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ORIGINAL ARTICLE

Usefulness of the Global Echo-Doppler Score (GEDS) in selection of patients with mitral stenosis for percutaneous balloon mitral valvuloplasty

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Abstract

Background: *We aimed to create a novel modified score by combining anatomic and hemodynamic Doppler-echocardiographic measures for selection of suitable patients with mitral stenosis for percutaneous balloon mitral valvuloplasty (PBMV) and its impact in prediction of outcome.*

Methods: *262 consecutive patients candidate for PBMV were enrolled. Wilkins score and a global score based on anatomical parameters (Wilkins score, posterior to anterior mitral leaflet ratio [PMVL/AMVL ratio]; left atrial diameter [LAD]) and hemodynamic parameters (mitral regurgitation [MR]; atrioventricular compliance [CN]; systolic pulmonary artery pressure [SPAP]) were assessed. Patients were classified into two groups according to their outcomes.*

Results: *Global Echo-Doppler Score (GEDS) for patients with favorable vs. those with unfavorable outcomes was (5.0 ± 0.9 vs. 8.9 ± 1.3; $p < 0.001$). Sensitivity, specificity, and accuracy of a GEDS ≥ 7 for prediction of cardiac events were 97.5%, 88%, and 97.5%, respectively. The area under the receiver operating characteristic curve was 0.95 ($p < 0.001$). The correlation coefficient was 0.852 ($p < 0.0001$) for GEDS 0.531 ($p < 0.002$), for Wilkins score 0.315 ($p < 0.02$), for PMVL/AMVL 0.460 ($p < 0.01$), for LAD; MR: Pre-PBMV ($r = 0.348$, $p < 0.03$); CN [mL/mm Hg] ($r = 0.579$, $p < 0.01$) and SPAP [mm Hg] ($r = 0.499$, $p < 0.01$). In the regression analysis, GEDS, Wilkins score, and LAD were entered into the model. The regression coefficient ($r = 0.695$) of GEDS was much higher than those of the other 2 factors.*

Conclusions: *GEDS is an independent predictor of PBMV success and clinical outcome and may be formulated in a scoring system that would help to identify the proper timing and best candidates for PBMV.* (Cardiol J 2014; 21, 2: 152–157)

Key words: echo-Doppler, mitral stenosis, balloon valvuloplasty

Introduction

With successful balloon mitral valvuloplasty (MV), there is generally a twofold increase in the mitral valve area (MVA) and an associated dramatic fall in transmitral valve gradient, left atrial pressure, and pulmonary artery pressure [1–4]. These hemodynamic benefits are associated with post-procedural improvement in the patients' symptoms and exercise tolerance [5]. The safety and success of balloon MV techniques is mostly dependent on the selection of patients. There are multiple predictors of the outcome, including age, functional class, previous commissurotomy,

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pre-procedure MVA, valve anatomy, and balloon size used [6]. Morphology of the mitral valve is considered the main predictor of a successful balloon MV and hence, mitral valve scoring system using echocardiography is of crucial importance [6]. Many scores are derived from the targeting patient selection before balloon MV and they correlate severity with immediate and long-term outcome.

We aimed to create a novel modified score by combining anatomic and hemodynamic Doppler-echocardiographic measures for selection of suitable patients with mitral stenosis for percutaneous balloon mitral valvuloplasty (PBMV) and to investigate its impact on outcome of PBMV. We have called it the Global Echo-Doppler Score (GEDS). We believe that the GEDS will provide new insight into the objective risk stratification in patients with mitral stenosis and suitability for PBMV.

Methods

We prospectively included 262 consecutive patients with rheumatic mitral stenosis who were subjected to PBMV using multitrack technique in Zagazig University Hospital. Our study is conformed to the Helsinki Declaration. All patients gave their informed consents to participate in the study. Inclusion criteria included symptomatic mitral stenosis (MS) with New York Heart Association functional class II or more with MVA ≤ 1.5 cm^2 and mitral valve echocardiographic score ≤ 11 according to scoring system described by Wilkins et al. [7]. Exclusion criteria were patients with mitral regurgitation (MR) or aortic regurgitation of grade II/IV or more, also, patients with Wilkins scoring of > 11 [7] and presence of left atrial (LA) thrombi assessed by trans-esophageal echocardiography.

