Heart Failure or Dysfunction?

What's the Difference?

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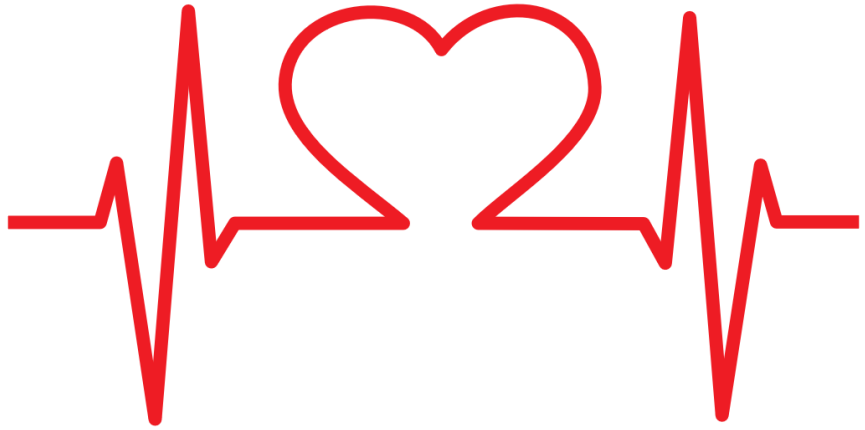
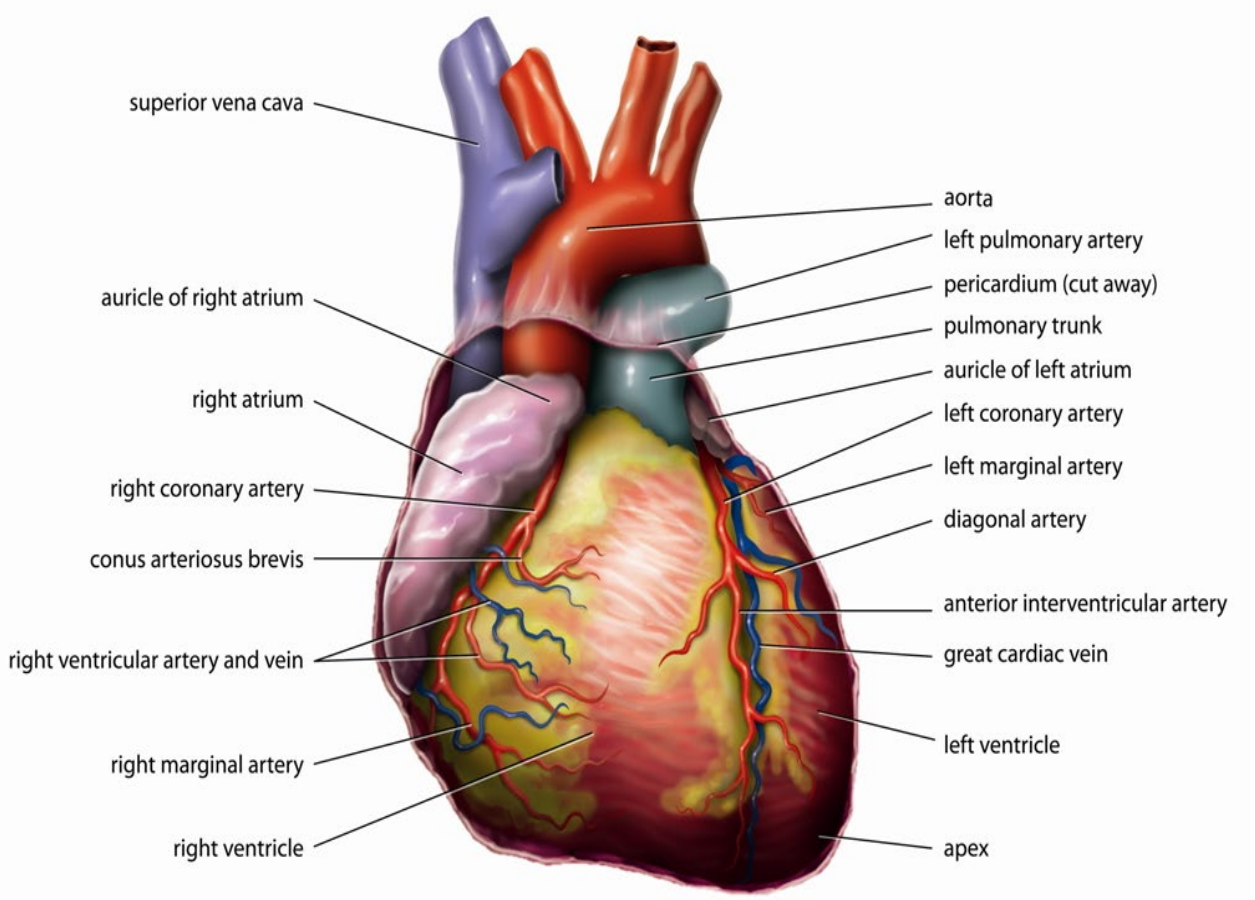
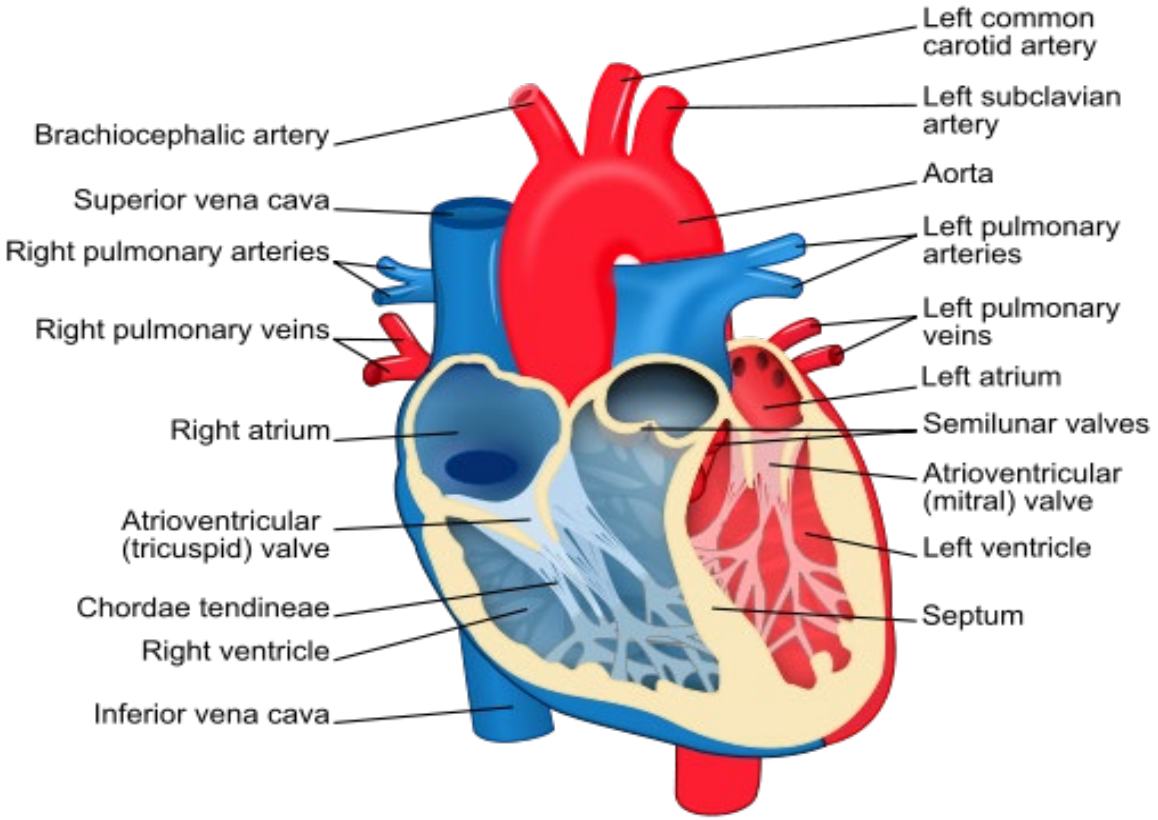
Agenda

- Systolic Function and Dysfunction
  - Ejection fraction and wall motion
  - Global longitudinal strain
  - LV dilatation
- Diastolic Function and Dysfunction
- Echo report example
- Heart Failure
- What's the difference?



