Mitral and Aortic Valve Repair in 2019: Similarities and Differences

Marc R. Moon, M.D.

John M. Shoenberg Chair in CV Disease
Chief, Cardiac Surgery
Director, Center for Diseases of the Thoracic Aorta
Washington University School of Medicine, St. Louis, MO
Vice President, American Association for Thoracic Surgery
Valve Analysis and Pathoanatomy

**MITRAL VALVE ANATOMY**

- **Hinge** – Junction between atrial and valvular tissue
- **Annulus Fibrosus** – where leaflet attaches to connective tissue
  - 2 mm external and deep to hinge
  - 3-D saddle shape
**Valve Analysis and Pathoanatomy**

*MITRAL VALVE ANATOMY*

- Chordae Tendineae
  - Primary (marginal):
    - From papillary tip to leading edge
    - Prevent prolapse during systole
  - Secondary (intermediary):
    - Insert on leaflet ventricular surface
    - “strut” chords (2 solitary, thicker)
  - Tertiary (basal):
    - From ventricular wall to post leaflet
September 1983

The Journal of THORACIC AND CARDIOVASCULAR SURGERY

Honored Guest’s Address

Cardiac valve surgery—the “French correction”

Alain Carpentier, M.D., Paris, France
Pathophysiologica1 Triad

- Etiology – cause of the disease
- Lesions – result from the disease
- Dysfunction – results from the lesions
Valve Analysis and Pathoanatomy

ETIOLOGY

• Etiology:
  – Helps establish preop/postop medical Tx
  – Expected complexity of valve repair
  – Most important predictor of long-term prognosis
• Primary:
  – congenital, inflammatory, degenerative, calcification, endocarditis, trauma, tumors
• Secondary:
  – Ischemic MR, DCM, HOCM, Afib
MV Analysis: Strategic Assessment
CARPENTIER’s Classification of MR

- I: normal leaflet motion (annular dilation)
- II: excessive leaflet motion (prolapse, rupture)
- III: restricted leaflet/chord motion
  - IIIa: rheumatic
  - IIIb: ischemic
MV Analysis: Strategic Assessment

Functional Anatomy of Mitral Valve

- Annulus
- Leaflets
- Chordae Tendineae
- Papillary Muscles
- LV Wall
MV Analysis: Strategic Assessment

**LESIONS - ANNULUS**

- Annulus Lesions: Dilatation, Calcification
MV Analysis: Strategic Assessment

**LESIONS - ANNULUS**

- Dilated Annulus: 64 yo man with AF, severe MR, normal leaflets → MV repair (29 mm band), Maze procedure

**PREOP:**

**POSTOP:**
Selecting / Sizing a Ring or Band

**BASIC OPTIONS**

- **RIGID RING**
- **FLEXIBLE RING/BAND**
- **SEMI-RIGID RING/BAND**

MITRAL ANNULOPLASTY
MV Analysis: Strategic Assessment

Functional Anatomy of Mitral Valve

- Annulus
- Leaflets
- Chordae Tendineae
- Papillary Muscles
- LV Wall
MV Analysis: Strategic Assessment
Segmental Analysis of Mitral Valve

- Segmental Analysis:
MV Analysis: Strategic Assessment

*LESIONS - LEAFLETS*

- Leaflet Lesions:
  - Cleft / Tear
  - Vegetations / Perforation
  - Thickening / Commissure Fusion
  - Calcification
  - Billowing
• Non-Pathologic “Clefts”
  – Posterior leaflet indentations between P1-P2 or P2-P3
    – Supported by chordae
    – function like commissures to facilitate opening
    – do not extend to annulus
MV Analysis: Strategic Assessment  

LESIONS - LEAFLETS

- Pathologic clefts:
  - Anterior or Posterior leaflet

- 36 yo woman with CHF, murmur since childhood
MV Analysis: Strategic Assessment

**LESIONS - LEAFLETS**

- Vegetations / Perforation:
  - Endocarditis, Trauma
MV Analysis: Strategic Assessment

**LESIONS - VEGETATIONS**

- 24 yo gentleman presented with CVA
  - B/C: lactobacillus endocarditis, TEE: small vegetations → ABX
  - Recurrent F/C, persistent vegetations after 6 wks
MV Analysis: Strategic Assessment

