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# Assessment of pulmonary artery pressure by echocardiography—A comprehensive review

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ABSTRACT

Pulmonary hypertension is a pathological haemodynamic condition defined as an increase in mean pulmonary arterial pressure ≥ 25 mmHg at rest, assessed using gold standard investigation by right heart catheterisation. Pulmonary hypertension could be a complication of cardiac or pulmonary disease, or a primary disorder of small pulmonary arteries. Elevated pulmonary pressure (PAP) is associated with increased mortality, irrespective of the aetiology. The gold standard for diagnosis is invasive right heart catheterisation, but this has its own inherent risks. In the past 30 years, immense technological improvements in echocardiography have increased its sensitivity for quantifying pulmonary artery pressure (PAP) and it is now recognised as a safe and readily available alternative to right heart catheterisation. In the future, scores combining various echo techniques can approach the gold standard in terms of sensitivity and accuracy, thereby reducing the need for repeated invasive assessments in these patients.



Pulmonary hypertension (PHT) is a pathological haemodynamic condition defined as an increase in mean pulmonary arterial pressure (mPAP) ≥ 25mmHg at rest, assessed using gold standard investigation by right heart catheterisation [1]. Pulmonary hypertension could be a complication of cardiac or pulmonary disease or a primary disorder of small pulmonary arteries. Transthoracic echocardiography (TTE) can be used to investigate and quantify pulmonary artery pressure (PAP). Elevated pulmonary pressure (PAP), measured by echocardiography, is associated with increased mortality, irrespective of the aetiology [2]. In addition, TTE can be used to assess the contribution of left ventricular systolic and diastolic dysfunction, valve function, and congenital lesions to the aetiology of PHT. Assessment can be challenging due to the complex pyramidal shape and retrosternal position of the right ventricle (RV) anatomy and load-dependent nature of the RV functional indices [3,4]. While TTE is not the gold standard, it is a readily available bedside technique accepted as the primary non-invasive tool in the assessment of PAP [5]. We present the common techniques currently in use, their advantages, disadvantages, and pitfalls in the echocardiographic measurement of pulmonary pressure.

## 1. Pulmonary artery systolic pressure by TR peak velocity

Continuous wave (CW) Doppler of the tricuspid regurgitation (TR) trace is used to measure the difference in pressures between the right ventricle and right atrium. The simplified Bernoulli equation ($P = 4[TRmax]^2$) is used to calculate this pressure difference using peak TR velocity. This method correlates well with PASP on right heart catheterisation [6,7]. A peak TR velocity value of ≤2.8 m/s is considered normal.

### 1.1. Method

A coaxial TR jet is identified in parasternal long axis (RV inflow), parasternal short axis, or apical 4-chamber view with the help of colour Doppler. CW Doppler is used with a sweep speed of 100 mm/s to achieve a satisfactory envelope (Fig. 1). The peak velocity of the envelope is then measured ($TR_{max}$). A value of ≤2.8 m/s suggests low probability, a value of 2.9–3.4 m/s indicates intermediate probability, and a value >3.4 m/s suggests a high probability for pulmonary hypertension [1]. Traditionally, right atrial pressure (RAP) is assumed by the size and distensibility of inferior vena cava (IVC) during inspiration at rest and during forced inhalation, and this value is added to the peak TR velocity [8]. However, recent ESC guidelines suggest just using the TRmax without

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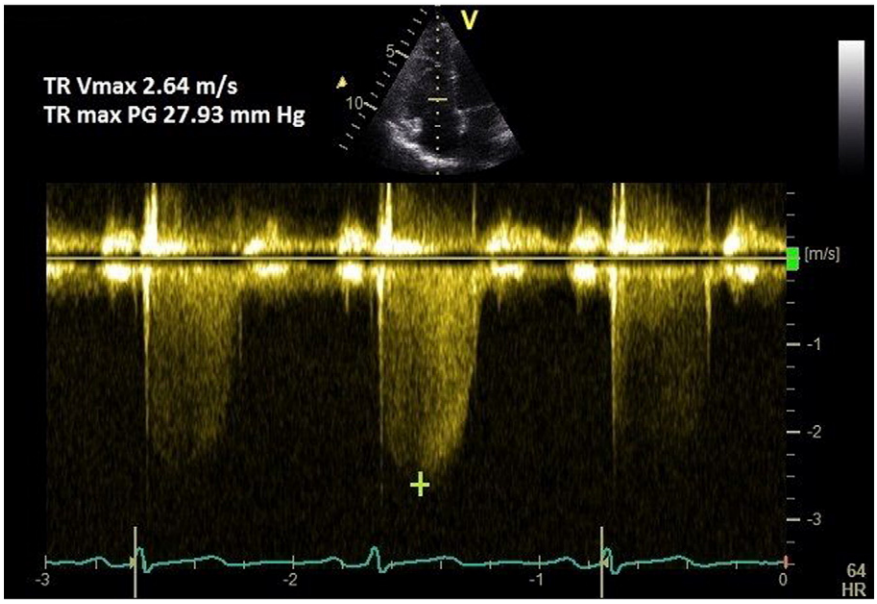


