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 12.
Arterial Bypass Grafts and Stents

Techniques In Noninvasive Vascular Diagnosis- 4th edition

Pre-operative Assessment
Saphenous Vein Mapping

- Used for coronary artery bypass grafts (CABG)
- Used to revascularize the leg with a femoro-popliteal or femoro-tibial bypass graft.
- GSV/SSV are assessed with duplex ultrasound preoperatively to determine suitability for the above procedures.

Definitions for This Chapter

- Atretic, Atresia
  - abnormally closed or absent , usually congenital
- Anastomosis
  - The location/site where a graft connects with an artery or vein
- AFG – Arterial-venous Fistula
  - A pre-capillary shunt between an artery and vein

Definitions for this Chapter

- Intimal hyperplasia
  - A rapid growth of vein wall (intima) that can compromise the vein or graft lumen
- Seroma
  - A pocket of clear fluid –serum , occasionally found adjacent to a bypass graft or surgery site.
- Percutaneous Angioplasty (PTA)
  - Local dilation of an artery or stenosis with an inflatable catheter

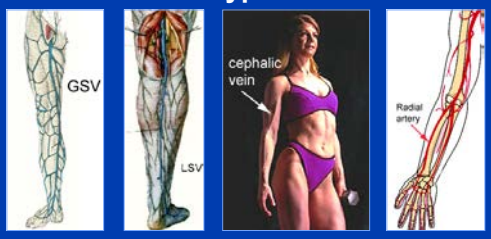
Definitions for this Chapter

- Percutaneous transluminal angioplasty (PTA)
  - Local dilation of an artery or stenosis with an inflatable catheter. Catheter is introduced through the skin (percutaneously)

Pre-operative Assessment

- Cephalic vein can be removed and used for short segment grafts.
- Cephalic & Basilic are carefully evaluated pre-op for hemodialysis access placement
- The radial artery (or ulnar) can be harvested and used for CABG material.

Veins and Arteries Used For Bypass



Great Saphenous Vein | Small Saphenous Vein | Cephalic Vein | Radial Artery

Saphenous vein mapping for bypass grafts consists of three basic procedures:

1. Procedure #1 determines vein suitability. The goals of this procedure:
   - Is the saphenous vein present and patent?
   - Is it continuous?
   - Does it consist of a double or duplicated system?
   - Does it harbor regions of residual thrombus?
   - Is it of appropriate size?

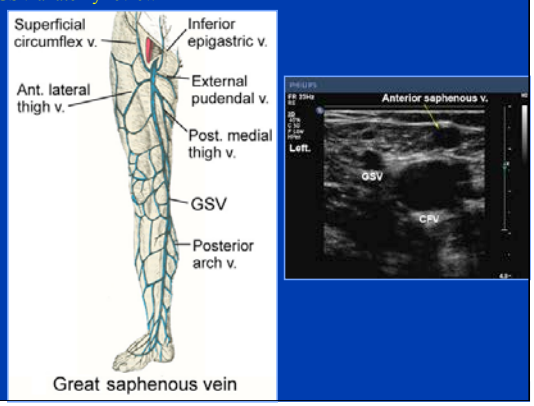
Mapping Procedure #2

2. Procedure #2 includes procedure #1 (vein suitability), but also involves mapping and marking the course of the saphenous or the superficial arm vein(s).

Mapping Procedure #3

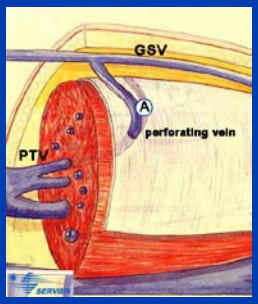
3. Procedure # 3 determines the suitability of the radial artery for CABG (if appropriate).

GSV anatomy review



Small Saphenous Vein

Perforating Veins



Perforating Vein Location

It's difficult to see normal perforators, but easy to identify incompetent ones.

90% of incompetent PVs are ≥ 3.5 mm

Most perforating veins are here.

Procedure #1. Determine Suitability of the GSV

- Patient in semi-Fowlers position
- Rule out chronic DVT
  - Quick check of CFV and popliteal veins.
  - If the GSV is functioning as a collateral vessel, it's removal (harvest) is contraindicated.

