



# Echocardiographic Assessment of Right Ventricular Function

## How to Account for Tricuspid Regurgitation and Pulmonary Hypertension

Lee Fong Ling, MD, Thomas H. Marwick, MD, PhD, MPH

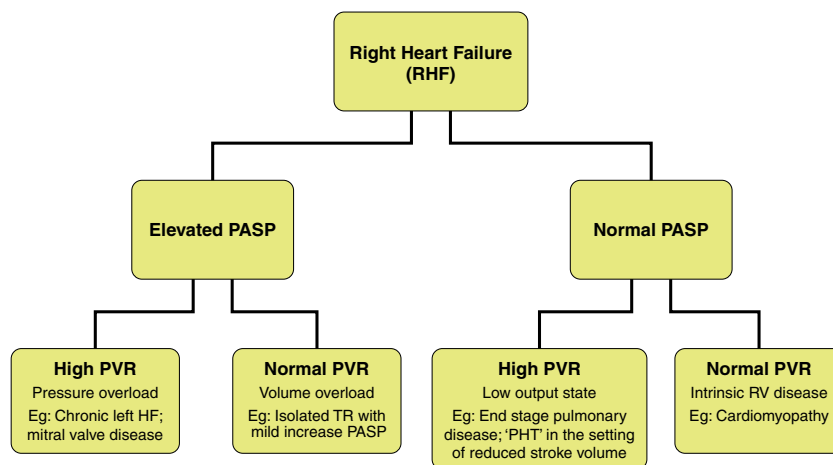
**ECHOCARDIOGRAPHY IS THE USUAL INITIAL TEST IN DYSPNEIC PATIENTS**, but its application to right ventricular (RV) analysis is challenging. RV evaluation involves 3 steps, starting with quantification of afterload and pre-load. RV afterload is assessed by measurement of pulmonary artery systolic pressure (PASP) from tricuspid regurgitation (TR) velocity and right atrial pressure; pulmonary regurgitation velocity can also be used to assess pulmonary artery (PA) diastolic and mean PA pressure. Estimation of pulmonary vascular resistance (PVR) is useful if RV function is impaired. The second step is to assess the mechanism and severity of TR. For quantification of RV performance, we usually use 1 conventional (tricuspid annular plane systolic excursion [TAPSE], fractional area change [FAC], or right ventricular index of myocardial performance [RIMP]) and 1 novel method (pulsed wave or color Doppler tissue imaging systolic velocity [s'], or strain imaging). RV volumes may be measured using 3-dimensional echocardiography (Fig. 1, Table 1).

**Case 1—RV dysfunction with increased PASP and PVR.** When RV dysfunction occurs in the setting of left ventricular dysfunction and mitral regurgitation, it may be due to myocardial disease or pulmonary hypertension (PHT). The patient shown in Figure 2 has elevation of both PASP and PVR. There is severe TR with tricuspid annular dilatation (Fig. 3). Although RV parameters show that RV systolic function is impaired (Fig. 4), this is in the context of increased afterload and pre-load.

**Case 2—preserved RV systolic function with increased PASP and normal PVR.** In patients with right heart failure and severe tricuspid regurgitation, the latter may be secondary from PHT or a primary valvular abnormality. Despite mild elevation of PASP to 44 mm Hg (Fig. 5), PVR was normal (1.3 Wood units). There is severe TR with apical displacement of the septal leaflet and coaptation point (Fig. 6). The RV is volume loaded but RV systolic function is normal (Fig. 7).

**Case 3—RV dysfunction with normal PASP and increased PVR.** Reduced stroke volume caused by RV dysfunction may compromise the assessment of RV afterload. Increased PA resistance (Fig. 8) is not apparent from PASP because forward RV stroke volume is reduced by severe TR (Fig. 9) and RV dysfunction (Fig. 10).

