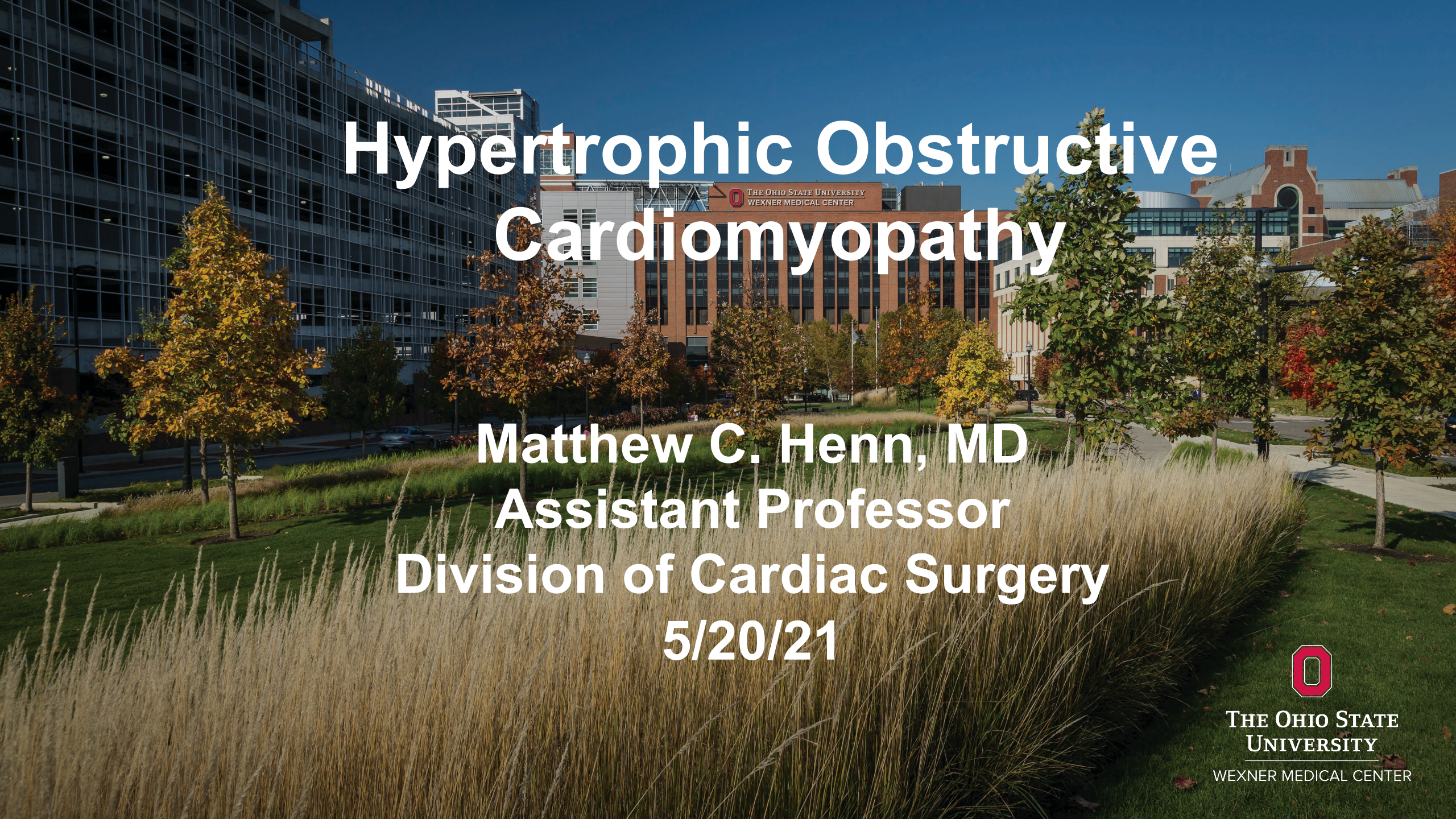

Hypertrophic Obstructive Cardiomyopathy

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Division of Cardiac Surgery

5/20/21

The Ohio State University
Wexner Medical Center

Outline

- History
- Disease morphology
- Clinical Presentation and Diagnosis
- Guidelines
- Surgical Myectomy and Results

Introduction - Definitions

- Left Ventricular Hypertrophy:
  - LV wall thickening
  - Most often associated with secondary systemic process
- Hypertrophic Cardiomyopathy (HCM):
  - Left Ventricular Hypertrophy in the absence of an underlying cause
  - Confined to the heart
- Hypertrophic Obstructive Cardiomyopathy (HOCM):
  - Septal hypertrophy and abnormal systolic anterior motion of the mitral valve combine to produce LVOT obstruction
  - Variable degrees of mitral regurgitation
  - Occurs in more than 70% of patients with HCM
  - Can also have mid-ventricular obstruction

History

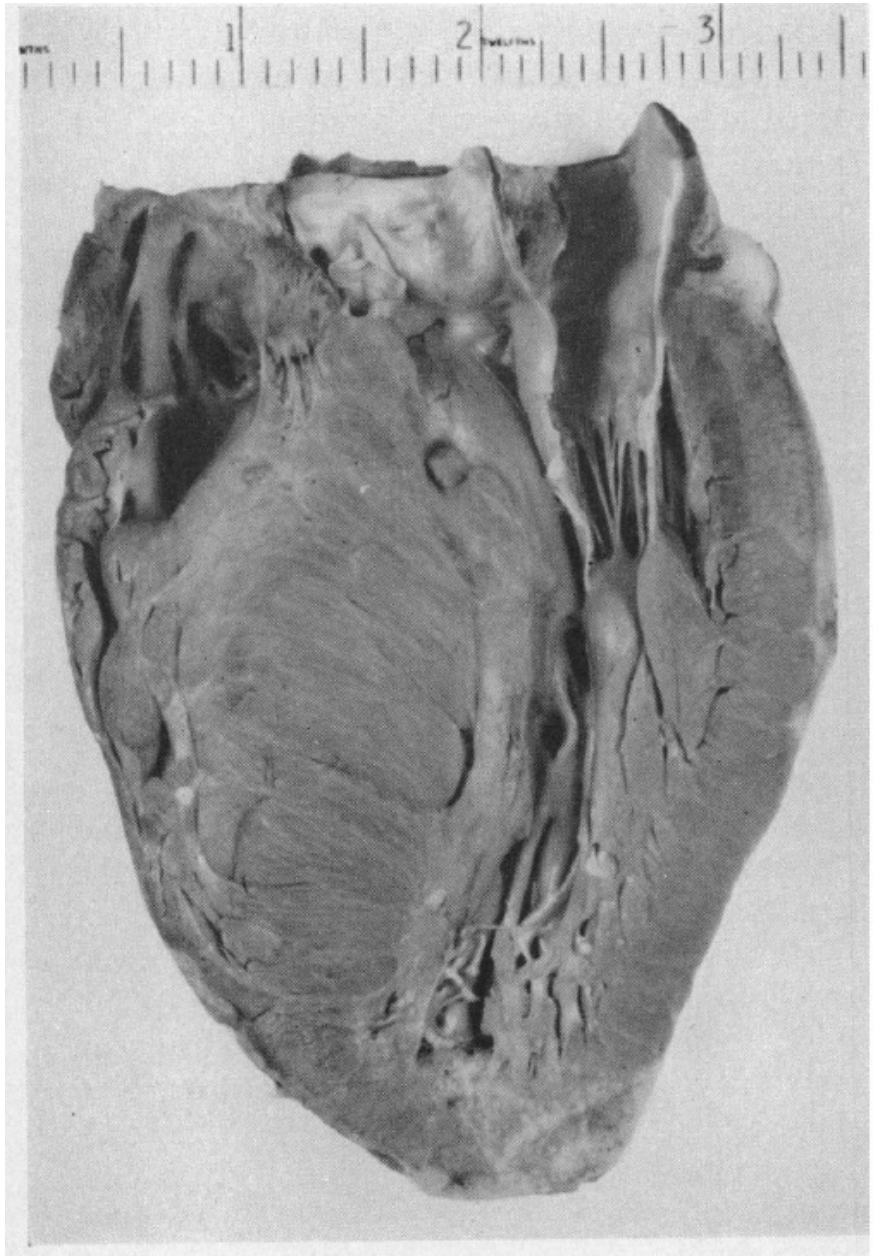
ASYMMETRICAL HYPERTROPHY OF THE HEART IN YOUNG ADULTS

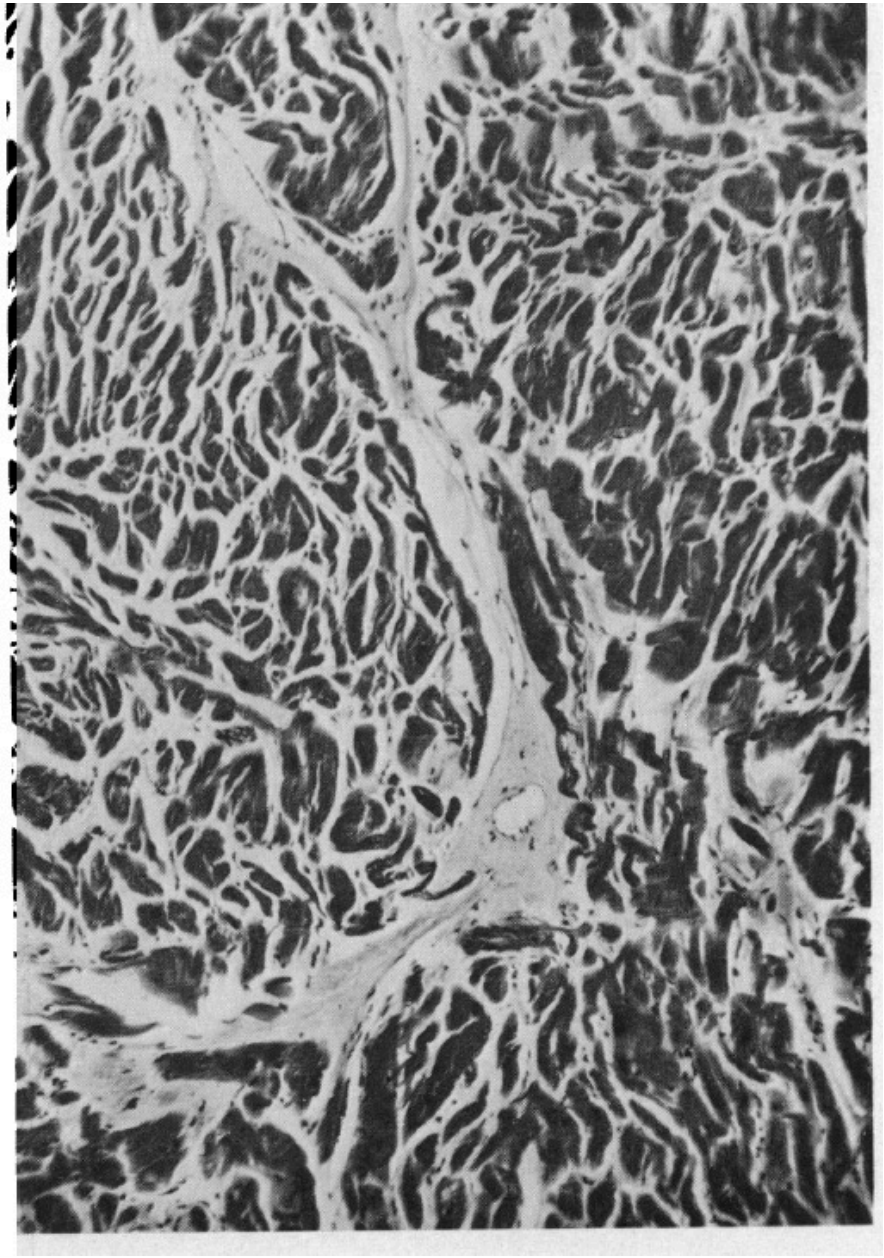
BY

DONALD TEARE

From the Department of Pathology, St. George's Hospital

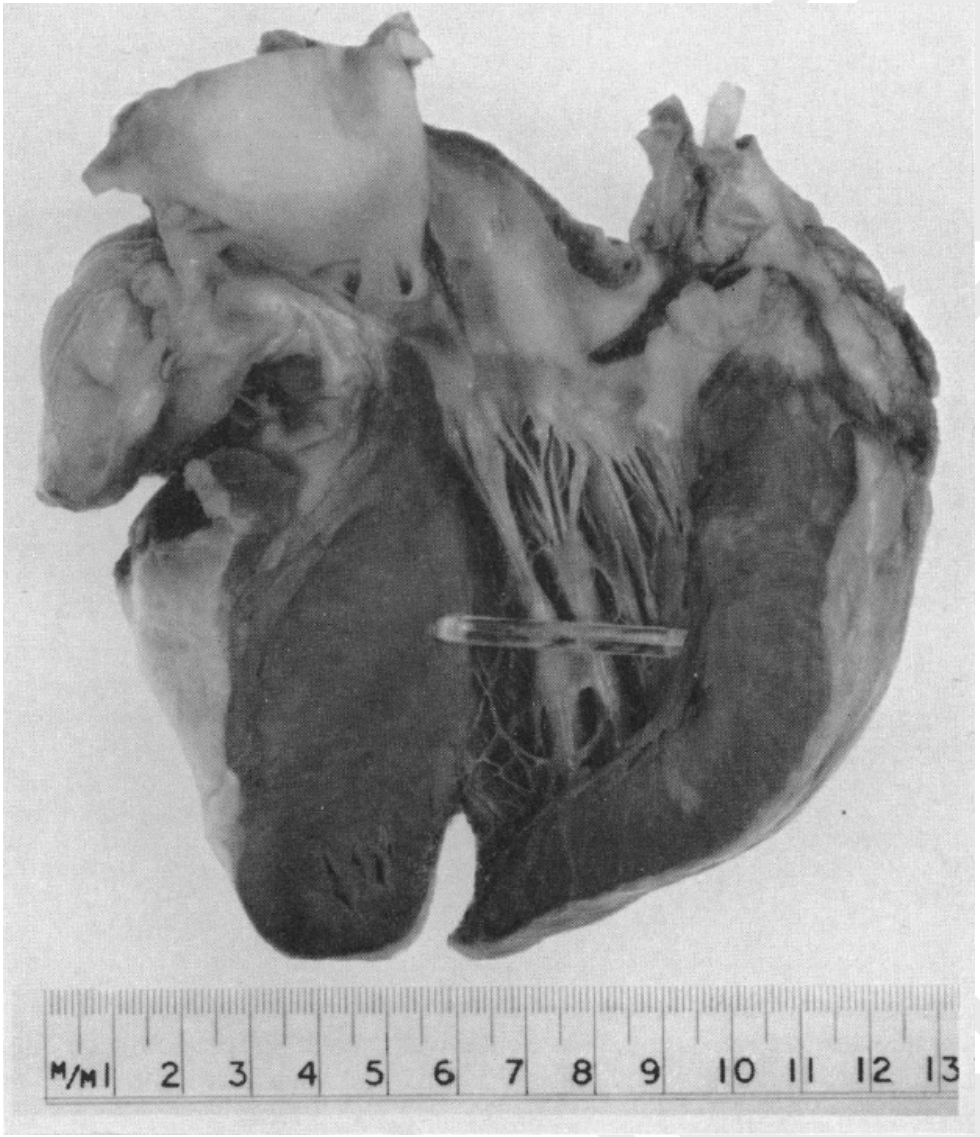
Received January 7, 1957





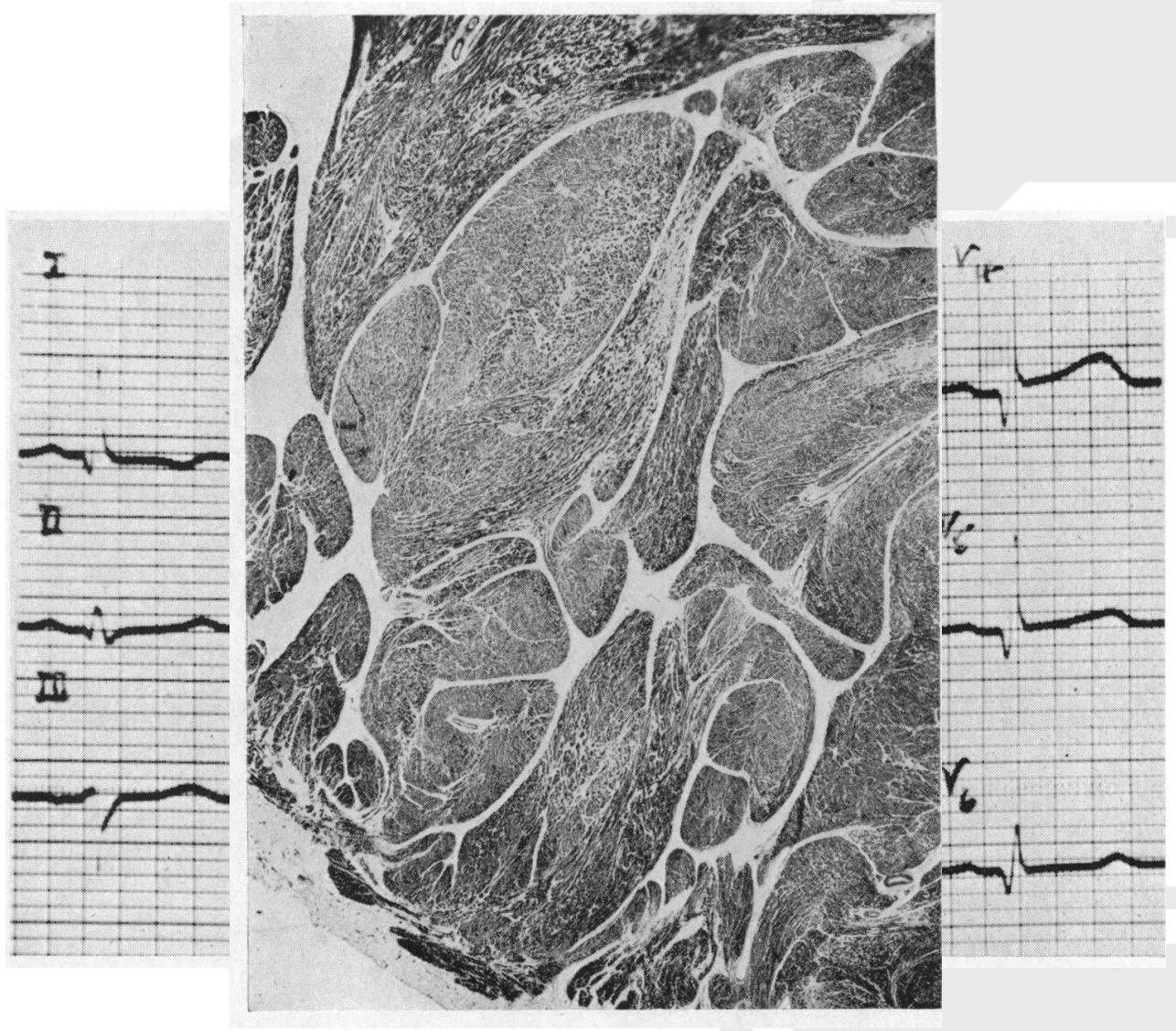
History – Case 2

- In 1953, a 25 year old male presented to general practitioner complaining of palpitations
- Was sent home, then re-presented in 1954 with atrial fibrillation with rapid ventricular response and was treated with digoxin
- 1 month later he collapsed and died before reaching medical care



History – Case 3

- 25 year old applied for employment in the RAF and was found to have a soft high-pitched systolic ejection murmur
- EKG was found to have T wave inversions and deep Q waves
- Was not approved for duty and was found dead 2 years later
- Pathology was identical to the other cases



History

Summary

Eight cases of asymmetrical hypertrophy or muscular hamartoma of the heart are discussed. Seven of these caused sudden death in young adults. The pathological picture is one of bizarre and disorganized arrangement of muscle bundles associated with hypertrophy of individual muscle fibres and their nuclei.

Addendum

On December 13, 1956, K. C., aged 16, a brother of Case No. 5, collapsed and died while riding his bicycle. No previous medical history was available. Post mortem he was found to be a well nourished and well developed young boy whose heart was virtually identical in appearance with that of his sister, showing a localized hypertrophy affecting the anterior wall and interventricular septum. By coincidence on the day of his death his younger sister attended the outpatient department of Hammersmith hospital and was found to have signs identical with her sister. This family will be the subject of another paper.

