The Application of Endovascular Techniques to Vascular Trauma – What Is Possible?

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- Avoids direct surgical exposure of the injury
- Temporize life-threatening injuries and allow for revascularization
- Could serve as primary treatment of acute vascular injury

Endovascular Techniques

- Avoids direct surgical exposure of the injury
- Temporize life-threatening injuries and allow for revascularization
- Could serve as primary treatment of acute vascular injury

Trauma and Endovascular Surgery
Agenda

- Temporizing vascular control
  - Occlusion balloon
- Embolization as a mean for hemorrhage control
  - Extremity vascular trauma
- Stent graft for revascularization
  - Axillo-subclavian vascular trauma

Penetrating Injury to the Abdomen

- 28 yo male assaulted by relative
- Reported active hemorrhage at scene
- Brought to, tachycardic, nl BP
The Beginning

Hemodynamic improvement in hemorrhagic shock by aortic balloon occlusion and hypertonic saline solutions

Preliminary Report on the Use of the Perculator® Occluding Aortic Balloon in Human Beings

23 patients:
15 trauma  5 AAA  3 others
2 survivors  4 survivors  0 survivors


AOB inserted if SBP < 80 mmHg
Inflation in 15 patients
11 pts with improvement in SBP of ≥ 50%

5/12 success  11/12 success

Inflation in 12 percutaneous  12 open exposure
The Role of Intra-aortic Balloon Occlusion in Penetrating Abdominal Trauma

- Good pre-hospital response system
  - 7 minutes on scene
  - 12 minutes average transport time
- Insertion in ED or in OR
  - 50:50 cut down versus percutaneous
- Balloon has center channel to monitor aortic pressure

287 patients with penetrating abdominal trauma

1. BP not responsive to fluid resuscitation
2. SBP < 80 mmHg
3. Hypotension during ex lap
   - Cardiac rhythm but no BP (5 patients)
   - Not responsive to fluid resuscitation (6 patients)
   - Hypotension during ex lap (10 patients)

DIOR

50% mortality

60% mortality

Intra-Aortic Balloon Occlusion to Salvage Patients With Life-Threatening Hemorrhagic Shocks From Pelvic Fractures

- FAST Exam
- Persistent Blood with SBP < 90 mmHg
- 3 L crystalloid or 2 L colloid + PRBC
- SBP persistent < 90 mmHg after 1 hour of resuscitation


2064 pts with pelvic fx

- FAST Exam
- Persistent Blood with SBP < 90 mmHg
- 3 L crystalloid or 2 L colloid + PRBC
- SBP persistent < 90 mmHg after 1 hour of resuscitation

Martinelli et al. J Trauma 2010;68: 942-948
Does It Work?

**Table 1: Ischemic LE**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1</th>
<th>Group 2</th>
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<tbody>
<tr>
<td>Incidence of LE</td>
<td>42/123</td>
<td>62/123</td>
</tr>
<tr>
<td>Incidence of paraplegia</td>
<td>2/42</td>
<td>3/62</td>
</tr>
<tr>
<td>Probability of survival</td>
<td>0.80</td>
<td>0.85</td>
</tr>
</tbody>
</table>

**Table 2: IAOB - Complications**

- Ischemic LE
- Aortic balloon exited through the aortic injury in 2/21
- One paraplegia

Penetrating Injury to the Abdomen
Penetrating Injury to the Abdomen

• Primary repair of stomach
• Return of bowel function on POD#6
• Discharge to home POD#8

Peripheral Vascular Trauma

50 yo male s/p SW, no bleeding, c/o pain and swelling
Peripheral Vascular Trauma

30 yo male s/p GSW, expanding L groin mass
Axillo-Subclavian Vascular Trauma

- Significant Morbidity and Mortality

### Table 19-4

**Outcomes following repair of upper extremity vascular injury: selected review of the recent literature**

<table>
<thead>
<tr>
<th>Artery</th>
<th>Series</th>
<th>Years</th>
<th>B &amp; D</th>
<th>AMP</th>
<th>AAA</th>
<th>VMS</th>
<th>MLA</th>
<th>Male (%)</th>
</tr>
</thead>
</table>


