TEVAR: Endovascular Approach to Aortic Disease

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Disclosures

• None
Aortic Pathology

• King George II of Great Britain
  – Born 1683, Coronated 1727
  – Longest serving British monarch at the time
  – Oct 25, 1760 after his morning coffee, his valet heard a loud crash and discovered him on the floor of his room
Aortic Pathology

• His personal physician, Frank Nicholls, observed that he “appeared to have come from his necessary-stool”

• Post-mortem revealed that “in the trunk of the aorta, we found a transverse fissure on its inner side, about an inch and a half long, through which some blood had recently passed, under its external coat, and formed an elevated ecchymosis. This appearance showed the true state of an incipient aneurysm of the aorta.”
Aortic Pathology

• Progression in Understanding and Treatment
  – Elucidation of pathophysiology
  – Advances in imaging
  – Establishment of clinical databases

• IRAD (International Registry of Acute Aortic Dissection)
Classification of Pathologies

• Thoracic Aortic Aneursym (TAAs)
• Acute Aortic Syndromes
  – Aortic dissection (TAAD)
  – Intramural hematoma (IMH)
  – Penetrating aortic ulcer (PAU)
Thoracic Aortic Aneurysms (TAAs)

- Described according to location
  - 60% ascending, 40% descending
- 3% prevalence at autopsy
- 2:1 male predominance
Thoracic Aortic Aneurysms (TAAs)

- Fusiform vs Saccular
Thoracic Aortic Aneurysms (TAAs)

Fusiform

Saccular
Thoracic Aortic Aneurysms (TAAs)

- **Predisposing Factors**
  - Modifiable – HTN, atherosclerosis, COPD
  - Genetic – Marfan syndrome, Loeys-Dietz syndrome, Ehlers-Danlos

- **Most diagnoses are incidental**
  - Only 5% symptomatic on presentation
Thoracic Aortic Aneurysms (TAAs)

- Indications for Intervention
  - Maximal diameter
  - Rate of growth
  - Presence of symptoms
Classification of Pathologies

• Thoracic Aortic Aneurysm (TAAs)
• Acute Aortic Syndromes
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  – Penetrating aortic ulcer (PAU)

• DYNAMIC PROCESS
Acute Aortic Syndromes

• Classification
  – Acute <14 days
    • Highest rate of morbidity & mortality
  – Subacute 14-90 days
  – Chronic >90 days
Acute Aortic Syndromes

• DeBakey Classification System
  Type I - originating ascending with propagation to arch
  Type II - originating and confined to ascending
  Type IIIa - originating and confined to descending
  Type IIIb - originating descending with propagation distally
Acute Aortic Syndromes

- DeBakey Classification System
Acute Aortic Syndromes

- Stanford Classification System
  - Type A
    - Involves ascending aorta
  - Type B
    - No involvement of ascending aorta
Acute Aortic Syndromes

DeBakey classification
- Type I
- Type II
- Type III

Stanford classification
- Type A
- Type B
Acute Aortic Dissection
- Intimal tear with propagation into media
  - Creation of true/false lumen separated by intimomedial flap
- 85-95% of pts with AAS
- Median age 61yo (range 4th to 7th decade)
- Presenting symptoms
  - Chest/back pain 85%
  - Pulse deficit 30%
  - Hypotension 25%
  - Syncope 13%
Acute Aortic Dissection
Acute Aortic Syndromes

• Intramural Hematoma (IMH)
  – Rupture of vasa vasorum into media
    • No identifiable intimal tear
  – 5-10% of AAS
    • <10% spontaneous regression
    • 47% may progress to dissection
  – Predominantly descending aorta
  – Older age than aortic dissection (mean 68 yrs)
  – Similar mortality to aortic dissection
Intramural Hematoma (IMH)
Intramural Hematoma (IMH)
Intramural Hematoma (IMH)
Intramural Hematoma (IMH)
Acute Aortic Syndromes

- Penetrating Aortic Ulcer (PAU)
  - Outpouching of blood through internal elastic lamina
  - Typically arising from atherosclerotic plaque
  - 2-7% of AAS
  - Often have associated IMH
  - May progress to dissection, pseudoaneurysm formation, or rupture
  - Typically older patients (mean 74 yrs)
  - Majority occur in descending aorta
Penetrating Aortic Ulcer (PAU)
AAS Continuum

Intramural hematoma

penetrating aortic ulcer in ascending aorta

Fig 1 Type A intramural hematoma
AAS Continuum
AAS Continuum
Thoracic Endovascular Aneurysm Repair (TEVAR)

- First performed by Dake et al. in 1992
- Initially reserved for non-surgical candidates
- FDA approval in 2005
- Gold standard for treating majority of TAAs and TBADs
  - Other applications – blunt thoracic injury, type A dissection, aorto-esophageal fistula
TEVAR