A FAMILY WITH OBSTRUCTIVE CARDIOMYOPATHY (ASYMMETRICAL HYPERTROPHY)

BY

A. HOLLMAN, J. F. GOODWIN, D. TEARE, AND J. W. RENWICK

From the Departments of Medicine, Postgraduate Medical School, and of Forensic Medicine, St. George's Hospital, and the Galton Laboratory, University College

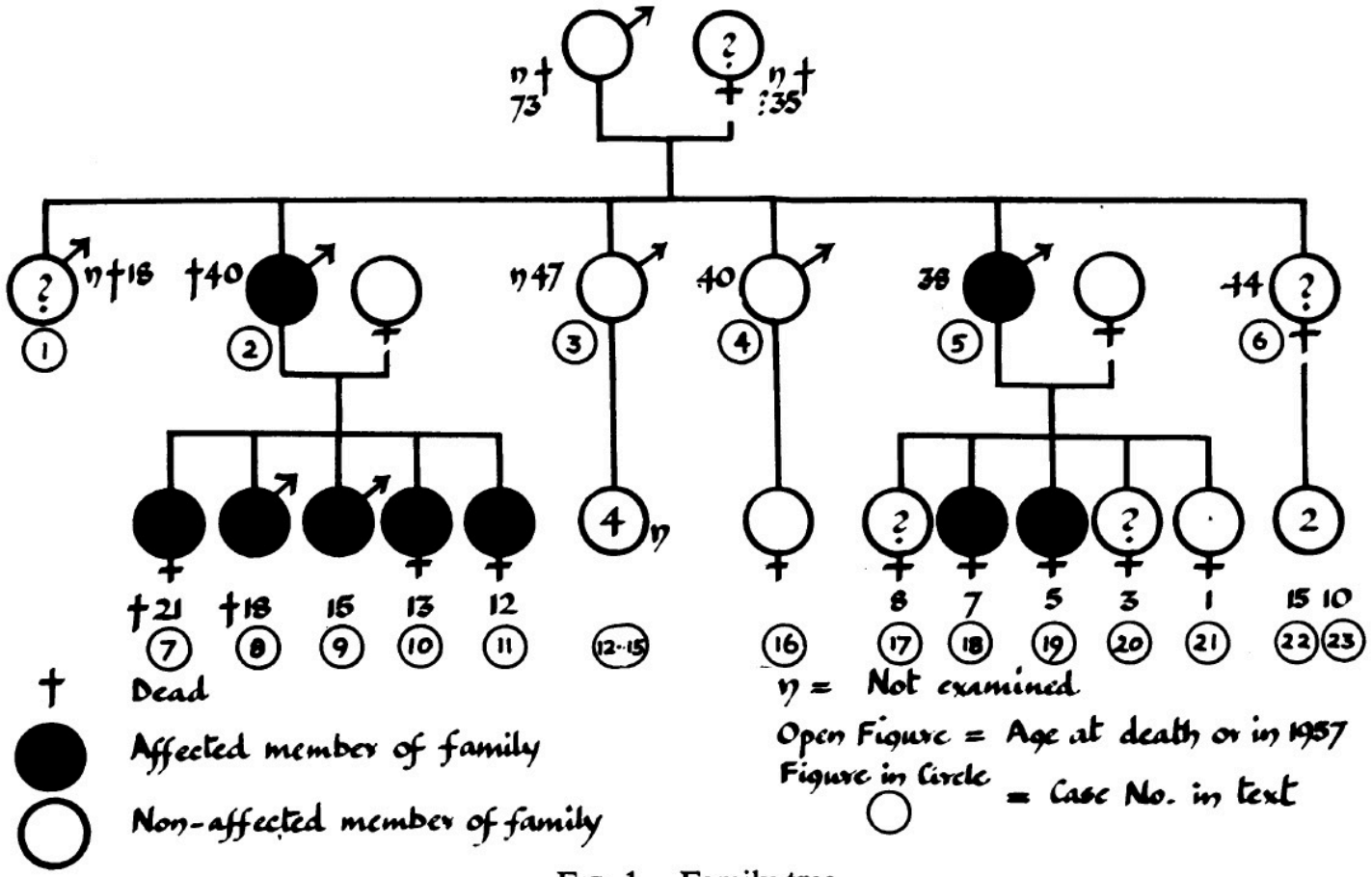


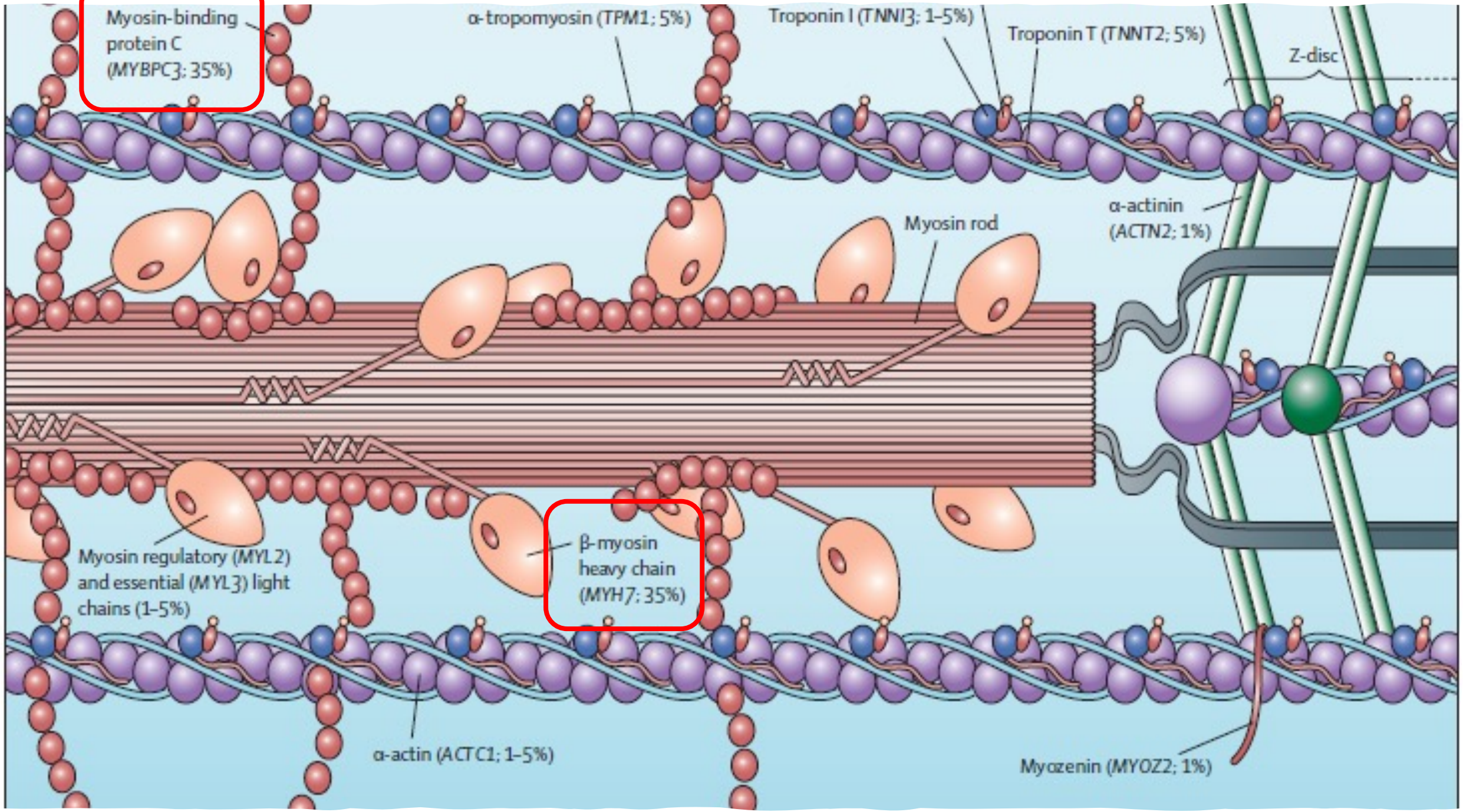
FIG. 1.—Family tree.

Genetics

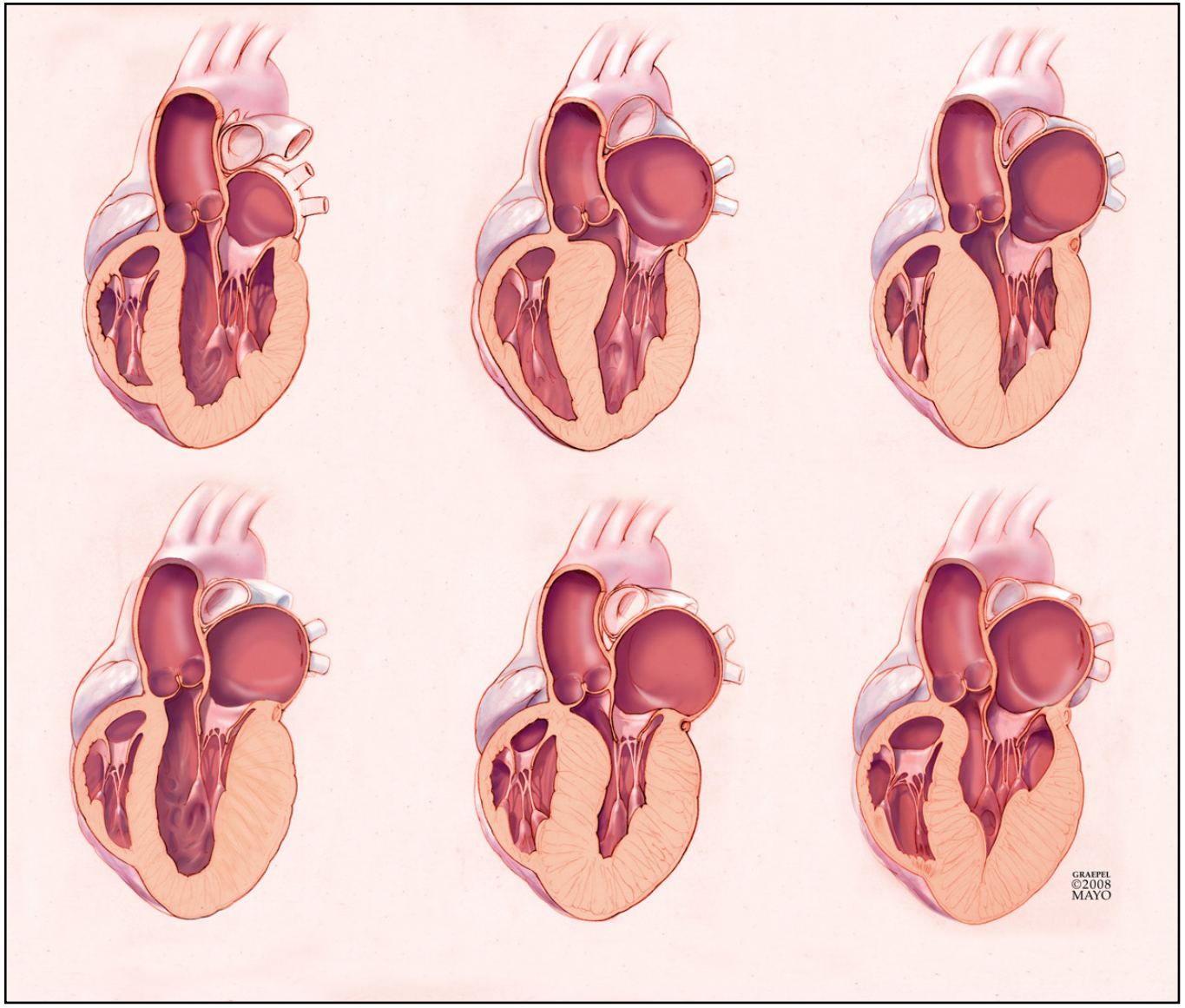
- Prevalence of between 1 in 200 (0.5%) to 1 in 500 (0.2%) in the general population
  - 60-80% of cases are familial
  - Transmitted in an autosomal dominant pattern

- Phenotypic heterogeneity is evident within families
  - Disease may be present within a family with varying clinical expression

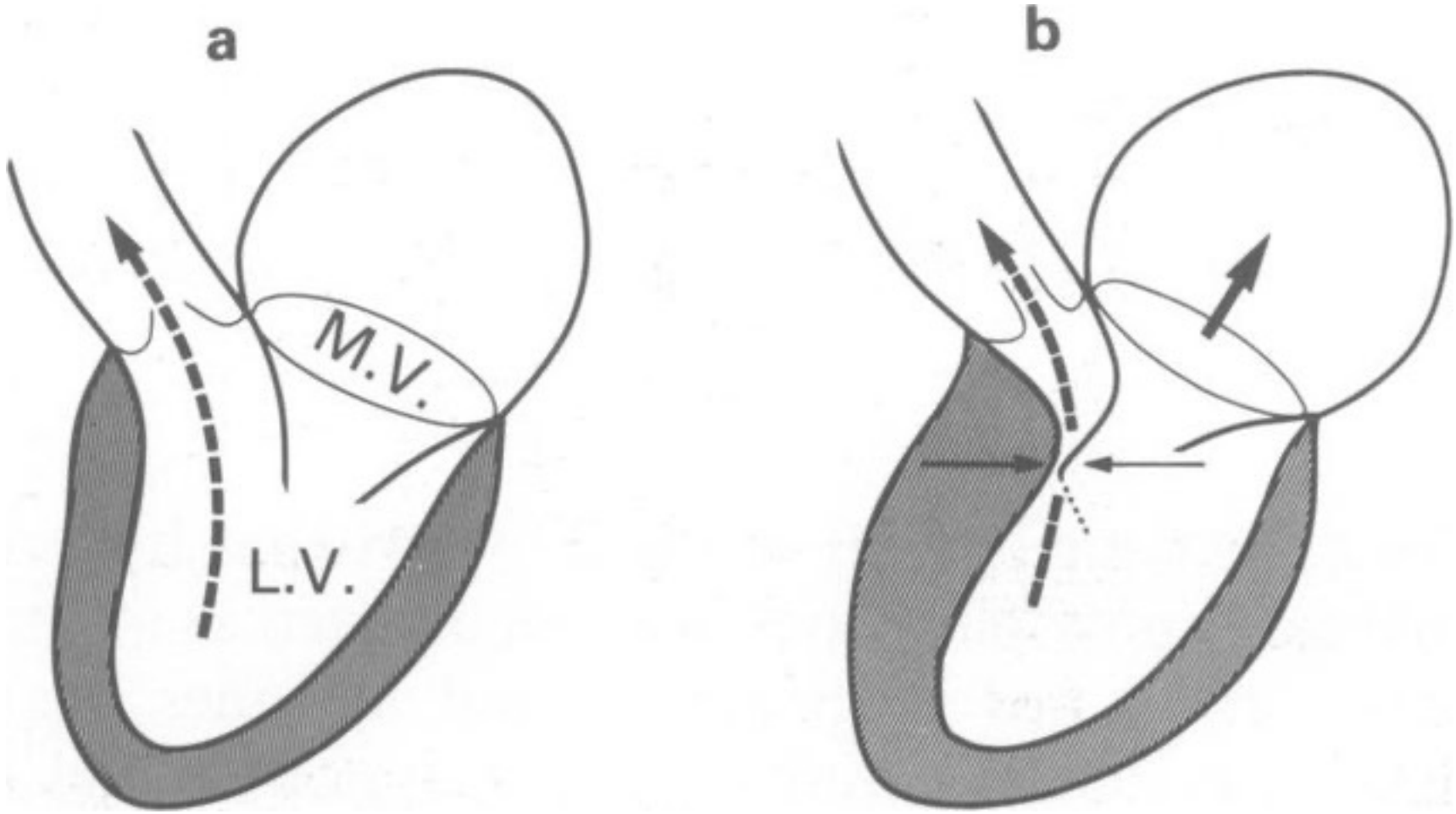
- Variants in 1 of 8 or more genes encoding proteins of cardiac sarcomere
  - Do not account entirely for all morphological features
  - Indicates a possible role for modifier genes and environmental factors


Myosin-binding protein C (MYBPC3; 35%)
α-tropomyosin (TPM1; 5%)
Troponin I (TNNI3; 1–5%)
Troponin T (TNNT2; 5%)
Z-disc
α-actinin (ACTN2; 1%)
Myosin rod
Myosin regulatory (MYL2) and essential (MYL3) light chains (1–5%)
β-myosin heavy chain (MYH7; 35%)
α-actin (ACTC1; 1–5%)
Myozenin (MYOZ2; 1%)

Morphology – Distribution of Hypertrophy



Morphology – Systolic Anterior Motion (SAM) of the Mitral Valve



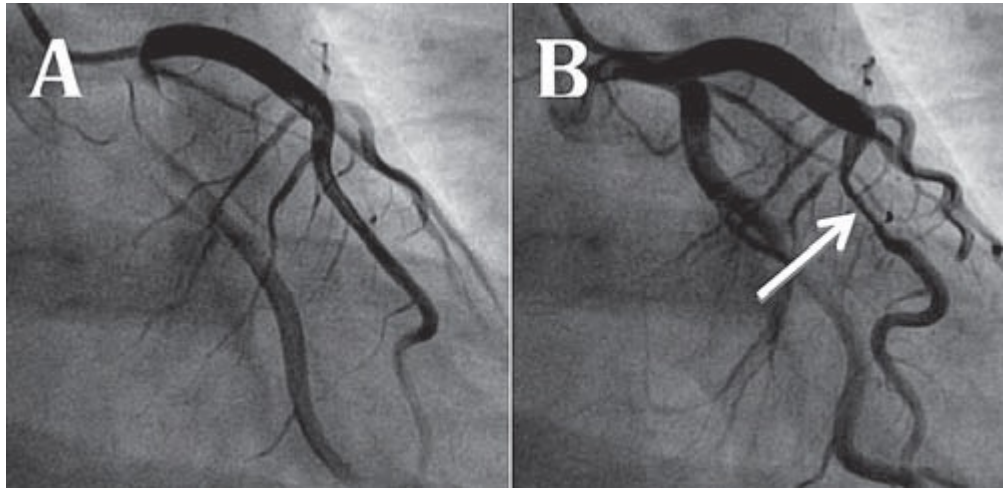
Wigle et al., 1985, Progress in Cardiovascular Diseases, 28, 1.

Morphology – Right Ventricle

- Right ventricular thickening documented in approximately 1/3 of HCM patients
  - 1/3 of those with >10mm
- Rarely leads to fibrosis or RVOT obstruction
  - Limited to children and young adults with severe phenotype
- RV hypertrophy can result from pulmonary hypertension from elevated end-diastolic pressure
- Pulmonary HTN is present in 50% of patients referred for myectomy

Morphology – Coronary Arteries

- Larger than normal in HCM patients
- Increased basal coronary, decreased coronary flow reserve
- Atherosclerosis present in 5-15% of patients with HCM
- Myocardial bridging of the left anterior descending coronary artery in 15% of patients



Clinical Presentation

- Symptoms of heart failure despite preserved LV function even in younger patients
  - Exertional dyspnea
  - Fatigue
  - Orthopnea
- Chest pain -typical or atypical angina
- Syncope (or near-syncope) and lightheadedness
  - Arrhythmias and outflow obstruction
- Symptoms and LV obstruction
  - Onset of symptoms is usually associated with development of LVOT obstruction (but not always)
  - Development of atrial fibrillation (25-30% of patients) can precipitate symptoms

Sudden Cardiac Death

- Can present at any age with no gender predilection
- Mortality rate of 1% per year
  - Most common cause of sudden death in young adults
  - Associated with vigorous physical activity
  - Most commonly ventricular tachycardia or fibrillation
  - Outflow gradient >30mmHg is independent predictor of death
- Drives athletic and family screening as well as prevention

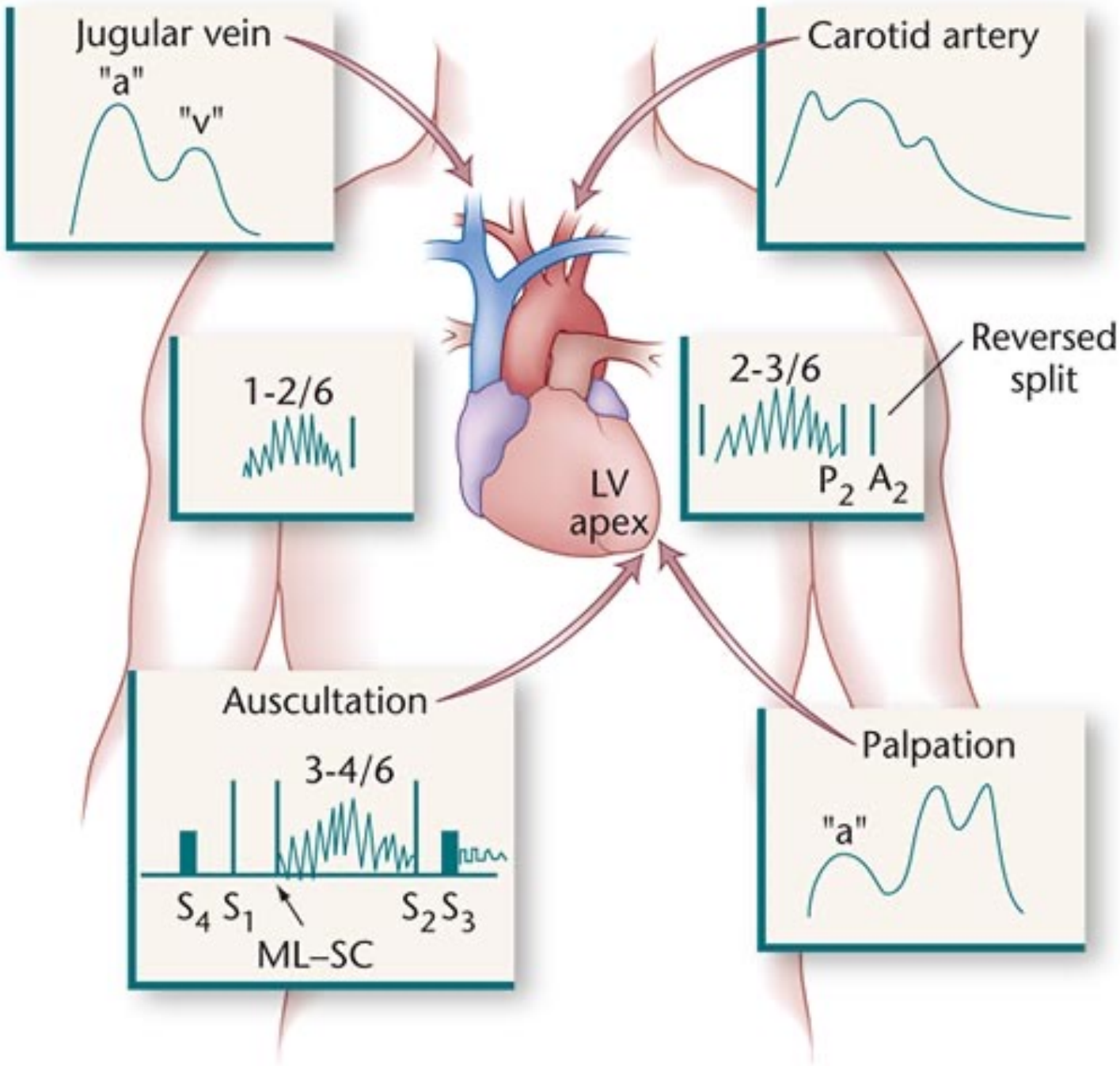
Physical Exam

With outflow obstruction

- Classic end systolic murmur at the lower left sternal border
  - Loud murmurs > 3/6 - LV outflow gradients >30 mm Hg
  - Diminishes with any increase in preload or any increase in afterload
  - Increases with any decrease in preload or with any decrease in afterload
- Double or triple apical impulses may be palpable
- Holosystolic murmur at apex

Without outflow obstruction

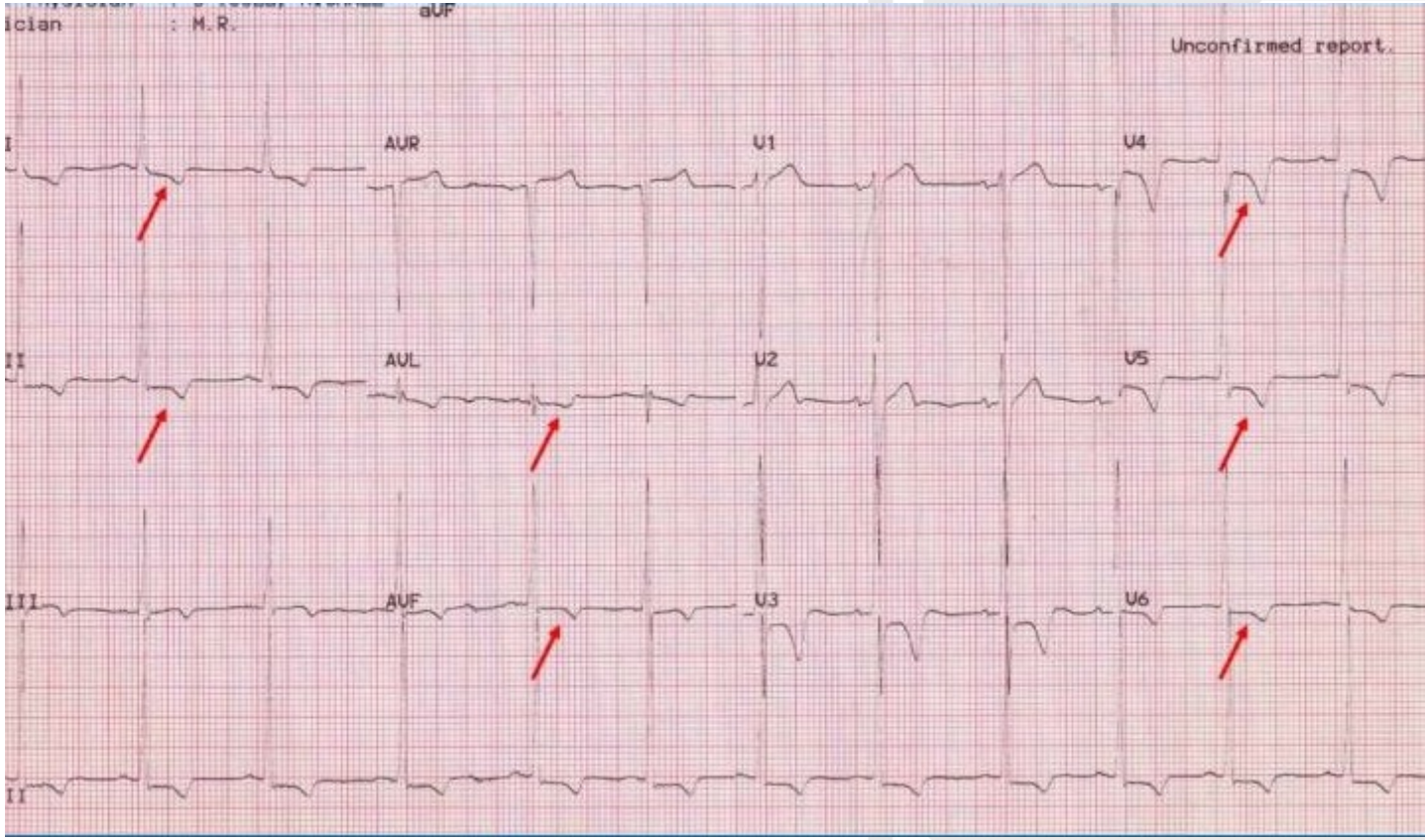
- Subtle - with no or soft systolic murmur
- Forceful apical impulse