Determine Vein Size

- Using a 7.5-14 MHz transducer, identify the GSV at the sapheno-femoral junction.
- In transverse, scan entire length
  - Is it continuous or dichotomous?
  - Is it a single or duplicated system?
  - Is there residual thrombus or wall irregularity?

Determine Vein Size

- In transverse, measure the GSV diameter using system integrated calipers at these locations:
  - Upper thigh, Mid thigh, Lower thigh
  - Upper calf, Mid calf, Lower calf
- Measure the diameter of both vein segments in a bifid systems.

Vein Suitability

- If the ipsilateral GSV is too small (< 2.0 mm) or unsuitable, evaluate the contralateral GSV.
- If requested, evaluate and measure the diameter of the small saphenous vein at proximal, mid, and distal locations.

Size Determination

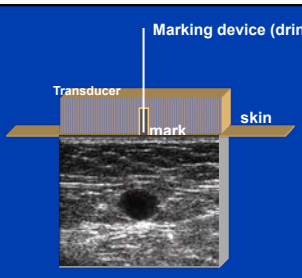
- Vein diameter will expand by 1.5 - 2 times when arterialized.
- Vein diameters of ≥ 2.5 mm have higher graft patency rates
- Veins < 2.5 mm have high graft failure rates in lower extremity bypass

Procedure #2: "Mapping" The Veins

- Determine whether the surgery is planned and scheduled, or whether the surgeon is just interested in "suitability".
- If surgery is planned, mark the leg, as described below. If only suitability is the goal, there is no need to mark the leg during that exam.

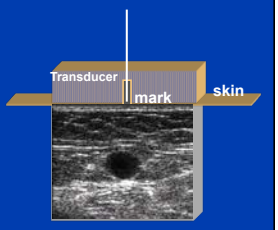
Preparation and Method

- Apply a strip of clear tape on the side of the transducer.
- Mark the center of the transducer



Place transducer over vein and center the vein in the field of view.
Place an "indent" in the skin directly over vein.
Move 1.5- 2 inches and repeat.

- Continue to distal thigh.
- Wipe off acoustic gel.
- Clean leg with alcohol.
- Connect "indentations" with a marking pen.
- Repeat procedure in calf.
- In double systems, mark accessory (smaller) vein with dotted line.



Vein Mapping

Radial Artery Harvest

- Radial A. for CABG, Carpentier 1973
- Advantages over saphenous v.
  - appropriate vessel caliber
  - thicker walls, less hyperplasia
  - better availability (not all candidates have an appropriate GSV)

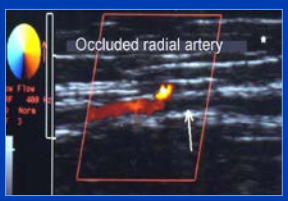
Radial Artery Harvest- Contraindications

- Ischemic digits.
- Raynaud's Syndrome.
- Ipsilateral athero-occlusive disease in arm.
- Sclerotic, atretic or occluded radial artery.
- Incomplete palmar arch in hand.

Pre-op RA Harvest

- Obtain bilateral brachial pressures to rule out subclavian disease
- Scan radial artery for:
  - Arterial stenosis.
  - Artery occlusion.
  - Vessel atresia.
  - Regions of wall calcification.

Radial Artery Origin

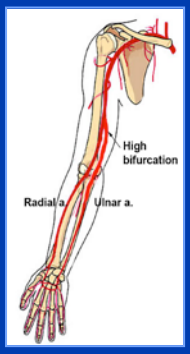


Measure the inside diameter at the distal, mid and proximal segments

- The average inside diameter of the distal radial artery is 2.8 mm for men, and 2.4 mm for women.

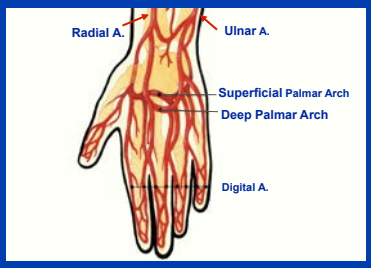
Pre-op Exam:

- Note any anatomy variations particularly the position of the radial and ulnar a. bifurcation.
- This sketch demonstrates an anomalous high bifurcation.