Anatomy of the Heart

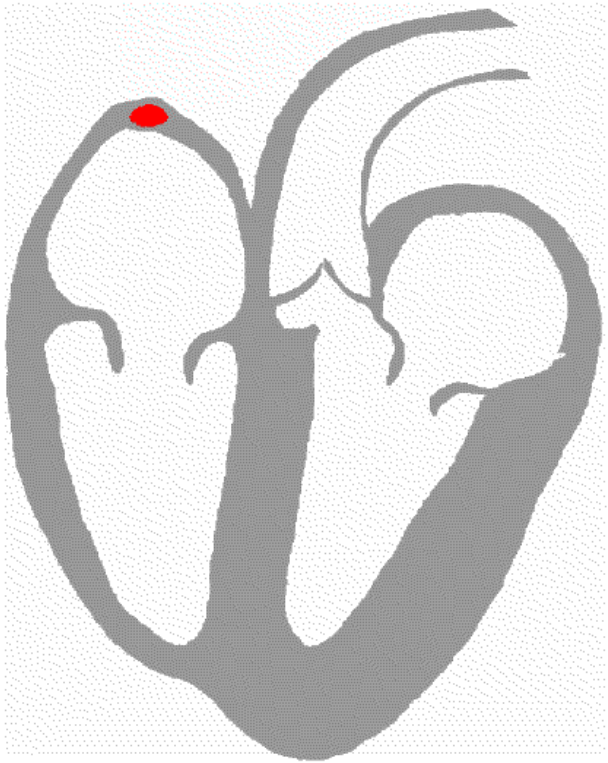




Author: Ties van Brussel Wikipedia
Author: ZooFari Wikipedia

Cardiac Output

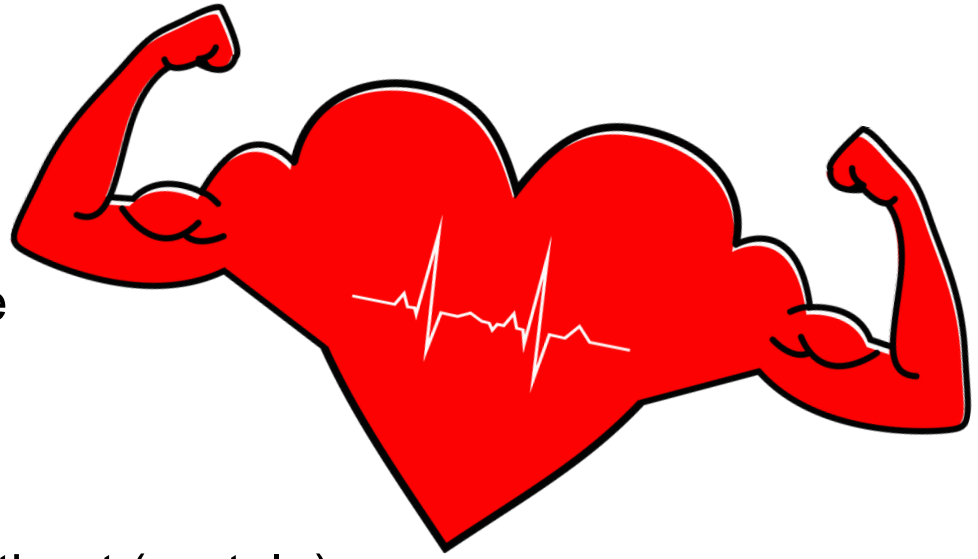
- The myocardium is constantly working
  - Cardiac output: About five liters of blood/minute
  - About 100,000 heartbeats/day
  - Pumps about 2,600 gallons of blood/day
- Cardiac reserve
  - Cardiac output may be increased to as much as 35 liters/minute
  - Early stages of disease of the heart often associated with reduced cardiac reserve
  - Cardiac reserve diminishes with aging



Author: Kalumet, selbst erstellt, 28.11.2005. - Wikipedia

Systolic Function and Dysfunction

Systolic Function: Cardiac Output



- Cardiac Output = Amount of blood pumped in one minute
  = Stroke volume x heart rate

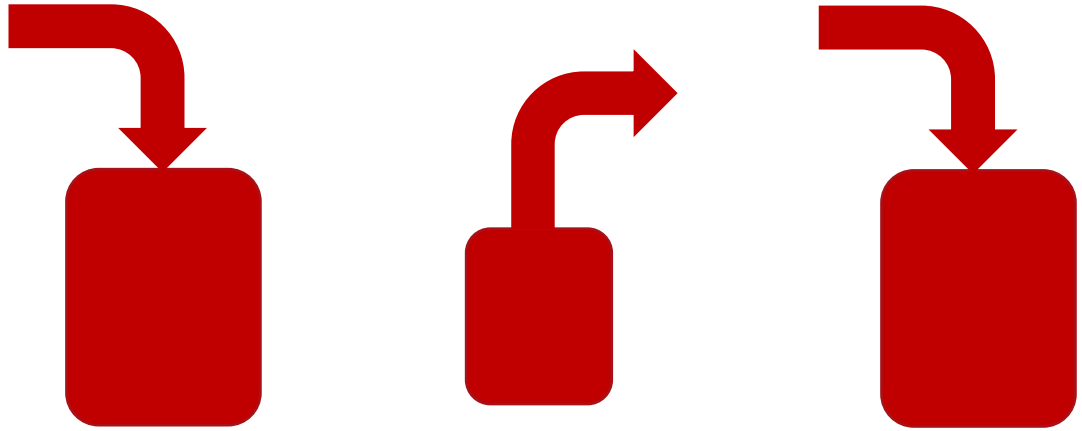
- Stroke Volume = Amount of blood pumped a single heartbeat (systole)
  = End diastolic volume – end systolic volume
  = Ejection fraction x end diastolic volume

- Ejection Fraction = Percentage of blood in ventricle at end diastole that is ejected during systole

$$= \frac{\text{Stroke volume}}{\text{End diastolic volume}}$$

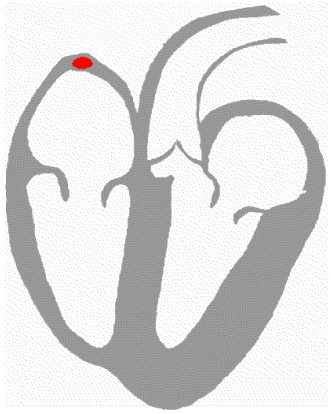
Systolic Function: Ejection Fraction and Wall Motion

- Ejection fraction
  - Normal: 50% - 75%
  - Reduced: < 50%
  - Hyperdynamic: > 75%



Diastole Systole Diastole

- Wall motion
  - Abnormal motion
    - Hypokinesis – decreased motion
    - Akinesis – no motion
    - Dyskinesis – abnormal motion
    - Hyperkinesis – increased motion
  - Focal or generalized abnormality



Left Ventricular Dilatation

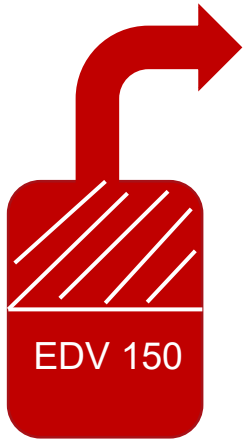
- LV dilatation is a sign of impaired systolic function
  - Myocardial damage (MI, myocarditis, CM)
  - Volume overload (AI, MR)
  - Pressure overload (HTN, AS)

Normal LV Size
- *Men - Up to 5.7 cm*
- *Women – Up to 5.4 cm*

Ejection Fraction x End Diastolic Volume = ***Stroke Volume***
Cardiac Output *= Stroke Volume x Heart Rate*

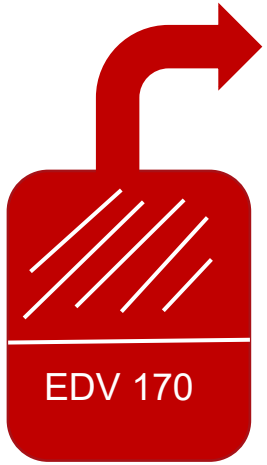
Normal LV

60% EF→ SV 72



Dilated LV

50% EF → SV 75



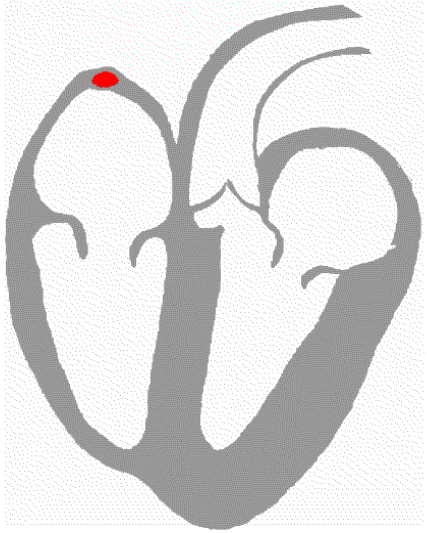
More Dilated LV

40% EF → SV 68

LV dilatation may help maintain SV and CO to a point, but is associated with reduced cardiac reserve

Systolic Function: Global Longitudinal Strain (GLS)

- Measure of longitudinal shortening of LV during systole compared to baseline
- Measured by echocardiography: speckle strain imaging
- Detects systolic dysfunction earlier than EF
- May be expressed as a negative number – use the absolute value
- Range for GLS
  - Normal: > 18%
  - Borderline: 16-18%
  - Significant systolic dysfunction: < 16%



Systolic Dysfunction

- Prevalence
  - Mayo Clinic study, ages ≥ 45, no history of heart failure: up to 6%
- Signs
  - Dilated LV
  - Decreased EF
  - Abnormal global longitudinal strain (GLS)
  - Increased NTproBNP
- Symptoms
  - Often asymptomatic (as many as 75% of cases)
  - Possibly reduced exercise capacity or DOE
  - In later stages, symptoms of heart failure
- Significance for underwriting: arrhythmias and progression to heart failure

Redfield MM et al. Burden of systolic and diastolic ventricular dysfunction in the community – appreciating the scope of the heart failure epidemic. JAMA 2003;289:194-202.

