302-8

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## Venous Requirements for AVF and Grafts

- Vein is within 1 cm of skin surface
- Continuity with proximal central veins

A strategy for increasing use of autogenous hemodialysis access procedures...  
Silva MB, Hobson RW, et al. J Vasc Surg 1998;27:302-8

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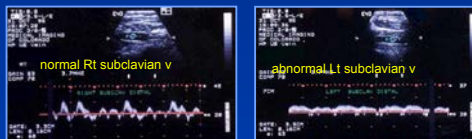
## Pre-op Exam: Venous

- Perform a unilateral venous exam of the non-dominant arm.
- Use ultrasound compression methods for arm veins; rely on image and Doppler waveforms for central veins.
- Are veins free of defects, residual thrombus, or sclerotic segments?

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## Pre-operative Venous

- Compare bilateral subclavian vein waveforms for central vein obstruction



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## Pre-op Exam: Venous

- Measure the diameter of the cephalic and basilic veins in the forearm. Use a tourniquet on the upper arm, a Penrose drain or latex glove to dilate veins
- Veins should be
  - $\geq 2.5$  mm for fistulas
  - $\geq 4.0$  mm for graft placement

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**Pre-operative examination has been shown to significantly reduce early graft/fistula failure rate.**

\* A strategy for increasing use of autogenous hemodialysis access procedures...Silva MB, Hobson RW, et al. J Vasc Surg 1998;27:302-8

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## Graft-Fistula Complications

- Thrombosis / Occlusion
- Stenosis
  - At proximal and distal anastomoses.
  - Within graft.
  - In venous outflow tract, due to intimal hyperplasia or thrombus.
- Arterial steal - digit ischemia

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## Graft-Fistula Complications

- Distal venous hypertension
- Aneurysms, Pseudoaneurysms
- Elevated right-side heart pressure due to excessive graft flow
- Infection (mostly synthetic grafts)

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## Graft and Fistula Facts

- Grafts & fistulas are allowed to "mature" for 4-6 weeks
- Up to 40% rate of initial failure
- Grafts (PTFE) are most common procedure,

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## Post-op Scan Protocol

- *Do not take a blood pressure over a synthetic dialysis graft*
- Determine the location of the fistula/graft, by patient history or from medical records.
- Determine the indication for the exam.
- Visually examine the graft/fistula location and note puncture sites and lumps.
- Palpate any lumps to determine if they are pulsatile (possible pseudoaneurysms).

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## Scan Protocol

- Start in transverse plane.
- Use high frequency linear transducer, 5-12 MHz
- Allow sufficient exam time
- Note the needle tracks, this will help define where the graft or fistula is located.

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## Perform a General "Survey" Scan

- Scan upper brachial a. to dist. radial a.
- Identify graft or fistula origin
- Scan course of graft or fistula
- Scan course of outflow vein

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## General "Survey" Scan

- In longitudinal view, standardize image orientation- hand to the right on screen



retrograde radial a. flow

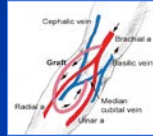
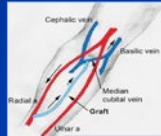


Heart → Hand

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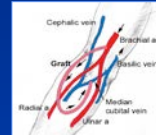
## Scan Protocol

- Evaluate arterial inflow to fistula/graft
  - Flow should be low resistance
- Assess arterial flow distal to graft-fistula
  - Note flow direction (retrograde arterial flow = steal)



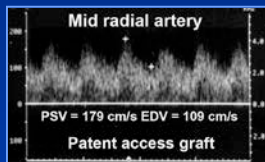
## Scan Protocol

- Assess proximal anastomosis
- Scan entire graft or fistula (vein) and distal anastomosis
  - Note any regions of flow disturbance or stenosis within graft or in outflow vein
- Measure and record PSV and EDV
  - Proximal, mid, distal graft
  - At any region of suspected stenosis
  - At anastomotic sites

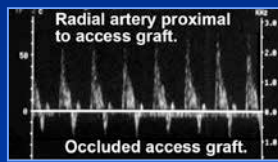


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## Radial Artery Flow



This patient's graft was patent.



This patient had an occluded graft.

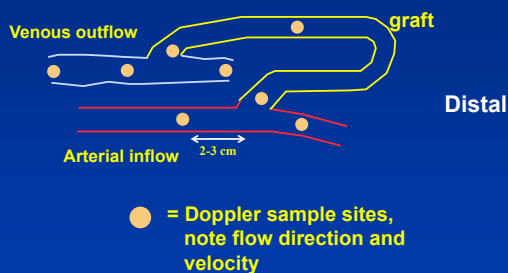
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## Scan Protocol

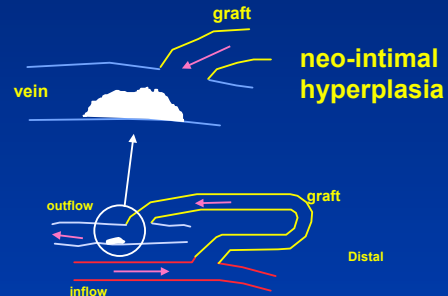
- Measure and record PSV, EDV
  - In outflow vein
  - Artery distal to anastomosis
    - Also, note flow direction.

