Technique And Limits Of Spinal Drainage With TAA And TAAA Repairs: How To Prevent Spinal Drain Complications

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Disclosures
• Cook - Research Support, Consultant, Clinical Trials
• WL Gore - Consultant, Clinical Trials
• Bolton Medical - Consultant
• Medtronic - Clinical Trials, Consultant
• Endologix - Clinical Trials, Consultant

Overview
• Incidence
• Pathophysiology
• Prevention strategies

Incidence Of Spinal Cord Ischemia

Modified Crawford Classification

Extent of aneurysm repair and clamp time correlated with complication risk for open repair

Current Publications

Surgical: 8-10%, Endovascular: 2-4%

Spinal cord injury after TAAA repair
Open vs endo

Mortality:
Open repair: 8.3%
Endo repair: 5.7%
P<0.12

Spinal Cord Injury:
Open repair: 7.8% (24/372)
Endo repair: 4.3% (15/352)
P<0.08

Predictors of SCI:
Aneurysm extent
(Type II>III>IV)
Prior distal aortic repair

Rates of Spinal Cord Injury by TAAA Type (%)

724 patients (2001-2006)

OR ER OR ER OR ER OR ER
14 10 22 19 10* 6 2 3
OR and ER, open and endo repair
* P<0.05

Classification: Descending Thoracic Aneurysms
Safi Extent Classification

Results of Open Repair of DTA (not TAAA)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mortality</th>
<th>Renal Failure</th>
<th>Paraplegia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coselli 2004</td>
<td>387</td>
<td>2.8%</td>
<td>7.4%</td>
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<tr>
<td>Estrera 2001</td>
<td>182</td>
<td>8.8%</td>
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<tr>
<td>Galloway 1996</td>
<td>78</td>
<td>10.3%</td>
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<tr>
<td>Verdant 1995</td>
<td>366</td>
<td>12%</td>
<td>2.4%</td>
<td>0%</td>
</tr>
<tr>
<td>Livesay 1985</td>
<td>360</td>
<td>11.7%</td>
<td>6%</td>
<td>6.5%</td>
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<tr>
<td>Svensson 1993</td>
<td>782</td>
<td>-</td>
<td>-</td>
<td>4.9%</td>
</tr>
<tr>
<td>Total</td>
<td>2155</td>
<td>8.8%</td>
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Results of Endovascular Repair of DTA

<table>
<thead>
<tr>
<th>Endoluminal Series</th>
<th>Cases of paraplegia</th>
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<tr>
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<td>0</td>
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Confounding Factors

- EV performed under normothermic conditions
- Embolization risk may be increased with EV
- More segmental vessels occluded with EV
- Steal into the excluded aneurysm - Both
- No aortic occlusion - less hypotension with EV
- Two cohorts are not case matched
  - Higher risk EV repairs

Classification: Descending Thoracic Aneurysms
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Courtesy: Makaroun, M and Bell, R, U Pitts and Guy’s Hospital, London
Paraplegia Risk with DTA Repair

Meta-Analysis

- **Open Repair**: 3.8%
- **Endo Repair**: 3%

Courtesy Makaroun, M and Bell, R. U Pittsburgh and Guy’s Hospital, London

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Peri-operative Comparative Results

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<th>TAA (N = 140)</th>
<th>OPEN (N = 94)</th>
<th>P</th>
</tr>
</thead>
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<tr>
<td>Operative Mortality</td>
<td>2 %</td>
<td>12 %</td>
<td>0.01</td>
</tr>
<tr>
<td>Paraplegia or Paraparesis</td>
<td>3 %</td>
<td>14 %</td>
<td>0.01</td>
</tr>
<tr>
<td>Stroke</td>
<td>4 %</td>
<td>4 %</td>
<td>1.0</td>
</tr>
<tr>
<td>Major* Adverse Events @ 30 days</td>
<td>28 %</td>
<td>70 %</td>
<td>0.0001</td>
</tr>
<tr>
<td>Major Adverse Events</td>
<td>23 %</td>
<td>58 %</td>
<td>0.001</td>
</tr>
<tr>
<td>Mean Hospital Stay</td>
<td>3 d</td>
<td>10 d</td>
<td>0.001</td>
</tr>
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*According to Sacks et al Criteria. JVIR 1997;8:137-149 Courtesy M Makaroun

