Assessment of Right Ventricle

J Am Soc Echocariogr 2005;18:1440-1463

Eur J Echocardiogr 2006;7:79-108

Eur J Echocardiogr 2010;11:81-96

Assessment of right ventricle

- The parasternal long and short axis views
- The RV inflow views
- The apical 4-chamber views
- The subcostal views

- Assessment the RV size and wall thickness is the integral to the assessment of RV function.

J Am Soc Echocariogr 2005;18:1440-1463

Assessment of right ventricle

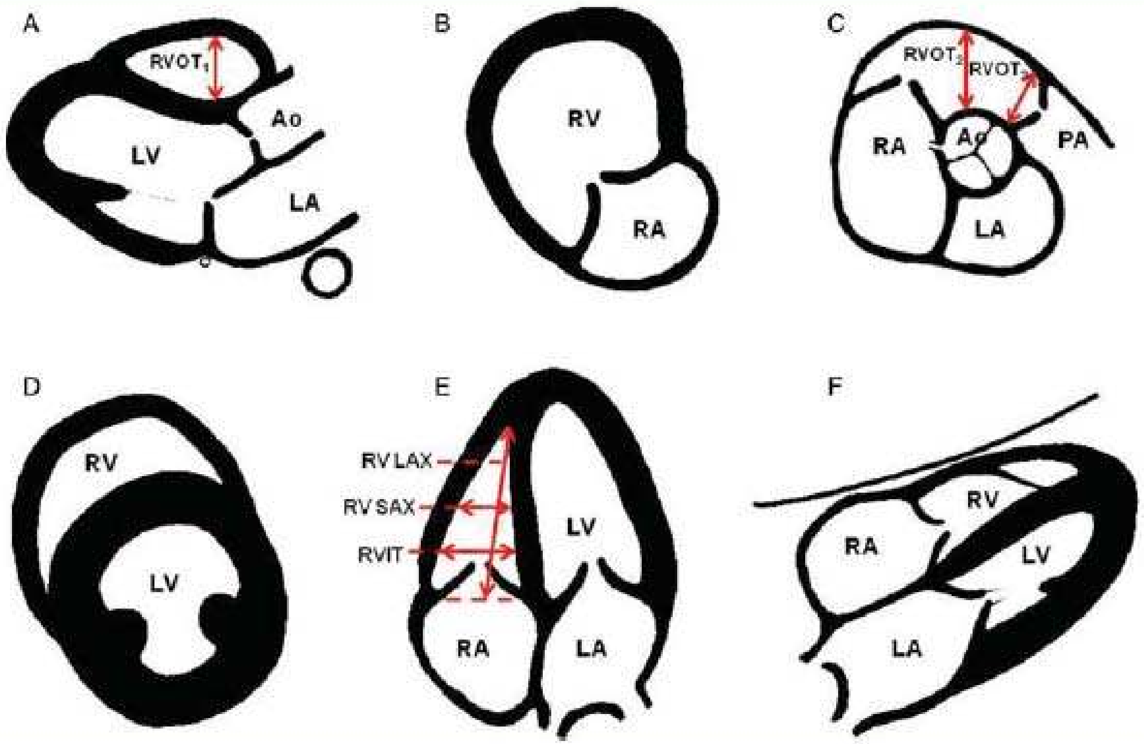

Figure 1 Graphic representation of the echocardiographic views used for evaluating the right ventricle. (*A*) Parasternal long-axis view; (*B*) long-axis view of the inflow tract; (*C*) parasternal short-axis view at the base of the heart; (*D*) parasternal short-axis view at the level of the papillary muscles; (*E*) apical four-chamber view; (*F*) subcostal view. Legend: Ao, aorta; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; RVIT, RV inflow tract; RV LAX, RV long axis; RV SAX, RV short axis; RVOT, RV outflow tract.

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Table 1 Echocardiographic sections for right ventricle evaluation

Echocardiographic section	Recommended measurements
Parasternal long axis	End-diastolic diameter of RVOT (2D, M-mode)
Long-axis view of the RV inflow tract (modified parasternal long axis)	Anatomy and function of the tricuspid valve (posterior and anterior cusps)
RV outflow tract view (modified parasternal long axis)	Pulmonary valve
Parasternal short axis—base of the heart	End-diastolic and end-systolic diameters of the RV outflow tract RVOT shortening fraction
Parasternal short axis—papillary muscles level	LV eccentricity index
Apical four-chamber view	RV long and short-axis diameters TAPSE RV fractional area change Tricuspid valve (anterior and septal cusps)
Subcostal view	RV free wall thickness

LV, left ventricle; RVOT, right ventricular outflow tract; RV, right ventricle; TAPSE, tricuspid annulus plane systolic excursion (after Lang et al.[13] and Ho and Nihoyannopoulos[31]).

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RV free wall thickness, *normally less than 0.5cm*, is measured either by M-mode, or 2D imaging

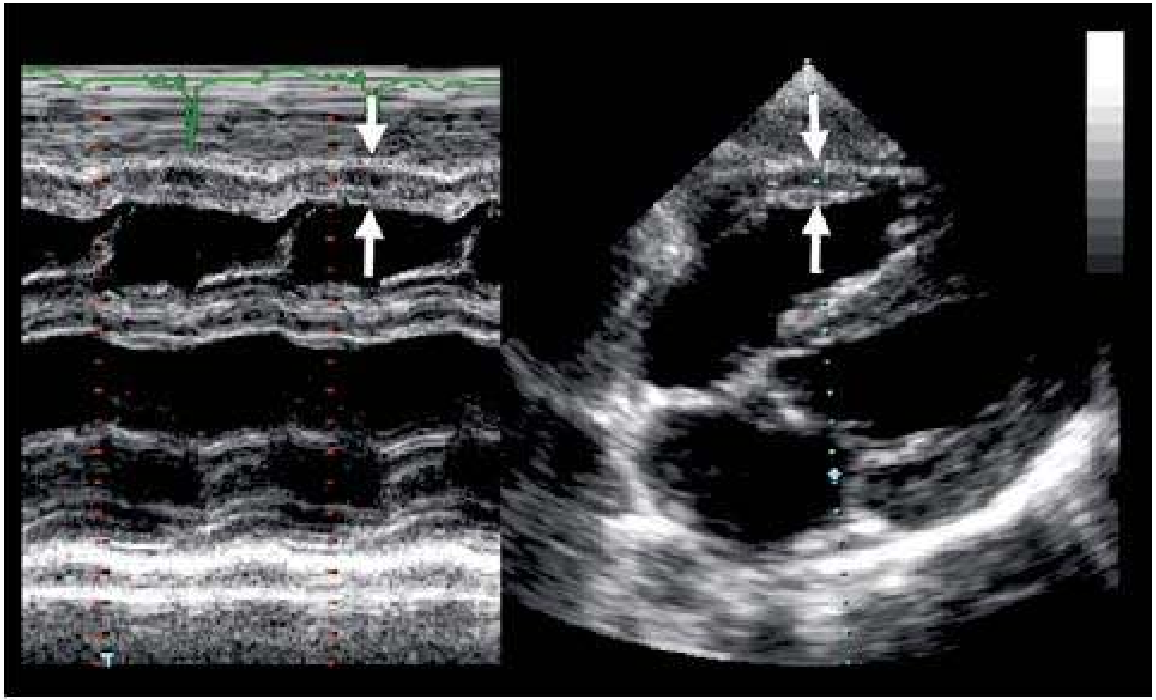

Figure 10 Methods of measuring right ventricular wall thickness (arrows) from an M-mode echo (left) and a subcostal transthoracic echo (right).

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RV hypertrophy

- RV free wall > 5mm→ RV hypertrophy
- RV hypertrophy:
  1. RV pressure overload
  2. Biventricular hypertrophic cardiomyopathies
  3. Deposit disease

