세종병원 SEJONG HOSPITAL

Mitral Valve Surgery

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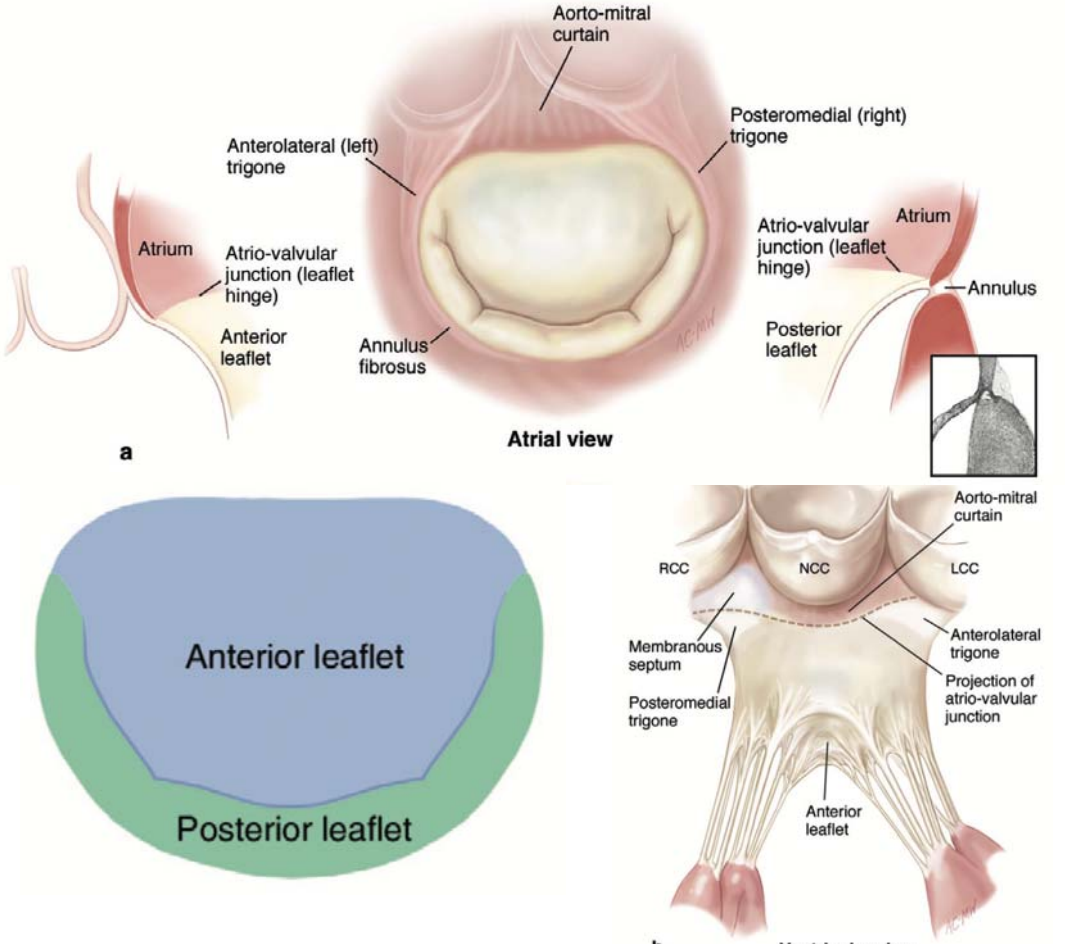
Anatomy

Anatomy

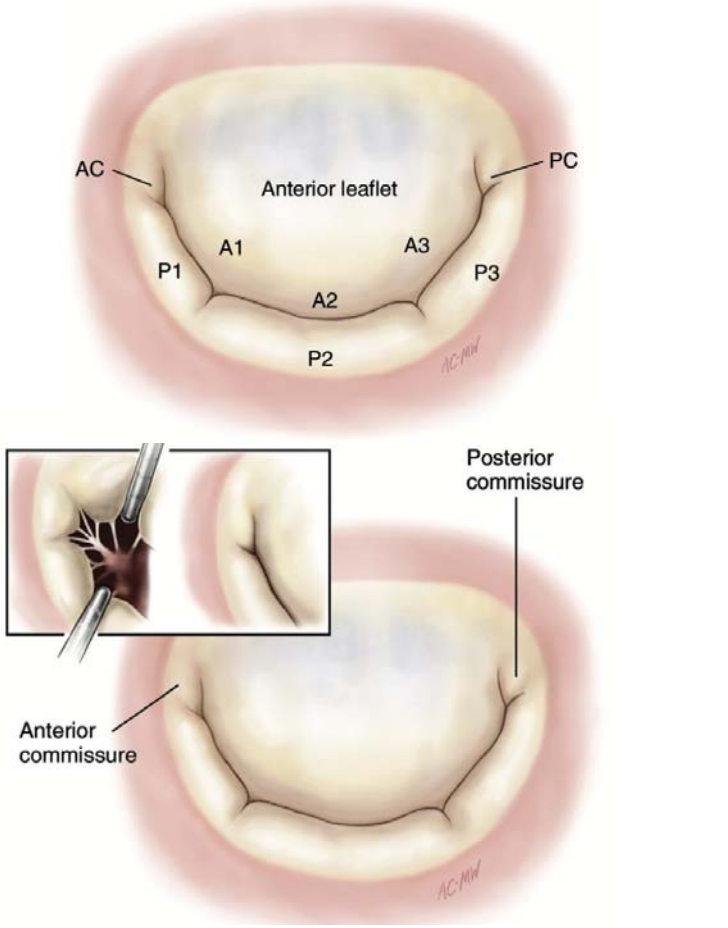
- **Leaflets**
  - Anterior
    - Trapezoidal shape
    - More extended vertically
    - 1/3 circumference of MV (Area 75%)
    - LVOT, aorto-mitral curtain
    - Trigones



Carpentier's reconstructive valve surgery, Elsevier, 2010

Anatomy

- **Leaflets**
  - Posterior
    - More extended transversally
    - 2/3 circumference of MV (Area 25%)
    - Muscular parietal base of LV
  - Commissures
    - Continuity between anterior and posterior leaflet
    - Small, triangular segment
    - Y shape coaptation zone

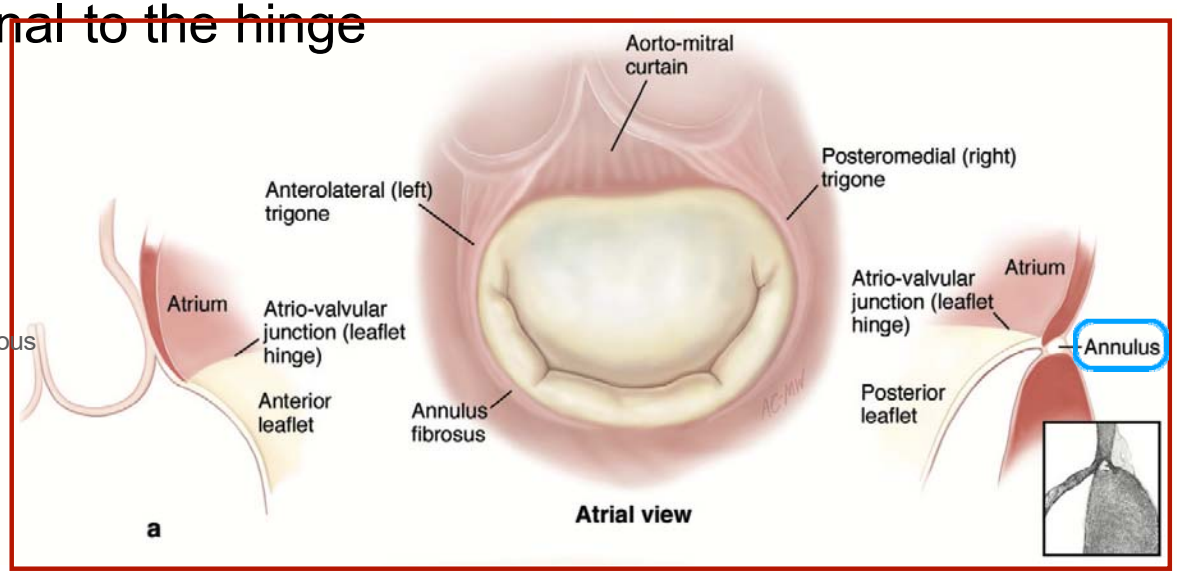


Carpentier's reconstructive valve surgery, Elsevier, 2010

Anatomy

- **Annulus**
  - Atrio-valvular junction
  - The hinge (leaflet motion)
  - Annular fibrosus
  - Located dipper and 2 mm external to the hinge

- Suture needles
  - ➡ 2mm away from the hinge
  - ➡ Oriented towards the ventricle, pass through the resistant fibrous body of the annulus

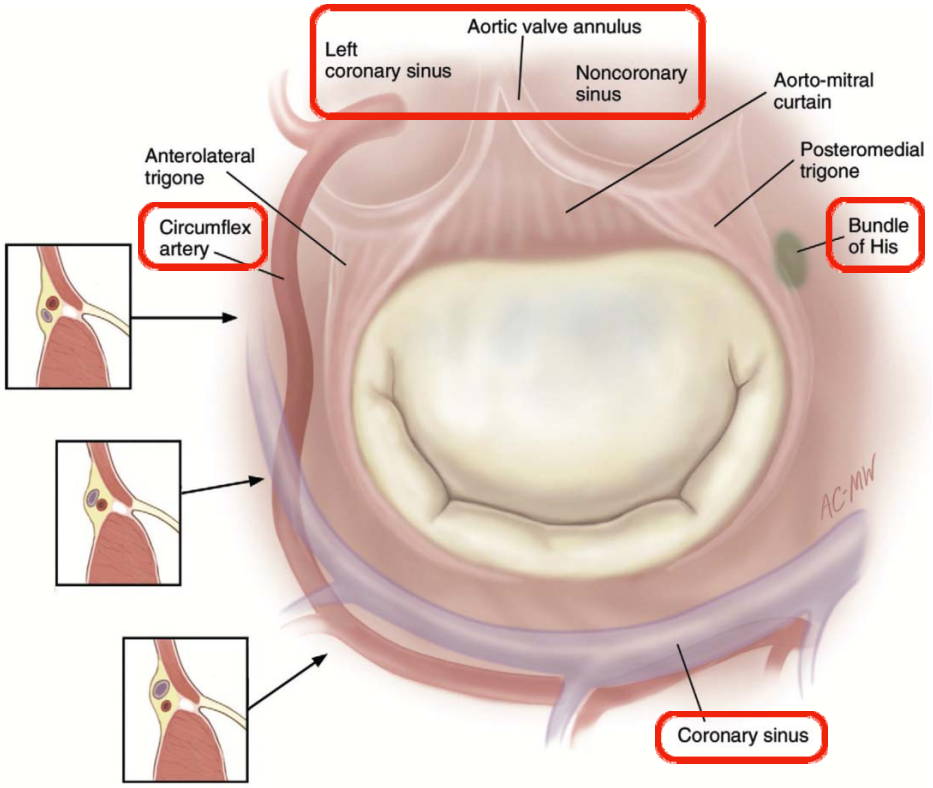


Carpentier's reconstructive valve surgery, Elsevier, 2010

Anatomy

Four anatomical structures close to the annulus

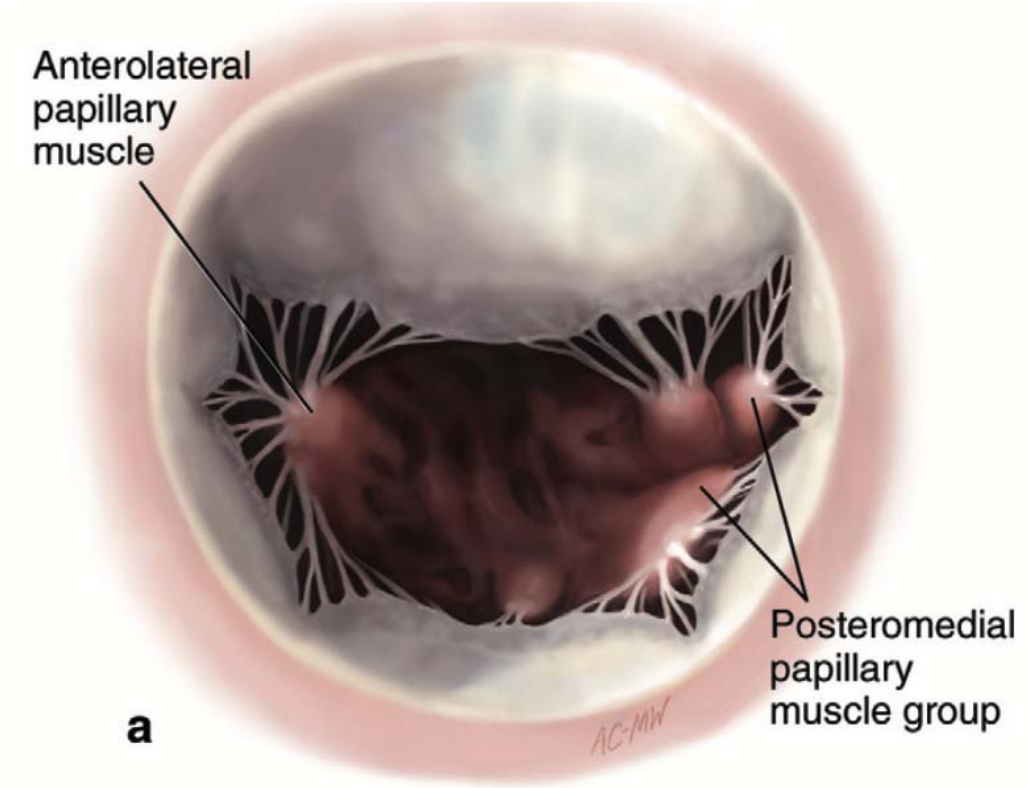
- Circumflex artery
- Coronary sinus
- Bundle of His
- Noncoronary & left coronary aortic cusps