Radial Artery Harvest

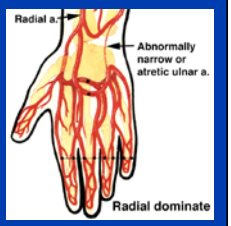
- Palmar arch patency is essential



Incomplete Palmar Arch

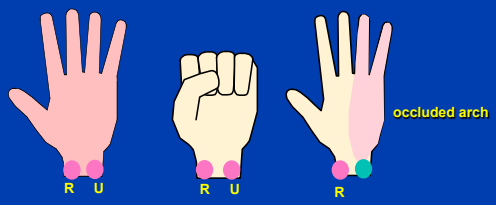
Mixed dominance

Ulnar dominate



Radial dominate

Allen Test: Palmar Arch Patency



Compress radial and ulnar arteries

Exsanguinate hand

Release ulnar compression

Repeat with release of radial compression

PPG Test Palmar Arch

- PPG sensors are placed on the thumb or index finger and the 5th digit (if a 2 channel system is available).
- PPG scale or gain is adjusted to establish similar amplitude
- Use a slow sweep-speed
- There should be no, or little, drop in the PPG amplitudes.

PPG Test -Palmar Arch

- Compress and hold RA ands UA simultaneously. Both waveforms should go "flatline".

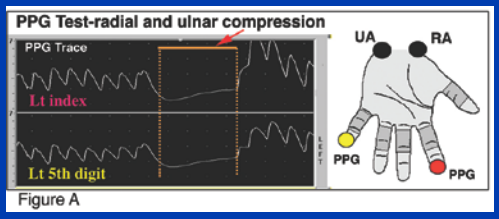


Figure A

PPG Test -Palmar Arch

- Next, compress and hold RA. Both waveforms should NOT go "flatline".

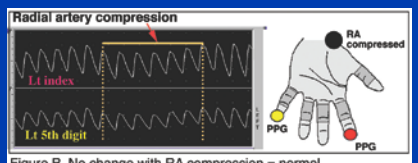
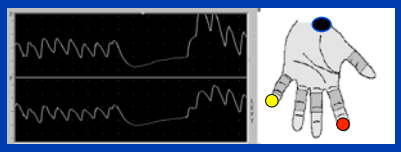


Figure B. No change with RA compression = normal

PPG Test -Palmar Arch

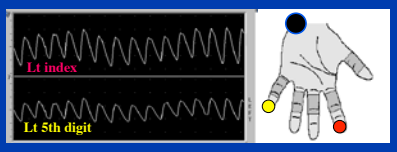
- If waveforms go flatline with RA compression (abnormal) = radial artery dominance
- RA harvest is contraindicated



Radial a. compression causes cessation of flow

PPG Test -Palmar Arch

- Perform Ulnar artery compression
- No change indicates adequate RA perfusion



UA compression, no change

Digit Pressures with and without Radial Compression

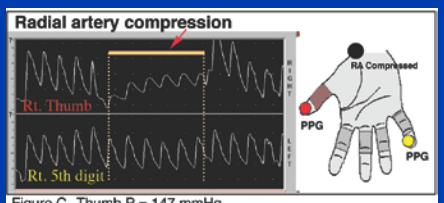


Figure C. Thumb P = 147 mmHg
Thumb P with RA compress. = 79 mmHg.

Thumb P. = 147 mmHg Thumb P. with RA compress. = 79 mmHg

Postoperative Assessment

- Obtain patient history and surgical record, if possible
- What type of graft?
- Graft location?
- Peripheral Stents?