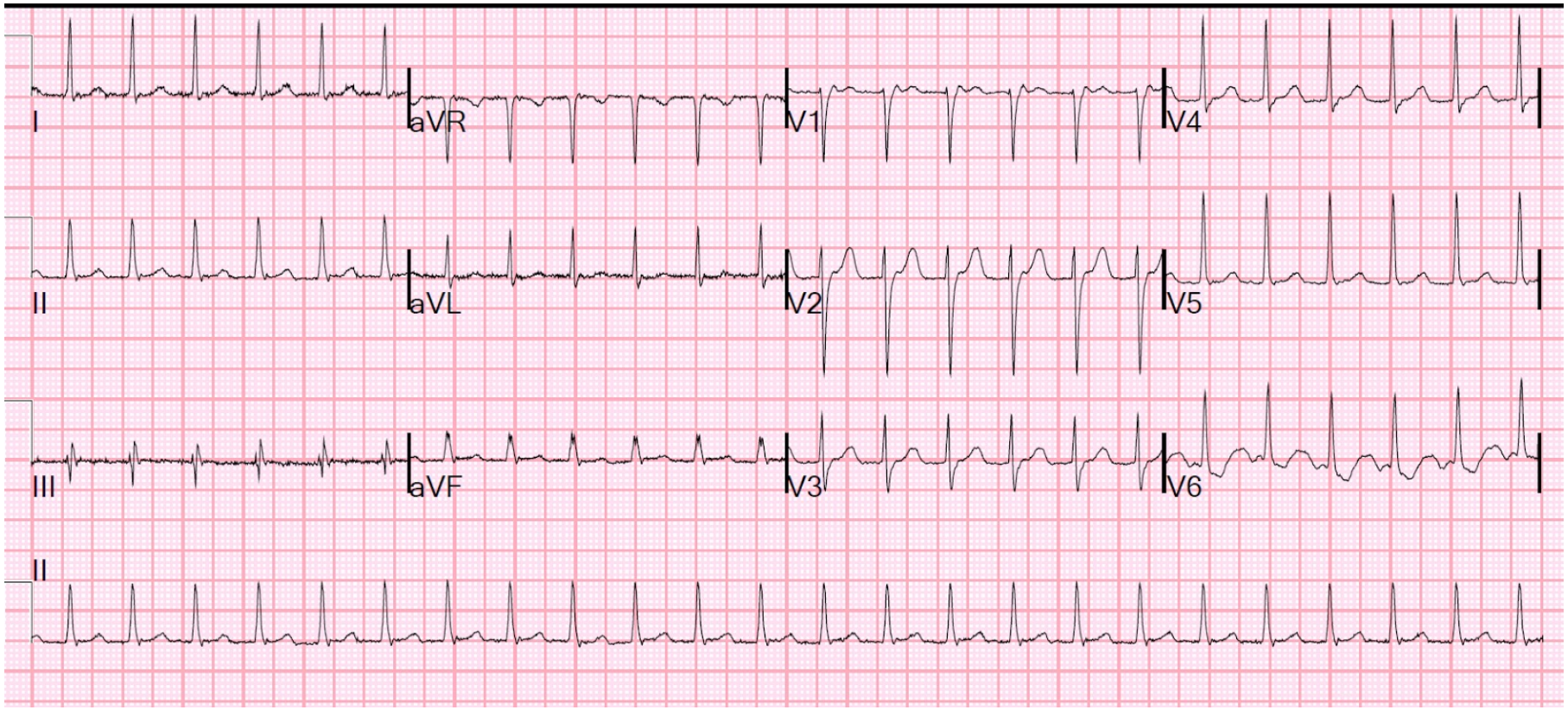
ECG Findings

- Abnormal in Majority of Patients
  - Increased voltages
  - ST-T changes
  - Left atrial enlargement
  - Deep and narrow Q waves
  - Diminished R waves

- Normal ECG - 5% of pts
  - Less severe phenotype and favorable course
  - Less likely of future sudden death



ECG Findings – Arrhythmias



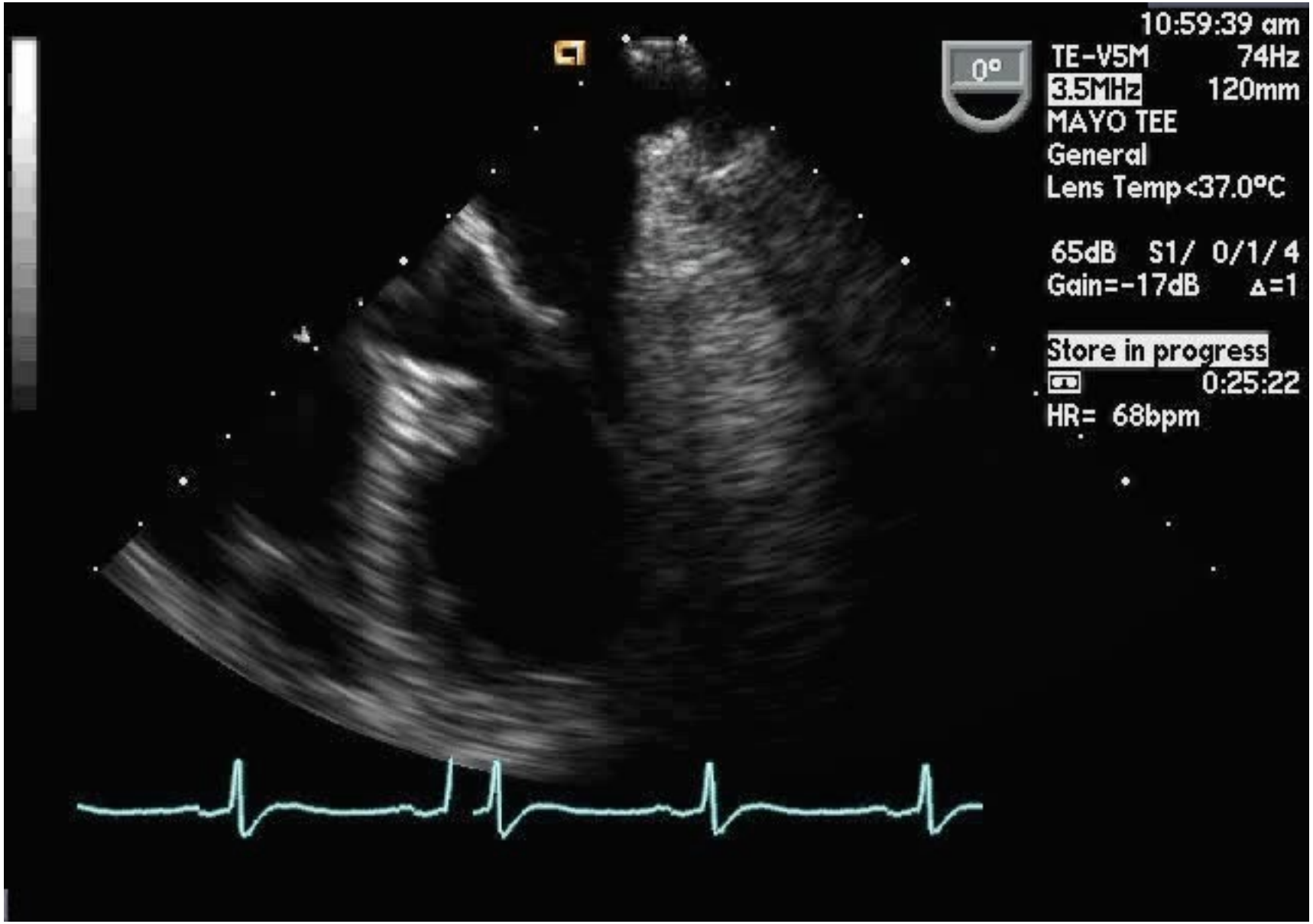
- Supraventricular tachycardia (46%)
- Premature ventricular contractions (43%)
- Nonsustained ventricular tachycardia (26%)
- Atrial fibrillation (25-30%)

Echocardiography

- Diffuse hypertrophy of the ventricular septum and anterolateral free wall (70% to 75%)
- Basal septal hypertrophy (10% to 15%)
- Concentric hypertrophy (5%)
- Apical hypertrophy (<5%)
- Hypertrophy of the lateral wall (1% to 2%).

- Average maximum LV wall thickness is 20-22mm

- Thickened atria should raise suspicion for not HCM



Echocardiography

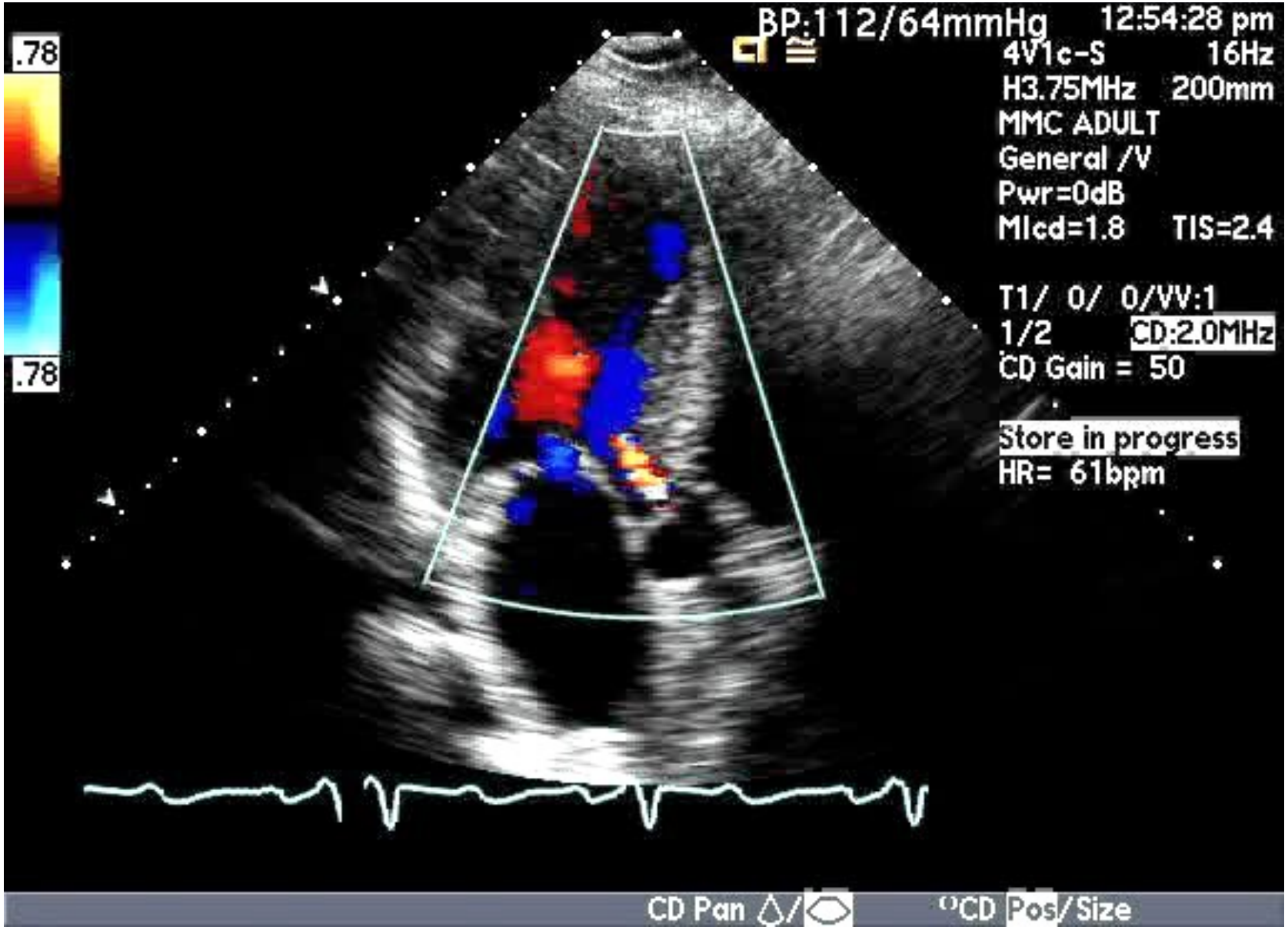
Other findings:

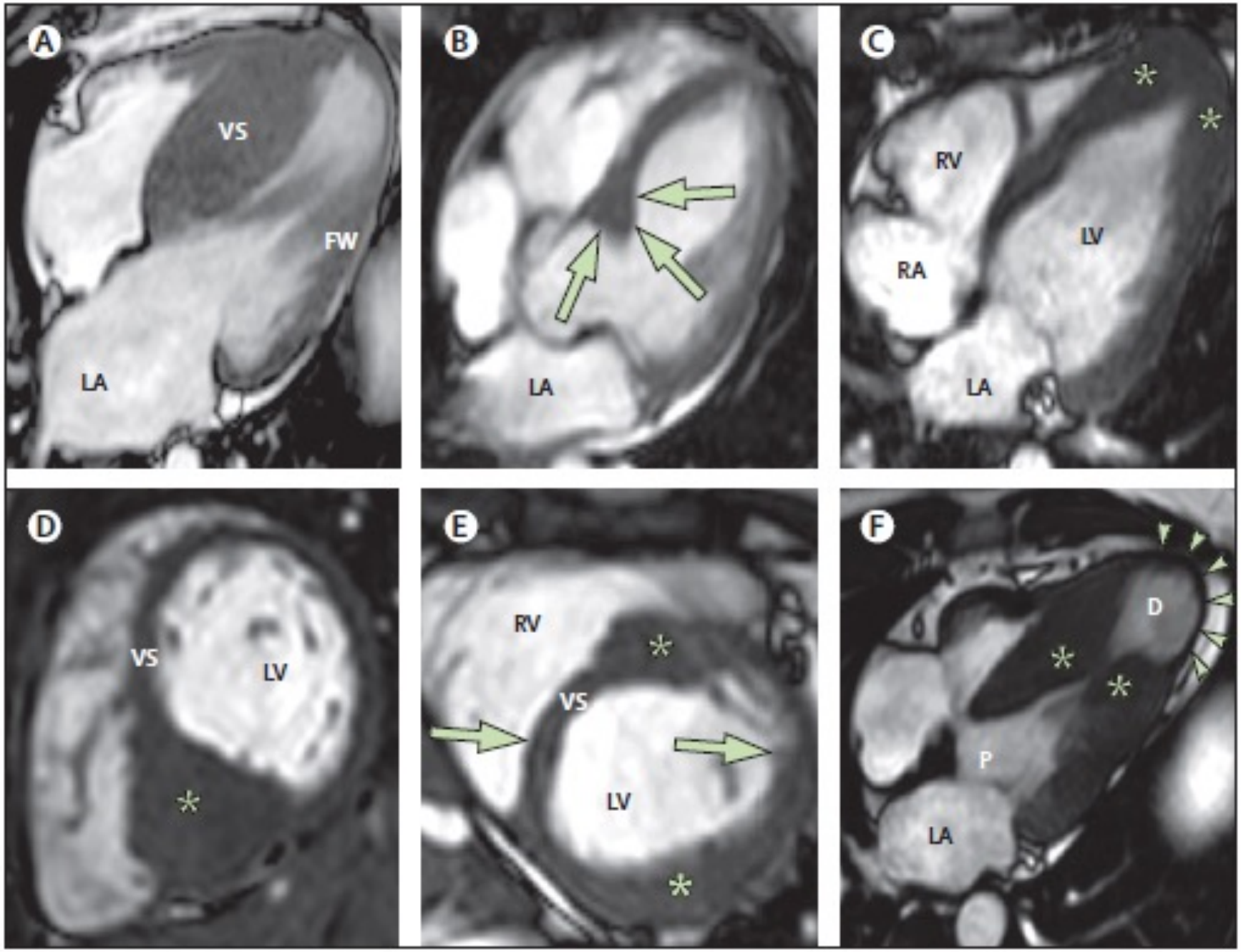
- A ground-glass appearance is noted either visually or by using quantitative texture analysis in both hypertrophied and non-hypertrophied regions of the ventricle

- Obstruction of the LVOT caused by hypertrophied IVS and the anterior leaflet of the MV

Mitral valve pathology:

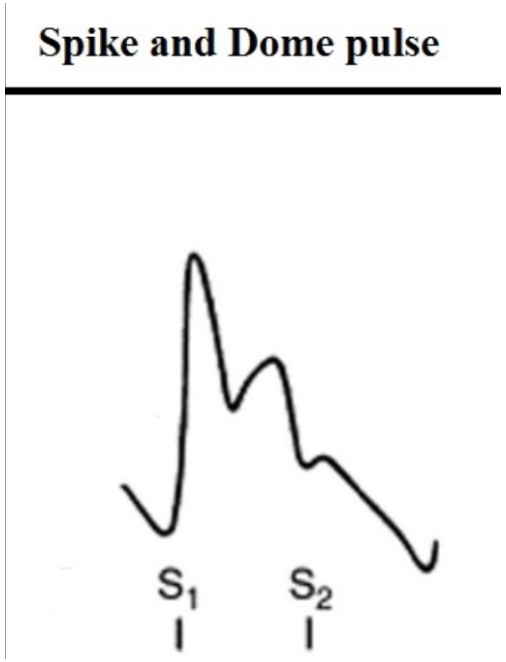
- May see systolic anterior motion (SAM) of the anterior leaflet of the MV
- Variable degrees of MR with an eccentric posteriorly directed jet.
- Increased leaflet area, elongation of the leaflet, and anomalous insertion of papillary muscle directly into the anterior mitral leaflet



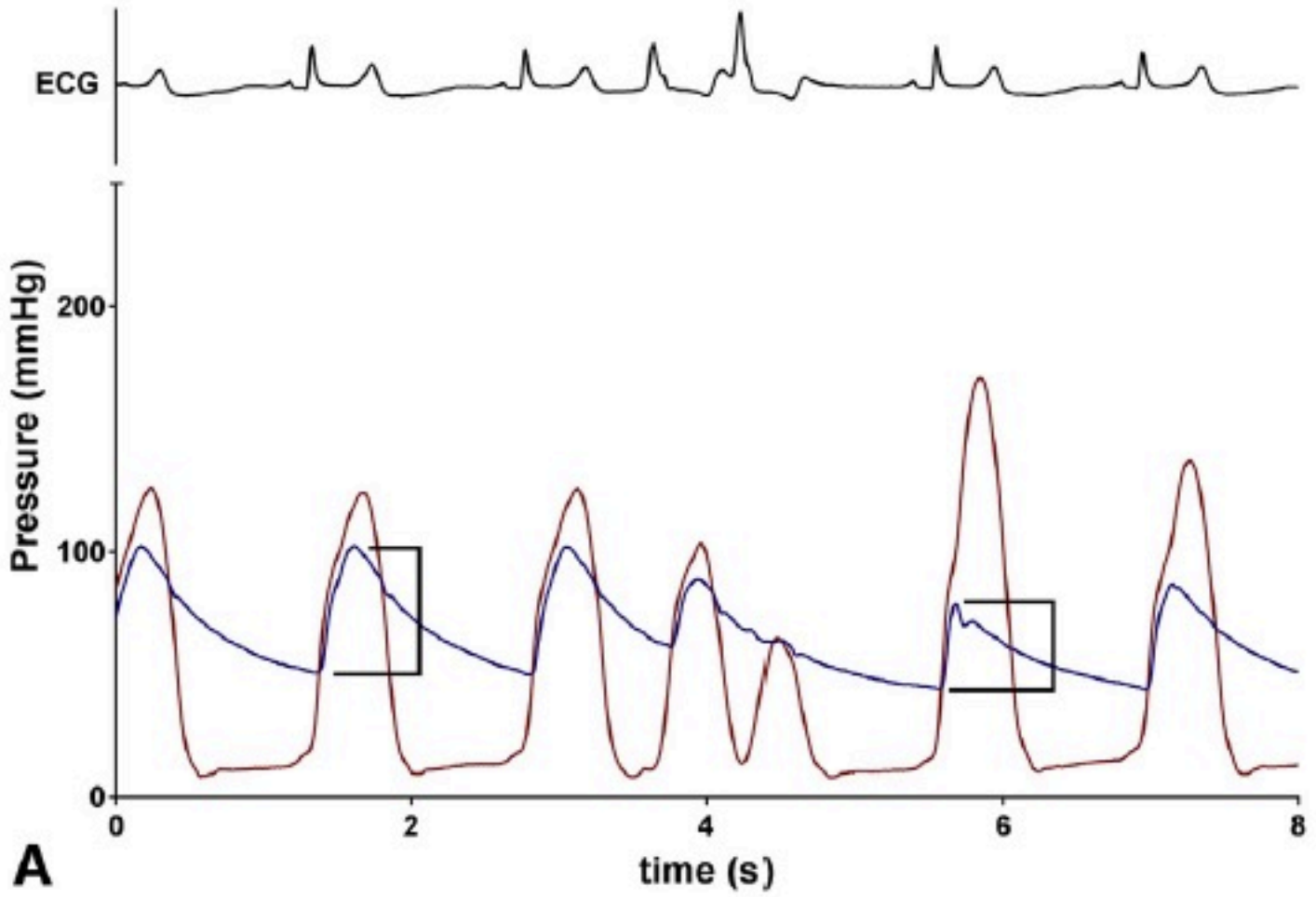


Heart Catheterization

- Dynamic intraventricular pressure gradient
- Spike-and-dome waveform – Proximal aorta
- Brockenbrough-Braunwald-Morrow sign



Brockenbrough-Braunwald-Morrow Sign



Cui H et al. *J Thorac Cardiovasc Surg.* 2018 Oct;156(4):1614-1615.

Differential Diagnosis

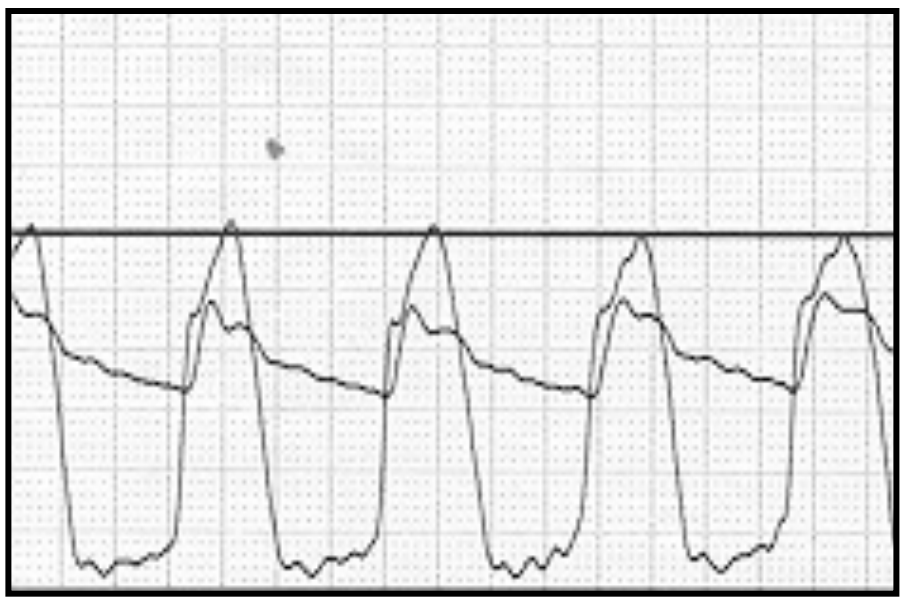
- Chronic hypertension
- Athlete's heart
- Cardiac amyloidosis
- Long-term hemodialysis
- Fabry disease
- Friedreich ataxia.

