Vascular Access 101\ Fistula First Conference July 31, 2004

Phu M. Do, M.D.
Vascular Surgeon
Corpus Christi, Texas

Vascular acess

- Arteriovenous Fistulas
- Arteriovenous Fistula Grafts
- Catheters

History

- First shown feasible in animal models in 1912
- 1944 – W. J. Kolff developed the first clinically compatible dialyzer
  - Glass and metal tubes used for intermittent cannulation
  - Rubber tubing carried blood to dialyzer
  - Required arterial/venous ligation after each treatment
  - Patient died after twelve dialysis sessions after all accessible vessels were exhausted

History

- 1953 – Seldinger
  - Described percutaneous technique for cannulation of arteries and veins using guide wire
    - Limits intimal damage to vessels

History

- 1960 – Quinton, Dillard, Scribner
  - Permanent external shunt
  - Two silastic tubes with tapered Teflon tip, implanted in radial artery and cephalic vein, connected outside the patients skin
    - Lifespan of shunt ~ 2-3 months
    - Frequent thrombosis and infections
    - Massive hemorrhage from occasional dislodgements

History

- Internal shunts
  - Arterio-arterial shunts with transposition of artery (e.g. superfical femoral artery transposed to more subcutaneous location)
  - 1962 - Cimino and Brescia
    - Demonstrated feasibility of venopuncture for both inflow and outflow from dialyzer
      - Required series of cuffs above and below the vein cannulation site to dilate the vein
      - Success limited by vein availability

History

- 1966 – Cimino and Brescia described the use of radial artery to cephalic vein arteriovenous fistula for dialysis access
- Prosthetic grafts development
  - Bovine heterograft
  - Dacron
  - Tanned human umbilical vein
  - PTFE

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- High Pressure of inflow artery
- Low pressure of proximal outflow vein
- Pressure gradient causes high blood flow towards the AVF, and back to the heart via the proximal vein
  - Due to low resistance, the flow in the direction of inflow artery is greater with AVF present than without (particulary in diastole)

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- Venous pressure rarely rise above 15mm Hg due to low resistance pathway, and due to capacity of veins to enlarge
- Blood flow rate ~ 150-400 cc/min
- Factors affecting flow
  - Anastomotic size
  - Diameters of inflow artery and proximal vein
  - Distal capillary bed
  - Collateral vessels
  - Competency of venous valves

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- Anastomosis size
  - Flow increases linearly until anastomosis reaches 75%-100% of inflow artery diameter
  - Flow rate does not increase beyond this point
  - Typical radial artery diameter : 2-4 mm
  - Typical anastomosis :6- 10 mm

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- Diameter of artery and veins
  - Resistance between distal artery and capillary bed and proximal vein is similar when initial diameter of proximal vein is small
  - As proximal vein dilates with time, resistance across AVF drops, leading to “steal syndrome”

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- Collateral vessels
  - Number and size of arterial collaterals will determine whether a large fistula will steal blood from distal capillary bed
    - Radial-cephalic AVF relies on ulnar artery to supply blood to hand via palmar arch and extensive collaterals
    - Brachiocephalic AVF has much less collaterals at elbow, and thus presents more risk for arterial steal

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- AVF is one of the most powerful stimuli to the creation of new arterial collaterals
  - Most steal syndromes should resolve with time as collateral arteries develop
  - Used also in children with leg-length discrepancy (femoral AVF) to improve arterial development of the shorter leg and accelerate growth of femur on that side.

Hemodynamics and Physiology of the Arteriovenous Fistula (AVF)

- Venous collaterals also develop, as proximal vein and tributaries enlarge and walls thicken
- Flow across AVF also reflux into distal veins, destroying venous valves and causing distal venous hypertension

Arteriovenous Fistulas

- Most optimal mode of dialysis access
  - Superior patency when compared to AVFG
  - Lower rate of complications
    - Infection
    - Arterial steal
  - Gradual proximal venous distension allows for easier revision when distal AVF fails
  - Requires only one anastomosis at surgery

