Comparison of mitral valve area by pressure half-time and proximal isovelocity surface area method in patients with mitral stenosis: effect of net atrioventricular compliance

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Aims
The aim of this study was to test the hypothesis that, unlike calculation of the mitral valve area (MVA) with the pressure half-time method (PHT), the proximal isovelocity surface area method (PISA) is not affected by changes in net atrioventricular compliance (Cn).

Methods and results
We studied 51 patients with mitral stenosis (MS) from two centres. MVA was assessed with the PISA (MVAPISA), PHT (MVAPHT), and planimetry (MVAPLN, serving as the gold standard) method. Cn was calculated with a previously validated equation using 2D echocardiography. MVAPISA closely correlated with MVAPLN (r = 0.96, P < 0.0001), while MVAPHT and MVAPLN showed a weaker but still good correlation (r = 0.69, P < 0.0001). The correlation between MVAPHT and MVAPLN for patients with Cn between 4 and 6 mL/mmHg (considered to be normal) was excellent (r = 0.93, P < 0.0001), but that for patients with Cn of less than 4 or more than 6 mL/mmHg was not as good (r = 0.64, P < 0.0001). Importantly, a significant inverse correlation was detected between the percentage difference among MVAPHT, MVAPLN, and Cn (r = −0.77, P < 0.0001), but the line of fit was nearly flat for the percentage difference among MVAPISA, MVAPLN, and Cn (r = 0.1, P = 0.388).

Conclusion
MVA calculated with both the PISA and PHT methods correlated well with MVA calculated with the planimetry method. However, the PISA rather than PHT is recommended for patients with MS and extreme Cn values because PISA, unlike PHT, is not affected by changes in Cn.

Keywords
Mitral stenosis • Proximal isovelocity surface area method • Pressure half-time • Net atrioventricular compliance

Introduction
The principal cause of mitral stenosis (MS) is rheumatic fever which remains endemic in developing countries, therefore, MS is still a major public health problem in these countries. Despite the striking decrease in the prevalence of rheumatic fever, MS is still a major problem for older patients in Western countries.¹ Assessment of the mitral valve area (MVA) is of considerable importance being the main factor in the clinical evaluation of patients with MS for the determination of various aspects, such as treatment options and long-term outcomes. Several echocardiographic techniques have been introduced as means of MVA assessment, two of which, the two-dimensional planimetry and pressure half-time (PHT) methods are currently the most widely used.²–⁶

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The PHT method, in particular, has gained widespread acceptance for MVA calculations, mainly because of its simplicity and acceptable reproducibility. However, the clinical value of MVA calculated with the PHT method remains controversial because it can be affected by a variety of clinical conditions including significant aortic regurgitation and impaired left ventricular (LV) compliance. The proximal isovelocity surface area (PI SA) method has been introduced as a promising tool for the assessment of MVA. It is based on the principles of the continuity equation and the preservation of mass. The main advantage of the PISA method is its close correlation with reference methods in all studies. This advantage is outweighed, however, by being a difficult and time-consuming technique, which has made the PISA method the least popular for the calculation of MVA.

Recently, net atrioventricular compliance (Cn), derived by Doppler echocardiography, has been shown to be an important physiological determinant of pulmonary hypertension in patients with MS. Cn can be also used for representing left atrial compliance in these patients in the absence of any condition that impairs LV compliance. More importantly, Cn was found to be significantly higher for patients with MS associated with atrial fibrillation than for those who were in sinus rhythm, causing significant under-estimation of the MVAPHT when compared with MVAPISA. Accordingly, the objective of this study was to test the hypothesis that the PISA method using the conventional hemispheric equation is not affected by the Cn for MVA calculations pertaining to patients with MS in comparison with the effects of Cn on PHT calculations.

**Methods**

**Study population**

A series of 56 consecutive patients from two centres with rheumatic MS without prior history of percutaneous balloon mitral valvuloplasty were prospectively enrolled in this study. This protocol was approved by the Institutional Review Board on Biomedical Research at the Kobe University Hospital, Kobe, Japan, and Ain-Shams University Hospital, Cairo, Egypt. All patients gave informed consent consistent with this protocol. Five patients (9%) were excluded from all subsequent analyses because of suboptimal images from poor echocardiographic windows. Accordingly, the patient study group consisted of 51 patients, 29 of whom were enrolled at Ain-Shams University Hospital, Cairo, Egypt, and 22 at Kobe University Hospital, Kobe, Japan.