Apical hypertrophy - can also be caused by hypereosinophilic syndrome or noncompaction

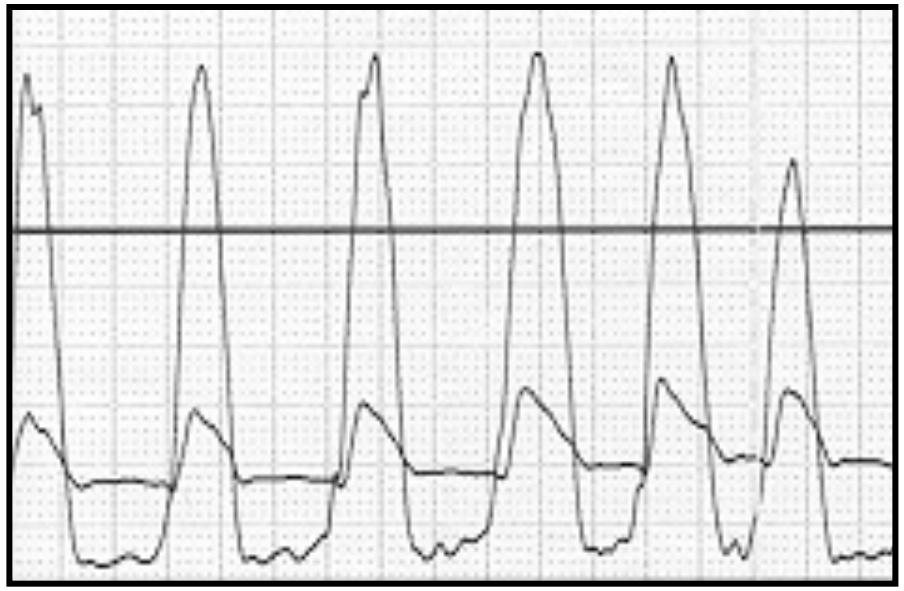
Diagnosis - HCM

- Often made in the setting of:
  - Early exercise fatigue, Sports eval, murmur, high voltage R waves or inverted T waves ECG
- LV hypertrophy in absence of secondary cause
- Maximal end-diastolic wall thickness of 15mm anywhere in the left ventricle
- 13-14mm can be diagnostic in patients with positive family history or genetic test
- Children: BSA-adjusted z-score of >2.5

Provokable LVOT Gradient



Rest



Isoproterenol

CLINICAL PRACTICE GUIDELINE

2020 AHA/ACC guideline for the diagnosis and treatment of patients with hypertrophic cardiomyopathy

A report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

Developed in collaboration with and endorsed by the American Association for Thoracic Surgery, American Society of Echocardiography, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, and Society for Cardiovascular Magnetic Resonance. Endorsed by The Pediatric & Congenital Electrophysiology Society

Guidelines

1	B-NR	1. In patients with suspected HCM, a TTE is recommended in the initial evaluation.[1-6]
1	B-NR children C-LD adults	2. In patients with HCM with no change in clinical status or events, repeat TTE is recommended every 1 to 2 years to assess the degree of myocardial hypertrophy, dynamic LVOTO, MR, and myocardial function[7-14] (Figure 1).
1	B-NR	3. For patients with HCM who experience a change in clinical status or a new clinical event, repeat TTE is recommended.[7,10,15-18]
1	B-NR	4. For patients with HCM and resting LVOT gradient <50 mm Hg, a TTE with provocative maneuvers is recommended.[19-22]
1	B-NR	5. For symptomatic patients with HCM who do not have a resting or provocable outflow tract gradient ≥50 mm Hg on TTE, exercise TTE is recommended for the detection and quantification of dynamic LVOTO.[21-26]

Family Screening

1	B-NR

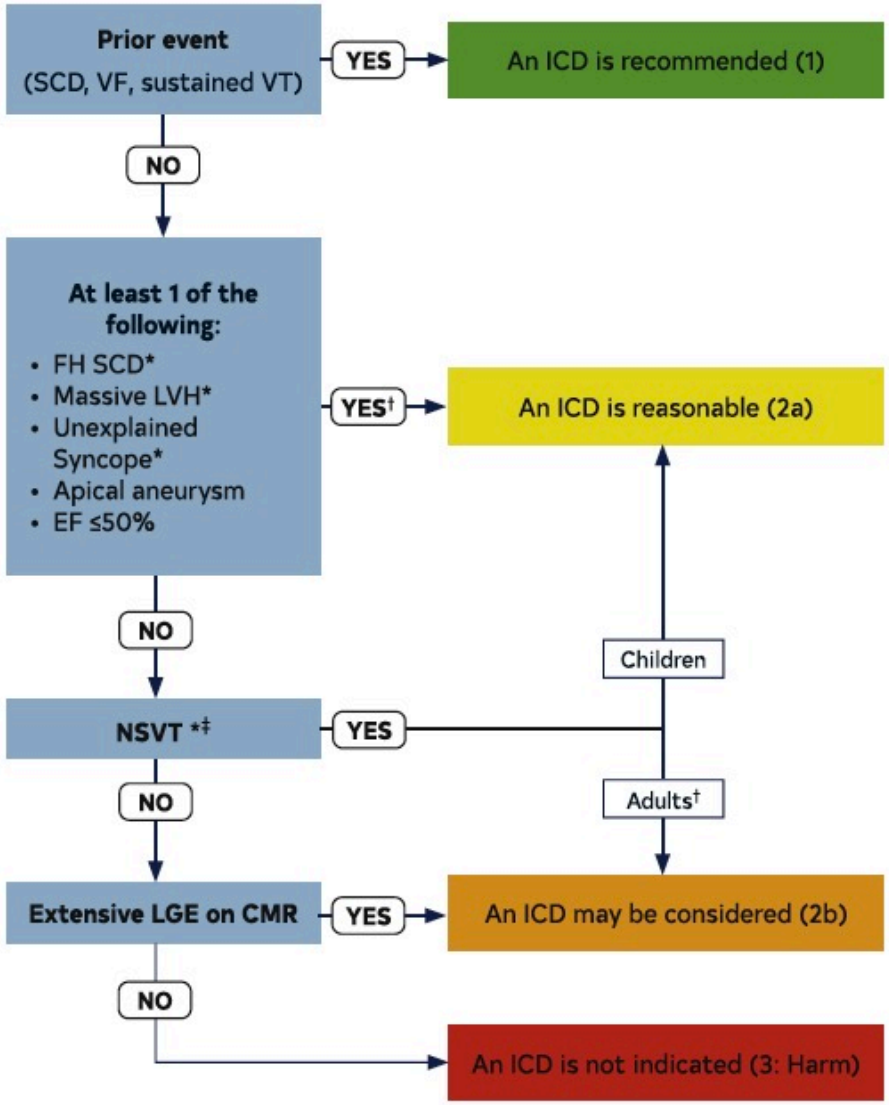
9. Screening: In first-degree relatives of patients with HCM, a TTE is recommended as part of initial family screening and periodic follow-up[3-5,7,8,33] (Figure 1, Table 6).

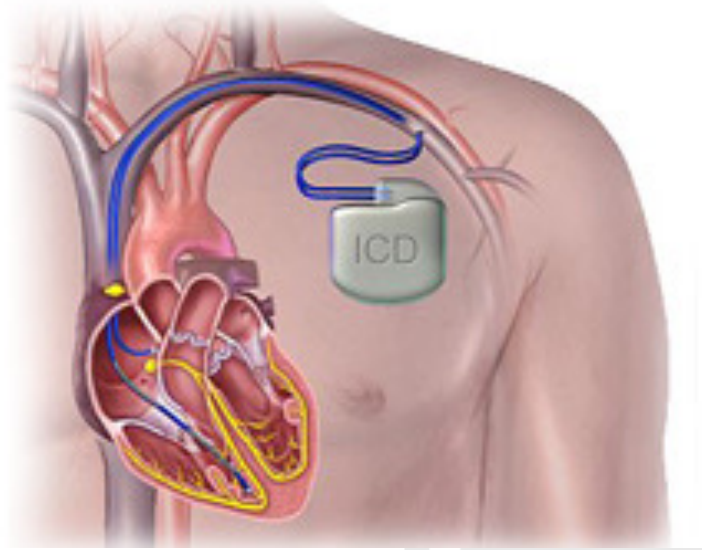
1	B-NR

10. Screening: In individuals who are genotype-positive or phenotype-negative, serial echocardiography is recommended at periodic intervals depending on age (1 to 2 years in children and adolescents, 3 to 5 years in adults) and change in clinical status[40-44] (Figure 1, Table 6).

Screening Asymptomatic First-Degree Relatives of Patients With HCM		
Age of First-Degree Relative	**Initiation of Screening**	**Surveillance Interval**
Children and adolescents from genotype-positive family and/or family with early onset HCM	At the time of diagnosis in another family member	Every 1-2 y
All other children and adolescents	At any time after the diagnosis in the family, but no later than puberty	Every 2-3 y
Adults	At the time of diagnosis in another family member	Every 3-5 y

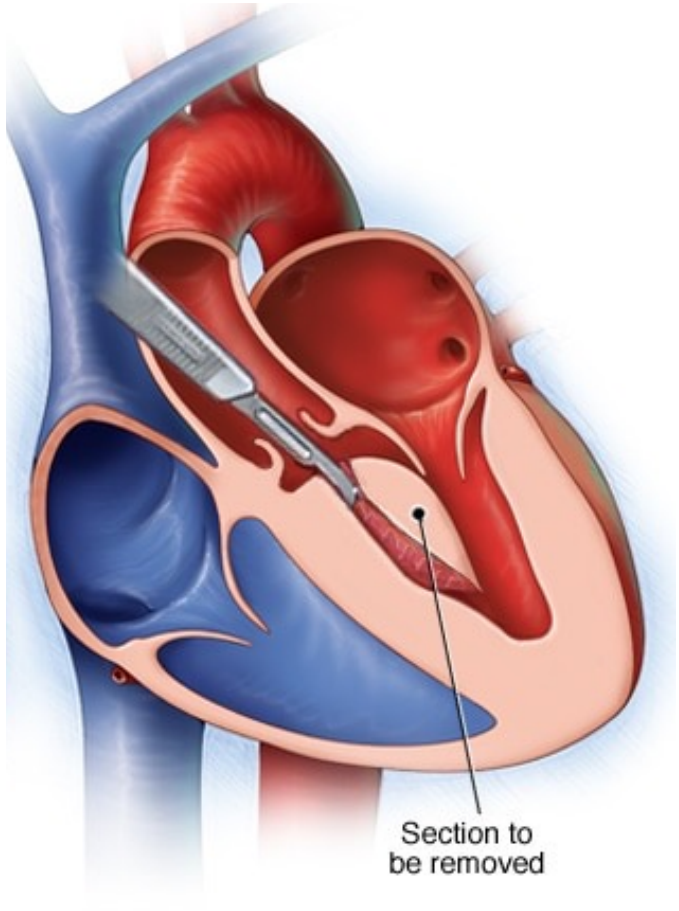
Prevention of Sudden Death



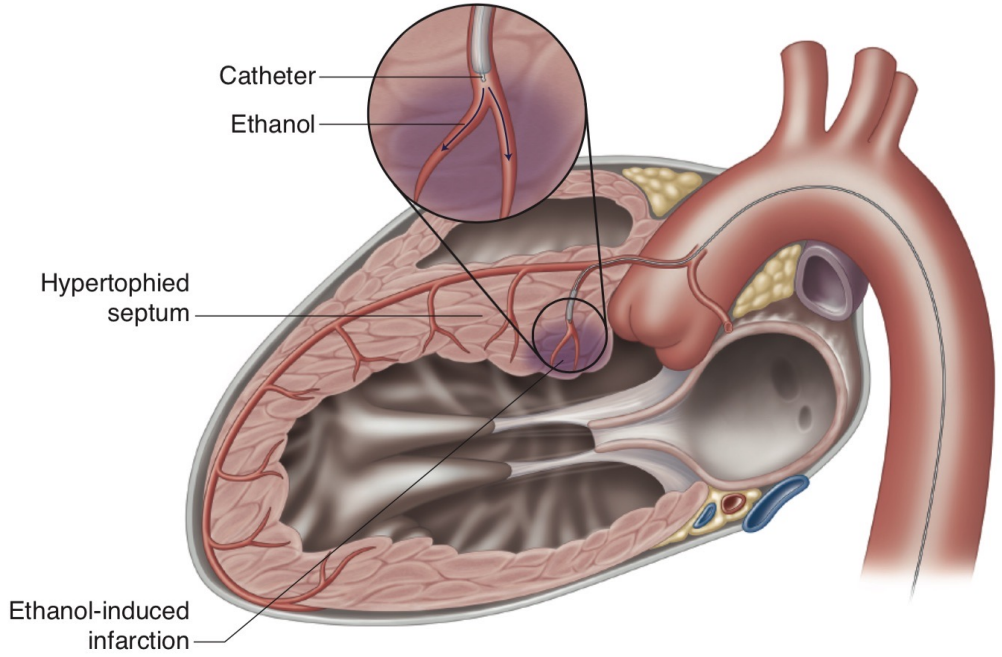


Mechanisms for Septal Reduction

Surgical Septal Myectomy

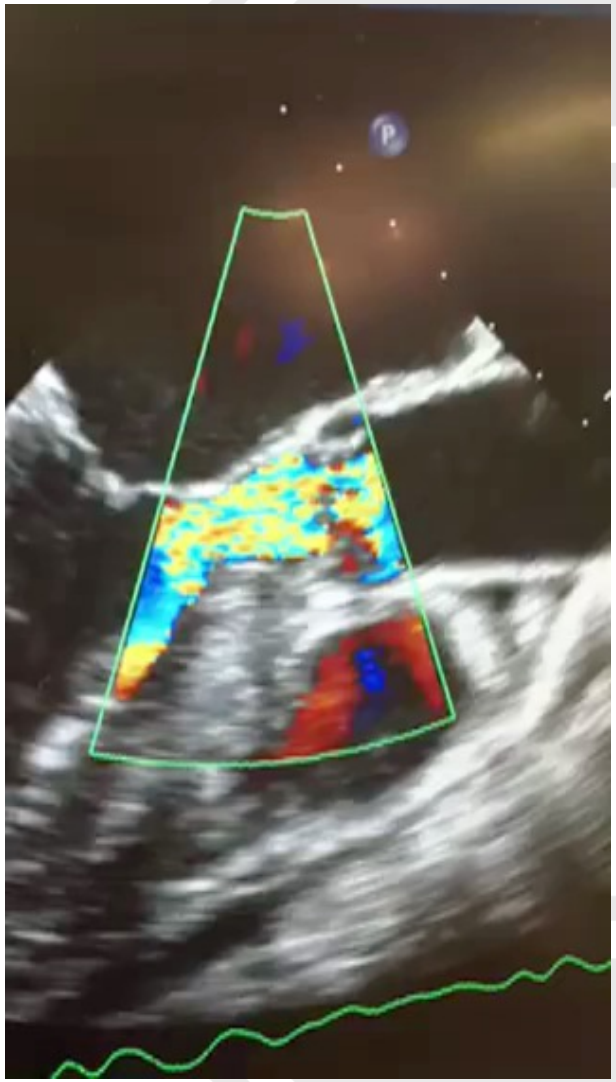


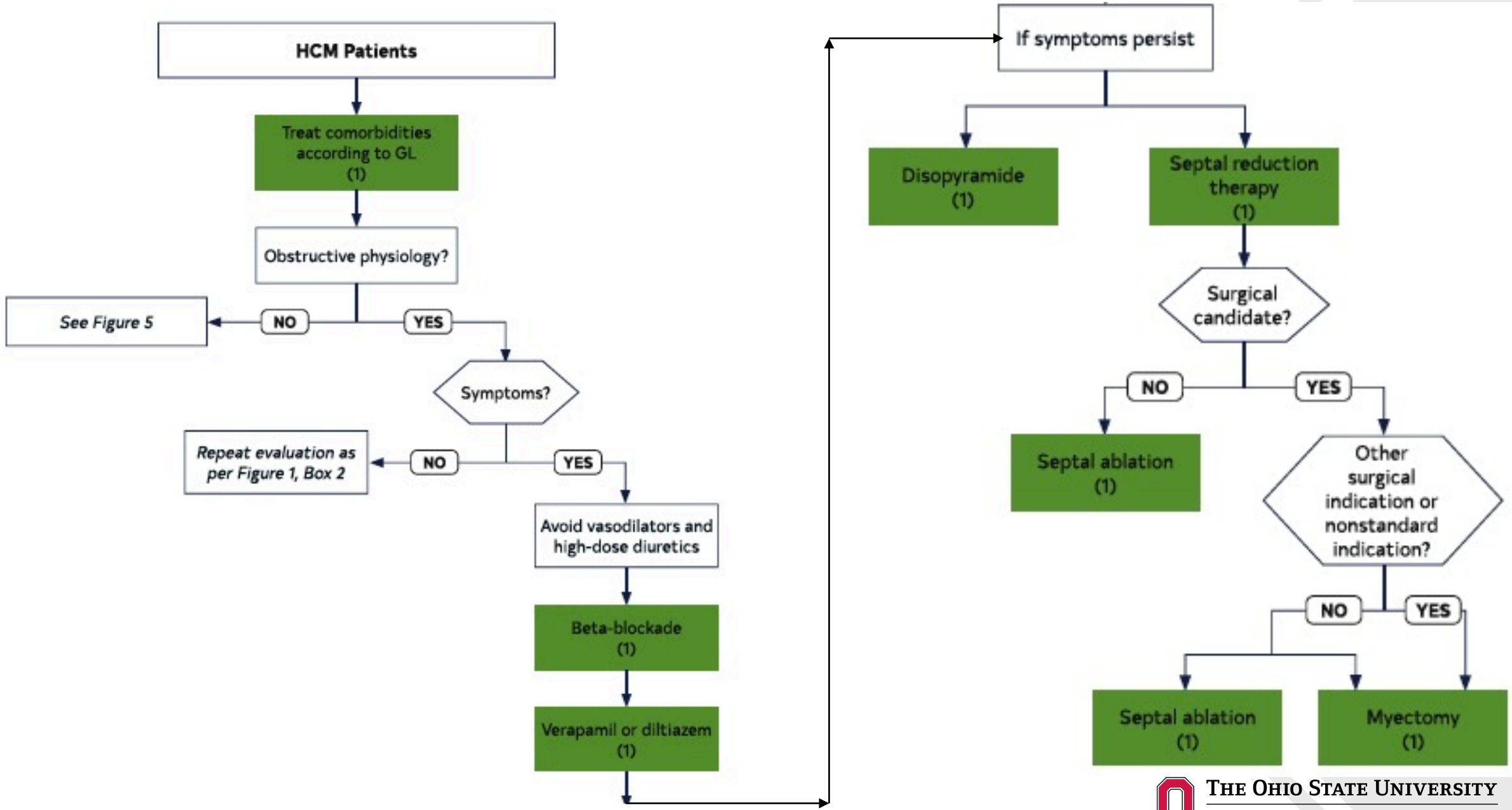
Percutaneous Septal Alcohol Ablation



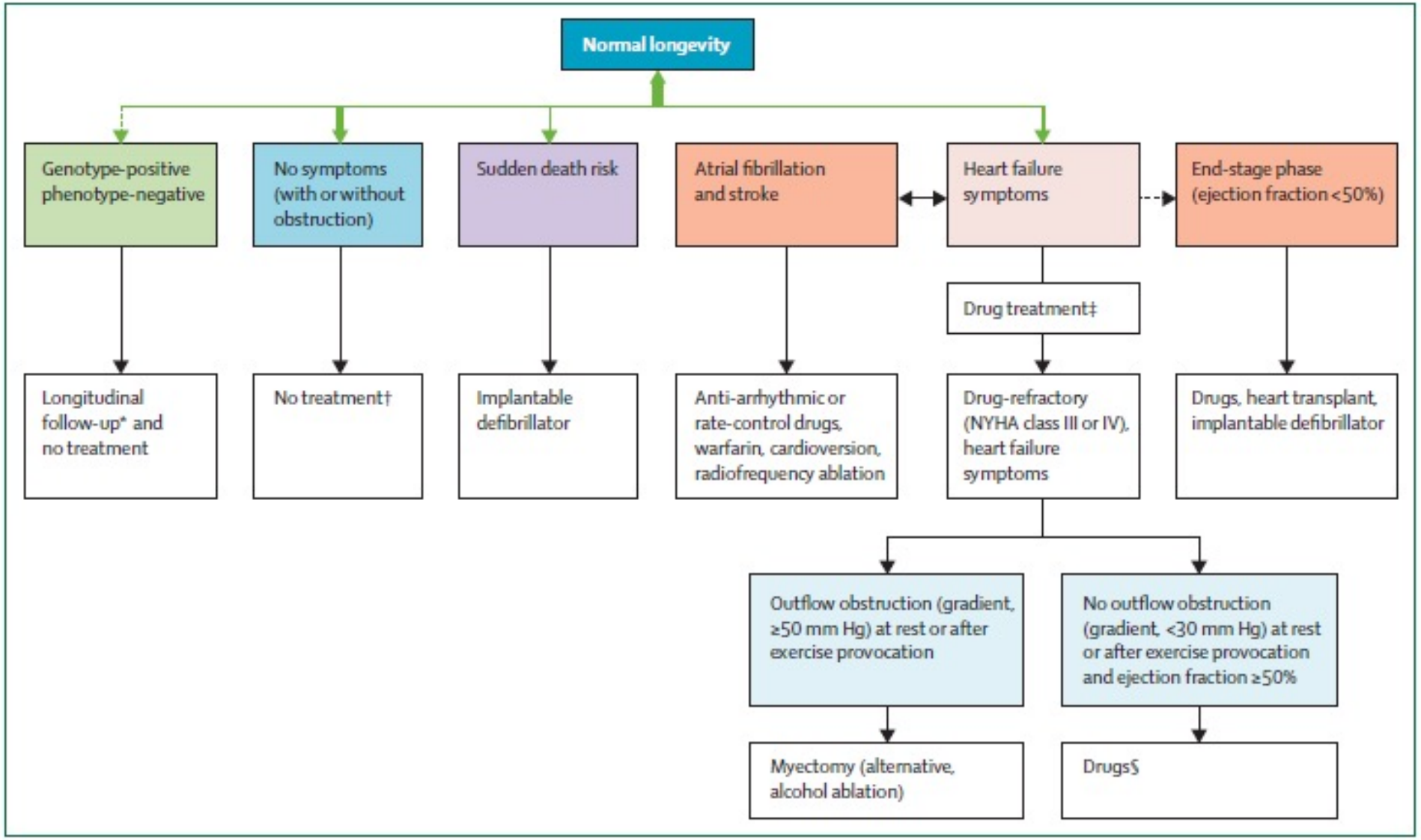
Indications for Septal Reduction

- Symptomatic (ie. DOE, angina, orthopnea, fatigue, presyncope) and refractory to medical management
- Outflow gradient of 50 mmHg or more (at rest or with physiological provocation)
  - LVOTO with resting gradient >30mmHg
  - Lower resting gradients and latent obstruction are becoming more acceptable
- Surgical myectomy is the gold standard treatment if adequate surgical candidate
- Percutaneous alcohol septal ablation is an alternative for poor surgical candidates





Treatment of HCM



Myectomy

- The description of a limited trans aortic septal myectomy given by Cleland et al in 1958 is considered the first surgical procedure for obstructive HCM.
- In 1960, Morrow and Brockenbrough performed a transaortic myectomy, which became known as the “Morrow operation.”
- This approach may need modification in midventricular or apical HCM variants or when the aortic annulus is small
- MVR for management of SAM is of historical significance

Role of TEE

• Pre-bypass

- To confirm ventricular septal anatomy
  - Site of maximal thickness
  - Its distance from aortic annulus
  - Location of endocardial scar (friction lesion)
  - Apical extent of septal bulge
- Assess the mitral valve and identify any other intrinsic abnormalities.