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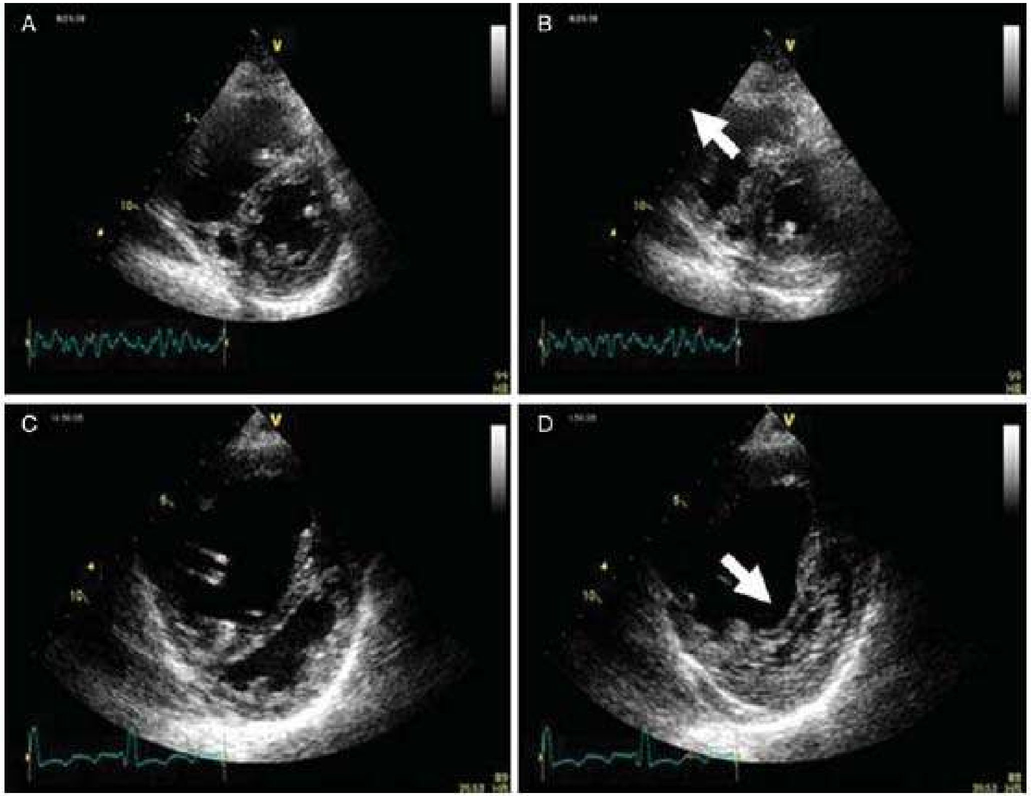
Qualitative evaluation

diastole systole



ASD II with RV volume overload

Severe pulmonary hypertension with pressure overload

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Eccentricity index(EccIx) of LV

- Defined as
  - the ratio of the LV antero-posterior to septo-lateral diameters in a short-axis view,
  - measured at both end systole and end diastole
- Normal individuals
  - a value of 1 in both systole and diastole
- Value > 1
  - at end diastole: RV volume overload
  - at end systole and end diastole : RV pressure overload.

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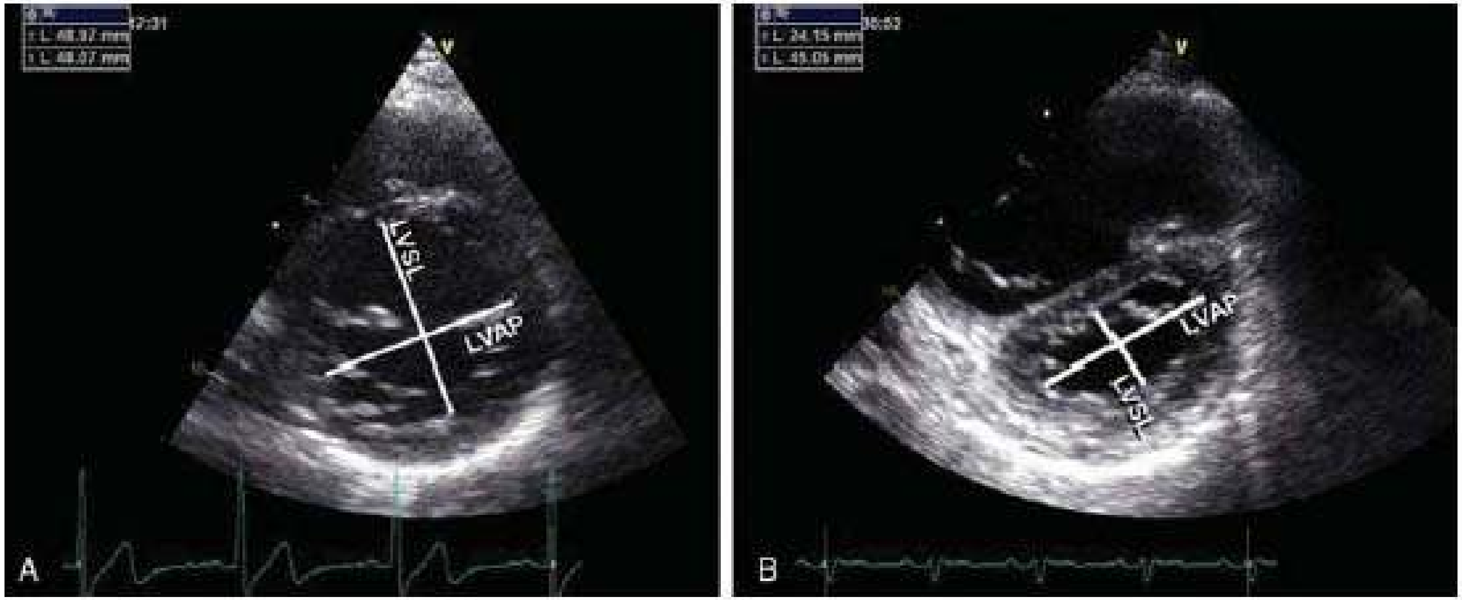
Eccentricity index(EccIx) of LV



Normal heart with diastolic EccIx =1

Patient with pulmonary hypertension with diastolic EccIx > 1.8

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Quantitative assessment of RV

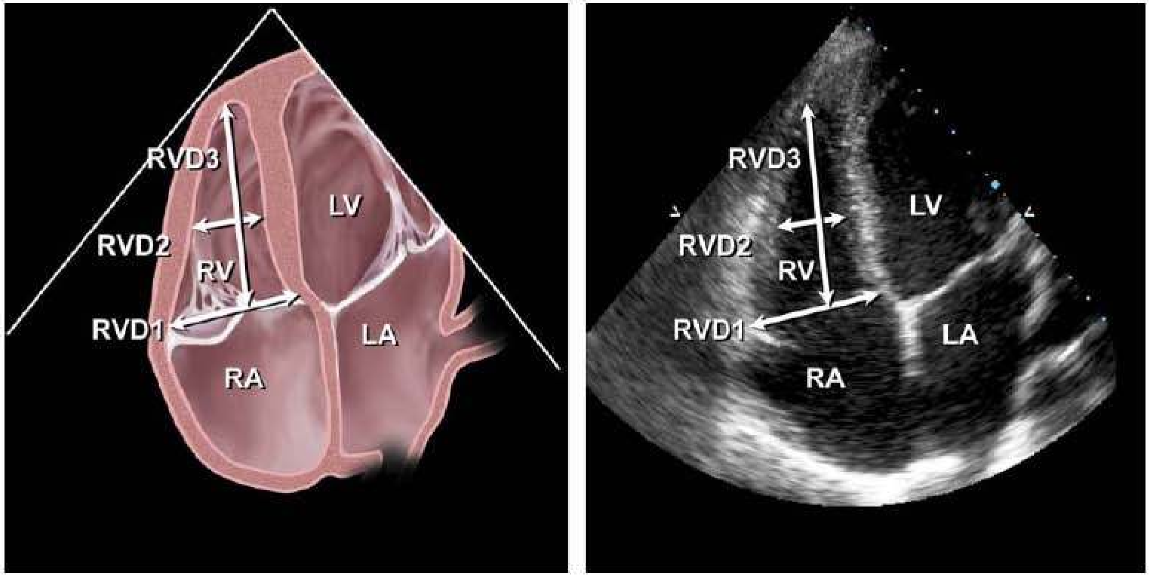

Figure 11 Mid right-ventricular diameter measured in the apical four-chamber view at level of left ventricular papillary muscles.

Measurement of the mid-cavity and basal diameter is the simple method to quantified RV size, and the RV longitudinal diameter can also be measured in this view.

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Table 7 Reference limits and partition values of right ventricular and pulmonary artery size[76]

	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal
RV dimensions				
Basal RV diameter (RVD#1) (cm)	2.0–2.8	2.9–3.3	3.4–3.8	≥3.9
Mid RV diameter (RVD#2) (cm)	2.7–3.3	3.4–3.7	3.8–4.1	≥4.2
Base-to-apex length (RVD#3) (cm)	7.1–7.9	8.0–8.5	8.6–9.1	≥9.2
RVOT diameters				
Above aortic valve (RVOT#1) (cm)	2.5–2.9	3.0–3.2	3.3–3.5	≥3.6
Above pulmonic valve (RVOT#2) (cm)	1.7–2.3	2.4–2.7	2.8–3.1	≥3.2
PA diameter				
Below pulmonic valve (PA#1) (cm)	1.5–2.1	2.2–2.5	2.6–2.9	≥3.0

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- ARVC
  - The presence of localized RV free wall aneurysms
    - a major diagnostic criteria
  - A high degree of trabeculation
  - increased thickness of the moderator band with a hyperechogenic appearance
  - RVOT dilatation.

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RV size may be assessed by TEE in the mid-esophageal 4-chamber view.

