Doppler detection of significant access stenosis

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Disclosure

Speaker name:

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☐ I have the following potential conflicts of interest to report:

☐ Consulting

☐ Employment in industry

☐ Shareholder in a healthcare company

☐ Owner of a healthcare company

☐ Other(s)

☑ I do not have any potential conflict of interest
Stenosis by fluid dynamics

Stenosis = pressure loss due to the flow reverberation, which constricts the flow jet

https://engineering.purdue.edu
Flow constriction

Where is the flow velocity highest?
Local effect of stenosis: Venturi

Static pressure

Wall shear stress
Local effects of stenosis
Wall shear stress (WSS)

• Very high velocity ($\sim \uparrow$WSS): activation of von Willebrand factor, endothelium denudation

• Low velocity, changing vector ($\sim \downarrow$WSS): acceleration of atherogenesis and probably also of intimal hyperplasia

$$\text{WSS} \approx \frac{\text{velocity} \times \text{viscosity}}{\text{diameter}}$$
The effect of stenosis length

Fig. 5. Comparison of pressure-drop curves for blunt plugs of varying lengths.

Seeley BD, Young DF, J Biomechanics 1976
Stenosis geometry

Novakova L et al. Physiol. Res. 2015

www.cacvs.org
Pressure changes in AVG with and without stenosis

A: feeding artery, AL = arterial anastomosis, MG = mid-graft, VL = venous anastomosis, CV = central vein

Vein stenosis

No stenosis

Hand edema
Prolonged bleeding

Stenosis percentage and flow in arteries
Flow acceleration ≈ pressure gradient

<table>
<thead>
<tr>
<th>Velocity (cm/sec)</th>
<th>Pressure gradient (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>150</td>
<td>9</td>
</tr>
<tr>
<td>200</td>
<td>16</td>
</tr>
<tr>
<td>250</td>
<td>25</td>
</tr>
<tr>
<td>300</td>
<td>36</td>
</tr>
<tr>
<td>350</td>
<td>50</td>
</tr>
<tr>
<td>400</td>
<td>63</td>
</tr>
</tbody>
</table>

Simplified Bernoulli equation: \( \Delta P = 4v^2 \)
Stenosis percentage

• Angiography

• B-mode ultrasonography
Stenosis percentage

- Is it significant?
- Where is the reference/unaffected diameter?
Angiography limitation

Stenosis on transversal section
(30%, 50%, 70% and 90%)

„Luminogram“ according to the angle

From: www.cardiologysite.com
Stenosis percentage by B-mode weakness

- Effect of ultrasound setting (gain, focus...)
- Effect of manual pressure on the vessel
- Shadows by calcified tissue
- Near-field artifact

Always measure in longitudinal section

> 50% diameter reduction as the only criterion in some trials
FORGET PERCENTAGE OF STENOSIS

MEASURE:
• VELOCITY
• ACCESS FLOW
• RESIDUAL DIAMETER

DUPLEX DOPPLER ULTRASONOGRAPHY
Stenosis: velocity criterion

- $\geq 2$-3fold velocity increase = significant stenosis
PSV above 400 cm/sec in low Qa (600 ml/min or decrease by 25%)

- = significant stenosis
- can be used also in the arterial anastomosis

- According to some studies it can be used even without visualization

Velocity measurement by USG

Weakness

- Doppler angle (cosinus of) – use always the same, ideally 60°
- Aliasing limitation
- Manual pressure
- Acceleration in arches, irregularities
Additional stenosis criteria

• Access flow volume

• Resistive index

• Residual diameter
Additional stenosis criteria

- Access flow volume:
  - decrease by 20-30% - corresponds to flow volume surveillance by dilution techniques
  - absolute value < 600 ml/min (< 500 in native AVFs)
Flow volume calculation (Qa) = „function“ of the access

\[ Q_a = \pi \times r^2 \times TAMEAN \]
\[ = \pi \times \text{cm}^2 \times \text{cm/sec} \times 60 \]
\[ = \text{ml/min} \]
Flow volume calculation
= „function“ of the access

• Measure in a straight smooth segment, far from stenosis or arterial anastomosis

• AVF: measure in brachial artery

• AVG: measure in the graft
Attempts to use RI for the detection of significant stenosis – conflicting results

↑ RI in the feeding artery = trombosis or stenosis close to the arterial anastomosis

Baird DE: J Ultrasound Med. 1994
**Definition of stenosis:**

- B-mode narrowing >50% + Aliasing + PSV >2

- Resistive index (RI) > 0.5 for diagnosis of significant stenoses:
  - Sensitivity 0.98
  - Specificity 0.74

\[ RI = \frac{\text{peak systolic velocity} - \text{end diastolic velocity}}{\text{peak systolic velocity}} \]
Residual diameter by USG (B-mode + BFI)

cutt-off value 2.0 mm

BFI = blood flow imaging (GE ®)


High-frequency (>10MHz) probe!
Residual diameter by quantitative angiography
Other factors influencing stenosis progression rate?

• Stenosis intima/media thickness

• Calcification score

• Shear stress

• Presence of diabetes mellitus....
Significant vs. borderline stenosis: complex DDU criteria

B-mode lumen narrowing > 50% + > 2x peak systolic velocity increase + 1 additional criterion:

a) resid. diameter < 2.0mm
b) QB decrease > 25%
c) QB < 600 ml/min

B-mode lumen narrowing > 50% + > 2x peak systolic velocity increase

No additional criterion

## Significant vs. borderline stenosis: complex DDU criteria

<table>
<thead>
<tr>
<th>Significant stenosis</th>
<th>Borderline stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>PTA</td>
<td>Repeat ultrasound</td>
</tr>
<tr>
<td></td>
<td>after 6-8 weeks</td>
</tr>
</tbody>
</table>

**PTA injures the vessel wall healing of the injury**: Restenosis

Restenosis development after PTA is faster than stenosis progression.
Functional/practical approach to the PTA indication

- Symptomatic vs. asymptomatic stenosis
- Is Qa sufficient for dialysis?
- Presence of collaterals? Suitable for puncture?
- Presence of thrombofilia? Frequent hypotension?
- Last possible access for the patient?
Effect of USG surveillance (every 3 months) on cumulative AVG patency

Malik et al. *Kidney Int* 2005
Is this stenosis significant?

NOT ENOUGH INFORMATION!!!

DO NOT FOLLOW „OCULO-STENOTIC REFLEX“

SAVE THE PATIENT AND MONEY
Conclusions (1)

• USG offers very precise and detailed description of both morphology and function of the access, even better than angiography (except for central veins)

• PTA = fast solution + long-term problem
Conclusions (2)

• Strict criteria of stenosis significance, indicated to PTA, must be applied

• Do not bury surveillance too fast
Thank you for your attention! malik.jan@vfn.cz

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EXTENDED TILL JANUARY 31