• Why?
TEVAR

• Endovascular vs Open (meta-analysis, JVS 2008)
  – Avoidance of sternotomy/thoracotomy
  – Avoidance of aortic cross-clamping
  – Less blood loss
  – Lower incidence of end-organ ischemia
  – Less ventilator dependence
  – Shorter hospitalization
TEVAR

• How?
  – Ultrasound-guided arterial access
  – Placement of catheters
  – Initial Angiography
  – Deployment
  – Completion Angiography
  – Closure
Angiography

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Deployment
## Vascular Closure

**Figure 2: Commercially Available Vascular Closure Devices**

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
<th>Fr Range</th>
<th>CE Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostar® XL</td>
<td>Suture-based</td>
<td>8.5–10 Fr</td>
<td>CE mark</td>
</tr>
<tr>
<td>ProGlide®</td>
<td>Suture-based</td>
<td>5–8 Fr</td>
<td>CE mark</td>
</tr>
<tr>
<td>MANTA™</td>
<td>Collagen-based</td>
<td>10–14 Fr (14 Fr system) 14–22 Fr (18 Fr system)</td>
<td>CE mark</td>
</tr>
<tr>
<td>PerQseal®</td>
<td>Patch-based</td>
<td>&lt; 24 Fr</td>
<td>CE mark</td>
</tr>
<tr>
<td>InSeal</td>
<td>Membrane-based</td>
<td>14–21 Fr</td>
<td>CE mark</td>
</tr>
</tbody>
</table>

**Source:** Abbott Vascular, Essential Medical, InSeal Medical and Vivasure Medical.
TEVAR - Devices

- Gore

1998
GORE® TAG®
Thoracic Endoprosthesis

2009
Conformable GORE® TAG®
Thoracic Endoprosthesis
TEVAR - Devices

• Medtronic
  – Valiant
TEVAR - Devices

• Cook
  – TX2
  – Alpha
TEVAR - Devices

- Bolton
- Relay
TEVAR - Devices

• Technical Considerations
  – Sheath Size
  – Structural Support (Nitinol)
    • More conformability = better seal
    • More kinking / thrombosis
  – Graft material
    • Dacron vs PTFE
TEVAR

• Procedural Planning
  – CT Angiography – gold standard
  • Chest, abdomen, pelvis, femorals
  • 3-D reconstruction preferable
Aortic CTA 3-D volume rendering

CTA: Oblique coronal view of the thoracic aorta

Centerline reconstruction
TEVAR

• Procedural Planning
  – MRA acceptable alternative to CTA
    • Doesn’t demonstrate vessel wall calcification
  – Intravascular Ultrasound (IVUS)
    • Confirmation of preoperative measurements
    • Identification of true/false lumens
    • Identification of branch vessels
TEVAR for Thoracic Aortic Aneurysm (TAA)

• Initial device trials
  – Valiant
    • 2% 30-day mortality, 41% morbidity (vs 84% in open repair)
  – TAG
    • 2% 30-day mortality
  – TX2
    • 15.6% morbidity (vs 44.3% in open repair)

• Open repair associated with 2x risk of spinal ischemia

• Prior to 2003 <10% of TAA underwent TEVAR
• Since 2007 >27% of TAA underwent TEVAR
TEVAR for Thoracic Aortic Aneurysm (TAA)

- 2017 European Society for Vascular Surgery Guidelines
  - Repair considered for >60mm (class II, level B evidence)
  - >66% chance of rupture over 5 yrs
  - 14.1%/yr risk of rupture, dissection, or death
    - 6.5%/yr between 50-60mm
TEVAR for Thoracic Aortic Aneurysm (TAA)

• 2017 European Society for Vascular Surgery Guidelines
  – Saccular aneurysms >20mm with total aortic diameter >50mm
  – Lower threshold of 50-55mm for women
  – Connective tissue disorder >50mm
  – Rapid growth >10mm/yr
TEVAR for Type B Aortic Dissection (TBAD)

- TEVAR has better long-term outcomes than medical management alone when treating TBAD
  - Five-year survival rates for TEVAR vs. medical management are 76% vs. 60% (Ianuzzi et al. JVS 2018)
  - Medical therapy fails in 58.4% of cases (29.2% aorta-related interventions, 38.3% deaths), TEVAR pts had higher survival rate at 6 years than those receiving medical management alone, 76.4% vs. 59.3% (Durham, et al. JVS 2015)
Type B Aortic Dissection (TBAD)

- **Acuity**
  - Acute <2 wks
  - Subacute 2 wks - 6 wks
  - Chronic > 6 wks
- **Uncomplicated vs Complicated**
  - End-organ malperfusion
  - Refractory pain
  - Rapidly expanding false lumen
  - Impending/frank rupture
  - Progressive aneurysmal dilation (chronic)
Indications for TEVAR in TBAD