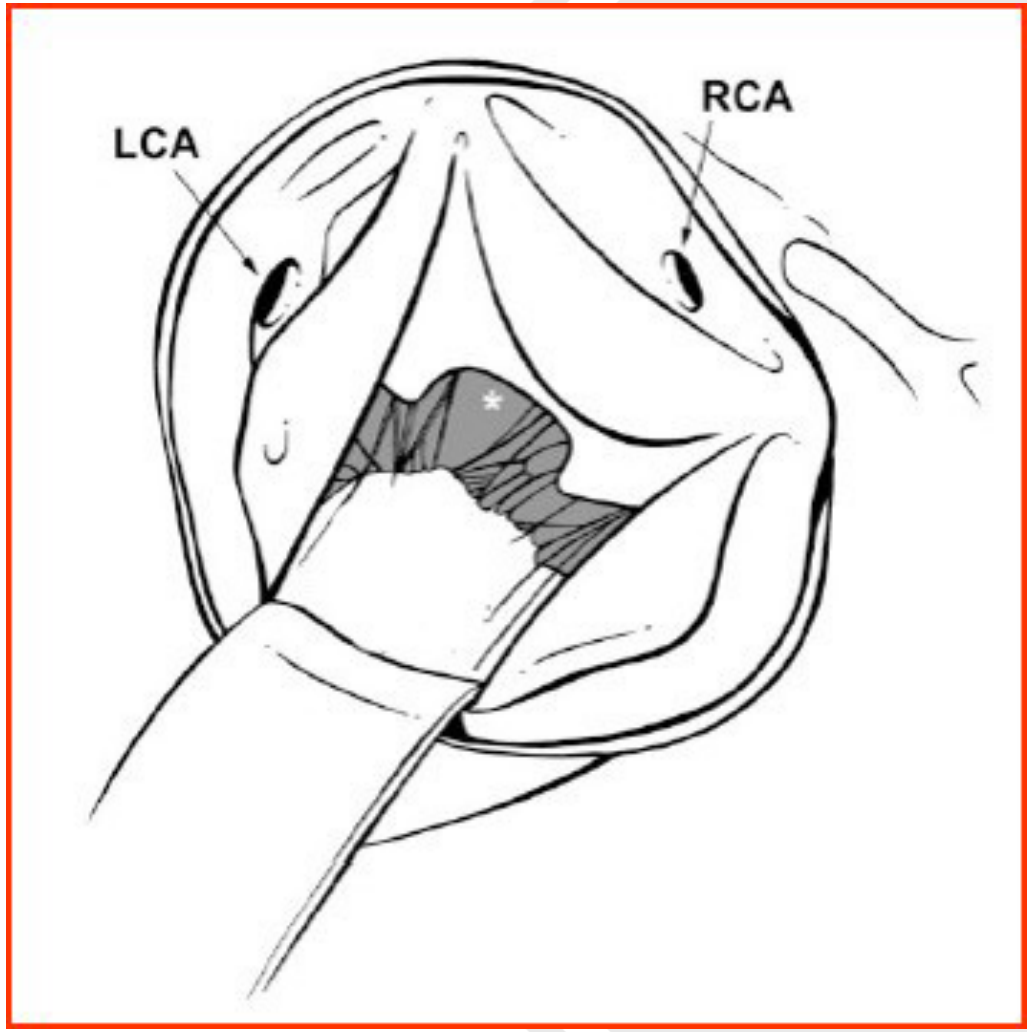
• Post-bypass

- To assess adequacy of myectomy and valve function
- Evaluate mitral valve function
- Confirm absence of mitral regurgitation
- Confirm absence of iatrogenic ventricular septal defect or AI

6. For patients with HCM undergoing surgical septal myectomy, intraoperative transesophageal echocardiogram (TEE) is recommended to assess mitral valve anatomy and function and adequacy of septal myectomy.[27-30]

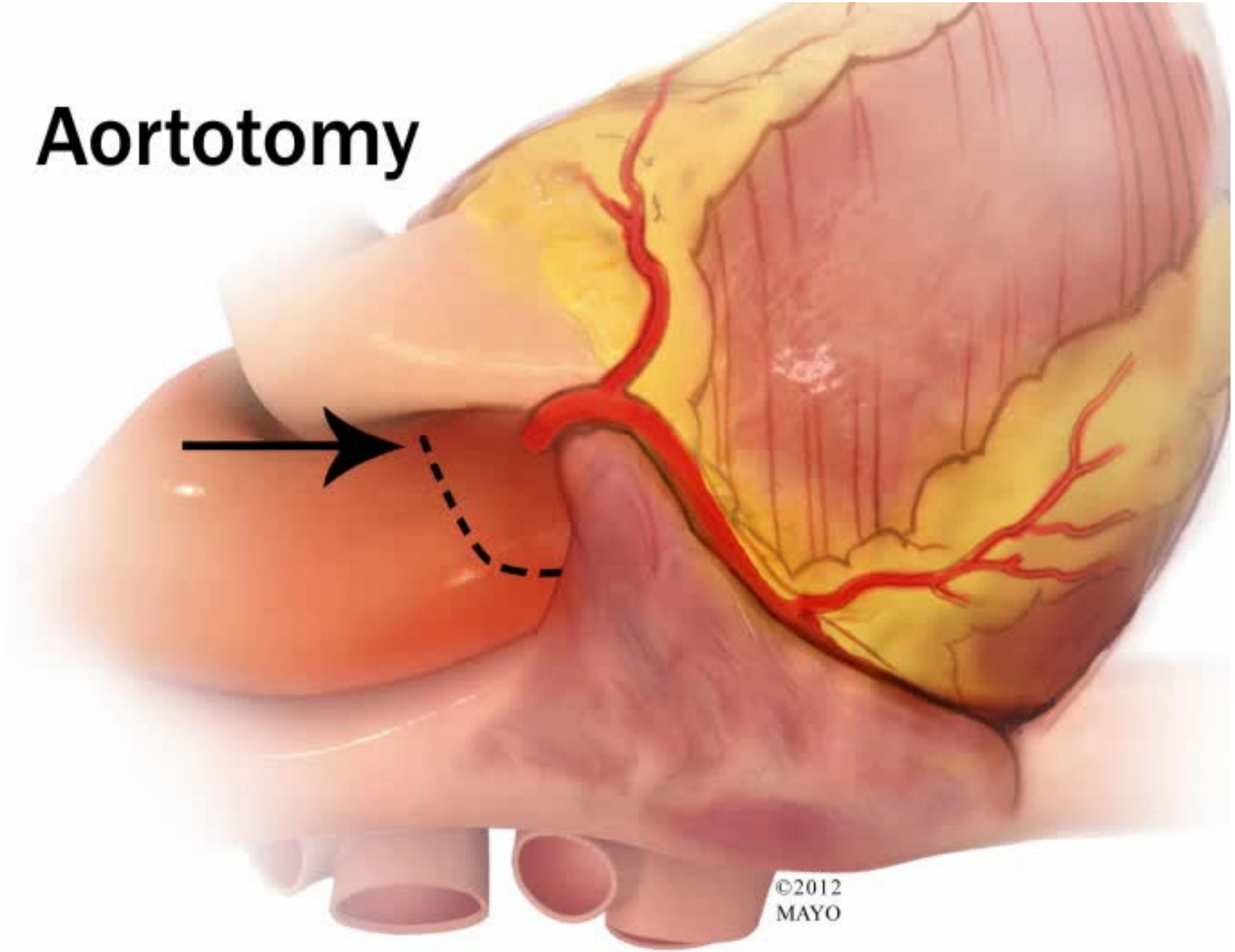
Myectomy – Surgical Approach

- Cardiopulmonary bypass
- Exposure of septum through transverse aortotomy
- Excision of septal muscle from beneath the nadir of right aortic sinus
- Division of any other subaortic obstruction of aberrant papillary muscles
- Intraoperative TEE to assess results

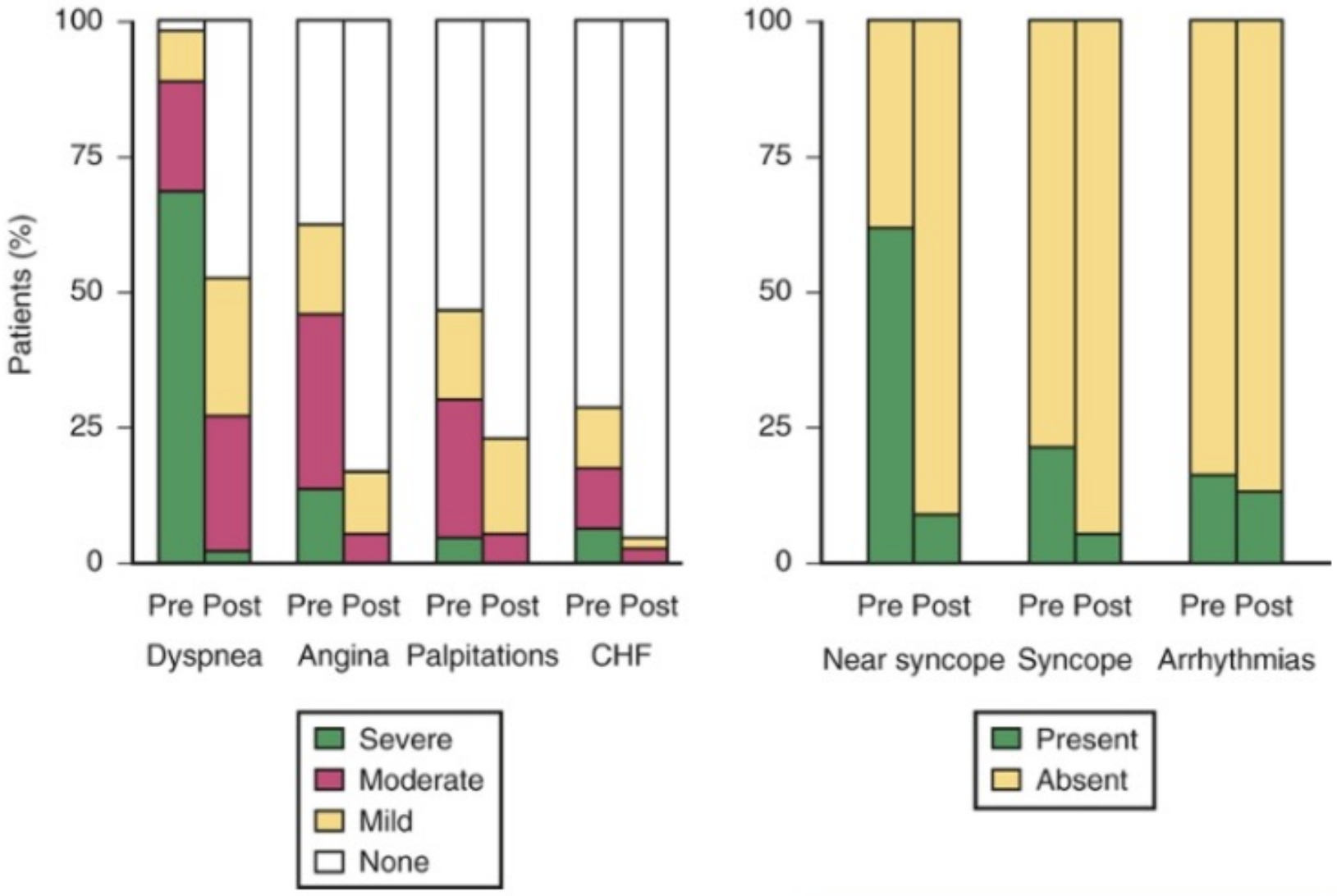


Van der Lee C et al. *Circulation* 2005;112:482-488

Aortotomy

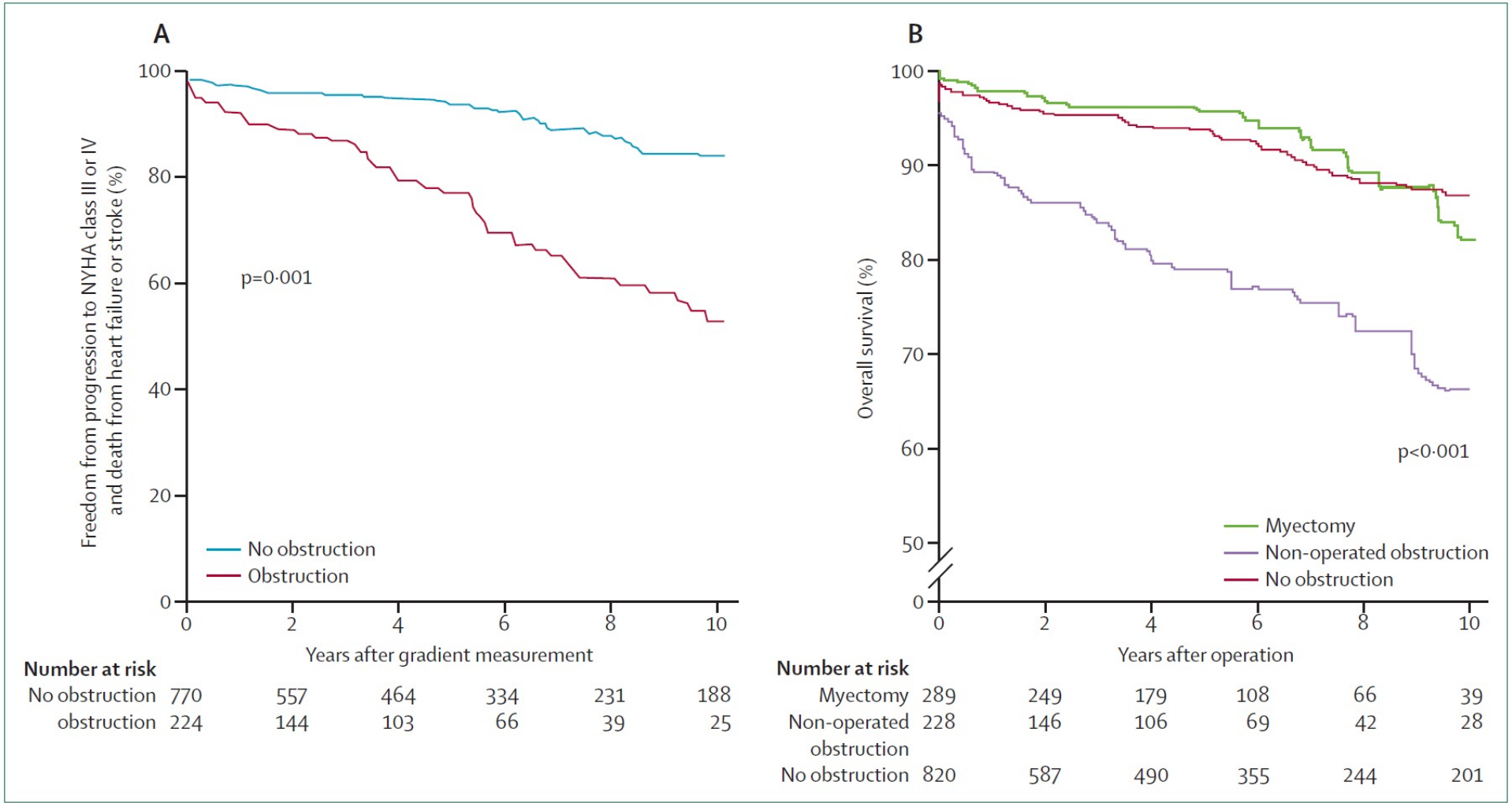


Myectomy – Symptom Relief



Schaff H. Chapter 96 – Surgical Management of HOCM. In Sabiston and Spencer Surgery of the Chest 9th Edition. 2016

Freedom from CHF or Death After Myectomy



Ommen SR, Nishimura RA, et al., JACC 2005; 46(3):470-476

Myectomy – Surgical Results

- Late recurrence of high resting gradient is extremely uncommon
- Perioperative risk of mortality is <1% for isolated myectomy in experienced centers
- Complete heart block – 1-2%
- Ventricular septal defect – <1%

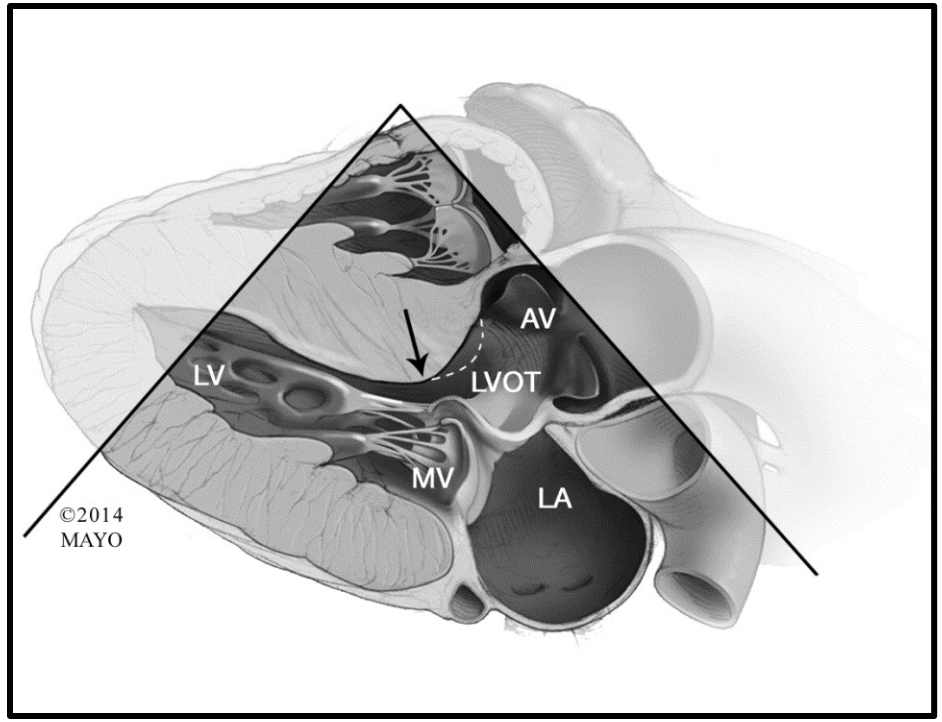
Residual and recurrent gradients after septal myectomy for hypertrophic cardiomyopathy—mechanisms of obstruction and outcomes of reoperation

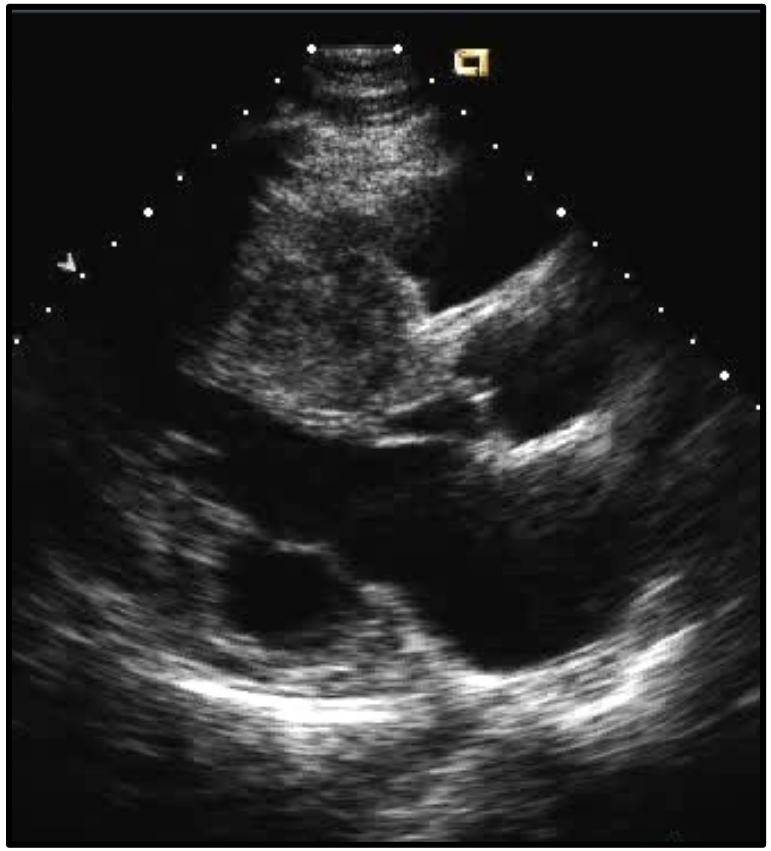
Yang Hyun Cho, MD, PhD,[a,b] Eduard Quintana, MD, FETCS,[a,c] Hartzell V. Schaff, MD,[a] Rick A. Nishimura, MD,[d] Joseph A. Dearani, MD,[a] Martin D. Abel, MD,[e] and Steve Ommen, MD[d]

- Inadequate length - 31 (59%)
- Inadequate length and depth - 13 (25%)
- Midventricular obstruction - 6 (12%)
- Inadequate length and midventricular - 2 (4%)

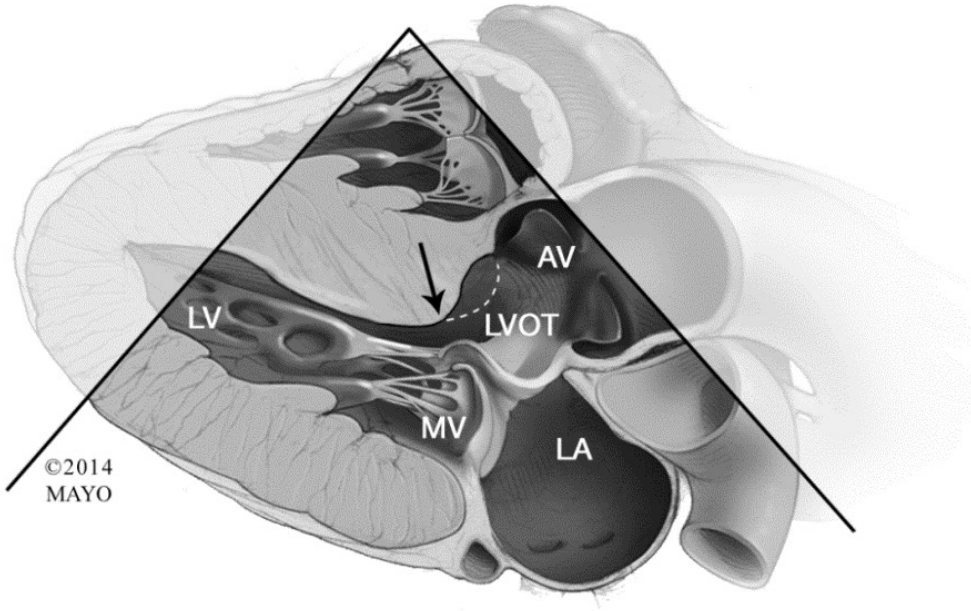
Cho YH, Ommen S, et al., JTCVS 2014:148(3) 909-16