LESIONS - LEAFLETS

- Thickening / Commissure Fusion

Anterolateral Fusion

Double Commissural Fusion
MV Analysis: Strategic Assessment

**LESIONS - LEAFLETS**

- Leaflet Billowing:
  - Classically with Barlow’s Syndrome / Marfan Syndrome
  - Billowing → No MR
  - Billowing + Chordal Elongation → MR
MV Analysis: Strategic Assessment

**LESIONS - Leaflet Fibrosis**

- Restricted Posterior Leaflet:
  52 yo man with ESRD, CHF, RF 47%, ↑ LV cavity size
MV Analysis: Strategic Assessment

**LESIONS - Leaflet Fibrosis**

- Restricted Posterior Leaflet (28 mm band):

  - Posterior Leaflet
  - Anterior Leaflet
  - Postop TEE
• Fibroelastic Deficiency – myxomatous change
  – Collagen deficiency
  – Older patients, single segment, short history
• Barlow’s Disease – diffuse involvement
  – Younger patients, multiple segments, longer history, large valve size
MV Analysis: Strategic Assessment

Functional Anatomy of Mitral Valve

- Annulus
- Leaflets
- Chordae Tendineae (Elongation, Rupture, Thickening / Fusion / Shortening)
- Papillary Muscles
- LV Wall
Valve Analysis and Pathoanatomy

LESIONS - CHORDAE

- Chordae Lesions:
  - Elongation
  - Rupture
  - Thickening / Fusion / Shortening
Valve Analysis and Pathoanatomy

**REPAIR TECHNIQUES**

**Quadrangular Resection with Annuloplasty**

**Edge-to-Edge (Alfieri) Leaflet Repair**
MV Analysis: Strategic Assessment

Spectrum of Degenerative Disease

- Chordal Elongation: 83 yo woman with symptomatic MR, P2 prolapse without rupture → P2 resection, 27 mm band

PREOP:  
POSTOP:
• Flail Mitral Valve: 87 yo man with CHF, P2 prolapse with ruptured chord → P2 resection, 29 mm band
MV Analysis: Strategic Assessment
Spectrum of Degenerative Disease

• Flail P3 (FED): 38 yo gentleman with P3 ruptured chord

Preop TEE
MV Analysis: Strategic Assessment

Spectrum of Degenerative Disease

- Flail P3 (FED): limited triangular resection, A3-P3 Alfieri, 32 mm Band

Postop TEE
MV Analysis: Strategic Assessment

Spectrum of Degenerative Disease

• Forme Fruste – Posterior Leaflet (normal anterior leaflet):
  57 yo woman with P1, P2, P3 prolapse → functional double cleft

Preop TEE
MV Analysis: Strategic Assessment
Spectrum of Degenerative Disease

- Forme Fruste – Posterior Leaflet:
  Quadrangular P2 resection, P1/P3 sliding plasty, 30 mm Band

Postop TEE
MV Analysis: Strategic Assessment
Spectrum of Degenerative Disease

- Anterior Leaflet Prolapse: Consider transfer to Reference Center?
MV Analysis: Strategic Assessment
*Spectrum of Degenerative Disease*

- Anterior Leaflet Flail (FED):
  54 year gentleman new onset AF, CHF, holosystolic murmur

Preop TEE

Postop TEE
MV Analysis: Strategic Assessment

Spectrum of Degenerative Disease

• Bileaflet Disease (FED+):
  59 yo gentleman with P2 prolapse / flail, A2 prolapse
  Preop TEE
MV Analysis: Strategic Assessment

Spectrum of Degenerative Disease

- Bileaflet Disease (FED+):
  Quadrangular P2 resection, P3 sliding plasty, A2 chord, 28 mm Band
MV Analysis: Strategic Assessment
Spectrum of Degenerative Disease

- Bileaflet Prolapse: 50 yo woman with CHF, severe MR (multiple jets)
MV Analysis: Strategic Assessment

Segmental Analysis of Mitral Valve

INTRAOP:
MV Analysis: Strategic Assessment

Forme Fruste: Bileaflet Prolapse

- **INTRAOP**: Triangular P1 resection, P2 sliding plasty, P2-P3 cleft, P3 neo chord, A3-P3 Alfieri, 33 mm Band
MV Analysis: Strategic Assessment

*Forme Fruste: Bileaflet Prolapse*

**POSTOP:**
MV Analysis: Strategic Assessment

**LESIONS - Chord & Leaflet Fibrosis / Ca^{2+}**

- Chord & Leaflet Fibrosis / Calcification:
  72 yo woman with CHF, severe PVD, COPD, EF normal with diastolic dysfunction, PA HTN, severely debilitated
MV Analysis: Strategic Assessment