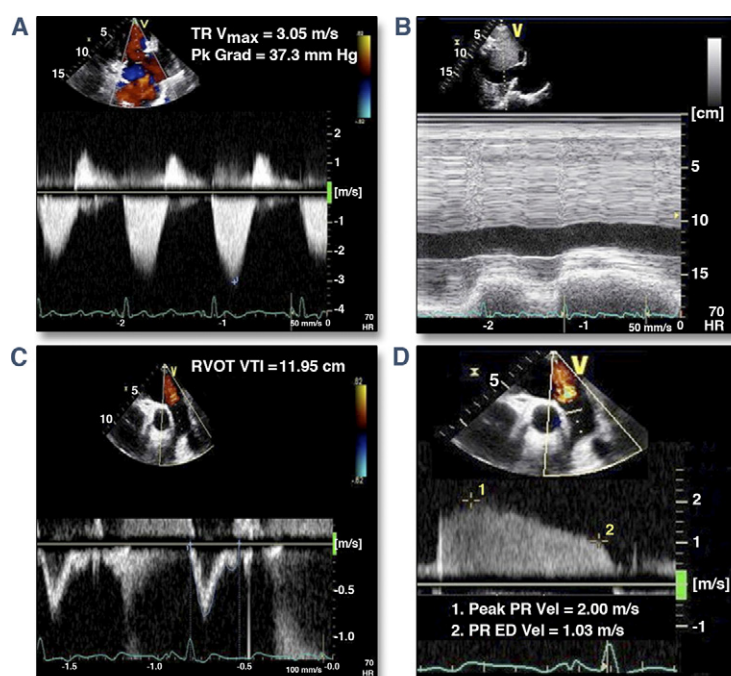
From the Heart and Vascular Institute, Cleveland Clinic, Cleveland, Ohio. Both authors have reported that they have no relationships relevant to the contents of this paper to disclose.



**Figure 1. Diagnostic Algorithm for Classification of RV Function**

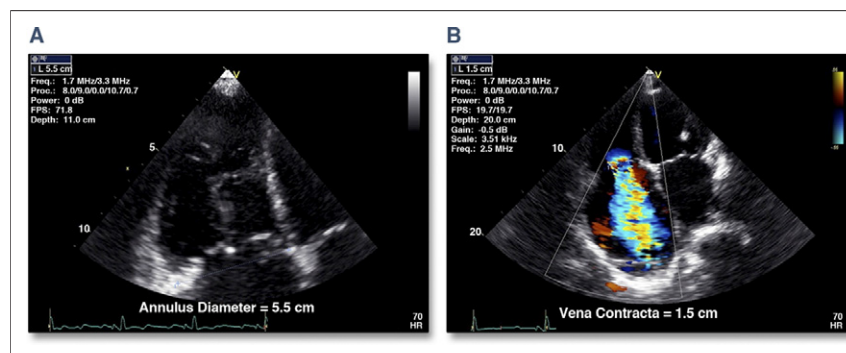
First, adjudicate the presence of increased right ventricular (RV) afterload (consider using pulmonary vascular resistance [PVR] if RV function is decreased). RV impairment may be confirmed or refuted using a combination of techniques. HF = heart failure; PASP = pulmonary artery systolic pressure; PHT = pulmonary hypertension; TR = tricuspid regurgitation.

**Case 4—RV dysfunction with normal PASP and PVR.** RV dysfunction due to intrinsic right heart disease requires a different management approach to that caused by PHT. In this instance, the PASP and PVR are normal (Fig. 11), and secondary TR (evident from lack of coaptation of the tricuspid valve leaflets and annular dilatation) is severe (Fig. 12). The RV is dilated and RV systolic function is impaired (Fig. 13).



