QUANTIFICATION OF MITRAL PARAPROSTHETIC REGURGITATION, COMPARISON OF VENA CONTRACTA WIDTH AND PROXIMAL CONVERGENCE METHODS

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In patients with a prosthetic valve in the mitral position, detection of paraprosthetic regurgitation and assessment of its severity are crucial in management and prognosis. In the assessment of severity of the mitral regurgitation (MR), vena contracta width (VCW) and proximal flow convergence region (FCR) methods are quantitative, more sensitive and reliable compared to color Doppler mapping. The aim of this study is to compare these two methods in patients with mitral paraprosthetic regurgitation (MPR) with the use of TEE.

The study population consisted of 26 patients with MPR; 12 male, 14 female with a mean age of 44±6 years. Largest diameter of contracted zone during systole on the ventricular side was measured and average values were used for VCW. Regurgitant stroke volume (RSV) was calculated according to the formula validated earlier. Routine cardiac catheterization was performed in each patient. Mitral paraprosthetic regurgitation was obtained semi-quantitatively by cardiac catheterization and TEE was graded as mild (grade I-II), moderate (grade III) and severe (grade IV). VCW values were found as 0.25±0.04 cm for mild regurgitation, 0.42±0.11 cm for moderate regurgitation, 0.54±0.11 cm for severe regurgitation. There was a good correlation between VCW and severity of mitral regurgitation. (r=0.78, p<0.0001). Regurgitant stroke volumes calculated by FCR method were 23.8±3.63 cm3 for mild regurgitation, 44.4±8.92 cm3 for moderate regurgitation, 69.6±7.83 cm3 for severe regurgitation. Also there was a good

correlation between FCR derived-RSV and severity of mitral regurgitation (r=0.9, p<0.0001).The comparison of FCR derived-RSV with VCW showed excellent correlation (r=0.89 and p<0.0001).
FCR method gives accurate estimation of regurgitant volume of MPR and correlates well with the established measures of severity.

Key words: Mitral paraprosthetic regurgitation, vena contracta width, flow convergence area

Mitral valve replacement is rarely complicated with paraprosthetic regurgitation (1). In patients with a prosthetic valve in the mitral position, detection of paraprosthetic regurgitation and assessment of its severity are crucial in management and prognosis. Color Doppler mapping of regurgitant jet is a well-established and useful semi-quantitative diagnostic technique (2-4). Nevertheless, depending on the regurgitant jet's characteristics, sensitivity of this technique might be impaired by hemodynamic variables and technical factors such as transducer frequency and gain setting (5-7). Since ultrasound beam can not pass through the materials that constitute mechanical valve, transthoracic echocardiography (TTE) may fail to detect regurgitant flow (8,9). However, with transesophageal approach, mechanical valve can not interfere with ultrasound as the transducer is in the vicinity of the left atrium (10-12). For that reason, transesophageal echocardiography (TEE) has been preferred over TTE in the detection of paraprosthetic regurgitation in patients with a mechanical valve.

In the assessment of severity of the mitral regurgitation, proximal flow convergence region (FCR) method is a quantitative method and more sensitive and reliable than color Doppler mapping (13,14). Another sensitive method for the assessment of severity of mitral regurgitation is the measurement of vena contracta width. This is also a quantitative method and relatively independent of hemodynamic variables (15-17). In previous studies, vena contracta and proximal flow convergence methods have been used for assessment of severity of the native mitral regurgitation (13-17). To our present knowledge, no clinical studies have compared these two methods in the detection of paraprosthetic regurgitation and assessment of its severity quantitatively.

The aim of this study is to compare these two methods in patients with mitral paraprosthetic regurgitation with the use of TEE as echocardiographic method.

MATERIALS AND METHOD

The study population consisted of 26 patients who were complicated with paraprosthetic regurgitation after a mechanical mitral valve replacement between 1986 and 1997 in our institution. Of these patients, 14 (53.8%) were female, 12 (46.2%) were male. Mean age was 44+ 6 years (range 22-54). 20 patients were in atrial fibrillation, while remaining was in sinus rhythm. Tricuspid valve pathology was found in 12 patients. Type of the mechanical prosthetic valves were St Jude (n=20) and Sorin (n=6). Valve sizes ranged between 27 and 31 mm (Table 1). All patients underwent cardiac catheterization and subsequent TEE (48 hours later).