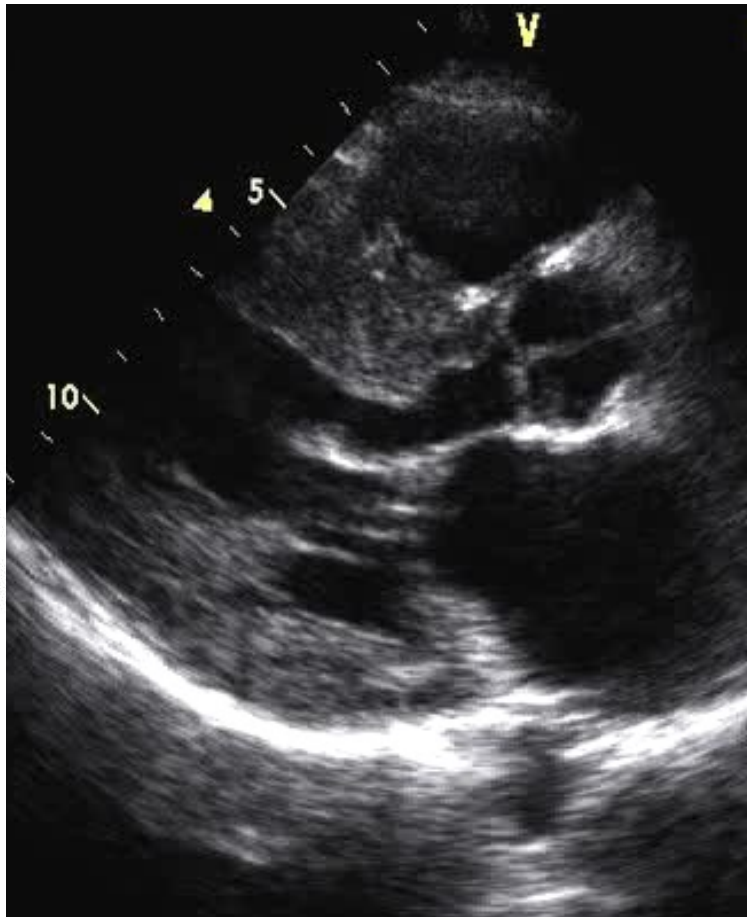
Inadequate Length or Depth of Myectomy



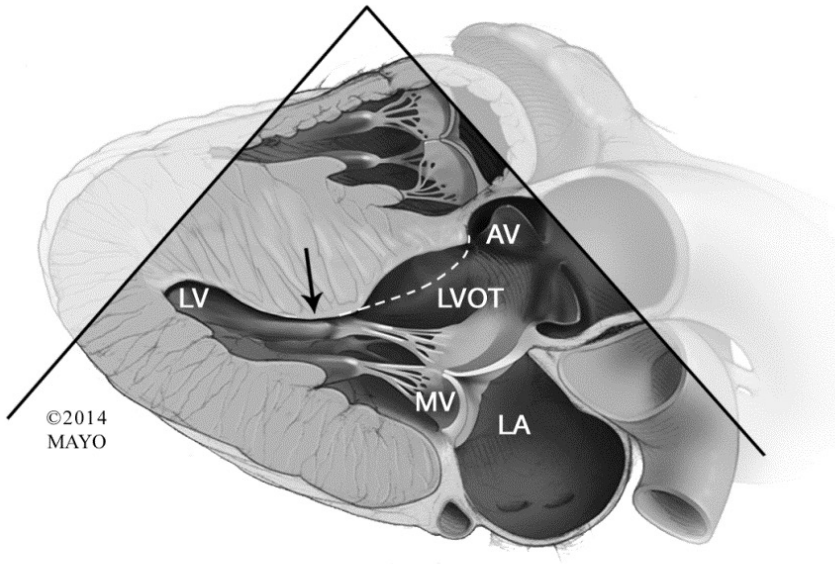


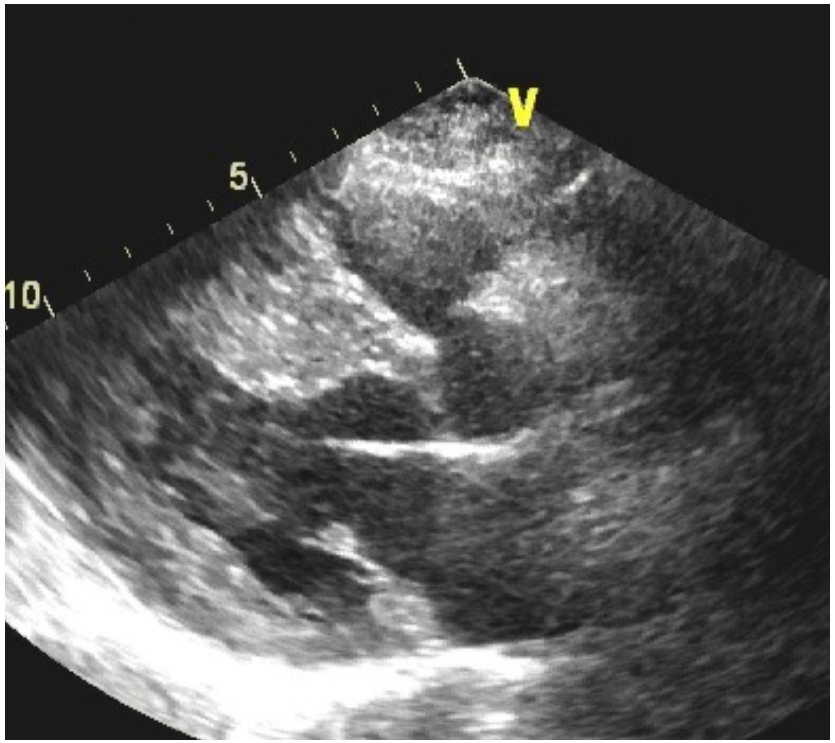
Inadequate Length of Myectomy





Midventricular Obstruction





Published in final edited form as:
Innovations (Phila). 2017 ; 12(6): 489–492. doi:10.1097/IMI.0000000000000421.

Minimally Invasive Septal Myectomy for Hypertrophic Obstructive Cardiomyopathy

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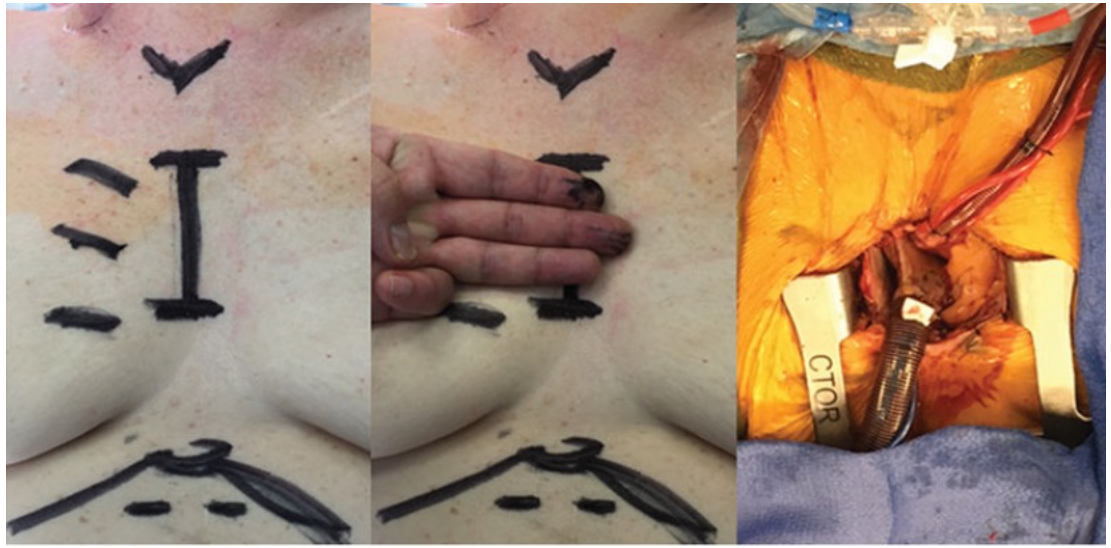
Division of Cardiothoracic Surgery, Department of Surgery, Washington University School of Medicine, Barnes-Jewish Hospital, St. Louis, MO USA



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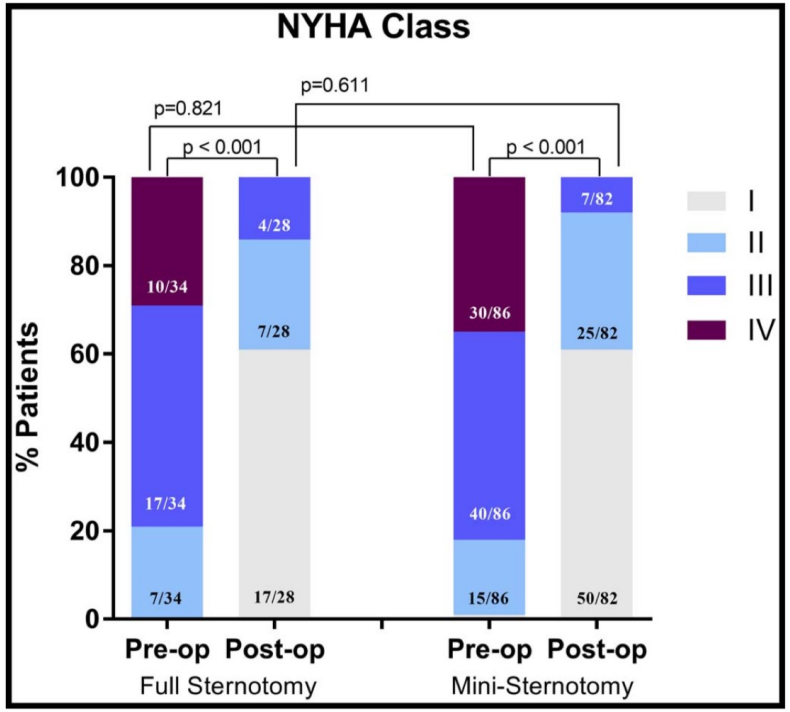
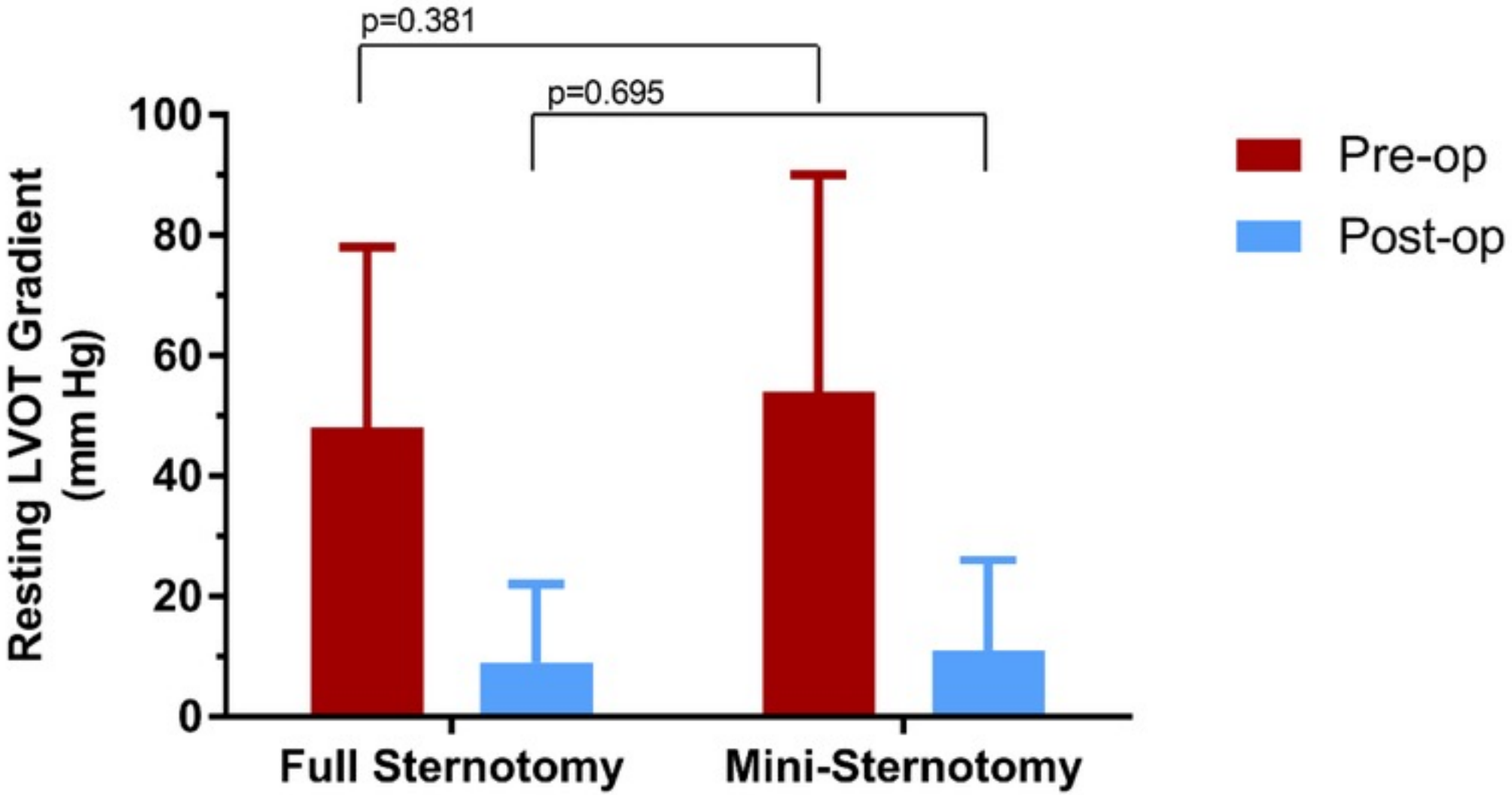
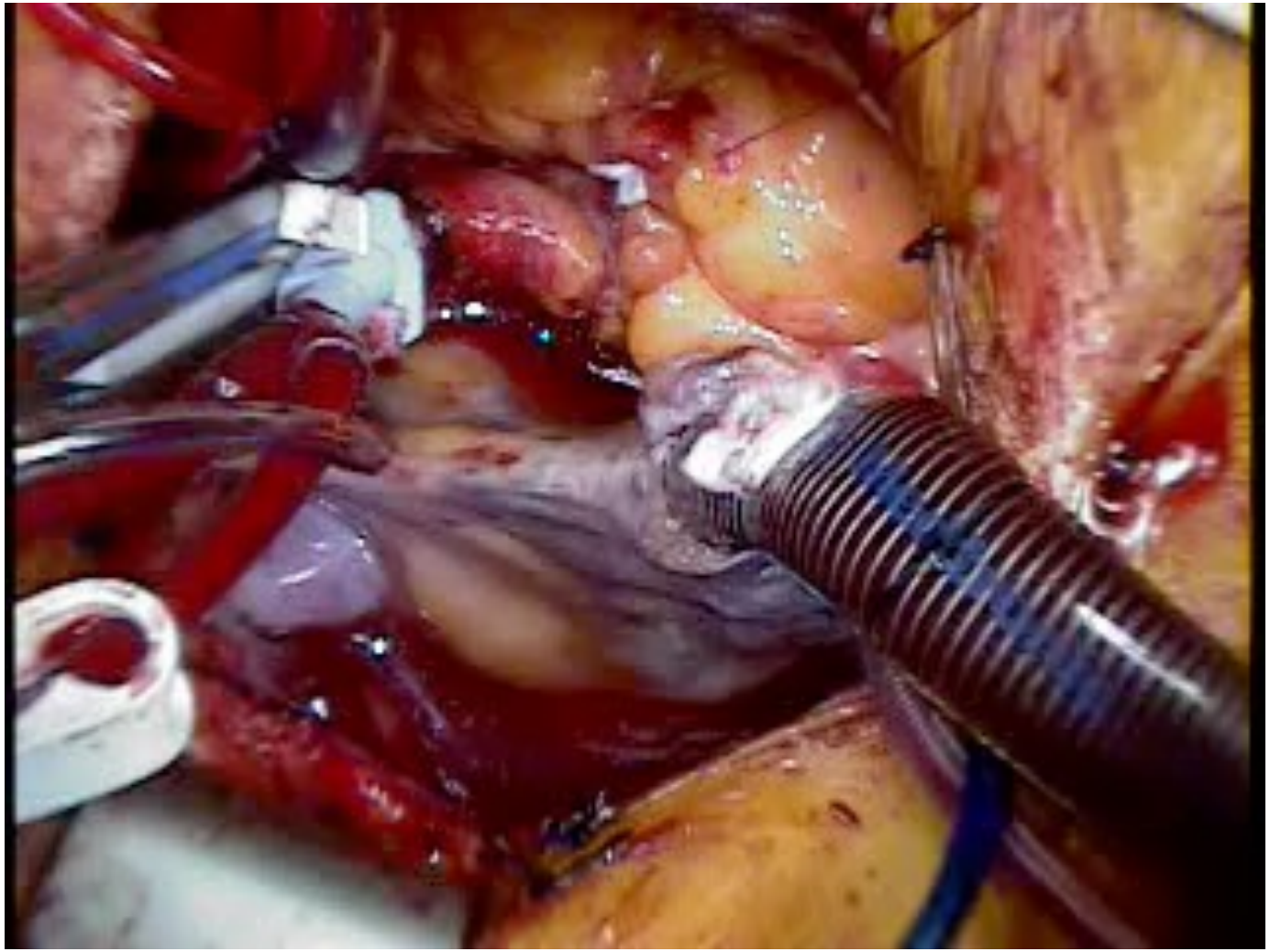
- 120 patients
  - 34 full sternotomy
  - 86 mini sternotomy
- No significant differences in post-op NYHA
- Cross clamp time 4 min longer in mini (p=0.017), no other periop op differences
- Learning curve was 20 patients
  - Median cross clamp of 47 vs 37min
  - Median CBP time of 90 vs 80 min





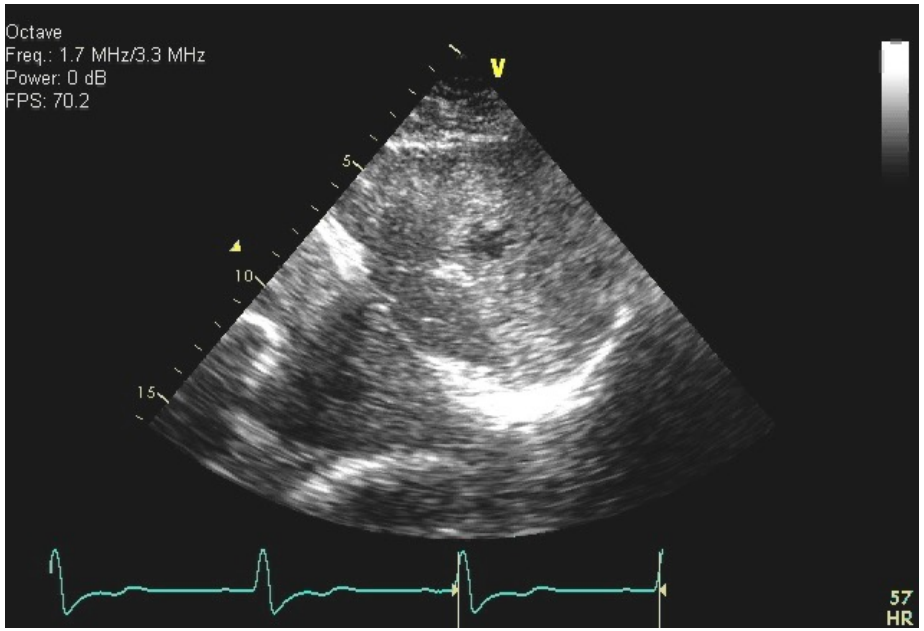
Myectomy – Minimally Invasive Approach

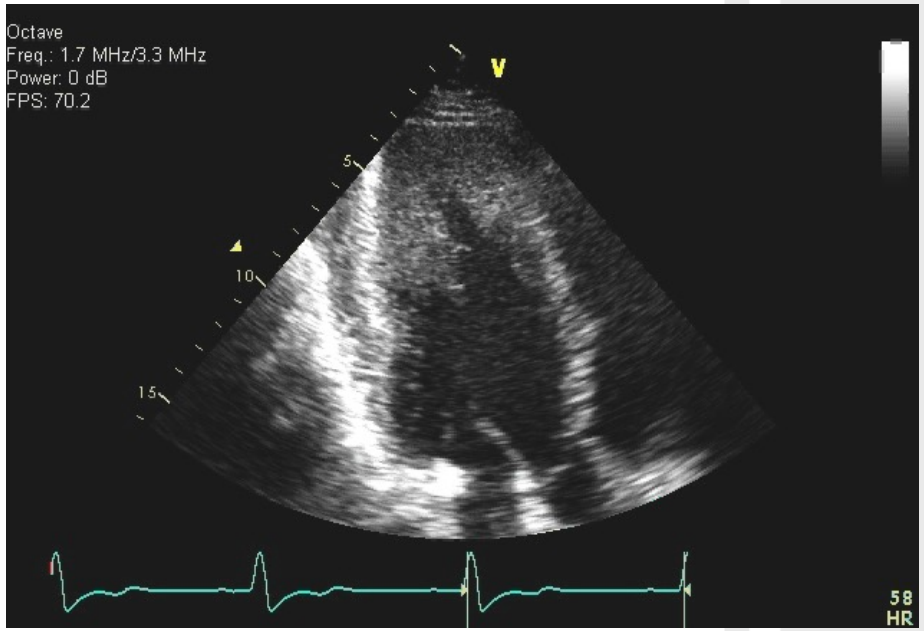


Transapical Myectomy

- Indicated when the obstruction is below the level of papillary muscle of the mitral valve (apical and midventricular variants)
- Apical variant results in a very small left ventricular cavity with diastolic dysfunction.
- The midventricular variant may develop an LV apical aneurysm leading to LV thrombus
- Generally these hypertrophied areas are unable to safely reached from a transaortic approach