**Echocardiography**

All echocardiographic studies were acquired with a commercially available echocardiography system using a 2.5 MHz multi-frequency phased array transducer (Vivid 5 or 7; GE Vingmed Ultrasound AS, Horten, Norway). Digital routine grayscale two-dimensional cine loops from three consecutive beats were obtained at end-expiratory apnoea from standard apical and LV short-axis views at depths of 12–20 cm. Sector width was optimized to allow for complete myocardial visualization while maximizing the frame rate. Gain settings were adjusted for routine clinical grayscale two-dimensional imaging to optimize endocardial definitions. The LV ejection fraction was calculated as follows: 

\[
\text{EF} = \frac{\text{Biplane Simpson's rule using manual tracing of the digital images}}{\text{measured area at end-systole}} \times 100\%
\]

The peak and mean transvalvular pressure gradients were calculated with the modified Bernoulli equation. All echocardiographic data were reviewed by two experienced echocardiographers working separately and all measurements were made in ≥3 consecutive cardiac cycles and in ≥5 cycles if the patient’s rhythm was atrial fibrillation. The average values were used for the final analyses. For the assessment of intra-observer and inter-observer variability, all studies were redone for eight randomly selected cases in a different setting by the same operator (A.M.S.O.) and another operator (K.Y.) who was blinded to the results of the first operator.

**Assessment of mitral valve area**

**The planimetry method**

The smallest orifice of the mitral valve was identified by scanning from the left atrium in the direction of the LV apex using basal-LV short-axis view. The gain settings were adjusted until the lowest level was determined, at which the circumference of the mitral orifice was still visible. After identification of the frame with the orifice at its maximal opening in early diastole, MVA determined with the planimetry method (MVAPLAN) was measured by planimetry of its contours, and the result served as the gold standard for MVA calculation in this study (Figure 1A). The severity of MS measured with MVAPLAN as well as MVAPHT and MVAPISA was defined as: mild if MVA was more than 1.5 cm², moderate if MVA was more than 1.0 and less than or equal to 1.5 cm², and severe if MVA was less than or equal to 1.0 cm².

**The pressure half-time method**

MVA determined with the PHT method (MVAPHT) was calculated in the apical four-chamber view using colour Doppler echocardiography with clearly visible mitral inflow colour flow mapping. The cursor line was moved across the mitral valve tips to the most parallel alignment in relation to the colour signal of the mitral inflow. Continuous wave Doppler was initiated and a clear spectral tracing of the mitral inflow wave was acquired. The deceleration time of the early mitral filling phase spectrum was obtained and MVAPHT was then calculated using the equation MVAPHT = 220/PHT (Figure 1B). From the same mitral flow envelopes, mean transmtral pressure gradient was calculated by means of manual tracing.

**The proximal isovelocity surface area method**

MVA determined with the PISA (MVAPISA) method is based on the analysis of the flow convergence proximal to the stenotic orifice. MVAPISA was obtained in the apical four-chamber view using the conventional equation of the hemispherical model: MVAPISA = \(2\pi r^2 \times \frac{\text{Val} \times \text{Vmax}}{\alpha}\), where: \(r\) (cm) is the radius of the PISA cap, Val (cm/s) is the aliasing velocity of colour Doppler, Vmax (cm/s) is the maximum velocity across the mitral valve in early diastole (i.e. maximum velocity of the E-wave), and \(\alpha\) (degree) is the mitral valve angle. Colour flow Doppler was applied on the mitral position and the aliasing velocity (Val) was selected, by shifting down the frequency, to 33 cm/s, followed by zooming the PISA flow and a cine loop was used to obtain the largest PISA cap radius (\(r\)) in early diastole by measuring the maximum distance between the apex of the triangle formed by both mitral leaflets at one end (defined as the point at which imaginary lines passing through both leaflets would meet below the mitral valve with the colour Doppler turned off), and the first line of aliasing at the other end (defined by the change of the colour from red to blue). The mitral valve angle was measured manually with a protractor on external paper pictures (Figure 1C).