- End-organ malperfusion
  - Branch occlusion
- May present early or late (dynamic process)
  - Visceral – abdominal pain, renal dysfunction
  - Spinal cord – paraplegia, paraparesis
  - Extremity – pulse deficit, hemiplegia
Indications for TEVAR in TBAD

• Refractory Pain despite adequate medical management
  – Significant predictor of in-hospital mortality, odd ratio 3.3 (IRAD database)
  – In-hospital mortality 4% vs 17.4% for TEVAR vs medical mgmt.
• Rapidly expanding false lumen
  – >5mm in 6 mos, >10cm in 1 yr
Indications for TEVAR in TBAD

- Impending/Frank rupture
  - Increasing periaortic or pericardial hematoma, hemothorax
Contraindications for TEVAR in TBAD

• Unfavorable anatomy
  – Inadequate proximal or distal seal zones (>20mm)
  – Tortuosity
  – Lack of vascular access
  – Extremes of aortic diameter (<21 or >46mm)
• Connective tissue disorder
• Inability to complete follow-up surveillance
Acute Type B Aortic dissections Algorithm

Diagnosis

- Acute Type B aortic dissection
  - Within 2 weeks

  Definitive diagnosis by clinical presentation and imaging

  Complicated defined as:
  - Impending rupture
  - Malperfusion
  - Refractory hypertension
  - Hypotension (<90mmHg systolic)
  - Shock

  Uncomplicated defined as:
  - No features of complicated dissection

Treatment

- Intervention
  - Medical Mgt & TEVAR
  - Medical Mgt & Open Surgery Repair (if TEVAR contraindicated)

- Medical Mgt & Imaging surveillance protocol:
  - admission, 7 days, discharge, and then as for chronic dissections
Subacute Type B Aortic dissections Algorithm

**Diagnosis**

- **Subacute Type B aortic dissection**
  - From 2 weeks to 6 weeks

**Complicated defined as:**
- Total aortic diameter $\geq 55$ mm or increase $>4$ mm
- New onset periaortic hematoma/pleural hemorrhagic effusion
- Recurrent symptoms

**Uncomplicated defined as:**
- No features of complicated dissection

**Treatment**

**Intervention**

- **Medical Mgt & TEVAR**
- **Medical Mgt & Open Surgery Repair**
  - (if TEVAR contraindicated)
- **Medical Mgt & Imaging surveillance protocol:**
  - 6 weeks (and annually thereafter)
Chronic Type B Aortic dissections Algorithm

Diagnosis

Chronic Type B aortic dissection
After 6 weeks

Complicated defined as:
- Total aortic diameter >= 55 mm
- Total aortic diameter yearly increase >4mm
- Recurrent symptoms

Uncomplicated defined as:
No features of complicated dissection

Treatment

Intervention

Medical Mgt & TEVAR

Medical Mgt & Open Surgery Repair (if TEVAR contraindicated)

Medical Mgt & Imaging surveillance protocol:
6 weeks and annually thereafter

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Expanding Indications for TEVAR in TBAD

• INSTEAD trial – TEVAR vs medical mgmt.
  – No difference in all-cause mortality at 1yr
  • Intervention unnecessary for uncomplicated
• INSTEAD XL trial – 5yr follow-up
  – Decrease in aorta-specific mortality and disease progression with TEVAR
  – Trend towards improved overall mortality
CENTRAL ILLUSTRATION: Algorithmic Framework for the Treatment of Type B Aortic Dissection

Initial Diagnosis of Type B Dissection

Complicated

- Favorable Thoracic Endovascular Aortic Repair (TEVAR) Anatomy?
  - Yes: TEVAR/Adjuvantive Procedures
  - No: Open Surgical Reconstruction/Adjuvantive Procedures

Uncomplicated

- High-risk Features Upon Initial Computed Tomography?
  - Yes: Continue Optimal Medical Therapy (OMT) with Surveillance
  - No: Favorable TEVAR Anatomy with High Risk Features and Life Expectancy >5 Years?
    - Yes: Consider TEVAR
    - No: Continue OMT with More Frequent Surveillance

Expanding Indications for TEVAR in TBAD

• Acute, Uncomplicated TBAD
  – High-Risk features
    • Primary entry tear
      – single
      – on concavity of distal arch
      – Size <1cm
    • Proximal descending aorta >40mm
    • False lumen
      – Located at inner curve
      – Size >22mm
      – Elliptical or saccular
      – Partially thrombosed or patent
    • Inadequate BP control despite maximal medical management or medication non-compliance
TEVAR Complications

• Endoleak (4-15% incidence)
  – Type I – proximal/distal seal zone (most common)
    • Ballooning
  – Type II – retrograde intercostal or left subclavian flow
    • Observation, embolization
  – Type III – junction of graft components
    • Ballooning, additional graft placement
  – Type IV – graft porosity
    • Observation
  – Type V – endotension (sac expansion despite no evidence of endoleak)
    • Re-lining, explant
Endoleak

