A Case for Mandatory Routine Graft Surveillance of lower extremity bypass grafts

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Outline:

- Definition
- Background of terms and studies
- U/S surveillance
  - What is it?
  - Start, frequency, duration
  - Procedure
- Other noninvasive techniques
- Conclusion
Facts

- During the first year s/p infrainguinal vein bypass, 10-20% occlude.
- Intimal hyperplasia causes fibrous stenoses in ~1/3 of vein grafts.
- Stenosed grafts have a 3-fold increased risk of occlusion.
- Secondary patency of occluded grafts is 20-40% at 5 years.

Pollock et al., Eur J. Surg, 2001
Fig. 1. Longitudinal color flow velocity image (CVI) of infrapopliteal arterial bypass graft. The numbers, +30.1 and −90.2, that define the color velocity scale and the angle (60°) are entered into the MATLAB computer program to calibrate the velocity profile within the graft.

Fig. 3. An infrapopliteal bypass graft velocity profile as a function of depth from skin and time. Note the bluntness and nonparabolic shape of the velocity profile.

parallel to the vessel wall. A 6-s epoch was recorded (Fig. 2). In the frozen M-mode image, the operator selected the vessel of interest; in this case, the bypass graft. Graft velocity and flow rate waveforms were inspected. Velocity and flow rate measurements were performed. After erasing the image of spurious vessels, arteries and veins that may have appeared, the image containing the velocity profile information was then transferred to a computer diskette for mathematical anal.
Definitions of patency

- **Primary patency**: patency without intervention
- **Primary assisted patency**: patency after intervention (surgical or endovascular) for graft stenosis
- **Secondary patency**: patency restored after occlusion (by any means)
- **Limb salvage**: survival with an intact limb
Graft Occlusion

Time:
- < 1 month
- 1 month - 2 years
- > 2 years

Cause:
- Technical error, poor outflow, infection, hypercoagulability
- Intimal hyperplasia*
- Ongoing atherosclerotic process

Intimal hyperplasia’s responsibility

- Triggered by vascular endothelial cell damage, mechanical
- Difference in compliance b/w vessel and graft
- $\Delta$ in direction of flow at anastomosis
- Luminal diameter difference at anastomosis
- Vessel wall damage
- Suture technique
<table>
<thead>
<tr>
<th>VR Classification</th>
<th>PSV Classification</th>
<th>Description</th>
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<tr>
<td>0 - 19% diameter reduction</td>
<td>VR &lt; 2.0, mild spectral broadening in systole, PSV &lt; 150 cm/sec</td>
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<tr>
<td>20% - 49% diameter reduction</td>
<td>VR 2.0, spectral broadening throughout systole, no change in waveform across stenosis, PSV &lt; 150 cm/sec</td>
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<tr>
<td>50% to 75% diameter reduction</td>
<td>VR &gt; 2.5, severe spectral broadening in systole with loss of reversed flow components, PSV &gt; 150 cm/sec</td>
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<tr>
<td>&gt;75% diameter reduction</td>
<td>VR &gt; 3.5</td>
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PSV = Peak systolic velocity  
VR = Velocity Ratio (PSV_{stenosis} / PSV_{proximal})
Fig. 9. The Kelso waveform of five follow-up examinations performed on the same patient shown in Figs. 7 and 8. (a, b) Figures generated by cropping Figs. 7 and 8 around anastomosis A. (a, b, c) Figures taken 2, 3, and 4 months after graft revision. (c) The peak systolic velocity increases from 85 cm/s at the prestenotic site to 440 cm/s at the stenotic site, and very focal intimal thickening can be seen on both proximal and distal walls. This restenosis was corrected by Dacron patch angioplasty, an artificial graft. (d) Figure taken 1 month after this revision. We can see that the previous stenosis/anastomosis was replaced by a Dacron patch, a dilated area. The velocity has dropped considerably. (e) Figure taken 3 months after the revision. There is no change of velocity; however, some intimal thickening noted as a “mound” on the distal wall at point C began developing.
When should we start surveillance?

- N=224 bypass grafts
- Early (<6 weeks) for 1st duplex scan
- 58/224 abnormal scans detected
- 30/58 required arteriography
- 23/30 necessitated graft revision w/in 3 mos
- Mean PSV>300 cm/s, VR 4
- Grafts harboring such lesions would be predicted to be at high risk for sudden raft occlusion

Nielsen. Eur J Vasc Endovasc Surg. 1996 “Stenoses identified w/in 3 mos of surgery associated w/ an increased risk of thrombosis compared to stenoses identified at a later stage”

Richardson et al. study

Premise: compare intensive surveillance (serial ABI + duplex) vs. clinically indicated procedures. N=615 (317 IS vs. 222 CI) similar age, sex, risk factors, indications

Results:
- Primary patency at 5 yrs same for IS and CI
- Secondary patency improved for IS (p<0.02)
- Limb salvage improved for IS (p<0.02)
Figure 1. Autogenous vein bypass grafts followed by intensive surveillance (closed circles) had a significantly higher (p < 0.02) secondary patency rate compared with follow-up by clinically indicated procedures (open circles).

Figure 2. Patients with grafts followed by intensive surveillance (closed circles) had a significantly higher (p < 0.02) limb salvage rate compared with follow-up by clinically indicated procedures (open circles).
So, why do we care?

- Detection (ABI + graft velocity) and correction of graft threatening lesions before thrombosis improves clinical outcome, decreases cost.