**Percentage difference from MVAPLAN**

The percentage difference between methods in relation to MVAPLAN was calculated as follows: 

\[
\text{PHT\%} = \left(\frac{\text{MVAPHT} - \text{MVAPLAN}}{\text{MVAPLAN}}\right) \times 100\%
\]

\[
\text{PISA\%} = \left(\frac{\text{MVAPISA} - \text{MVAPPLAN}}{\text{MVAPPLAN}}\right) \times 100\%
\]
Assessment of Cn

Cn was determined non-invasively by means of Doppler echocardiography as previously described\textsuperscript{7,8,14} using the following equation:

\[
Cn = \frac{1270 \times (MVAPLN/E-wave downslope)}{MVAPLN} \times 100,
\]

where Cn was expressed in millilitres per millimetres of mercury (mL/mmHg), MVAPLN was expressed in square centimetres (cm\textsuperscript{2}) and the E-wave downslope was the mitral flow E-wave downslope expressed in centimetres per square second (cm/s\textsuperscript{2}).

Statistical analysis

All data were expressed as mean ± SD. Correlation analyses were performed using linear regression and expressed as Pearson correlation coefficients. P-value < 0.05 was considered statistically significant. All the analyses were performed with commercially available software (SPSS version 16.0, SPSS, Inc., Chicago, IL, USA). The authors had full access to the data and take full responsibility for their integrity.

Results

The study group consisted of 51 patients with MS for each of whom three complete sets of MVA calculations were obtained. The mean age was 48 ± 19 years, and 28 (55%) patients were female. The clinical and echocardiographic characteristics of all study subjects are summarized in Table 1. Nine patients (18%) were classified as mild MS, 19 (37%) as moderate, and 23 (45%) as severe. Severity was defined in terms of MVAPLN. Thirty patients (59%) were in sinus rhythm and 21 (41%) in chronic atrial fibrillation. All patients had normal LV ejection function of 61 ± 6% (all ≥ 55%).

Correlations between different methods

Linear regression analysis showed that the MVAPISA correlated closely with the MVAPLN (r = 0.96, P < 0.0001; Figure 2A). A lower but good and statistically highly significant correlation was also found between MVAPLN and MVAPHT (r = 0.69, P < 0.0001; Figure 2B).
Effect of $C_n$ on pressure half-time and proximal isovelocity surface area methods

Plotting $C_n$ against PHT% and PISA% showed that there was a significant inverse correlation between PHT% and $C_n$ ($r = -0.77$, $P < 0.0001$, Figure 3A), but a nearly flat line of fit was shown between PISA% and $C_n$ ($r = 0.1$, $P = 0.388$, Figure 3B). Patients were divided into two groups according to their $C_n$ values. Group 1 consisted of 20 patients with $C_n$ values ranging between 4 and 6 mL/mmHg (values considered to be more or less normal). Group 2 consisted of 31 patients with low (less than 4 mL/mmHg) or high (more than 6 mL/mmHg) $C_n$ values. $C_n$ less than 4 mL/mmHg was defined as abnormal on the basis of a previous study by Schwammenthal et al.14 The correlation between MVAPHT and MVAPLN for Group 1 was excellent ($r = 0.96$, $P < 0.0001$, Figure 4A), while that for Group 2 was still good, but weaker than the original overall correlation ($r = 0.64$, $P < 0.0001$, Figure 4B).

Thirty-four patients showed the same severity grade of MS according to MVA PLN and MVA PHT (MVA PLN = 1.07 ± 0.28, MVA PHT = 1.05 ± 0.34, PHT% = −2.0 ± 16.5). Six patients showed MVAPHT severer by one grade than MVAPLN (MVAPLN = 1.8 ± 0.27, MVAPHT = 1.29 ± 0.22, PHT% = −28.9 ± 7.5), and 11 patients showed MVAPHT milder by one grade than MVAPLN (MVAPLN = 1.0 ± 0.22, MVAPHT = 1.3 ± 0.25, PHT% = 32.7 ± 23). It is noteworthy that $C_n$ values were almost within the assumed normal range for patients with the same grade of severity (4.9 ± 1.8 mL/mmHg), but $C_n$ values were higher for patients with severer MS according to MVAPHT (7.9 ± 1.1 mL/mmHg), and lower for patients with milder MS (3.6 ± 1.1 mL/mmHg) (Table 3). In case of the PISA method, differences in severity were fewer and showed smaller values of PISA%. The MVAPISA was found to be severer by one grade than MVAPLN in only two cases (MVAPLN = 1.34 ± 0.38, MVAPISA = 1.16 ± 0.36, PISA% = −1.9 ± 5%), and milder by one grade in seven cases (MVAPLN = 1.16 ± 0.26, MVAPISA = 1.27 ± 0.27, PISA% = 10 ± 5%).