Interventional Procedures: Lower Extremities

- Bypass graft
  - Synthetic: Polytetrafluoroethylene (PTFE) , Dacron
  - Autogenous vein grafts
    - Reversed
    - In situ
- Percutaneous angioplasty (PTA)
- Stents

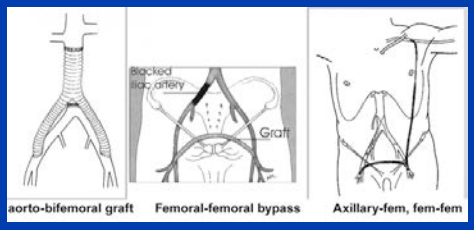
Inflow Grafts

- Aorto-bifemoral
  - From aorta to distal iliac or CFA, bilateral
  - Used to bypass distal aorta or more commonly, iliac artery disease.
- Femoral to femoral "jump" graft
  - Used to bypass one iliac artery stenosis or occlusion
  - One iliac artery will supply flow to both legs

Inflow Grafts

- Axillo-femoral graft
  - From the axillary artery to the distal external iliac artery or CFA
  - Used in conjunction with a fem-fem-jump graft
  - Bypasses severe aortoiliac disease

Aorto-femoral Grafts



The entire graft, as well as the graft inflow and outflow, should be evaluated for stenosis Careful attention should be given to the anastomotic sites as technical problems, graft failure and infection are more likely to occur in these regions.

Below Inguinal Ligament Grafts

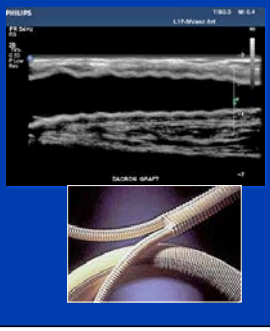
1) Synthetic polytetrafluoroethylene (PTFE) graft.
   - Common femoral artery (CFA) to distal superficial femoral artery (SFA) or proximal popliteal a.
   - Newer flexible fabrication may allow placement to extend below knee.

PTFE Graft

Below Inguinal Ligament Grafts

2) Synthetic Dacron.

- Often used for fem-fem, and iliac grafts.
- Advances in Dacron material is now allowing femoral-distal bypass grafts.



Below Inguinal Ligament Grafts, Autogenous vein grafts

3) In situ vein graft

- Used to bypass femoro-popliteal occlusion.
- Graft often extended from CFA to distal tibial artery (aka, fem-distal graft).
- Vein grafts appear to have better patency rates than synthetic grafts in the legs.

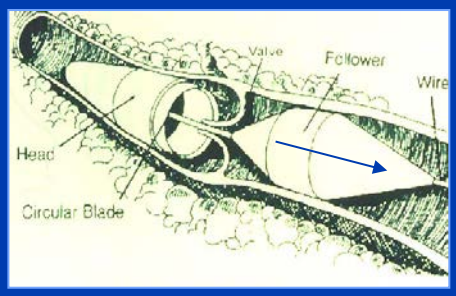
In Situ Vein Graft

- Uses great saphenous vein (GSV) in it's native bed; it's not removed.
- Valve leaflets are excised with a valvulatome.
- Graft lies superficially in prox. Segments, but is deeper at the distal anastomosis

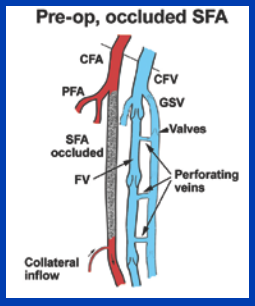
In Situ Vein Graft

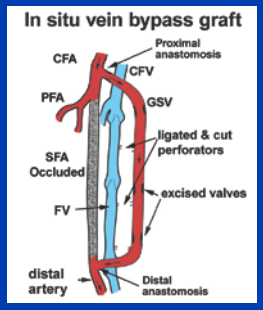
- Perforators / tributaries are ligated.
- Proximal and distal ends of the vein are connected to artery.
- Proximal anastomosis may original at the CFA (most common), PFA or SFA
- Vein grafts may extend to distal PTA, or (less frequently) to the ATA.

