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When the gold standard is not always golden: The value of invasive hemodynamic assessment to overcome the pitfalls of echocardiography in challenging cases of mitral stenosis

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Abstract

Mitral stenosis is a uncommon valvular lesion in the developed countries. Noninvasive evaluation is the first-line modality for assessment of mitral stenosis, however the noninvasive methods may have limitations in certain cases. Invasive hemodynamics can be used as adjunct tool for assessment of mitral stenosis in such difficult cases. Mitral valve using three-dimensional planimetry is a promising technique for assessment of mitral stenosis.

KEYWORDS

hemodynamics of mitral stenosis, echocardiography, cardiac catheterization

1 | INTRODUCTION

Transthoracic echocardiography (TTE) is considered first-line modality for assessment of mitral stenosis (MS). Continuous wave Doppler (CW), mean gradient (MG), mitral valve area (MVA) by planimetry, pressure half time (PHT), and the continuity equation are considered class I recommendations for assessment of the MVA.[1] Evaluation of the severity of MS can indeed be challenging. The limitations of the aforementioned techniques may lead to inaccurate evaluations of disease severity and will be discussed later on in this paper. We present 4 patients who underwent evaluation for MS both by echocardiography and invasive hemodynamic measurements. In all 4 studies, all the class 1 recommended techniques had shortcomings in identifying severity of stenosis. Three-dimensional (3D) planimetry by transesophageal echo (TEE) was consistent in identifying the severity of MS.

2 | CASE 1

A 55-year-old morbidly obese female (body surface area [BSA] 2.27 m^2) and a body mass index of 50 was admitted for new onset of shortness of breath. Physical examination revealed respiratory distress requiring oxygen and bibasilar crackles. Brain natriuretic peptide was 98 pg/mL. Chest x-ray revealed bilateral pulmonary edema. Intravenous diuresis was started for heart failure (HF).

Transthoracic echocardiography revealed a thickened MV with diastolic doming of the anterior MV leaflet concerning for rheumatic MS (Figures 1 and 2). MG was 8.1 mm Hg at heart rate (HR) of 76 beats/min (Figure 3). MVA by PHT was 1.85 cm^2 (Figure 4). These values suggested moderate MS that was inconsistent with clinical presentation. TEE data were consistent with TTE data except the MV appeared more stenotic (Figure 5). On catheterization right ventricular (RV) pressure was 48/5 mm Hg and a pulmonary capillary wedge pressure (PCWP) was 23 mm Hg. PCWP to left ventricular diastolic pressure (LVDP) MG was 11 mm Hg (Figure 6) with MVA of 1.6 cm^2. She was considered to have moderate MS assuming that PCWP overestimated the gradient due to phase delay. Medical therapy and smoking cessation were recommended.

Subsequently, she had 3 ED visits for HF that responded to diuretic therapy. As she continued to have NHYA III-IV symptoms, repeat catheterization with transseptal puncture revealed that RV pressures were 52/17 mm Hg and PCWP was 26 mm Hg. Left atrium (LA) to LVDP MG was 12 mm Hg (Figure 7). Calculated MVA was 1.5 cm^2. MVA by 3D multiplanar reconstruction was 1.6 cm^2 (0.7 cm^2/m^2) (Figure 8). MV was favorable for valvuloplasty with a Wilkins score of 7, minimal mitral regurgitation, and no LAA thrombus. At the time of mitral balloon valvuloplasty (MBV), the LA to LVDP MG was 16 mm Hg. Initial MBV was unsuccessful. Subsequently, she developed moderate MR and underwent MV replacement. Pathology confirmed a severely stenosed rheumatic MV.