Causes of Systolic Dysfunction

Myocardial Damage

- Hypertensive heart disease
- Chronic ischemia or MI
- Myocarditis
- Cardiomyopathy
  - Dilated (nonischemic) CM
  - Tachycardia-mediated
  - Peripartum
  - Alcoholic
- Infiltrative diseases

Volume Overload

- Mitral regurgitation
- Aortic regurgitation
- Iatrogenic (over hydration)

Pressure Overload

- Aortic stenosis
- HTN
- Obstructive HCM

Miscellaneous

- Volume depletion
- Hypoxia
- Congenital heart disease
- Tachyarrhythmias
- Bradyarrhythmias

Systolic Dysfunction: Pathway to Heart Failure

Systolic Dysfunction

Heart Failure

Abnormal Global Longitudinal Strain (GLS)

Normal: >18%*
Mild abnl: 16-18%*
Mod abnl: 13-15.9%*
Sev abnl: <13%*

**May be expressed as a negative number. Use absolute number*

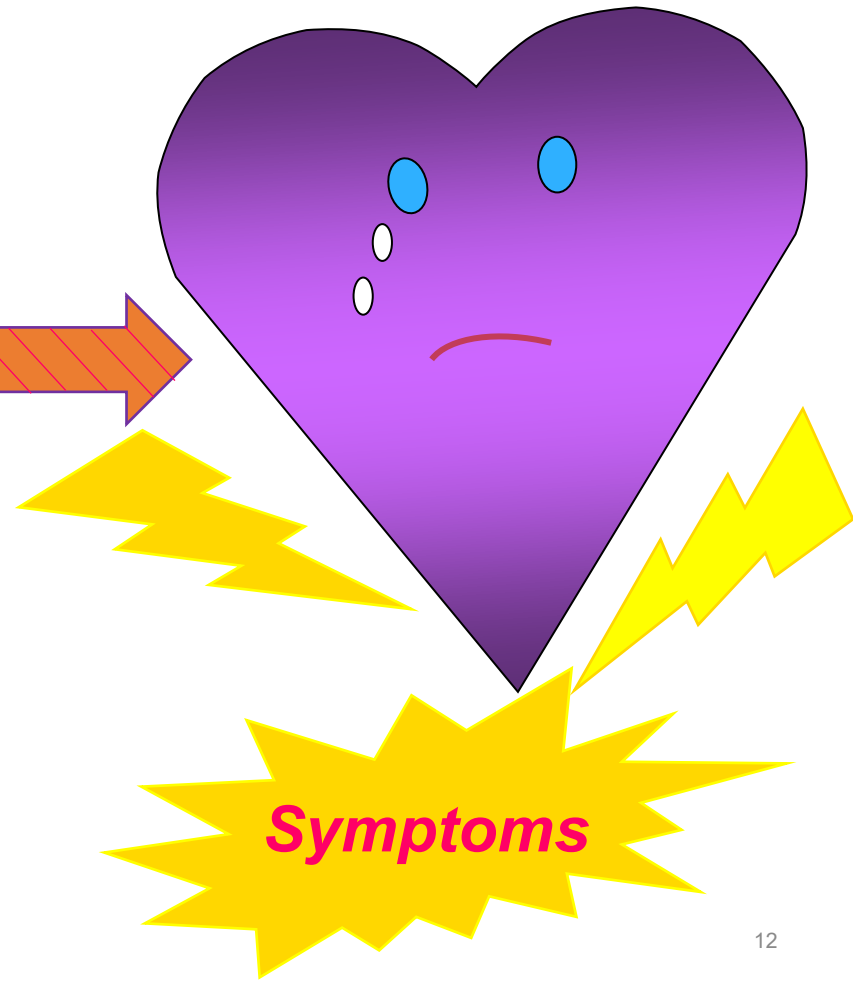
LV Dilatation

Men
- Normal: ≤5.7cm
- Mild abnl: 5.8-6.0cm
- Mod abnl: 6.1-6.4cm
- Sev abnl: >6.4cm

Women
- Normal: ≤5.4cm
- Mild abnl: 5.5-5.7cm
- Mod abnl: 5.8-6.0cm
- Sev abnl: >6.0cm