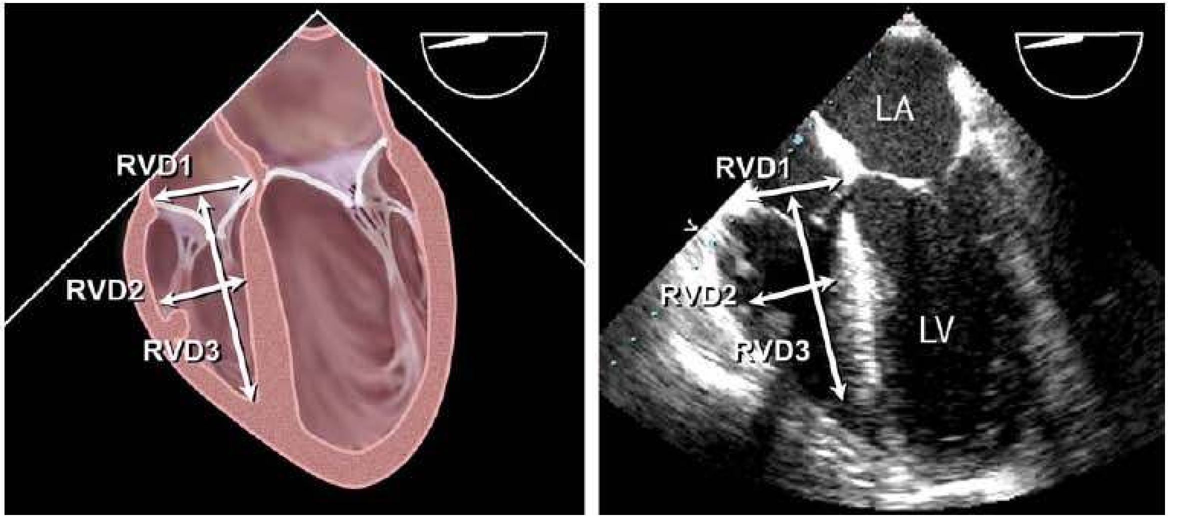

Figure 12 Transesophageal echo measurements of right ventricular diameters from the mid-esophageal four-chamber view, best imaged after optimizing the maximum obtainable RV size by varying angles from approximately 0–20 degrees.

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Assessment of RV function

- Displacement of tricuspid annulus
  - In systole, the tricuspid annulus will descend toward apex 1.5-2.0cm
  - If < 1.5 cm: poor prognosis in a variety of cardiovascular diseases.
- Direct calculation of RV volume and EF
  - Problematic, lack of standard methods for assessing RV volume.
- RV fractional area changes(FAC)
- Others
  - Tissue imaging of tricuspid annular velocity
  - RV index of myocardial performance(Tei index)

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Assessment of global RV function

- Standard parameters
  - Right ventricular outflow tract shortening fraction (RVOT-SF)
  - Right ventricular fractional area change (RVFAC)
  - Tricuspid annular plane systolic excursion (TAPSE)
  - Myocardial performance index (MPI, Tei index)
  - RV dP/dt

- Novel method
  - Doppler myocardial image (DMI)

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Right ventricular outflow tract shortening fraction (RVOT-SF)

- From a parasternal short-axis view at the base of the heart
- RVOTSF(%)= (EDRVOTD-ESROVTD)/EDRVOTD
- Correlates well with longitudinal function, pulmonary pressure gradient and RV-RA pressure gradient (Lindqvist et al)

There are no defined landmarks for orienting the image with precision→ significant inaccuracies may result from oblique plane acquisitions

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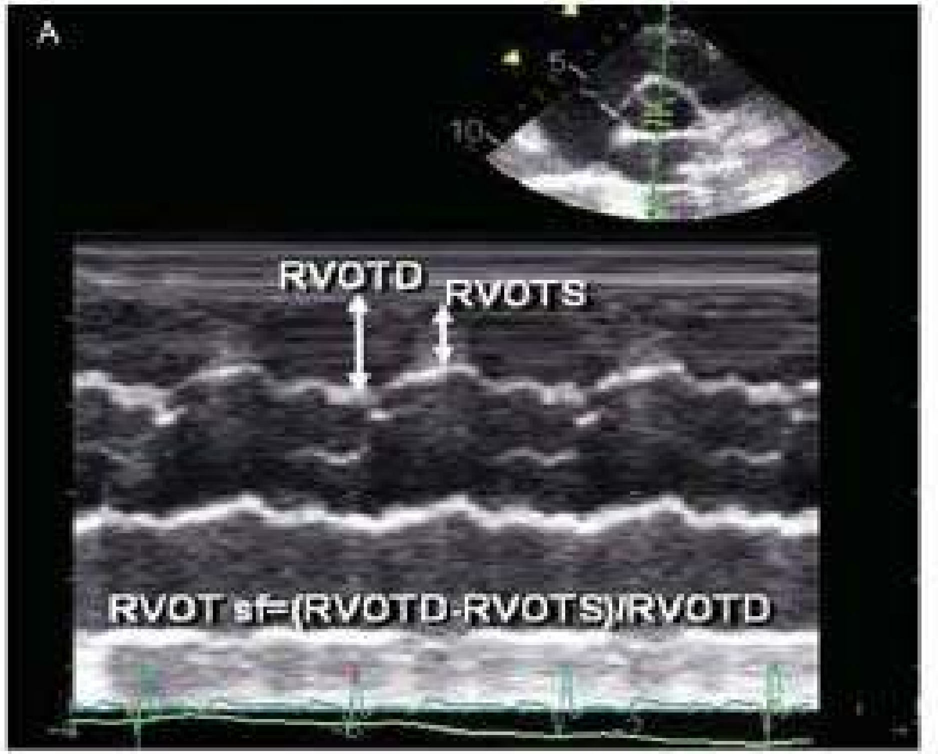
Right ventricular outflow tract shortening fraction (RVOT-SF)



RVOTSF(%)= (EDRVOTD-ESROVTD)/EDRVOTD

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Right ventricular fractional area change (RVFAC)

- Expresses the percentage change in RV area between end-diastole and end-systole
- Form a 4-chamber view

- RVFAC(%)=(RVEDA-RVESA)/RVEDA

- A good correlation with MRI-derived RVEF
  - shown to have prognostic significant in patients with myocardial infarction and pulmonary hypertension
- Main limitation
  - the need of good endocardial border delineation
    - be difficult to achieve in the high trabeculated RV

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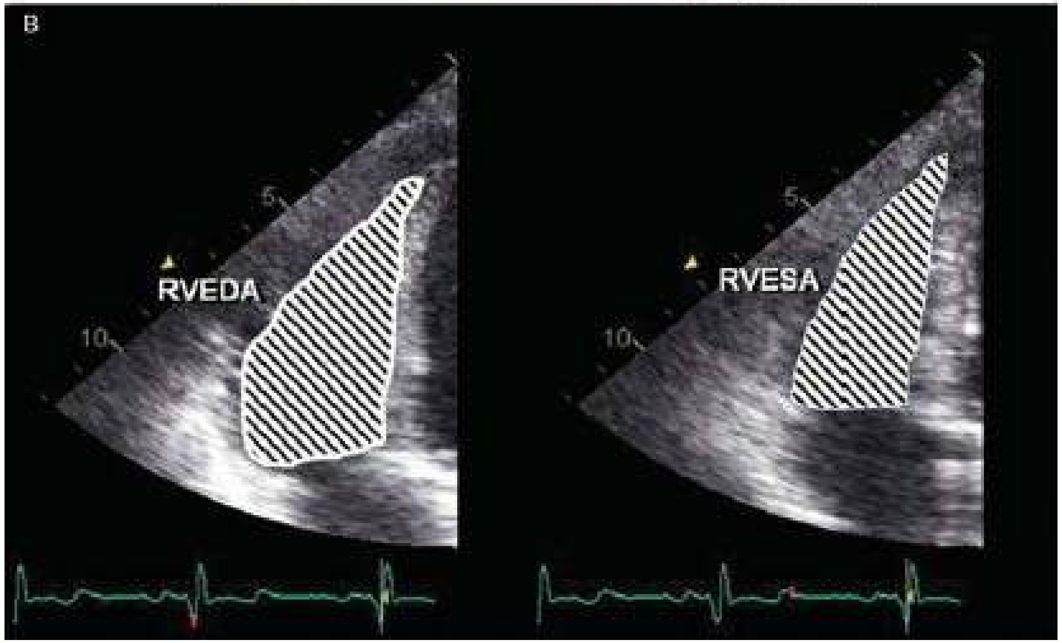
Right ventricular fractional area change (RVFAC)



RVFAC(%)=(RVEDA-RVESA)/RVEDA

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Right ventricular fractional area change (RVFAC)

Table 8 Reference limits and partition values of right ventricular size and function as measured in the apical four-chamber view [80]

	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal
RV diastolic area (cm^2)	11–28	29–32	33–37	≥38
RV systolic area (cm^2)	7.5–16	17–19	20–22	≥23
RV fractional area change (%)	32–60	25–31	18–24	≤17

The RV fractional area change(FAC) measured in the apical 4-chamber view is the simple method for assessment of RV function .

