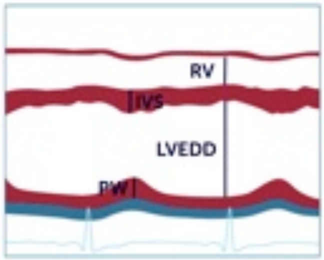
003 // Heart Chambers and Walls

The Left Ventricle

Quantification of LV Diameter		
		
PLAX	MMODE	4 ch view

NOTE: only use MMode values if your line of interrogation is perpendicular to the LV cavity and walls

NOTE: Measure end-diastolic diameter where the LV is largest, shortly before contraction begins (beginning of QRS complex).

LVED Diameter — Reference Values	♂	♀
Normal (mm)	42—59	39—53
Mild (mm)	60—63	54—57
Moderate (mm)	64—68	58—61
Severe (mm)	≥ 69	≥ 62

NOTE: Measure distances between the endocardial borders, not the pericardium (lateral)

LVED Diameter/Body Surface Area (BSA) — Reference Values	♂	♀
Normal (cm/m^2)	2.2—3.1	2.4—3.2
Mild (cm/m^2)	3.2—3.4	3.3—3.4
Moderate (cm/m^2)	3.5—3.6	3.5—3.7
Severe (cm/m^2)	≥ 3.7	≥ 3.8

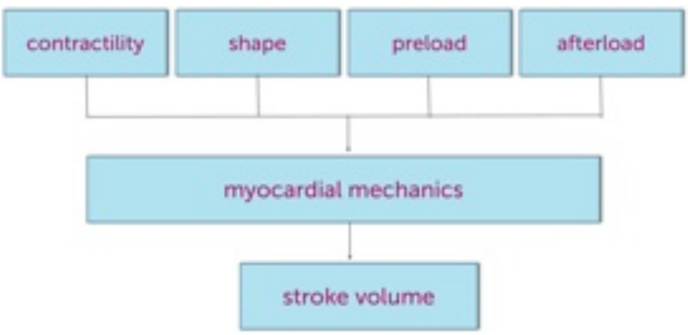
NOTE: Normal chamber size increases with body surface area (and body size)

LV Diastolic Volume (4ch view) — Reference Values		
	♂	♀
Normal (mL)	67—155	56—104
Mild (mL)	156—178	105—117
Moderate (mL)	179—200	118—130
Severe (mL)	≥ 201	≥ 131
NOTE: Volume measurements are superior to diameter and area measurements		

LV Systolic Volume (4ch view) — Reference Values		
	♂	♀
Normal (mL)	22—58	19—49
Mild (mL)	59—70	50—59
Moderate (mL)	71—82	60—69
Severe (mL)	≥ 83	≥ 70
NOTE: Don´t exclude the papillary muscles when tracing the LV volumes. Their volumes should be included in the calculation		

Pathophysiology

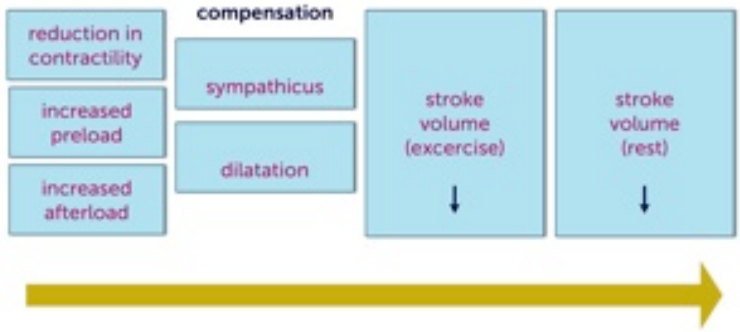
Principles of LV Function:



Factors influencing ejection fraction / stroke volume

NOTE: A reduction in longitudinal function is an early marker of LV dysfunction

Pathophysiology of LV Failure: Cascade and Compensatory Mechanisms



NOTE: Contractility, pre- and afterload influence myocardial function. A reduction in contractility is initially compensated by an activation of the sympathetic nervous system (compensatory increase in heart rate and contractility) as well as dilatation of the LV. Stroke volume is kept adequate at rest but can not adapt to exercise (reduced functional reserve). In the endstage stroke volume is also reduced at rest (decompensation)