Subclavian/Axillary Injury

- First reported by Patel et al 1996
  - Penetrating injury
  - PTFE graft sutured on Palmaz stent
  - Mean F/U of 19 months
    - One stent fracture @ 8 month


**Endovascular Graft Repair of Penetrating Subclavian Artery Injuries**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Mechanism of Injury</th>
<th>Lesion</th>
<th>Cannulation Site</th>
<th>Stent Type</th>
<th>Length</th>
<th>Access</th>
<th>In-hospital Mortality</th>
<th>Hospital Stay</th>
<th>Vascular Access Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1101</td>
<td>Knife</td>
<td>Median</td>
<td>PTA</td>
<td>Palmaz</td>
<td>PTFE</td>
<td>PTA</td>
<td>7</td>
<td>30</td>
<td>Right FJ</td>
</tr>
<tr>
<td>1102</td>
<td>Ball</td>
<td>Median</td>
<td>PTA</td>
<td>Palmaz</td>
<td>PTFE</td>
<td>PTA</td>
<td>4</td>
<td>26</td>
<td>Right FJ</td>
</tr>
<tr>
<td>1103</td>
<td>Artery</td>
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<td>PTA</td>
<td>Palmaz</td>
<td>PTFE</td>
<td>PTA</td>
<td>8</td>
<td>33</td>
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<td>PTA</td>
<td>Palmaz</td>
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<td>PTA</td>
<td>6</td>
<td>22</td>
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<td>Palmaz</td>
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<td>PTA</td>
<td>4</td>
<td>18</td>
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<td>PTA</td>
<td>Palmaz</td>
<td>PTFE</td>
<td>PTA</td>
<td>3</td>
<td>7</td>
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<tr>
<td>1107</td>
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<td>Palmaz</td>
<td>PTFE</td>
<td>PTA</td>
<td>7</td>
<td>7</td>
<td>Right FJ</td>
</tr>
</tbody>
</table>

• 10 patients treated
  – 7 AV fistula
  – 3 pseudoaneusym
  – All were with Viabahn via transfemoral route
Axillo-Subclavian Vascular Trauma
The HMC Experience

Endovascular Therapy in Trauma

- Increase utilization of catheter/endovascular therapy in the management of solid organ injury and hemorrhage from pelvic fracture
- Problem
  - Division between angio suite and the operating theater

The Hybrid OR

- Combined capability of both the angio suite and the operating theater
  - High resolution fixed imaging
  - Traditional OR with full anesthetic support
One Stop Shopping

Long Bone Fracture
  ORIF

Pelvis Fracture
  Embolization

Blunt thoracic aortic injury
  TEVAR

Exploratory Laparotomy

The Hybrid OR

Summary

- Endovascular therapy has great potential in the management of vascular trauma
  - “damage control”
  - Definite repair
- The “hybrid OR” allows for both open and endovascular procedures to be done in the same physical setting
- Need
  - Multi center data
  - Long term follow up
Both are complementary
Facile with both and offer the best therapy for a given clinical situation
The Application of Endovascular Techniques to Vascular Trauma – What Is Possible?

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One Stop Shopping

The unstable patient with multiple injuries requiring both endovascular treatment and traditional open surgical procedure

Angio Suite

Operating Room

???

