New Frontiers in Thoracic Aortic Disease

A look into the future

43rd Annual Meeting of the Japanese Society for Cardiovascular Surgery

February 27th, 2013

Jehangir Appoo
Calgary, Alberta, Canada

1.1 Million people

Major industry: Oil & Gas

Western Canada

Close to the Canadian Rockies
Foothills Medical Centre
University of Calgary
“The world is moving toward evidence-based guidelines, but these guidelines should be thought of as the minimal knowledge that surgeons should possess... That is why modern cardiovascular surgeons must understand guidelines as basic, default information and, based on the evidence behind the guidelines in the manuals, use their five senses—and sometimes their sixth senses; perceive the situation with their own eyes, ears, and hands; think with their own minds; and select safe, high-quality treatment for their patients”

Professor Koyoma, President Japanese Society of Cardiovascular Surgery

43rd Meeting of JSCVS, February 2013, Tokyo, Japan
Today:

Innovative Imaging  Novel Techniques  Futuristic Treatment Alternatives
Size & growth rate not great predictors of rupture/dissection

Need more science
Clinical Problem
Need for more science

34 y.o female
• Why does an aneurysm rupture?
  – Applied stress exceeds yield stress of wall

• Estimating risk of aneurysmal rupture
  • Simplistic
    • related to diameter of aneurysm
  • Complicated
    • Mathematical modelling based on 3D model of aneurysm shape to determine peak areas of wall stress

• Wall stress may be a better predictor of risk of rupture than diameter alone

• Arterial wall shear stress also induces a cellular biochemical response directly linked to aneurysm formation/progression
Wall stress is a better predictor of risk of rupture than diameter alone
Fluid–structure interaction within realistic three-dimensional models of the aneurysmatic aorta as a guidance to assess the risk of rupture of the aneurysm

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The equations governing the fluid (CFD) are:
\[ \frac{\partial u}{\partial t} + (u \cdot \nabla)u = -\frac{1}{\rho} \nabla p + \nu \nabla^2 u + f \]
where \( u \) is the velocity, \( p \) is the fluid density, \( \rho \) is the mass, \( f \) is the body force at time \( t \) per unit mass, \( \nu \) is the viscous stress at time \( t \) and \( \nabla^2 u \) is the diverging gradient of the velocity. The fluid is described as a nearly incompressible fluid. The effect of the second derivative of the velocity is negligible.

The equations governing the structural domain (SDE) are the momentum equations, the equilibrium equations and the constitutive equations, respectively:
\[ \rho \frac{\partial \varepsilon}{\partial t} + \rho \varepsilon \cdot \nabla u = -\nabla p + \nabla \cdot \sigma \]
\[ \frac{\partial \sigma}{\partial t} + \nabla \cdot (\sigma u) = 0 \]
\[ \sigma = \sigma_0 \varepsilon + \mu \varepsilon \cdot \varepsilon \]
where \( \varepsilon \) is the acceleration of a material point, \( \nabla p \) is the pressure tensor of the external point, \( \nabla \cdot \sigma \) is the divergence of the stress tensor, \( \mu \) is the shear modulus and \( \sigma_0 \) is the yield stress.

The mesh is defined (SDE) under the assumption that it behaves like an elastic medium deformed by the same displacement of the fluid.

Fig. 1. Topologic image and three-dimensional geometric model of an aneurysm.

Fig. 2. Anatomically-simulated model of the aneurysm. The left side is the aneurysm and the right side is the normal aorta. The right side simulates the aorta on which the aneurysm is attached. The volumetric tensors that are considered for each node.
Mathematical Model
Stress results from mathematical model
Current Research Projects with Thoracic Aortic Biomechanics:

Changes in Ascending Aortic Biomechanics after TEVAR

prospective
retrospective

Assessment of Distal Arch Biomechanics at time of Type A dissection

correlate with intraop distal ascending aortic tissue to assess collagen/elastin content, thickness of media layer

help predict which aortas are susceptible to early aneurysm growth after Type A dissection
Is there a change in mechanical properties of the proximal aorta after descending aortic aneurysm therapy?
Can 4D MR help us understand aortas at risk?

