“Mature” Fistula?
What is a “Mature” AVF?

- Vein able to be safely and reliably accessed 3 times per week with two 17, 16, or 15 ga. dialysis needles
  - Diameter: >6 mm
  - Depth: <6 mm
  - Length: >6 cm
    - Straight
  - Vessel Wall quality
    - “Arterialization”

- Fistula flow sufficient to deliver necessary rate of blood to the dialysis circuit
  - >150% of desired pump speed: e.g. 400 ml/min
  - >600 ml/min

- Dependent upon
  - Cardiac output
  - Blood pressure
  - Artery size & quality
Fistula Maturation & Adequacy of Hemodialysis

- Adequacy as assessed by urea clearance
- Kt/V: Fraction of total body distribution volume cleared during dialysis session equals
  - $K_{\text{urea}}$ = Dialyzer urea clearance
  - $T_d$ = Dialysis time
  - $V_{\text{urea}}$ = Urea distribution volume
    - Approximates total body water
- Target Kt/V >1.4
KT/V & Adequacy: One Size Doesn’t Fit All
KT/V & Adequacy: One Size Doesn’t Fit All

100 kg patient: Kt/V=1.4
• Urea volume = 60,000 ml
• Time = 240 minutes
• $K_{\text{urea}} = 350 \text{ ml/min}$

50 kg patient: Kt/V=1.4
• Urea volume = 30,000 ml
• Time = 240 minutes
• $K_{\text{urea}} = 175 \text{ ml/min}$

Less efficient dialyzer urea clearance at higher blood flow rates
• Blood flow to dialyzer
  – 450-550 ml/min
  – ≥15 gauge needles

Requires access blood flow 50% greater than dialyzer pump speed
• Access flow >750 ml/min
• Access flow 300 ml/min
AVF Maturation: Hemodynamic Factors

1. Circumferential Deformation
2. Circumferential Stress
3. Longitudinal Deformation
4. Longitudinal Stress
5. Radial Deformation
6. Radial Stress
7. Pulsatile Deformation
8. Pulsatile Stress


Courtesy of Arif Asif, M.D.
AVF Maturation: Humoral Factors

- **Adaptive Remodeling**
  - Reorganization of cellular and extracellular components

- **Role of Endothelial Cells:**
  - De-endothelialized vessels fail to increase diameter in response to increased blood flow (1, 2)

- **Shear stress:**
  - Apical surface of the endothelial cell
  - Transduction of hemodynamic forces
  - Subendothelial compartment
    - Nitric oxide, prostacyclin
    - Activation of a variety of transcription factors and matrix metalloproteinases (3)
  - **NO and MMPs:** Appear to play a major role.


Courtesy of Arif Asif, M.D.
LUA Transposed Cephalic AVF: Delayed Maturation
Native Arteriovenous Fistula: Patterns of Maturation
Some Fistulas Fail to Mature

- Miller et al, Kidney Int, 2001: 53.5%
- Oliver et al, Kidney Int, 2001: 26.0%
- Dixon et al, AJKD, 2001: 31.5%

- Lower Arm Fistula: 66.0%
- Upper Arm Fistula: 41.1%
- Total: 50%

% Failed to Mature
Effect of clopidigrel (Plavix™) on Early Failure of AV Fistulae

### Table 3. Fistula Suitability Failure

<table>
<thead>
<tr>
<th></th>
<th>No. (%) of Patients</th>
<th>Relative Risk (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clopidogrel (n = 385)</td>
<td>Placebo (n = 373)</td>
</tr>
<tr>
<td>Suitability failure (all patients)</td>
<td>238 (61.8)</td>
<td>222 (59.5)</td>
</tr>
<tr>
<td>By location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forearm fistula</td>
<td>144 (66.9)</td>
<td>137 (64.0)</td>
</tr>
<tr>
<td>Upper arm fistula</td>
<td>94 (55.3)</td>
<td>85 (53.4)</td>
</tr>
<tr>
<td>By failure reason</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fistula abandoned with no expectation of future use</td>
<td>115 (29.9)</td>
<td>134 (35.9)</td>
</tr>
<tr>
<td>Fistula not yet in use despite treatment with dialysis</td>
<td>57 (14.8)</td>
<td>47 (12.6)</td>
</tr>
<tr>
<td>Fistula in use during ascertainment period but failed to meet suitability criteria</td>
<td>66 (17.1)</td>
<td>41 (11.0)</td>
</tr>
</tbody>
</table>

a Fifty-six of the 441 patients randomized to clopidogrel and 63 of the 436 patients randomized to placebo were not included because suitability was not ascertained (Figure).  
b Relative risks were stratified for fistula location and center.  
c \( P = .40 \)