Endoleak types:

- Type I endoleak
- Type II endoleak
- Type III endoleak
- Type IV endoleak
- Type V endoleak
TEVAR Complications

- Stroke – incidence of 4-8%, comparable to open
  - Higher risk
    - seal zone proximal to arch
    - mural thrombus
    - h/o CVA
  - PCA stroke d/t left subclavian (LSCA) coverage or embolization via subclavian
TEVAR Complications

• Paraplegia
  – Risk factors
    • Extensive coverage of thoracic aorta
    • Prior AAA repair
    • Coverage of LSCA
    • Post-procedure hypotension
  – Between 3% and 11% in large series
  – Comparable or lower incidence vs open repair
Avoidance of Spinal Cord Ischemia

- CSF drainage
  - Preoperative or immediately if symptoms
- Optimal BP management
  - MAP >80mmHg
- LSCA revascularization
  - Carotid-subclavian bypass or transposition
  - Laser fenestration of graft
  - Chimney/snorkel technique
  - Branched endograft
LSCA Revascularization
LSCA Revascularization
LSCA Revascularization
Figure 2. The GORE TAG Thoracic Branch Endoprosthesis placed in Zone 2 of the thoracic aorta.
TEVAR Complications

• Retrograde type-A dissection (RTAAD)
  – 2.5% incidence
  – Every 1% of oversizing beyond 9% carries with it a 14% increased risk of RTAAD (Canaud, et al. Annals of Surgery 2014)
TEVAR Complications

• Visceral ischemia
  – Accidental or intentional coverage of celiac origin
    • Less common if intact pancreaticoduodenal artery
  – Static malperfusion
    • Compression by false lumen or thrombosis
  – Dynamic malperfusion
    • Prolapse of septum into vessel ostium during cardiac cycle
Malperfusion Syndrome

Dynamic obstruction

Static obstruction
Malperfusion Syndrome

TEVAR + Bare Stent (40 patients) vs. TEVAR Alone (21 Patients)
- In hospital mortality: 5% vs 9%
- Aortic related mortality: 3% vs 9%
- Visceral Malperfusion Related Mortality: 0% vs 17% (p=0.02)
- Unplanned secondary interventions: 11% vs 43%
- Complete False Lumen Thrombosis
  - Thoracic: 72% vs 46%
  - Abdominal: 40% vs 15%

- PETTICOAT Technique
  - Provisional Extension to Induce Complete Attachment
TEVAR Late Outcomes

- 57.6 months median survival (Medicare database)
- Secondary intervention
  - Between 3.6% and 24% depending on follow-up
  - Dependent on Pathology
    - Acute TBAD 21.3%, chronic TBAD 16.7%, TAA 10.8%, PAU 1.5%
Case #1

• 77yo M
• PMH: HTN, hypothyroid
• p/w acute chest/back while playing tennis
• BIBA to ED
• c/o pain to back and LLE
• Unable to move left foot, cool/mottled
Case #1
Case #1

- CT - DeBakey type I, Stanford type A dissection with involvement of left subclavian artery, celiac axis, SMA and left renal artery and markedly collapsed true lumen
Case #1

• Emergent ascending and arch replacement with 32mm graft, debranching of innominate and left carotid with 10mm graft, ligation of LAA
Case #1

• Postoperative Course
  – Immediate return of lower extremity pulses
    • Persistent LLE weakness, unable to ambulate
    • Developed delayed toe ischemia bilaterally
  – Required HD initially with subsequent return of UOP
    • Delayed decrease in UOP and rising Cr
    • Reinstituted HD
Case #1

- Repeat CTA POD #21
  - Stable surgical repair with innominate/carotid debranching
  - No dissection of RSCA, RCCA, LCCA
  - Residual dissection flap involving LSCA and descending thoracic aorta
  - Descending thoracic aorta 4.3x4.5cm, stable from preop
  - non-aneurysmal abdominal aorta with residual dissection flap
  - Patent renal arteries bilaterally (Left – true lumen, Right – false lumen), patent celiac (false/true), patent SMA (true), patent IMA (false)
  - Dissection flap terminating in left external iliac artery and right common femoral artery

- Vascular Duplex
  - High grade stenosis of left external iliac
  - Normal waveforms in right external iliac and distally
Case #1

- POD #25
  - TEVAR with 40x217mm endograft
  - TEVAR with 46x185 dissection stent
  - Left carotid – subclavian bypass with 8mm PTFE graft
Case #1

• POD #27
  – Off hemodialysis

• POD #72
  – Clinic follow-up
    • Remains off HD
    • Ambulatory without cane
• THANK YOU