Introduction to the Native Arteriovenous Fistula: A primer for medical students and radiology residents

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No Disclosures
Objectives

• Introduce options for renal replacement therapy
• Discuss hemodialysis and introduce the permanent and temporary options
• Discuss the main types of arteriovenous fistulas and the advantages and disadvantages to each
• Illustrate the appearance of characteristic sites of stenosis on conventional venography
• Briefly discuss the causes, effects, and treatment for each of the discussed sites of stenosis.
Renal Replacement Therapy

• Therapy options
  1. Hemodialysis: the most common, ~64%
     • Catheters
     • Arteriovenous Fistulas (AVF)
     • Arteriovenous Grafts (AVG)
  2. Renal Transplant, ~29%
  3. Peritoneal dialysis
Renal Replacement Therapy

• When is therapy initiated?
  – Serum Creatinine > 4 mg/dL
  – GFR less than or equal to 25 mL/min

• Based on KDOQI guidelines
  – Influenced by the IDEAL trial
    • No evidence of improved outcomes, including overall mortality, with early vs later initiation of dialysis
    • Do NOT deny patients that may benefit from therapy
      – Refractory volume overload
      – Refractory hyperkalemia
Hemodialysis

• Approximately 230,000 patients in the US are on Permanent Dialysis
  – Permanent access
    • Fistula
    • Graft
  – Temporary access
    • Catheter
      – Tunneled
      – Non-tunneled

• National Kidney Foundation
  – Established goals for optimized care
    • Dialysis Outcomes Quality Initiative (DOQI) Guidelines
      – Public document with major goal of improving outcomes of dialysis access
Hemodialysis

• US Renal Data System
  – Majority of hemodialysis patients in the US are using Catheters (80%)
    • Major problem

• Venous catheters do not provide reliable long term access
  – Infection
  – Malfunction

• Creation of arteriovenous fistula (AVF) is the preferred therapy option
  – Fistulas have superior longevity compared to Grafts
    • Grafts require higher flow rates than Fistulas $\geq 450$ mL/min
Hemodialysis Access Options

A. Permanent Dialysis options

1. Autogenous/Native (Fistula)
   - Lower rates of thrombosis
   - Longer access lifespan
   - Less number of needed secondary interventions
   - Less rates of Infection, Steal syndrome, and central stenosis
   - 20% decreased mortality relative to Grafts
      - Preferred method per National Kidney Foundation

2. Synthetic (Graft)
   - Polytetrafluoroethylene or Dacron material
Hemodialysis Access Options

B. Temporary Dialysis options

1. Tunneled Catheters
2. Non-tunneled Catheters
   - Compared to both Grafts and Fistulas, catheters have highest rates of:
     - Thrombosis
     - Infection
     - Central stenosis
   - Compared to both Grafts and Fistulas, catheters have:
     - Lowest flow rates
     - Higher mortality
Access complications

A. Early

1. Thrombosis

2. Inadequate flow rates
   - Blood flow rate: normal $\geq 300$ mL/min
   - Dialysate flow rate: normal $\geq 500$ mL/min
     - Technical error
     - Pre-existing venous outflow obstruction
     - Unrecognized arterial inflow disease

- Treatment at this stage is surgical revision/thrombectomy
  - Venography useful in planning
Access complications

B. Late

1. Venous outflow stenosis
   • common

2. Anastomotic stenosis
   • Less common, fewer than 4% of patients
     • Angioplasty is the preferred treatment method
     • Once a stenosis has occurred, recurrence is common
       – Up to 70% may require additional intervention within 6 months
Permanent Access

A. Arteriovenous Fistula

• Physical exam
  – Normal findings
    • Continuous thrill at the anastomosis
    • Low pitched bruit in the outflow vein
  – Abnormal findings
    • Systolic thrill
    • Pulsatile

• Access Parameters
  – Maximum flow rate
    • Forearm: 300 mL/min
    • Upper arm: 1000 mL/min

• Up to 30% of fistulas fail to mature
  – Once established, fistulas can maintain patency with flow rates as low as 80 mL/min
Permanent Access

B. Dialysis Graft

• Physical exam
  – Normal findings
    • Thrill at the Arterial anastomosis
    • Bruit audible throughout the graft
  – Abnormal findings
    • High pitched bruit
    • Pulsatile

• Access Parameters
  – Maximum flow rate bridge graft
    • 800 mL/min
  – Indicator of Venous Outflow stenosis
    • Flow < 600 mL/min or decreased by 25%
    • Venous pressure > 125 mm Hg
    • Ratio of Venous to Systemic Arterial pressure > 0.4
Indications for Imaging

- Unsatisfactory flow rates
- Physical exam suggests decreased flow
- Upper extremity swelling or Hand ischemia

- Venography indicated
  - Access planning
  - Malfunctioning but patent access
  - Thrombosed access
  - Upper extremity swelling with patent access
  - Upper extremity ischemia with patent access
Native AV Fistula

• 3 main types
  – Radiocephalic (forearm)
    – Also known as Brescia-cimino
      • End of Cephalic vein attached to side of Radial artery
  – Brachiocephalic (upper arm)
    • End of Cephalic vein attached to side of Brachial artery
  – Brachial artery to Transposed Basilic vein (BTB) (upper arm)
    • End of superficialized Basilic vein to side of Brachial artery
Radiocephalic Fistula

• A **forearm** fistula surgically created by joining the end of the cephalic vein to the side of the radial artery
  – Also referred to as Brescia-Cimino fistula