Dember, et al., JAMA 2008
Physical Training:
Myth of the Red Rubber Ball

- **Immediate effects**
  - Oder (ASAIO 2003)
    - 23 patients
    - AVF 2.8 months old
    - 5 minutes hand exercise
      - Red rubber ball
    - Fistula diameter increased 9.3%
      - 20/23 patients

- **Long-term effects**
  - Rus (Blood Purif 2003)
    - 14 ESRD patients without AVF
    - 8 weeks Handgrip training
    - Increased
      - Radial artery diameter
      - Maximum vein diameter
Failure to Mature

• Focal venous stenosis
  – Pre-existing vein damage or disease
  – Surgery-related vein damage
    • Juxta-anastomotic or “swing-point” stenosis

• Diffuse vein stenosis
  – Intrinsic vessel disease

• Accessory or “competing” veins

• Hemodynamic factors
  – Arterial calcification
  – Poor cardiac output and/or blood pressure

• Failure to squeeze the ball
“Swing-point” Stenosis
Juxta-Anastomotic Stenosis
Endovascular versus Surgical Preemptive Repair of Forearm Arteriovenous Fistula Juxta-Anastomotic Stenosis: Analysis of Data Collected Prospectively from 1999 to 2004

Nicola Tessitore,* Giancarlo Mansueto,† Giovanni Lipari,‡ Valeria Bedogna,* Stefano Tardivo,§ Elda Baggio,† Daniela Cenzi,† Giovanni Carbognin,† Albino Poli,§ and Antonio Lupo*†

*Divisione di Nefrologia, †Dipartimento di Radiologia, ‡Dipartimento di Scienze Chirurgiche, and §Dipartimento di Medicina e Sanità Pubblica, Università di Verona, Verona, Italy

Primary Patency

Assisted Primary Patency
AVF Maturation: Competing or Accessory Vein Ligation
Balloon Assisted AVF Maturation: “Silk purse from sows ear?”
“Balloon Maturation”
Definition

• Use of balloon angioplasty to achieve long-segment vein dilation that has not occurred spontaneously
  – Involves the intended fistula puncture zone
  – Sequentially larger balloons

• Distinct from treatment of focal stenosis
  – Juxta-anastomotic or swing-point

• Limited data
Staged Balloon-Assisted Aggressive Maturation (BAM)

- 122 patients retrospective
  - Class I
    - Large (6-8 mm) vein
    - > 6 mm deep
  - Class II
    - Small (2-5 mm) vein

- Sequential dilation
  - Angioplasty at 2-4 week intervals
    - Start with at least 6-7 mm diameter balloon
    - Successively larger balloons :10-12 mm (max 16 mm)
    - Long length balloons for long segment lesions
  - Repeated until fistula usable
  - Successful maturation: 118/122 (96.7%)

Miller et al: JVA 2009
Staged Balloon Assisted Aggressive Maturation Protocol

Class I & II Primary Patency

Secondary Patencies

Miller et al: JVA 2009
Interventions to Improve Fistula Maturation Rates

- Meta-analysis
  - 12 Reports, 745 patients
  - Variety of surgical and percutaneous methods
    - Angioplasty, stent, thrombectomy
    - Branch vein ligation
    - Surgical revisions
  - 86% success in achieving functional fistula
  - At 1 year
    - Primary patency 51%
    - Secondary patency 76%