Valvulatome for In Situ Method

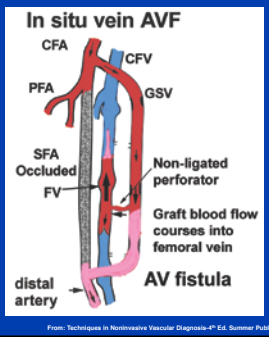


In Situ Graft Method





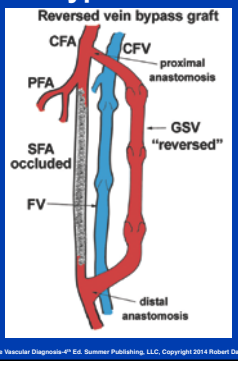
Complication: non-ligated large perforator causing an AVF



Reversed Vein Bypass

4) Reversed-vein bypass

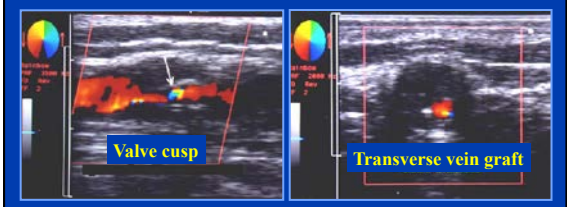
- Perforating veins and tributaries are ligated and cut
- GSV is removed
- Vein is reversed and implanted as bypass.
- Valves are not excised
- Can be used in contralateral leg.



Other Grafts

- Veins and arteries harvested from cadavers are also used.
- The small saphenous vein (SSV) is used for small segments or for graft revisions.
- The cephalic or basilic veins in the arm may be used for small graft extensions or revisions.

Reverse Vein Graft Stenosis



In situ femoro-popliteal graft

In situ fem-tibial graft

In Situ Graft Surveillance

- 20-30 % stenosis rate within 1 year.
- Stenosis in post-op 1-30 days is due to technical error or valve issues
- Beyond 30 days, failures occur due to:
  - Intimal hyperplasia
  - Graft kinks
  - Infection

In Situ Graft Surveillance

- If a graft thromboses: high failure rate if graft undergoes thrombectomy.
- 60% of graft stenoses are ASX, due to limited ambulation -
- Many grafts are performed for limb salvage. If the graft fails or cannot remain open, the patient faces limb amputation.

Follow-up Surveillance of Bypass Grafts-Rationale

- Allows the surgeon to detect early graft stenosis prior to thrombosis and occlusion.
- Graft defects and stenosis may be followed for progression or resolution.
- Intervention can be initiated with onset of symptoms and confirmation of progressive occlusive disease.

Bypass Graft Scan Method

- Identify graft type & location. Any revisions?
- Perform ABI
- Use image, color and spectral Doppler

Evaluate:

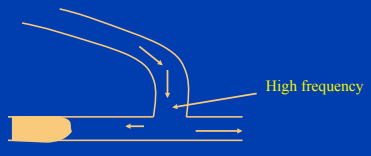
- Graft inflow and anastomosis
- Entire graft for:
  - Stenosis
  - Wall irregularity
  - Aneurysm, pseudoaneurysm
  - A-V in non-ligated perforators (in situ only)
  - Partially excised valve leaflets causing stenosis

Evaluate:

- Distal anastomosis
- Run-off (graft outflow vessel)
- Note seroma or hematomas adjacent to graft.
- Assess profunda femoral artery origin

Vein graft aneurysm

Distal anastomosis is often difficult to assess due to weird Doppler angles.



Stenosis has an abrupt increase in velocity

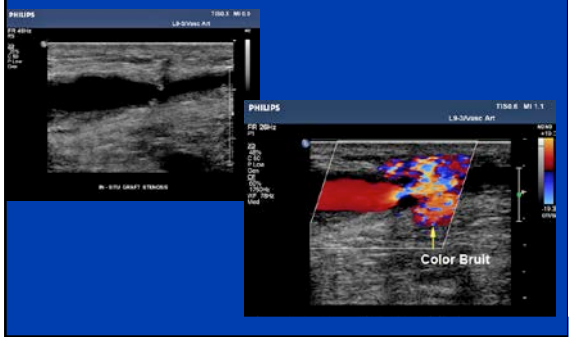
Obtain and record peak systolic velocities from the following locations:

- Proximal to, at and distal to a stenotic segment.
- The artery segment proximal to the graft.
- Within the graft:
  - Proximal graft
  - Mid graft
  - Distal graft segments.
- The artery segment distal to the graft.