Carpentier's reconstructive valve surgery, Elsevier, 2010

Anatomy

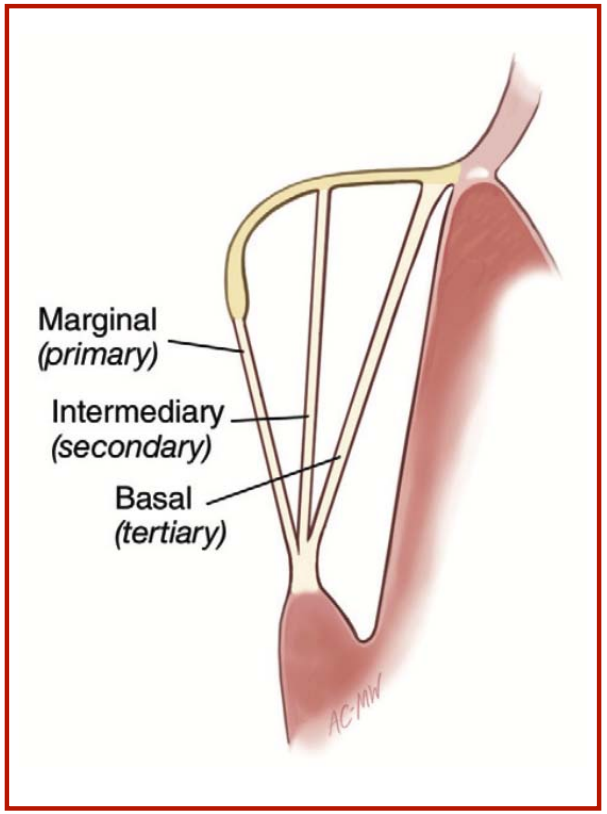
- **Papillary muscle**
  - Posteromedial
  - Anterolateral



Carpentier's reconstructive valve surgery, Elsevier, 2010

Anatomy

- **Chordae tendinae**
  - *Basal (or tertiary) chordae*
    - attached to the **base** of the posterior and commissural leaflets or to the **annulus**
  - *Intermediary (or secondary) chordae*
    - attached to the **ventricular side** of the leaflets
  - *Marginal (or primary) chordae*
    - attached to the **margin** of the leaflets



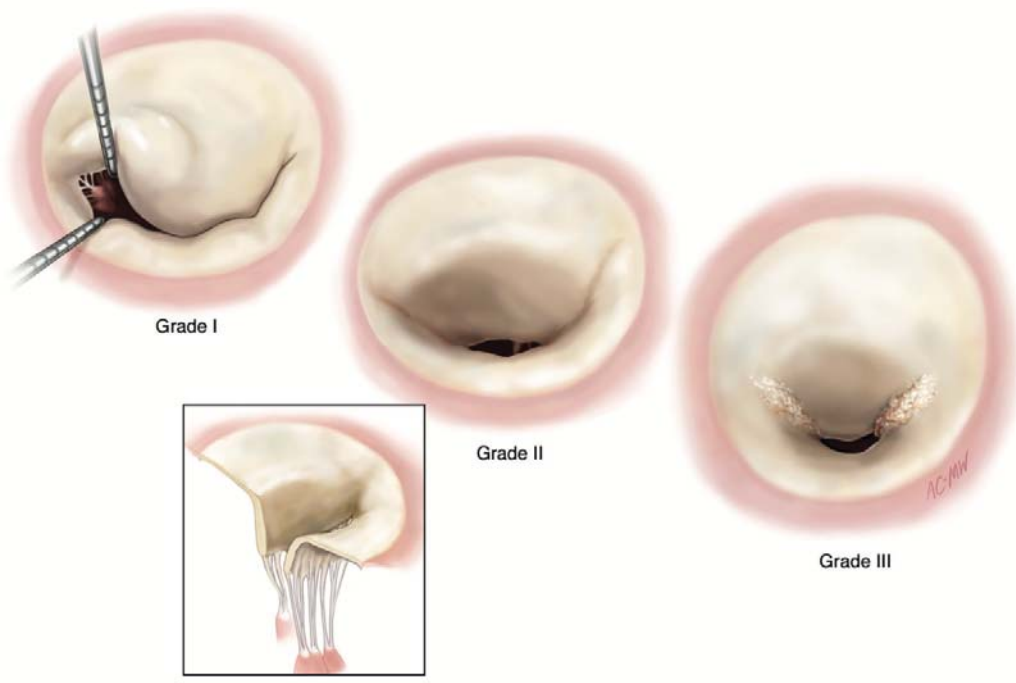
Carpentier's reconstructive valve surgery, Elsevier, 2010

Pathophysiology

Mitral stenosis

Mitral stenosis

- Etiology
  - Rheumatic
  - Degenerative (calcification)
  - Congenital
  - Carcinoid
  - Neoplasm



- Characteristic rheumatic changes
  - A Commissural fusion
  - “Fish-mouth” appearance of the MV orifice
  - Leaflet thickening, especially at the free edges

Carpentier's reconstructive valve surgery, Elsevier, 2010

Stages of MS

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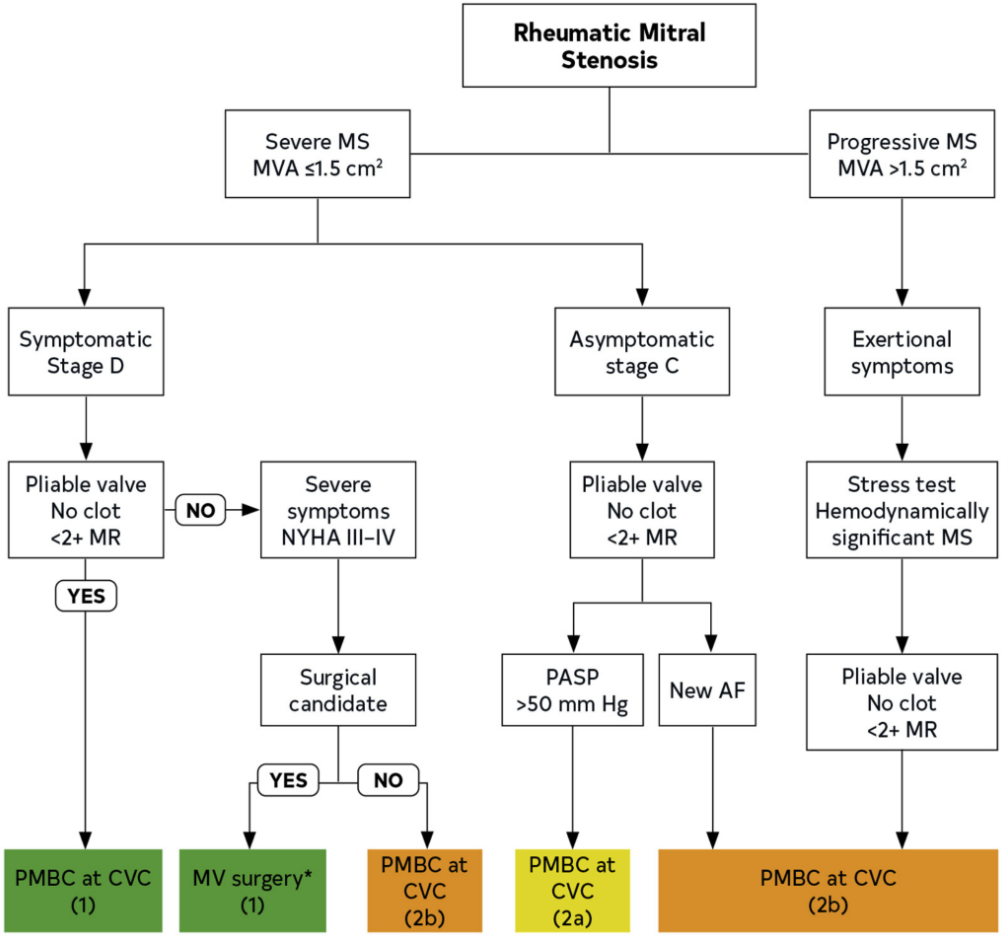
Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
A	At risk of MS	■ Mild valve doming during diastole	Normal transmitral flow velocity	None	None
B	Progressive MS	■ Rheumatic valve changes with commissural fusion and diastolic doming of the mitral valve leaflets ■ Planimetered mitral valve area >1.5 cm^2	■ Increased transmitral flow velocities ■ Mitral valve area >1.5 cm^2 ■ Diastolic pressure half-time <150 ms	■ Mild to moderate LA enlargement ■ Normal pulmonary pressure at rest	None
C	Asymptomatic severe MS	■ Rheumatic valve changes with commissural fusion and diastolic doming of the mitral valve leaflets ■ Planimetered mitral valve area ≤1.5 cm^2	■ Mitral valve area ≤1.5 cm^2 ■ Diastolic pressure half-time ≥150 ms	■ Severe LA enlargement ■ Elevated PASP >50 mm Hg	None
D	Symptomatic severe MS	■ Rheumatic valve changes with commissural fusion and diastolic doming of the mitral valve leaflets ■ Planimetered mitral valve area ≤1.5 cm^2	■ Mitral valve area ≤1.5 cm^2 ■ Diastolic pressure half-time ≥150 ms	■ Severe LA enlargement ■ Elevated PASP >50 mm Hg	■ Decreased exercise tolerance ■ Exertional dyspnea

The transmitral mean pressure gradient should be obtained to further determine the hemodynamic effect of the MS and is usually >5 mm Hg to 10 mm Hg in severe MS; however, because of the variability of the mean pressure gradient with heart rate and forward flow, it has not been included in the criteria for severity.

LA indicates left atrial; MS, mitral stenosis; and PASP, pulmonary artery systolic pressure.

Catherine M. Otto, Rick A. Nishimura et al. JACC. 2021

Interventions for MS



Catherine M. Otto, Rick A. Nishimura et al. JACC. 2021

Mitral regurgitation

Pathophysiology

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Pathophysiological Triad[2]
Etiology—*The cause of the disease*
↓
Lesions—*Result from the disease*
↓
Dysfunction—*Result from the lesions*

Application of the Pathophysiological Triad in Degenerative Mitral Valve Diseases	
Etiology	***Barlow's disease*** instead of *myxoid, myxomatous, billowing, floppy valves* and *mitral valve prolapse*
	Fibroelastic deficiency should be recognized as a cause of degenerative valve disease (see Ch. 26)
Lesions	***Leaflet billowing*** instead of *stretching, distension, ballooning* and *overshooting leaflet*
	Chordae elongation instead of *chordae stretching* or *distension*
Dysfunctions	***Leaflet prolapse*** instead of *flail, partial flail, overshooting leaflet, floppy valve, mitral valve prolapse etc.*

Carpentier's reconstructive valve surgery, Elsevier, 2010

Pathophysiology

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Etiology of Valvular Diseases

Primary Valve Diseases

- Congenital malformations
- Inflammatory diseases
  - Rheumatic
  - Lupus erythematosus
  - Valve sclerosis
- Degenerative diseases
  - Barlow's disease
  - Marfan's disease
  - Fibroelastic deficiency
- Bacterial endocarditis*
- Valvular or annular calcification*
- Trauma
- Valvular tumors

Secondary to Myocardial Diseases

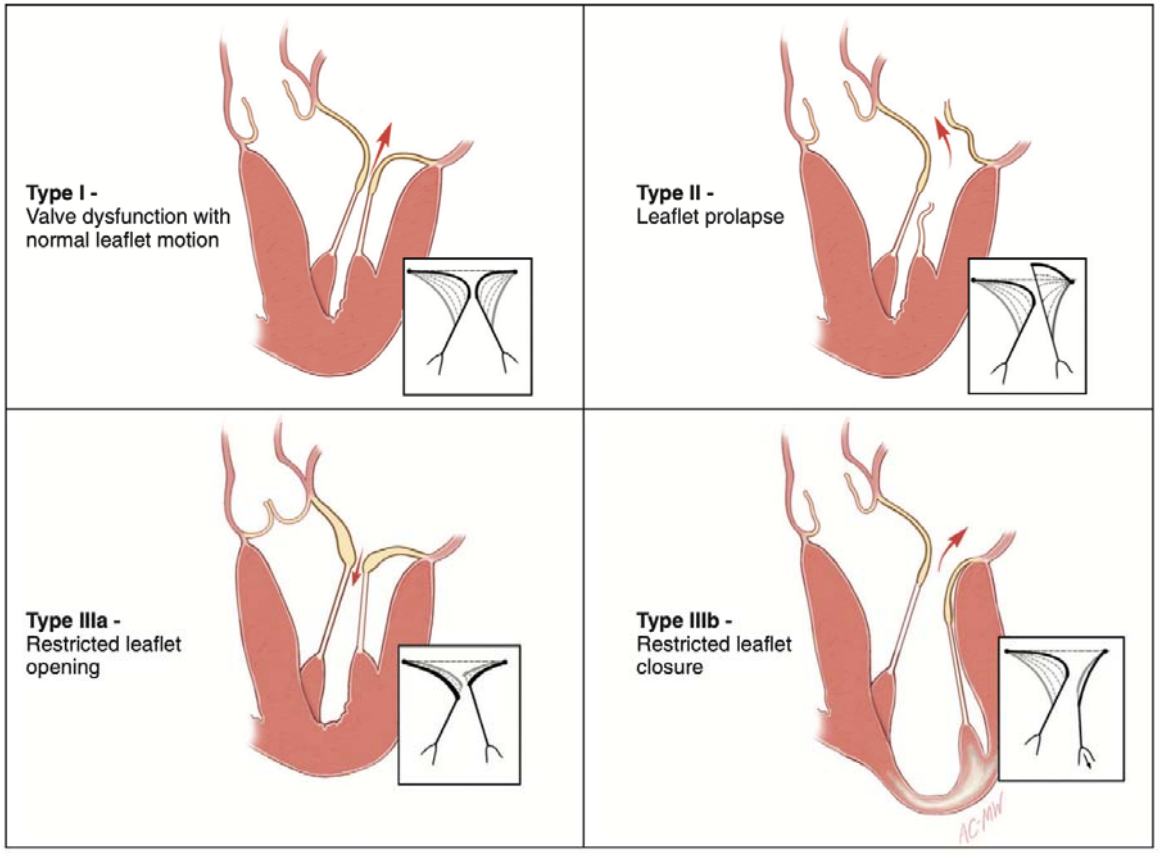
- Ischemic cardiomyopathy
- Dilated cardiomyopathy
- Hypertrophic obstructive cardiomyopathy
- Myocardial sarcoidosis
- Endomyocardial fibrosis
- Myocardial tumors