**LESIONS - Chord & Leaflet Fibrosis / Ca^{2+}**

- Chord & Leaflet Fibrosis / Calcification (29 mm MVR):

  ![Image of posterior leaflet and chords]

  **Posterior Leaflet and Chords**

  **Likelihood of Repair**

  - **subvalvular involvement**
    - minimal
    - severe: Ca^{2+}
  - Pliable Leaflets: yes
  - Rigid Leaflets: probably yes
  - probably no

  
  
  Carpentier, Adams, Filsoufi, 2010

  **PATH**: fibrosis with calcification
MV Analysis: Strategic Assessment

Functional Anatomy of Mitral Valve

- Annulus
- Leaflets
- Chordae Tendineae
- Papillary Muscles (elongation / rupture)
- LV Wall
MV Analysis: Strategic Assessment

LESIONS – PAPILLARY MUSCLE

- Ruptured Posteromedial Papillary Muscle: 62 yo man, acute MI with CHF
MV Analysis: Strategic Assessment

Functional Anatomy of Mitral Valve

- Annulus
- Leaflets
- Chordae Tendineae
- Papillary Muscles
- LV Wall (Aneurysm / Dyskinesis of inferobasal wall, LV Ischemia / Infarction)
MV Analysis: Strategic Assessment

**LESIONS – LV WALL**

- Restricted PL motion – IIIb:
  57 yo man with chronic ischemic MR $\rightarrow$ 28 IMR Ring

**PREOP:**

**POSTOP:**
MV Analysis: Strategic Assessment

COMBINATION LESIONS – Leaflet / LV Wall

- 76 yo woman with severe MR, non-bypassable circumflex underwent P2 resection and 31mm Band

COMING OFF PUMP:
MV Analysis: Strategic Assessment

**COMBINATION LESIONS – Leaflet / LV Wall**

- Removed true-sized flexible band → placed downsized 28 mm Ring
MV Analysis: Strategic Assessment

PRINCIPLES FOR SUCCESS

• Goals of valve assessment:
  – Establish a precise diagnosis – preop ECHO then intraop
  – Determine most appropriate treatment option
  – Consider transfer to Reference Center for complex lesions

• Segmental Valve Analysis:
  – Localize and categorize dysfunction
  – Complete inventory of specific lesions to plan repair
What About the Aortic Valve?

**SURGICAL OPTIONS**

- **Aortic valve replacement:**
  - Low morbidity & mortality, widely available
  - Excellent late durability, especially in older patients
  - Applicable for all patients with AS or AR

- **Aortic valve repair:**
  - Avoids anticoagulation, prosthetic SVD
  - Appropriate for selected patients with AR (but which pts?)
  - Requires a dedicated approach (reference center?)
Aortic Valve  
FUNCTIONAL ANATOMY

- Functional Aortic Annulus (FAA)
  - Aortic annulus (ventriculo-aortic junction)
  - Sinotubular junction
- Leaflets
- Commissures
- Sinus of Valsalva
- Aorta

Carpentier’s Reconstructive Valve Surgery  
Carpentier, Adams, Filsoufi: Saunders/Elsevier, 2010  
El khoury et al. Curr Opin Cardiol 20:115, 2005
Aortic Valve

FUNCTIONAL ANATOMY

• Functional Aortic Annulus (FAA):
  – Bordered by VA Junction & ST Junction
  – Anchors the aortic root: leaflets, sinus of Valsalva, coronary ostia

• Normal relations:
  – AA: 22 ± 1.1 mm
  – sinuses: 24 ± 1.1 mm
  – STJ: 19 ± 0.9 mm
  – Normalized: STJ 1.0 : AA 1.15 : HT 0.8
Pathophysiologic Triad

- Etiology – cause of the disease
- Lesions – result from the disease
- Dysfunction – result from the lesions
Valve Analysis & Pathoanatomy

**ETIOLOGY**

- Etiology:
  - Helps establish pre/postop medical Tx
  - Expected complexity of valve repair
  - Most important predictor of long-term prognosis

- Primary:
  - Congenital (bicuspid), inflammatory (rheumatic, lupus), degenerative, calcification, endocarditis, trauma, tumors

- Secondary:
  - Aortic annular ectasia (Marfan), aortic aneurysm, aortic dissection
Aortic Regurgitation