Trauma and Endovascular Surgery

TECHNICAL NOTES

Temporary Percutaneous Aortic Balloon Occlusion to Enhance Fluid Resuscitation Prior to Definitive Embolization of Post-TRAUMATIC Liver Hemorrhage


Use of an endovascular occlusion balloon for control of unremitting venous hemorrhage

Bryan W. Tillman, MD, PhD, Patrick S. Vaccaro, MD, Jesse E. Stern, MD, and R. Mohan Das, MD, Columbus, Ohio

Disclaimers

- Imaging
- Blunt thoracic aortic injury
  - Not guidelines or recommendations as most data are level IIb to III/IV
    - Case/institution series
    - Case report

Management of Vascular Trauma in the Endovascular Era

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1. Blunt thoracic aortic injury ---> TEVAR
2. Long bone fracture ---> ex fix
3. + DPL ---> ex lap
4. Pelvic Fracture ---> ex fix, pelvic embo

Harborview- 10 years, 140 patients

The Harborview Experience 1999-2008

0.5% of all trauma patients who survive to ED presentation

BAI N = 140
- Mean age: 40 years old (range 10-89)

Endovascular repair n = 49
- Patients with multiple injuries

BAI presented at the 64th Society for Vascular Surgery annual meeting
Background

- Explosion of endovascular technology within the last decade
- Shifting paradigm in the treatment of vascular disease
  - EVAR for AAA
  - TEVAR for TAAA
  - Renal, iliac, LE PTA/stent

Thoracic Vascular Trauma

Reduced mortality, paraplegia, and stroke with stent graft repair of blunt aortic transections: A modern meta-analysis

From the Society for Vascular Surgery

Reduced mortality, paraplegia, and stroke with stent graft repair of blunt aortic transections: A modern meta-analysis

Giss K. Yang, MD, Hanmin E. Kim, MD, O.C.R., Joel Vonsah, B.S., Washington University, St. Louis, MO

Objective: To determine if the use of endovascular grafting has become the first-line approach to traumatic thoracic aortic transection (TTAT) in some trauma centers due to a paradigm shift, and to critically appraise the current literature comparing open and endovascular repair of traumatic thoracic aortic transection. Methods: Systematic review of the literature from 1950 to 2019 was performed, using PubMed, EMBASE, and the Cochrane Library. Inclusion criteria included publications evaluating the use of endovascular grafting for traumatic thoracic aortic transection with at least 10 patients. Meta-analysis was performed using a random effects model. Results: Eight studies met inclusion criteria, involving 811 patients. Of these, 437 patients underwent open surgery and 374 patients underwent endovascular repair. Mortality was significantly lower in the endovascular group (5% vs. 9%), p = 0.04. Paraplegia and stroke rates were also lower in the endovascular group (2% vs. 8% and 0% vs. 4%, respectively). Conclusion: The use of endovascular grafting for traumatic thoracic aortic transection is associated with lower mortality, paraplegia, and stroke rates compared to open surgery.
9/29 were iatrogenic
- Only one blunt injury
- Mean f/u was 24 months

699 procedures
- 370 Endo
- 329 Open

Mortality
- 7.6% Endo
- 15.2% Open
  p=.0076

Paraplegia
- 0% Endo
- 5.6% Open
  p=.001

Stroke
- 0.85% Endo
- 5.3% Open
  p=.0028

Use of IAOB During Pelvic ORIF

Average Blood Loss

N = 10

Anterior
  Tylenol
  Standard

Posterior
  Tylenol
  Standard
Table 3

<table>
<thead>
<tr>
<th></th>
<th>Intimal tear</th>
<th>Large Intimal Flap</th>
<th>Pseudoaneurysm</th>
<th>Rupture</th>
<th>Total</th>
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<tbody>
<tr>
<td>Wallgraft trial</td>
<td>23</td>
<td>2</td>
<td>20</td>
<td>3</td>
<td>0</td>
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<tr>
<td>Iliac</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Subclavian</td>
<td>100</td>
<td>43</td>
<td>14</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Femoral</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>140</td>
<td>55</td>
<td>36</td>
<td>35</td>
<td>20</td>
</tr>
</tbody>
</table>

Harborview- 10 years, 140 patients

- Wallgraft trial 1997 – 2003 (n = 62)
  - Iliac (33)
  - Subclavian (18)
  - Femoral (11)
- Comparison to OPC (objective performance criteria) – i.e surgical repair
  - Historical control based on literature search

Agenda

- Cervical Vascular Trauma
- Axillo-Subclavian Trauma
- Extremity Vascular Trauma
  - Thoracic Vascular Trauma
  - Abdominal and Ileo-Femoral Vascular Trauma

Arch Vessels Trauma

- 55 yo male crushed between a back hoe and a rock crusher - unconscious at scene
- Multiple rib fractures
- Mediastinal hematoma
- Injury to the left vertebral artery with active extravasation
Should Blunt Arterial Trauma to the Extremities be Treated with Endovascular Techniques?