3D MR with flow velocity mapping
Are flow velocities in residual false lumen after Type A dissection predictive of:

rate of growth?
false lumen thrombosis?
Novel Techniques
Different treatment strategies for acute type A dissection

Is more extensive treatment of aorta helpful? short term? long term?
Different treatment strategies for acute type A dissection
An Alternative Approach to Diffuse Thoracic Aortomegaly: On-Pump Hybrid Total Arch Repair Without Circulatory Arrest

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Diffuse thoracic aortomegaly has conventionally been managed with a two-stage elephant trunk procedure, requiring prolonged circulatory arrest, with an inherent risk of major morbidity and mortality. Recently, to improve outcomes, several hybrid arch procedures have been proposed using on-pump techniques. We have adopted an alternative, single-stage hybrid strategy using cardiopulmonary bypass without circulatory arrest to replace the ascending aorta and perform arch declamping and percutaneous endovascular stent graft deployment. Unlike off-pump procedures, pathology of the aortic valve, root, and ascending aorta is addressed while avoiding the complications of stent graft placement in the native ascending aorta.


Ascending, Total Arch, and Descending Thoracic Aortic Repair for Acute DeBakey Type I Aortic Dissection Without Circulatory Arrest

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Complications may arise from the residual dissected arch and descending thoracic aorta after conventional ascending and hemiarch repair of acute DeBakey type I aortic dissection. To mitigate these complications, a total arch and elephant trunk procedure has been advocated. This case demonstrates a less invasive hybrid technique, performed in a single-stage fashion through a sternotomy without circulatory arrest or deep hypothermia, to achieve the benefits of the total arch and elephant trunk operation.

Obliteration of false lumen in arch & prox descending aorta

Pigtail catheter in true lumen after ascending aortic replacement
39y.o Type A
BMI 60
Ischemic leg
Primary Intimal Tear in Mid or Distal Arch

Arch Aneurysm

Visceral/Renal/Extremity Malperfusion

Radiologic risk factors for future aneurysm formation
New Devices are arriving...
Combining innovating imaging and intervention – “Takumi”

Thoracic aneurysm & residual isolated infrarenal tear is unusual
Infra-renal aorta to innominate artery collateral
Right radial access

Guide wire fell into true lumen

Atrium iCAST stent in innominate artery

Restoration of antegrade flow in innominate artery

Obliteration of false lumen in innominate artery

Palpable blood pressure in right arm for first time
Increase in true lumen size, decrease in false lumen

Aneurysm shrunk 7.3cm → 6.8cm → 6.2cm

Minimal flow velocity in F.L vs. brisk flow preop

Aorta protected?
Futuristic Treatment Alternatives
Alternative Surgical Approach to Repair of the Ascending Aorta
Holly E. Mewhort, MD, Jehangir J. Appoo, MDCM, Glen L. Sumner, MD, Eric Hereet, MD, and Jason Wong, MD (Ann Thorac Surg 2011;92:1108–10)
Computed tomography-based anatomic characterization of proximal aortic dissection with consideration for endovascular candidacy

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Background: Proximal aortic dissections are life-threatening conditions that require immediate surgical intervention to avert an untreated mortality rate that approaches 50% at 48 hours. Advances in computed tomography (CT) imaging techniques have permitted increased characterization of aortic dissection that are necessary to assess the design and applicability of new treatment paradigms.

Methods: All patients presenting during a 2-year period with acute proximal aortic dissections who underwent CT scanning were reviewed in an effort to establish a detailed assessment of their aortic anatomy. Imaging studies were assessed in an effort to document the location of the primary proximal fenestration, the proximal and distal extent of the dissection, and numerous morphologic measurements pertaining to the aortic valve, root, and ascending aorta to determine the potential for an endovascular exclusion of the ascending aorta.

Results: During the study period, 162 patients presented with proximal aortic dissections. Digital high-resolution preoperative CT imaging was performed on 76 patients, and 59 scans (77%) were of adequate quality to allow assessment of anatomic suitability for treatment with an endograft. In all cases, the dissection plane was detectable, yet the primary intimal fenestration was identified in only 41% of the studies. Scans showed 24 patients (32%) appeared to be anatomically amenable to such a repair (absence of valvular involvement, appropriate length and diameter of proximal sealing regions, lack of need to occlude coronary vasculature). Of the 42 scans that were determined not to be favorable for endovascular repair, the most common exclusion finding was the absence of a proximal landing zone (n = 15; 36%).