Arteriovenous Fistulas

- Disadvantages
  - More technically demanding
  - Only 70-80% of patients have suitable veins at wrist
    - Outflow vein must be superficial for cannulation
    - At least 3mm in diameter with proximal cuff insufflation
    - Often veins have thrombosed due to multiple hospitalizations and venipunctures, or are difficult to find in obese patients

AVF disadvantages

- Requires adequate planning, as 6-8 weeks is needed for maturation of the AVF (enlargement and thickening of proximal outflow vein)
- Requires skilled cannulation
- Lower rate of flow (250-350 cc/min) compared to graft (600-700 cc/min)
  - Only 30% reduction in flow would reduce AVF delivery to dialyzer below the 200cc/min requirement for optimal membrane exchange

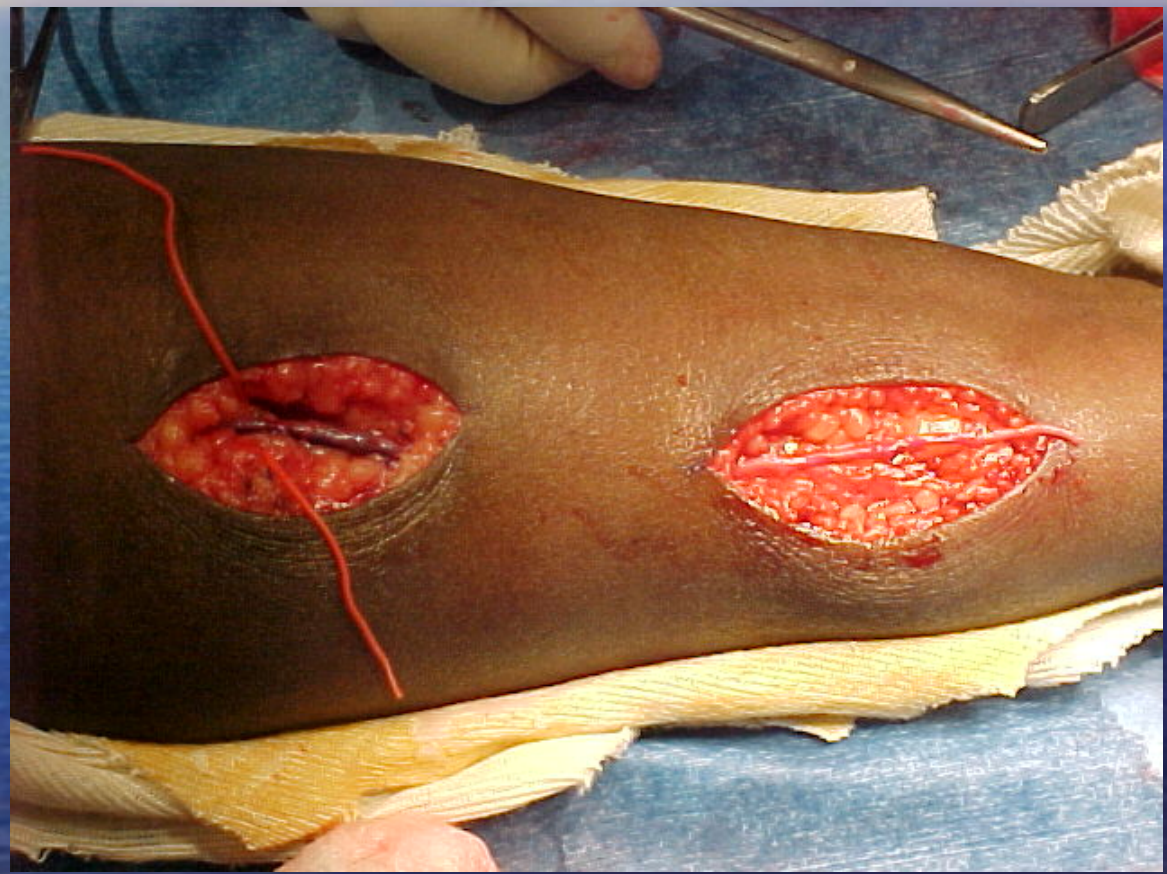
AVF – Choice of sites

- General principles
  - Distal are preferred over proximal sites to preserve venous territory and to allow for “arterialization” of more proximal veins for subsequent access over time
  - Vein quality is most important – 3mm with now proximal obstruction
  - Arterial quality – must not be calcific