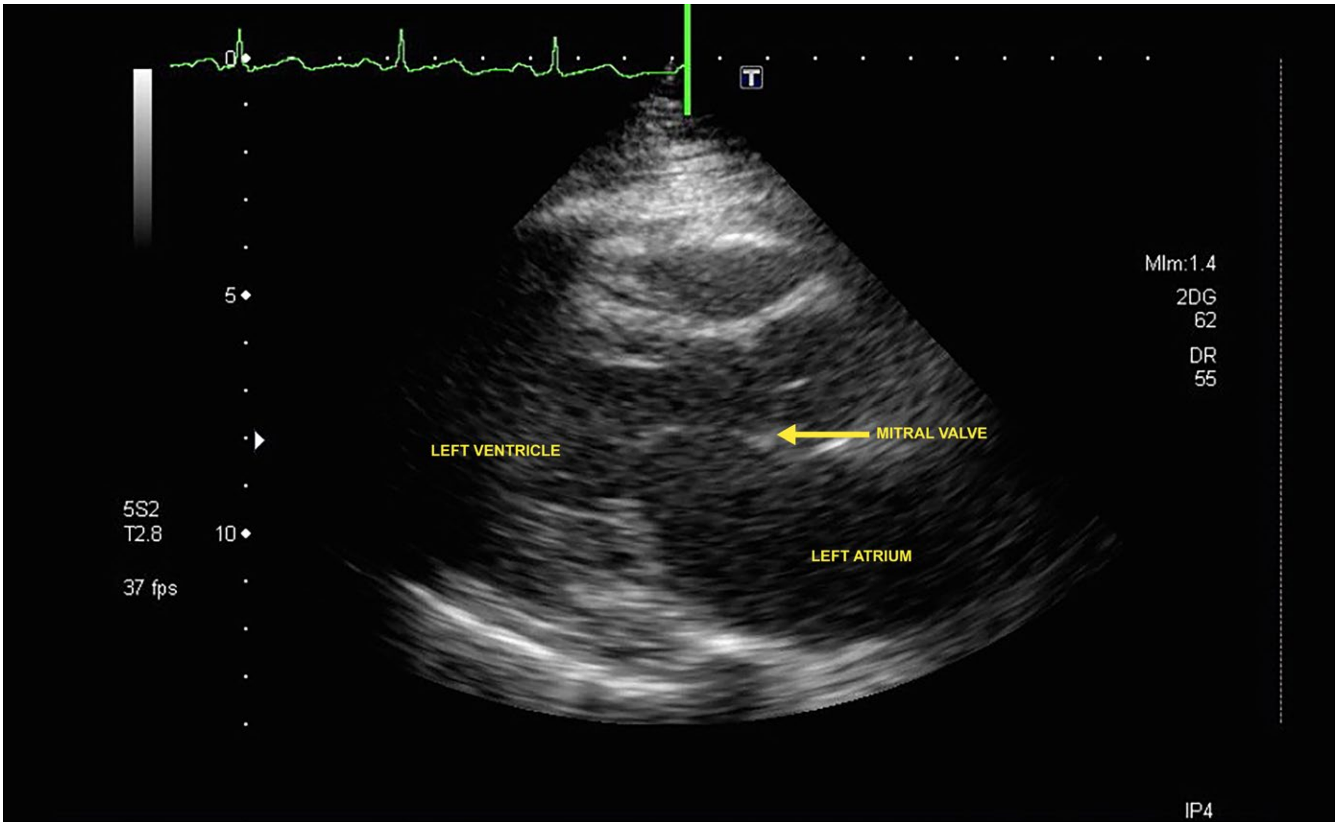

FIGURE 1 Parasternal long-axis view (transthoracic echocardiography) showing restricted mitral valve opening with diastolic doming

Patients 2, 3, and 4 all presented with MS and NYHA class III/IV symptoms. They had also undergone evaluation by 2D and 3D echo and invasive testing to undercover the severity of their MS. The findings of all patients will be summarized in Table 1.