We used angioplasty as a means of ‘gluing’ the injured intima to the vessel wall. The intima is actually ‘hacked’ to
Dissection of the abdominal aorta in blunt trauma: Endovascular or conventional surgical management?
Cervical Vascular Trauma

- Normal Neuro Exam
- 325 mg ASA
- No Heparin
- TCD's – 8 emboli/hr
Prospective Study of Blunt Aortic Injury: Multicenter Trial of the American Association for the Surgery of Trauma. Fabian, Timothy; Richardson, J; Croce, Martin; Smith, J; Rodman, George; Kearney, Paul; Flynn, William; Ney, Arthur; Cone, John; Luchette, Fred; Wisner, David; Scholten, Donald; Beaver, Bonnie; Conn, Alasdair; Coscia, Robert; Hoyt, David; Morris, John; Harviel, J; Peitzman, Andrew; Bynoe, Raymond; Diamond, Daniel; Wall, Matthew; Gates, Jonathan; Asensio, Juan; McCarthy, Mary; Girotti, Murray; VanWijngaarden, Mary; Cogbill, Thomas; Levison, Marc; Aprahamian, Charles; Sutton, John; Allen, C; Hirsch, Erwin; Nagy, Kimberly; Bachulis, Ben; Bales, Charles; Shapiro, Marc; Metzler, Michael; Conti, Vincent; Baker, Christopher; Bannon, Michael; Ochsner, M; Thomason, Michael; Hiatt, Jonathan; OMalley, Keith; Obeid, Farouck; Gray, Perry; Bankey, Paul; Knudson, M; Dyess, Donna; Enderson, Blaine


Location, Location, Location

Triage

Hemorrhage
TBI
BAI

Treatment Options

<table>
<thead>
<tr>
<th>Variable</th>
<th>Clamp and Snares</th>
<th>Snares-Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complications</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Operative injury</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Head injury</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Intracranial</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Extrapontal</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Triage with high surgical risk</td>
<td>High</td>
<td>Medium</td>
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<tr>
<td>Triage with severe head injury</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Triage with challenging anatomy</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>


Table 5: Comparative Results from Bayesian Analysis

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Prior Estimates</th>
<th>Posterior Distribution</th>
<th>Evidence</th>
<th>Probability</th>
</tr>
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<tbody>
<tr>
<td>Operative/postoperative complications (N=30)</td>
<td>(50% - 80%)</td>
<td>(75% - 90%)</td>
<td>Strong</td>
<td>90%</td>
</tr>
<tr>
<td>Late complications (N=60)</td>
<td>(50% - 60%)</td>
<td>(60% - 70%)</td>
<td>Moderate</td>
<td>60%</td>
</tr>
<tr>
<td>Operative/postoperative mortality</td>
<td>(50% - 60%)</td>
<td>(60% - 70%)</td>
<td>Strong</td>
<td>90%</td>
</tr>
<tr>
<td>Late procedure-related mortality</td>
<td>(50% - 60%)</td>
<td>(60% - 70%)</td>
<td>Moderate</td>
<td>60%</td>
</tr>
<tr>
<td>Late or cause mortality</td>
<td>(50% - 60%)</td>
<td>(60% - 70%)</td>
<td>Strong</td>
<td>90%</td>
</tr>
</tbody>
</table>
Timing of Intervention

- AAST 1997: mean time from injury to surgical repair
  16.5 hrs
- AAST 2008: mean time from injury to surgical repair
  54.6 hrs