Mitral Valve Lesions

Annulus:	Dilatation Abscess Calcification
Leaflets:	Excess leaflet tissue Thickening Vegetations Abscess, perforation Tear Calcification
Commissures:	Fusion Thickening Calcification
Papillary muscles:	Rupture Elongation Calcification
Ventricle:	Infarction Fibrosis Dilatation Aneurysm Myocarditis Calcification

Carpentier's reconstructive valve surgery, Elsevier, 2010

Pathophysiology



Valve Dysfunctions and Corresponding Lesions

Valve Dysfunctions	Lesions
Type I: Normal leaflet motion	Annular dilatation Leaflet perforation Vegetation
Type II: Leaflet prolapse	Leaflet rupture, distension Commissure detachment
Type IIIa: Restricted leaflet closure and opening	Leaflet thickening Commissure fusion Calcification
Type IIIb: Restricted leaflet closure only	Sino-tubular dilatation

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Stages of Chronic primary MR

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Stage	Definition	Valve Anatomy	Valve Hemodynamics *	Hemodynamic Consequences	Symptoms
A	At risk of MR	■ Mild mitral valve prolapse with normal coaptation ■ Mild valve thickening and leaflet restriction	■ No MR jet or small central jet area <20% LA on Doppler ■ Small vena contracta <0.3 cm	■ None	■ None
B	Progressive MR	■ Moderate to severe mitral valve prolapse with normal coaptation ■ Rheumatic valve changes with leaflet restriction and loss of central coaptation ■ Prior IE	■ Central jet MR 20%-40% LA or late systolic eccentric jet MR ■ Vena contracta <0.7 cm ■ Regurgitant volume <60 mL ■ Regurgitant fraction <50% ■ ERO <0.40 cm^2 ■ Angiographic grade 1+ to 2+	■ Mild LA enlargement ■ No LV enlargement ■ Normal pulmonary pressure	■ None
C	Asymptomatic severe MR	■ Severe mitral valve prolapse with loss of coaptation or flail leaflet ■ Rheumatic valve changes with leaflet restriction and loss of central coaptation ■ Prior IE ■ Thickening of leaflets with radiation heart disease	■ Central jet MR >40% LA or holosystolic eccentric jet MR ■ Vena contracta ≥0.7 cm ■ Regurgitant volume ≥60 mL ■ Regurgitant fraction ≥50% ■ ERO ≥0.40 cm^2 ■ Angiographic grade 3+ to 4+	■ Moderate or severe LA enlargement ■ LV enlargement ■ Pulmonary hypertension may be present at rest or with exercise ■ C1: LVEF >60% and LVESD <40 mm ■ C2: LVEF ≤60% and/or LVESD ≥40 mm	■ None
D	Symptomatic severe MR	■ Severe mitral valve prolapse with loss of coaptation or flail leaflet ■ Rheumatic valve changes with leaflet restriction and loss of central coaptation ■ Prior IE ■ Thickening of leaflets with radiation heart disease	■ Central jet MR >40% LA or holosystolic eccentric jet MR ■ Vena contracta ≥0.7 cm ■ Regurgitant volume ≥60 mL ■ Regurgitant fraction ≥50% ■ ERO ≥0.40 cm^2 Angiographic grade 3+ to 4+	■ Moderate or severe LA enlargement ■ LV enlargement ■ Pulmonary hypertension present	■ Decreased exercise tolerance ■ Exertional dyspnea

*Several valve hemodynamic criteria are provided for assessment of MR severity, but not all criteria for each category will be present in each patient. Categorization of MR severity as mild, moderate, or severe depends on data quality and integration of these parameters in conjunction with other clinical evidence.

ERO indicates effective regurgitant orifice; IE, infective endocarditis; LA, left atrium/atrial; LV, left ventricular; LVEF, left ventricular ejection fraction; LVESD; left ventricular end-systolic dimension; and MR, mitral regurgitation.

Catherine M. Otto, Rick A. Nishimura et al. JACC. 2021

Stages of Secondary MR

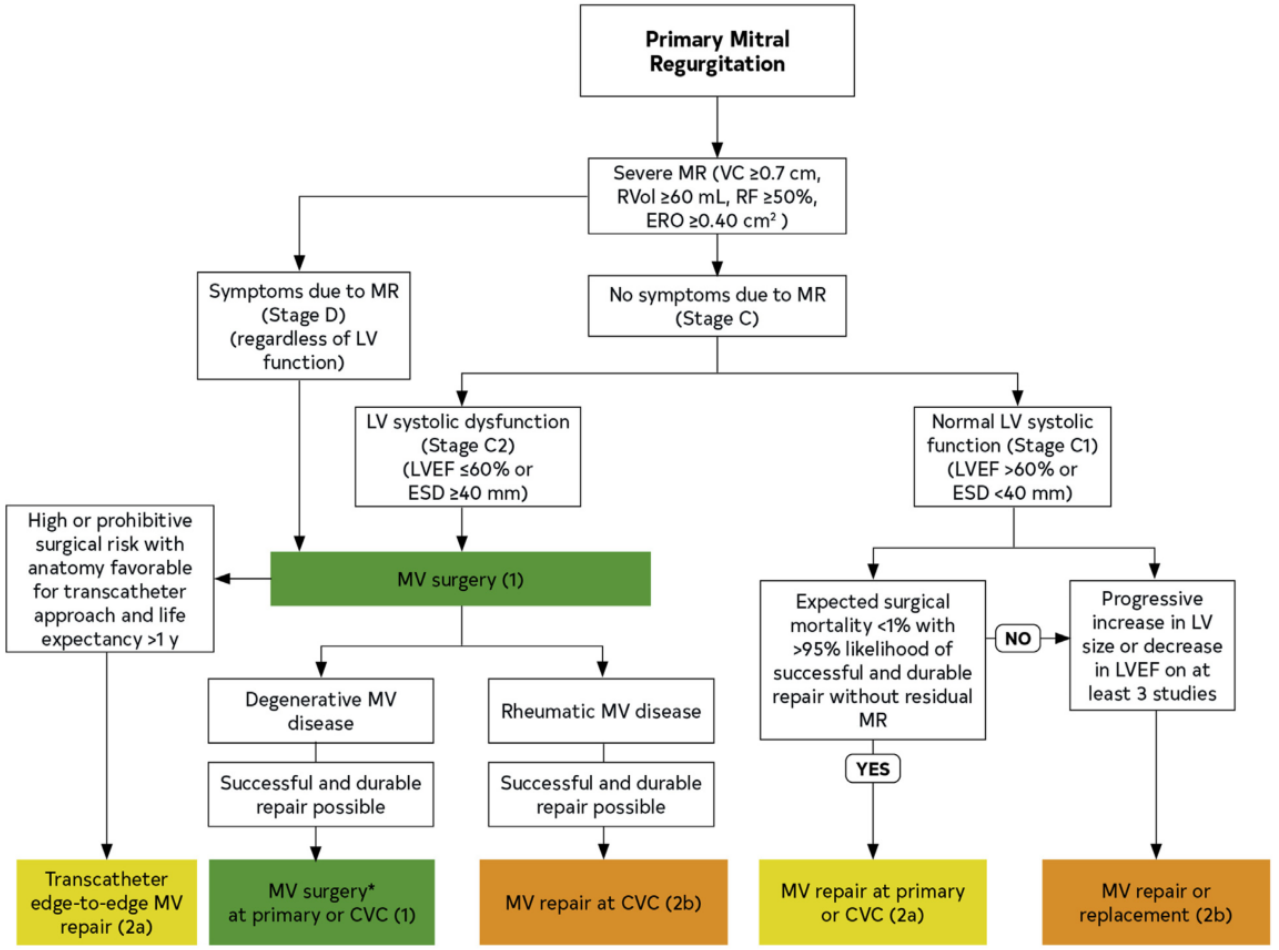
Stage	Definition	Valve Anatomy	Valve Hemodynamics*	Associated Cardiac Findings	Symptoms
A	At risk of MR	■ Normal valve leaflets, chords, and annulus in a patient with CAD or cardiomyopathy	■ No MR jet or small central jet area <20% LA on Doppler ■ Small vena contracta <0.30 cm	■ Normal or mildly dilated LV size with fixed (infarction) or inducible (ischemia) regional wall motion abnormalities ■ Primary myocardial disease with LV dilation and systolic dysfunction	■ Symptoms attributable to coronary ischemia or HF may be present that respond to revascularization and appropriate medical therapy
B	Progressive MR	■ Regional wall motion abnormalities with mild tethering of mitral leaflet ■ Annular dilation with mild loss of central coaptation of the mitral leaflets	■ ERO <0.40 cm^2† ■ Regurgitant volume <60 mL ■ Regurgitant fraction <50%	■ Regional wall motion abnormalities with reduced LV systolic function ■ LV dilation and systolic dysfunction attributable to primary myocardial disease	■ Symptoms attributable to coronary ischemia or HF may be present that respond to revascularization and appropriate medical therapy
C	Asymptomatic severe MR	■ Regional wall motion abnormalities and/or LV dilation with severe tethering of mitral leaflet ■ Annular dilation with severe loss of central coaptation of the mitral leaflets	■ ERO ≥0.40 cm^2† ■ Regurgitant volume ≥60 mL ‡ ■ Regurgitant fraction ≥50%	■ Regional wall motion abnormalities with reduced LV systolic function ■ LV dilation and systolic dysfunction attributable to primary myocardial disease	■ Symptoms attributable to coronary ischemia or HF may be present that respond to revascularization and appropriate medical therapy
D	Symptomatic severe MR	■ Regional wall motion abnormalities and/or LV dilation with severe tethering of mitral leaflet ■ Annular dilation with severe loss of central coaptation of the mitral leaflets	■ ERO ≥0.40 cm^2† ■ Regurgitant volume ≥60 mL ‡ ■ Regurgitant fraction ≥50%	■ Regional wall motion abnormalities with reduced LV systolic function ■ LV dilation and systolic dysfunction attributable to primary myocardial disease	■ HF symptoms attributable to MR persist even after revascularization and optimization of medical therapy ■ Decreased exercise tolerance ■ Exertional dyspnea

*Several valve hemodynamic criteria are provided for assessment of MR severity, but not all criteria for each category will be present in each patient. Categorization of MR severity as mild, moderate, or severe depends on data quality and integration of these parameters in conjunction with other clinical evidence.
†The measurement of the proximal isovelocity surface area by 2D TTE in patients with secondary MR underestimates the true ERO because of the crescentic shape of the proximal convergence.
‡May be lower in low-flow states.

2D indicates 2-dimensional; CAD, coronary artery disease; ERO, effective regurgitant orifice; HF, heart failure; LA, left atrium; LV, left ventricular; MR, mitral regurgitation; and TTE, transthoracic echocardiogram.

Catherine M. Otto, Rick A. Nishimura et al. JACC. 2021

Intervention for Primary chronic MR



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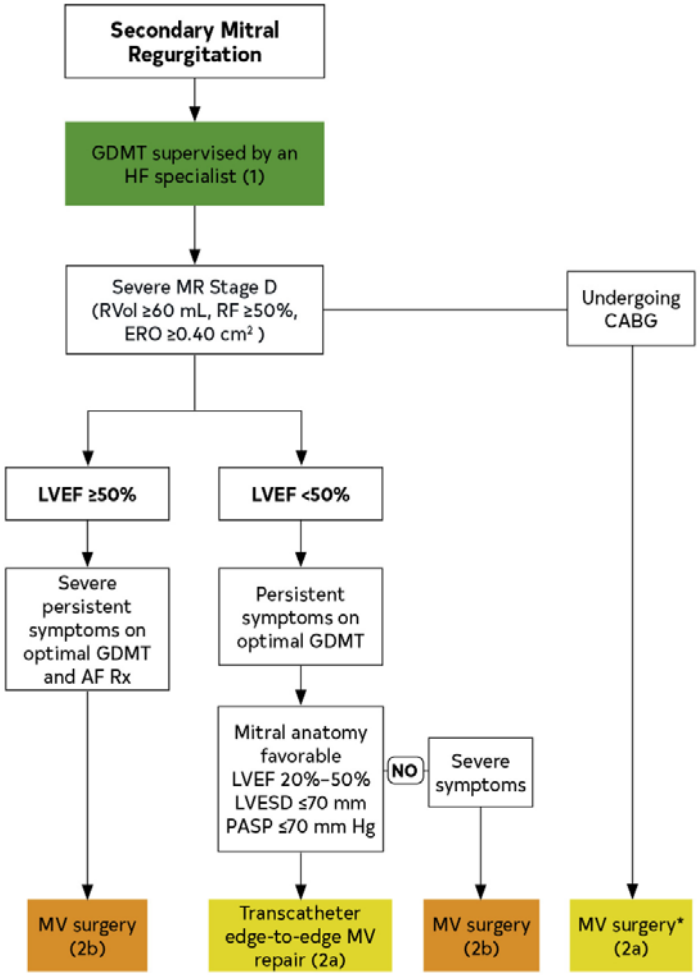
Intervention for Secondary MR