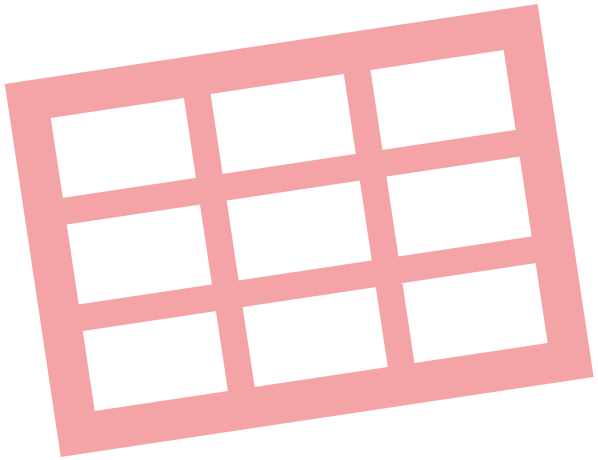
Decreased LV Ejection Fraction

Normal ≥ 50%

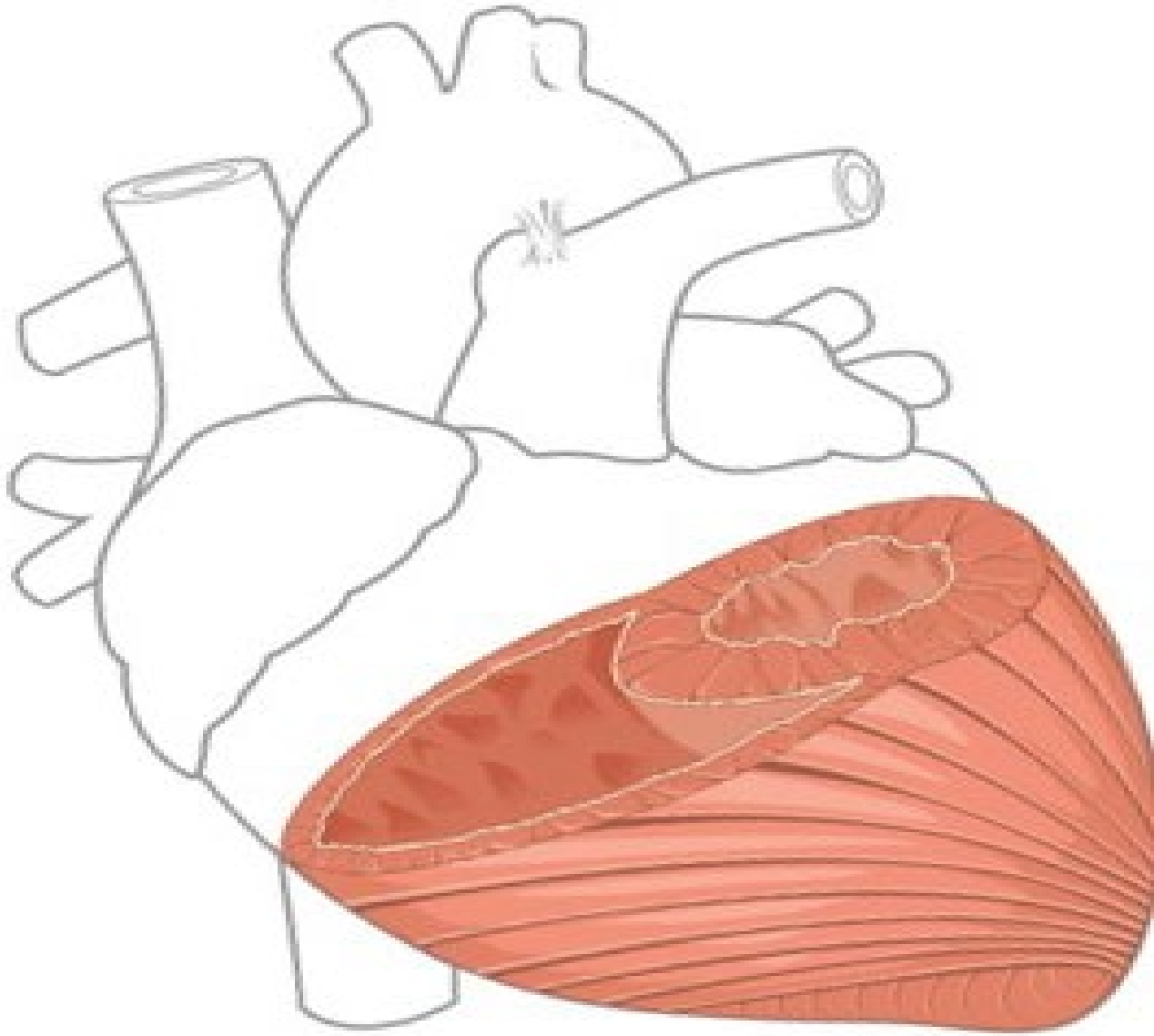


Systolic Dysfunction – Risk Assessment

- Systolic dysfunction includes
  - Decreased EF (< 50%)
  - LV dilatation
  - Abnormal global longitudinal strain (GLS)
  - Diagnosed nonischemic / dilated cardiomyopathy
- Risk depends on
  - Cause, if known
  - Age
  - LV size
  - EF and GLS
  - Arrhythmias
- Modified by NTproBNP



Diastolic Function and Dysfunction



Diastolic Function

- Includes
  - Ability of myocardium to relax in between contractions (active, energy-dependent process)
  - Compliance (stretchiness) of myocardium (characteristic of the tissue)
  - Filling pressures
    - Left atrial pressure
    - Left ventricular end diastolic pressure
- Good diastolic function is necessary for optimal cardiac function
- If ventricle doesn't fill properly, less blood gets pumped out

Ejection Fraction x End Diastolic Volume = Stroke Volume

↓ EF or ↓ EDV → ↓ SV

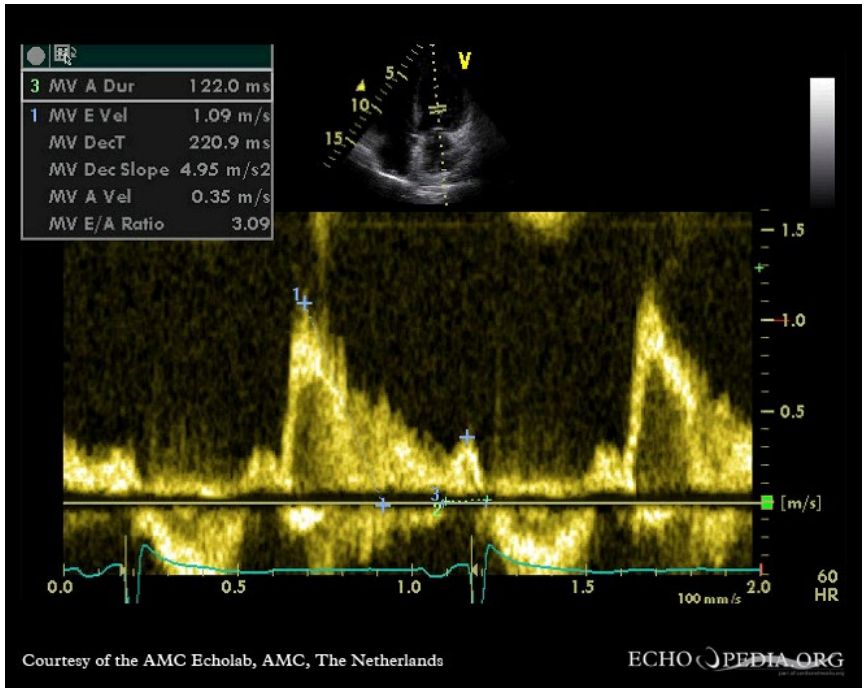
Stroke Volume x Heart Rate = Cardiac Output

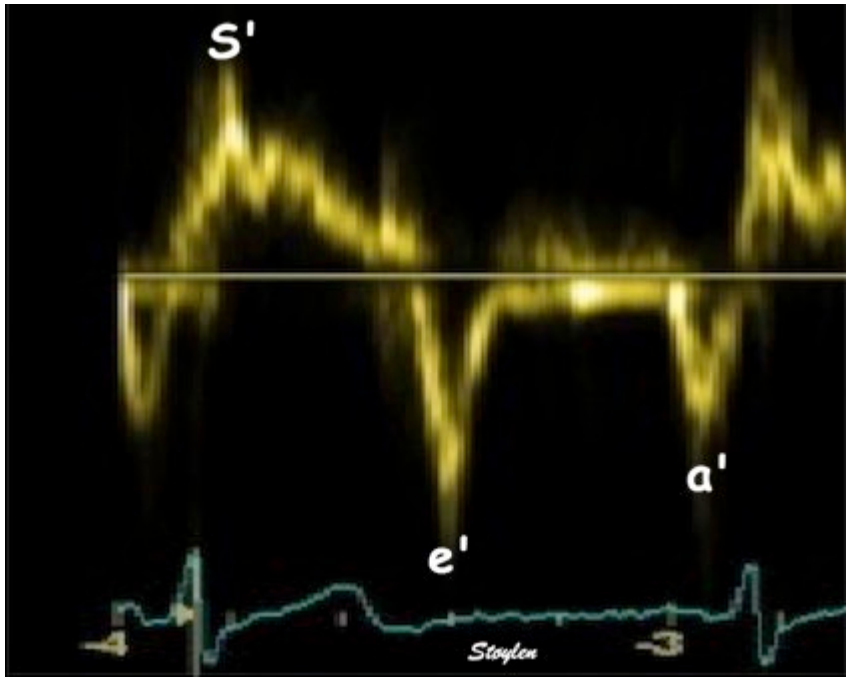
↓ SV or ↓ HR → ↓ CO

Assessment of Diastolic Function

- Difficult, complicated. No single measurement like EF
- Must consider multiple factors to determine if normal or abnormal
- If abnormal, other factors determine severity or grade
- Almost all factors dependent on Doppler echo