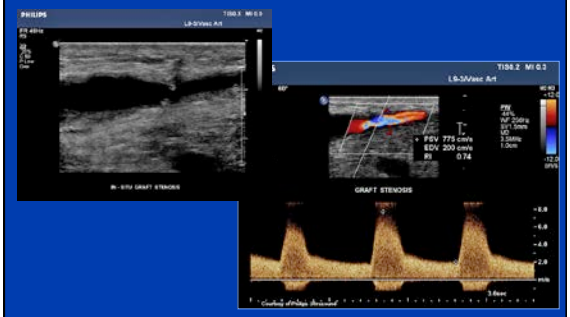
Calculate the GFV

- **Acquire and average the 3-4 peak systolic velocities from within the graft to calculate a "graft flow velocity" (GFV)**

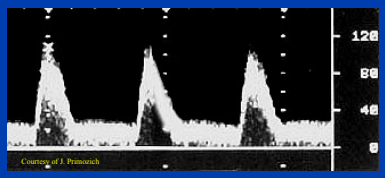
In Situ Graft Stenosis



In Situ Graft Stenosis



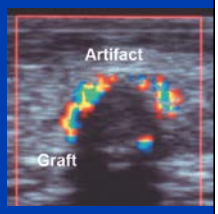
Graft Waveform 1 Week Post Op



Hyperemia will usually occur in normal, patent grafts in the early post op period.

New PTFE Grafts

- **PTFE grafts contain air in the material which dissipates in the first few days.**
- **An artifact occurs a "fresh" graft**
- **Graft has an aura of "Christmas tree" lights**
- **Ultrasound may not penetrate the air**



Graft Interpretation

- Velocities in normal reversed vein grafts will decrease distally as the diameter becomes larger.

Interpretation: ≥ 50% stenosis

- > 50% graft stenosis
  - Focal velocity acceleration followed by post stenotic turbulence.
  - PSV ≥ 150 cm/sec and velocity ratio of ≥ 2.0
- 0.15 decrease in ABI

Interpretation: ≥ 70% stenosis

- Velocity ratios ≥ 3.5
- PSV > 300 cm/sec.
- GFV < 40 cm/sec. in a normal-sized graft.
  - GFV may be lower (<40 cm/sec) in a NORMAL large graft (>6 mm) or in graft to single run-off vessel

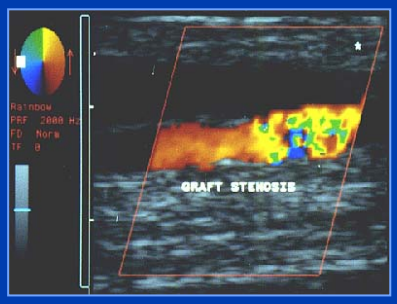
Graft Occlusion

- No flow by color or spectral Doppler
- Visualization of thrombus

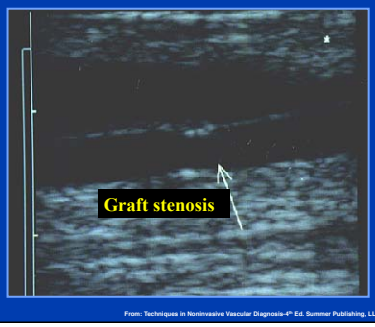
Case Studies: Pt. #1

- Recent in-situ femoro-popliteal vein bypass graft.
- No increase post-op in ABI. Cause for concern so a STAT color duplex scan was ordered.