**Fig. 1.** TR Vmax method for measuring PASP.

additional RAP, as IVC assessment is error prone [1]. Mean PAP can be approximated from the systolic PAP (SPAP) using the following formula: mPAP = 0.61*SPAP + 2 mmHg [9].

If there is marked sinus arrhythmia, the trace should be obtained at expiratory apnoea. If the patient is in atrial fibrillation, then 8 consecutive TR velocities are averaged to give the best estimate [7]. In case of pulmonary valve or right ventricular outflow tract (RVOT) stenosis, this method overestimates the PASP; then the peak pressure gradient across the valve or RVOT should be subtracted from the measured PASP.

### 1.2. Common pitfalls

A lesser degree of TR may occur in a compensated right ventricle (due to elevated ventricular pressure) and this could lead to underestimation of PASP. Similarly, severe TR could cause equalisation of right atrial and ventricular pressures which may cause the TR Doppler envelope to be cut short, leading to underestimation of PASP (Fig. 2-C) [8]. RAP is often overestimated if IVC measurement is used, leading to overestimation of PASP [10]. Calculations using the TR trace assume that there is no pulmonary valve stenosis and may be inaccurate in the presence of RV systolic dysfunction. TR signal could be poor in a good proportion of patients with lung disease, and TRmax measurement should be avoided in the absence of a good Doppler envelope (Fig. 2) [11].

### 1.3. Tricks

- The best TR signal is often "off-axis," in-between parasternal and apical windows. An RV-focussed or fore shortened 4-chamber view might give the best signal [12]. Sometimes, subcostal long and short axis windows provide the optimal signal and incident angle.
- The frame rate should be optimised to ≥20 Hz with colour Doppler.
- The faster the heart rate, the higher the frame rate needed to assess regurgitant jets.
- If the TR signal is poor, consider intravenous agitated saline.

## 2. Mean pulmonary artery pressure from peak PR Doppler signal

### 2.1. Method

A pulmonary regurgitation (PR) signal is obtained in the parasternal short axis view using colour Doppler. CW Doppler at a sweep speed of 100 mm/s is used to measure the peak PR velocity (Fig. 3). Peak pressure difference (measured by the Bernoulli equation) is then added to the RAP. This method has been validated against gold standard catheter-measurements [13,14]. Mean PAP can be approximated from the peak PR Doppler signal using the following formula: mPAP = 4(PRpeak velocity)$^2$ + RAP.

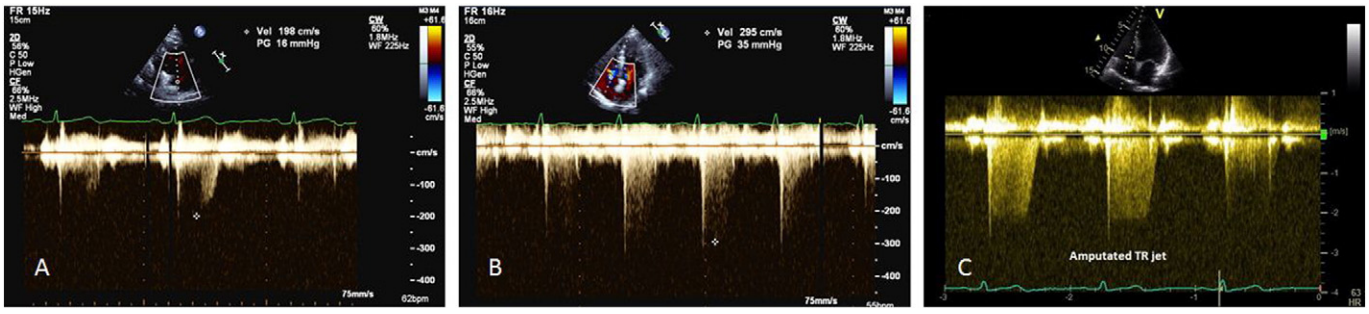


**Fig. 2.** Pitfalls in TR peak measurement. A, B—Peak TR measurement with incomplete trace could lead to underestimation. C—Amputated jet could occur in severe TR that could lead to underestimation.