Echocardiographic and Doppler examinations

Comprehensive 2-dimensional (2D) and color Doppler transthoracic echocardiogram was performed before PBMV. The morphologic features of the mitral valve were categorized using the Wilkins echo score [7] and the total echocardiographic score was obtained by adding the scores of leaflet mobility, thickness, calcification, and sub-valvular lesions. The structure of the valve and the sub-valvar apparatus were imaged in the parasternal long-axis and apical 4-chamber views. Furthermore, maximal leaflet lengths of MV leaflets were measured in the parasternal long-axis view at end-diastole, then a posterior to anterior mitral valve leaflets length (PMVL/AMVL) ratio was calculated [8]. LA diameter was measured, and continuous wave Doppler was used to calculate peak pressure gradient of tricuspid regurgitation. Mitral and tricuspid regurgitations were graded from 0 to 4+, depending on the spatial extent of the color flow jet area expressed as percentage of the left or right atrial area. Patients were screened for LA thrombus with a 2D trans-esophageal echocardiogram in 24 h preceding the procedure. If thrombus was detected, the patient was not a candidate for PBMV. Doppler velocity tracings were recorded at a speed of 100 mm/s. The duration of the diastolic filling period and maximal and mean trans-mitral pressure gradients (Bernoulli equation) were obtained from the continuous-wave Doppler signal of mitral flow velocity. Stroke volume was calculated as left ventricular outflow tract area multiplied by the time integral of the outflow tract velocity (pulsed-wave Doppler). Outflow tract area was determined as $D2\pi/4$, where D is its diameter measured from a zoomed systolic freeze-frame in the parasternal long-axis view. With the continuity equation, MVA was calculated as stroke volume divided by mitral time-velocity integral [9, 10]. Severity of MR was determined by expressing the ratio of maximal jet area to LA area in the same view using color flow mapping and graded from 1 to 4 [11]. Systolic pulmonary artery pressure (SPAP) was derived from the tricuspid regurgitant jet velocity (v) with the modified Bernoulli equation (4v2) and assuming a right atrial pressure of 10 mm Hg [12].

Calculation of net atrioventricular compliance

Atrioventricular compliance (CN) can be calculated from the deceleration rate (dV/dt) of the mitral velocity profile (E-wave downslope) and effective MVA, determined by the continuity equation, as demonstrated by Flachskampf et al. [13]:

$$CN = 1270\ (MVA/E\text{-wave downslope})$$

Where CN is obtained in cm^3/mm Hg (mL/mm Hg) if MVA is expressed in cm^2 and the E-wave downslope in cm/s^2. CN was assessed only from the resting measurements, and the E-wave downslope (curvilinear in 2 cases) was determined by the average slope method.

Description of the scoring system

A scoring system designed by us was used in accordance with the multiple indices mentioned above (Table 1).

Table 1. Indices of modified echo-Doppler score.

Variable	Points
Anatomic variables	
Wilkin's score:	
≤ 8	1
> 8	2
PMVL/AMVL ratio:	
> 1/2	1
≤ 1/2	2
Left atrial diameter:	
< 5 cm	1
≥ 5 cm	2
Doppler variables	
MR: Pre-PBMV:	
No MR	0
Grade I	1
Grade II	2
CN [mL/mm Hg]:	
≤ 4	1
> 4	2
SPAP [mm Hg]:	
≤ 50	1
> 50	2

CN — atrioventricular compliance; MR — mitral regurgitation; PBMV — percutaneous balloon mitral valvuloplasty; PMVL/AMVL ratio — posterior mitral valve leaflet to anterior mitral valve leaflet; SPAP — systolic pulmonary artery pressure

Table 2. Baseline demographic and echocardiograpic data of patients with mitral stenosis included in the study.