Vein Graft Stenosis

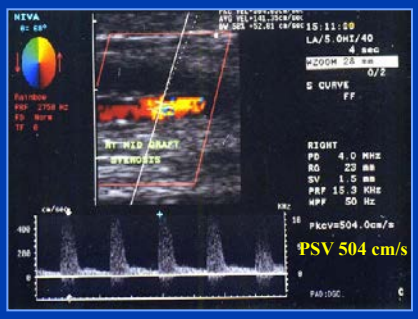


Graft – Valve Stenosis



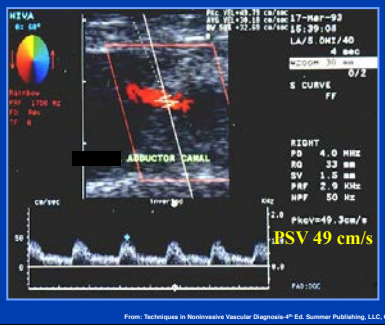
Vein Graft – Pre Stenosis

Vein Graft, Max Stenosis



Graft- Post Stenosis

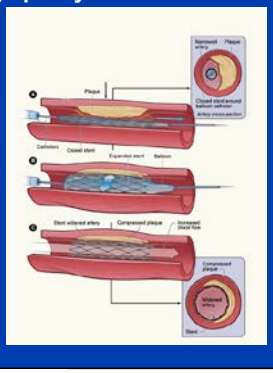
Distal Vein Graft

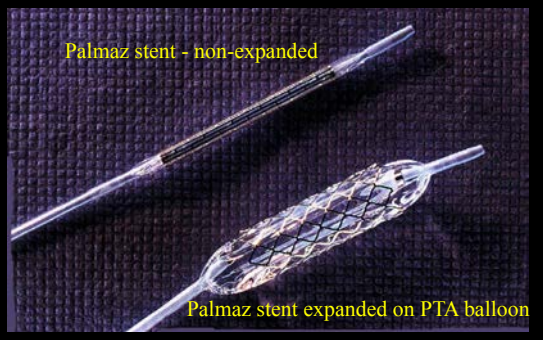


Peripheral Stents

- **2 Basis types**
  - **Palmaz - balloon deployed- Used in conjunction with angioplasty**
  - **Wallstent - self expanding- Contained in a sheath-like catheter that is drawn back allowing the stent to expand**

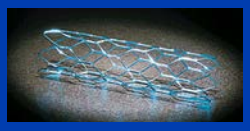
Angioplasty with Stent Placement





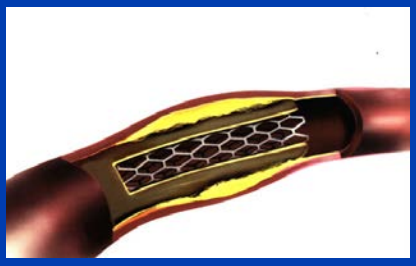
Stent Sites: Peripheral Vascular

- Aorta
- Renals
- Iliacs
- Femoral - popliteal



Open, uncovered stent

Covered Stent



Iliac Stent Assessment

- Challenging due to depth, obesity, bowel gas
- Obtain Doppler Waveforms and PSV
  - Proximal to stent
  - 2-3 sites (depending on length) within stent
  - In native vessel distal to stent

Femoro-Popliteal Stents

- Obtain patient surgical history and:
  - Stent type (covered, uncovered)
  - Single or multiple stents
  - Overlapping?
  - Stent location
- Obtain and ABI or Limited physiologic exam.

Do not obtain segmental pressures with the cuff over a stent

Duplex Protocol

- Image (grey scale) entire stent.
- Image in longitudinal and transverse.
- Spectral Doppler assessment of inflow, outflow vessels and multiple points within stent. Record PSV.
- Record velocity from proximal SFA.

Femoro-popliteal Stent Complications

- Restenosis (intimal hyperplasia)
- Thrombosis
- Stent shift
- Stent fracture (risk increases with length)
- Aneurysm at stent edge

Peripheral Stent Criteria

- Obtain post-operative velocity within stent.
- Use this as a reference during follow-up exams

In-stent Restenosis- SFA

% Stenosis	PSV	VR*
50-79%	> 190 cm/s	1.5
≥ 80%	> 275 cm/s	3.5

*VR-Velocity ratio of in-stent PSV to proximal SFA PSV

Duplex criteria for determination of in-stent stenosis after angioplasty and stenting of the SFA.
Baril DT, Rhee RY, Kim K. J Vasc Surg I vol. 49, 133-139 2009

Endoluminal AAA Repair with covered stents-EVAR

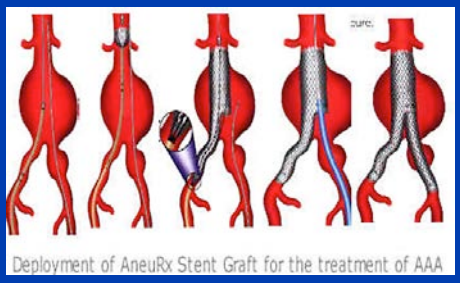
EVAR

- A covered stent is placed within the aortic aneurysm to allow flow through to the legs.
- Reduces the risk of aneurysm rupture, thrombosis and embolization.
- Relatively minor, minimally invasive procedure.

