ESC echo examen TTE

- Indeling:
  - Fysiologie
  - Formules
  - Normaalwaardes
  - Guidelines

Fysiologie

- Echogolven: backscatter, refractie en transmissie
  - Backscatter produceert het meeste van het ultrasound beeld
  - Refractie en transmissie komen niet terug naar de transducer

Fysiologie formules

- V = f x wavelength
  - Snelheid ultrasound soft tissue 1540m/s
  - Gemakkelijke formule: 1.54 / Mhz = wavelength in mm
  - Snelheid geluid in bot hoger dan bloed, soft tissue, lucht
- L (length of the nearfield) = r 2 / wavelength
  - Hoe hoger de frequentie, hoe langer de nearfield
- Doppler shift = 2 x f 0 x v / c cos hoek

Fysiologie

- Pulse duration or length (mm)
  - Physical length that pulse occupes
  - Affected by source of ultrasound
- PRF
  - Rate at which pulses are emitted from transducer
  - Affected by source of ultrasound
  - 77.000/depth in cm
- Duty factor (N 0.1%)
  - Fraction of time that transducer is emitting ultrasound
  - Pulse duration / dead time
- Impedance
  - Rayls: density in kg/m3 x speed of sound in m/s
  - Differences in impedance determine the ratio of transmitted versus reflected sound

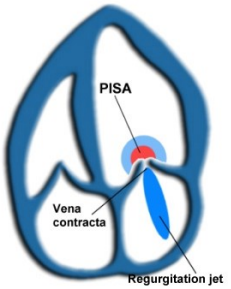
Resolutie

- Spatial resolutation
  - Axial resolution (Z)
    - Pulse length, transducer frequency
  - Lateral resolution (X, Y)
    - Beam width, depth, gain
- Temporal resolutie
  - Synoniem = frame rate
  - Depth, sweep angle, line density, PRF

Belangrijke formules

- PISA
- Continuity equation
- Bernouilli
- Flow en CO
- PHT

PISA



- Principe = PISA flow gelijk aan MR flow
  - 2 pi r2 x Vn (Q in cc / sec) = ERO x MR Vmax
- ERO = flow rate / MR Vmax
  - MR velocity in cm / s
- ERV = ERO x VTI MR

Bernouilli

- Snelheid is een schatting van de drukgradient over een klep, naar aanleiding van de eerste wet van behoud van energie (Newton)

- Vereenvoudigde vergelijking
  - Drukgradient = 4 x v 2
  - Niet meegenomen: deceleratie na klep en viscositeit bloed

- Wel voor berekening:
  - Stenotische klep (AS)
  - PH met TI signaal + RAP (5/10/15)
  - LVOT contour en VTI
  - Snelheid VSD: LVsp – PGjet = RVsp = sPAP
    - Een lage snelheid over VSD betekent een hoge sPAP
  - Eind diastolische snelheid PI jet: drukberekening is edRVdruk + RAP
  - Schatting PVR
  - MR (Dp/Dt): LV pressure increase early systolic: EH mmHg/sec = 32/tijdsinterval in sec

- Niet te gebruiken bij dubbele klepvitiae, bij aorta ascendens van minder dan 30mm (pressure recovery), bij V1 > 1 m/s

Continuity equation

- Tweede wet van Newton: law of conservation of mass
  - Mass cannot be destroyed, flow rates are the same at different locations in a flow stream
- Flow rate op punt 1 is gelijk aan punt 2
- A1 x V1 = A2 x V2
  - LVOT area x LVOT VTI = AVA x aortic VTI
  - AVA = LVOT area x LVOT VTI/aortic VTI

Flow en CO

- Flow rate = CSA x flow velocity (Vmax)
- SV = CSA x VTI = pi 2 r x VTI
  - Assuming a circular shape
  - Ook voor berekening RV / R fractie / Qp : Qs (intracardiac shunt)
- CO = SV x HF
- Fick
  - Less than transaortic flow (Fick + RV)

Doppler

- Aliasing
  - Nyquist limit is highest obtainable velocity
  - When frequency is higher than Nyquist
  - Nyquist limit = PRF/2
- Doppler tissue imaging
  - Filter out low amplitudes and high Doppler shifts
- MPI CW 4/5CH: IVCT (systole)/IVRT (diastole) / ET