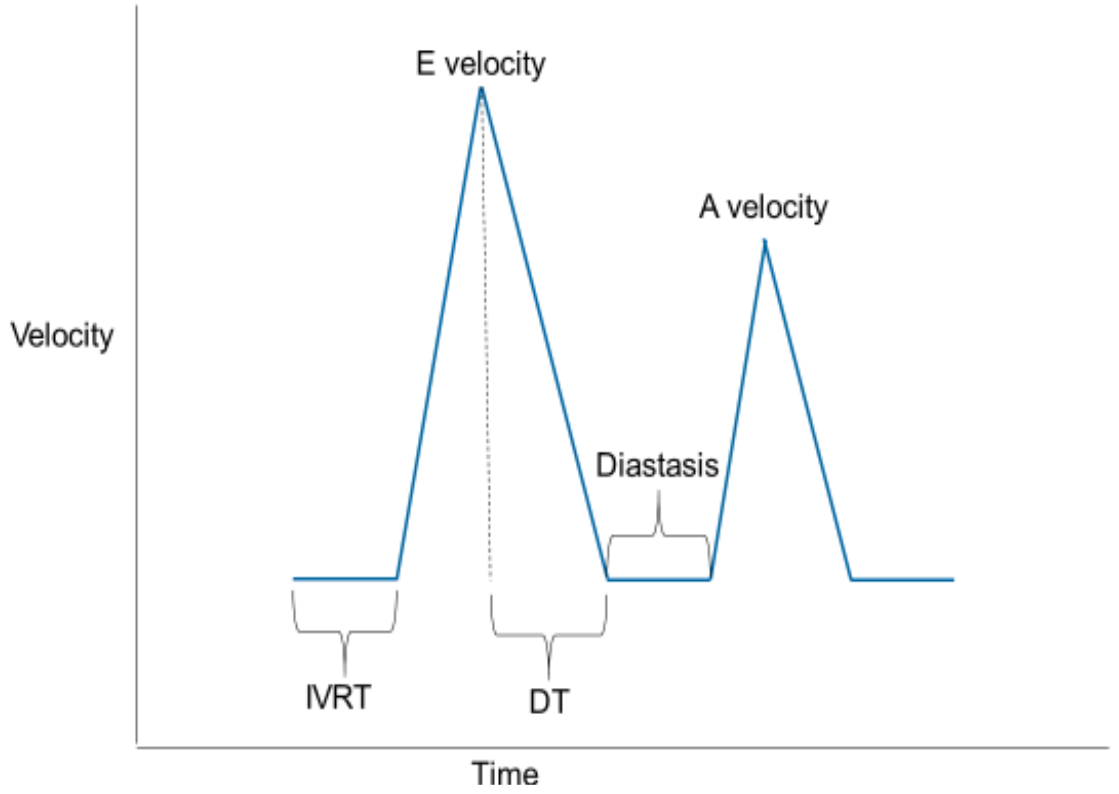
BAD NEWS



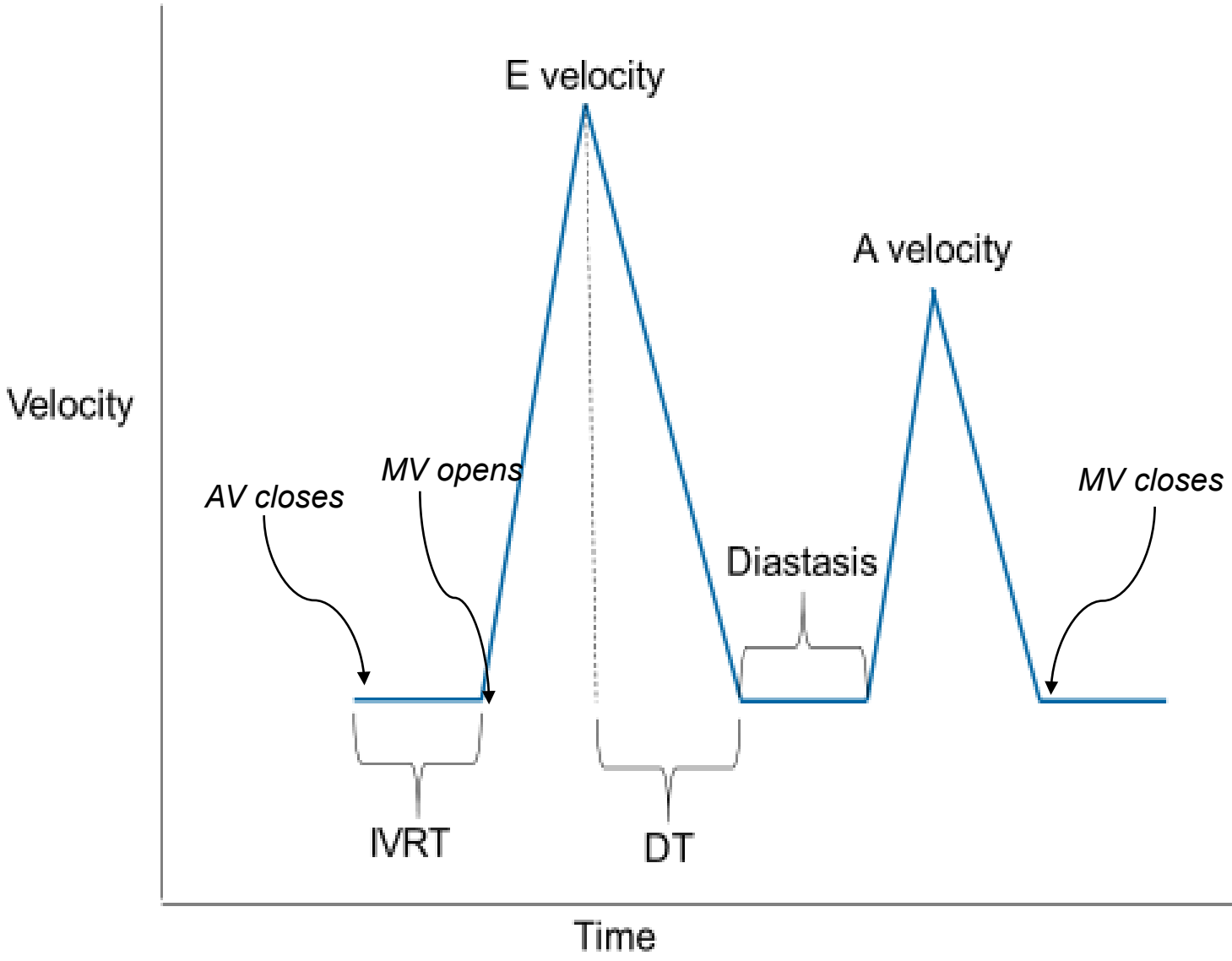


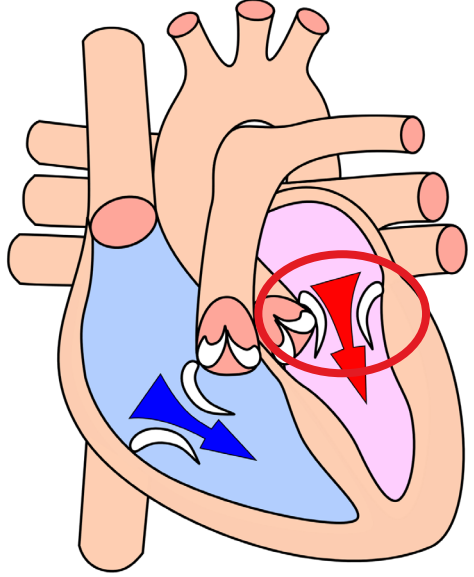
Diastolic Transmitral Flow

- One of easier ways to assess diastolic function; done often
- Measured by pulse wave Doppler (looking at blood flow characteristics)
- Only one component of diastolic function – cannot determine presence or absence of diastolic dysfunction by transmitral flow alone
- Values change with age
  - E velocity decreases with increasing age
  - A velocity increases with increasing age
  - E/A ratio decreases with increasing age



Doppler Diastolic Transmitral Flow Velocity





Diastole - time from aortic valve closure to mitral valve closure. 4 components:

- IVRT
- Early rapid filling
- Diastasis
- Late filling

E velocity – early rapid filling

A velocity – atrial contraction (late filling)

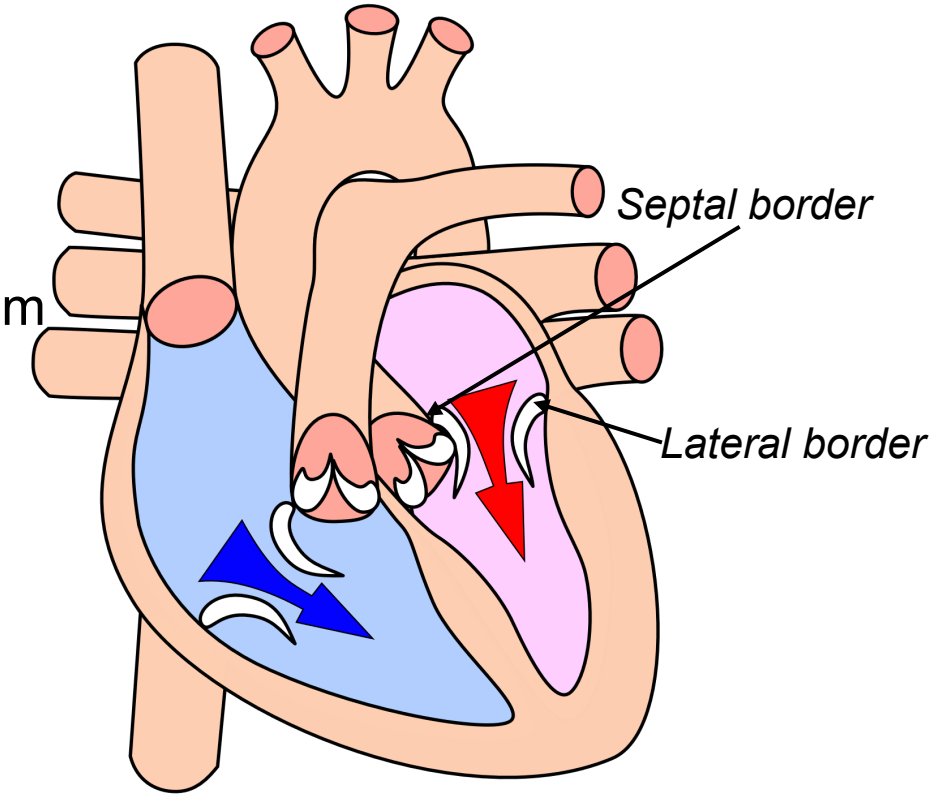
E/A ratio – normal 0.8 – 2.0 (age dependent)