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Tricuspid annular plane systolic excursion (TAPSE)

- A useful index for evaluating RV longitudinal function
- Using an M-mode cursor passed through the tricuspid lateral annulus in 4-chambr view
  - Measuring the extent of systolic motion of the lateral portion of the tricuspid ring towards the apex.
- Good correlation with isotopic derived RVEF
- *Normal: 15-20mm*
- Prognostic value in cardiac failure and myocardial infarction
  - Samad et al : TAPSE ≦15mm increased mortality (45% at 2 years)
- Limitations :
  - restricted to the longitudinal function of the RV free wall, disregarding the distribution of IVS and the RVOT.
  - Relative to transducer position
  - be influenced by the functional status of LV.*

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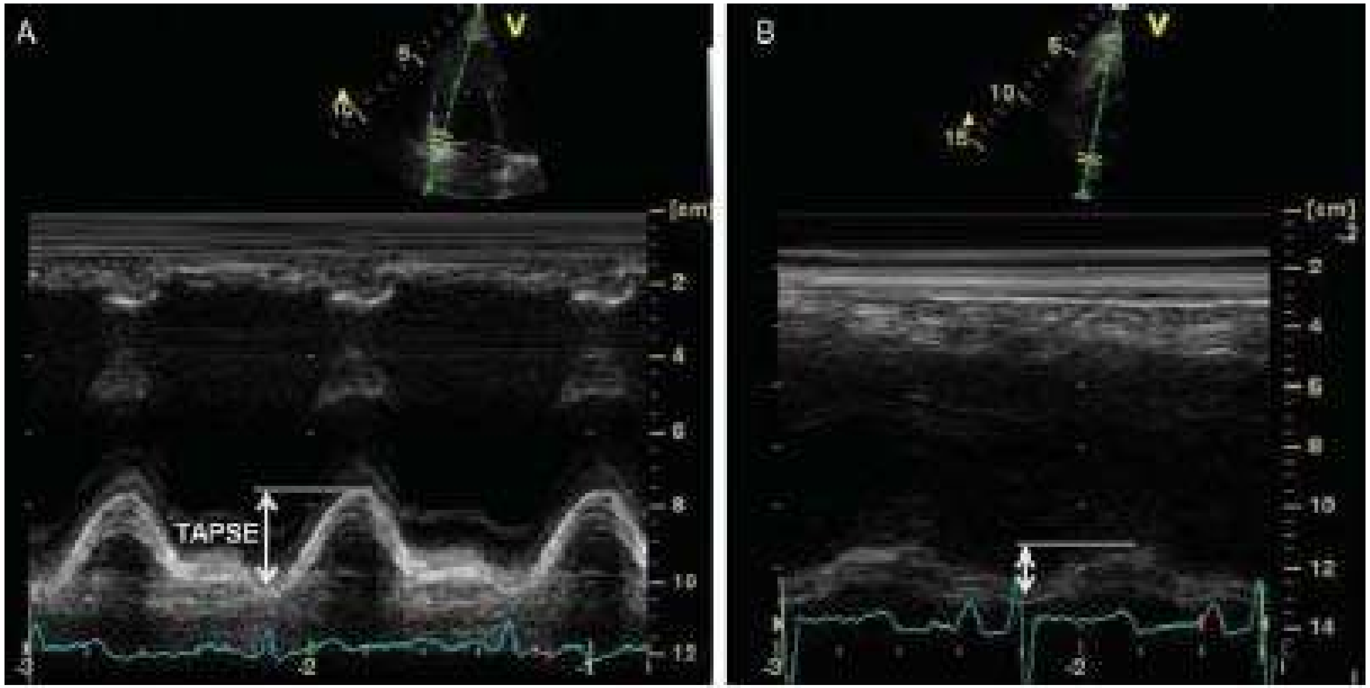
Tricuspid annular plane systolic excursion (TAPSE)

Normal individual | Patient with pulmonary hypertension



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Myocardial performance index

- Derived from physiological rather than structural features.
- MPI= (ICT+ IVRT) / ejection time of the RV.
  - A parameter of global function*
- correlates with radionuclide-derived RVEF
- Normal: 0.28 +/- 0.04.
  - increases in diseases associated with RV dysfunction
  - Useful in the longitudinal follow-up of patients with chronic thrombo-embolic pulmonary hypertension who undergo pulmonary thormbendarterectomy.
- Limited by the absence of the isovolumic periods in the normal RV and the pseudonormalization of index when RA pressure is increased (Yoshifuku et al) **

ICT: isovolumic contraction time
IVRT: isovolumic relaxation time

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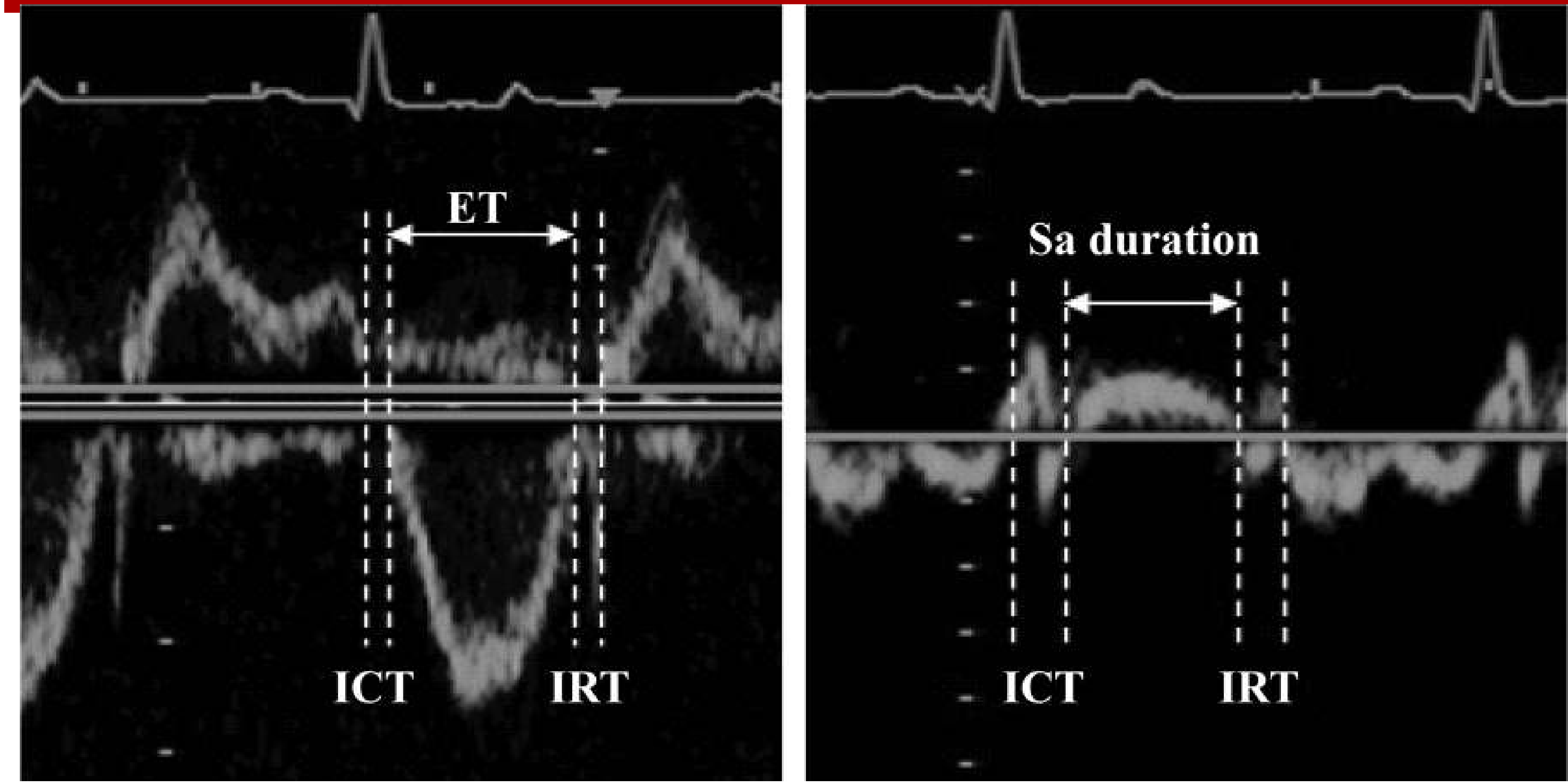
Myocardial performance index



Hori Y et al. Am J Physiol Heart Circ Physiol 2007;293:H120-H125

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Myocardial performance index