3 | DISCUSSION

We present a case series of MS where the recommended methods of evaluation of did not accurately classify the severity of MS. In our series, echocardiography-derived variables for MS assessment included MG, and MVA by 3D-planimetery, PHT, and proximal isovelocity surface area (PISA). MVA by cardiac catheterization was calculated using Gorlins equation.

In case 1, MVA was between 1.5 and 1.6 cm^2 based on the echo assessment with a MG of 8 mm Hg. Percutaneous mitral balloon commissurotomy (PMBC) is considered class IIb recommendation for symptomatic patient with a MVA greater than 1.5 cm^2 which implies that this patient does not have a strong indication for PMBC. A valve area cutoff of 1.5 cm^2 is reasonable for normal sized individual and may not be applicable in patients with large body surface. Currently, there is no recommendation or data to support the use of indexed the MVA for MS. Theoretically, individuals with a large body surface may need larger MVA for adequate left ventricular filling. Indexed MVA in case 1 was 0.66 cm^2. Considering MVA less than 1.5 cm^2 as severe, and assuming a normal BSA of 1.7 m^2 in females and 1.9 m^2 in males, MVA less 0.9 cm^2 in females and 0.8 cm^2 in males would be considered severe. Our patient would have been in the severely stenotic range if adjusted for her body size (BSA 2.3). Patients with a MVA