Conclusions: Appropriately procoded CT imaging provides detailed anatomic information about the aortic root and ascending aorta, allowing the assessment of which dissections have proximal fenestrations that may be amenable to an endovascular repair. (J Vasc Surg 2011;53:942-9.)

Endovascular Approaches to Acute Aortic Type A Dissection: A CT-Based Feasibility Study


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Abstract: Background: Open graft replacement of the ascending aorta is the current treatment of choice for Stanford type A dissections. However, approximately 20% of patients are deemed unfit for open surgery. To determine if an endovascular option exists for this latter group of patients, we performed a computed tomography (CT)-based feasibility study.

Methods: A cohort of consecutive patients presenting to the cardiovascular care unit (CVCU) for an acute Stanford type A aortic dissection between 2006 and 2009 was retrospectively analyzed. Inclusion criteria was a high-quality preoperative angio-CT scan that could be analyzed on a three-dimensional (3D) workstation. Numerous anatomical parameters of the dissection were studied, including the location and the length of the primary proximal entry tear. Finally, we determined which of the patients would have been potential candidates for an endovascular repair (stentgraft implantation).

Results: A total of 112 patients were included in our study. The median distance of the primary entry tear to the closest coronary artery was 23 mm (range 6–123). The median true lumen and true + false lumen (total) diameters at the level of the entry tear was 38 mm (range 22–78) and 46 mm (range 28–93), respectively. The median length of the ascending aorta was 84 mm (range 40–130). An endovascular repair with a tubular stentgraft was deemed feasible in 37 patients. An additional 8 patients were also candidates for a tubular endovascular repair but would have required a coldblooded cross-over bypass. Finally, an arch-branched stentgraft could have been used in 13 patients to exclude an entry tear located in the arch.

Keywords: Type A dissection; Endograft; Workstation
In the future:

What % of pts would be eligible for isolated endovascular repair of acute type A dissection?

Which patients benefit from conventional surgery vs. hybrid surgery vs. endovascular?

Strategies

Surgical asc ao replacement followed by branch grafts?
FRIDAY 19 OCTOBER 2012

8.30 am  Registration and refreshments

8.55 am  Welcome and introduction
          George Geroulakos, President, RSM Vascular Medicine Section

9.00 am  SESSION ONE: AORTA ONE
          Chairs: Peter Harris, London, UK and Duke Cameron, Baltimore, USA

          What are the clinical implications of genetic research into aortic aneurysmal disease?
          Anne Child, London, UK

          Aortic valve replacement prior to vascular surgery: When is it indicated for what
          pathologies and does TAVI broaden the indications for intervention?
          Duke Cameron, Baltimore, USA

          Will endovascular treatment become the preferred option for repair of acute type A
          dissection?
          Matt Thompson, London, UK
Does the future include M.A.R.S?
M.A.R.S.
Multilayer Aneurysm Repair System
Flow Modulator

Suitable for all kind of aneurysms
3D Multilayer Braided Technology
Branch Patency
Thrombus Management
WEDNESDAY | February 16 2011

6:30 AM  Continental Breakfast in the Exhibit Halls

7:30 AM  Session X: Challenges of the Thoracic Aorta
          Moderators: Edward B. Diethrich, MD • Matt Thompson, MD

- Thoracic Aortic Aneurysms: Is There Still Room for Open Surgery?
  Joseph S. Coselli, MD

- Aortic Arch Aneurysm: Which Treatment Options to Choose From: Total Endovascular Repair, Hybrids, Arch Replacement
  Patrice Bergeron, MD

- The Pathologies of the Ascending Aorta: The Next Frontier in Endovascular Interventions
  Matt M. Thompson, MD

- Endovascular Treatment of Aberrant Subclavian Pathologies
  Venkatesh G. Ramaiah, MD

- Re-Coarctation and Post-Surgical Aneurysm After Coarctation Surgery: Surgery, Stents or Stent-Grafts for a Definitive Repair?
  Zvonimir Krajcer, MD

- In Situ Fenestration in Total Arch Replacement
  Martin Malina, MD

- Future Potential for an Endovascular Bental
  Edward B. Diethrich, MD
Summary:

Hopefully we can strive to be perceptive, thoughtful cardiovascular surgeons and achieve Safe, High Quality Treatment – “Takumi”. 
“Good judgement comes from experience...
Experience comes from bad judgement”

C. Walton Lillehei, 1918-1999