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## Graft Evaluation

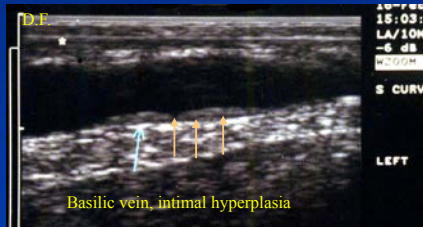


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## Neointimal Hyperplasia



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## Scan Venous Outflow Track

- Follow outflow veins to central veins
  - venous thrombus
  - kinking
  - extrinsic compression
- Color Doppler and high flow facilitates the process.

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## Graft Flow Volume

- Some labs will obtain graft flow volumes
- Flow volume accuracy is questionable
- Not practical in AVFs

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## Graft Flow Volume

- select a "clean" site mid graft
- obtain lumen diameter measurement



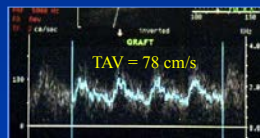
- expand sample gate to diameter of vessel



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## Graft Flow Volume

- Turn off color when measuring diameter/ area
- In longitudinal plane obtain several spectral waveforms and calculate time average velocity (TAV)



Your ultrasound system may or may not be able to calculate TAV

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## Flow Volume (ml/min)

$$Q = \text{Area } (\pi r^2) \times \text{TAV} \times 60 \text{ sec.}$$

or

$$Q = \text{Area} \times \text{Avg Max Vel.} \times 60 \text{ sec.}$$

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## Patient: DF

- Left radial artery to basilic vein straight 6 mm PTFE graft
- recent revision

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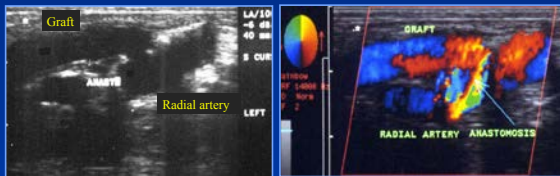
## Pt. DF



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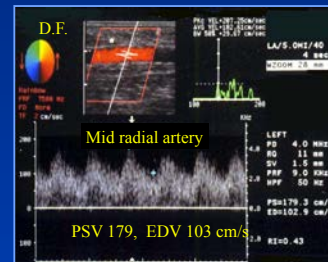
## Radial a. to cephalic v. straight PTFE graft

DF



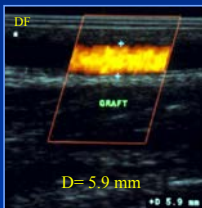
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## Radial artery to cephalic vein access graft



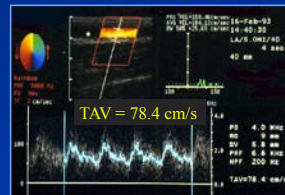
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## Graft diameter



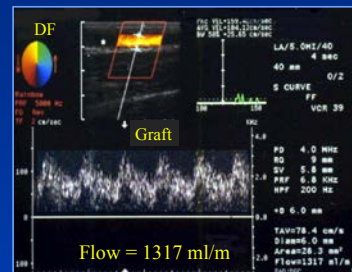
Diameter initially measured in transverse

## Time Average Velocity calculation

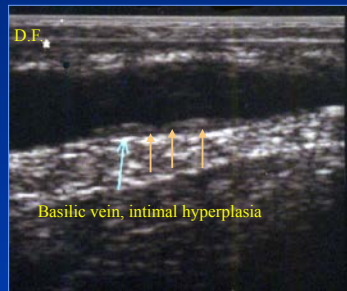


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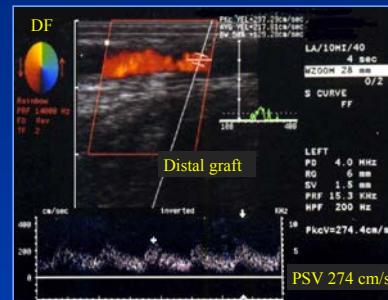
## Flow Volume Calculation



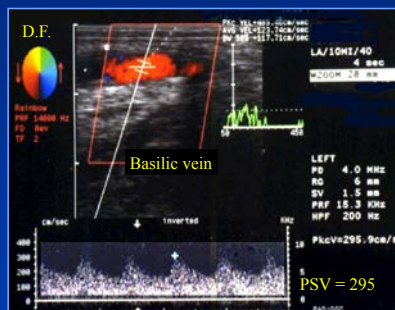
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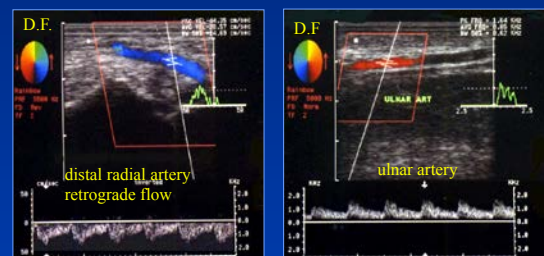


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## Radial Artery "Steal"