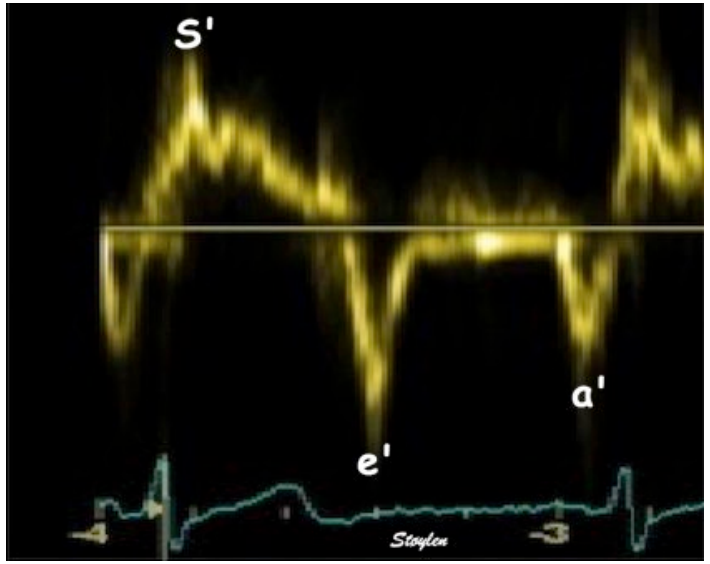
IVRT – isovolumic relaxation time

DT – deceleration time

Tissue Doppler Imaging (TDI)

- Usual (pulse wave) echo Doppler assesses flow of blood
- Tissue Doppler imaging (TDI) assesses motion of myocardium
- Assessment of diastolic function includes TDI of the septal and lateral borders of the mitral annulus
  - e' – early diastolic motion
  - a' – late diastolic motion
- e' – reflects relaxation of myocardium
- E/e' ratio – can be used to estimate left atrial pressure in those with diastolic dysfunction





Diagnosis of Diastolic Dysfunction with Normal EF

✓*Average E/e' ≥ 14*
✓*Septal e' velocity < 7 cm/s or lateral e' velocity < 10 cm/s*
✓*Peak velocity of tricuspid regurgitation > 2.8 m/s*
✓*LA volume index > 34 ml/m^2*

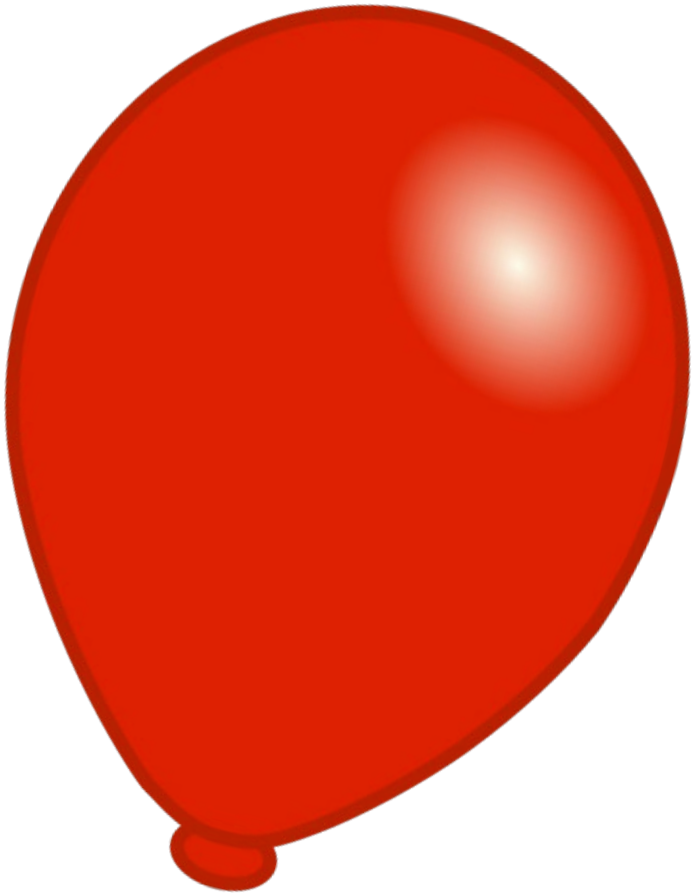
- If 0-1 of above criteria met: Normal diastolic function
- If 3-4 of above criteria met: Abnormal diastolic function
- If exactly 2 of above criteria met: Indeterminate diastolic function

Severity (Grade) of Diastolic Dysfunction

Diastolic Function	Normal	Grade 1 Impaired Relaxation	Grade 2 Pseudonormal	Grade 3 Restriction
LV relaxation	Normal	Impaired	Impaired	Impaired
LV compliance	Normal	Normal or ↓	Decreased	Decreased
LA pressure	Normal	Low or normal	Increased	Increased
Mitral inflow	E/A>0.8 but <2	E/A≤0.8 Peak E ≤50 cm/s	E/A>0.8 but <2	E/A≥2
IVRT	<70 msec	>90 msec	<90 msec	<70 msec
DT	>140 msec	>220 msec	<220 msec	<140 msec
Mitral inflow, Valsalva	ΔE/A <0.5	ΔE/A <0.5	ΔE/A ≥0.5	ΔE/A ≥0.5 (reversible) ΔE/A <0.5 (fixed)
Tissue Doppler	E/e'<10	E/e'<10	E/e' ≥10-14	E/e' ≥14
Pulmonary venous	S≥D	S>D	S<D	S<D
Peak TR velocity	<2.8	<2.8	>2.8	>2.8
LA volume index	Normal	Normal or ↑	Increased	Increased

Diastolic Dysfunction

- Prevalence
  - Mayo Clinic study, ages ≥ 45, no history of heart failure: up to 25%
- Signs
  - Echo Doppler abnormalities
  - Increased NTproBNP
- Symptoms
  - Often asymptomatic
  - Possibly reduced exercise capacity or DOE
  - In later stages, symptoms of heart failure
- Significance for underwriting
  - Marker for underlying disease process
  - Risk of progression to heart failure



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Risk Assessment for Diastolic Dysfunction

- History of heart failure – Very High Risk
- LVEF < 50% - rate for systolic dysfunction, no additional rating needed for DD
- Ratable cardiac impairment (valvular disease, cardiomyopathy, CAD, LVH) - rate for cardiac impairment, no additional rating needed for DD
- With LVEF ≥ 50%, no other cardiac impairment

Grade of Diastolic Dysfunction	Rating
Grade 1: Impaired relaxation	Very favorable, consider normal with aging
Grade 2: Pseudonormal	Favorable in absence of other abnormalities
Grade 3: Restriction	Refer to MD, usually high risk

- ✓*Average E/e' ≥ 14*
- ✓*Septal e' velocity < 7 cm/s or lateral e' velocity < 10 cm/s*
- ✓*Peak velocity of tricuspid regurgitation > 2.8 m/s*
- ✓*LA volume index > 34 ml/m²*

CO

Normal left ventricular cavity size. Normal left ventricular wall thickness. Normal global left ventricular systolic function. EF estimated at 60-65%. Abnormal diastolic filling pattern for age. Normal pulmonary artery systolic pressure.
No significant valve abnormalities noted in current study.