Apical Hypertrophy





Transapical approach for myectomy in hypertrophic cardiomyopathy

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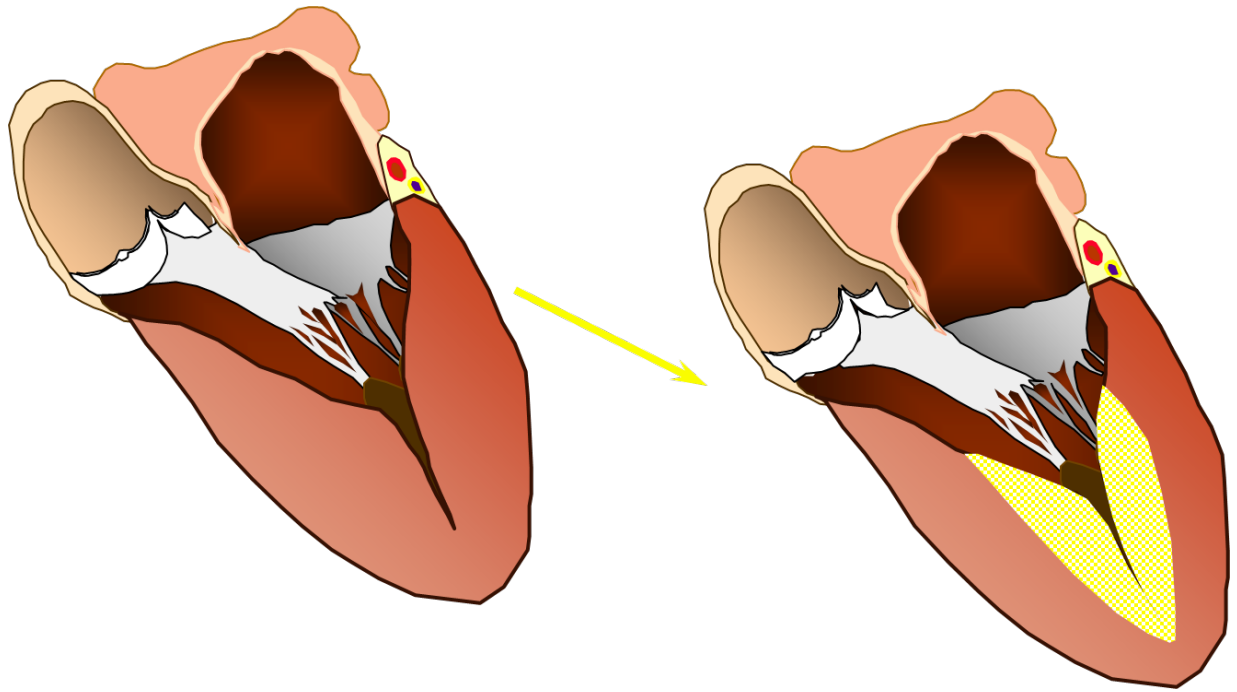
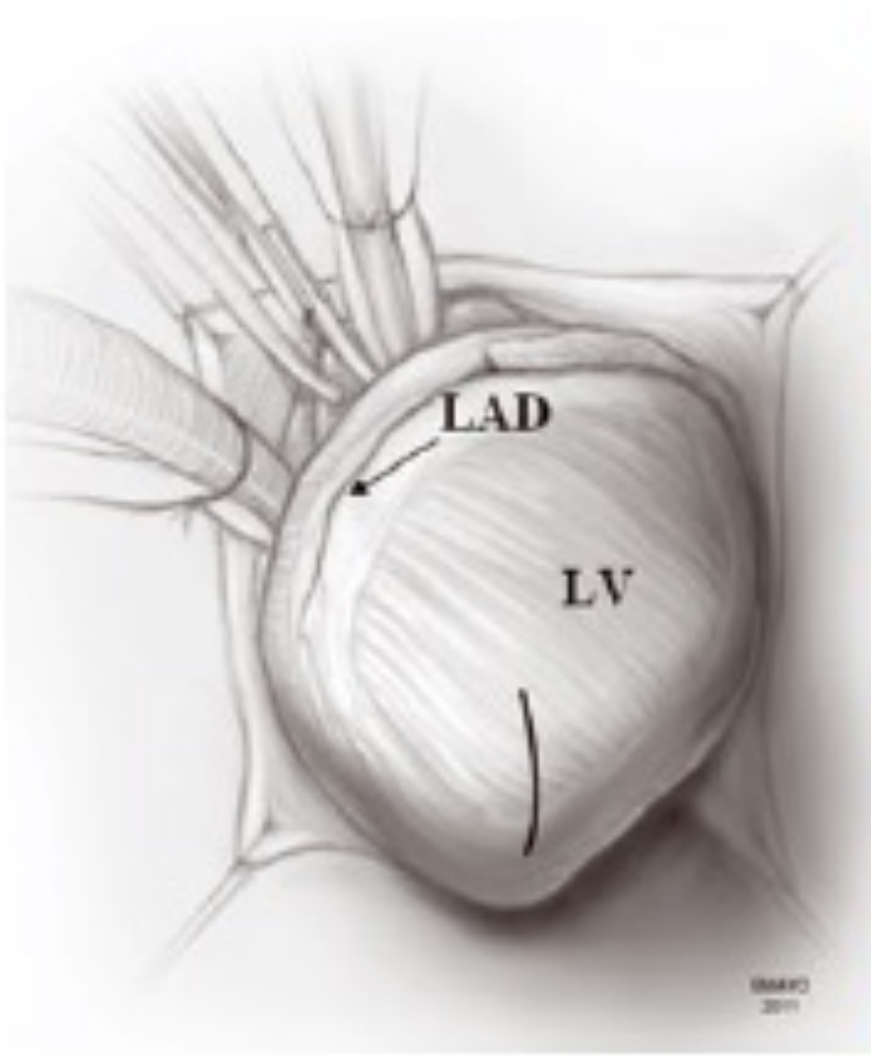
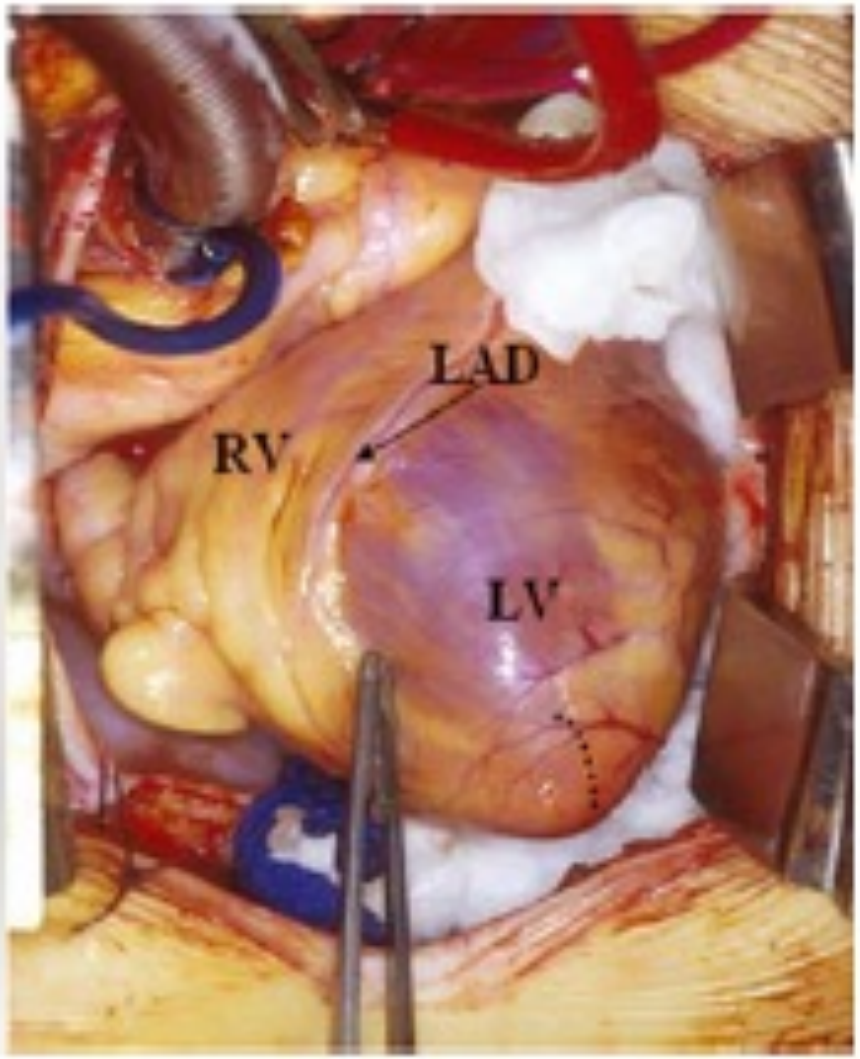
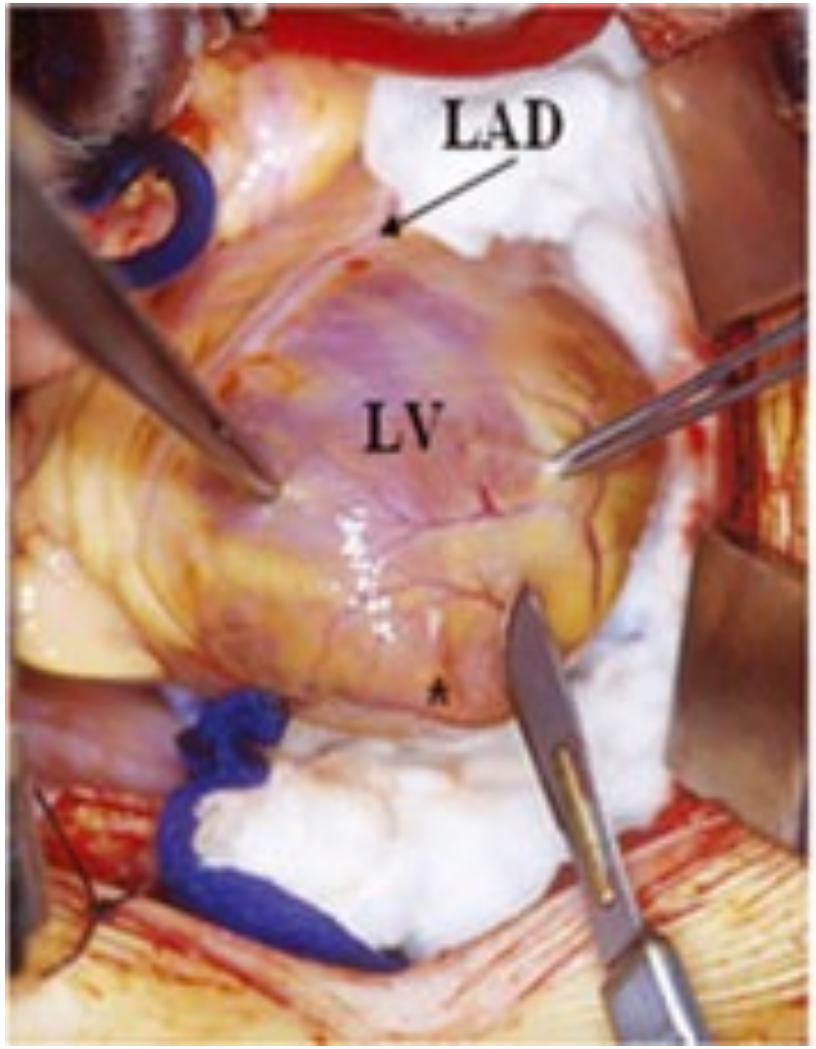
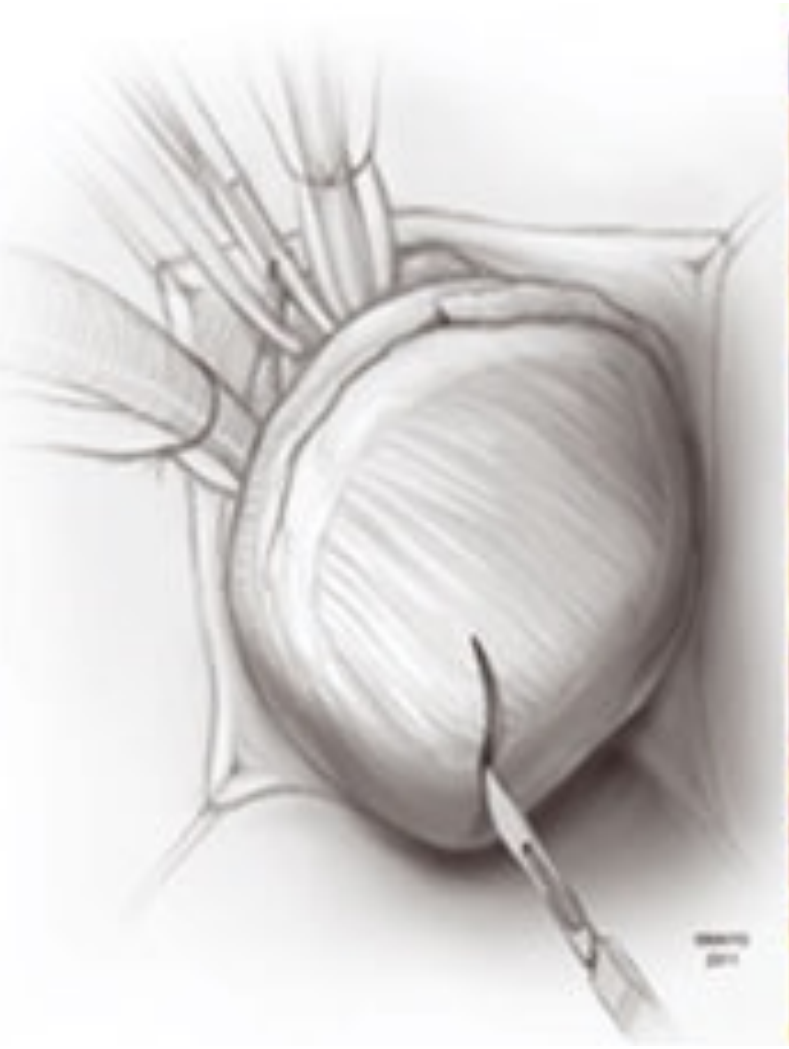


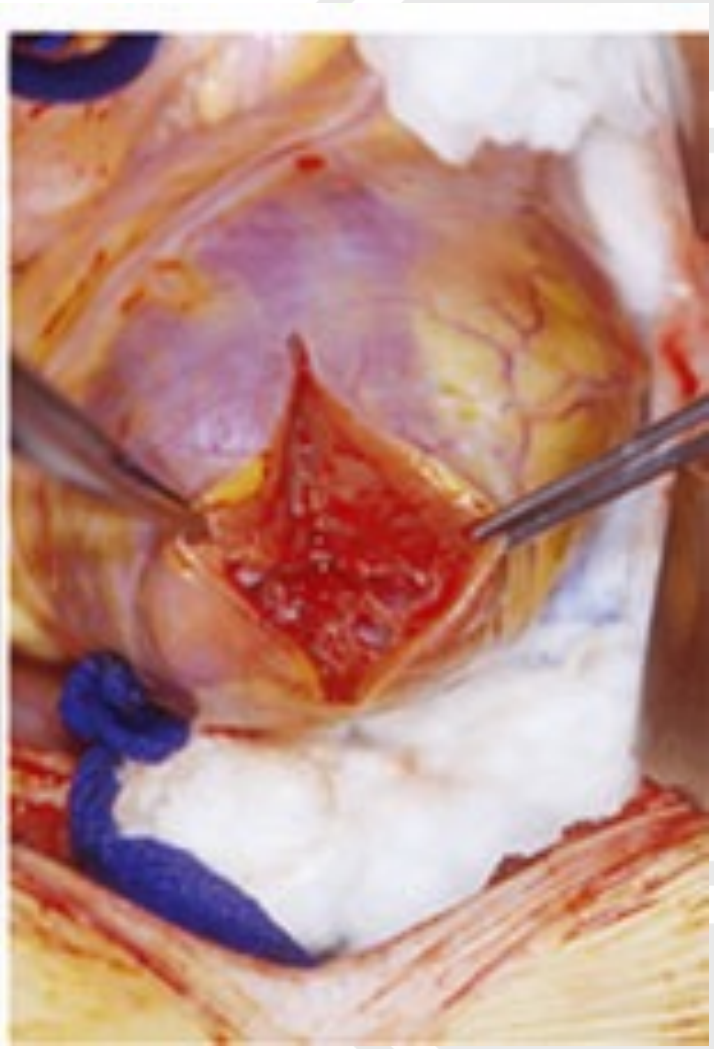
Kotkar KD, Schaff HV et al. Ann Cardiothorac Surg 2017;6(4):419-422.