### Table IV. Efficacy of early nonmaturation treatment

<table>
<thead>
<tr>
<th>First author</th>
<th>Year</th>
<th>AVF age, mon Mean (range)</th>
<th>Detected lesions</th>
<th>Techniques used</th>
<th>Success %</th>
<th>IY PP %</th>
<th>IY SP %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turmel-Rodrigues</td>
<td>2001</td>
<td>2.5 (1.0-6.5)</td>
<td>AI 4 JAn 38 VO 27 CV 0 AccV 0</td>
<td>PTA</td>
<td>97</td>
<td>39</td>
<td>79</td>
</tr>
<tr>
<td>Song</td>
<td>2006</td>
<td>2.7 (1.0-13)</td>
<td>AI 0 JAn 18 VO 4 CV 0</td>
<td>AVE</td>
<td>96</td>
<td>28</td>
<td>85</td>
</tr>
<tr>
<td>Falk</td>
<td>2006</td>
<td>2.0 (0.3-8.5)</td>
<td>AI 16 JAn 32 VO 33 CV 21</td>
<td>AVL</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shin</td>
<td>2005</td>
<td>1.5 (1.3-3.5)</td>
<td>AI 1 JAn 13 VO 5 CV 14</td>
<td>Surg</td>
<td>74</td>
<td>61</td>
<td>82</td>
</tr>
<tr>
<td>Nassar</td>
<td>2005</td>
<td>4.6 (2-24)</td>
<td>AI 62 JAn 76 VO 95 CV 10</td>
<td>Surg</td>
<td>83</td>
<td>62</td>
<td>95</td>
</tr>
<tr>
<td>Clark</td>
<td>2007</td>
<td>3.5 (0.7-14)</td>
<td>AI 6 JAn 37 VO 44 CV 2</td>
<td>PTA</td>
<td>88</td>
<td>34</td>
<td>72</td>
</tr>
<tr>
<td>Beathard</td>
<td>2003</td>
<td>4.7</td>
<td>AI 42 JAn 15 VO 20 CV 9</td>
<td>4</td>
<td>92</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Faiyaz</td>
<td>2002</td>
<td>4.0 (1.7-7.5)</td>
<td>AI ... JAn ... VO ... CV ...</td>
<td>PTA</td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asif</td>
<td>2006</td>
<td>...</td>
<td>AI 69 JAn 0 VO 0 CV 0</td>
<td>AVE</td>
<td>93</td>
<td>46</td>
<td>94</td>
</tr>
<tr>
<td>McLafferty</td>
<td>2007</td>
<td>...</td>
<td>AI ... JAn ... VO ... CV ...</td>
<td>PTA</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beathard</td>
<td>1999</td>
<td>5.0 (1-13.9)</td>
<td>AI 0 JAn 17 VO 4 CV 0</td>
<td>PTA</td>
<td>88</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Singh</td>
<td>2007</td>
<td>...</td>
<td>AI ... JAn ... VO ... CV ...</td>
<td>PTA</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td>AI 131 JAn 246 VO 232 CV 24</td>
<td>PTA</td>
<td>86</td>
<td>51</td>
<td>76</td>
</tr>
<tr>
<td>Percentage, %</td>
<td></td>
<td></td>
<td>AI 17 JAn 32 VO 30 CV 18</td>
<td>PTA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- AI, arterial inflow stenosis, located in the radial or brachial artery up until the start of the anastomosis.
- CV, central venous stenosis, located in the subclavian vein, innominate vein, or superior vena cava.
- AccV, accessory veins.
- AVE, accessory vein embolization.
- AVL, arteriovenous fistula.
- JAn, juxta-anastomotic stenosis, located in the initial 5 cm (2 inches) of the AVF starting just proximal of the anastomosis.
- PTA, percutaneous transluminal angioplasty, including balloon dilation, cutting balloon dilation, stenting, and endovascular thrombus aspiration techniques.
- Rev, revision surgery, including all techniques with which a new anastomosis was created.
- Surg, nonrevision surgery, including all surgical procedures where the original AVF was preserved (e.g., mainstream banding, superficialization, and thrombectomy).
- VO, venous outflow stenosis, located >5 cm proximal of the anastomosis up until the distal edge of the subclavian vein.

*a* IY PP: 1-year primary patency rate.

*b* IY SP: 1-year secondary patency rate.
• Risk factors for FTM in 422 patients receiving first AVF

• Risk Equation
  – Age ≥65 (OR: 2.23)
  – Peripheral Vascular Disease (OR: 2.97)
  – Coronary Artery Disease (OR: 2.83)
  – White Race (OR: 0.43)

• Scoring System
  – Base score “3”
  – Add score for factors

• Values
  +2
  +3
  +2.5
  -3

* Factors NOT correlated with FTM: Diabetes, obesity, gender, smoking
Scoring System

- Total Score 0 to 10.5
- Risk for Failure to Mature validated in prospective in group of 445 patients receiving first AV Fistula