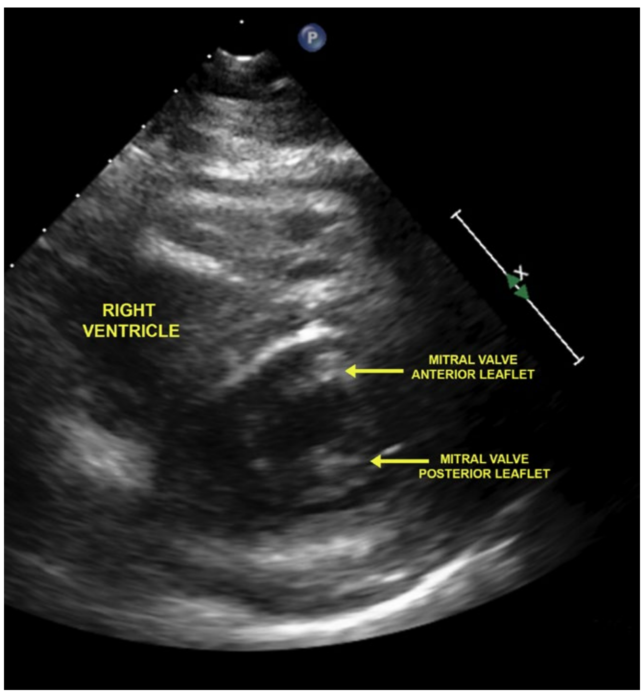

FIGURE 2 Short-axis view of the mitral valve

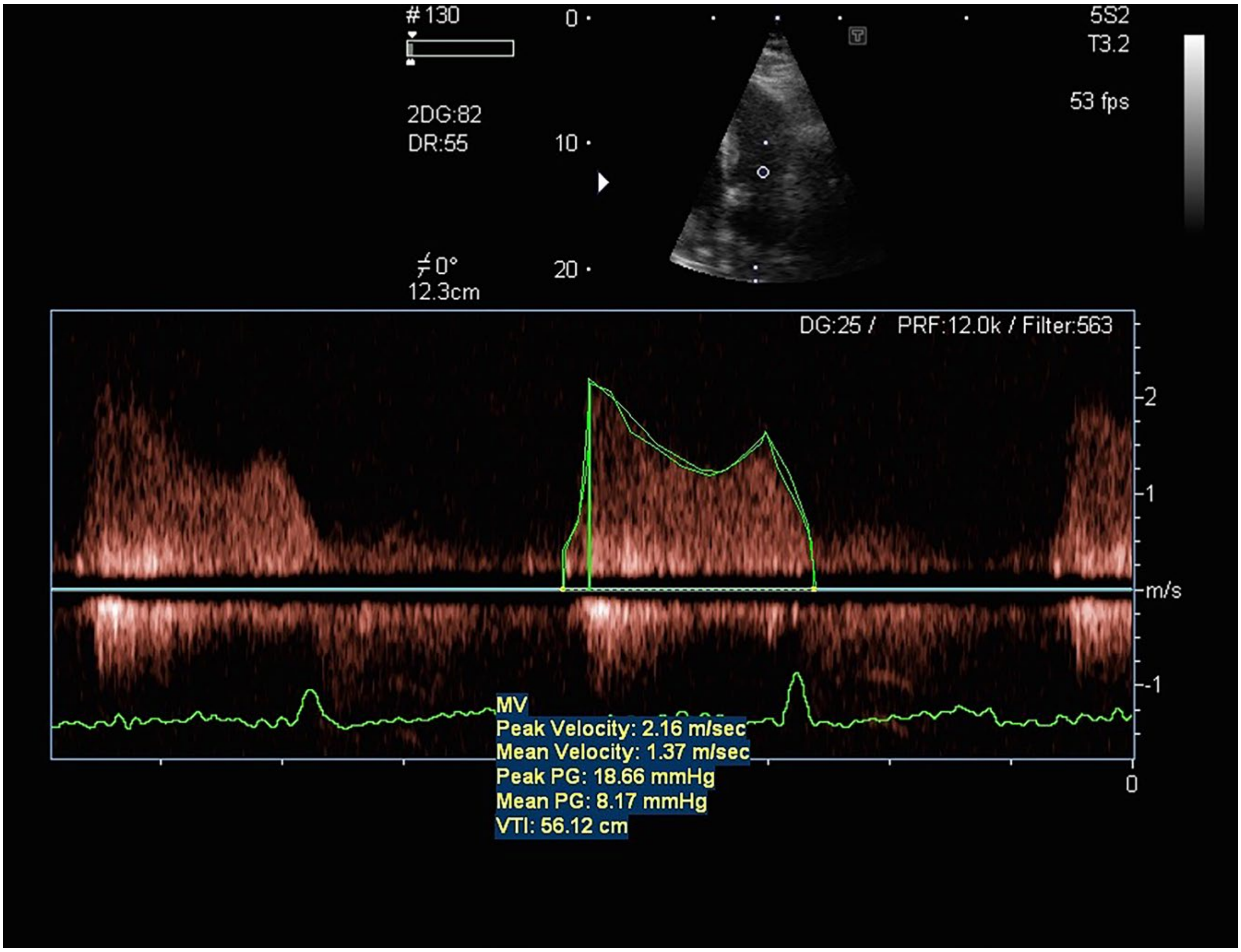

FIGURE 3 Continuous wave Doppler across the mitral valve (transthoracic echocardiography)

greater than 1.5 cm^2 and less than 2.0 cm^2 can have symptomatic MS,[2] and in these individuals in particular it may be more practical to index the MVA for body surface area. Exercise echocardiography was considered in all four patients and was not feasible as all of these patients were unable to exercise due to either significant shortness of breath or obesity.

3.1 | Pitfalls of mitral valve gradient by echo

Mitral valve gradient assessed by invasive method and TTE have shown very good correlation in the previous studies.[3] Doppler pressure gradient using simplified Bernoulli gradient has level I recommendation of assessment of severity of MS.[1] CW Doppler pressure gradient is very useful tool and, however, has several pitfalls. CW Doppler pressure gradient is dependent on HR, cardiac output, and MVA. Moreover, the CW Doppler pressure gradient can be underestimated due to inadequate Doppler signal alignment to the mitral inflow. In all four cases, the Doppler MG was significantly lower than invasive gradient measurements (Table 1). In case 1 and case 2, direct LA-LVDP gradient was available in addition to PCWP-LVDP gradient. Catheter-based gradients were much higher than the gradient obtained by TTE.