Hemodynamiek

- Flow: laminair/turbulent
- Vroege sluiting MK: AoI
- B-hump: vertraagde sluiting MK, verhoogde einddiastolische LV druk
- Vroegsystolisch naar beneden bewegen IVS: LBTB
- Afplatting IVS: systolisch (drukbelasting RV), diastolisch (volumebelasting RV)
- IVC dilatatie: verhoogde RA druk

Artefacten

- Side lobes
  - Posterieure mitralisklepannulus
- Reverberaties
  - Posterieure pericard
- Shadowing
  - Kunstkleppen
- Near-field clutter
  - Lijkt op LV thrombus

Normaalwaardes

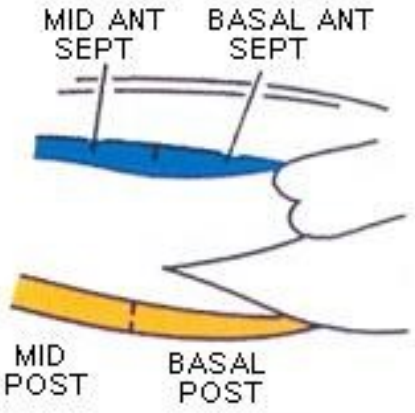
- Bij mannen van volwassen leeftijd

LV

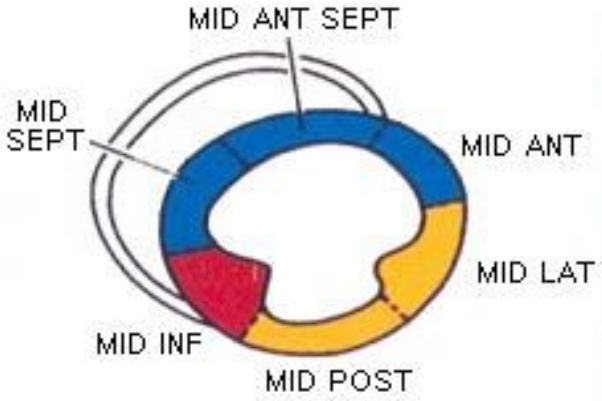
- FS = (LVEDD-LVESD)/LVEDD x 100%
- LV massa = 0.8 x 1.04 x $(IVS+LVPW+LVEDD)^3$ + 0.6g
- LVMI = LV massa/BSA

LV

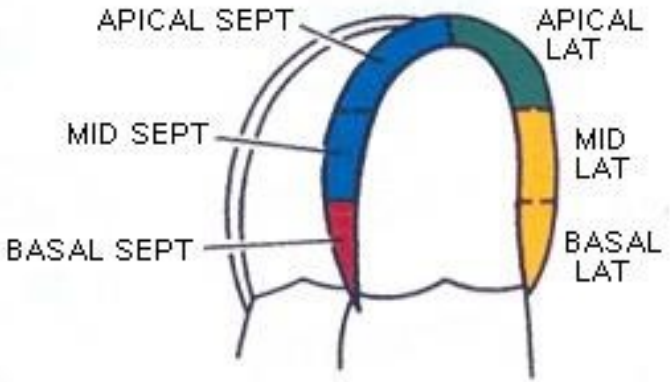
- Septum < 10mm
- Posterior wand <10mm
- LVEDD <59mm
- LVEDV <155ml
- LVESV <58ml
- EF >55%
- FS >25%
- LV massa <224g
- LVMI <115g/m^2
- WMSI <1.5
- dP/dT >1200mmHg/s



