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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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(課程博士関係)
学位論文の内容要旨

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

僧帽弁狭窄症患者の弁口面積測定における PISA 法の有用性

神戸大学大学院医学研究科医科学専攻　内科学講座　循環器内科学分野

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【BACKGROUND】

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. 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. The pressure half-time (PHT) method, in particular, has gained widespread acceptance for MVA calculations, mainly because of simplicity and reproducibility. However, MVA by PHT can be affected by a variety of clinical conditions including significant aortic regurgitation and impaired left ventricular (LV) compliance. The proximal isovelocity surface area (PISA) method has been introduced as a promising tool for the assessment of MVA. PISA overcomes PHT problems but this advantage is outweighed, by the difficult calculations.

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. 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 centers with rheumatic MS without prior history of percutaneous balloon mitral valvuloplasty were prospectively enrolled in this study. 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.

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. MVA determined with the planimetry method (MVA_{PLN}) was measured by planimetry of its contours, and the result served as the gold standard for MVA calculation in this study.

The pressure half-time method

MVA determined with the PHT method (MVA_{PHT}) was calculated in the apical four-chamber view using color Doppler echocardiography with clearly visible mitral inflow color flow mapping. The deceleration time of the early mitral filling phase spectrum was obtained and MVA_{PHT} was then calculated using the equation $MVA_{PHT} = 220/PHT$.

The proximal isovelocity surface area method

MVA determined with the PISA (MVA_{PISA}) method is based on the analysis of the flow convergence proximal to the stenotic orifice. MVA_{PISA} was obtained in the apical four-chamber view using the conventional equation of the hemispherical model: $MVA_{PISA} = 2\pi r^2 \times (Val/Vmax) \times (\alpha/180)$, where: r (cm) is the radius of the PISA cap, Val (cm/second) is the aliasing velocity of color Doppler, Vmax (cm/second) is the maximal velocity across the mitral valve in early diastole (i.e. maximum velocity of the E-wave), and α (degree) is the mitral valve angle.

The severity of MS measured with MVA_{PLN}, as well as MVA_{PHT} and MVA_{PISA}, was defined as: mild if MVA was more than 1.5 cm^2, moderate if MVA was more 1.0 and less than or equal to 1.5 cm^2, and severe if MVA was less than or equal to 1.0 cm^2.

Percentage Difference from MVA_{PLN}

The percentage difference between methods in relation to MVA_{PLN}, was calculated as follows: PHT% (MVA_{PHT} vs. MVA_{PLN}) = [(MVA_{PHT} – MVA_{PLN}) / MVA_{PLN}] × 100, and PISA% (MVA_{PISA} vs. MVA_{PLN}) = [(MVA_{PISA} – MVA_{PLN}) / MVA_{PLN}] × 100.

Assessment of Cn

Cn was determined non-invasively by means of Doppler echocardiography as previously described using the following equation: Cn = 1270 × (MVA_{PLN}/E-wave downslope), where Cn was expressed in milliliters per millimeters of mercury (mL/mmHg), MVA_{PLN} was expressed in square centimeters (cm^2) and the E-wave downslope was the mitral flow E-wave downslope expressed in centimeters per square second (cm/s^2).

【RESULTS】

Correlations between Different Methods

Linear regression analysis showed that the MVA_{PISA} correlated closely with the MVA_{PLN} ($r = 0.96$, $p < 0.0001$). A lower but good and statistically highly significant correlation was also found between MVA_{PLN} and MVA_{PHT} ($r = 0.69$, $p < 0.0001$).

Effect of Cn on Pressure Half-time and Proximal Isovelocity Surface Area

Methods

The correlation between MVA_{PHT} and MVA_{PLN} for patients with Cn between 4–6 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 MVA_{PHT}, MVA_{PLN} and Cn ($r= -0.77$, $p<0.0001$), but the line of fit was nearly flat for the percentage difference among MVA_{PISA}, MVA_{PLN} and Cn ($r= 0.1$, $p=0.388$). Thirty-four patients showed the same severity grade of MS according to MVA_{PLN} and MVA_{PHT}. Six patients showed MVA_{PHT} severer by one grade than MVA_{PLN}, and 11 patients showed MVA_{PHT} milder by one grade than MVA_{PLN}. Cn values were almost within the assumed normal range for patients with the same grade of severity (4.9±1.8 mL/mmHg), but Cn values were higher for patients with severer MS according to MVA_{PHT} (7.9±1.1 mL/mmHg), and lower for patients with milder MS (3.6±1.1mL/mmHg). In case of the PISA method, differences in severity were fewer and showed smaller values of PISA%. The MVA_{PISA} was found to be severer by one grade than MVA_{PLN} in only two cases, and milder by one grade in seven cases.

[DISCUSSION]

Impact of Cn on Mitral Valve Area Calculations with the Pressure Half-time Method

The relationship between PHT and Cn was previously described as: PHT = (11.6 x Cn x $\Delta P^{1/2}$) / MVA. However, the well known formula introduced by Hatel et al (MVA = 220/PHT) suggests that the numerator of the first equation (11.6 x Cn x $\Delta P^{1/2}$) 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 ($r = -0.41$ 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 x Cn x $\Delta P^{1/2}$) 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, changes in Cn values did not have any effect on MVA_{PISA}. The only value that can theoretically be affected by the changes of Cn in the PISA calculation is the Vmax. In our study, we noticed that there was a negative correlation between Cn and Vmax ($r = -0.47$ and $p=0.001$) However, in our study, Cn did not have any effect on the PISA%. This may be attributed to the fact that Vmax in the PISA calculation is a part of the ratio r^2/Vmax. To clarify this point, we compared the correlations between MVA_{PLN} and each variable of the PISA equation, and we observed that MVA_{PLN} correlated with all of these variables but the correlation was stronger for r^2 than for Vmax ($r=0.79$, 0.43 and $p<0.0001$) and became strongest and very close to the original correlation between the MVA_{PISA} and MVA_{PLN} in case of r^2/Vmax ($r=0.94$, $p<0.0001$).

Clinical Implications

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.

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.

【CONCLUSIONS】

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.

神戸大学大学院医学系研究科（博士課程）

論文審査の結果の要旨			
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論文題目 Title of Dissertation	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 僧帽弁狭窄症患者の弁口面積測定における PISA 法の有用性		
審査委員 Examiner	主査 Chief Examiner 秋田穂束 副査 Vice-examiner 丈達弘 副査 Vice-examiner 伊藤智雄		

（要旨は１，０００字～２，０００字程度）

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determined with the PISA (MVA_{PISA}) method was calculated using the equation $MVA_{PISA} = 2\pi r^2 \times (Val/Vmax) \times (\alpha/180)$, where: r (cm) is the radius of the PISA cap, Val (cm/second) is the aliasing velocity of color Doppler, Vmax (cm/second) is the maximal velocity across the mitral valve in early diastole , and α (degree) is the mitral valve angle.

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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.

The candidate, having completed studies on the utility of the PISA method using the conventional hemispheric equation for MVA calculations, with a specialty in the PISA method is not affected by the Cn unlike the PHT method, and having advanced the field of knowledge in the area of the relationship between noninvasive MVA calculation and Cn, is hereby recognized as having qualified for the degree of ph.D.(Medicine).