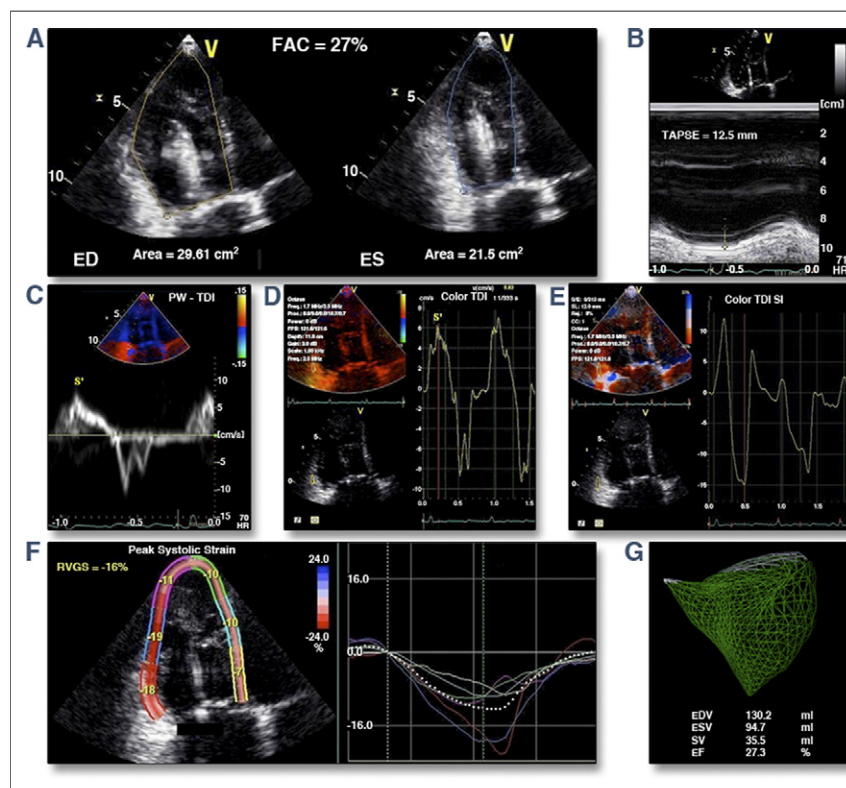
**Figure 2. Determination of PASP and PVR (Case #1)**

(A) Based on TR velocity and (B) inferior vena cava diameter, PASP is elevated to 52 mm Hg ( $37.3 + 15.0$ ). (C) RV stroke volume is normal, so this is matched by an increase of PVR to 2.7 Wood units ( $[3.05 \times 10.0 / 11.95] + 0.16$ ). Mean PASP ( $4 \times [2]^2 + 15 = 31.0$  mm Hg) and PAEDP ( $4 \times [1.03]^2 + 15 = 19.2$  mm Hg) were also elevated based on PR velocity and estimated right atrial pressure (D). Abbreviations as in Figure 1.



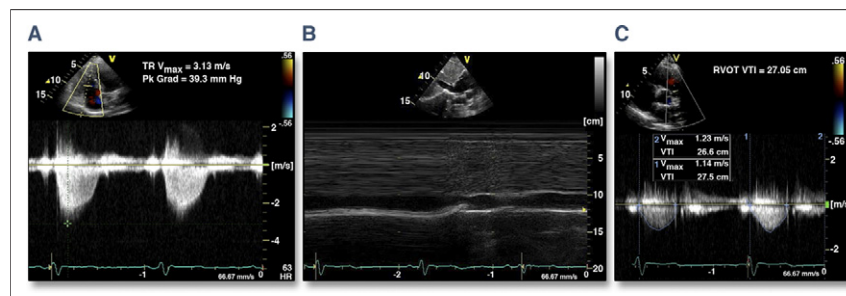
**Figure 3. Tricuspid Valve and Regurgitation (Case #1)**

Tricuspid annulus diameter was dilated (A) with severe TR as indicated by vena contracta (VC) of 1.5 cm (B). Abbreviation as in Figure 1.



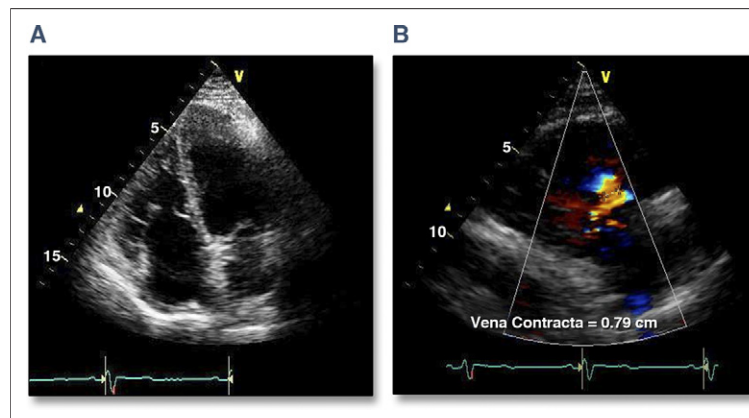
**Figure 4. Determination of RV Systolic Function (Case #1)**

RV systolic function was moderately reduced as indicated by (A) fractional area change (FAC) = 27%, (B) tricuspid annular plane systolic excursion (TAPSE) = 12.5 mm, (C)  $s' = 7$  cm/s by pulsed wave and (D) 5.8 cm/s at base by color coded analysis, (E) Doppler peak strain rate at base = -15%, (F) RV global strain = -16% by 2-dimensional speckle, and (G) 3-dimensional RV ejection fraction = 27%. Abbreviation as in Figure 1.