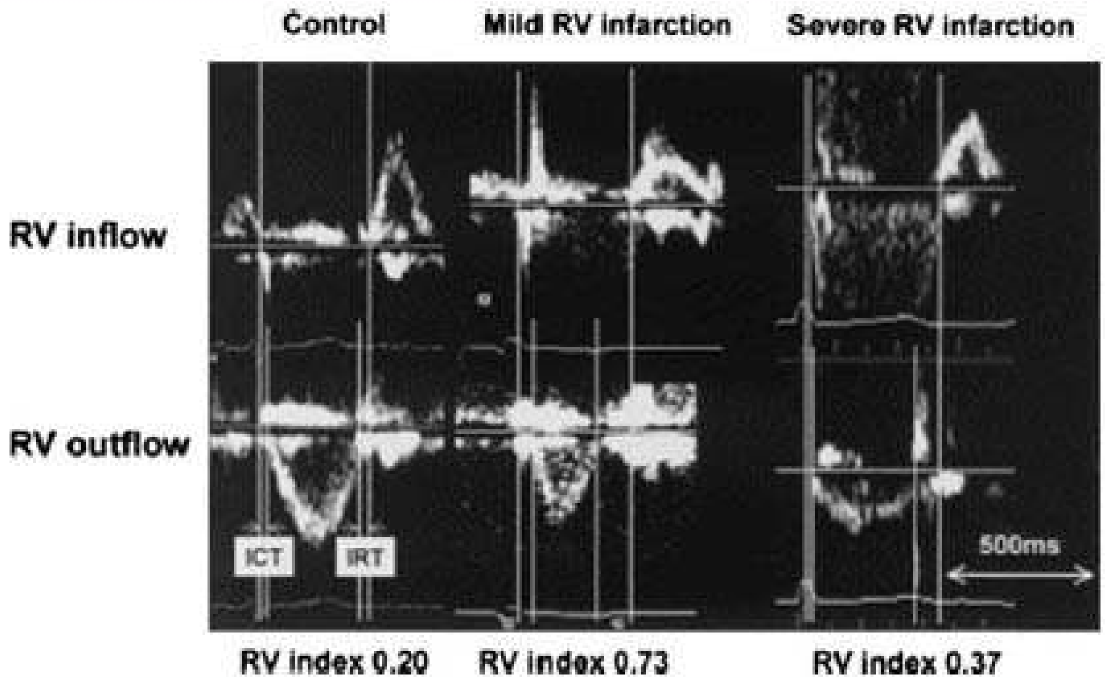

Figure 6 Pseudonormalization of the right ventricular Tei index—representative patients. Left panel: a control subject with normal isovolumic contraction time (ICT) and isovolumic relaxation time (IRT). Middle panel: this patient had mild/moderate right ventricular infarction and a larger Tei index with prolonged ICT and IRT. Right panel: this patient had severe right ventricular infarction with paradoxic shortening of ICT, resulting in a pseudonormalized right ventricular Tei index. Reproduced with permission from Yoshifuku *et al.*[61]

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RV dP/dt

- A parameter of contractility
- Measured on the tricuspid regurgitation (TR) envelope
- Highly load-dependent
- Not reflecting the contractile status of the RV muscle
- Useful for repeated longitudinal assessment

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Doppler myocardial imaging (DMI)

- Offers information on myocardial velocities.
  - allowing a quantitative assessment of myocardial function during the entire cycle.
- Alignment with the ultrasound beam is very important.
  - an improper alignment (> 20 ◦) yields erroneous results
- Less dependent on chamber geometry*
- No endocardial border delineation is needed
  - making DMI useful even if the echocardiographic image quality is suboptimal

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Pulse DMI

- Simple to use online
- A very good temporal resolution
- Meluzin et al*
  - a cut-off value of 11.5 cm/s for tricuspid ring systolic velocities is able to accurately predict global RV dysfunction(defined as RVEF < 45%)
- Main disadvantage :
  - Angle dependency
  - Sample volume is fixed
  - Does not enable tracking of the region of interest as it translates with cardiac cycle and respiration.

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Pulse DMI

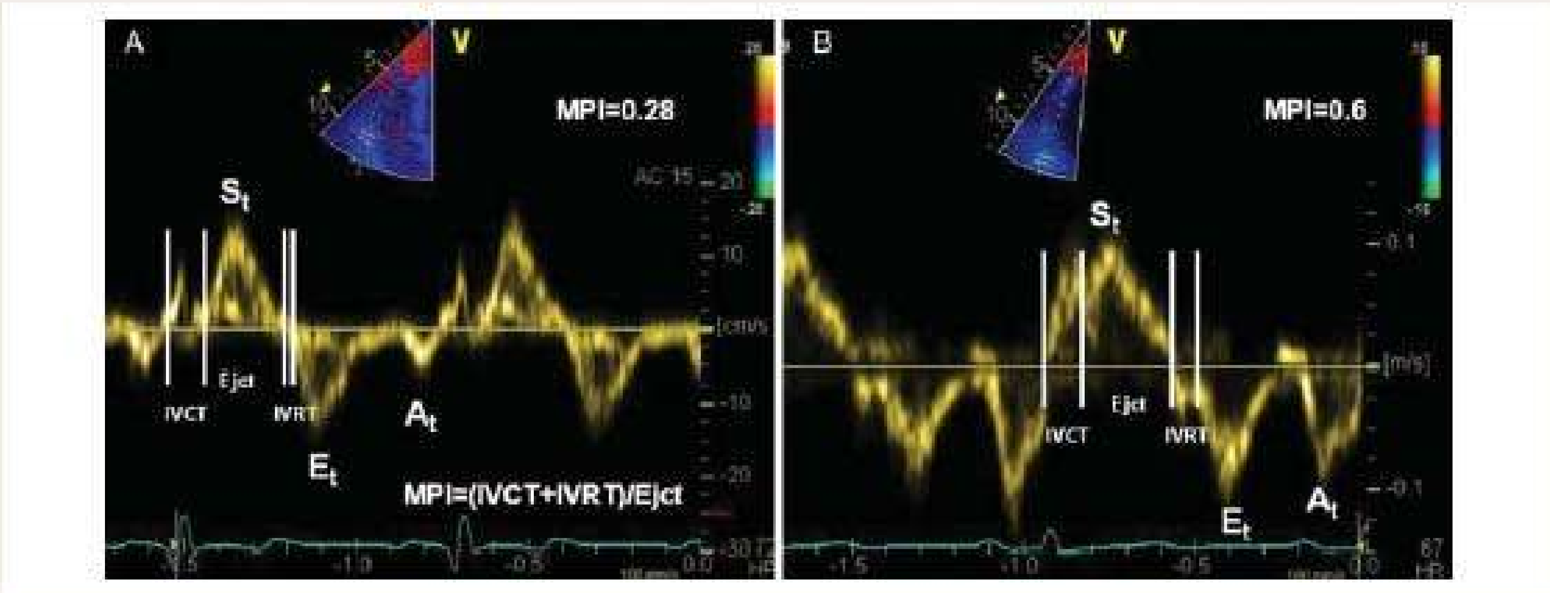

Figure 7 Pulsed-wave Doppler at the tricuspid level of the right ventricular free wall in a normal individual (*A*) and in a patient with pulmonary hypertension (*B*). MPI, myocardial performance index; IVRT, isovolumic relaxation time; IVCT, isovolumic contraction time; Ejct, ejection time; S_t, peak systolic velocity at the tricuspid valve; E_t, peak early filling velocity at the tricuspid ring; A_t, peak late filling (atrial) velocity at the tricuspid ring.

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Color DMI

- An alternative to pulse DMI
- An offline analysis of several myocardial segments during the same cardiac cycle
- Sample volumes can be set to allow cardiac motion.
- Representing the median of the velocity spectrum
- Around 25% lower than those obtained using pulsed DMI, in which the maximal spectral velocity value is measured.

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Tissue Doppler Imaging (TDI)

- Parameters derived from TDI techniques which may aid in the estimation of global RV function are
  - IVRT
  - Tei index
  - isovolumic myocardial acceleration

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IVRT

- A normal RV that functions with preserved contractility and under normal loading conditions does not have a measureable IVRT.
- The end of systolic movement is immediately followed by early filling.
- A pressure increase in the RV leads to a sustained prolongation of the IVRT
- In patients with supoptimal alignment with the TR flow, measuring IVRT using TDI technique can be an alternative for estimating pulmonary systolic pressure.

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Tei index

- The Tei index using DMI methods has the advantage of measuring the isovolumic periods in the same cycle
- Good correlation between the Tei index derived from DMI and conventional Doppler.