AAA - EVAR

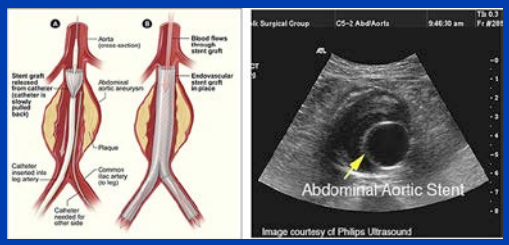
- **Complications include:**
  - **Graft infection.**
  - **Vessel rupture during deployment.**
  - **Distal embolization.**
  - **Endoleak.**

Stent Graft for AAA



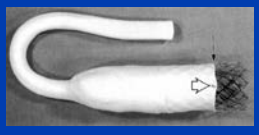
Deployment of AneuRx Stent Graft for the treatment of AAA

Endoluminal AAA Stent

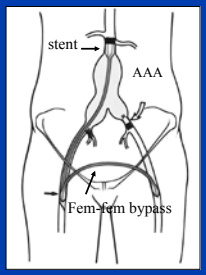


Courtesy of Philips Ultrasound

Another method of Endoluminal AAA repair with covered stent



Covered stent



Pre-stent (AAA) Evaluation

1) Obtain pressure measurements and calculate an ankle to brachial index (ABI).
2) Carefully assess the aorta from the diaphragm to the bifurcation of iliac arteries, and to the CFA bilaterally.
3) Measure aneurysm outside diameter, its length, and residual lumen. Does the aneurysm extend above the renal arteries (RA)?

Pre-stent (AAA) Evaluation

4) Measure the diameter of the aorta proximal to the aneurysm, and if possible, the distance between the left RA and the aneurysm.

   To allow for proper stent anchoring, there should be at least 1 cm of normal aorta between the left RA and the aneurysm.

Pre-stent (AAA) Evaluation

5) Measure the diameter of the iliac arteries. Measurements of the proximal and distal anchoring sites will enable the correct size selection of stent.

Post-op EVAR Evaluation

1. ABIs.
2. Monitor stent for patency.
3. Is the graft in the same position or has it moved proximally or distally?
4. Look carefully for low velocity endoleaks into the aneurysm sac.

Post-op EVAR Evaluation

5. Look for retroperitoneal fluid that may represent a leak outside of the aorta.
6. Measure diameter of aorta.

Endoleaks

- A complication of EVAR that results in blood flow into the peri-stent region (aneurysm sac)
- Classified by types
- Some resolve spontaneously
- Types 1 & 2 are the most significant

Endoleaks

- Type I
  - Perigraft leakage at proximal or distal graft attachment sites (near the renal and iliac arteries)
- Type II
  - Retrograde flow from collateral branches such as the lumbar, testicular and inferior mesenteric arteries

Endoleaks

- Type III -
  - Leakage between different parts of the stent (at the anastomosis between components)
- Type IV -
  - Leakage through the graft wall due to the quality of the graft material- Rare
- Type V -
  - Leakage from unknown origin

AAA-EVAR Follow-up

- CTA appears to be best method
- MRA- depends on stent material
- Neither CTA or MRA are optimum for identifying the source/type of leak

AAA-EVAR Follow-up

- Ultrasound-sensitivities (compared to CTA) 25% to 100%
- AbuRahma study* - 367 paired CT and US examinations.
- Sensitivity of US was 68%

** AbuRahma AF, Welch CA, Mullins BB, Dyer B. Computed tomography versus color duplex ultrasound for surveillance of abdominal aortic stent-grafts. J Endovasc Ther 2005;12:568–573*

Endoleaks