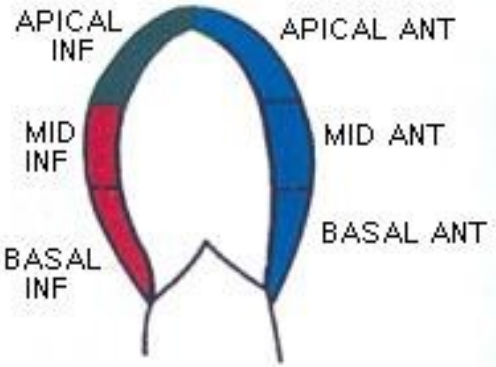
LAX



SAX PM

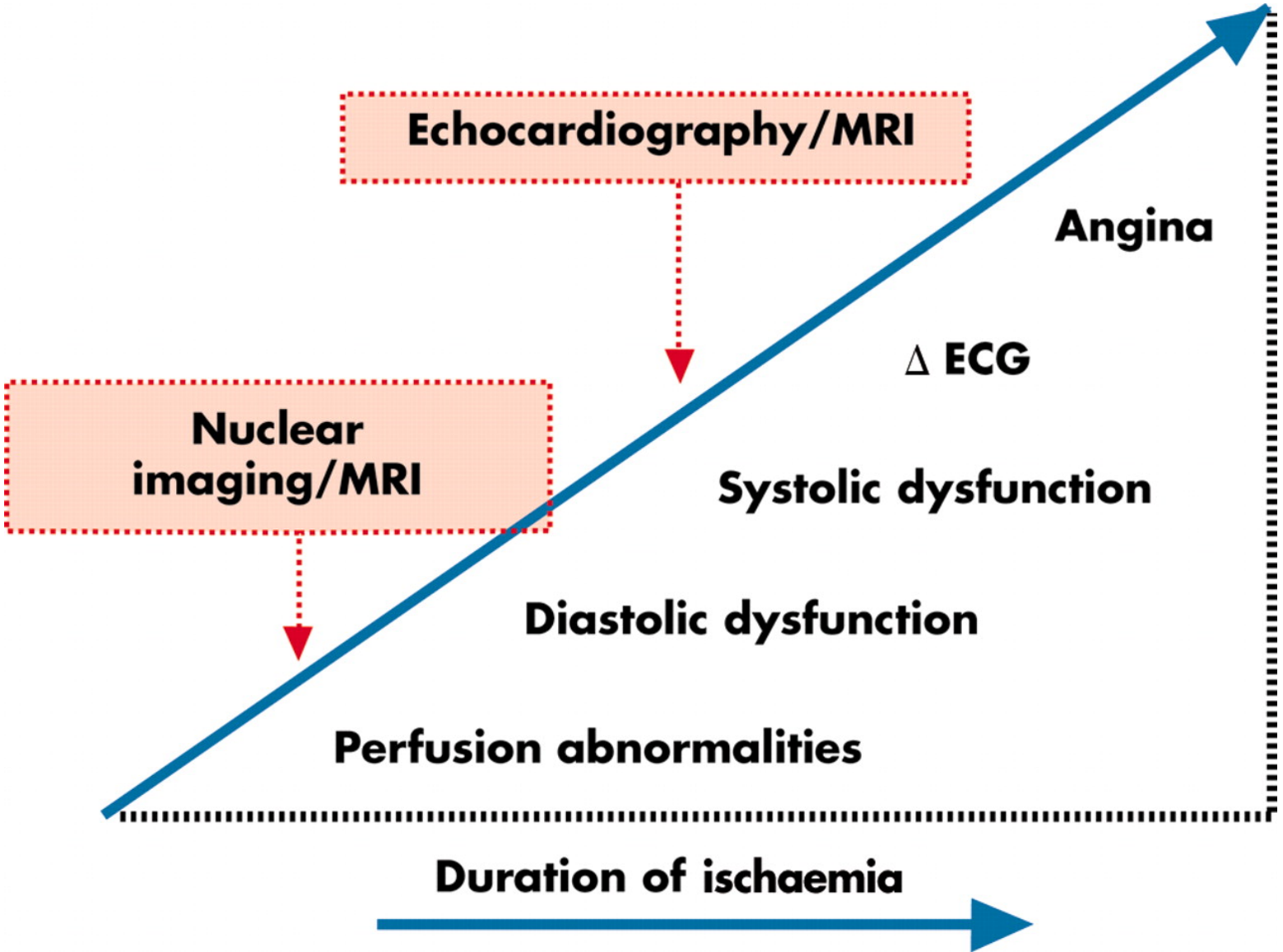


4C



2C

Left anterior descending distribution
Right coronary artery distribution
Circumflex distribution
Left anterior descending / circumflex overlap
Left anterior descending / right coronary artery overlap


Echocardiography/MRI
Angina
Δ ECG
Nuclear imaging/MRI
Systolic dysfunction
Diastolic dysfunction
Perfusion abnormalities
Duration of ischaemia