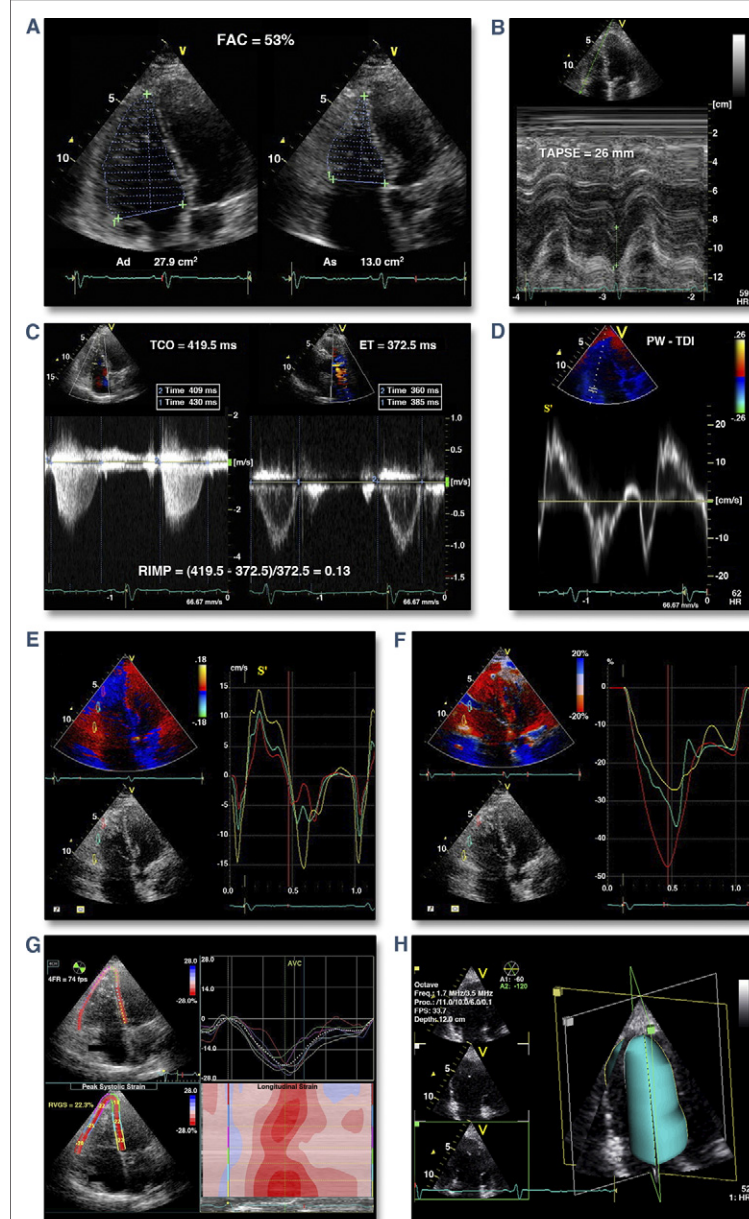
**Figure 5. Determination of PASP and PVR (Case #2)**

Based on TR velocity (A) and inferior vena cava (B), PASP is mildly elevated ( $39 + 5 = 44$  mm Hg). RV stroke volume (C) is more increased, so PVR ( $3.13 \times 10 / 27.05 + 0.16 = 1.32$  Wood units), is in the normal range. Abbreviations as in Figure 1.