Discussion

It has been previously reported that PHT is an inaccurate measure of MVA if MS is associated with tachycardia, atrial fibrillation, nonlinear Doppler velocity curves, pregnancy or more importantly changes in atrial or ventricular compliance.3,7–10,17–19 which raised question about the appropriateness of PHT for clinical practice. Moreover, differences between PHT and planimetry of more than 0.3 cm² have been found in 20% of patients.9,20 The PISA method, on the other hand, has been validated in almost all

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Table 2 The intra-observer and inter-observer variability

<table>
<thead>
<tr>
<th></th>
<th>MVAPISA (cm²)</th>
<th>MVAPHT (cm²)</th>
<th>MVAPLN (cm²)</th>
<th>$C_n$ (mL/mmHg)</th>
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<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
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<td>Mean ± SD</td>
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<tr>
<td>Intra-observer</td>
<td>0.06 ± 0.05</td>
<td>0.08 ± 0.08</td>
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<td>0.6 ± 0.5</td>
</tr>
<tr>
<td>Inter-observer</td>
<td>0.06 ± 0.06</td>
<td>0.07 ± 0.07</td>
<td>0.07 ± 0.09</td>
<td>0.5 ± 0.2</td>
</tr>
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MVAPISA, mitral valve area by proximal isovelocity surface area method; MVAPHT, mitral valve area by pressure half-time method; MVAPLN, mitral valve area by planimetry method; $C_n$, net atrioventricular compliance.

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Figure 2 (A) Dot plots of the mitral valve area obtained with the proximal isovelocity surface area method (MVAPISA) in relation to the mitral valve area calculated with the planimetry method (MVAPLN), demonstrating a close and linear correlation. (B) Dot plots of the mitral valve area calculated with the pressure half-time method (MVAPHT) in relation to MVAPLN, demonstrating a weaker, but still good and statistically highly significant correlation.
conditions that tend to render the PHT inaccurate. Our study demonstrated that both MVAPISA and MVAPHT correlated well with MVAPLN, with a closer correlation in case of PISA ($r = 0.96, 0.69$). Given the simplicity of the PHT method compared with the reputed technically difficult PISA technique, it seems that PHT has advantage over PISA. This concept did not hold true for our study; however, when we took into consideration the effect a changing $C_n$ has on the PHT and PISA calculations. Plotting the values of $C_n$ against the percentage difference between MVAPHT and MVAPLN (PHT%) showed that there was a strong negative correlation between both values ($r = -0.77$ and $P < 0.0001$). A similar finding was reported in a study by Kim et al. ($r = -0.86$ and $P < 0.001$). In case of PISA, we could not find any correlation between the percentage difference between MVAPISA and MVAPLN (PISA%) and $C_n$. We then classified patients according to the $C_n$ values into two groups: group 1 with $C_n$ values between 4 and 6 mL/mmHg (considered more or less normal), and group 2 with $C_n$ values more than 6 or less than 4 mL/mmHg (extremely high or low $C_n$ values). The correlation between MVAPHT and MVAPLN changed to excellent and even approached that between MVAPISA and MVAPLN for group 1 ($r = 0.93$ and $P < 0.0001$), and became worse than the original overall correlation for group 2 ($r = 0.64$, original $r = 0.69$, and $P < 0.0001$).

The previous findings suggest that $C_n$ does not change the overall accuracy of PISA for calculating MVA in MS as it does in case of PHT. To confirm these findings, we compared the severity of MS as determined with the planimetry method to that determined with the PHT and PISA methods, and the PHT method was found to have overestimated the severity of MS in six cases.

**Figure 3** (A) Dot plots of the percentage difference between the mitral valve area obtained with the pressure half-time and planimetry method (PHT%) and net atrioventricular compliance ($C_n$) demonstrating a significant inverse correlation. (B) Dot plots of the percentage difference between the mitral valve area calculated with the proximal isovelocity surface area and with the planimetry method (PISA%) and $C_n$, showing a nearly flat line of fit.