LV Function

Parameters of LV Function		
	Fractional shortening	Cardiac output/index
	"Eyeballing" of LVF	Deformation parameters (strain, strain rate)
	Ejection fraction (EF) - Simpson method	Contractility (dp/dt)
	Stroke volume	Tei index
	TDI velocity of the myocardium	MAPSE (mitral annular plane systolic excursion)

NOTE: LVF and (longitudinal) contractility can be reduced despite „normal" ejection fraction. Especially in patients with small ventricles

Fractional Shortening — Reference Values		
	♂	♀
Normal	25 - 43%	27 - 45%
Mild	20 - 24%	22 - 26%
Moderate	15 - 19%	17 - 21%
Severe	≤ 14%	≤ 16%

NOTE: Fractional shortening is a rough estimate of global left ventricular function. Do not use the Teichhholz formula to derive an ejection fraction from these values

Fractional Shortening — Contraindications		
	LBBB / Dyssynchrony/ Pacemaker	Abnormal septal motion
	Regional wall motion abnormalities	Inadequate (oblique) MMode orientation
	Poor image quality	“Pseudo-shortening“ of the LV (very small ventricle)

NOTE: In these settings fractional shortening can either over- or underestimate left ventricular function

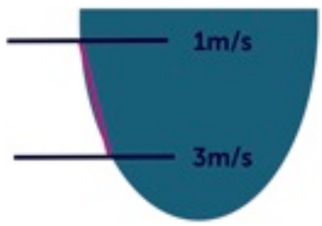
Ejection Fraction — Simpson Method		
$EF = \frac{ED_{vol} - ES_{vol}}{ED_{vol}} \times 100$	Normal	> 55 %
	Mild	45 — 54 %
	Moderate	30 — 44 %
	Severe	< 30%

NOTE: 1) Ejection fractions tend to be higher in small ventricles. 2) Athletes often have ejection fractions in the low normal range. 3) Ejection fraction does not predict exercise capacity. 4) Ejection fraction is super-normal in patients with reduced afterload (e.g. mitral regurgitation)

Stroke Volume, Cardiac Output, Cardiac Index — Reference Values		
	Rest	Exercise
Stroke volume	70 – 110mL	80 – 130mL
Cardiac output	5 – 8.5 L/min	10 – 17 L/min
Cardiac index	> 2.5 L/min/m^2	> 5 L/min/m^2

NOTE: The calculation of these parameters critically depend on the correct measurement of the LVOT width.

dP/dt — Reference Values



Normal	> 1200 mmHg/sec
Borderline	800 — 1200 mmHg/sec
Reduced	< 800 mmHg/sec
Severly reduced	< 500 mmHg/sec

Limitations: Mitral regurgitation (MR) signal needed, inexact, not completely load independent

NOTE: A rough estimate of contractility can also be obtained by eye balling the slope of the MR curve.

The Right Ventricle

Characteristics

Wall thinner (<5mm)	Moderator band
Trabeculations	Wraped around LV

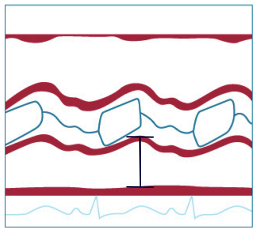
Measurement of RV (ASE Guidelines 2010)	
Measurements of the Right Ventricle	
	Abnormal
RV basal diameter	>4.2cm
RV subcostal wall thickness	>0.5cm
RVOT PSAX distal diameter	>2.7cm
RVOT PLAX proximal diameter	>3.3cm
RV systolic function	
TAPSE	<1.6- 1.8cm
PW Peak at the annulus	<10 cm/s
PW myocardial performance index	>0.4
Tissue doppler myocardial performance index	>0.55
NOTE: Longitudinal strain of the free right ventricular wall is a promising new technique.	
RV diastolic function	
E/A ratio	<0.8 or >2.1
E/e'	>6
Deceleration time (ms)	<120ms
NOTE: The RV diameters appears larger if the transducer position is too far cranial!	

Causes of RV Dilatation		
	Dil. CMP	Right heart infarction
	Myocarditis	Pulmonary embolism/ hypertension
	Right ventricular dysplasia	RV volume overload (e.g. ASD, TR, pulmonic regurgitation
NOTE: Always search for a cause of RV dilatation!		