RV

- RV mediolateraal midventriculair d 35mm
- RV lengte d <79mm
- RV lengte s <63mm
- RV oppervlakte <28cm2
- RV dikte < 5mm
- TAPSE >16mm
- RVOT <2.3mm

Diastologie

- Diastole bestaat uit: IVRT, early filling (reservoir), diastasis, atrial systole (pomp)

- TTE:
  - E/A (LA-LV gradient, N>1)
  - Deceleratietijd (compliance, prognosis MI, N 140-240ms)
  - E’ (ventricular relaxation, LV filling pressure in diastolic dysfunction, lateraal hoger dan septaa, N>12cm/sl)
  - E/E’ (LV filling pressure=LVEDP, N 5-10)
  - IVRT (LA pressure, early active LV relaxation, N 80ms)
  - S/D/A pulmonaalvenen (N S>D>A), Ar-A (LV filling pressure, N 0)
  - LA volume (chronicity, prognosis, N<29ml/m2)
  - Vp (early diastolic relaxation, estimation PCWP) , N>50cm/s)
  - LV functie
  - sPAP
  - Valsalva (differentiating stages, in pseudonormal stage E decreases, A increases)

Diastologie

- Zie volgende tabel +
- E 72 cm/s
- A 40 cm/s

- Verhoogde LA druk bij:
  - IVRT < 70ms
  - E/A > 2
  - Deceleratietijd <150ms
  - S/D < 1
  - Toegenomen AR-duur en amplitude
  - E/E’ > 15
  - LA dilatatie

EAE

Table 1 Normal values for Doppler-derived diastolic measurements

Measurement	Age group (y)			
	16–20	21–40	41–60	>60
IVRT (ms)	50 ± 9(32–68)	67 ± 8(51–83)	74 ± 7(60–88)	87 ± 7(73–101)
E/A ratio	1.88 ± 0.45(0.98–2.78)	1.53 ± 0.40(0.73–2.33)	1.28 ± 0.25(0.78–1.78)	0.96 ± 0.18(0.6–1.32)
DT (ms)	142 ± 19(104–180)	166 ± 14(138–194)	181 ± 19(143–219)	200 ± 29(142–258)
A duration (ms)	113 ± 17(79–147)	127 ± 13(101–153)	133 ± 13(107–159)	138 ± 19(100–176)
PV S/D ratio	0.82 ± 0.18(0.46–1.18)	0.98 ± 0.32(0.34–1.62)	1.21 ± 0.2(0.81–1.61)	1.39 ± 0.47(0.45–2.33)
PV Ar (cm/s)	16 ± 10(1–36)	21 ± 8(5–37)	23 ± 3(17–29)	25 ± 9(11–39)
PV Ar duration (ms)	66 ± 39(1–144)	96 ± 33(30–162)	112 ± 15(82–142)	113 ± 30(53–173)
Septal é (cm/s)	14.9 ± 2.4(10.1–19.7)	15.5 ± 2.7(10.1–20.9)	12.2 ± 2.3(7.6–16.8)	10.4 ± 2.1(6.2–14.6)
Septal é/á ratio	2.4*	1.6 ± 0.5(0.6–2.6)	1.1 ± 0.3(0.5–1.7)	0.85 ± 0.2(0.45–1.25)
Lateral é (cm/s)	20.6 ± 3.8(13–28.2)	19.8 ± 2.9(14–25.6)	16.1 ± 2.3(11.5–20.7)	12.9 ± 3.5(5.9–19.9)
Lateral é/á ratio	3.1*	1.9 ± 0.6(0.7–3.1)	1.5 ± 0.5(0.5–2.5)	0.9 ± 0.4(0.1–1.7)

Data are expressed as mean ± SD (95% confidence interval). Note that for é velocity in subjects aged 16 to 20 years, values overlap with those for subjects aged 21 to 40 years. This is because é increases progressively with age in children and adolescents. Therefore, the é velocity is higher in a normal 20-year-old than in a normal 16-year-old, which results in a somewhat lower average é value when subjects aged 16 to 20 years are considered.

*Standard deviations are not included because these data were computed, not directly provided in the original articles from which they were derived.