- DMI-derived parameters : (Hsiao et al)
  - RV pressure overload: tricuspid ring velocities ↓ , IVRT ↑
  - RV volume overload: tricuspid ring velocities ↑ , IVRT ↓

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Pulse DMI

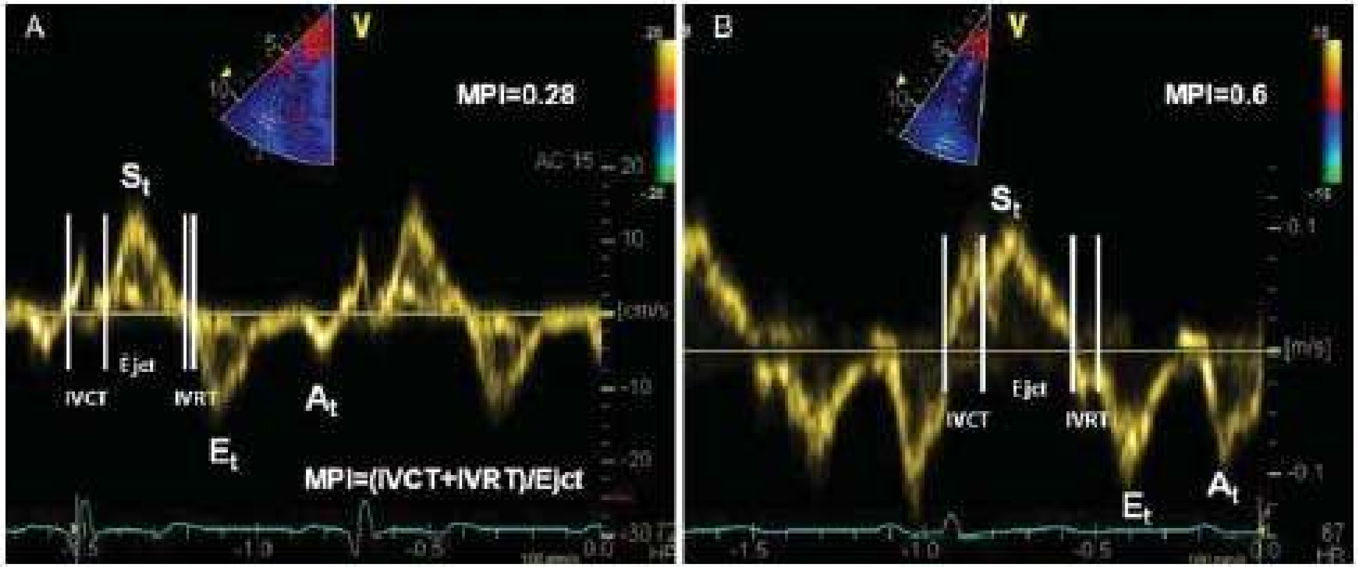

Figure 7 Pulsed-wave Doppler at the tricuspid level of the right ventricular free wall in a normal individual (*A*) and in a patient with pulmorary hypertension (*B*). MPI, myocardial performance index; IVRT, isovolumic relaxation time; IVCT, isovolumic contraction time; Ejct, ejection time; S_t, peak systolic velocity at the tricuspid valve; E_t, peak early filling velocity at the tricuspid ring; A_t, peak late filling (atrial) velocity at the tricuspid ring.

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Isovolumic acceleration time (IVA)

- A DMI-derived index
- Less dependent on loading conditions

- IVA= maximum systolic velocity/time to maximum systolic velocity

- IVA in the basal segment of the RV free wall of > 1.1 m/s^2 correlates well with MRI RVEF > 45%
  - 90% sensitivity and specificity

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Isovolumic acceleration time (IVA)

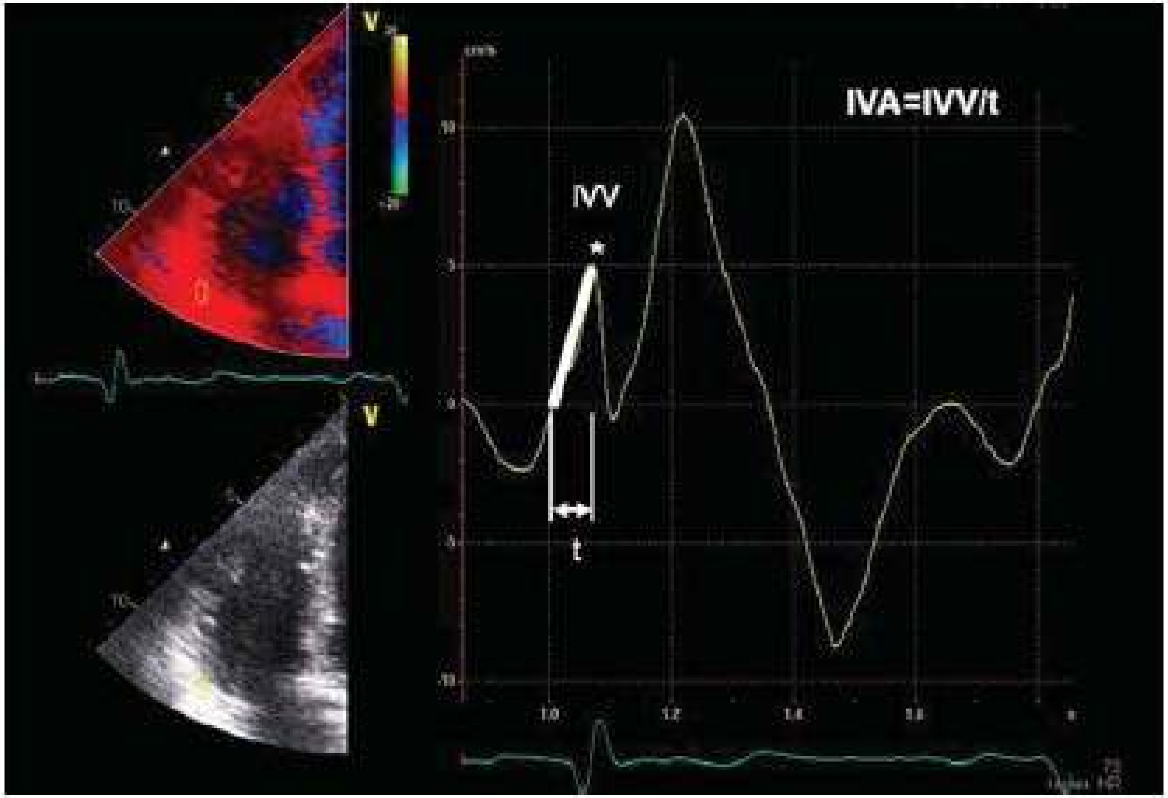

Figure 8 Measuring isovolumic acceleration (IVA) during isovolumic contraction at the basal segment of the right ventricular free wall. IVV, peak isovolumic velocity, t, time from zero crossing to peak isovolumic velocity.

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3D echocardiographic imaging

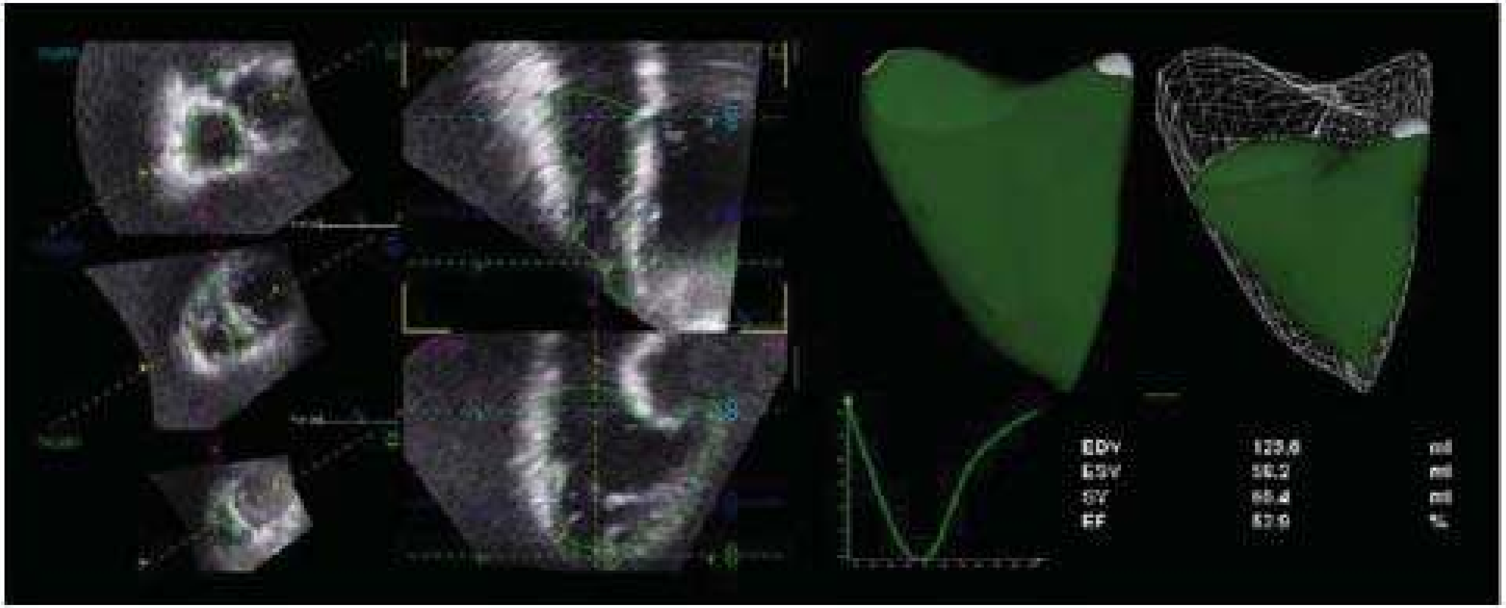

Figure 9 Three-dimensional imaging of the right ventricle with measurements of the right ventricular volumes and ejection fraction in a healthy individual.

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RV regional function

- Tissue velocities can be measured using pulsed or colored DMI at 3 levels of RV free wall:
  - basal, mid and apical.

- Longitudinal and radial velocities recorded at the level of the RV free wall using color TDI in normal individuals were shown to be higher than those measured in the LV.