Fig 3. Cumulative patency for grafts revised after duplex identified stenoses (n = 46) and for grafts revised after thrombosis (n = 15).
Table VI. Cost-benefit analysis of an intensive surveillance program versus revision for clinical indication

<table>
<thead>
<tr>
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<th>Intensive surveillance (n = 150)*</th>
<th>Clinically indicated revision (n = 222) †‡</th>
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<tbody>
<tr>
<td>No. of grafts revised (%)</td>
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<tr>
<td>Revision before thrombosis</td>
<td>58 (37)</td>
<td>34 (13)</td>
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<tr>
<td>Revision after thrombosis</td>
<td>46 (29)</td>
<td>9 (4)</td>
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<tr>
<td>Cumulative graft patency (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 y</td>
<td>91</td>
<td>84</td>
</tr>
<tr>
<td>5 y</td>
<td>82</td>
<td>67</td>
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<tr>
<td>Limb salvage (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 y</td>
<td>96</td>
<td>83</td>
</tr>
<tr>
<td>5 y</td>
<td>92</td>
<td>73</td>
</tr>
<tr>
<td>Estimated cost per graft ($)</td>
<td></td>
<td></td>
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<tr>
<td>1 y</td>
<td>7,742</td>
<td>10,842</td>
</tr>
<tr>
<td>5 y</td>
<td>12,194</td>
<td>16,352</td>
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*Excluding early failures (< 30 days) from current series.


‡It is assumed that 75% of all revisions are performed within 1 year of implantation and reminders are performed in following 4 years. Cost estimation is based on 1998 cost data at the University of Arizona Health Science Center.

Estimated cost/patient = (% amputees)(cost amputation) + (% revision for stenosis)(cost revision for stenosis) + (% revision for thrombosis)(cost of revision for thrombosis) + cost of duplex examination (3 scans in first year, 9 scans in 5 years) [surveillance group only].
Retrospective analysis:

- Pollock et al. 2001. n=61, underwent surveillance program at 1 week, 6 weeks, 3 months and then every 3 months for 1 year. Graft at risk if ABI dropped >0.15, focal disturbance of flow on doppler, or Δ in waveform on duplex.

- Patency: 1° – 63%, PA – 88%, 2° – 88%, LS - 90%

Figure 2  (A) Duplex scan of a focal (< 1 cm) stenosis at the distal segment of a left femoral–anterior tibial reversed vein graft 12 months postoperatively. The graft was otherwise in good shape (4.0-mm diameter). PSV = 567 cm/s and V/\text{V}_{	ext{graft}} = 9.4. (B) Nine months after successful dilation of the vein, the PSV is 93 cm/s.
Threshold intervention criteria for graft lesions: PSV > 300 cm/sec, Vr > 3.5, PSV < 45 cm/sec throughout graft, or an ABI decrease >0.15.

Rates of graft occlusion

- N=97
- Claudication, CHI
- n=64 with u/s
- n=42 w/o u/s
- Graft occlusion 29/42 w/o u/s
- 14/64 w/ surveillance
- After 1,3 yrs (p=0.0001)
- 16 amputations in nonsurveillance group
3D graft geometry and spectral waveforms, allows 1) evaluation of graft anatomy. 2) PSV at any location on graft.
Prospective, randomized trial of PTFE and vein grafts

n=156 (79 IS/77 RS)

IS -> clinical exam, ABI, duplex q3 months x 12

RS -> clinical exam, ABI q12 months x 3

↓ ABI >0.015 + graft or anastomotic stenosis >50% ------ > angio

Significant improvement in 1º Assisted and 2º patency (p<0.05)
No statistical significance b/w routine or intense surveillance in PTFE/composite grafts’ patency.
Duration of Surveillance

N=341 autogenous vein grafts.
5 year study
Abnormal: focal flow disturbance, PSV>150 cm/s <3 months after surgery
82% of graft revisions w/in 2 years (69% in 1st year)
2-4% incidence of late appearing graft stenosis

Fig 4. The percentage of grafts at risk that required an initial revision for an intrinsic lesion is plotted in time by months. The solid line represents the grafts with early flow disturbances; the broken line represents grafts with normal early scan results.

Duration of surveillance

Fig 1. Primary patency rates for grafts with early (within the first 3 months) abnormal duplex scan results, compared with grafts with early normal scan results.

Fig 2. Assisted primary patency rates for grafts with early (within the first 3 months) abnormal duplex scan results, compared with early normal duplex scan results.

Routine surveillance s/p popliteal aneurysm repair

- n=55 PAs needing repair
- Duplex pre d/c, 4 weeks, q3 months for 2 yrs
- Duplex identified 20/55 abnormalities in mainly asympt. pts.
- at 3 years: PP 76%, PAP 88%, LS 100%
What about arm veins?

- Infrainguinal bypass grafting w/arm vein associated with ↓ patency rates 2/2 stenosis and aneurysm

- Arm vein bypasses require life long duplex u/s surveillance
- duplex u/s also helps document technical success of interventions, esp. ndovascular

n=89 pts
f/u every 3 months for 36 mos

Intervention by surgery or PTA for PSV>300 cm/s and VR>3.5

Retrospective study re. value of duplex surveillance in axillofemoral bypass grafts describes greater likelihood of patency if flow velocities through midportion of graft remain > 140 cm/s.

Doppler surveillance of AV grafts proven to be helpful in maintaining patency by early detection of stenoses or aberrant velocities.
Conclusions

1. Graft surveillance is mandatory
2. It improves primary assisted and secondary graft patency
3. Leads to improved patency compared to revised grafts following thrombosis
4. DS surveillance for CLI leads to reduction in amputations and overall costs, Hunink et al.
5. Future studies for vein graft surveillance include assessment of transfer function index (of PVR), impedance index, and peak-peak pulsatility index