Gradering

- 1
  - Impaired relaxation
    - Delayed LV early diastolic active relaxation, normal LA pressure
    - IVRT lengthens
- 2
  - Pseudonormalisation
    - Mildly elevated LA pressure, low LA-LV gradient, reduced LV suction force
    - *High filling pressure combined with impaired relaxation*
    - E wave reduced, IVRT reduced
- 3
  - Restrictive filling
    - Noncompliant LV chamber, increased stiffness ,elevated LA pressure, high opening LA-LV pressure gradient, failing LA contractility, responds positively to preload reduction (Valsalva, diurese)
    - Ar-A>30ms
- 4
  - Restrictive filling, irreversible
    - Inflow by pushing blood

Constrictief vs restrictief

- Restrictief (diastolische dysfunctie graad 3, amyloidose)
  - LA >
  - LVF N
  - E/A > 1.5 (geen verandering op preloadvermindering)
  - DT < 160ms
  - Es’ < 8cm/sec
  - PH, TI>MI, inspiratoire diastolische leverveneflowomkering
- Constrictief
  - Valsalva: >25% verandering E
  - IVRT variatie met ademhaling

Atria

- LA <30mm
- RA <45mm
- LA <20mm2
- LA volume minder dan 58ml
- LA-volume/BSA < 28ml/m2
- Flowsnelheid bij TTE N > 64cm/sec
  - Verhoogde kans op thrombusvorming bij >30cm/sec
- Schatting RA-druk:
  - 5 RA N
  - 10 Vmax TI 2.6-4m/s VCI gedilateerd
  - 15 Severe TI Geen respiratoire variatie VCI

Longvenen

- S1: atriale relaxatie
- S2: inflow door RV contractie

- S-flowsnelheid 40-60 cm/sec
- D-flowsnelheid 35-45 cm/sec

Aorta

- Boog <30mm
- Descendens <30mm
- Abdominalis <30mm

Schatting sPAP

- sPAP = 4x Vmax TI + RA druk

- Pulmonale acceleratietijd >120ms

MI

Table 3 **Grading the severity of organic mitral regurgitation**

Parameters	Mild	Moderate	Severe
Qualitative			
MV morphology	Normal/Abnormal	Normal/Abnormal	Flail lefleat/Ruptured PMs
Colour flow MR jet	Small, central	Intermediate	Very large central jet or eccentric jet adhering, swirling and reaching the posterior wall of the LA
Flow convergence zone[a]	No or small	Intermediate	Large
CW signal of MR jet	Faint/Parabolic	Dense/Parabolic	Dense/Triangular
Semi-quantitative			
VC width (mm)	<3	Intermediate	≥ 7 (>8 for biplane)[b]
Pulmonary vein flow	Systolic dominance	Systolic blunting	Systolic flow reversal[c]
Mitral inflow	A wave dominant[d]	Variable	E wave dominant (>1.5 cm/s)[e]
TVI mit /TVI Ao	<1	Intermediate	>1.4
Quantitative			
EROA (mm^2)	<20	20–29; 30–39[f]	≥ 40
R Vol (mL)	<30	30–44; 45–59[f]	≥ 60
+ LV and LA size and the systolic pulmonary pressure[g]			

CW, continuous-wave; LA, left atrium; EROA, effective regurgitant orifice area; LV, left ventricle; MR, mitral regurgitation; R Vol, regurgitant volume; VC, vena contracta.
[a]At a Nyquist limit of 50–60 cm/s
[b]For average between apical four- and two-chamber views.
[c]Unless other reasons of systolic blunting (atrial fibrillation, elevated LA pressure).
[d]Usually after 50 years of age;
[e]in the absence of other causes of elevated LA pressure and of mitral stenosis.
[f]Grading of severity of organic MR classifies regurgitation as mild, moderate or severe, and sub-classifies the moderate regurgitation group into 'mild-to-moderate' (EROA of 20–29 mm or a R Vol of 30–44 mL) and 'moderate-to-severe' (EROA of 30–39 mm^2 or a R Vol of 45–59 mL).
[g]Unless for other reasons, the LA and LV size and the pulmonary pressure are usually normal in patients with mild MR. In acute severe MR, the pulmonary pressures are usually elevated while the LV size is still often normal. In chronic severe MR, the LV is classically dilated. Accepted cut-off values for non significant left-sided chambers enlargement: LA volume <36 mL/m^2, LV end-diastolic diameter <56 mm, LV end-diastolic volume <82 mL/m^2, LV end-systolic diameter <40 mm, LV end-systolic volume <30 mL/m^2, LA diameter <39 mm, LA volume <29 mL/m^2.