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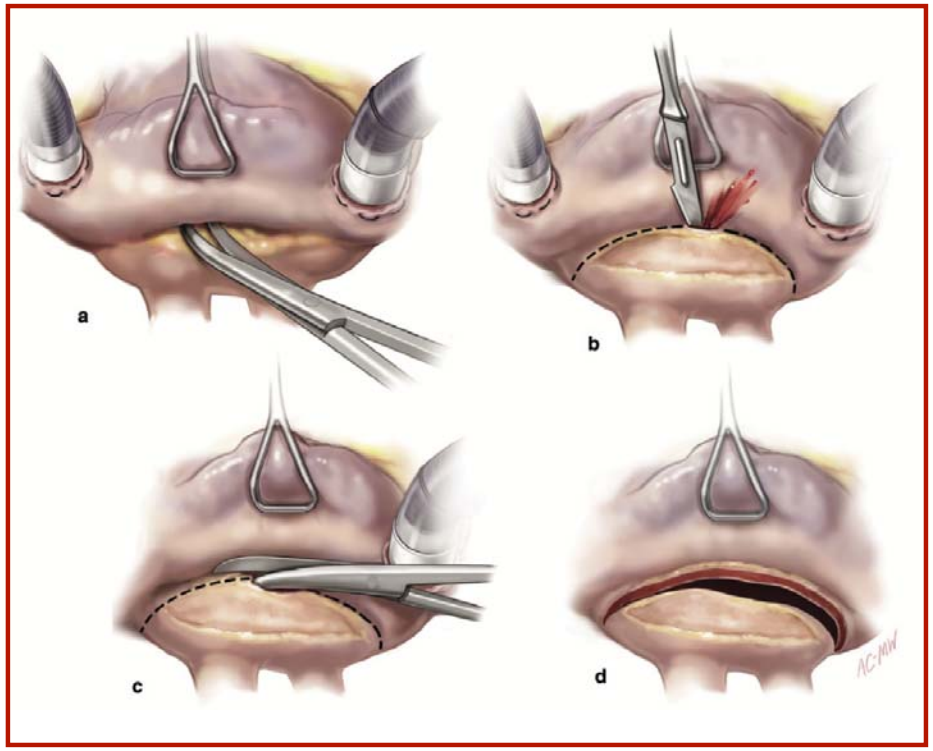
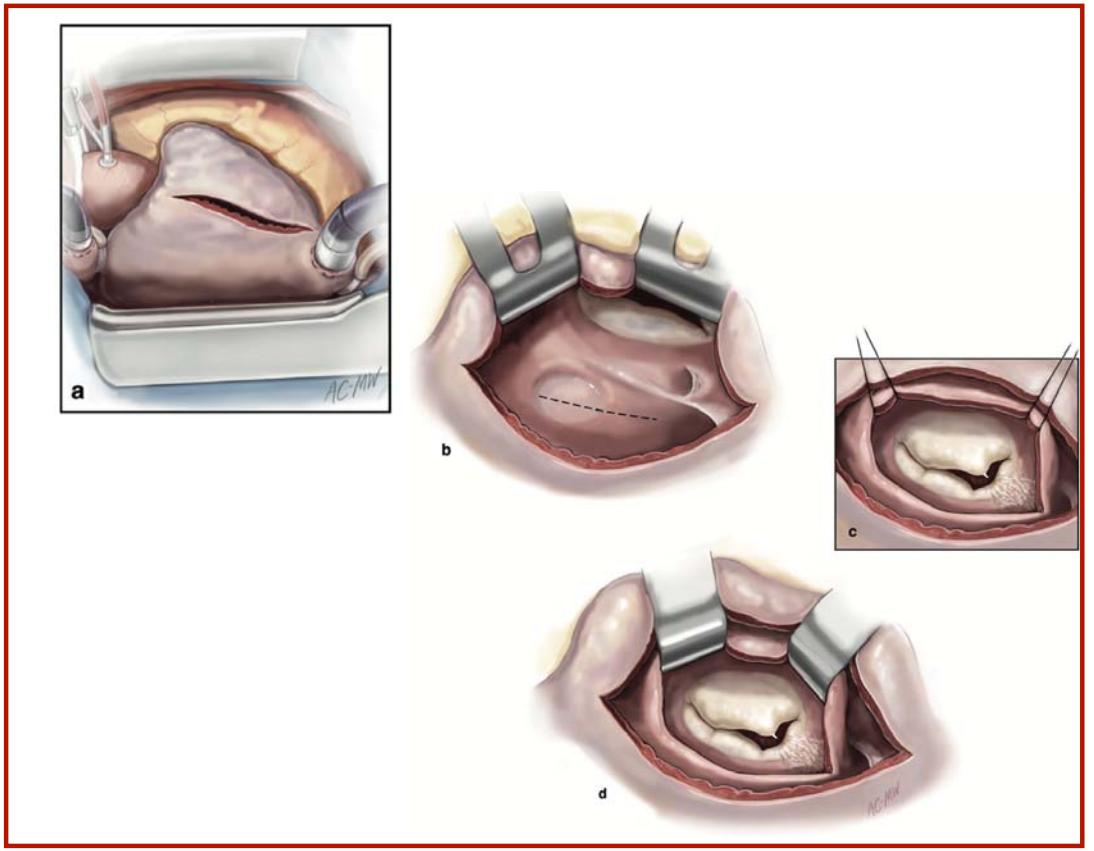
Mitral valve operations

MV exposure



Traditional LA approach
(Waterston's groove)



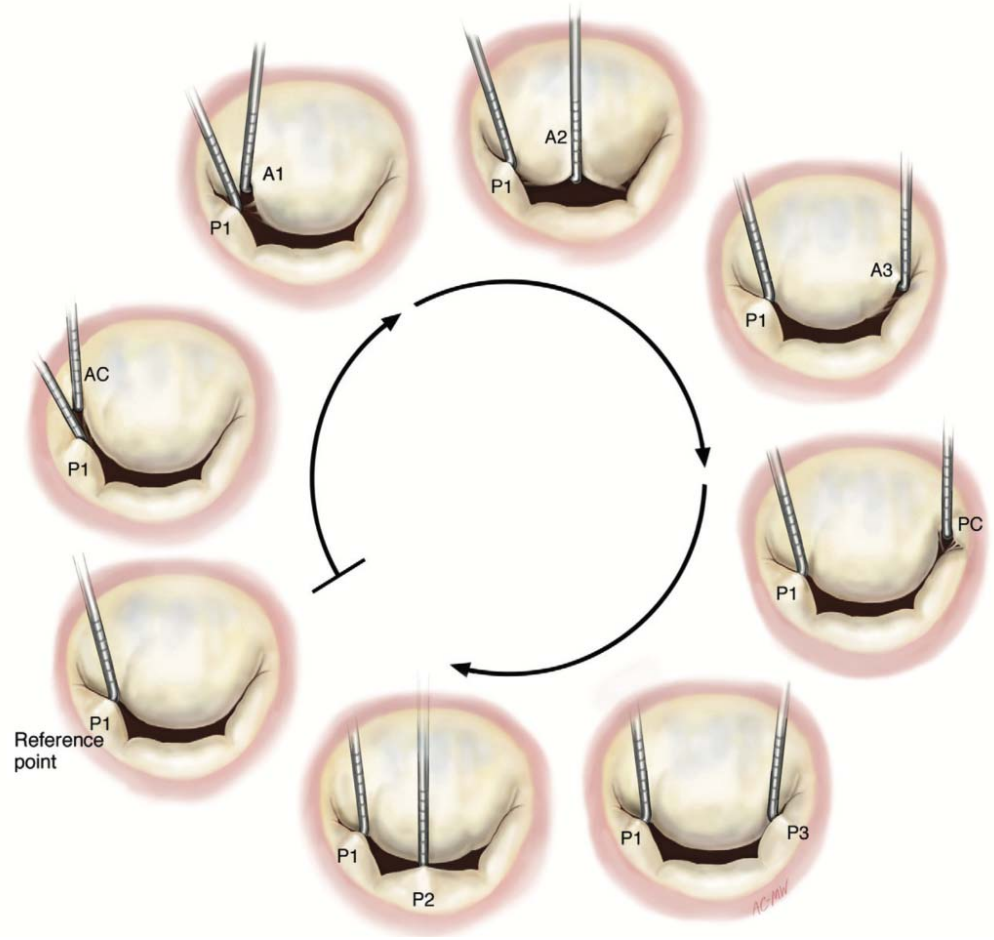
Trans-septal LA approach

Carpentier's reconstructive valve surgery, Elsevier, 2010

MV analysis

- Reference point
  - Free edge of **P1**

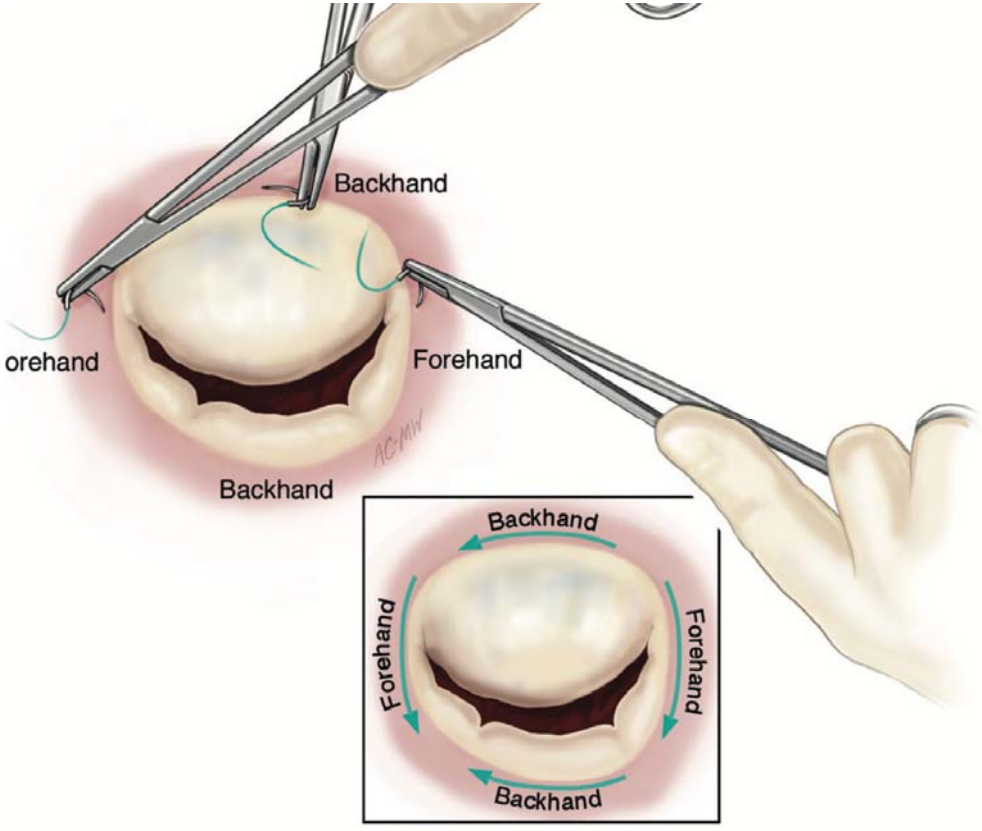
- Segmental functional analysis
  - ➡ the ***"Fil d'Ariane"*** of mitral valve reconstructive surgery