Table 1. The clinical characteristics of the patients.

	n
Sex	
Male	12
Female	14
Mean age (year)	44 ± 6
Rhythm	
SR	6
AF	20
Organic tricuspid valve disease	12
Prosthetic valve (27-31)	
St Jude	20
Sorin bileaflet	6
Follow-up (year)	7.52 ± 3.05

Echocardiographic method

TEE was performed with a multiplane 5MHz probe (VINGMED CFM 800). The patients fasted 4 hours before TEE. Intravenous diazepam 2.5-5 mg was given for sedation and 10% lidocaine spray was used for topical numbing. Echocardiographic techniques and measurements were used as recommended by the American Society of Echocardiography (18). TEE was started with standard horizontal position (0°) and transducer was rotated till reversed transverse position (180°) to obtain a better view. In all patients, color Doppler gains were set at a level immediately below that which resulted in minimal aliation. Paraprosthetic regurgitation was graded semi-quantitatively according to the standard criteria (19). Subsequently the paraprosthetic regurgitation was stratified as mild (grade I-II), moderate (grade III) and severe (grade IV).

Mitral regurgitation was classified according to its detection at inner or outer part of the sewing ring of the valve prosthesis. Regurgitant jets located outside the sewing ring were considered paraprosthetic. All investigations were recorded on 0.5 in VSH tape for subsequent analyses. Records were assessed independently by two experienced observers who were blind to the results of the angiography.

Vena contracta width

The narrowest central flow region of a regurgitant jet is defined as the vena contracta. Vena contracta was obtained by measuring the width of the regurgitant jet proximal to the paraprosthetic regurgitant orifice area (Figure 1). The vena contracta width was measured in each view for >3 cardiac cycles. The largest diameter of the vena contracta during any portion of the systole was taken. For eccentric jets, vena contracta width was always measured perpendicular to the long axis of the jet.

Proximal flow convergence region method

Proximal flow convergence region was found by choosing the best view of paraprosthetic regurgitant jet at different angles with the use of multiplane TEE. Because proximal flow convergence region can be observed in patients with moderate and severe MR, this method was not used in patients with grade I MR. The angle between the ultrasound beam and the direction of the mitral inflow was minimized by fine adjustment of the direction

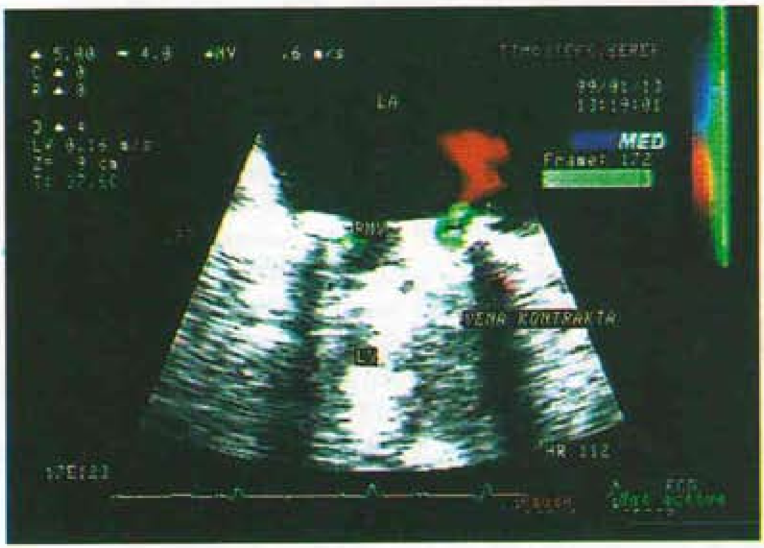

Figure 1. Measurement of vena contracta width (arrow) in the long axis view during TEE (PMV: prosthetic mitral valve, vena kontrakta (in Turkish): vena contracta; LV: left ventricle; LA: left atrium).