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Anatomy of Spinal Cord Blood Supply


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The Artery of Adamkiewicz

- No single intercostal is absolutely necessary for SC integrity
- Multiple collaterals allow for sacrifice of several collaterals
- Risk of paraplegia increases when the number of intercostal pairs sacrificed > 10 (i.e. Type II TAAA)

Functionally continuous anterior spinal artery stretching from the foramen magnum to the cauda equina


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Collateral Network Theory

- Network of axial arteries in the
  - Spinal Canal
  - Paravertebral tissue
  - Paraspinal muscles
- Inflow sources
  - Segmental arteries
  - Subclavian
  - Hypogastric
- Perfusion can increase from one source when reduced in another
- Steal can occur from low resistance pathways
- Nitroprusside
- Open repair
Possible Mechanisms of Spinal Cord Ischemia

Pathophysiology of Paraplegia Following Endovascular Thoracic Aortic Aneurysm Repair

Alfio Carrocio MD, Michael Marin MD, Sharif Ellozy MD, and Larry Hollier MD
Division of Vascular Surgery, Mount Sinai, NY, NY

Pathophysiology

- Spinal Cord PP = MAP-CSF Pressure
- When clamping and unclamping the aorta and tying of collateral blood vessels
- Decreasing PP
- Ischemia → increasing the CSF pressure by swelling and ischemia reperfusion of the spinal cord
- In Fenestrated or Branched endovascular repair: covering lumbar arteries and require collateral blood supply to maintain perfusion pressure
- Contribution from
  - hypogastric
  - L SCA

Determinants

- Impacted by Event
  - Embolic, Occlusion, Hypotension
  - Duration
  - Severity
- Neuronal metabolic rate during the ischemic period
- Subsequent reperfusion injury

Mechanism of Spinal Cord Ischemia

Open Repair

- Segmental blood supply / sometimes discontinuous
- Length of replacement directly related to incidence of paraplegia
- SC perfusion pressure = Mean BP – CSF P
  - Both affected by clamping and medications
- Reperfusion Injury: O2 Radicals, cytokines from visceral ischemia
- Steal from open IC arteries (back-bleeding)
Mechanism of Spinal Cord Ischemia

TEVAR
- Coverage of critical intercostals leading to immediate paraplegia
- Episodes of hypotension with subsequent loss of collaterals
- Delayed thrombosis of IC (via endoleak resolution)
- Visceral ischemia from abdominal repair or embolization with release of cytokines
- Steal from endoleak/shunting
- Embolic events

Recent Findings
- Eurostar Data - Number of Stent inserted may play a role
- Arizona Heart - Length of Stents inserted

Predictors Of Spinal Cord Ischemia


Predictors of Spinal Cord Ischemia

Delayed Deficits
- 854 patients February 1991 - May 2001
- 38 Immediate neuro deficits excluded
- Incidence: 2.7% (21/790)
- Evaluated numerous factors including pre-operative and operative data

Predictors of Spinal Cord Ischemia

<table>
<thead>
<tr>
<th>Predictor</th>
<th>OR</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal Dysfunction</td>
<td>5.9</td>
<td>&lt; 0.006</td>
</tr>
<tr>
<td>Acute Dissection</td>
<td>3.9</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Extent II Replacement</td>
<td>3.0</td>
<td>&lt; 0.03</td>
</tr>
</tbody>
</table>


