## B. How to Grade Pulmonary Stenosis

***Pulmonic stenosis severity*** Quantitative assessment of pulmonary stenosis severity is based mainly on the transpulmonary pressure gradient. Calculation of pulmonic valve area by planimetry is not possible since the required image plane is in general not available. Continuity equation or proximal isovelocity surface area method, although feasible in principle, has not been validated in pulmonary stenosis and is rarely performed.

*B.1.1. Pressure gradient.* The estimation of the systolic pressure gradient is derived from the transpulmonary velocity flow curve using the simplified Bernoulli equation $\Delta P = 4v^2$. This estimation is reliable, as shown by the good correlation with invasive measurement using cardiac catheterization.[101] Continuous-wave Doppler is used to assess the severity when even mild stenosis is present. It is important to line up the Doppler sample volume parallel to the flow with the aid of colour flow mapping where appropriate. In adults, this is usually most readily performed from a parasternal short-axis view but in children and in some adults the highest gradients may be found from

**Table 11** Grading of pulmonary stenosis

| | Mild | Moderate | Severe |
|---|---|---|---|
| Peak velocity (m/s) | <3 | 3–4 | >4 |
| Peak gradient (mmHg) | <36 | 36–64 | >64 |

the subcostal window. A modified apical five-chamber view may also be used where the transducer is angled clockwise to bring in the RV outflow tract. Ideally, the highest velocity in multiple views should be used for the determination.[102,103]

In most instances of valvular pulmonary stenosis, the modified Bernoulli equation works well and there is no need to account for the proximal velocity as this is usually, 1 m/s. There are exceptions to this, however. In the setting of subvalvular or infundibular stenosis and pulmonary stenosis as part of a congenital syndrome or as a result of RV hypertrophy, the presence of two stenoses in series may make it impossible to ascertain precisely the individual contribution of each. In addition, such stenoses in series may cause significant PR resulting in a higher Doppler gradient compared with the net pressure drop across both stenoses.[104] Pulsed-wave Doppler may be useful to detect the sites of varying levels of obstruction in the outflow tract and in lesser degrees of obstruction may allow a full evaluation of it. Muscular infundibular obstruction is frequently characterized by a late peaking systolic jet that appears 'dagger shaped', reflecting the dynamic nature of the obstruction; this pattern can be useful is separating dynamic muscular obstruction from fixed valvular obstruction, where the peak velocity is generated early in systole.

In certain situations, TEE may allow a more accurate assessment of the pulmonary valve and RVOT. The pulmonary valve may be identified from a mid-esophageal window at varying transducer positions from 50 to 90, anterior to the aortic valve. The RVOT is often well seen in this view. It is in general impossible to line up CW to accurately ascertain maximal flow velocity. Other windows in which the pulmonary outflow tract may be interrogated include the deep transgastric view in which by appropriate torquing of the transducer, the RV inflow and outflow may be appreciated in a single image. This view can allow accurate alignment of the Doppler beam with the area of subvalvar/valvular stenosis through the RV outflow tract.

In pulmonary valve stenosis, the pressure gradient across the valve is used to ascertain severity of the lesion more so than in left-sided valve conditions due in part to the difficulty in obtaining an accurate assessment of pulmonary valve area. The following definitions of severity have been defined in the 2006 American College of Cardiology/American Heart Association (ACC/AHA) guidelines on the management of valvular heart disease:[1]

Severe stenosis (Table 11): a peak jet velocity >4 m/s (peak gradient >64 mmHg) Moderate stenosis: peak jet velocity of 3–4 m/s (peak gradient 36–64 mmHg)

Mild stenosis: peak jet velocity is: <3 m/s (peak gradient less than 36 mmHg).

In determining the need for intervention, no specific Doppler gradients have been agreed on.

Severity of pulmonary stenosis using Doppler gradients has been based on catheterization data with demonstration of reasonable correlation between instantaneous peak Doppler gradients and peak-to-peak gradients obtained by catheterization. Typically though, Doppler peak gradients tend to be higher than peak-to-peak catheterization gradients.[102] Doppler mean gradient has been shown in one study to correlate better with peak-to-peak catheterization gradient but is not commonly used.[105]