Physiologic Basis for Staging in Extensive Endovascular TAAA Repairs: How to do it: What are the indications, advantages and limitations?

Matthew J. Eagleton, MD
Associate Professor
Walter W. Buckley Endowed Chair in Research
Director Vascular Surgery Training Programs
Vascular Surgery Director of Cleveland Clinic Aortic Center
Cleveland Clinic Lerner College of Medicine-CWRU

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Disclosures
• Bolton Medical – Consultant
• Cook Medical – Consultant
• Centerline Biomedical – Advisory Board/Consultant

Spinal Cord Ischemia (SCI)

• Devastating complication after aortic surgery

• We need to limit this risk if endovascular repair of complex TAAA is to be successful

Etiology of SCI Events Following Endo Repair

• Intercostal interruption – Length of coverage
• Collateral flow interruption – Vertebral – Internal iliac
• Hypotension
• Embolic
• Management – Hemodynamic support – CSF drainage

Strategies to Decrease SCI

• Neuroprotective measures
  – Reduces metabolic activity of spinal cord
  – Reduce neural cell apoptosis
  – Prevent/limit spinal cord inflammation and swelling

• Attempts to maintain spinal cord perfusion
  – Maintain direct perfusion
  – Augment perfusion – particularly important when cannot maintain direct perfusion

Collateral Network Theory

In endovascular, given the coverage of the segmental arteries, we rely on peri-spinous collateral network
**PHYSIOLOGIC BASIS OF STAGING REPAIRS**

**Evidence Supporting Staged Procedures**

**Experimental Data**
- Porcine model
- Underwent ligation of T13-L5 spinal arteries
- Randomized to...
  - Group 1: Immediate TEVAR
  - Group 2: Staged TEVAR (7 days later)
- 50% of Group 1 animals developed paraplegia
- None in Group 2 developed paraplegia

Bischoff MS et al., Ann Thorac Surg 2011; 92: 138-146

**Collateral Network Pressure Outcomes**

- Immediate TEVAR
  - ↓ 24 mm Hg after TEVAR
  - Returned to baseline by 5 days

- Staged TEVAR
  - Returned to baseline before second stage
  - Only dropped to 54 mm Hg after TEVAR

Baseline CNP was 74 mmHg ↓ to 41-43 mm Hg after ligation

**Collateral Network Orientation**

- Epidural Arterial Network: (within 5 days)
  - Increased in diameter 80-100%
  - Increased in density of intramuscular paraspinous vasculature
  - Re-alignment of paraspinous arterioles to run parallel to the spinal cord

Etz CD et al, J Thorac Cardiovasc Surg 2011; 141: 1029-36

**HOW CAN WE EMPLOY THIS IN CLINICAL PRACTICE?**

**Methods of Staging**
- Leave fenestrations/branches open
- Paraplegia prevention branches
- Staged aortic coverage
- Staged intercostal embolization

Data is LIMITED…
Perfusion Branches

Staged Occlusion of Perfusion Branches
- Performed percutaneously
- After patient has recovered from primary procedure (5-10 days)

Intercostal embolization – staged fashion
- First-in-man endovascular preconditioning of the paraspinous collateral network by segmental artery coil embolization to prevent ischemic spinal cord injury

Outcomes:
SCI higher in single stage approach

<table>
<thead>
<tr>
<th></th>
<th>Single Stage</th>
<th>Two Staged</th>
<th>Unintent. Staged</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI</td>
<td>12 (37.5%)</td>
<td>3 (11.1%)</td>
<td>4 (14.3%)</td>
<td>0.025</td>
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</tbody>
</table>
Outcomes: Intentional staging was associated with less severe symptoms

<table>
<thead>
<tr>
<th>Severity Score</th>
<th>Single Stage</th>
<th>Two Staged</th>
<th>Unintent. Staged</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 1 (Weak v. gravity)</td>
<td>5 (42%)</td>
<td>2 (67%)</td>
<td>1 (25%)</td>
<td>0.025</td>
</tr>
<tr>
<td>- 2 (Weak v. no gravity)</td>
<td>0 (0%)</td>
<td>1 (33%)</td>
<td>1 (25%)</td>
<td></td>
</tr>
<tr>
<td>- 3 (Paralysis)</td>
<td>7 (58%)</td>
<td>0 (0%)</td>
<td>2 (25%)</td>
<td></td>
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</tbody>
</table>

Outcomes: Intentional staging was associated with improvement from SCI symptoms

<table>
<thead>
<tr>
<th>Duration</th>
<th>Single Stage</th>
<th>Two Staged</th>
<th>Unintent. Staged</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved</td>
<td>7 (58%)</td>
<td>3 (100%)</td>
<td>1 (25%)</td>
<td>0.03</td>
</tr>
<tr>
<td>Permanent</td>
<td>5 (42%)</td>
<td>0 (0%)</td>
<td>3 (75%)</td>
<td></td>
</tr>
</tbody>
</table>

Survival Type II Repairs

How do we approach patients?
- Pre-operatively optimize patient’s medical condition
- Evaluate the aorta and choose appropriate proximal and distal landing zone
- Decide whether staging is feasible – if so plan staging method
- Assure collateral bed patency if possible
  - Preserve hypogastric
  - Preserve subclavian arteries
- Expedite surgery and early restoration of flow to the pelvis and legs
- Meticulous post-operative management

Future Questions and Investigations
- Is there a “best method” for staging?
- Can we use selective staging?
- What is the best timing for staging?
- Why may staging limit SCI – better understanding of the physiology?
  - Limit time of each OR
  - Limit degree of embolization
  - Promote spinal collateralization