Management Strategies Of Spinal Cord Ischemia

- SCD
- Avoid hypotension
- Staged repair
- Pharmacotherapy
- Pressure
- EPO

Prevention

- Temporary Device
  - Reported, but not in clinical use (perfusion branch)
- Staged Repair
- CSF Drainage
- Monitoring
- Pharmacotherapy
  - Erythropoietin
  - Free radical scavengers
- Identify critical vessels

Spinal cord injury Preventive strategies

- CSF drainage
- MEP and SSEP monitoring
- Femoral conduits
- Paraplegia prevention branch
Perfusion Branch

- Risk of rupture > 0%

Paraplegia prevention branch

- Staged occlusion POD 24
- Dismissed in 72 hrs

Paraplegia prevention branches

Management Strategies Of Spinal Cord Ischemia

- Evidence supports the use of CSF drainage as an adjuvant to prevent paraplegia when adjuvant is used in centers with large experience.

Staged Repair


Spinal cord perfusion

Changes after total segmental arterial ligation

Bischoff M, Griepp RK; In: Oderich G, Greenberg R. Endovascular Treatment of Complex Aortic Aneurysms; Perspec Vasc Endovasc Surg 2011

Staging of evTAAA Repairs

Many repairs involve a thoracic proximal component
- conduit placement is also necessary in some patients
- ilio-femoral bypass with access branch
- Hypothesis is that staging may reduce risks of paraplegia


<table>
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<tr>
<th>Pts</th>
<th>SCI</th>
<th>Permanent</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staged</td>
<td>37</td>
<td>37.5%</td>
<td>15.6%</td>
</tr>
<tr>
<td>Staged Intentional</td>
<td>27</td>
<td>11.1%</td>
<td>0%</td>
</tr>
<tr>
<td>Staged Unintentional</td>
<td>28</td>
<td>14.3%</td>
<td>10.7%</td>
</tr>
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Staged patients had significantly more aortic coverage

Staged endovascular repair of thoracoabdominal aortic aneurysms limits incidence and severity of spinal cord ischemia

- Cohort of 87 pts with Extent II TAAA
- January 2008 to July 2013

Spinal cord perfusion

Changes after total segmental arterial ligation

Bischoff M, Griepp RK; In: Oderich G, Greenberg R. Endovascular Treatment of Complex Aortic Aneurysms; Perspec Vasc Endovasc Surg 2011

Staged patients had significantly more aortic coverage
Spinal cord injury
Single vs. two-stage aortic repair

Management Strategies Of Spinal Cord Ischemia

Cerebrospinal fluid drainage reduces paraplegia after thoracoabdominal aortic aneurysm repair: Results of a randomized clinical trial

CSF Drainage and Distal Reperfusion

Prevention of Spinal Cord Ischemia
Effect of Monitoring and Early Treatment

75 TEVAR patients
- Selective Monitoring: AAA or long replacement
- Lumbar Drains: 23 Pts / SSEP 15 Pts
  - If weakness: keep Mean BP > 90 mmHg and CSF < 10 cm H2O
- 5 patients with paraplegia or paraparesis (6.6%)
  - 2 immediate loss of SSEP after stent
  - 4 delayed onset paraplegia
  - Two full recovery with increasing mean BP alone
  - Two full and one partial recovery from increasing BP and Spinal Fluid Drainage

Management Strategies Of Spinal Cord Ischemia

36 TEVAR patients
- Lumbar Drains / SSEP / Transcranial motor evoked potential
- Adjustment of BP and CSF drainage
- Survival without paraplegia 100%

EPO and NO

Pharmacologic treatment with EPO or free radical scavengers may have some benefit in patients based on laboratory data
- No clinical trial data to date

Conclusions

- SCI rates are as low if not lower with endovascular repair
- Modern theory suggests not single critical vessel
- Prevention strategies involves multi-modality approach with SCD, elevated MAP, and possible pharmacologic therapy

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"The future is here. It's just not widely distributed yet."

William Gibson

University of North Carolina