<table>
<thead>
<tr>
<th>Score</th>
<th>Risk</th>
<th>FTM</th>
<th>Suggested Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 2</td>
<td>Low</td>
<td>24%</td>
<td>PE &amp; Routine mapping</td>
</tr>
<tr>
<td>2-3</td>
<td>Moderate</td>
<td>34%</td>
<td>Add venography</td>
</tr>
<tr>
<td>3.1-7.9</td>
<td>High</td>
<td>50%</td>
<td>Intense follow-up</td>
</tr>
<tr>
<td>≥ 8</td>
<td>Very High</td>
<td>69%</td>
<td>Consider graft</td>
</tr>
</tbody>
</table>
Fistula Maturation Protocol

Fistula Creation
Side: Right Left
Site/Type: ____________
Surgeon: ____________
Date: ________________

Examine at 4 weeks
Date: ________________
1. Is fistula adequate size for cannulation (>6 mm)?
2. Is fistula superficial (<6 mm deep)
3. Does fistula have a good continuous “thrill” & bruit without excessively pulsatile quality?

Attempt Needle Cannulation at 8 weeks
Date: ________________
1. Begin single 17 gauge cannulation
2. Advance to 16 gauge and then 2 needles as able
3. Measure access flow after successful 2 needle cannulation (if available)

Refer to Interventionalist or Surgeon for evaluation and possible ultrasound examination or fistulogram.
Potential problems include:
1. Inadequate inflow
2. Venous outflow stenosis
4. Accessory veins limiting flow

Re-examine 4 weeks after intervention, or per recommendations of interventionalist.
Date: ________________
Attempt fistula cannulation

Two weeks of continuous successful fistula cannulation?
Date: ________________

Refer to Interventionalist or Surgeon for evaluation

After evaluation and/or intervention, attempt cannulation protocol.
If still not successful, patient should be referred back for re-evaluation every four weeks. Log dates here for interventional evaluation.
Date ________________
Date ________________
Date ________________
Date ________________

Yes
No

Yes
No

Schedule catheter removal
Successful cannulation?

Yes
No
Fistula Maturation in CKD Patients not yet Receiving HD

- Reports demonstrate effective imaging, low risk for CIN with low-dose contrast in CKD patients
  - Asif et al, Semin Dial 18:239-242, 2005
    - 25 patients CKD 4 or 5
    - Venography using 10-20 cc
    - No CIN
  - Kian et al., KI 69:1444-9, 2006
    - 34 patients CKD-4
    - 65 studies
    - Mean contrast volume 7.8 cc
    - CIN in 4.6% at one week, no sequelae, returned to baseline

- Recommend:
  - Treat AVF maturation failure in CKD patients similar to ESRD
  - Low volume contrast
    - Targeted imaging
  - Be relatively patient
    - Don’t wait for thrombosis
    - Don’t wait until needed to start HD
What does one do with this fistula?!

- Stenosis
- Variant arch to external jugular vein
- Needle site pseudoaneurysms
- Collateral or accessory veins
- Collateral veins to basilic system
- Tortuous Cephalic vein

- Vein deep
- Chronic steroid skin changes
What to do with this fistula?

- Opinions solicited from interventional online discussion group, nephrologists, radiologists, vascular surgeons
  - Abandon & place graft in same arm
  - Abandon & create new fistula in left arm
  - Angioplasty everything in sight
  - Stent-graft entire putative puncture segment
  - Surgically straighten, transpose, turndown to basilic vein
  - Attempt to use “as-is” with buttonhole needles
AV Fistula Maturation: Summary

• A “good” fistula will have
  – Thrill & high flow immediately post-creation
  – Dominant dilated superficial vessel

• Evaluate early for poor maturation
  – Inflow stenosis
  – Calcified radial artery
  – Sclerotic vein
  – Competing vein branches
  – Deep vein

• Don’t wait months or years to intervene
  – Intervene early and often until usable or failed
  – Establish “forward progress”

• Abandon “hopeless” AVF sooner rather than later & create something better
AV Fistula Maturation Information

• Fistula First “Change Concepts”

  1. Routine CQI Review of Vascular Access
  2. Early referral to nephrologist
  3. Timely referral to surgeon for AVF “only”
  4. Surgeon selection based upon outcomes
  5. Utilize full range of techniques for AVF
  6. Secondary AVF
  7. Track catheters & convert to AVF
  8. Cannulation
  9. Monitoring & maintenance
  10. Education
  11. Outcomes Feedback