**Figure 4** (A) Dot plots of the mitral valve area calculated with the pressure half-time method (MVAPHT) in relation to the mitral valve area obtained with the planimetry method (MVAPLN) of patients with net atrioventricular compliance ($C_n$) between 4 and 6 mL/mmHg, demonstrating an excellent correlation. (B) Dot plots of MVAPHT in relation to MVAPLN of patients with $C_n$ of less than 4 or more than 6 mL/mmHg, demonstrating a worse correlation than the one in (A) and the overall original correlation.
with a mean PHT% of −29%, and to have underestimated the severity in 11 cases with a mean PHT% of 33%. It was noticed that Cn values were lower in cases with milder MS determined with PHT (3.6 ± 1.1 mL/mmHg), and higher in case with severer MS (7.9 ± 1.1 mL/mmHg). The severity grades of the remaining 34 cases showed agreement between PHT and planimetry, with a mean PHT% of −2.0%. In this subset of patients, the mean Cn values were relatively normal (4.9 ± 1.8 mL/mmHg). For PISA, differences in severity were fewer and showed smaller values of PISA%. The PISA method was found to show more severe MVA in only two cases with a mean PISA% of −1.9%, and milder MVA in seven cases with a mean PISA% of 10%. These findings, together with the previous findings suggest that it is only acceptable to use the PHT when Cn values fall somewhere between 4 and 6 mL/mmHg and that clinical misjudgments may occur in patients with extreme Cn values when depending on the PHT.

**Impact of Cn on mitral valve area calculations with the pressure half-time method**

The relationship between PHT and Cn was previously described as:

\[ \text{PHT} = \left(11.6 \times C_n \times \Delta P^{1/2}\right)/\text{MVA} \]

However, the well-known formula introduced by Hatle et al.\(^2\) (MVA = 220/PHT) suggests that the numerator of the first equation \((11.6 \times C_n \times \Delta P^{1/2})\) must be close to 220, which needs a fixed relation between Cn and \(\Delta P^{1/2}\). This in fact proven inaccurate in our study by the identification of a weak correlation between Cn and the mean trans-mitral gradient \((r = -0.41 \text{ and } P = 0.003)\). Comparable results were reported in the study by Kim et al. \((r = -0.48, P = 0.001)\). To clarify that, the value of \((11.6 \times C_n \times \Delta P^{1/2})\) was calculated for each patient and was found to be 174.1 ± 66.7, which is clearly very different than the constant of 220 suggested by Hatle et al.

**Utility of proximal isovelocity surface area method for mitral valve area calculation**

In this study, too, an excellent correlation was observed between MVA\(_\text{PLN}\) and MVA\(_\text{PHT}\) \((r = 0.96 \text{ and } P < 0.0001)\). Furthermore, the correlation between PISA% and Cn was very week \((r = 0.1 \text{ and } P = 0.388)\), so that changes in Cn values might have almost no effect on MVA\(_\text{PISA}\). We used a fixed aliasing velocity of 33 cm/s, which was not so different from previous studies.\(^4,25,26\) As expected from the PISA equation, the radius of the PISA cap depends on the MVA as well as the aliasing velocity. Fixing the aliasing velocity, helped us to clarify what effect the radius may have on the calculations of the MVA\(_\text{PISA}\) in relation to changing Cn values. The only value that can theoretically be affected by the changes of Cn in the PISA calculation is the \(V_{\text{max}}\). In our study, we noticed that there was a negative correlation between Cn and \(V_{\text{max}}\) \((r = -0.47 \text{ and } P = 0.001, \text{Table 4})\). This means that Cn should have some indirect effect on MVA\(_\text{PISA}\). However, in our study, Cn did not have any effect on the PISA%. This may be attributed to the fact that \(V_{\text{max}}\) in the PISA calculation is a part of the ratio \(r^2/V_{\text{max}}\), and changes in the squared radius of PISA can neutralize any intrinsic changes in the PISA calculations caused by \(V_{\text{max}}\). To clarify this point, we compared the correlations between MVA\(_\text{PLN}\) and each variable of the PISA equation separately while disregarding the effect of the angle, and we observed that MVA\(_\text{PLN}\) correlated with all of these variables but the correlation was stronger for \(r^2\) than for \(V_{\text{max}}\) \((r = 0.79, 0.43 \text{ and } P < 0.0001, \text{Table 4})\) and became strongest and very close to the