Age [years]	34.2 ± 13.5
Male/female	107/155
Body surface area [m^2]	1.62 ± 0.83
AF rhythm	31/262
NYHA class	2.5 ± 0.7
Systolic BP [mm Hg]	119 ± 11
Diastolic BP [mm Hg]	70 ± 8
Echo-score	8.4 ± 1.9
MVA — 2D planimetry [cm^2]	0.91 ± 0.28
MVA — PHT [cm^2]	1.09 ± 0.21
Mean transmitral gradient [mm Hg]	16.4 ± 5.2
LA antero-posterior diameter [mm]	49.9 ± 0.57
LVEDD [mm]	42.8 ± 3.6
LVESD [mm]	28.5 ± 3.2
LVEF [%]	69.2 ± 10.5
RV diastolic diameter [mm]	31.1 ± 1.4
SPAP [mm Hg]	69.5± 23.8
MR grade	0.85 ± 0.71
CN [mL/mm Hg]	4.6 ± 1.9

AF — atrial fibrillation; BP — blood pressure; NYHA — New York Heart Association; MVA — mitral valve area; 2D — two-dimensional; PHT — pressure half time; LA — left atrium; LVEDD — left ventricular end diastolic diameter; LVESD — left ventricular end systolic diameter; LVEF — left ventricular ejection fraction; RV — right ventricular; SPAP — systolic pulmonary artery pressure; MR — mitral regurgitation; CN — atrioventricular compliance

The score value for Wilkins score is 1 or 2 points according to severity (≤ 8 or > 8). Score values for LA diameter is 1 or 2 points according to the degree of LA dilatation (≤ 5 cm or > 5 cm), PMVL/AMVL ratio 1 or 2 points according to the ratio (≥ 1/2 or < 1/2 cm^2), SPAP are 1 or 2 points for (< 50 mm Hg or ≥ 50 mm Hg), score for CN is 1 or 2 points according to the value (≤ 4.0 mL/ /mm Hg or > 4.0 mL/mm Hg) and a score of 0, 1 or 2 for the presence and degree of MR. The totals, when scores for all factors are added, constitute the GEDS.

Clinical and echocardiographic follow-up

A detailed clinical and echocardiographic (2D, continuous-wave Doppler and color-flow imaging) assessment was conducted at every 3 months for the first year and at 6-month intervals thereafter, with a median duration of 28 (range 12–42) months. The predefined study endpoints were assessed: a composite clinical events endpoint including cardiovascular death, mitral valve re-intervention, newly developed atrial fibrillation (AF), progressive re-elevation of pulmonary artery pressure, and hospital admission due to decompensated heart failure. The patients were divided into two groups (favorable and unfavorable) according to clinical events and the need for post-PBMV mitral re-intervention.

Statistical analysis

All continuous variables are reported as mean ± SD or as percentages. Analysis was done with SPSS 16.0 (SPSS, an IBM company; Chicago, Ill). Receivers operating characteristic (ROC) curves were used to evaluate the sensitivity and specificity of GEDS for predicting cardiac events after PBMV. Associations of GEDS and echocardiographic parameters with outcomes were evaluated by use of the Spearman correlation coefficient. Independent predictors of GEDS were determined by means of multiple regression analysis, with candidate variables added to a model containing GEDS as the dependent variable and Wilkins score and LA diameter as covariates. Standardized β regression coefficients and their significance as determined by multilinear regression analysis were reported.

Results

The demographic and echocardiographic data are presented in Table 2. The echocardiographic variables in patients with MS were significantly improved after PBMV (Table 3). During follow-up, 8 patients showed worsening of MR, 29 patients showed newly developed AF, 33 patients showed progressive re-elevation of pulmonary artery pressure and, 9 underwent repeat PBMV; 1 patient underwent valve replacement. In addition, 8 hospital admissions due to decompensated heart failure were recorded. No death was recorded. Table 4 shows a comparison between patients with favorable vs. those with unfavorable outcomes after PBMV. The mean GEDS scores for patients with cardiac events vs. those without events were (5.0 ± 0.9 vs. 8.9 ± 1.3, respectively, $p < 0.001$).

The ability of GEDS to predict patients with cardiac events was evaluated by means of ROC analysis (Fig. 1). The area under the ROC curve was 0.95 (95% confidence interval 0.93–0.98, $p < 0.001$). A GEDS value ≥ 7 had a sensitivity of 97.5%, a specificity of 88%, and an accuracy of 97.5% for predicting cardiac events. Table 5 shows the univariate and multivariate relationships of GEDS and echocardiographic parameters to cardiac events during follow-up. In Spearman analysis, statistically significant correlations were found between GEDS and other echocardiographic parameters. The correlation coefficient of GEDS was 0.852 ($p < 0.001$), greater than that of the Wilkins score ($r = 0.531$, $p < 0.002$); MVA ($r = 0.315$, $p < 0.004$); LA diameter ($r = 0.460$, $p < 0.002$); MR: Pre-PBMV ($r = 0.348$, $p < 0.004$); CN ($r = 0.579$, $p < 0.002$) and SPAP ($r = 0.499$,

Table 3. Echocardiographic variables before and immediately after percutaneous balloon mitral valvuloplasty (PBMV).