-

- Peak systolic velocities measured in the basal segment of the free RV wall have proved useful indices in the diagnosis and prognosis of patients with RV infarction
  - Patients with systolic annular velocities ≧ 8cm/s : better event-free survival at 1 year Eur J Echocardiogr 2010;11:81-96

RV regional function

- Strain(S)/strain rate(SR) represents deformation and deformation rate.
  - Strain: defined as the deformation of an object compared with its initial shape
    - Shortening: negative, lengthening: positive
  - Strain rates defines the speed of deformation and correlates well with regional contractility parameters,
    - less dependent on the loading conditions.

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RV regional function

- Speckle-tracking-based myocardial deformation imaging
  - Angle-independent
  - User-friendly:
    - shorter learning curve
  - Need for excellent image quality:
    - endocardial border delineation: most important

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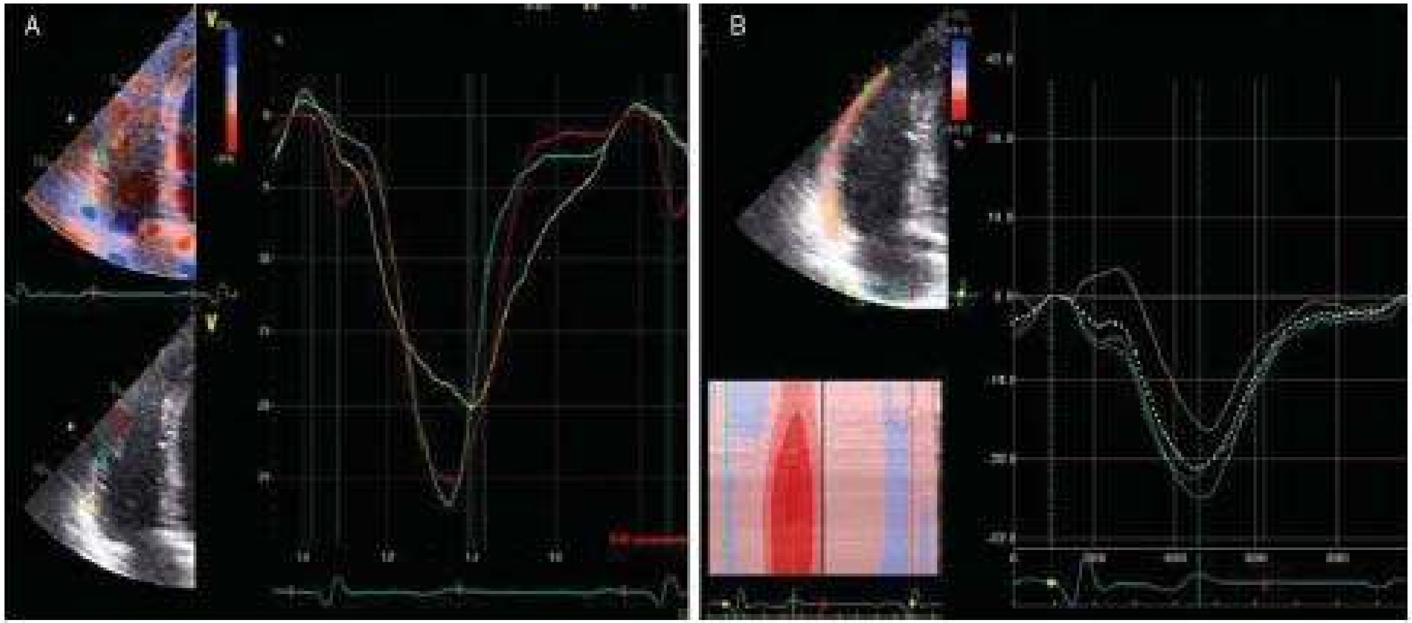

Figure 10 Strain measurements in the right ventricular free wall of a normal individual using tissue Doppler techniques (*A*) and speckle-tracking techniques (*B*).

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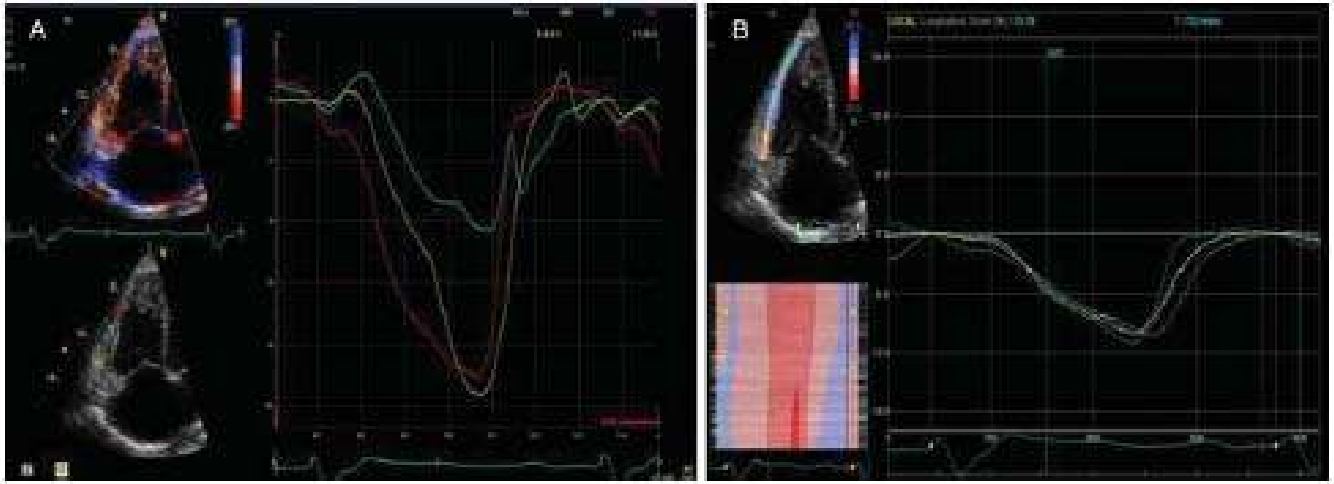

Figure 11 Strain rate imaging of the right ventricular free wall in a pulmonary hypertension patient using tissue Doppler techniques (*A*) and speckle-tracking techniques (*B*).

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RV diastolic function

- Tricuspid inflow pattern
  - Obtained in apical 4-chamber view
  - Similar to mitral pattern, although velocities are smaller and there are marked inspiratory variations
- Transhepatic flow
  - Presence of S, D, and A wave
  - Hepatic flow fraction= TVI S/(TVI S+TVI D)
    - Correlates with RA pressure
    - < 55% predicting RA pressure > 8 mmHg
- Estimation of RA pressure
  - By assessing the IVC diameter and its degree of collapse with inspiration
- TDI
  - E/E’ > 6 : detecting an RA pressure > 10 mmHg (79% sensitivity and 73% specificity)

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Tricuspid inflow pattern

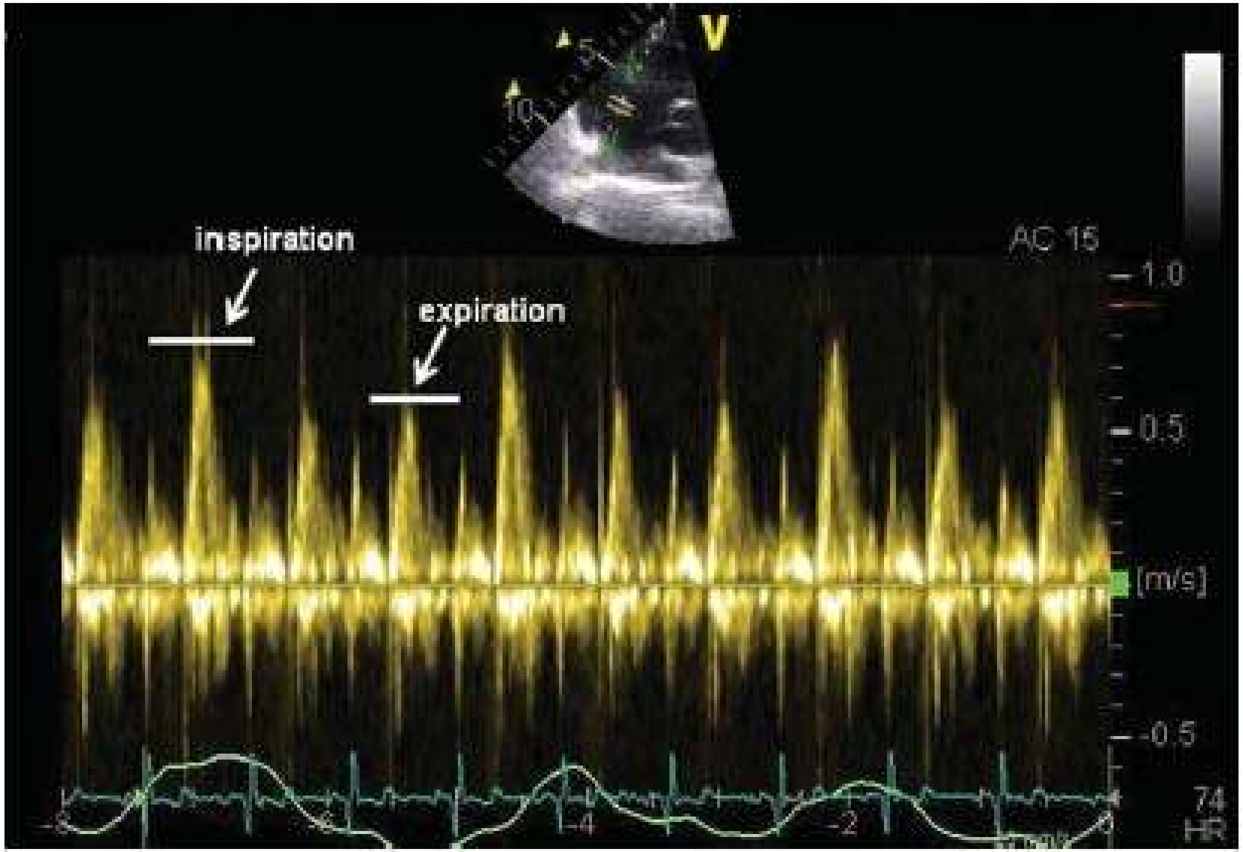

Figure 12 Normal respiratory variations of the tricuspid inflow velocities.