As noted earlier, in case 1, PCWP to LVDP pressure gradient was 11 mm Hg as compared to pressure gradient of 8 mm Hg by echocardiogram. PCWP is known to overestimate mitral valve stenosis due to phase delay.[3] As the pressure gradient by echocardiography and mitral valve by PHT suggested moderate MS, we assumed that PCWP overestimated the mitral valve gradient. We opted to medically manage with diuretic, β-blockers and encouraged her to quit smoking. As the patient continued to remain symptomatic despite smoking cessation, we performed direct LA to LVDP gradients which were found to be 12 mm Hg. Mean LAP was 25 mm Hg, and mean LVDP was 13 mm Hg.

Although pressure gradient with CW Doppler had excellent correlation with direct LA to LVEDP gradient in a previous study of 17 patients,[3] we think that CW Doppler underestimated the gradient across the mitral valve in all four cases. CW Doppler is well known to underestimate RV systolic pressure and aortic valve gradient in aortic stenosis due to inadequate Doppler signal alignment. Hence, caution should be exercised while using CW Doppler gradients to assess MS severity.

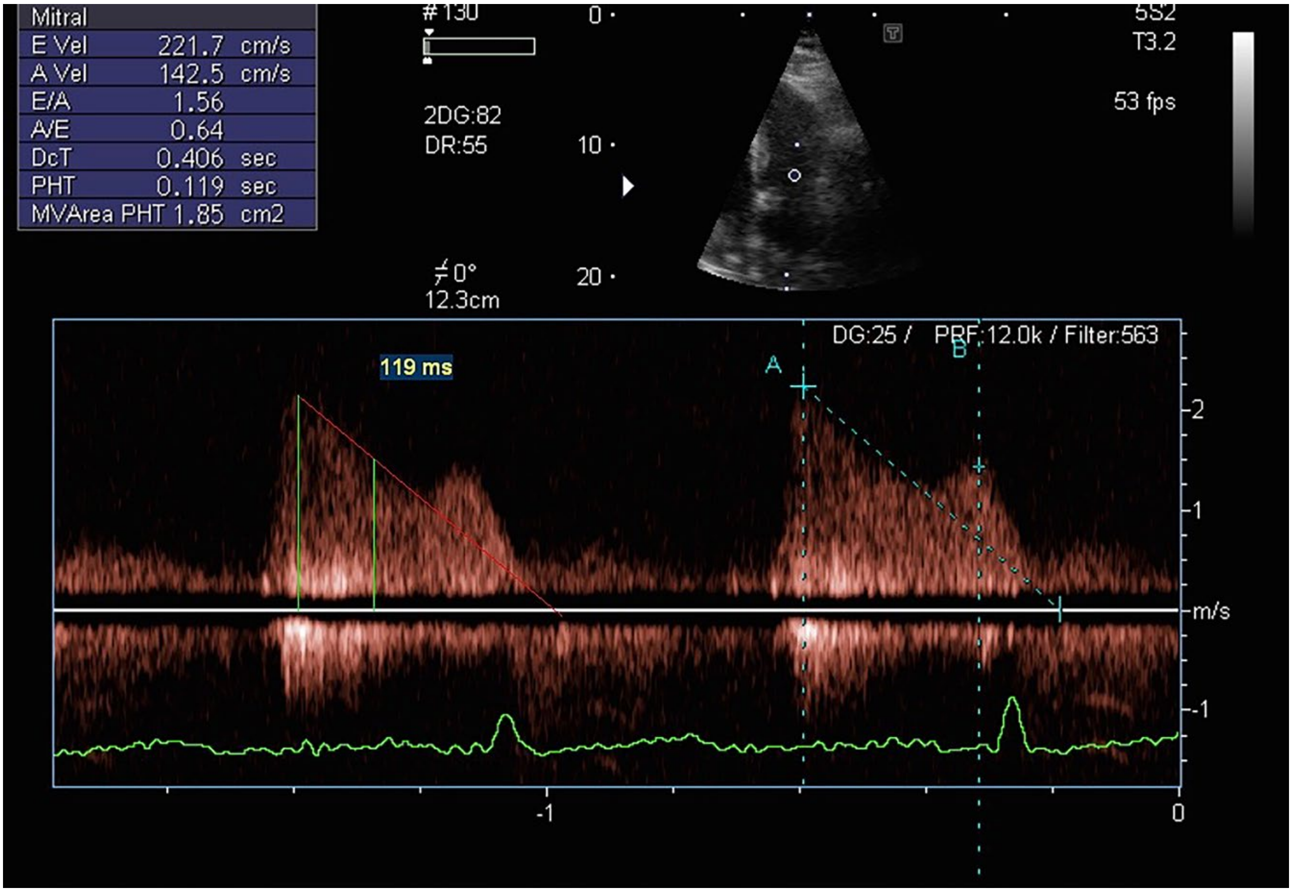

FIGURE 4 Mitral valve area assessment using pressure half time

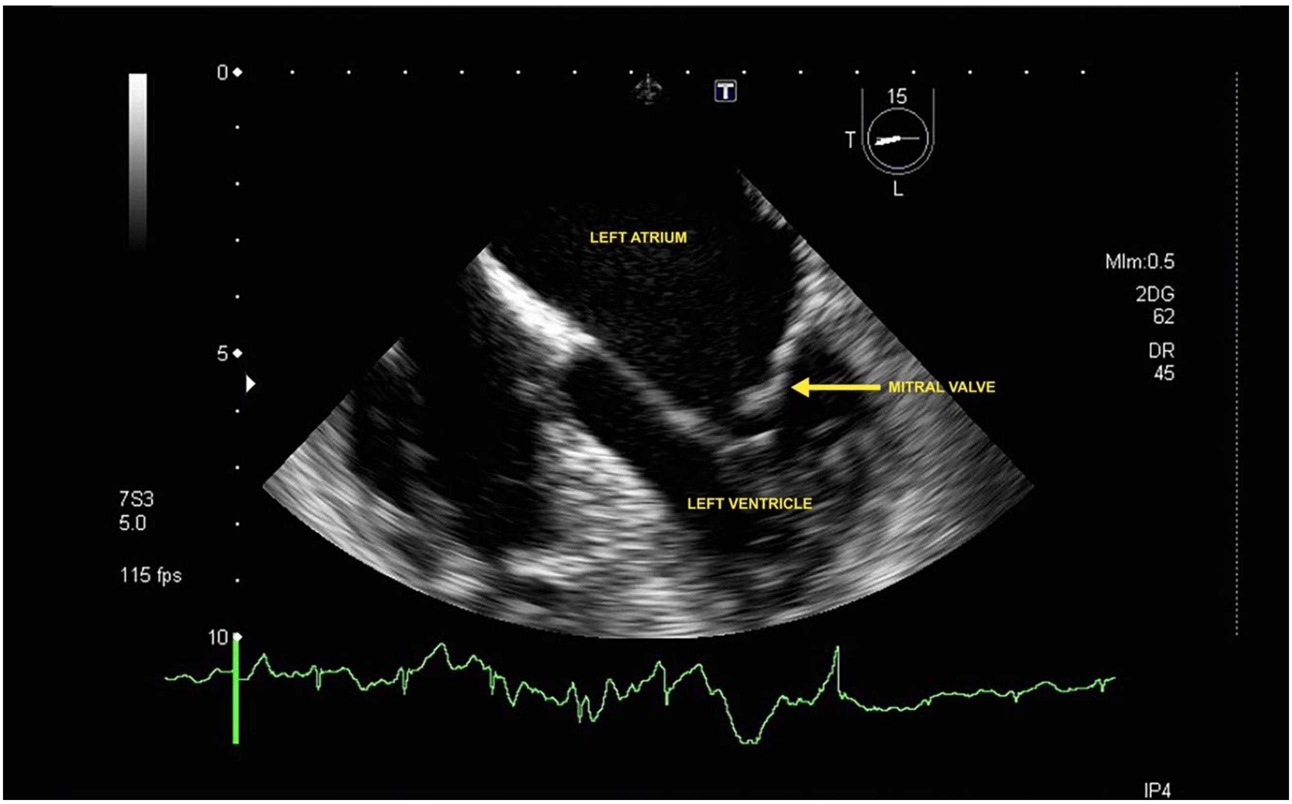

FIGURE 5 Mid-esophageal (transesophageal echo) showing restricted mitral valve opening with diastolic doming

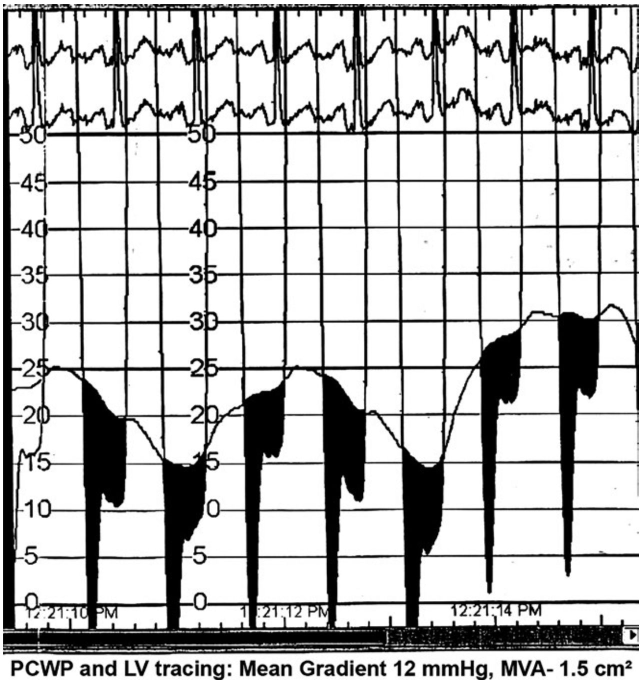