• National Kidney Foundation
  – Dialysis Outcomes Quality Initiative (KDOQI) in 2006
    • Recommends Radiocephalic Fistula as the **first choice** for vascular access
Radiocephalic Fistula

• Advantages
  – lowest rate of steal syndrome compared to the brachiocephalic and BTB
  – Preserves future opportunity for creation of more proximal fistulas

• Disadvantages
  – high rate of failure to mature
    • seen in approximately 30%
  – major cause of failure is stenosis = limits INFLOW
    • Stenosis = decrease of the luminal diameter by > 50%
Radiocephalic Venography

Cephalic vein (direction of flow IS towards the heart)
Radial artery (direction of flow is towards the hand)
Yellow arrow indicates the anastomosis of vein end to the arterial side wall
Radiocephalic Venogram

- **Juxta-anastomotic stenosis**: most common site of stenosis
  - due to neointimal hyperplasia
    - Shear stress, turbulence, torsional stress may all contribute to pro-inflammatory cascade
  - Limits **INFLOW** from the arterial side into the venous Fistula
    - Limits proper maturation
Radiocephalic Fistula

• Signs of failure
  – Decreased thrill on physical exam
  – Decreased flow, difficulty cannulating, and increased arterial pump pressures at Hemodialysis

• Minimum AVF flow rate = 350-400 mL/min
  – If less than 300 mL/min → recirculation problems
  – If less than 200 mL/min → clotting problems
Radiocephalic Fistula

• Treatment
  – Endovascular
    • Balloon angioplasty
      – Undersizing $\rightarrow$ suboptimal results
      – Oversizing $\rightarrow$ risk of rupture
    • Cutting balloon $\rightarrow$ for lesions that resist angioplasty
    • Stenting $\rightarrow$ for lesions that recoil
  – Surgical
    • Better rates of restenosis however,
      – Assisted primary & secondary patency rates are similar to angioplasty
      – More invasive
      – Sacrifices puncturable vein
      – Longer wait until newly created fistula is ready
Brachiocephalic Fistula

• A **Upper arm** fistula surgically created by joining the end of the Cephalic vein to the side of the Brachial artery

• Indications for placement of Brachiocephalic
  – Failure of Forearm access
  – Forearm vessels are inadequate
    • Proper vessel diameter should be:
      – Arteries > 2 mm
      – Veins > 2.5 mm
Brachiocephalic Fistula

• Advantages
  • Better maturation compared to Radiocephalic Fistula
  • Longer patency compared to Radiocephalic Fistula

• Disadvantages
  • 5-20x higher rates of Steal Syndrome
    – Due to higher flow rates
      » Greater flow predisposes to aneurysmal dilation
Brachiocephalic Venogram

- **Cephalic Arch** – most common site of stenosis
  - Mechanism can be thought of as an overall increase in turbulence due to a combination of
    - High flow rates
    - Compression by clavipectoral fascia
    - Sharp angle of the cephalic arch
    - High number of venous valves
  - Limits **OUTFLOW**
    - Leads to Aneurysmal dilation
Cephalic Arch stenosis
Brachiocephalic Fistula

Toward central veins (distal aspect of fistula)

CAS leads to pressure build up in the proximal aspect of the fistula
*proximal = closer to the anastomosis

Aneurysmal dilation
toward Anastomosis (proximal aspect of fistula)
Brachiocephalic Fistula

• Signs of failure
  – Decreased access flow rates at hemodialysis
  – Thrombosis at access site
  – Increased venous pressures at hemodialysis

• Treatment
  – Endovascular
    • Angioplasty is first line
      – Only ~20% primary patency at 1 year
      – resistant in up to 5% of cases
      – Cephalic arch has higher rates of rupture
  – Stenting
    • avoided due to risk of stent fracture
  – Surgical
    • Indication = recurrent stenosis
This patient was treated with balloon angioplasty up to 10 mm
CA stenosis Post balloon angioplasty

Improved patency and flow
Brachial Artery to Transposed Basilic Vein (BTB)

- A **Upper arm** fistula surgically created by superficializing the Basilic vein and joining the end of the Basilic vein to the side of the Brachial artery — 3rd option in the order of preferred fistulas per KDOQI

Curved portion = **Proximal Swing Segment** of the Basilic Vein

- transition from its normal deep location and curves towards a more superficial position
Brachial artery to Transposed Basilic Vein Fistula

• Indication for a BTB
  – Failure of a radiocephalic or brachiocephalic fistula

• Advantages
  – Improved maturation rate compared to radiocephalic fistula in diabetic patients

• Disadvantages
  – Increased Peri-operative morbidity
    • Hematoma
    • Infection
    • Arm swelling
Brachial artery to Transposed Basilic Vein Fistula

- **Proximal swing segment**
  - Surgically created curvature at the transition from its normally deep location to a more superficial and lateral position
  - Most common location for stenosis in a BTB
Brachial artery to Transposed Basilic Vein Fistula

• Signs of failure
  – At Hemodialysis
    • Prolonged bleeding
    • Elevated venous pressures
    • Poor access flows
    • Thrombosis

• Treatment
  – Endovascular
    • Angioplasty
      – ~24% require 4 or more interventions/angioplasties
BTB Venoplasty

Proximal Swing Segment Stenosis
“waist sign”

Towards Central Veins —>

← Towards Hand
Resolution of the “waist sign” after treatment with Balloon Angioplasty up to 10 mm in this patient
Improved patency and fast flow after treatment with balloon angioplasty in same patient


• United States Renal Data System