1. Left Ventricle: Normal left ventricular cavity size. Normal left ventricular wall thickness. Normal global left ventricular systolic function. EF estimated at 60-65%. Abnormal diastolic filling pattern for age.
2. Right Ventricle: Normal right ventricular size. Normal right ventricular global systolic function.
3. Left Atrium: Normal left atrial size.
4. Right Atrium: Normal right atrial size. Right atrial pressure estimated at 3 mmHg.
5. Interatrial Septum: Intact interatrial septum.
6. Mitral Valve: Structurally/functionally normal mitral valve. No mitral regurgitation noted.
7. Aortic V
regurgitatio
8. Tricuspi
Trace tricu
systolic pre
9. Pulmoni
pulmonary
10. Aorta:
in size.
11. Perica

- *E/A 0.81*
- *Peak velocity of TR: 208 cm/s = 2.08 m/s*
- *LA size by measured diameter is normal*
- *No tissue Doppler (e' or a') values*

MEASUREMENTS (Normal Values)

2D ECHO		
LV Diastolic Diameter PLAX	4.46 cm	4.2 - 5.9 / 3.9 - 5.3 cm
LV Systolic Diameter PLAX	2.43 cm	2.1-4.0 cm
LV Fractional Shortening PLAX	45.47 %	25-46 %
RV Internal Dim ED PLAX	2.11 cm	
IVS Diastolic Thickness	1.10 cm	
LVPW Diastolic Thickness	1.06 cm	
LA Systolic Diameter LX	3.19 cm	3.0-4.0 / 2.7-3.8 cm
LVOT Diameter	1.73 cm	
LVOT Area	2.34 cm2	
Aorta at Sinuses Diameter	2.98 cm	
LV Systolic Volume 2D Cubed	14.41 cm3	
Ascending Aorta Diameter	3.35 cm	
DOPPLER		
AV Velocity Time Integral	27.66 cm	
AV Peak Velocity	135.06 cm/s	
AV Peak Gradient	7.30 mmHg	
AV Mean Velocity	94.40 cm/s	
AV Mean Gradient	3.93 mmHg	
LVOT Velocity Time Integral	23.48 cm	
LVOT Peak Velocity	106.79 cm/s	
LVOT Peak Gradient	4.56 mmHg	
LVOT Mean Velocity	78.11 cm/s	
LVOT Mean Gradient	2.67 mmHg	
AV Area Cont Eq vti	1.99 cm2	
AV Area Cont Eq pk	1.85 cm2	
Mitral E Point Velocity	81.11 cm/s	
Mitral A Point Velocity	99.91 cm/s	
Mitral E to A Ratio	0.81	
MV Deceleration Time	220.03 ms	
TR Peak Velocity	208.27 cm/s	
TR Peak Gradient	17.35 mmHg	
PV Peak Velocity	88.88 cm/s	
PV Peak Gradient	3.16 mmHg	

Diagnosis of Diastolic Dysfunction with Normal EF

Case Details

- *E/A 0.81*
- *Peak velocity of TR: 208 cm/s = 2.08 m/s*
- *LA size by measured diameter is normal*
- *No tissue Doppler (e' or a') values*

Diagnostic Criteria for Diastolic Dysfunction

✓Average E/e' ≥ 14
✓Septal e' velocity < 7 cm/s or lateral e' velocity < 10 cm/s
✓Peak velocity of tricuspid regurgitation > 2.8 m/s
✓LA volume index > 34 ml/m^2

If 0-1 of above criteria met: Normal diastolic function
If 3-4 of above criteria met: Abnormal diastolic function
If exactly 2 of above criteria met: Indeterminate diastolic function

Summary
0 criteria met
2 unknown
At worst, indeterminate

Risk Assessment for Diastolic Dysfunction

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Grade 2: Pseudonormal	Favorable in absence of other abnormalities
Grade 3: Restriction	Refer to MD, usually high risk

Indeterminate Diastolic Function: Consider favorably

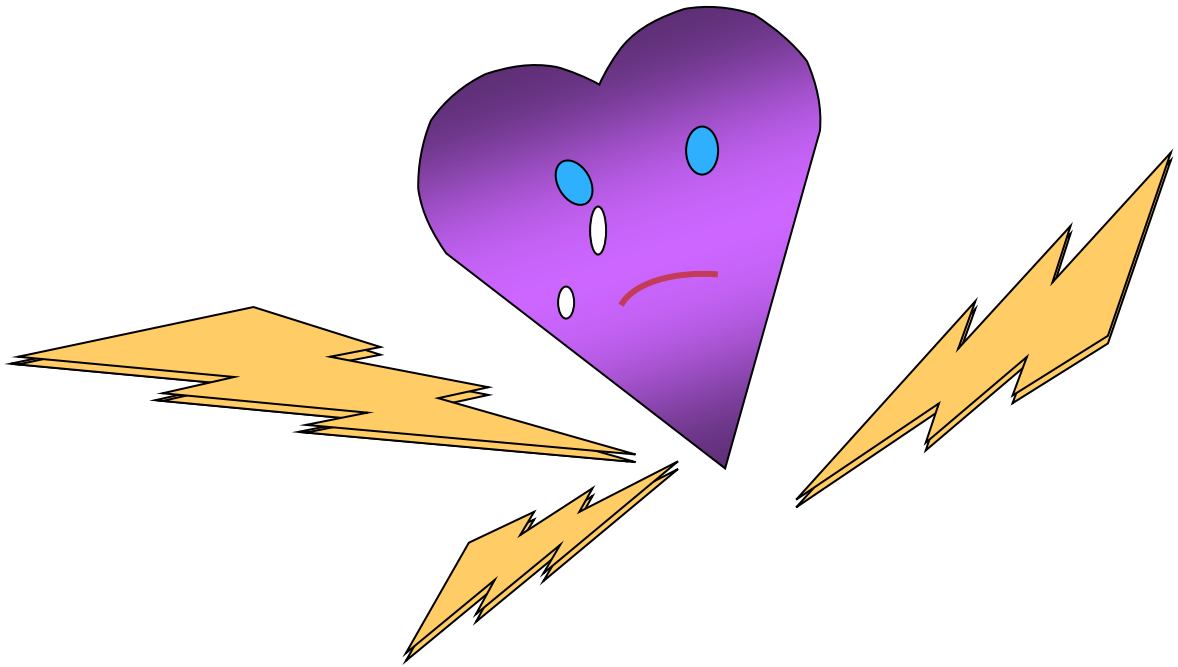
Heart Failure

Public domain

What is Heart Failure?

"Heart failure is a complex clinical syndrome that results from any structural or functional impairment of ventricular filling or the ejection of blood."

"Heart fails to pump blood at a rate commensurate with the requirements of metabolizing tissues or is able to do so only with an elevated diastolic filling pressure"



Signs and <u>symptoms</u> of inadequate cardiac output

Yancy CW et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. JACC 2013;62:e147-239.

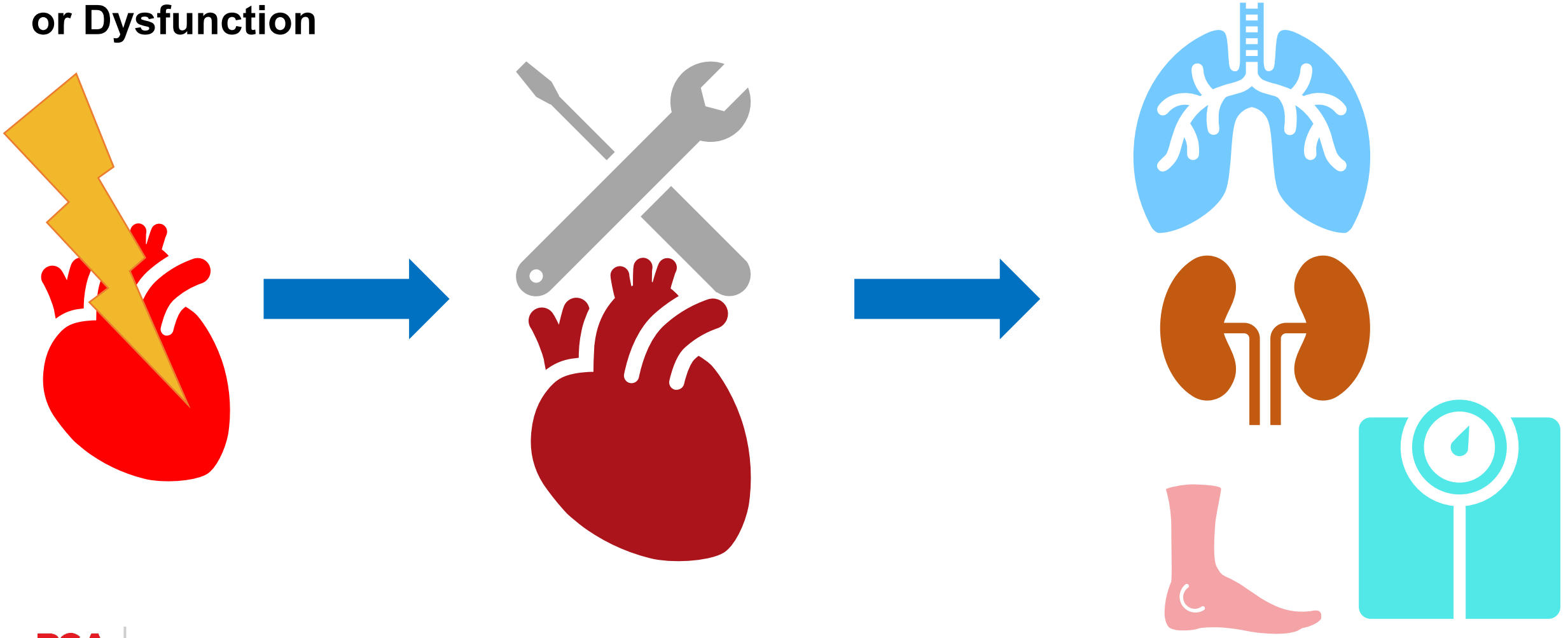
Dumitru I. Heart Failure. The Heart.org/Medscape. Updated 3/2/21. Accessed 7/7/21