Variable	Before PBMV	After PBMV	P
MVA — 2D planimetry [cm^2]	0.91 ± 0.28	1.89 ± 0.24	< 0.001
MVA — PHT [cm^2]	1.09 ± 0.21	2.09 ± 0.13	< 0.001
Mean transmitral gradient [mm Hg]	16.4 ± 5.2	4.5 ± 2.1	< 0.0001
LA antero-posterior diameter [mm]	49.9 ± 0.57	44.1 ± 0.2	< 0.02
LVEDD [mm]	42.8 ± 3.6	42.9 ± 0.9	> 0.05
LVESD [mm]	28.5 ± 3.2	27.3 ± 0.8	> 0.05
LVEF [%]	69.2 ± 10.5	68.9 ± 9.5	> 0.05
RV diastolic diameter [mm]	31.1 ± 1.4	26.7 ± 0.8	< 0.02
SPAP [mm Hg]	69.5 ± 23.8	38.2 ± 17.9	< 0.001

MVA — mitral valve area, 2D — two-dimensional; PHT — pressure half time; LA — left atrium; LVEDD — left ventricular end diastolic diameter; LVESD — left ventricular end systolic diameter; LVEF — left ventricular ejection fraction; RV — right ventricular; SPAP — systolic pulmonary artery pressure

Table 4. Comparison between patients with favorable vs. those with unfavorable outcomes after percutaneous balloon mitral valvuloplasty.

Variable	Favorable outcome group (n = 174)	Unfavorable outcome group (n = 88)	P
Age [year]	32.9 ± 11.5	33.2 ± 13	> 0.05
LA diameter [mm]	48.6 ± 14	52.0 ± 13	< 0.05
PMVL/AMVL ratio [cm^2]	0.62 ± 0.02	0.32 ± 0.03	< 0.01
Wilkins score	8.2 ± 1.2	8.9 ± 1.1	< 0.01
Transmitral mean PG	16.2 ± 2.2	18.2 ± 2.5	> 0.05
Right ventricular diameter [mm]	29 ± 4	30 ± 2	> 0.05
Pre-procedure MR	0.8 ± 0.6	0.9 ± 0.3	> 0.05
SPAP [mm Hg]	48.3 ± 11.5	66.5 ± 12.7	< 0.01
CN [mL/mm Hg]	5.5 ± 0.7	3.1 ± 0.4	< 0.001
Global Echo-Doppler Score	5.0 ± 0.9	8.9 ± 1.3	< 0.001

LA — left atrial; PMVL/AMVL — posterior mitral valve leaflet to anterior mitral valve leaflet; PG — pressure gradient; MR — mitral regurgitation; SPAP — systolic pulmonary artery pressure; CN — atrioventricular compliance

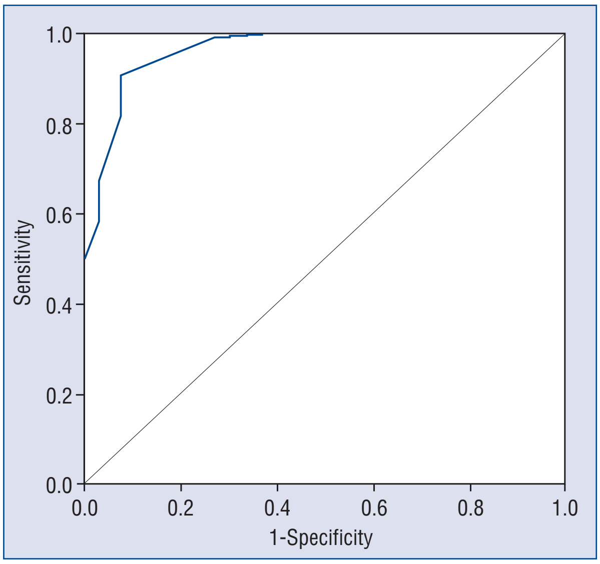

Figure 1. Receiver operating characteristic (ROC) curve of sensitivity and specificity of global echo-Doppler score in predicting cardiac events after percutaneous balloon mitral valvoplasty. The area under the curve was 0.95 ($p < 0.001$).