**Figure 6. Tricuspid Valve and Regurgitation (Case #2)**

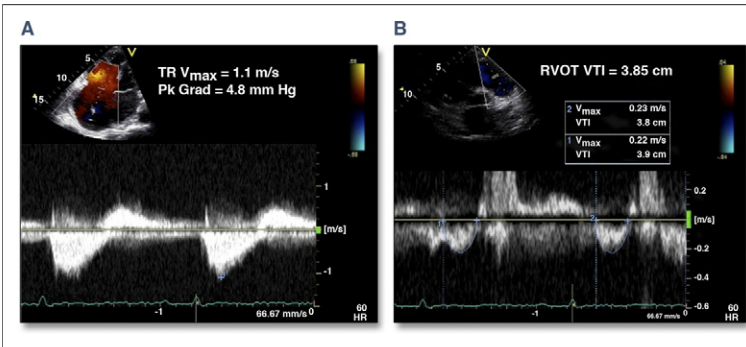
Tricuspid valve septal leaflet is displaced apically (A) with severe TR, confirmed by VC of 0.79 cm (B). Abbreviations as in Figures 1 and 3.



**Figure 7. Determination of RV Systolic Function (Case #2)**

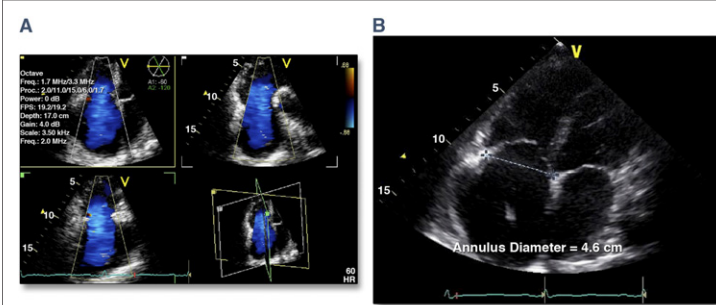
RV systolic function was normal as indicated by FAC = 53% (A), TAPSE = 26 mm (B), RIMP = 0.13 (C),  $s' = 17$  cm/s by pulsed wave (D) and 15 cm/s by color (E), RV global strain = 37% by Doppler strain (F) and 22.3% by 2D speckle (G), triplane RVEF = 58% (H). Abbreviations as in Figures 1 and 3.





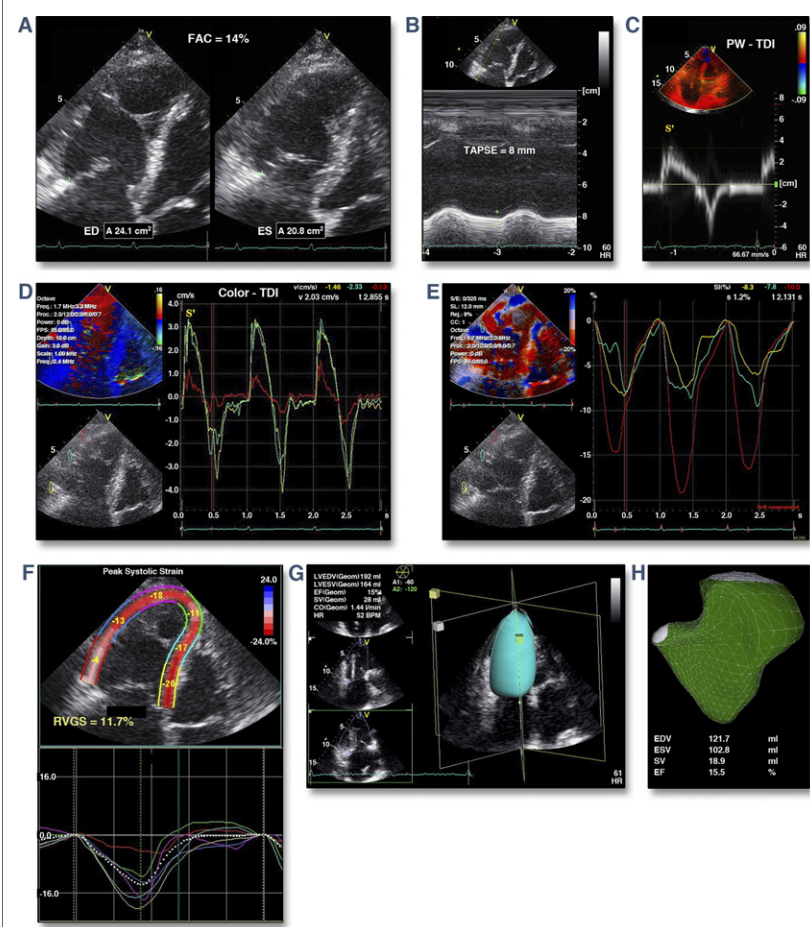
**Figure 8. Determination of PASP and PVR (Case #3)**

The normal PASP ( $4.8 + 15 = 19.8$  mm Hg) is misleading. Increased RV afterload is apparent if reduced RV stroke volume is considered by calculation of PVR ( $[(1.1 \times 10/3.85) + 0.16 = 3$  Wood units). Abbreviations as in Figure 1.