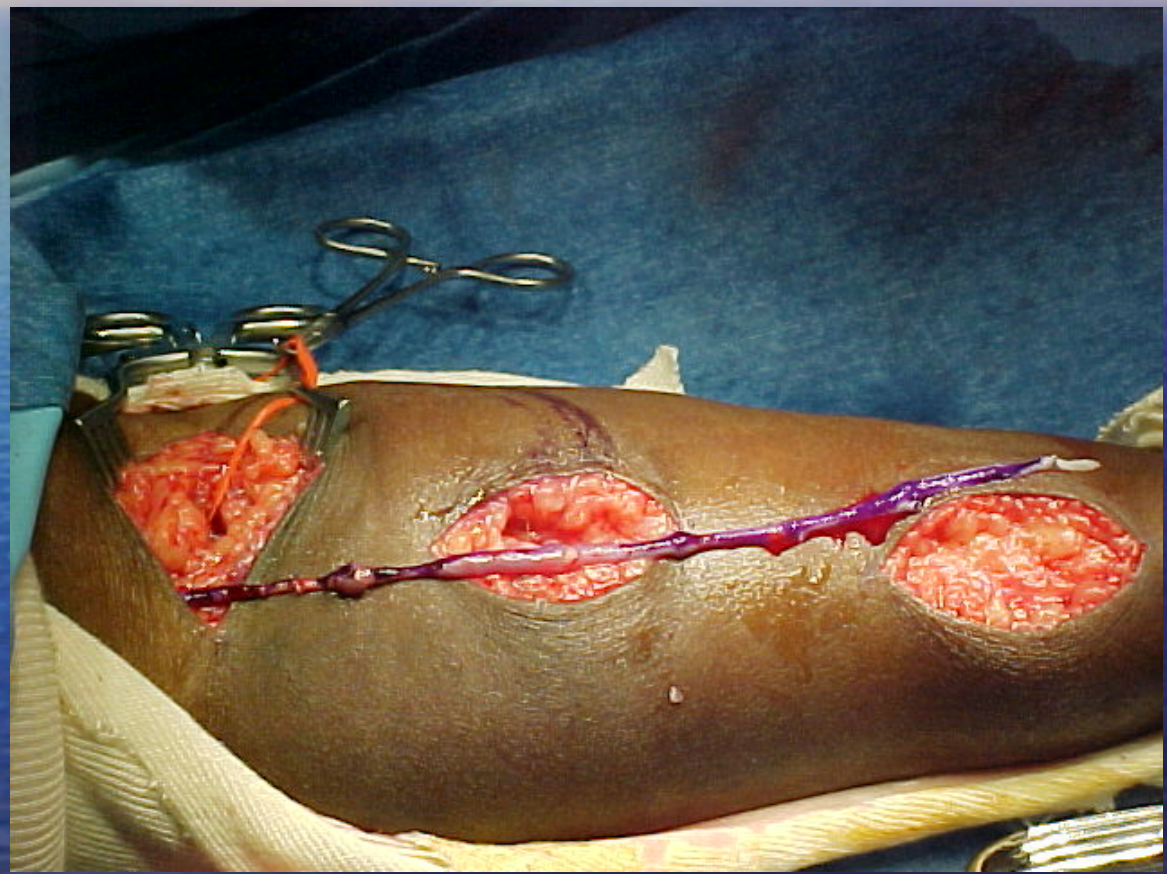
AVF – Choice of sites

- Radiocephalic “Cimino” fistula at wrist
- “Snuffbox” fistula on dorsum of wrist and base of thumb (origination of cephalic vein)
- Brachiocephalic
- Brachiobasilic upper arm with vein transposition
- AVF with forearm vein transposition
- “Reverse Fistula” in forearm
- Superfical A-Saphenous vein transposition in leg