FIGURE 6 Pulmonary capillary wedge pressure to left ventricular pressure gradient tracing with a mean gradient of 12 mm Hg and a mitral valve area of 1.5 cm^2

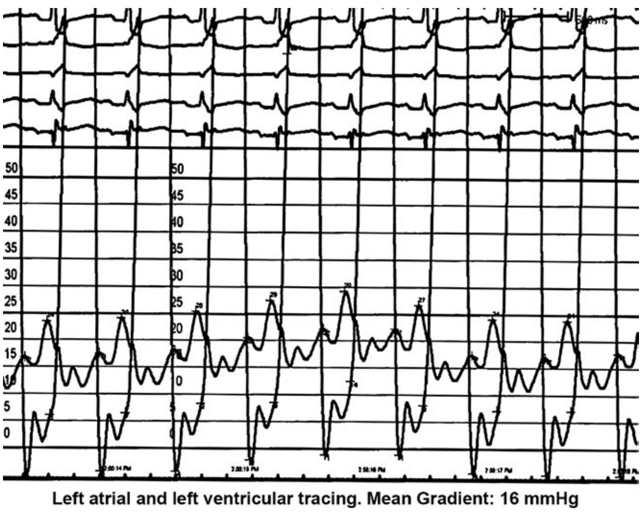

FIGURE 7 Simultaneous left atrium/left ventricular pressure tracing at the time of balloon valvuloplasty showing a gradient of 16 mm Hg

3.2 | Limitations of pressure half time for MVA

Pressure half time is routinely utilized to calculate the MVA and has level 1 recommendation for assessment for severity of MS.[1] PHT is dependent on left atrial and left ventricular compliance and can be inaccurate in patients with abnormal compliance.[4,5] The routinely used equation for MVA (MVA = 220/PHT) as proposed