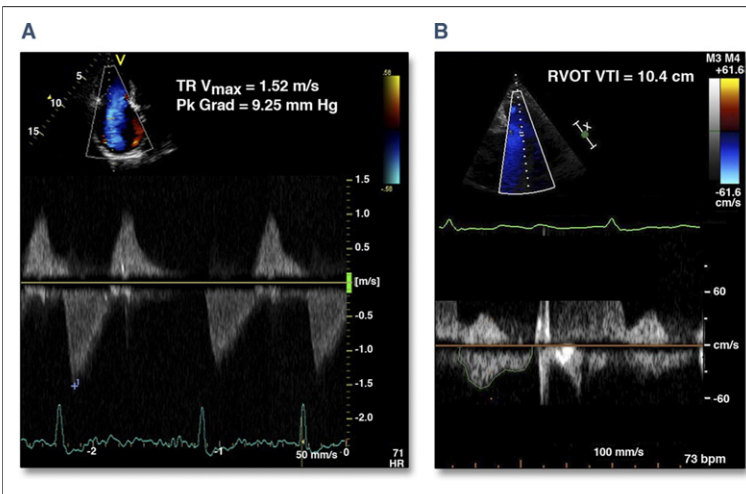
**Figure 9. Tricuspid Valve and Regurgitation (Case #3)**

Severe TR (A) with noncoaptation of the tricuspid valve leaflets and annular dilatation (B). Abbreviation as in Figure 1.



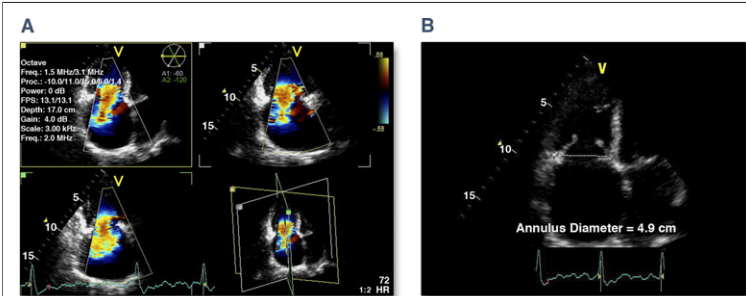
**Figure 10. Determination of RV Systolic Function (Case #3)**

RV systolic function was severely reduced as indicated by FAC = 14% (A), TAPSE = 8 mm (B), Doppler tissue imaging  $s' = 3$  cm/s at annulus by pulsed wave (C) and 3 cm/s at base by color coded analysis (D), RV global strain =  $-10\%$  by Doppler (E) and  $-11.7\%$  by 2-dimensional speckle (F), triplane RVEF 15% (G), and 3-dimensional RVEF of 15.5% (H). TDI  $s' =$  tissue Doppler septal velocity; other abbreviations as in Figures 1 and 3.