TRIGGERS FOR SURGERY

- Progression slow, symptoms develop late
- LV overload, adaptive chamber dilation
- Indications for surgery:
  - Symptomatic (exertional dyspnea, CHF)
  - Asymptomatic with ↓ EF (50%) or LV dilation (ESD 50-55mm, EDD 65-75mm)
  - Exercise testing: ↓ EF, LV dilation
  - Moderate AI undergoing other cardiac surgery
- Aortic Regurgitation 2° dilated aorta
  - > 5.5 – 6.0 cm (less with Marfan syndrome, bicuspid valve?)
Valve Analysis & Pathoanatomy

FUNCTIONAL CLASSIFICATION OF AR

**Dysfunction**
- I: normal leaflet motion
- II: excess leaflet motion
- III: restricted leaflet motion

**Lesions**
- STJ / AA dilation (FAA Dilation)
  - cusp perforation (vegetation)
- cusp prolapse
- commissural disruption
- Commissural fusion
  - valve thickening / calcification

**Type I**

**Type II**

**Type III**
El Khoury Classification

<table>
<thead>
<tr>
<th>AI Class</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal cusp motion with FAA dilatation or cusp perforation</td>
<td>Cusp Prolapse</td>
<td>Cusp Restriction</td>
</tr>
<tr>
<td></td>
<td>Ia</td>
<td>lb</td>
<td>lc</td>
</tr>
</tbody>
</table>

Valve Analysis & Pathoanatomy

**FUNCTIONAL CLASSIFICATION OF AR**
Valve Analysis & Pathoanatomy

FAA DILATION

NORMAL

TYPE Ia

TYPE Ib

TYPE Ic
Valve Analysis & Pathoanatomy

CUSP LESIONS

<table>
<thead>
<tr>
<th>TYPE ID</th>
<th>TYPE II</th>
<th>TYPE III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cusp Perforation</td>
<td>Cusp Prolapse</td>
<td>Cusp Restriction</td>
</tr>
</tbody>
</table>

Images of Cusp Perforation, Cusp Prolapse, and Cusp Restriction.
Aortic Valve Repair

PRINCIPLES

• GOAL: Create and support an optimal surface of coaptation
  – Remodel and stabilize proximal and distal ends of functional aortic annulus
  – Repair abnormal cusps and restore normal geometry / motion
Aortic Valve Repair

NORMAL LEAFLET MOTION – TYPE Ia

Type Ia – STJ dilation (tricuspid AoV):

- Ascending aortic aneurysm: ↑ STJ, nl AA
- Normal cusp motion with FAA dilation

CASE REPORT
- 69 yo gentleman with atheroscerotic ascending aortic aneurysm, trileaflet valve with moderate AR, ascd aorta 5.8 cm
Aortic Valve Repair

NORMAL LEAFLET MOTION – TYPE Ia

Type Ia – STJ Dilation (trileaflet AoV):

- AscAo replacement with 34mm Dacron graft

Postop TEE
**Aortic Valve Repair**

**NORMAL LEAFLET MOTION – TYPE Ib**

**Type Ib – STJ & AA Dilation:**

- **CASE REPORT**
  - 34 yo gentleman with Marfan syndrome, severe AR, asc/d/ root 5.4 cm

- Annuloaortic Ectasia: ↑ STJ, ↑ VAJ, ↑ HT
- Normal cusp motion with FAA dilation

[Preop TEE image]
Aortic Valve Repair

NORMAL LEAFLET MOTION – TYPE Ib

Type Ib – STJ & AA Dilation:

Postop TEE
Aortic Valve Repair

NORMAL LEAFLET MOTION – TYPE Ic

Type Ic – VAJ Dilation (STJ not dilated):

Suture annuloplasty

Subcommissural

External aortic ring

Geometric internal ring

ATS 101:783, 2016 (Schafers)
www.ctsnet.org, 2010 (Mckeller & Zehr)
JTCVS 149:S37, 2015 (Lansac)
JTCVS 148:168, 2014 (Rankin)
Aortic Valve Repair
NORMAL LEAFLET MOTION – TYPE Id

Type Id – Cusp Perforation / Vegetation:
- Infectious
  - 43 yo woman, endocarditis with 1.5cm vegetation on LCC with severe AI
- Non-infectious
  - Perforation of NCC after minimally invasive MV repair