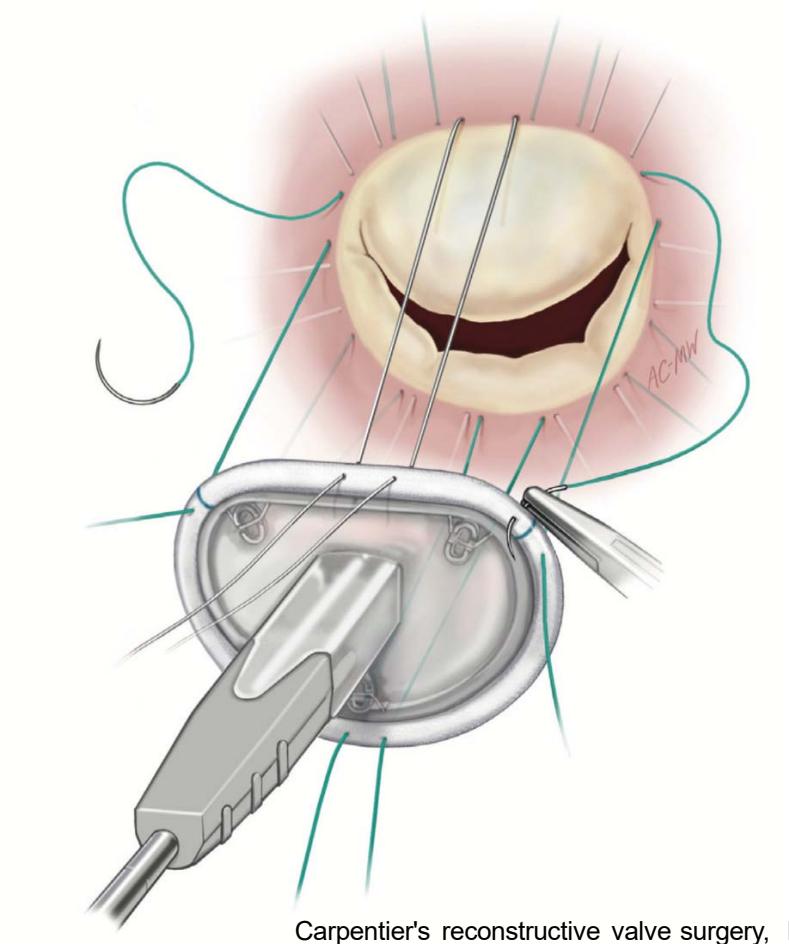


Carpentier's reconstructive valve surgery, Elsevier, 2010

MV repair

- Ring annuloplasty

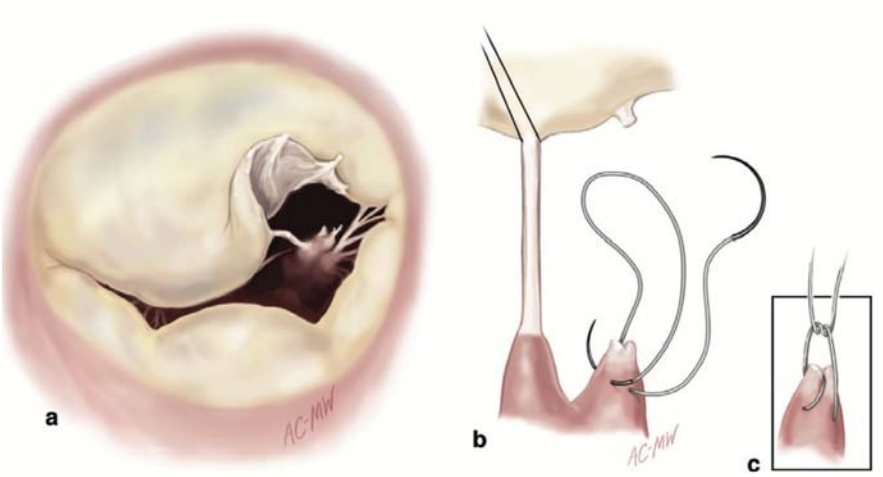


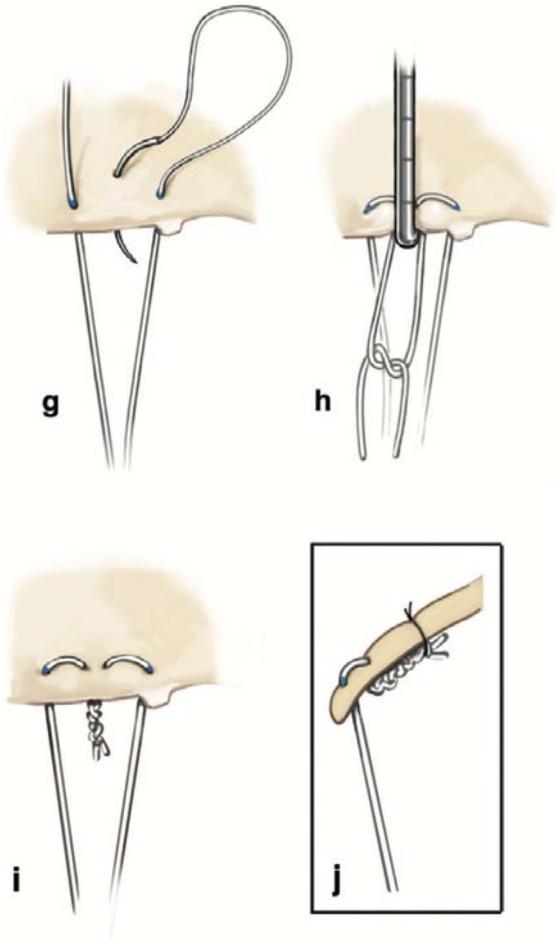


Carpentier's reconstructive valve surgery, Elsevier, 2010

MV repair

- Artificial chordae

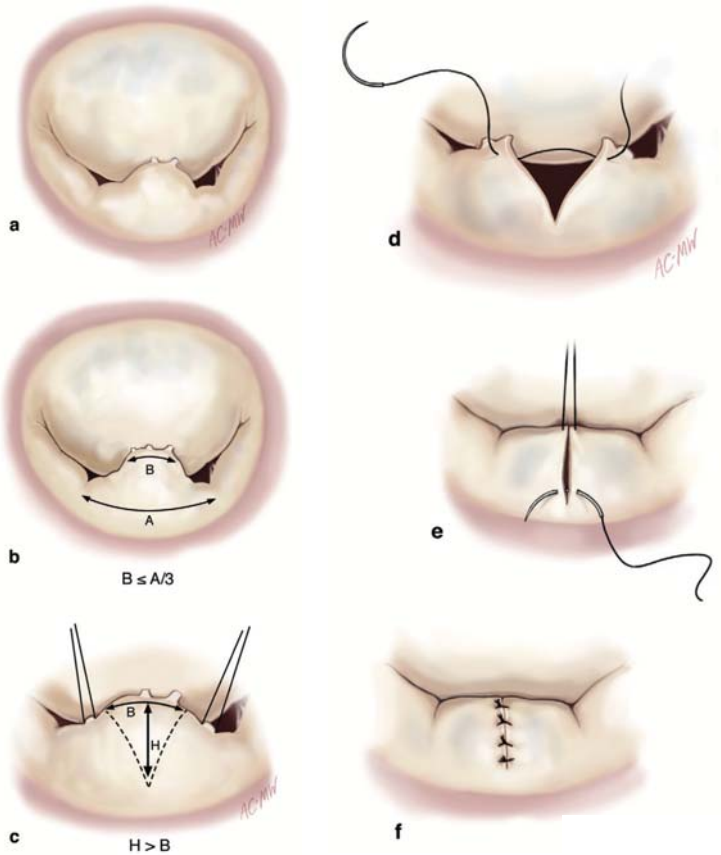




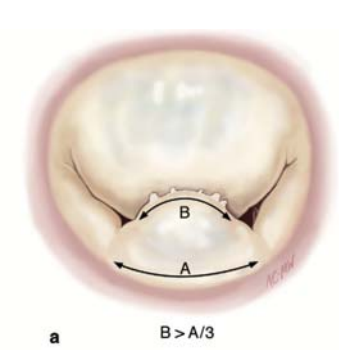
Carpentier's reconstructive valve surgery, Elsevier, 2010

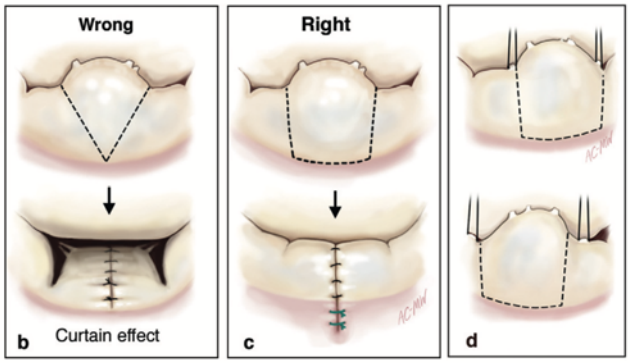
MV repair

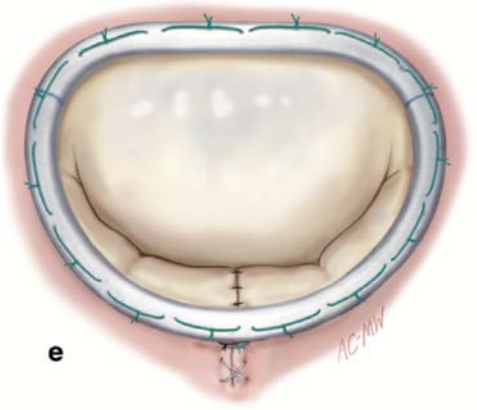
- Triangular resection



- Quadrangular resection



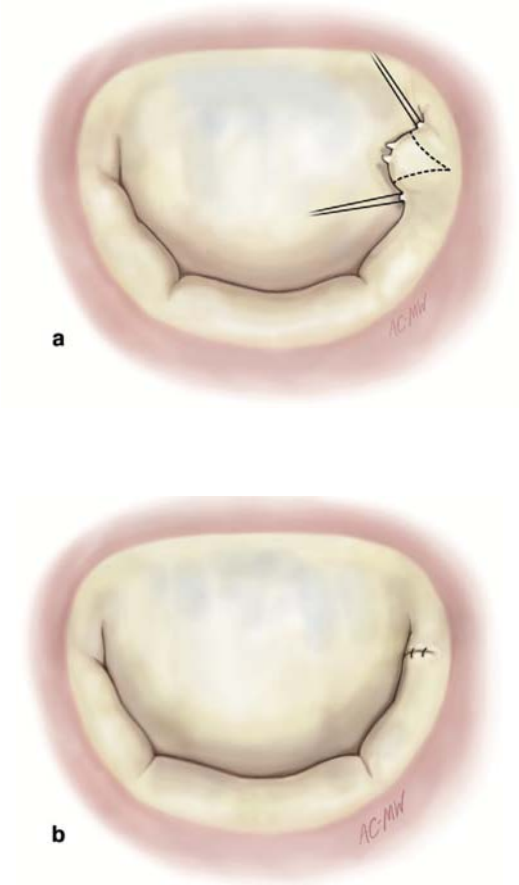


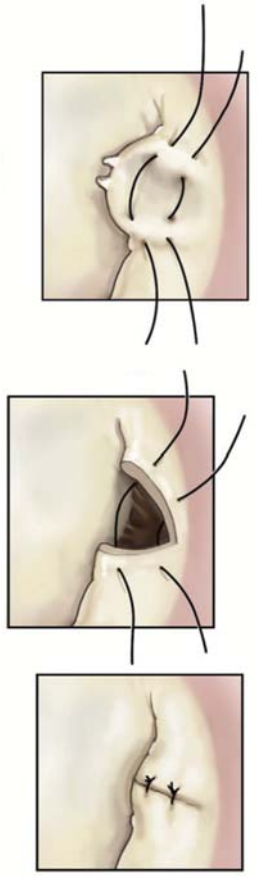


Carpentier's reconstructive valve surgery, Elsevier, 2010

MV repair

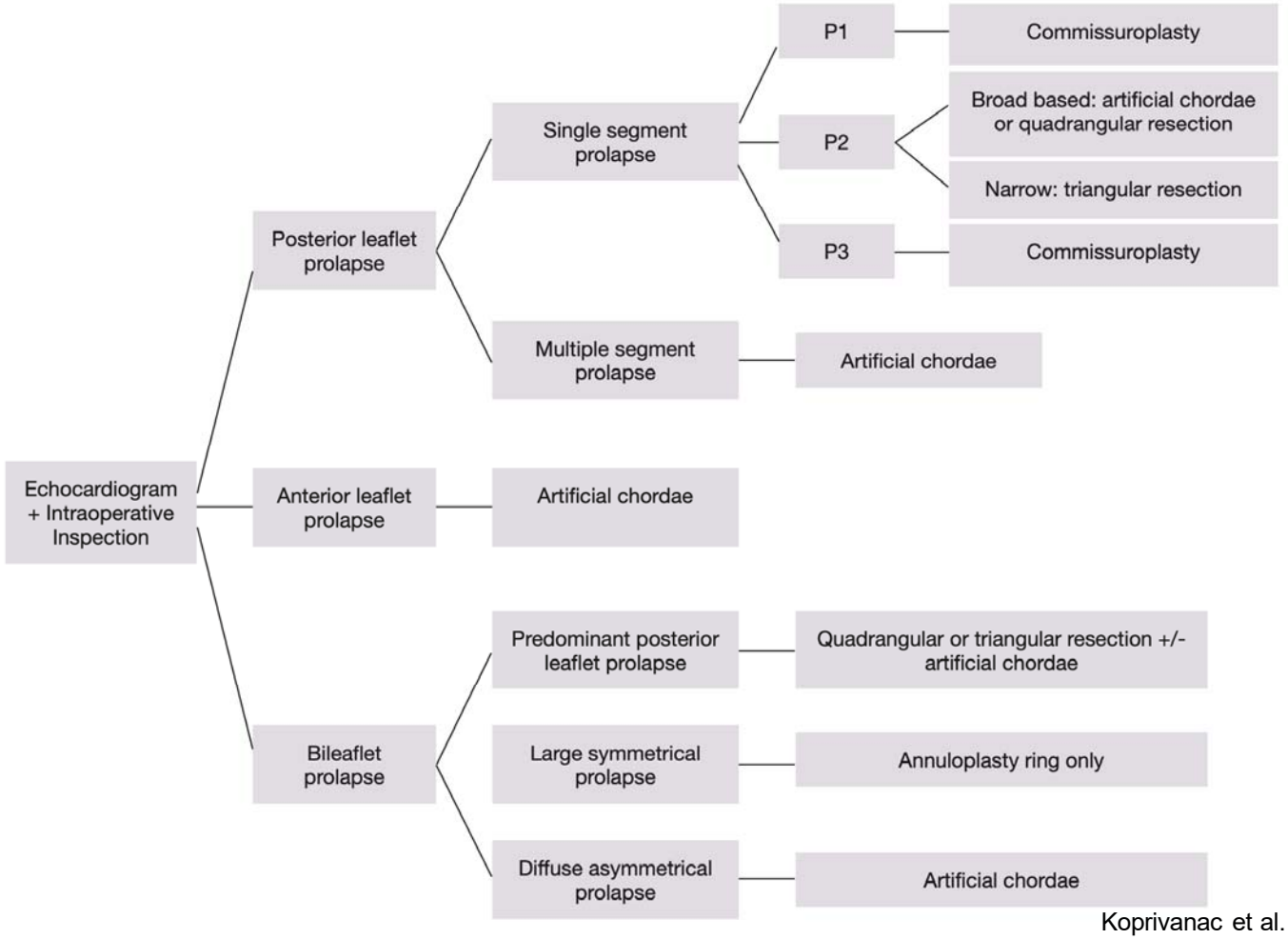
- Commissuroplasty





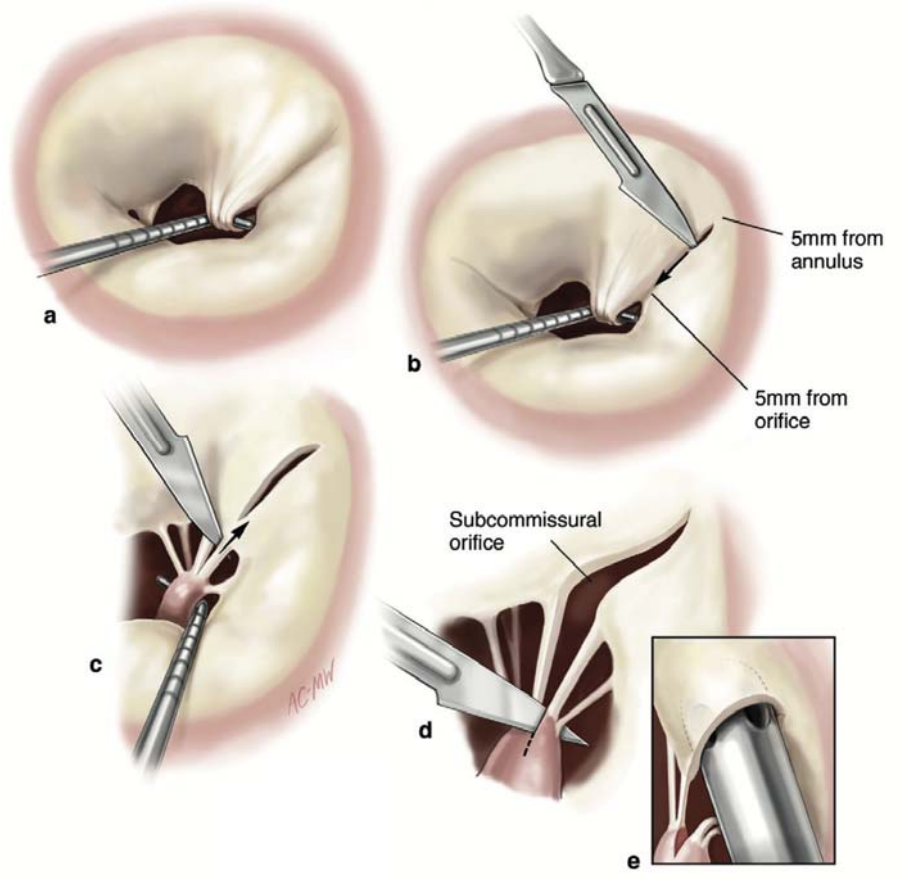
Carpentier's reconstructive valve surgery, Elsevier, 2010