AoS

Table 3 Recommendations for classification of AS severity

	Aortic sclerosis	Mild	Moderate	Severe
Aortic jet velocity (m/s)	$\leq$2.5 m/s	2.6–2.9	3.0–4.0	$>$4.0
Mean gradient (mmHg)	–	$<$20 ($<$30[a])	20–40[b] (30–50[a])	$>$40[b] ($>$50[a])
AVA (cm^2)	–	$>$1.5	1.0–1.5	$<$1.0
Indexed AVA (cm^2/m^2)		$>$0.85	0.60–0.85	$<$0.6
Velocity ratio		$>$0.50	0.25–0.50	$<$0.25

[a]ESC Guidelines.
[b]AHA/ACC Guidelines.

AoI

Table 2 **Grading the severity of AR**

Parameters	Mild	Moderate	Severe
Qualitative			
Aortic valve morphology	Normal/Abnormal	Normal/Abnormal	Abnormal/flail/large coaptation defect
Colour flow AR jet width[a]	Small in central jets	Intermediate	Large in central jet, variable in eccentric jets
CW signal of AR jet	Incomplete/faint	Dense	Dense
Diastolic flow reversal in descending aorta	Brief, protodiastolic flow reversal	Intermediate	Holodiastolic flow reversal (end-diastolic velocity >20 cm/s)
Semi-quantitative			
VC width (mm)	<3	Intermediate	>6
Pressure half-time (ms)[b]	>500	Intermediate	<200
Quantitative			
EROA (mm^2)	<10	10–19; 20–29[c]	≥30
R Vol (mL)	<30	30–44; 45–59[c]	≥60
+LV size[d]			

AR, aortic regurgitation; CW, continuous-wave; LA, left atrium; EROA, effective regurgitant orifice area; LV, left ventricle; R Vol, regurgitant volume; VC, vena contracta.
[a]At a Nyquist limit of 50–60 cm/s.
[b]PHT is shortened with increasing LV diastolic pressure, vasodilator therapy, and in patients with a dilated compliant aorta or lengthened in chronic AR.
[c]Grading of the severity of AR classifies regurgitation as mild, moderate or severe and subclassifies the moderate regurgitation group into 'mild-to-moderate' (EROA of 10–19 mm or an R Vol of 30–44 mL) and 'moderate-to-severe' (EROA of 20–29 mm^2 or an R Vol of 45–59 mL).
[d]Unless for other reasons, the LV size is usually normal in patients with mild AR. In acute severe AR, the LV size is often normal. In chronic severe AR, the LV is classically dilated. Accepted cut-off values for non-significant LV enlargement: LV end-diastolic diameter <56 mm, LV end-diastolic volume <82 mL/m^2, LV end-systolic diameter <40 mm, LV end-systolic volume <30 mL/m^2.

TI

Table 5 Grading the severity of TR

Parameters	Mild	Moderate	Severe
Qualitative			
Tricuspid valve morphology	Normal/abnormal	Normal/abnormal	Abnormal/flail/large coaptation defect
Colour flow TR jet[a]	Small, central	Intermediate	Very large central jet or eccentric wall impinging jet
CW signal of TR jet	Faint/Parabolic	Dense/Parabolic	Dense/Triangular with early peaking (peak <2 m/s in massive TR)
Semi-quantitative			
VC width (mm)[a]	Not defined	<7	≥ 7
PISA radius (mm)[b]	≤ 5	6–9	>9
Hepatic vein flow[c]	Systolic dominance	Systolic blunting	Systolic flow reversal
Tricuspid inflow	Normal	Normal	*E* wave dominant (≥ 1 cm/s)[d]
Quantitative			
EROA (mm^2)	Not defined	Not defined	≥ 40
R Vol (mL)	Not defined	Not defined	≥ 45
+ RA/RV/IVC dimension[e]			