Aortic Valve Repair

EXCESS LEAFLET MOTION – TYPE II

Type II – Leaflet Prolapse:

Tricuspid Valve

- Isolated RCC prolapse
- Free margin elongation
- Transverse fold → discontinuity of normal curvature of cusp body

Bicuspid Valve

- Discrete raphe with commissures at 180°
- Prolapse is most common cause of AR
- Free margin elongation with prolapse of both conjoint & non-conjoint cusps
Aortic Valve Repair

CUSP LESIONS – REPAIR TECHNIQUES

- Free-Margin Plication (prolapse)
- Free-Margin Resuspension (prolapse, commissure tears)
- Patch Repair (perforation)
- Triangular Resection (bulky raphe)
- Cusp Augmentation (rheumatic)
- Commissure Resuspension (dissection)
Aortic Valve Repair

**EXCESS LEAFLET MOTION – TYPE II**

Cusp Repair – Free-Margin Plication (Tricuspid AoV):

- Reference stitch & Initial central plication
- Resection if excluded tissue is bulky
- Running suture to complete plication
Aortic Valve Repair

EXCESS LEAFLET MOTION – TYPE II

Commissure Disruption – F-M Resuspension:

CASE REPORT
- 42 yo gentleman with new murmur, severe AI, LV dilation, tricuspid AoV
- MRI: LVEDV 296 ml (>246 ml)
  RF 52% (> 33%)

Preop TEE

Postop TEE
Aortic Valve Repair

RESTRICTED LEAFLET MOTION – TYPE III

Type III – Restricted Leaflet Motion:

- **Calcified bicuspid AoV**
  - commissures positioned at 240°:120° configuration
  - not bismmetrical
  - incomplete fusion of L-R cusps → heavily Ca²⁺ raphe
  - Restrictive leaflets

- **Unicuspid AoV**
  - Unicuspid valve
  - 1 normal commissure and 2 raphes surrounded by fibrous thickening

- **Fibrosis (rheumatic / RXT)**
  - Thickened, foreshortened leaflets
  - Nodular retraction
Aortic Valve Repair
COMBINED LESIONS

Type Ia + II – FAA Dilation, Bileaflet Prolapse:

CASE REPORT
- 23 yo gentleman with progressive SOB, LV dilatation, bicupsid valve with eccentric AR, ascending aorta 5.3 cm
Aortic Valve Repair

COMBINED LESIONS

Type Ia + II – FAA Dilation, Bileaflet Prolapse:

Postop TEE after Ao ascd replacement & bileaflet repair of prolapsing bicuspid valve
Aortic Valve Repair

WHICH VALVES SHOULD WE REPAIR?

### TABLE 1. Surgical and TEE Classification of Aortic Regurgitant Lesions

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Enlargement of the aortic root with normal cusps.</td>
</tr>
<tr>
<td>2</td>
<td>Cusp prolapse or fenestration.</td>
</tr>
<tr>
<td>3</td>
<td>Poor cusp tissue quality or quantity.</td>
</tr>
</tbody>
</table>

![Graph showing event free survival over time for Type I, II, and III aortic valve repairs.]

![Bar chart showing repairability and event rate for Type I, II, and III aortic valve repairs.]

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le Polain de Waroux et al.  
Mechanisms of Recurrent Aortic Regurgitation After Aortic Valve Repair

Predictive Value of intraoperative Transesophageal Echocardiography

Jean-Benoît le Polain de Waroux, MD,* Anne-Catherine Pouleur, MD,* Annie Robert, PhD,‡ Agnès Pasquet, MD, PhD, PtiD,* Bernard L. Gerber, MD, PtiD,* Philippe Noirhomme, MD, ‡ Gebrine El Khoury, MD, † Jean-Louis J. Vanoverschelde, MD, PtiD*
Brussels, Belgium

JACC: CV Imag 2:931, 2009

• 186 pts over 10 years
• Predictors of recurrence:
  – ↓ coaptation length
  – Tips below level of Ao annulus
  – ↑ Ao annulus size
  – Residual AR
Mitral and Aortic Valve Repair

PRINCIPLES FOR SUCCESS

• Goals of valve assessment:
  – Establish a precise diagnosis
  – Determine most appropriate treatment option (repair vs. replace)
  – Consider transfer to Reference Center for complex lesions

• Segmental Valve Analysis:
  – Localize and categorize dysfunction
  – Complete inventory of specific lesions to plan intervention
  – One lesion → one technique