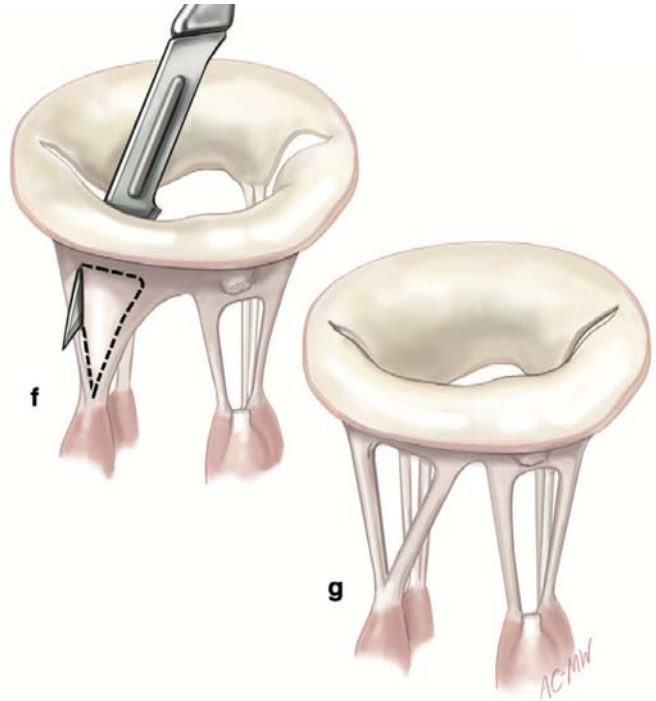
MV repair



Koprivanac et al. Ann Cardiothorac Surg 2017

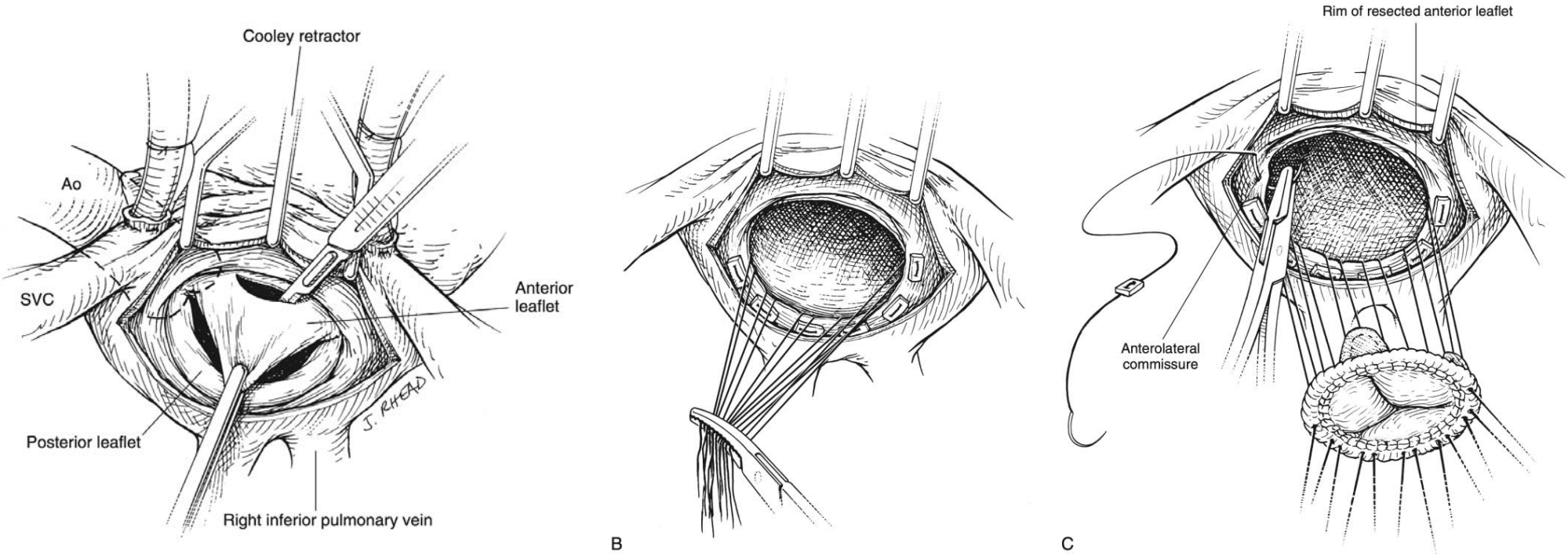
Mitral commissurotomy





Carpentier's reconstructive valve surgery, Elsevier, 2010

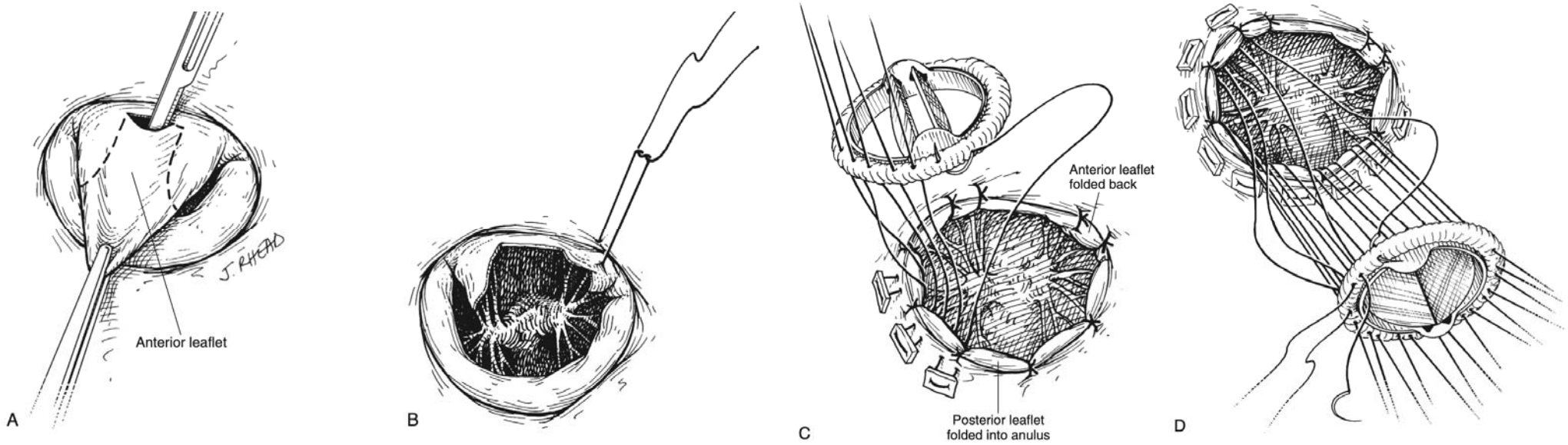
Mitral valve replacement



Kirklin Barratt-Boyes - Cardiac Surgery, 4th edition, Elsevier, 2013

Mitral valve replacement

- Chordae-sparing MVR



Kirklin Barratt-Boyes - Cardiac Surgery, 4th edition, Elsevier, 2013

MICS MV surgery

MICS MV surgery

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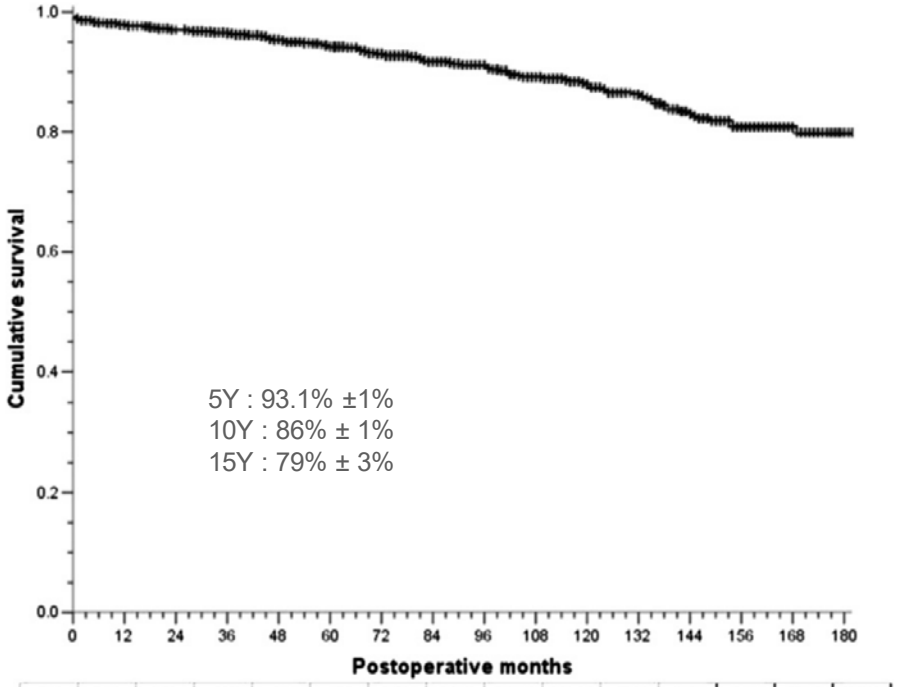
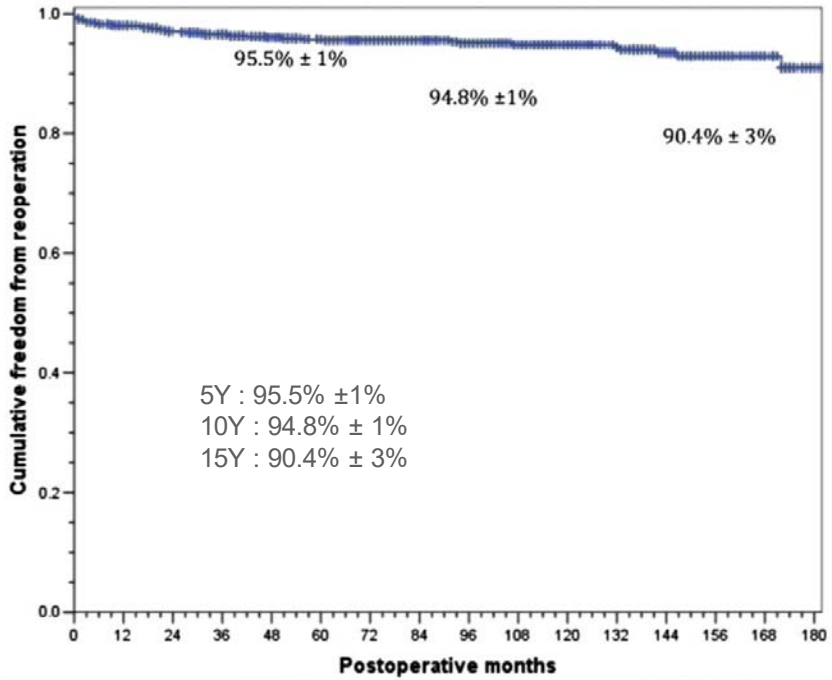
Overall survival



12	24	36	48	60	72	84	96	108	120	132	144	156	168	180
981	917	864	802	727	657	580	507	442	375	321	264	192	120	51

Reoperations



12	24	36	48	60	72	84	96	108	120	132	144	156	168	180
898	830	775	709	635	566	495	428	359	299	255	206	145	90	40

McClure et al. J Thorac Cardiovasc Surg 2013

MICS MV surgery

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Levels of ascent in MICS

Level 1	Direct vision	Limited (10–12 cm) incisions
Level 2	Direct vision/video assisted	Mini (4–6 cm) incisions
Level 3	Video directed and robot assisted	Micro (1.2–4 cm) incisions
Level 4	Robotic (computer telemanipulation)	Port (<1.2 cm) incisions

FIGURE 1: Level 2 minimally invasive approach (4–6 cm incision).

Ritwick et al. Minim Invasive Surg 2013

MICS MV surgery

Acquired Cardiovascular Disease

Early and late
An eleven-yea

R. Scott McClure, MD, S
R. Morton Bolman, III, M

Objective: This
evaluates long-te
regurgitation and

Methods: Betwe
patients (mean fo
remaining 707 pa
was 60% ± 10
(24%), right thor
the left atrium in
(96%) of 707 rep

Results: There w
(20%), reoperatio
wound infection
required blood tra
repairs necessitati
dom from reopera
up. A total of 236
0.47–11.09). Mea
ejection fraction
rence of moderate

Conclusion: Min
rent mitral regurg

Two Hundred Forty Minimally Invasive Mitral Operations Through Right Minithoracotomy

Tayfun Aybek, MD, Selami Dogan, MD, Petar S. Risteski, MD, Andreas Zierer, MD, Thomas Wittlinger, MD, Gerhard Wimmer-Greinecker, MD, PhD, and Anton Moritz, MD, PhD

Department for Thoracic and Cardiovascular Surgery, Johann Wolfgang Goethe University, Frankfurt/Main, Germany

Background. This study reports of our 7-year experience with minimally invasive mitral valve operations using the transthoracic clamp technique, reviewing morbidity and mortality as well as echocardiographic follow-up results.