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## Complications

- **Pseudo-aneurysm**
  - Less than 1 cm in size, no problem
  - > 1cm problematic
- **Graft disintegration, anastomotic failure**



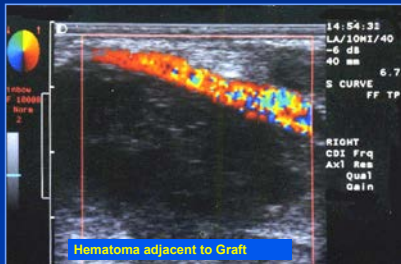
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## Assessment of "Steal"

- Steal may be asymptomatic or cause digit ischemia.
- If SX, obtain PVR or PPG waveforms from ipsilateral digits.
- Obtain pressure from the most symptomatic digit
  - Digit pressures < 60 mmHg are associated with ischemia

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## Hematoma Adjacent to Access



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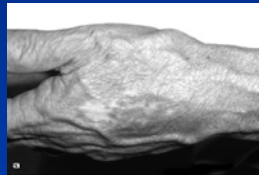
## Other Complications

- **Infection: etiology:**
  - operative contamination
  - puncture
  - wound infection
  - appears as perigraft fluid
- **Seroma**
  - Serum fluid collection adjacent to graft

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## Complications

- Venous hypertension
- Outflow stenosis
- Arterial flow decrease



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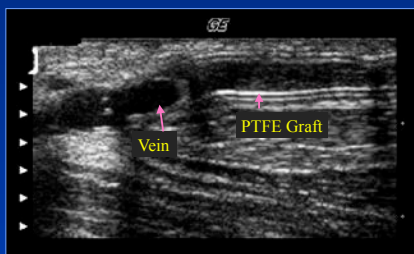
## Complication- Venous hypertension

- Forearm loop graft with venous stenosis
- Retrograde venous flow
- Patient with hand swelling and venous stasis



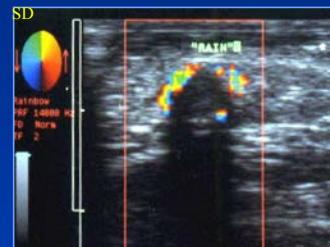
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## Graft Occlusion



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Occluded 2 day old RA to basilic v. graft,  
*color artifact from graft air*



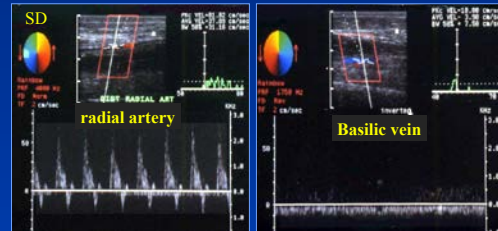
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## Occluded Graft



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## Occluded 2 day old radial a. to basilic v. access graft



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## Interpretation

- Normal grafts and fistulas have very high systolic and diastolic velocities
- Flow is very "low-resistance"
- Flow can be chaotic and spectral broadening the norm.

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## Occlusion

- No flow in graft detectable by color or spectral Doppler.
- No flow in efferent vein distal to fistula anastomosis
- High resistance flow pattern in "feeding" artery
- Low venous outflow

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## Most fistulas and grafts develop stenosis

- **Duplex eval of 87 new fistulas/grafts**
  - In 72% of fistulas and 82 % of grafts
  - > 50% D stenosis within 1 month
  - no significant relationship between stenosis and graft occlusion

Duplex ultrasound detection of stenosis in newly created hemodialysis AV fistulas...  
Ermiens EJ, Langeveld AP, et al. J Vasc. Technol 16 (6):285-297, 1992

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## Criteria: Dialysis Graft Stenosis: > 50% diameter stenosis

- Peak systole > 400 cm/s
- Velocity ratio 2:1
- or 3:1 (some reports)

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### Criteria for > 50% Fistula Stenosis radial a. to cephalic v. (end to side)

- PSV > 400 cm/sec, *plus*
- Ratio 2:1 or 3:1 (Anastomotic stenosis PSV / radial artery PSV).
- For outflow cephalic vein stenosis, ratio of  $\geq 3:1$

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### Graft Flow Volumes (ml/min)

- **Access Grafts**
  - < 350 - poor dialysis, pending graft failure
  - < 500 - increased risk of failure
  - > 800 - normal flow
  - > 1500 - possible congestive heart failure

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### Fistula Flow Volume

- Difficult due to variable vein diameter
- Obtain flow volume from feeding artery (brachial, radial or ulnar)

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### Fistula Flow Volumes (ml/min)

- **Fistulas- *can survive at lower flow volumes***
  - < 300 poor dialysis
  - 300 - 500 borderline
  - > 500 (with 4 mm outflow vein) OK
  - > 800 = normal

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### FAQ

- **Do not obtain blood pressure on arm with graft or fistula**
- **Digit pressures are OK**

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### Summary

- **Pre operative assessment reduces early failure in grafts and fistulas.**
- **Post operative duplex scanning of dialysis access is challenging- Bring creativity and problem solving skills.**

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## Summary

- Important to identify at risk grafts/fistulas prior to occlusion.

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