FAC — Reference Values	
Normal	> 39 %
Mild	35—39 %
Moderate	30—35 %
Moderate- severe	25—30 %
Severe	< 25 %
NOTE: Trace the RV contour in diastole and systole in an optimized 4-ch view. to obtain the areas. Calculate the percentage of change. (RV Area enddiastole – RV Are ensystole)/ RV area enddiastole *100	
NOTE: Tracing of RV contour may be difficult (trabeculations, thin wall)	

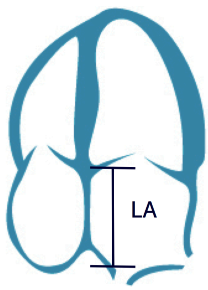
The Left Atrium

MMode Measurements of LA — Reference Values		
	♂	♀
Normal (mm)	30—40	27—38
Mild (mm)	41—46	39—42
Moderate (mm)	47—52	43—46
Severe (mm)	≥ 52	≥ 47

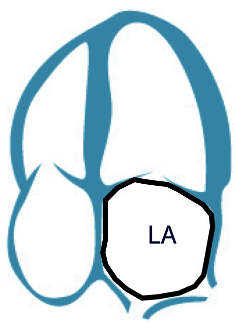


NOTE: LA size and volume predict events (i.e. Afib, stroke) and is a marker of disease severity.

LA Length — Reference Values (4ch view)	
Normal (mm)	≤ 50
Mild (mm)	51—60
Moderate (mm)	61—70
Severe (mm)	> 70



LA Area — Reference Values	
Normal (cm^2)	≤ 20
Mild (cm^2)	20—30
Moderate (cm^2)	30—40
Severe (cm^2)	> 40



$V = \frac{8\pi}{3} \times \frac{A_{4c} \times A_{2c}}{L}$	LA Volume (Area Length Method) — Reference Values		Practical Scale
	♂	♀	
Normal (mL)	18 - 58	22 - 52	<40
Mild (mL)	59 - 68	53 - 62	40- 70
Moderate (mL)	69 - 78	63 - 72	70- 90
Severe (mL)	$\geq$ 79	$\geq$ 73	> 90
NOTE: LA volume measurements are superior to MMode and 2D diameter measurements. LA volumes >200ml denote very severe atrial dilatation (LA volumes > 1L have been reported)			

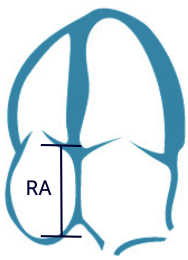
Pittfalls Calculating LA Volume		
	Inclusion of pulm. veins	Tenting area of MV
	Alignment / atrial foreshortening	Lateral resolution
	Measuremtent not performed at end-systole	Oblique view of the LA
NOTE: Optimize the 4ch view specifically to the left atrium to obtain best results.		

Parameters of LA Function		
	Doppler (MV inflow)	Area changes systolic/ diastolic
	Pulmonary vein flow	TDI / 2D Strain
NOTE: In most cases the Doppler (MV-inflow) signal is sufficient to estimate LA function! Functional assessment of the LA is still a matter of ongoing research.		
NOTE: The area under the A-wave correlates with the ejection of blood by the left atrium (atrial contraction) into the left ventricle (booster pump function). A small A-wave either means there is poor contraction, high resistance to filling or the main portion of blood has already entered the ventricle during passing filling phase.		

Causes of LA Dilatation		
	Diastolic dysfunction (hypertension)	Mitral stenosis/regurgitation
	Aortic stenosis	Restrictive/hypertrophic CMP
	Atrial fibrillation	Impaired LV function

The Right Atrium

Causes of RA Dilatation		
	Pulmonary hypertension	TV - disease
	RV - failure	Atrial fibrillation
NOTE: The RA can be stretched in length if the LA expands		