of the continuous-wave beam by using color Doppler guidance to obtain highest peak velocities. The color baseline, sector angle, depth, gain, frame rate and aliation velocity were set for determining satisfactory red-green aliation boundary to obtain consistent image of the largest radius. The maximal radius (r, in centimeters) of the FCR in a cardiac cycle was selected with cine-loop function. It was measured from the proximal to the paraprosthetic regurgitant orifice area to the first color aliation along the long axis of the flow (Figure 2). After determination of blue-red borderline at the proximal flow convergence region, radius measurements were done on the largest one with the use of cine-loop and magnification function of the device. All measurements were done at mid-systole. During measurements, optimal aliation velocity was chosen for each patient while aliation velocity was kept between 35-40 cm/s, and this value was used as Va value on the equation to calculate " regurgitant stroke volume (RSV)". Maximal regurgitant velocity (Vp) was found by adjusting the sample volume perpendicular to the flow at the best view of the paraprostetic regurgitation. Velocity-time integral (VTI) value was subsequently found by the use of continuous-wave Doppler technique. RSV was calculated by "RSV= 2Pr2 x Va x VTI/Vp". Calculated RSV values were compared with vena contracta width and the correlation between the assessment methods in the severity of regurgitation was found semiquantitatively.

Cardiac catheterization

Routine cardiac catheterization was performed after each patient gave informed, written consent to confirm that they were informed about the clinical diagnosis of paraprosthetic regurgitation. Left ventriculography was performed by administration of 40-50 cc urographin at a rate of 10-12 cc/s at 30° right oblique position. Severity of mitral regurgitation was assessed as defined by Grossman and associates (20).

Statistics

Data were expressed as median and range, mean±standard deviation. Analyses of variance (ANOVA) was used to compare the correlation of FCR-derived RSV and VCW with severity of MR. The correlation between RSV and VCW was tested by linear regression analyses. Interobserver variability was assessed by linear regression with Bland-Altman analysis. Statistical significance was defined as a p value less than or equal to 0.05. All data were analyzed using SAS system software (SAS Institute Inc.,Cary, NC).

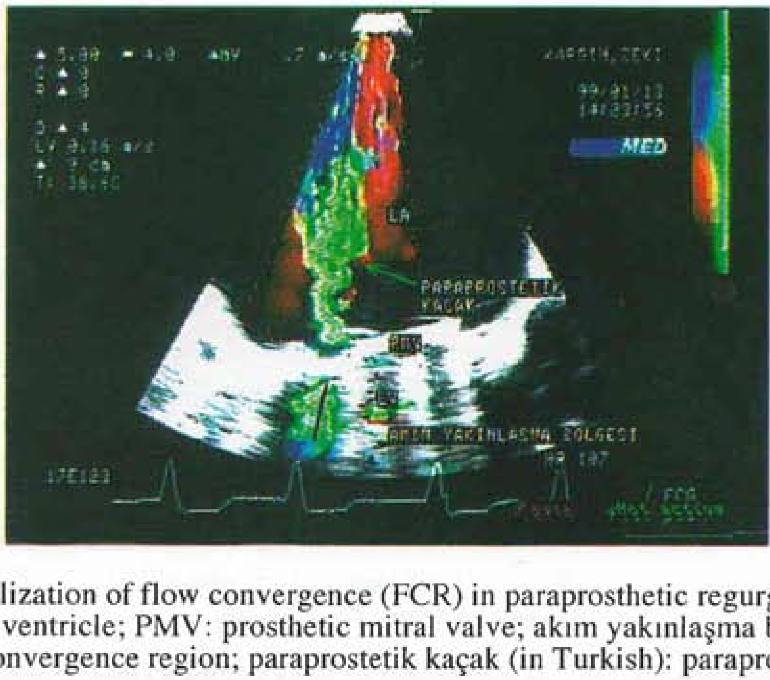

Fig 2. The visualization of flow convergence (FCR) in paraprosthetic regurgitation (LA: left atrium, LV: left ventricle; PMV: prosthetic mitral valve; akım yakınlaşma bölgesi (in Turkish):flow convergence region; paraprostetik kaçak (in Turkish): paraprosthetic leak).