CW, continuous-wave; EROA, effective regurgitant orifice area; RA, right atrium; RV, right ventricle; R Vol, regurgitant volume; TR, tricuspid regurgitation; VC, vena contracta.
[a]At a Nyquist limit of 50–60 cm/s.
[b]Baseline Nyquist limit shift of 28 cm/s.
[c]Unless other reasons of systolic blunting (atrial fibrillation, elevated RA pressure).
[d]In the absence of other causes of elevated RA pressure.
[e]Unless for other reasons, the RA and RV size and IVC are usually normal in patients with mild TR. An end-systolic RV eccentricity index >2 is in favour of severe TR. In acute severe TR, the RV size is often normal. In chronic severe TR, the RV is classically dilated. Accepted cut-off values for non significant right-sided chambers enlargement (measurements obtained from the apical four-chamber view): Mid RV dimension ≤ 33 mm, RV end-diastolic area ≤ 28 cm^2, RV end-systolic area ≤ 16 cm^2, RV fractional area change $>32\%$, maximal RA volume ≤ 33 mL/m^2.
An IVC diameter <1.5 cm is considered normal.

PI

Table 4 **Grading the severity of PR**

Parameters	Mild	Moderate	Severe
Qualitative			
Pulmonic valve morphology	Normal	Normal/ abnormal	Abnormal
Colour flow PR jet width[a]	Small, usually <10 mm in length with a narrow origin	Intermediate	Large, with a wide origin; may be brief in duration
CW signal of PR jet[b]	Faint/slow deceleration	Dense/variable	Dense/steep deceleration, early termination of diastolic flow
Pulmonic vs. Aortic flow by PW	Normal or slightly increased	Intermediate	Greatly increased
Semi-quantitative			
VC width (mm)	Not defined	Not defined	Not defined
Quantitative			
EROA (mm^2)	Not defined	Not defined	Not defined
R Vol (mL)	Not defined	Not defined	Not defined
+RV size[c]			

PR, pulmonic regurgitation; CW, continuous wave; EROA, effective regurgitant orifice area; PW, pulse wave; RV, right ventricle; R Vol, regurgitant volume; VC, vena contracta.
[a]At a Nyquist limit of 50–60 cm/s.
[b]Steep deceleration is not specific for severe PR.
[c]Unless for other reasons, the RV size is usually normal in patients with mild PR. In acute severe PR, the RV size is often normal. Accepted cut-off values for non-significant RV enlargement (measurements obtained from the apical four-chamber view): Mid RV dimension ≤33 mm, RV end-diastolic area ≤28 cm^2, RV end-systolic area ≤16 cm^2, RV fractional area change >32%, maximal.

PS

- Ernstige PS > 80mmHg

MS

- Ernstige MVA < 1.0cm2 en gradient >12mmHg
- MVA = 220/PHT
- Bij prothese obstructie of mismatch bij mean gradient >10mmHg en PHT >160ms

Table 9 Recommendations for classification of mitral stenosis severity

	Mild	Moderate	Severe
Specific findings			
Valve area (cm^2)	>1.5	1.0–1.5	<1.0
Supportive findings			
Mean gradient (mmHg)[a]	<5	5–10	>10
Pulmonary artery pressure (mmHg)	<30	30–50	>50

[a]At heart rates between 60 and 80 bpm and in sinus rhythm.

Table 5 Assessment of mitral valve anatomy according to the Wilkins score[64]

Grade	Mobility	Thickening	Calcification	Subvalvular Thickening
1	Highly mobile valve with only leaflet tips restricted	Leaflets near normal in thickness (4–5 mm)	A single area of increased echo brightness	Minimal thickening just below the mitral leaflets
2	Leaflet mid and base portions have normal mobility	Midleaflets normal, considerable thickening of margins (5–8 mm)	Scattered areas of brightness confined to leaflet margins	Thickening of chordal structures extending to one-third of the chordal length
3	Valve continues to move forward in diastole, mainly from the base	Thickening extending through the entire leaflet (5–8 mm)	Brightness extending into the mid-portions of the leaflets	Thickening extended to distal third of the chords
4	No or minimal forward movement of the leaflets in diastole	Considerable thickening of all leaflet tissue (>8–10 mm)	Extensive brightness throughout much of the leaflet tissue	Extensive thickening and shortening of all chordal structures extending down to the papillary muscles

The total score is the sum of the four items and ranges between 4 and 16.