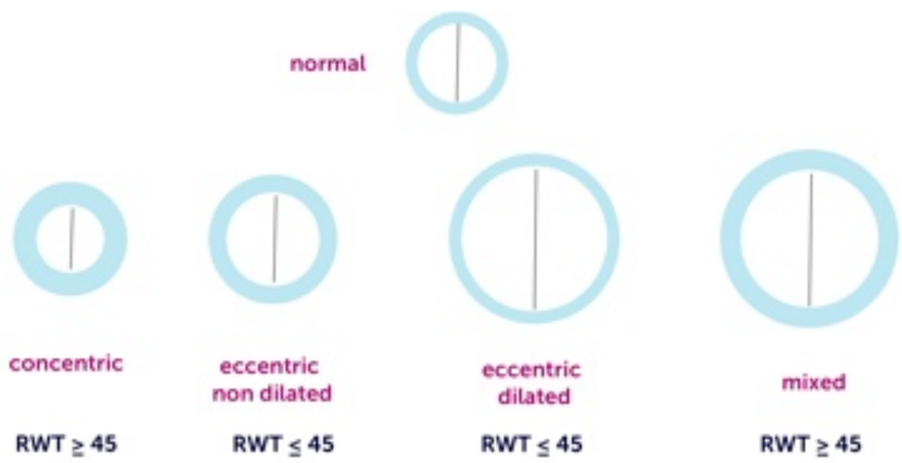
RA Length — Reference Values (4ch view)		
Normal (mm)	29—45	
Mild (mm)	46—49	
Moderate (mm)	50—54	
Severe (mm)	≥ 55	
NOTE: For practical reasons you can also use the scale presented for the left atrium.		

Coronary Sinus
Reference value = 4-8mm (upper limit 15 mm)
Causes of a dilated coronary sinus: elevated RA pressure, V. cava sin. persistens, malformation (aneurysm/diverticula)

Vena Cava Inferior
Size < 17mm, Inspiratory collapse ≥ 50%
NOTE: The normal size of the VCI varies greatly. VCI size reflects fluid status, central venous pressure, tricuspid regurgitation and allows an estimation of RA pressure!
NOTE: A large vena cava inferior does not always indicate a medical condition. Some patients simply have a large vena cava inferior (even in the absence of elevated RA pressure.

Left Ventricular Hypertrophy

Forms of LVH



Relative Wall Thickness (RWT) (PWT = posterior wall thickness) (LVID = Left ventricular internal dimension)	$RWT = \frac{2 \times PWT}{LVID}$	Normal values 22— 42 %

NOTE: Most patients with hypertension have concentric LVH

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Quantification of LVH — Septal Thickness Severity		
	♂	♀
Normal (mm)	6—10	6—9
Mild (mm)	11—13	10—12
Moderate (mm)	14—16	13 — 15
Severe (mm)	≥ 17	≥ 16

2D-measurements: end diastole, mid septum, 4ch view

Potential problems: Measurements were not performed at enddiastole (2D)", RV structures interfere with measurement, shape of the IVS (basal septal buldge), incorrect MMode orientation (non-perpendicular)

Sigmoidal Septum		
	Less than 3 cm in length	Associated with HTN/
	Not associated with hypertrophic CMP	Associated with LVH

NOTE: May cause obstruction and SAM especially in certain clinical conditions (hypovolemia, hyperkinesia, catecholamines).

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Quantification of LV Mass (Devereux Formula)

$$LV\ mass\ (AL) = 1{,}05 \times \{[\,^5/_6 \times A_1 \times (a + d + t)] - [\,^5/_6 \times A_2 \times (a + d)]\}$$

NOTE: LV mass better reflects the extent of LVH then measurements of septal thickness. But only perform LV mass measurement in patients with good image quality!

LV Mass — Reference Values

	♂	♀
Normal (g/m^2)	50 - 102	44 - 88
Mild (g/m^2)	103 - 116	89 - 100
Moderate (g/m^2)	117 - 130	101 - 112
Severe (g/m^2)	≥ 131	≥ 113

Additional Findings in Hypertensive Patients

Left atrial enlargement	RV hypertrophy
Diastolic dysfunction	Dilated aorta
AV sclerosis	Mitral annular calcification

NOTE: If these findings are present it is likely that LVH is a consequence of hypertension

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Athlete's Heart		
Septum rarely > 13mm	Normal or supernormal diastolic function	
Only following intensive, prolonged endurance training (> 1h/d) over years	RWT ≤ 45	

NOTE: Endurance training/isotonic (i.e. marathon running) causes a more eccentric form of LVH vs. isometric exercise (i.e. weight lifting) causes a more concentric form of LVH.

NOTE: Deconditioning reverses LVH

Differential Diagnosis: Hypertension vs. Hypertrophic CMP		
	HTN	HCMP
RR	+	-
Sclerosis/Calcification of valves	+	(-)
Noncardiac manifestions of HTN	+	-
Young age	-	+
Fam. history of HCMP	-	+
Genetics	-	+
Strain	Basal/global longitudinal strain reduced	Patchy reduced