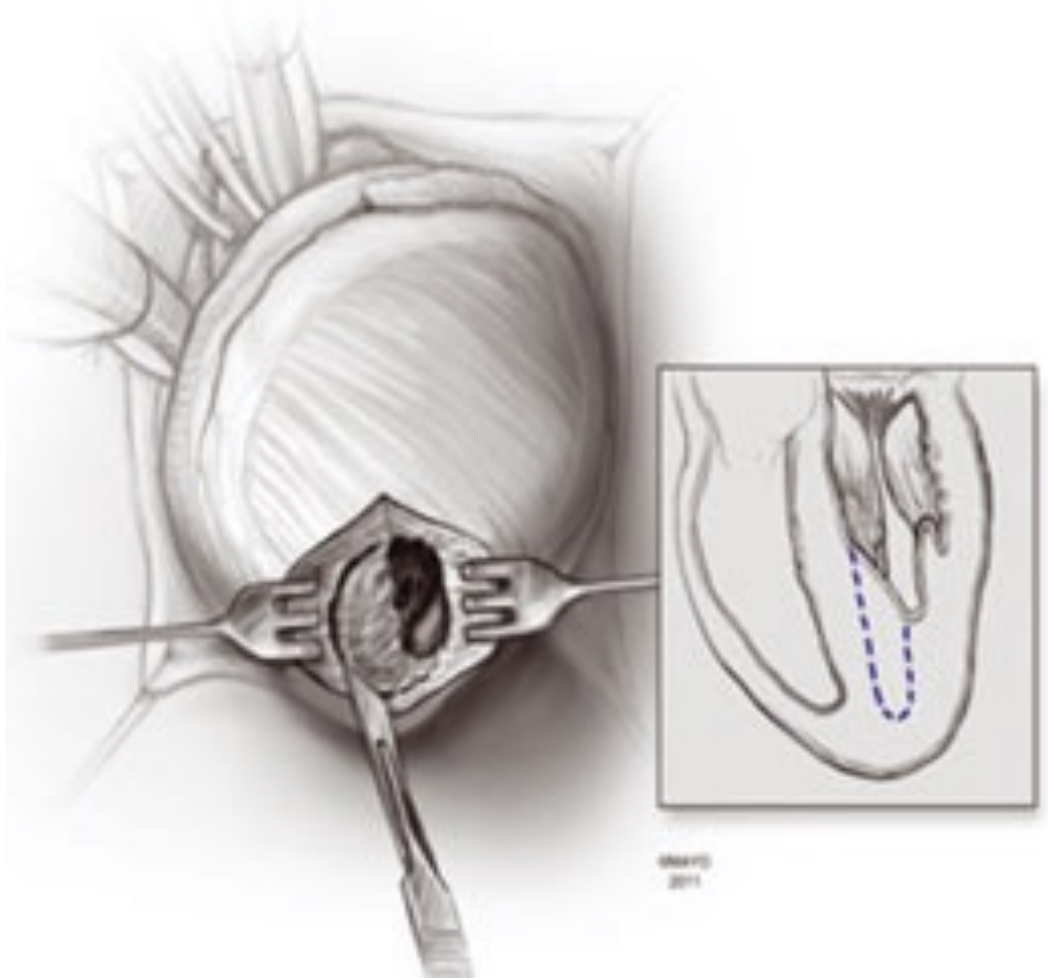

LAD
LV

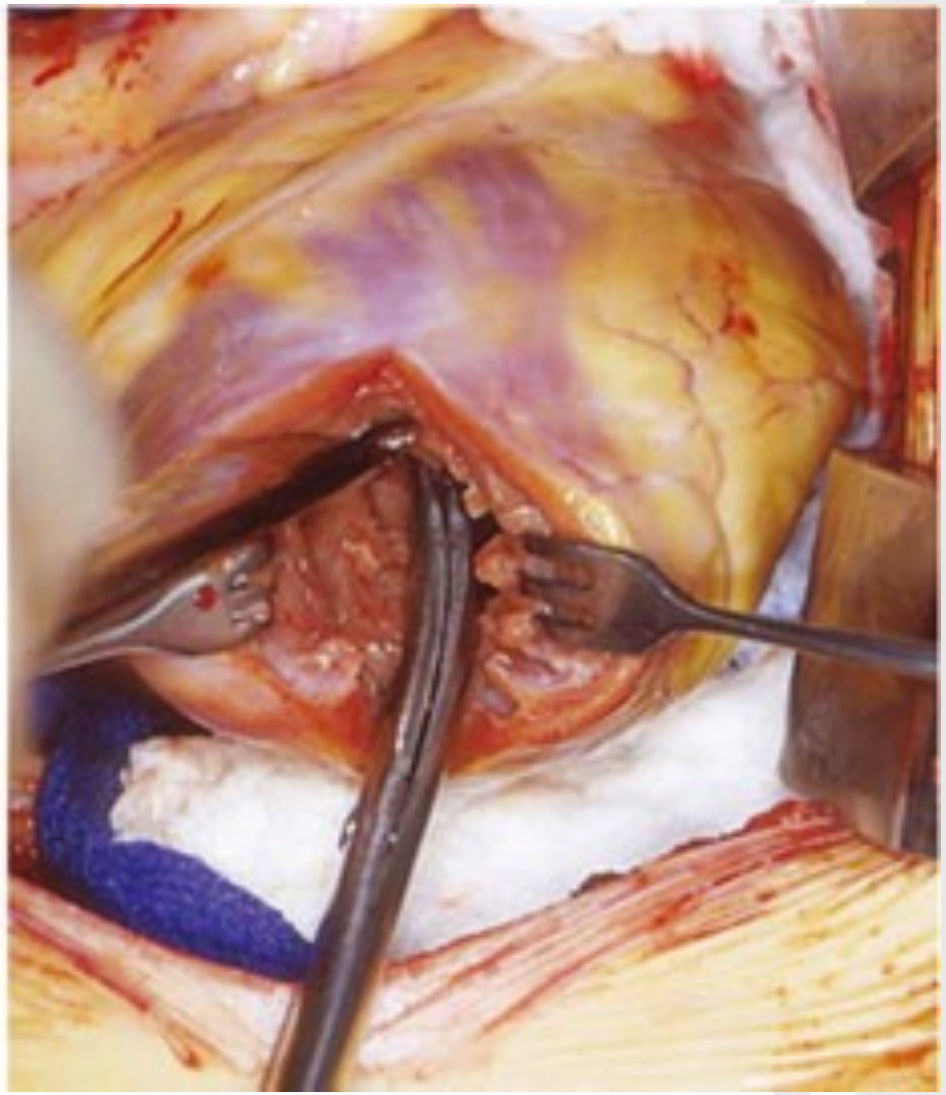

LAD
RV
LV

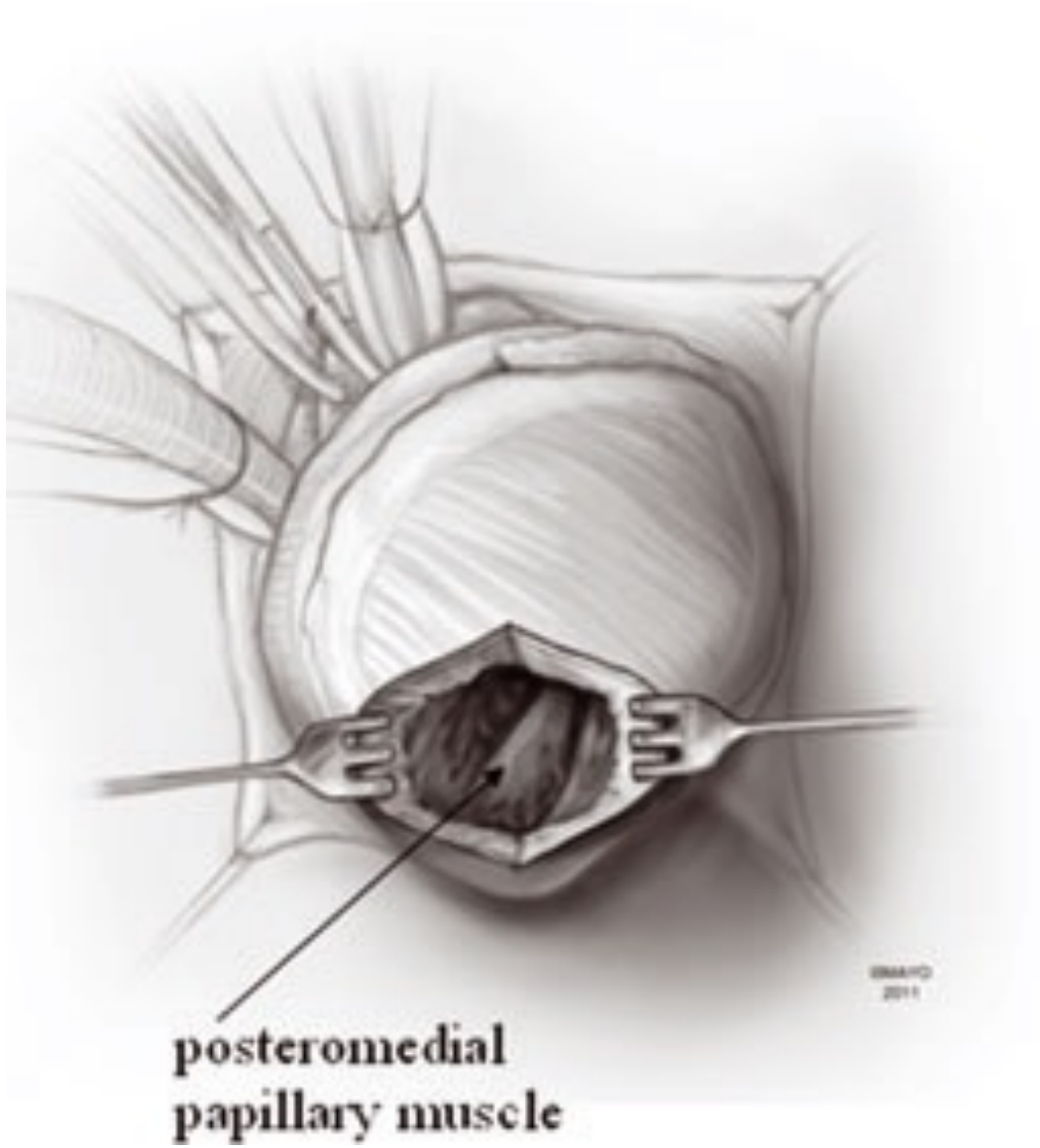

LAD
LV

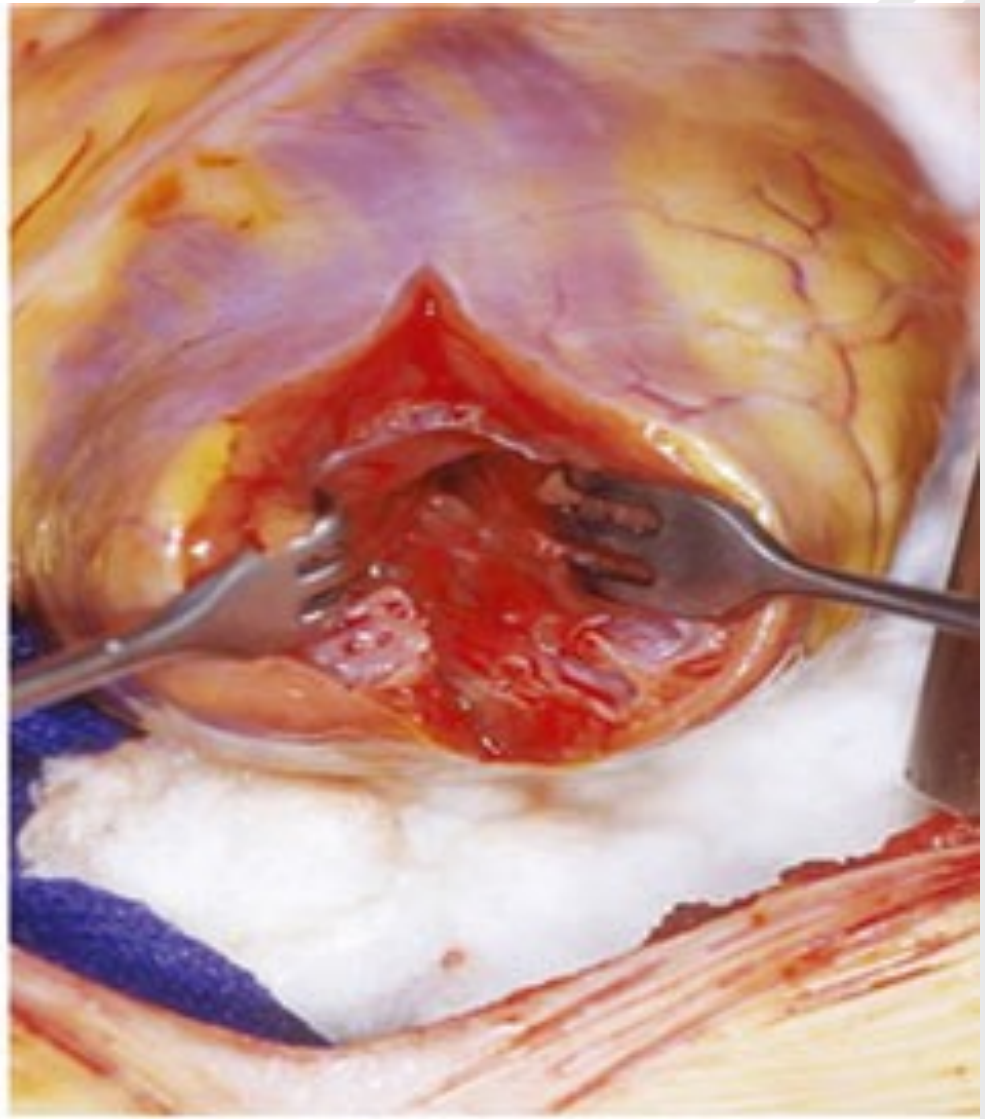


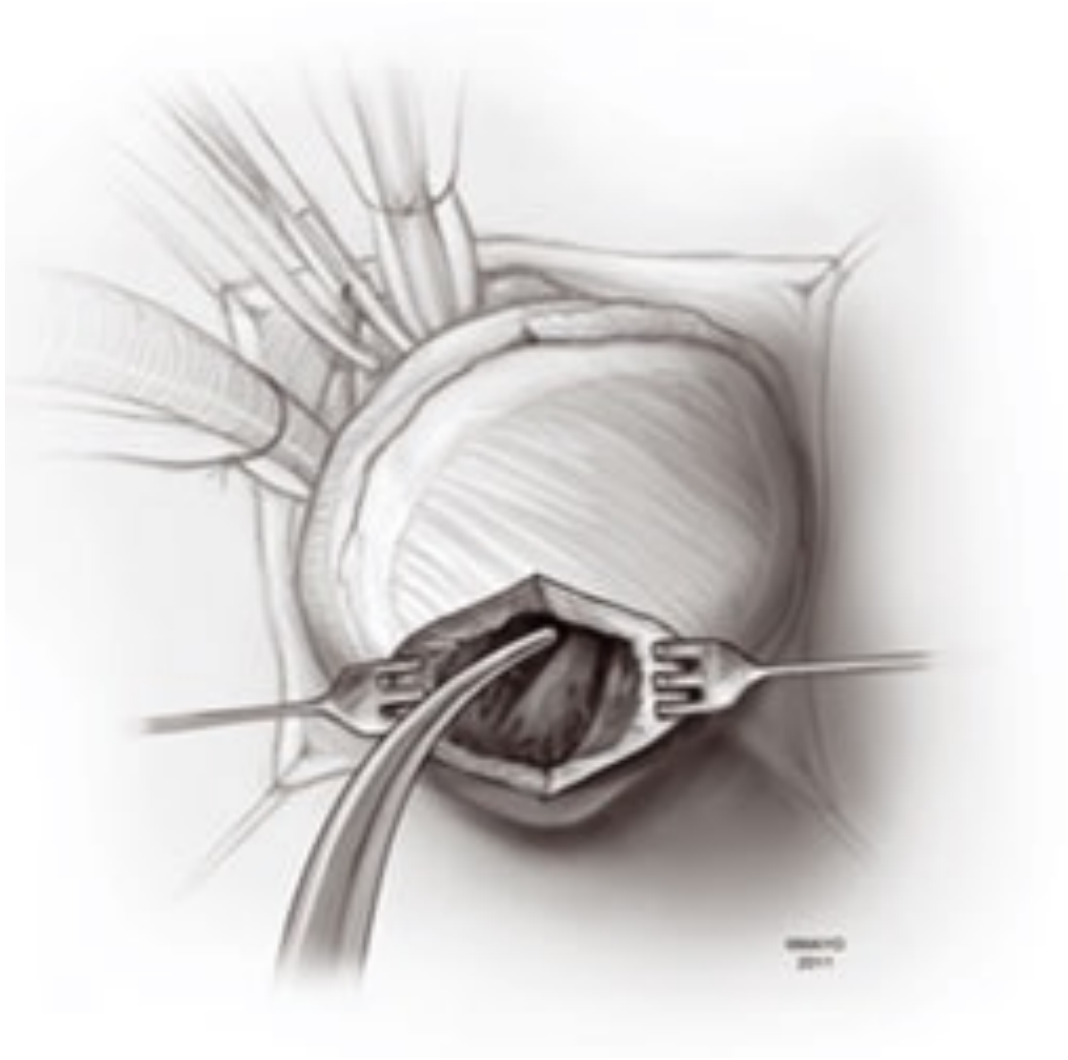


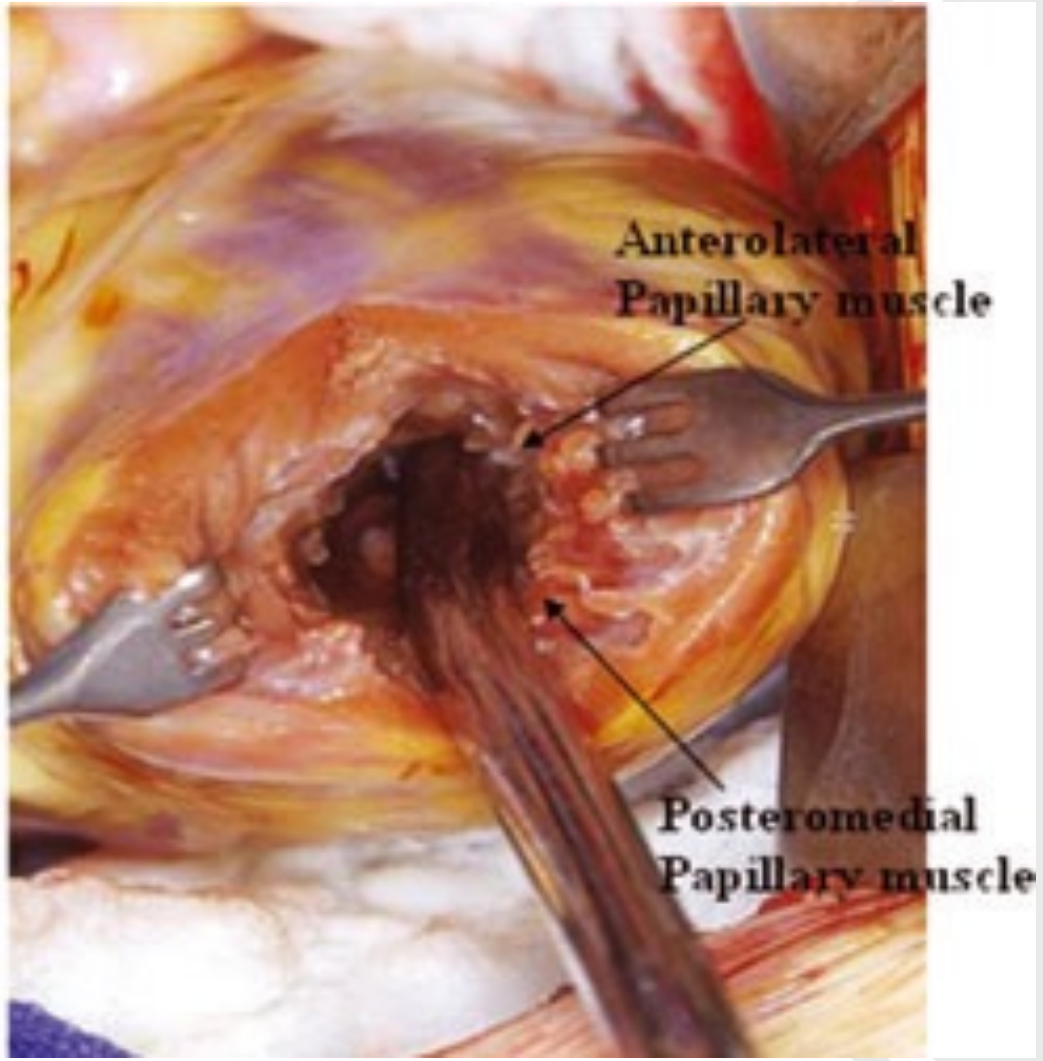


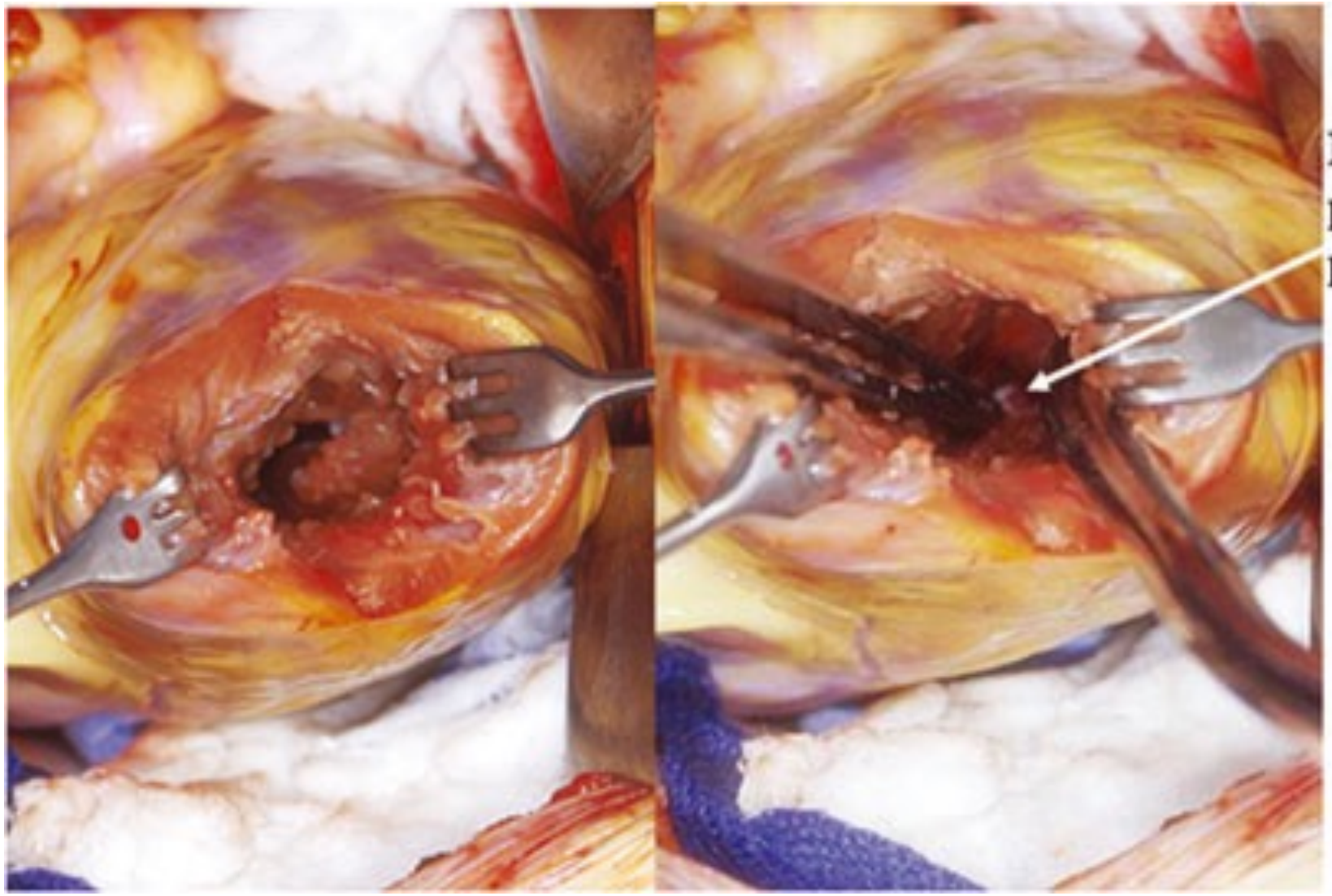


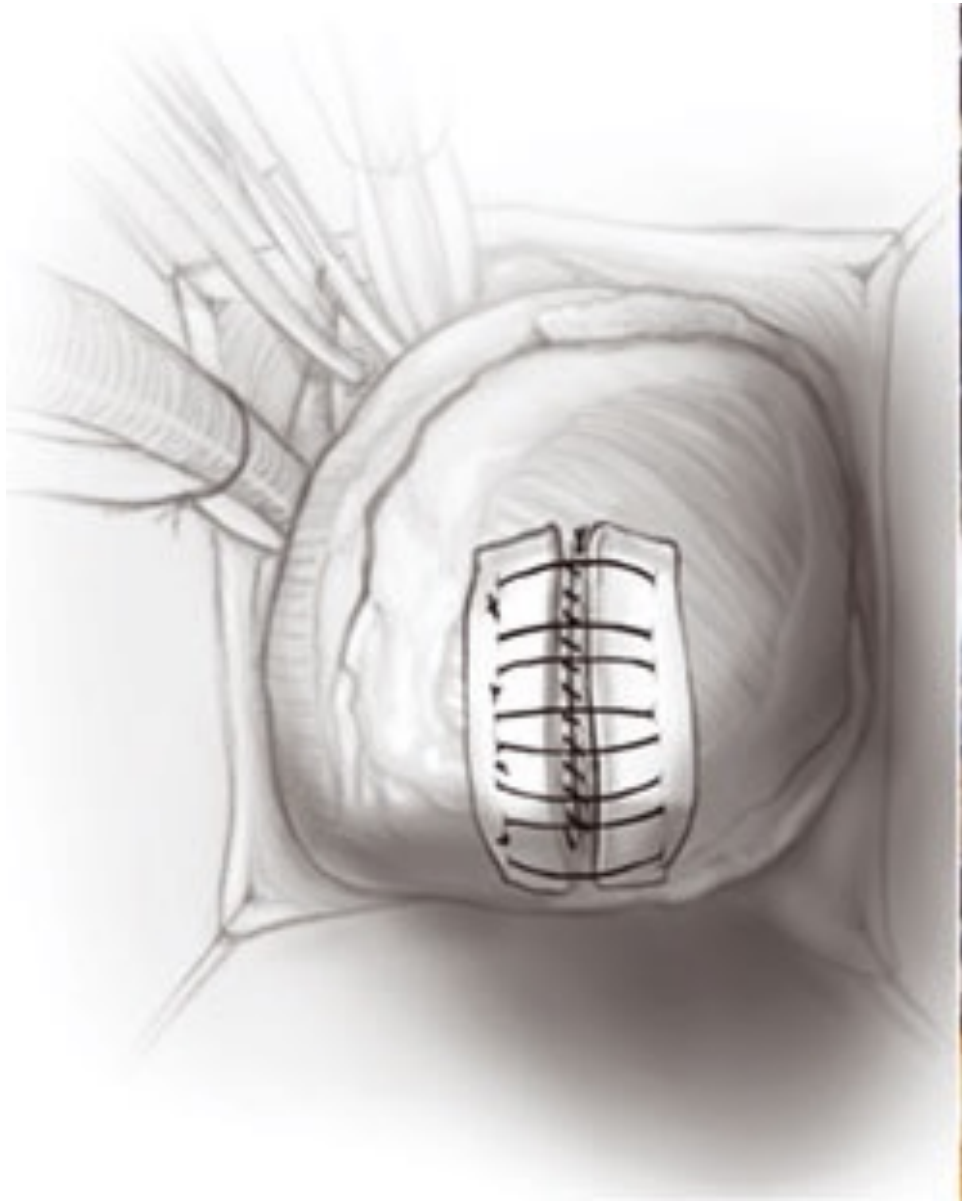


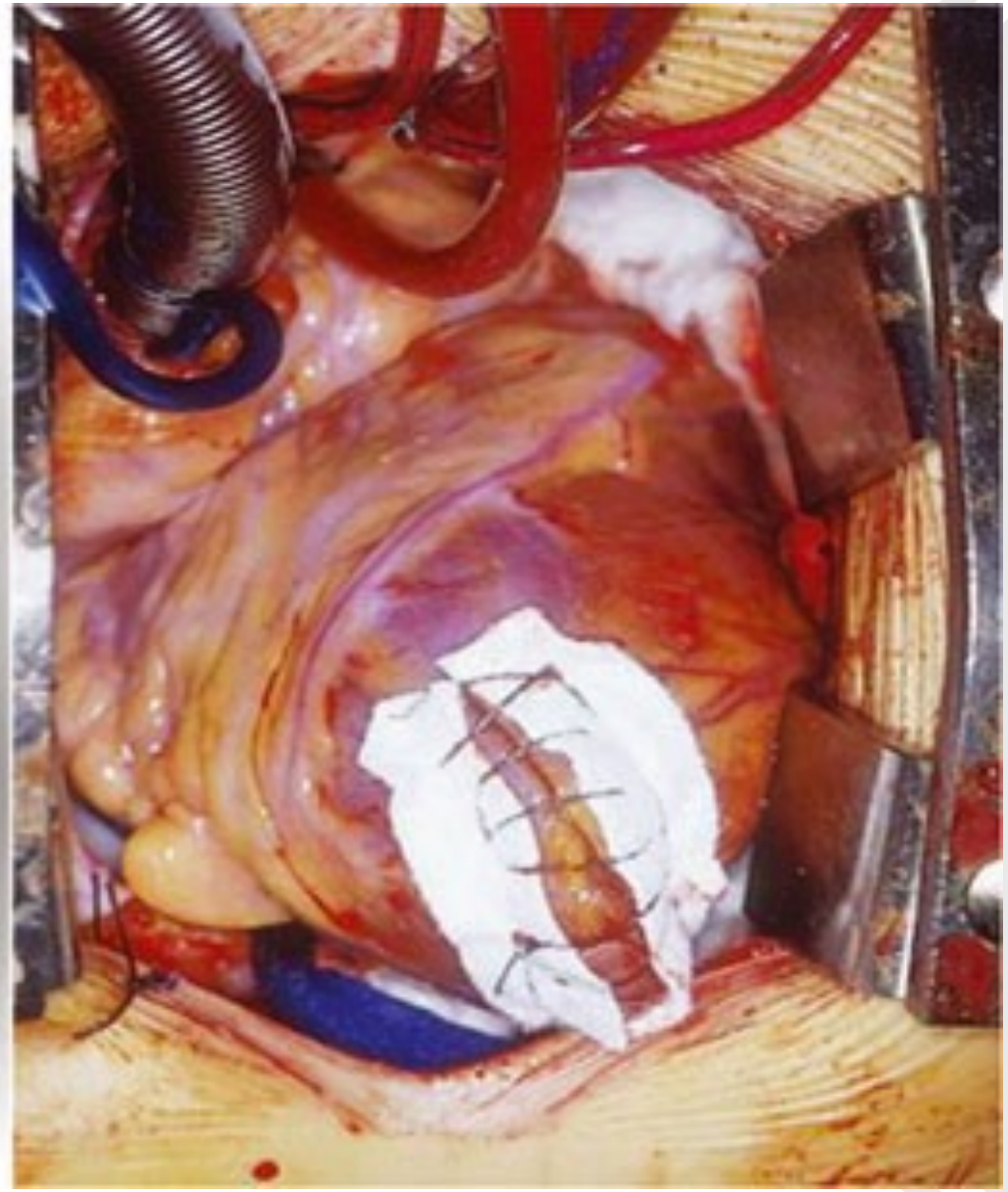





Anterolateral
Papillary muscle
Posteromedial
Papillary muscle







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- All 115 patients had relief of their gradient
- Produces area of akinesis in apex
- Increases LV stroke volume, larger LV end-diastolic volume at lower end-diastolic pressure
- Can combine with transaortic approach in tough cases

Septal Alcohol Ablation

- Creates a large septal infarct (usually transmural, occupying about 10% of the left ventricle) by infusion of absolute alcohol into the first major septal perforator artery
- Procedural mortality of 2%
- 10 – 20% likelihood of requirement of PPM
- Risk of life threatening ventricular tachyarrhythmias (and sudden death) is present, attributable to the septal scar
- Recommended as an alternative for older patients, those with comorbidities, or patients with an absolute reluctance toward surgery.
- Septal Myectomy after alcohol ablation: Alcohol ablation causes RBBB or CHB. Septal myectomy causes LBBB. So these patients are at a high risk for PPM implantation

Myectomy vs Ablation

TABLE 4. Example targets for invasive septal reduction therapies outcomes

	Rate	
	Myectomy	Alcohol septal ablation
30-d mortality	≤1%	≤1%
30-d adverse complications (tamponade, LAD dissection, infection, major bleeding)	≤10%	≤10%
30-d complete heart block resulting in need for permanent pacemaker	≤5%	≤10%
Mitral valve replacement within 1 year	≤5%	
More than moderate residual mitral regurgitation	≤5%	≤5%
Repeat procedure rate	≤3%	≤10%
Improvement ≥ NYHA class	>90%	>90%
Rest and provoked LVOT gradient <50 mm Hg	>90%	>90%

LAD, Left anterior descending; *NYHA*, New York Heart Association; *LVOT*, left ventricular outflow tract.

Conclusion

- Hypertrophic Cardiomyopathy represents a broad spectrum of disease
- Surgical septal myectomy is safe and effective for the treatment of symptomatic LVOT obstruction
- Septal myectomy can safely be performed through a mini-sternotomy unless transapical approach is warranted

Thank You for Your Attention