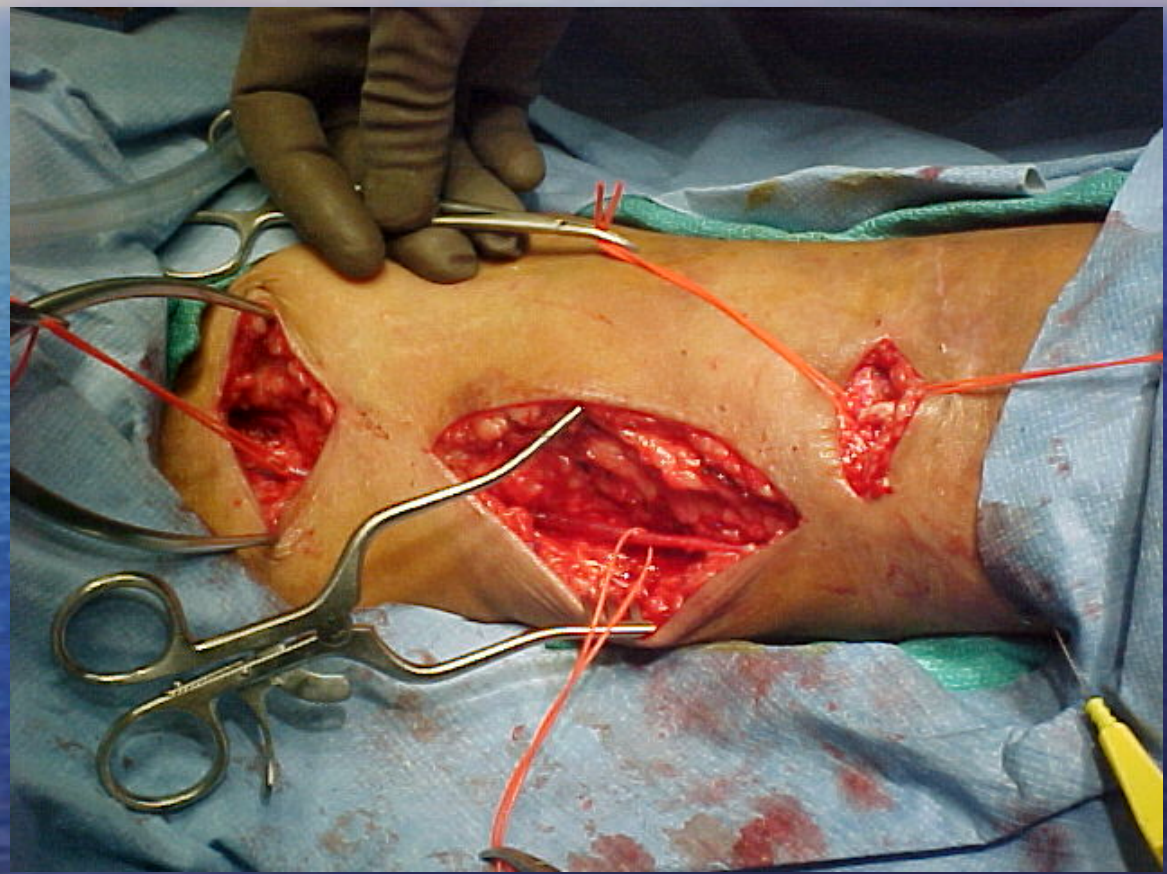
AVF with forearm vein transposition



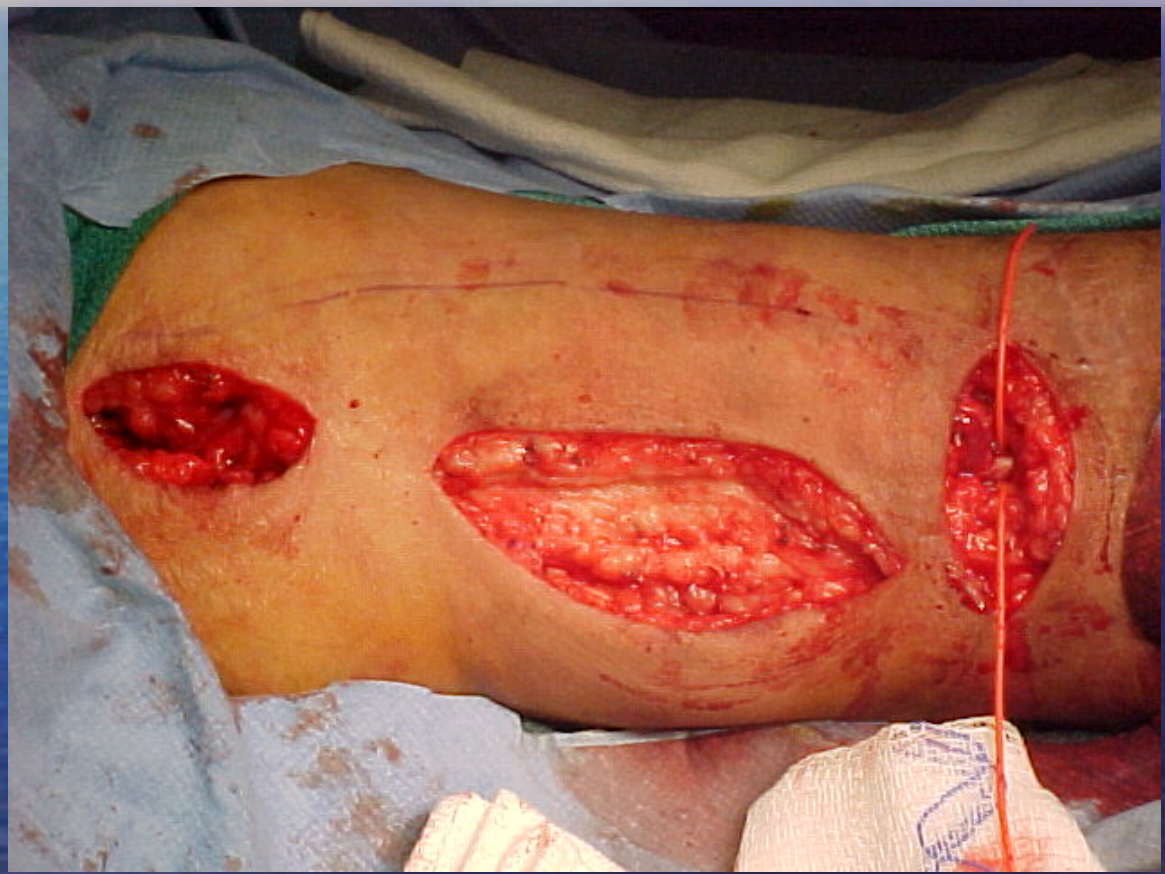
AVF with forearm vein transposition



Brachiobasilic AVF with vein transposition (upper arm)



Brachiobasilic AVF with vein transposition (upper arm)



AVF – Patency

- 20% early failure
  - Trying to use questionable quality veins in attempt to create fistula rather than grafts
- 1 year – 75%
- 3 years – 60%
- 5 years – 45%

Arteriovenous Fistula Grafts (AVFG)

- High flow conduit between artery and vein
- Required in at least 30% or more of patients
  - Unsuitable small veins
  - Thromboses from iv lines and venipunctures
  - IVDA
  - Obese patients

Arteriovenous Fistula Grafts (AVFG) General Principles

- Arterial inflow
  - Disease free artery at least 4mm diameter
  - Proximity to proximal vein
  - Distal artery should be used prior to proximal
  - Arms are preferable to legs
  - Non-dominant arm is preferred

Arteriovenous Fistula Grafts (AVFG) General Principles

- Venous Outflow
  - Veins need to be at least 4 mm
  - Distal veins preferred to proximal veins