RESULTS

Cardiac catheterization

Mitral regurgitation was not observed in 3 of the patients despite positive physical examination and TEE findings. In the remaining 23 patients, the severity of mitral regurgitation was: mild in 5 patients, moderate in 12 patients, severe in 6 patients.

Transesophageal echocardiography

The mitral valve was scanned in the long axis view to obtain optimal vena contracta width in all patients. Mitral paraprosthetic regurgitation obtained semi-quantitatively by cardiac catheterization and TEE was graded as mild (grade I-II), moderate (grade III) and severe (grade IV). In patients with mild, moderate and severe MR, the measured mean VCW were as follows; 0.25±0.04 cm, 0.42±0.11cm and 0.54±0.11 (Table 2). There was a good correlation between VCW and severity of mitral regurgitation [$r=0.78$, $p<0.0001$] (Figure 3).
In patients with mild, moderate and severe MR, the mean RSVs were as follows: 23.8±3.63cm^3, 44.4±8.92 cm^3 and 69.6±7.83cm^3. The positive correlation was found between FCR-derived RSV and severity of MR [$r=0.9$, $p<0.0001$] (Table 3) [Figure 4]. The positive correlation was also found between FCR-derived RSV and measured VCW in the subgroups classified according to severity of regurgitation [$r=0.89$, $p<0.0001$](Figure 5). Cut-off point values were as follows: 55cm^3 for RSV and 0.51 cm for VCW .

Table 2. Vena contracta width according to the degree of mitral regurgitation.

	Vena contracta width (cm)		
Degree of MR	**n=26**	**average**	**sd**
mild	8	0.25	0.04
moderate	12	0.42	0.11
severe	6	0.54	0.11
		r =0.78, p<0.0001	

MR: mitral regurgitation

Table 3. FCR derived RSV according to the degree of MR.

	Regurgitant stroke volume (cm^3)		
Degree of MR	**n=23**	**average**	**sd**
mild	5	23.8	3.63
moderate	12	44.4	8.92
severe	6	69.6	7.83
		r =0.9, p<0.0001	

FCR: flow convergence region,
RSV: regurgitant stroke volume,
MR: mitral regurgitation.

Interobserver variability

The measurement data of the two observers were closely related to each other for both VCW measurements and FCR-derived RSVs with correlation coefficients of $R_1=0.96$ and $R_2=0.92$.

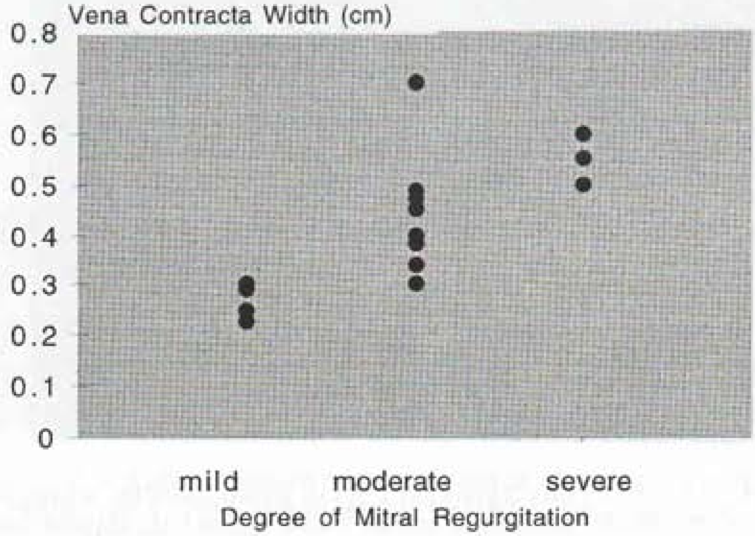

Figure 3. Relation between long-axis diameter of vena contracta and degree of mitral regurgitation ($r=0.78$, $p < 0.0001$).