$p < 0.002$). In multiple linear regression analysis, GEDS, Wilkins score, and LA diameter were added to the model ($p < 0.001$); no other parameters were added. The standardized regression coefficient ($r = 0.695$) of GEDS was much higher than those of Wilkins score and LA diameter, 0.375 and 0.242, respectively, which suggested that GEDS was a powerful independent predictor of cardiac events after PBMV.

Discussion

Our results have shown that GEDS derived from both anatomic and hemodynamic echo-Doppler indices can predict clinical outcome of PBMV in patients with MS. The rise in GEDS correlates with unfavorable outcome at follow-up. GEDS in patients with unfavorable outcomes often exceeds 7 points.

For a proper selection of therapeutic strategy in patients with MS, clinical evaluation and assessment of MV anatomy are essential [14–16]. Transthoracic 2D echocardiography allows classification of patients into anatomic groups to predict immediate and long-term outcome [17, 18]. Although most cardiologists use the Wilkins score, several echocardiographic scoring systems have been suggested for evaluation of MV anatomy [19–22]. None of the available scores has been shown to be superior to any of the others [23].

The current study shows that the correlation coefficient of GEDS was greater than that of the Wilkins score. In multiple linear regression analysis, the standardized regression coefficient of GEDS was much higher than those of Wilkins score and LA diameter, which suggested that GEDS was a powerful independent predictor of cardiac events after PBMV for patients with MS.

In the selection of patients for PBMV, the echocardiographic assessment of the MV morphology plays a crucial role [24–27] and it is now performed routinely in most centers. The Wilkins score is one of the most widely used echocardiographic scoring systems [24, 26, 28, 29] and it provides a semi-quantitative assessment of mitral leaflets thickening, mobility, calcification, and the extent of the sub-valvular apparatus disease. A favorable Wilkins score (< 8 points) is highly predictive of an optimal outcome after PBMV [24, 27, 29]. Nevertheless, there are studies which have questioned the precision of this score as a predictor of the outcome and have suggested the

Table 5. Univariate and multivariate relationships of Global Echo-Doppler Score (GEDS) and echocardiographic parameters to cardiac events.

Variable	Spearman coefficient	P	Standardized RC	P
Wilkins score	0.531	< 0.002	0.375	< 0.004
MVA [cm^2]	0.315	< 0.02	—	
LA diameter [mm]	0.460	< 0.01	0.242	< 0.004
MR: Pre-PBMV	0.348	< 0.03	—	
CN [mL/mm Hg]	0.579	< 0.01	—	
SPAP [mm Hg]	0.499	< 0.01	—	
GEDS	0.852	< 0.0001	0.695	< 0.001

RC — regression coefficient; MVA — mitral valve area; LAD: LA — left atrial; MR — mitral regurgitation; PBMV — percutaneous balloon mitral valvuloplasty; CN — atrioventricular compliance; SPAP — systolic pulmonary artery pressure need for more refined and comprehensive echocardiographic assessments [28, 30, 31]. Many patients with MS may have limited symptoms despite unimpressive findings. When resting gradients and SPAP do not reflect the real severity of the disease, a dynamic evaluation becomes necessary. Valvular capacity exhaustion should be tested on a dynamic background, as no single resting index can predict potential hemodynamic adaptation to exercise. In such context, the contribution of exercise echocardiography remains extremely valuable [32]. But the assessment of hemodynamic consequences of MS noninvasively is simpler and more valuable for prognostic implication.

Nunes et al. [33], in a wide spectrum of severity of MS, demonstrated that CN is a powerful predictor of adverse outcome, adding incremental prognostic value to clinical data and MVA. In addition, CN was a determinant factor of pulmonary hypertension, which was independent of the MS severity.

Conclusions

GEDS derived from combined anatomic and hemodynamic echocardiographic variables is an independent predictor of PBMV success and clinical outcome and could be formulated in a scoring system that would help to identify the proper timing and best candidates for PBMV.

Conflict of interest: none declared

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