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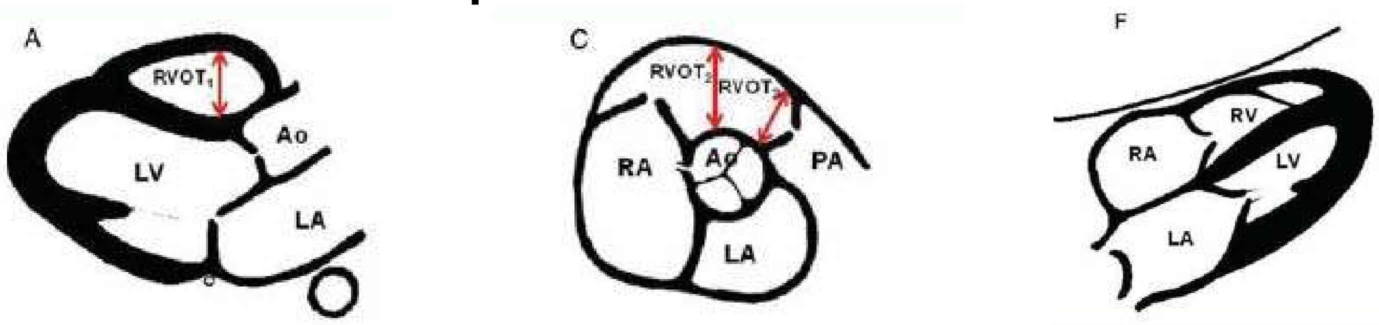
RV outflow tract (RVOT)

- Parasternal long-axis view(angled superiorly)
- Parasternal short-axis view at the base of the heart
- Subcostal long and transverse windows as well as the apical views



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Measurement of RVOT is most accurate from the parasternal short-axis just proximal to the pulmonary valve

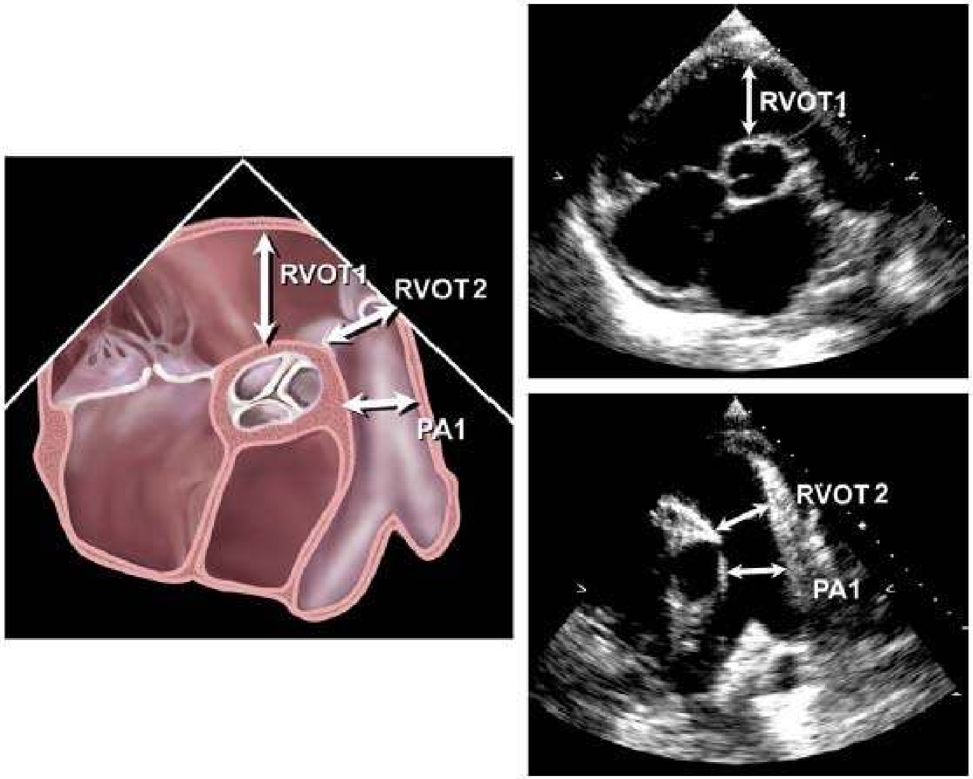

Figure 13 Measurement of the right ventricular outflow tract diameter at the subpulmonary region (RVOT1) and at the pulmonic valve annulus (RVOT2), in the mid-esophageal aortic valve short axis view, using a multiplane angle of approximately 45–70 degrees.

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With TEE, the mid-esophageal RV inflow-outflow view is the best image of the RVOT just proximal to the pulmonary valve

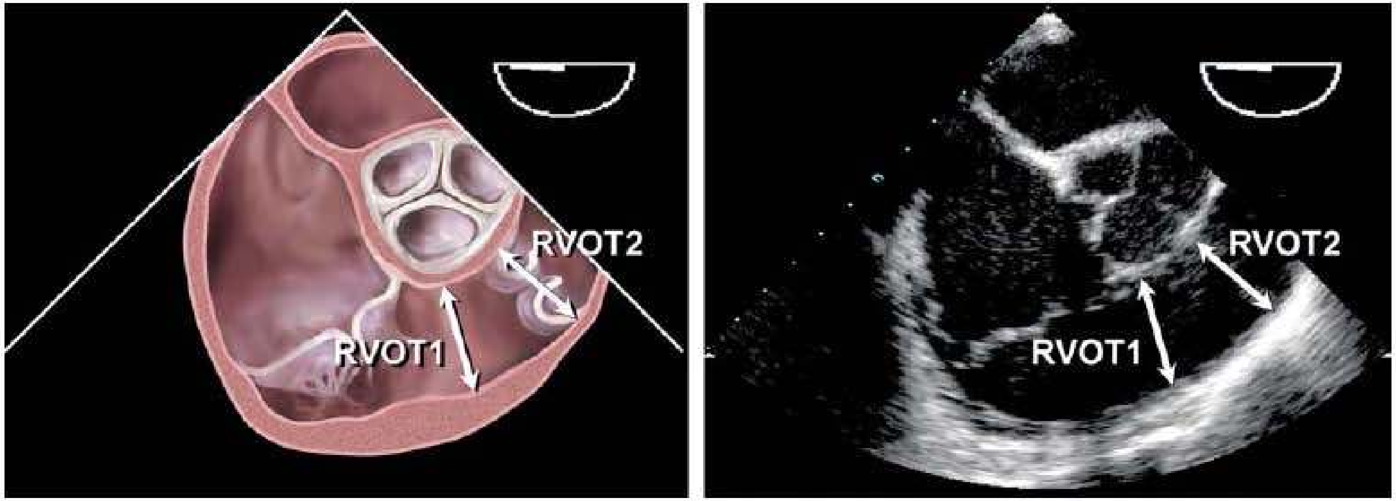

Figure 14 Measurement of the right ventricular outflow tract at the pulmonic valve annulus (RVOT2), and at and main pulmonary artery from the midesophageal RV inflow-outflow view.

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Table 7 Reference limits and partition values of right ventricular and pulmonary artery size[76]

	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal
RV dimensions				
Basal RV diameter (RVD#1) (cm)	2.0–2.8	2.9–3.3	3.4–3.8	≥3.9
Mid RV diameter (RVD#2) (cm)	2.7–3.3	3.4–3.7	3.8–4.1	≥4.2
Base-to-apex length (RVD#3) (cm)	7.1–7.9	8.0–8.5	8.6–9.1	≥9.2
RVOT diameters				
Above aortic valve (RVOT#1) (cm)	2.5–2.9	3.0–3.2	3.3–3.5	≥3.6
Above pulmonic valve (RVOT#2) (cm)	1.7–2.3	2.4–2.7	2.8–3.1	≥3.2
PA diameter				
Below pulmonic valve (PA#1) (cm)	1.5–2.1	2.2–2.5	2.6–2.9	≥3.0

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