Methods. Between 1997 and 2004, 241 patients (121 male; aged 56 ± 14 years) underwent minimally invasive mitral valve surgery through right thoracotomy using the transthoracic clamp technique. Reconstructions were done in 199 patients, and 42 valves were replaced. Mean length of incision was 7.0 ± 1.2 cm. Mean preoperative New York Heart Association functional class was 2.6 ± 0.9.

Results. Thirty-day mortality was 3.3% (n = 8). Operating, bypass, and cross-clamp times averaged 241 ± 52, 142 ± 40, and 84 ± 26 minutes, respectively. Seven patients (2.9%) had conversion to sternotomy. Nine patients (3.7%) underwent reexploration for bleeding. Mean intensive care unit and hospital stay were 18 hours and 8.1 days, respectively. Mean follow-up was 30 ± 18 months (range, 3 to 76). Echocardiographic follow-up documented persistently competent valve function in all but 6 patients who had grade III regurgitation. Five of them underwent mitral valve re-reconstruction and 1 underwent transplantation. At 76 months, freedom from nontrivial recurrent mitral regurgitation and reoperation were 92.3% and 96.2%, respectively. Actuarial survival at 76 months, including early mortality, was 90.7%. Thoracic wounds were free from infection in all patients.

Conclusions. This study demonstrates that the direct vision, transthoracic clamp technique for minimally invasive mitral valve surgery is reproducible with low mortality and morbidity rates. It results in excellent cosmesis and abolished the risk of thoracic wound infection. Results are comparable to midterm outcomes of conventional operations.

(Ann Thorac Surg 2006;81:1618–24)

Minimal Access Versus Sternotomy for

Check for updates

MICS MV surgery

세종병원 SEJONG HOSPITAL

Totally endoscopic mitral valve surgery: early experience in 188 patients

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Yi Chen, Ling-chen Huang*, Dao-zhong Chen, Liang-wan Chen, Zi-he Zheng and Xiao-fu Dai*

Abstract

Introduction: Totally endoscopic technique has been widely used in cardiac surgery, and minimally invasive totally endoscopic mitral valve surgery has been developed as an alternative to median sternotomy for many patients with mitral valve disease. In this study, we describe our experience about a modified minimally invasive totally endoscopic mitral valve surgery and reported the preliminary results of totally endoscopic mitral valve surgery. The aim of this retrospective study is to evaluate the results of totally endoscopic technique in mitral valve surgery.

Material and methods: We retrospectively reviewed the profiles of 188 patients who were treated for mitral valve disease by modified totally endoscopic mitral valve surgery at our institution between January 2019 and December 2020. The procedure was performed under endoscopic right minithoracotomy and with femoro-femoral cannulation using the single two-stage venous cannula.

Results: A total of 188 patients underwent total endoscopic mitral valve surgery. Fifty-six patients had concomitant tricuspid valvuloplasty, 11 patients underwent concomitant ablation of atrial fibrillation and atrial septal defect repair was performed in three patients. Only one patient postoperatively died of multi-organ failure. Two patients were converted to median sternotomy. Except for one patient underwent operation to stop the bleeding from the incision site, no other serious complications nor reintervention occurred during the follow-up period.

Conclusions: The modified totally endoscopic mitral valve surgery performed at our institution is technically feasible and safe with the same efficacy as reported studies.

Keywords: Minimally invasive, Totally endoscopic, Mitral valve surgery

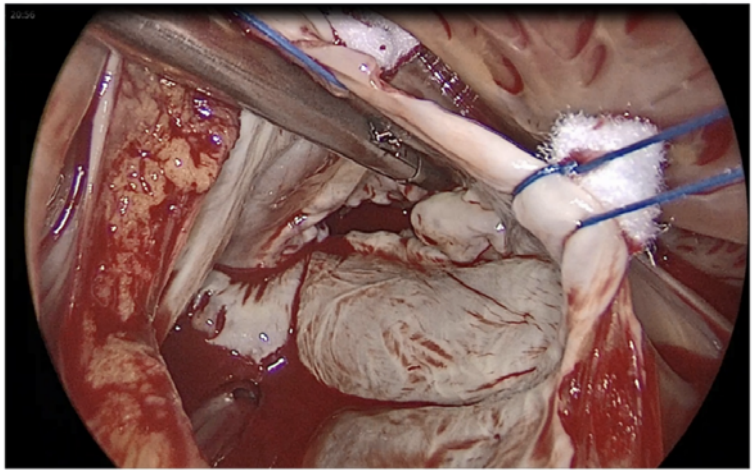

Fig. 4 Mitral valve surgery using the totally endoscopic technique

Chen et al. J Cardiothorac Surg 2021

MICS MV surgery

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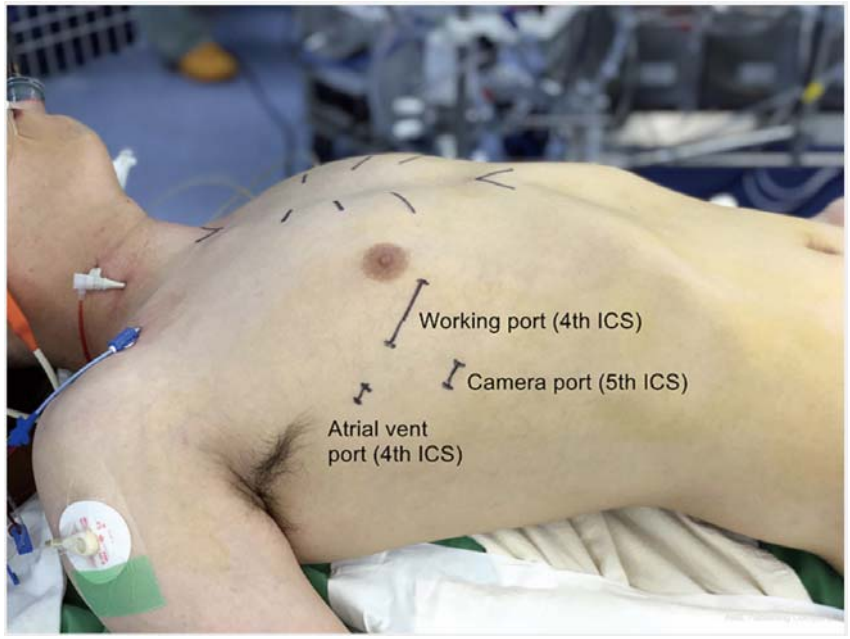
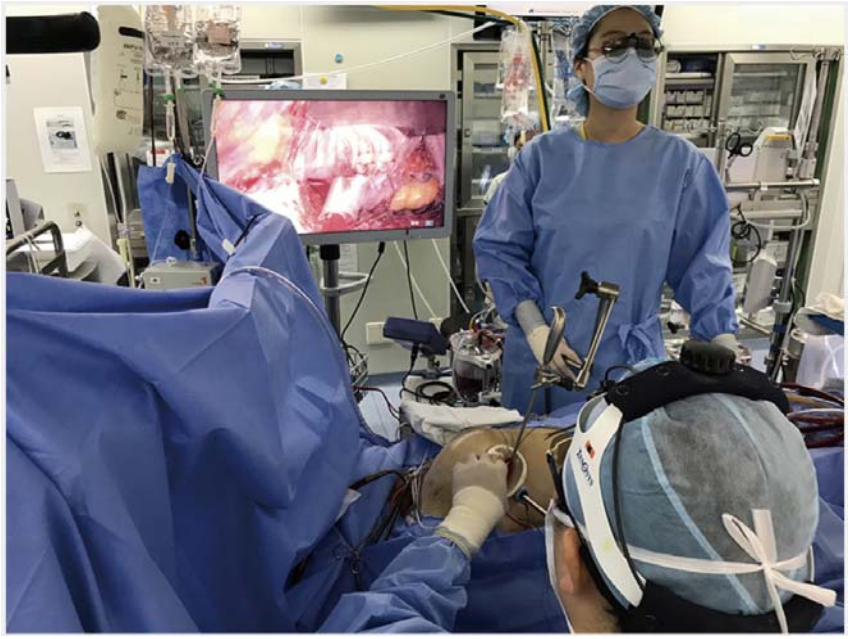
3D totally endoscopic mitral valve repair





Kim and Yoo J Thorac Dis 2020

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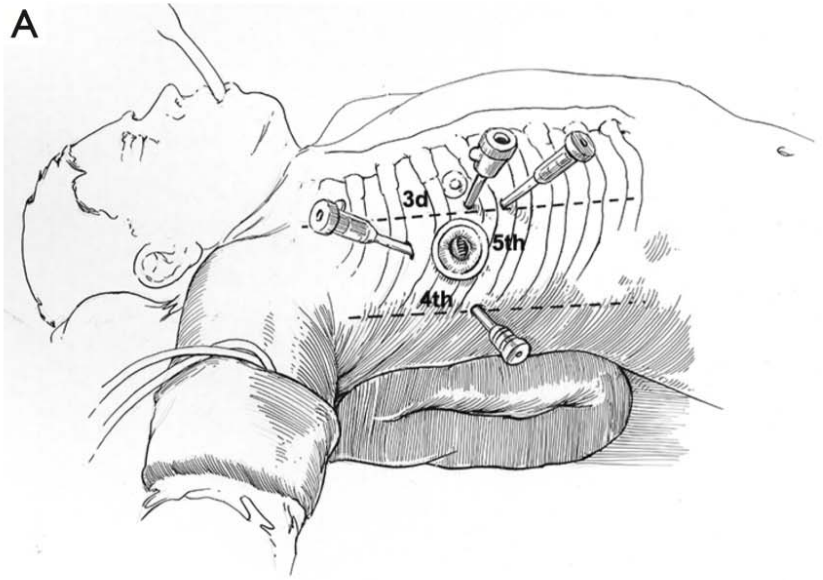
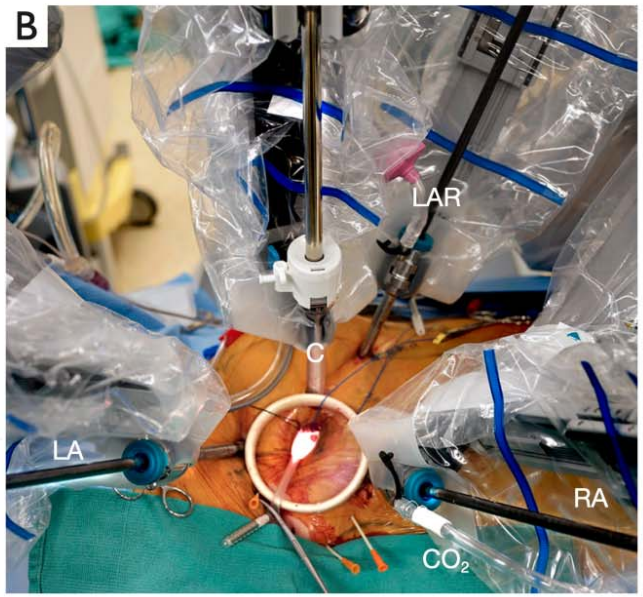
Robotic mitral valve repair





Chitwood WR Jr. Ann Cardiothorac Surg 2016

MICS MV surgery

- Indications
  - Isolated or combined mitral valve procedure

- Contraindications
  - Severe annular calcification
  - Concomitant CABG
  - Reduced ejection fraction
  - Combined aortic surgery
  - Obesity
  - Chest wall deformities
  - Intolerable for single lung ventilation
  - Previous right chest surgery
  - High pulmonary artery pressure

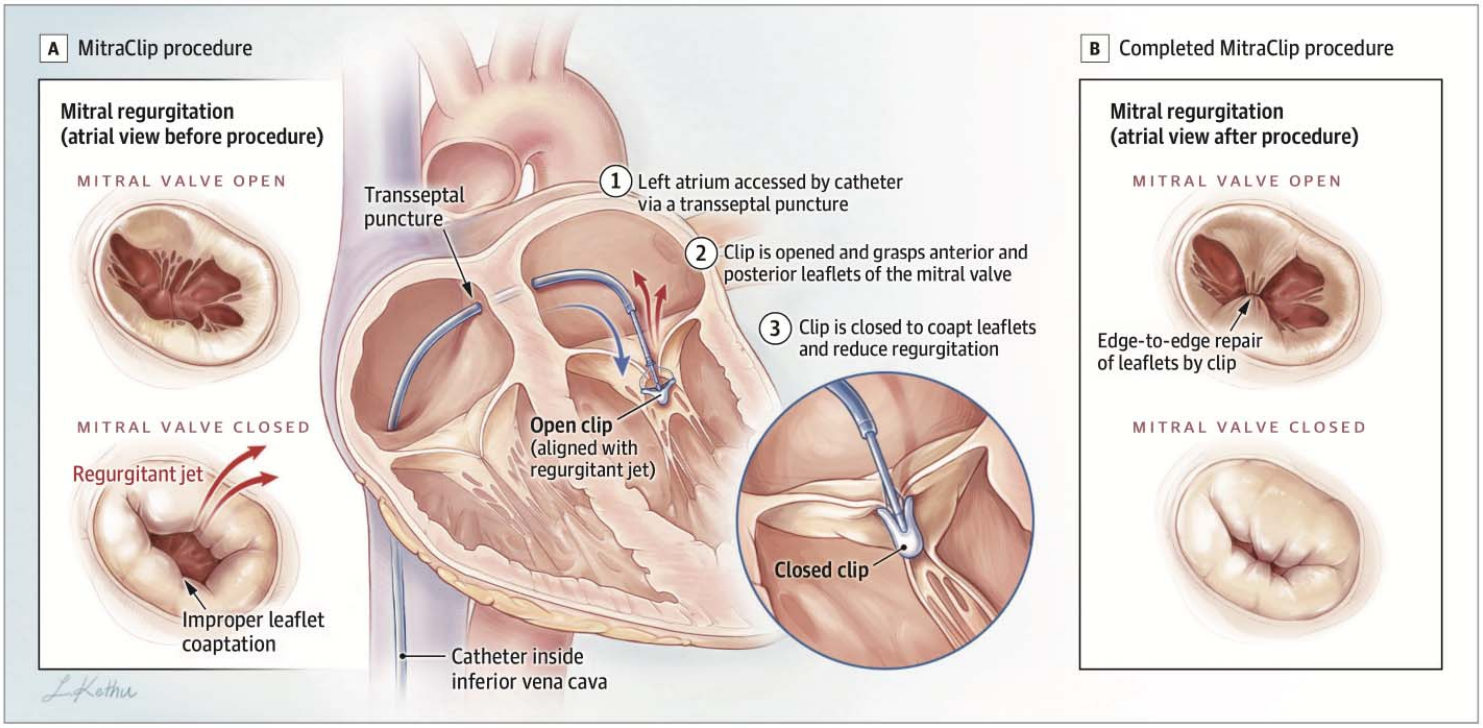
Müller et al. J Vis Surg. 2018

Transcatheter MV intervention

Transcatheter edge-to-edge repair (TEER)