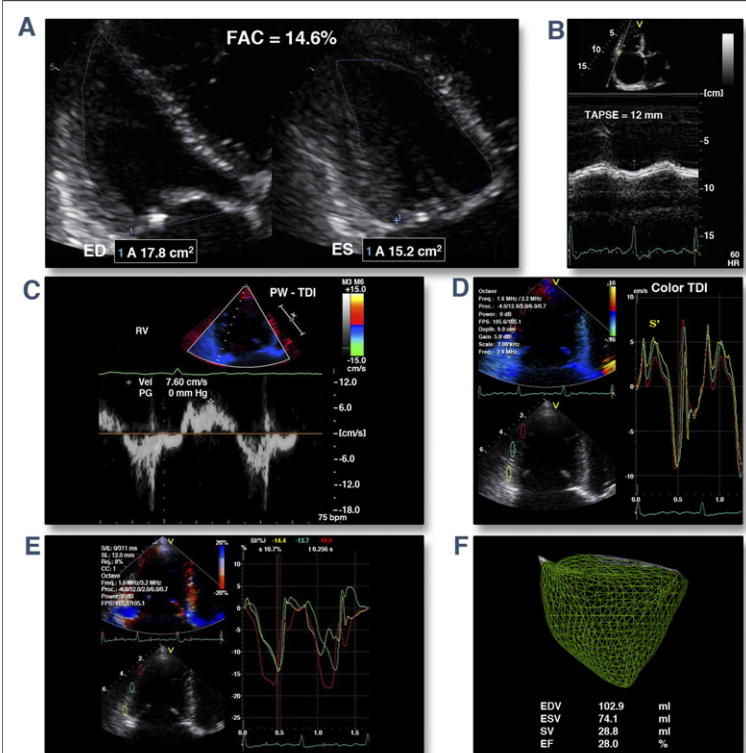
**Figure 11. Determination of RV Afterload (Case #4)**

Both PASP ( $9 + 5 = 14$  mm Hg) (A) and PVR ( $[(1.52 \times 10/10.4) + 0.16 = 1.62$  Wood units) (B) are normal. Abbreviations as in Figure 1.



**Figure 12. Tricuspid Valve and Regurgitation (Case #4)**

Severe TR (A) with lack of coaptation of the tricuspid valve leaflets and annulus dilatation (B). Abbreviation as in Figure 1.



**Figure 13. Determination of RV Systolic Function (Case #4)**

RV systolic function is moderately reduced as indicated by FAC = 14.6% (A), TAPSE = 12 mm (B), Doppler tissue imaging  $s' = 7.6$  cm/s by pulsed wave (C) and 5 cm/s by color Doppler (D), RV global strain =  $-15.2\%$  by Doppler (E), and 3-dimensional RVEF 28% (F). Abbreviations as in Figures 1, 3, and 10.

**Table 1. Summary of Reference Limits for Selected Measurements of RV**

RV Parameter	Unit	Abnormal
RV FAC	%	<35.0
TAPSE (displacement)	cm	<1.6
RIMP (index of myocardial performance, pulse Doppler)	–	>0.4
DTI s' (pulsed wave) at the annulus	cm/s	<10.0
DTI s' (color coded) at base	cm/s	<6.2
PVR (Doppler)	WU	>2.0
3D RVEF	%	<44.0
DTI global strain (free wall)	%	>–15.9
2D speckle global strain (free wall)	%	>–19.8
Vena contracta width in severe TR	cm	>0.7
Tricuspid annulus diameter	cm	>3.1

RV FAC = [end diastolic area (cm<sup>2</sup>) – end systolic area (cm<sup>2</sup>)] / end diastolic area (cm<sup>2</sup>). RIMP = (IVRT + IVCT)/ ET = (TCO – ET)/ ET. PASP = 4 × (TRVmax)<sup>2</sup> + RA pressure based on IVC size and collapse. PVR = TRV (m/s)/TVI RVOT (cm) × 10 + 0.16 (Wood units).  
2D = 2-dimensional; 3D = 3-dimensional; DTI = Doppler tissue imaging; DTI s' = Doppler tissue imaging septal velocity; ET = ejection time; FAC = fractional area change; IVC = inferior vena cava; IVCT = isovolumic contraction time; IVRT = isovolumic relaxation time; PASP = pulmonary artery systolic pressure; PVR = pulmonary vascular resistance; RIMP = right ventricular index of myocardial performance; RA = right atrial; RV = right ventricular; RVEF = right ventricular ejection fraction; RVOT = right ventricular outflow tract; TAPSE = tricuspid annular plane systolic excursion; TCO = tricuspid closure-opening time; TR = tricuspid regurgitation; TRV = tricuspid regurgitation velocity; TVI = time velocity integral; WU = Wood units.

**Address for correspondence:** Dr. Thomas H. Marwick, Cleveland Clinic, Cardiovascular Medicine J1-5, Euclid Avenue, Cleveland, Ohio 44195. *E-mail:* [marwick@ccf.org](mailto:marwick@ccf.org).