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<th>Table 3</th>
<th>Differences in severity between MVA(<em>\text{PLN}) and MVA(</em>\text{PHT})</th>
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<tr>
<td>MVA(_\text{PLN}) (cm(^2))</td>
<td>1.07 ± 0.28</td>
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<td>MVA(_\text{PHT}) (cm(^2))</td>
<td>1.05 ± 0.34</td>
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<tr>
<td>PHT%</td>
<td>−2.0 ± 16.5</td>
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<td>Cn (mL/mmHg)</td>
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<th>Table 4</th>
<th>The relation between individual parameters of PISA and MVA</th>
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<td>(V_{\text{max}}) (cm/s)</td>
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<td>(r)-value</td>
<td>(P)-value</td>
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<tr>
<td>MVA(_\text{PLN})</td>
<td>0.43</td>
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<tr>
<td>MVA(_\text{PISA})</td>
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MVA\(_\text{PLN}\), mitral valve area by planimetry method; MVA\(_\text{PHT}\), mitral valve area by pressure half-time method; PHT%, the percentage difference between the mitral valve area by pressure half-time and planimetry method; Cn, net atrioventricular compliance.
original correlation between the MVA_{PISA} and MVA_{PLN} in case of \( r^2 / \sqrt{r_{\text{max}}} \) \( (r = 0.94, p < 0.0001, \text{Table 4}) \).

**Clinical implications**

In the study presented here, we strongly advise against using the PHT method because it can be a great source of inaccuracy when Cn values are not known. We also recommend the use of the PISA rather than the PHT method as PISA, using the conventional hemispheric equation, though time consuming, is not affected by the changes in the Cn, commonly seen in cases of rheumatic MS especially extremely high or low Cn values which render the PHT method inaccurate.

MVA_{PLN}, determined as the gold standard in our study, is actually not true gold standard for MVA calculation in the clinical settings, since it is difficult to obtain MVA in a significant number of patients because of poor image quality, asymmetrical affection of leaflets, funnel-shaped structures or severe calcifications, therefore, an alternative should be there when any of these conditions is encountered. This study shows that PISA method appears to be a better alternative to planimetry than do PHT.

Despite not affecting the PISA method, we still recommended the routine measurement of Cn in all patients with MS because, in addition to clarifying the inaccuracies of PHT in calculation of MVA out of the 4–6 mL/mmHg range, it is also considered a predictor of the left atrial and pulmonary pressures, exercise capacity, and the need for mitral valve replacement as suggested by previous studies.\(^{14,27,28}\)

**Study limitations**

This study included a relatively small number of patients. However, the study protocol was adequate for the purpose of ‘hypothesis-generation’. Future studies with larger patient populations are necessary to verify the relationship between Cn, and calculations of MVA with the PISA technique, and to substantiate the upper limit of the normal range of Cn. Although we used the planimetry method as the gold standard, it has some limitations in that it may be influenced by severe leaflet or subvalvular calcification, asymmetrical leaflet affection, imaging technique or poor image quality. Careful selection of patients included in our study could avoid most of these limitations. The major problem was the funnel-shaped structure that was seen in significant large number of patients that had symmetrical affection of both leaflets. To avoid this limitation, we have measured the distance between the anterior and posterior mitral leaflets in the LV parasternal long-axis view in its narrowest area for these patients. When viewing the LV short axis, planimetry of the mitral valve was not done until making sure that the level of measurement was the level that had the smallest distance between anterior and posterior leaflets, which was closest to the smallest distance obtained from the LV parasternal long-axis view; and thus serving as the narrowest area possible by planimetry of the mitral orifice. Newly developed imaging modalities, such as three-dimensional echocardiography, magnetic resonance imaging or computed tomography may reduce the operator dependence of the planimetry method and overcome most of its limitations. Another limitation of this study was that no invasive haemodynamic measurements of MVA and Cn were performed. Although Gorlin’s method using cardiac catheterization remains the standard technique for direct assessment of MVA, this method has its own limitations and errors of as much as 20–40% may be encountered.\(^{29,30}\) Moreover, MVA determined with the echocardiographic planimetry method has been shown to closely correlated with anatomic MVA,\(^{2,10,28}\) and has been used as the gold standard for MVA calculation in many centres.\(^{8,31}\) Finally, The result of echocardiographic assessment of Cn was previously demonstrated to correlate well with that of the invasive measurement of Cn, and showed acceptable accuracy.\(^{14}\) However, Since Cn was derived from the equation that contains the value of MVA_{PLN}, Cn calculation depends on accurate measurement of the MVA by planimetry, and MVA_{PLN} might be a confounding factor and a source of under- or over-estimation of Cn. In our study, we have reduced this effect by careful measurement and selection of patients as mentioned above.

**Conclusion**

The PISA method is recommended rather than the PHT method for measuring MVA for patients with MS especially those with extreme Cn values because, unlike PHT, the PISA method, though time consuming, is not affected by changes in the Cn.

**Conflict of interest:** none declared.

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