Arteriovenous Fistula Grafts (AVFG) General Principles

- Grafts
  - Saphenous vein – pseudoaneurysms and stenoses
    - Also required for CAD and PVD bypasses
  - Dacron – hematomas and aneurysms common
  - Bovine heterograft – expensive and difficult to handle
  - PTFE (polytetrafluoroethylene) – IMPRA, Gore-tex
    - Hemostasis depends on perigraft fibrosis, which takes 2-4 weeks after surgery to develop
  - Vectra – Self-sealing, can be used immediately
    - Pain of recent surgery is limiting factor

Arteriovenous Fistula Grafts (AVFG)

- Size – 5-6mm
- Configuration
  - Straight (eg brachial artery- axillary vein)
    - 20 cm
  - Loop (eg brachial artery- antecubital vein)
    - 30-35 cm
- Adequate length is required for rotation of puncture sites

Arteriovenous Fistula Grafts (AVFG)

- Desperate graft sites for desperate situations
  - Iliac artery-iliac vein grafts (looping onto abdominal wall and back to retroperitoneum)
  - Femoral artery to subclavian vein graft
  - Axillary artery to contralateral subclavian vein
  - Arterial to arterial grafts
    - Proximal SFA to distal SFA
    - Brachial artery to radial artery

Patient follow-up and surveillance

- Physical exam – thrill and bruit
- Dialyzer hemodynamic measurements
  - Inflow (arterial) pressure :20-80 mm Hg
  - Outflow (venous) pressure :50-100 mmHg
  - Flow rate
    - AVF 250-400cc/min
    - AVFG 600-700cc/min
  - BUN recirculation ratio – should be <20%
    - (Systemic BUN-Inflow BUN)/(Systemic BUN – Outflow BUN)

Patient follow-up and surveillance

- Duplex US
  - Flow = 0.6(velocity)(cross-section area)
- Fistulagram

Complications

- Thrombosis
  - Early (<30 days)
    - Technical
    - Hypercoagulability
    - Poor cardiac output
    - Poor arterial inflow (atherosclerosis)
    - Proximal venous outflow (stenosis or small size)

Complications

- Late thrombosis (>30 days)
  - Progressive arterial inflow stenosis (atherosclerosis or intimal hyperplasia)
  - Poor cardiac output
  - RN experience
    - Cannulation technique
    - Excessive pressure on AVF/AVFG following dialysis to stop bleeding
  - Venous outflow stenosis (intimal hyperplasia)

Complications

- Infection
  - Accounts for 10% of deaths in dialysis patients
  - Staph. Epi and Staph Aureus most comon
  - Overt – pus, erythema, swelling of graft site
  - Covert – diagnosis of exclusion when all other work-up for infection fails

Complications

- Arterial Steal
  - Poor collateral arterial vessels to hand
  - Diabetic and women with small arteries
  - 7-10%
  - Aggravated with decreased BP during dialysis
  - Rx
    - Observation for improvement (1-3 weeks)
    - Banding
    - Ligation of distal artery if collateral vessels are sufficient in cases of reverse flow to fistula

Complications

- Venous Hypertension
  - Incompetent veins and poor venous collaterals distally
  - Stenosis of proximal vein
  - Rx
    - Hand elevation
    - Treat underlying problem (eg angioplasty for proximal vein stenosis)

Complications

- Pseudoaneurysm
  - Failure of punctures to seal after needle removal
  - Hematoma expands outside of vein/graft into soft tissue until elastic limit of tissue is reached
    - Resorbed if clot formation takes place
    - Becomes pseudoaneurysm if remains patent
  - Rx : ligation and interposition graft

Complications

- Lymphocele and gelatinoma
  - Distinguishable from hematoma by U/S and aspiration
  - Usually resolves and requires no treatment
- Carpal Tunnel Syndrome
  - Due to nerve compression by venous hypertension
  - Rx: surgical release of carpal ligaments

Complications

- CHF
  - When graft flow exceeds 1.5 L/min (30% of cardiac output)
  - Branham's sign : cardiac strain decreases and heart rate slows with graft compression
  - Rx: banding or graft ligation

Complications

- Inadequate dialysis
  - Poor flow < 200cc/min (inflow or outflow stenosis)
    - dx - fistulagram
  - Recirculation
    - Outflow venous resistance
    - Dx- fistulagram
  - Rx – surgical revision