Pathophysiology of Heart Failure

Myocardial Damage or Dysfunction

Compensation

Signs and Symptoms



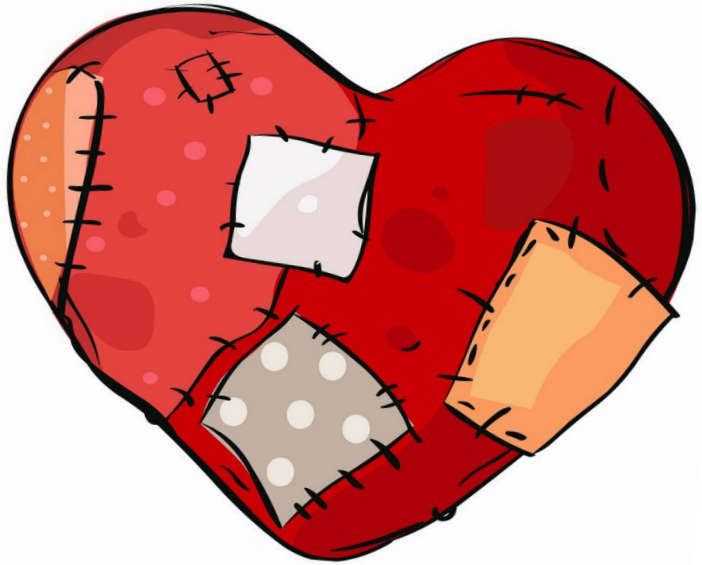
Cardinal Manifestations of HF

- Dyspnea, fatigue and exercise intolerance
- Symptoms of fluid retention
  - PND, orthopnea and nocturnal cough
  - Cardiac asthma (wheezing)
  - Anorexia, nausea, early satiety
  - Right upper quadrant pain
  - Peripheral edema

In heart failure, there is poor correlation between measures of cardiac performance and symptoms

Causes of Heart Failure

- Risk Factors
  - Obesity
  - Hypertension
  - Diabetes/Metabolic syndrome
  - Atherosclerotic disease
- Any cardiac disease: Final Common Pathway
  - CAD
  - Myocarditis/Cardiomyopathy
  - Valvular heart disease
  - Congenital heart disease
  - Hypertensive heart disease
  - Chronic arrhythmias
  - Pericardial diseases
- Chronic lung disease
- Pulmonary vascular disorders
- High output states such as thyrotoxicosis, chronic anemia, systemic AV shunting



Epidemiology

- Worldwide problem, with more than 20 million affected (5 million in US)
- Prevalence in developed countries about 2% and increasing
- Incidence increases with age
- May occur with normal (preserved) EF – HFpEF (40 - 50% of cases)
- May occur with reduced EF – HFrEF (50-60% of cases)
- Development of symptomatic heart failure carries poor prognosis
  - > 20% die within 1 year of diagnosis
  - 50% die within 5 years of diagnosis
  - Functional class (NYHA) is a predictor of outcome

Heart Failure with Reduced or Preserved (Normal) Ejection Fraction

HFrEF

Heart Failure with Reduced EF

- Formerly called systolic heart failure
- Impaired ability to eject blood (systolic dysfunction)
- Reduced ejection fraction, usually ≤ 40%
- Wall motion abnormalities
- Often dilated LV (50% of cases)

HFpEF or HFnEF

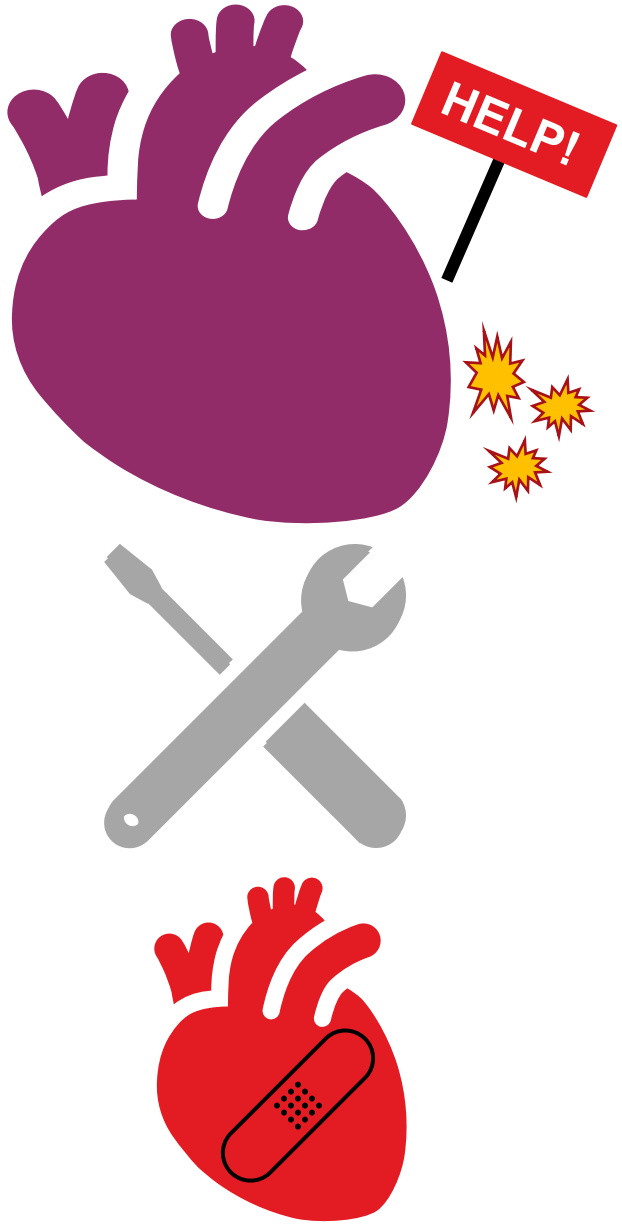
Heart Failure with Preserved or Normal EF

- Formerly called diastolic heart failure
- Impaired ability to fill with blood (diastolic dysfunction)
- Normal ejection fraction, usually ≥ 50%
- Often thick walls (LVH) with dilated LA
- Usually normal LV size
- Diagnosis of exclusion

Additional Terminology

- Overt or Decompensated heart failure
  - Signs and symptoms present
  - Acute episode of pulmonary edema
  - Increasing lethargy and malaise
  - Decreased exercise tolerance/increased DOE

- Compensated heart failure
  - Improved or no signs or symptoms currently
  - Stabilized on medications
  - Prone to “decompensating” and requiring med adjustment
  - Limited cardiac reserve



What is Heart Failure? Everything You Need to Know by Dr. Jason L. Guichard 3/16/14. MyHeart.net

Stages of Heart Failure

ACC/AHA Stage	Description	NYHA Class
A	*At high risk for heart failure* but without symptoms, structural heart disease or blood tests indicating myocardial injury (Ex: HTN)	None
B	*Pre-heart failure*. No signs or symptoms of heart failure, but evidence of one of the following: • Structural heart disease (Ex: reduced EF, LV enlargement, LVH, valvular heart disease) • Increased filling pressures as measured by cath or echo • Risk factors from Stage A plus elevated BNP/NTproBNP or persistently elevated troponin	None
C	Symptomatic heart failure. Structural heart disease with previous or current symptoms of heart failure	Could be Class I, II or III
D	Advanced heart failure with symptoms that interfered with daily life, are difficult to control and result in recurrent hospitalizations despite guideline-directed medical therapy	Class IV

Heidenreich PA et al. 2022 AHA/ACC/HFSA guideline for the management of heart failure. J Am Coll Cardiol 2022;79:e263

Key Takeaways

- ✓ LV dilatation is a key marker for systolic dysfunction
- ✓ Risk with systolic dysfunction should be assessed according to
  - Cause, if known
  - Age
  - LV size
  - EF
  - GLS
- ✓ Diastolic function and dysfunction is very complicated to assess, but has limited mortality implication in isolation
- ✓ Systolic and diastolic dysfunction can lead to heart failure
- ✓ Heart failure means symptoms related to inadequate cardiac function
- ✓ Mortality and morbidity are very high in heart failure