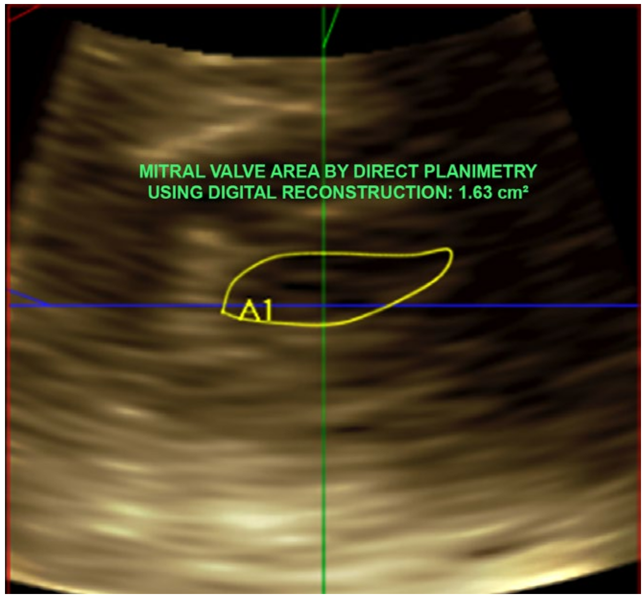

FIGURE 8 Mitral valve area by 3D reconstruction using QLAB

by Hatle et al.[6] also has potential pitfalls. The numerator in the equation "220" is derived from the equation 11.6 × Cn × delta P½. Cn is net atrioventricular compliance, and the assessment of Cn has been described previously.[4,5] In these studies, it was observed that for patients with abnormal (increased and decreased) atrioventricular compliance (Cn) the correlation of the MVA with PISA method or planimetery was not as good as patients with normal compliance. All the patients in our case series had severely dilated LA and presumably abnormal left atrial compliance. We observed that MVA calculated by PHT was overestimated in 3 patients (Cases 1, 3 and 4). We believe that PHT overestimates the MVA due to abnormal left atrial compliance and hyperdynamic left ventricle.

3.3 | Role of 3D planimetry for MVA

3D echocardiography has a very robust application in mitral valve pathology. We performed 3D planimetry with multiplanar reconstruction using QLAB in all 4 patients. We noticed that MVA with 3D planimetery had excellent correlation with the MVA obtained by the Gorlins equation during cardiac catheterization.

4 | CONCLUSION

In summary, CW Doppler gradient may underestimate gradient in MS. In addition, PHT can overestimate the MVA as observed in our cases. Thus, in symptomatic patients with MS, who are unable to exercise and have incongruent echocardiography data cardiac catheterization should be considered to assess direct LA to LVDP gradient and MVA by Gorlins equation. In patients with

TABLE 1 A summary of the 2D echo and invasive hemodynamic findings across the 4 patient cases

	Mean gradient (mm Hg)	PCWP to LVDP (mm Hg)	LA to LVDP gradient (mm Hg)	MVA PHT, cm^2	MVA planimetery (3D), cm^2	Indexed MVA, cm^2/m^2	MVA by Gorlrin equation, cm^2	Indexed MVA, cm^2/m^2
Case 1	8	12	16	1.8	1.6	0.7	1.5	0.66
Case 2	12	24	23	1.1	1.3	0.68	1.3	0.68
Case 3	9	20	NA	1.8	1.3	0.61	1.3	0.61
Case 4	9	20	NA	1.65	1.0	0.6	0.71	0.46

PCWP, pulmonary capillary wedge pressure; LVDP, left ventricular diastolic pressure; LA, left atrium; MVA, mitral valve area; PHT, pressure half time.

adequate image quality, MVA by 3D planimetery can be excellent initial tool to assess the severity of MS. MVA indexed for body surface area might be more appropriate for assessment of severity of MS.

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