High-risk Patient And Delayed Repair

- Serial surveillance CT Q 48hr for 7 days
- Earlier intervention
  ✓ Expanding mediastinal hematoma
  ✓ Hemotorax
  ✓ Distal malperfusion
  ✓ Free extravasation

Simo et al. J Trauma 2001

“Non-operative” Therapy

- Anti-impulse therapy
  ✓ Short acting B-blocker with reduction of wall stress by reduction of ∆BP/∆HR
- Goals
  ✓ SBP < 120 mmHg
  ✓ MAP < 60-70 mmHg
  ✓ HR: 55-70


“Non-operative” Therapy
One Stop Shopping

Case Presentation: 17 yo female involved in a head on MVC with fatality at scene. Her injuries include:
1. Blunt thoracic aortic injury
2. Grossly positive DPL
3. Unstable pelvic fracture with hemodynamic instability
4. Multiple long bone fractures

Blunt Thoracic Aortic Injury (BTAI)

- 2nd cause of death after traumatic brain injury: 8,000 deaths/yr
- 80% die before reaching the hospital
- Rare injury
  - Most centers: 1-2/yr
  - High volume: 8-15/yr

Mechanisms
Classification

- Those who reached the hospital alive have partial disruption of the intima and medial only
  - Grade I to III
- Disruption of all three layers is common and lead to exanguinating hemorrhage
  - Grade IV


Imaging Modality

Right paratracheal soft tissue density
Tracheal deviation
Widened left Paraspinal stripe

[Imaging modality images]
Multicenter (18 institutions) prospective database to evaluate BAI outcomes
- 193 patients (2 years)
  - 125 stent graft and 68 open repair


**AAST 2 Trial**

- Multicenter (18 institutions) prospective database to evaluate BAI outcomes
  - 193 patients (2 years)
  - 125 stent graft and 68 open repair

<table>
<thead>
<tr>
<th></th>
<th>ENDO</th>
<th>OPEN</th>
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<tbody>
<tr>
<td>Mortality</td>
<td>13.5%</td>
<td>23.5%</td>
</tr>
<tr>
<td>ISS</td>
<td>43</td>
<td>31</td>
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<tr>
<td>Systemic Comp</td>
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</table>

20% of endovascular repairs had a device-related complication
- 18/32 endo leaks
- 4/32 access vessel injuries
- 1/32 paralysis

Most surgeons select stent grafts for traumatic thoracic aortic ruptures, irrespective of associated injuries, injury severity, and age. Stent grafts are associated with significantly lower mortality and fewer blood transfusions, but there is a considerable risk of serious device-related complications. There is a major and urgent need for improvement of the available endovascular devices.

AAST Conclusion

• No FDA approved device for tx of BTAI
• Current commercially available grafts
  ✓ 22 mm (Medtronic Talent)
  ✓ 26 mm (W.L. Gore TAG)
  ✓ 28 mm (Zenith Cook TX2)

AVERAGE AORTIC DIAMETER = 16-19 mm
• Iliac limb, aortic cuff and “off labeled” device modifications

Limitation of Current Endovascular Technology: The “Small Aorta”

Bird Beak Phenomenon
– Acute angulation of arch → lack of apposition of graft to inner curve of arch → stent graft collapse
Complication of TEVAR: Stent Graft Collapse

- 19 yo male involved in MCC with BUE fractures and BTAI
- Aortic diameter small at 19 mm
- Treated with iliac stent graft (Cook ELSE 22x65 mm).
  - Post-op completion angio normal
  - Post-op CXR normal

Complication of TEVAR: Stent Graft Collapse

- On POD#4, pt. presented with coarctation physiology.
  - Tachycardia
    - Upper extremities in splints so BP cuff in the L calf
    - A line was then placed R radial when pt. became unstable

HR
A line
NBP
Conformable “cTAG” Endograft

- Released in Europe (March 2010)
- Aortic diameters: 16-42 mm
Axillo-Subclavian Vascular Trauma

24 yo male involved in a MCC while running from police. Brought in with hemodynamic instability and rapidly expanding L shoulder hematoma.