MitraClip

- First implantation: 2003
- FDA approve
  - Primary MR: 2013
  - Secondary MR: 2019
- More than 100,000 pts



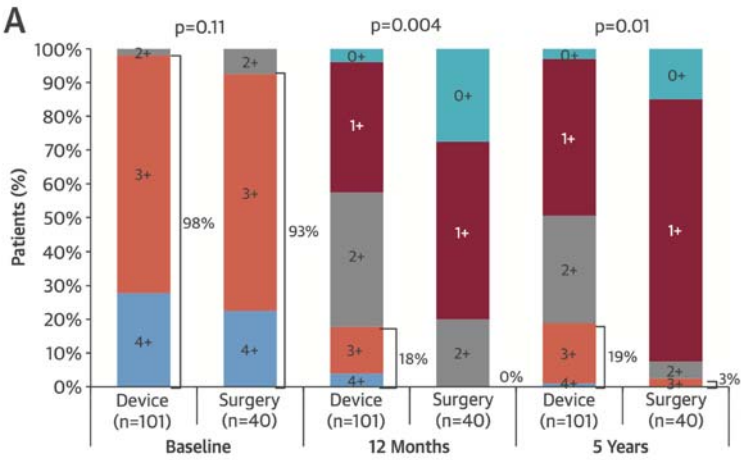
Davidson LJ and Davidson CJ JAMA 2021

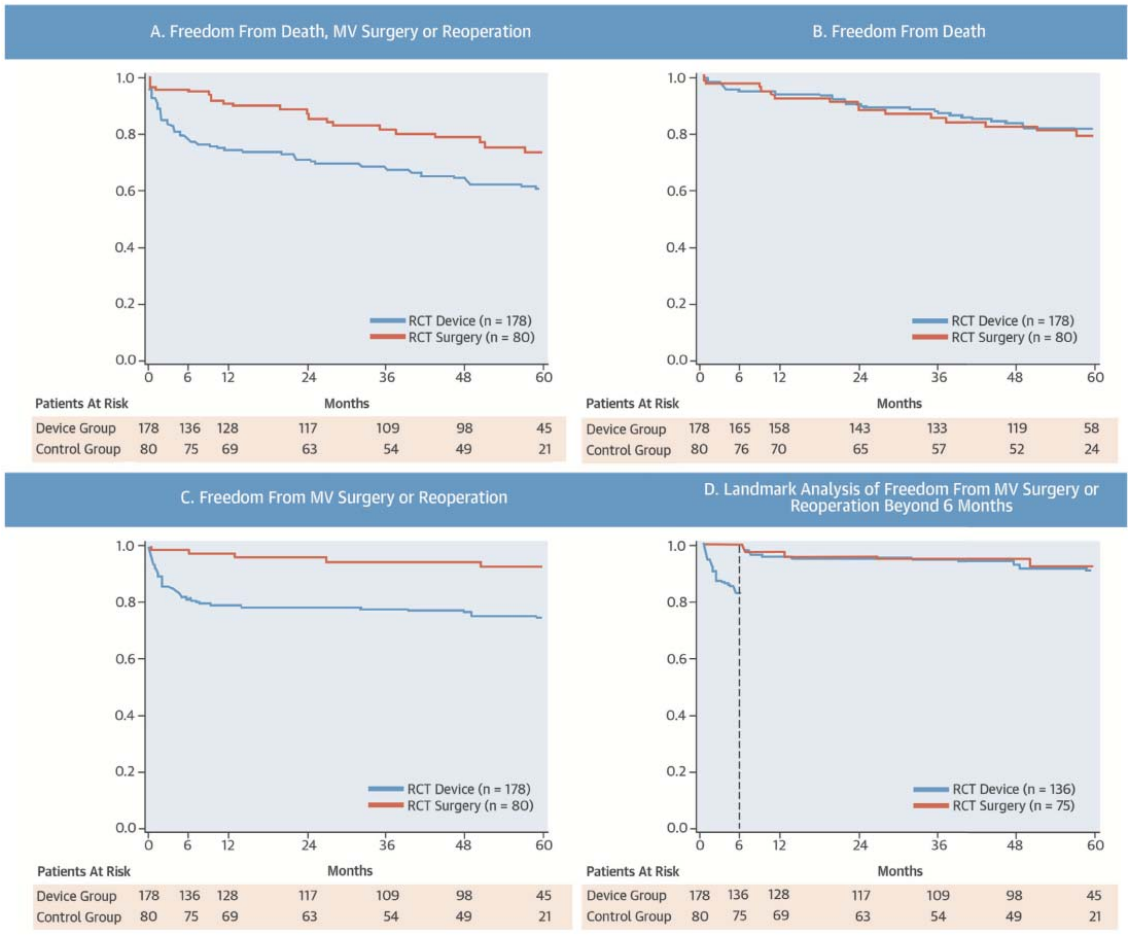
Transcatheter edge-to-edge repair (TEER)

EVEREST II 5-Year Results

- Multicenter RCT
- 37 centers
- Primary MR
- 184 MitralClip vs. 95 surgery

Severity of MR





Feldman et al. JACC 2015

Transcatheter edge-to-edge repair (TEER)

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2020 ACC/AHA guidelines

Primary MR

COR	LOE	RECOMMENDATIONS
2a	B-NR	6. In severely [redacted] and [redacted] transcatheter edge-to-edge repair (TEER) is reasonable if mitral valve anatomy is favorable for the repair procedure and patient life expectancy is at least 1 year (17,18).

Secondary MR

COR	LOE	RECOMMENDATIONS
2a	B-R	1. In patients with [redacted] who have persistent symptoms (NYHA class II, III, or IV) while on optimal GDMT for HF (Stage D), TEER is reasonable in patients with appropriate anatomy as defined on TEE and with LVEF [redacted] (1-8).

Catherine M. Otto, Rick A. Nishimura et al. JACC. 2021

Transcatheter mitral valve repair

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Edge-to-Edge

MitraClip
Abbott

Pascal
Edwards

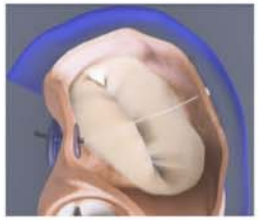
Chordal Repair

NeoChord
NeoChord

Harpoon
Edwards

Indirect Annuloplasty

Carillon
Cardiac Dimension



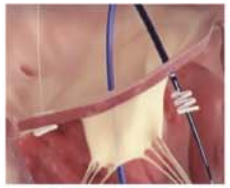
ARTO
MVRx

Mitral Loop Cerclage
Tau-PNU Medical Company

Direct Annuloplasty

Cardioband
Edwards

Millipede
Boston



Mitralign
Mitralign

AccuCinch
ANCORA Heart

Scotti et al. Vessel Plus 2021

Transcatheter mitral valve replacement

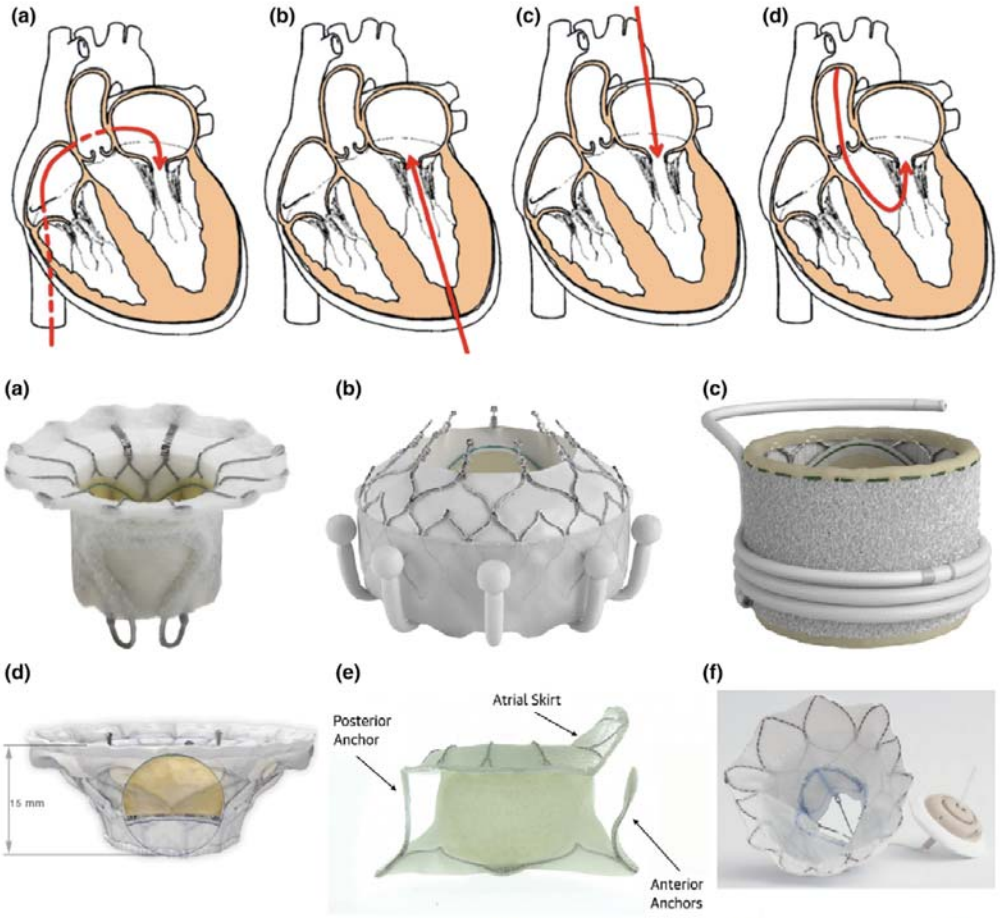
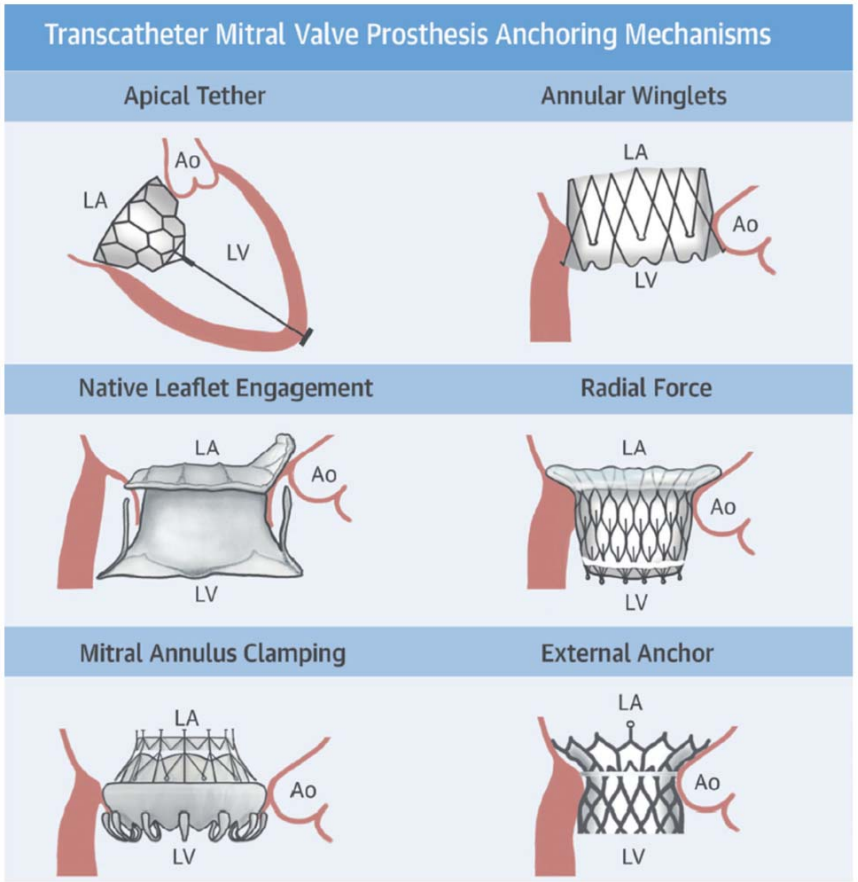


FIGURE 4. TMVR systems in clinical evaluation (a) FORTIS.[123] (b) EVOQUE TMVR System.[68] (c) Sapien M3 System.[153] (d) Cardiovalve TMVR System.[89] (e) Tiara TMVR System.[29] (f) Tendyne Mitral Valve System.[122]



Goode et al. Cardiovasc Eng Technol 2020


THANK YOU :)