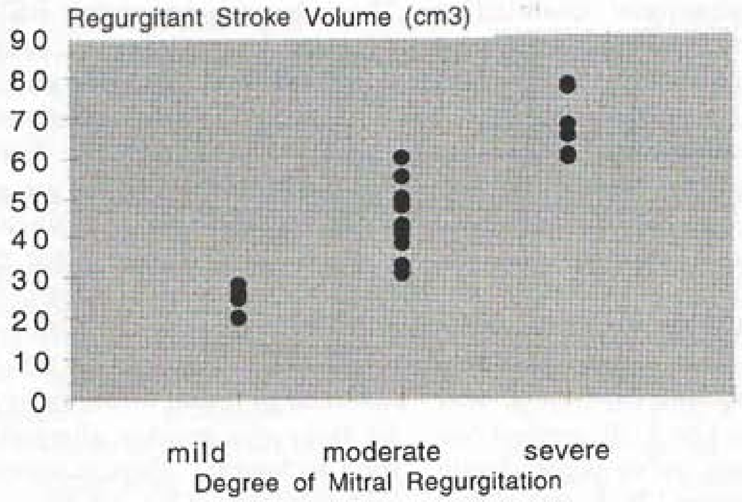

Figure 4. Relation between long-axis diameter of flow convergence region derived regurgitant stroke volume and degree of mitral regurgitation (r=0.9, p < 0.0001).

DISCUSSION

Color Doppler mapping is the most commonly used parameter for assessing the severity of both native and prosthetic mitral valve regurgitation (2-4). Proper Doppler penetration is prevented by materials that constitute prosthetic valves, which either absorb or reflect most of the ultrasound beam (21). Since the distance between the transducer and left atrium prevents receiving the Doppler signals, TTE may accurately visualize the jet area in 60% of the cases (22). However, transesophageal approach overcomes this limitation due to masking effect because the transducer is located in close proximity to the left atrium, and Doppler ultrasound is not impaired by the prosthetic valve (10-12). In clinical practice, contrast left ventriculography (25) and color Doppler mapping (26,27) are commonly used methods for assessment of severity of MR. However, these methods are semi-quantitative and dependent on hemodynamic and technical

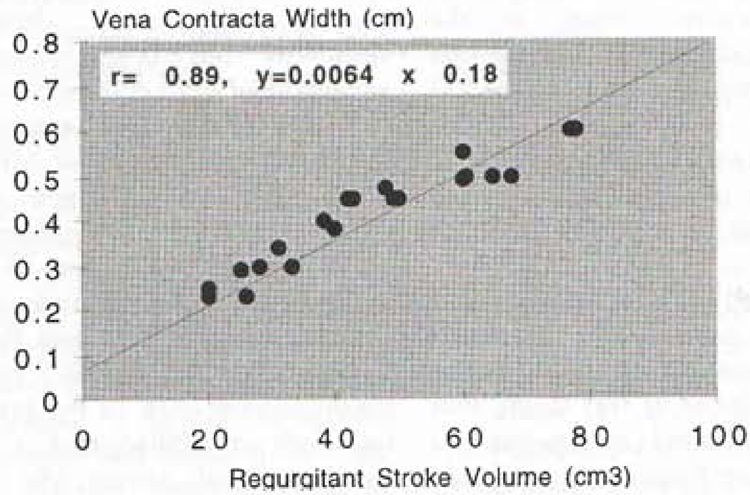

Figure 5. Linear regression plot showing good correlation between vena contracta width and flow convergence region derived regurgitant stroke volume in paraprosthetic regurgitation.

variables. An independent and quantitative method has been searched for the assessment of the severity of MR. An alternative method using proximal flow convergence has been developed to quantitatively measure regurgitant stroke volume and flow rate (13,17). This method has been reported as reliable for MR > grade 2, especially with the use of multiplan TEE (13,17). Although, it is more sensitive than color Doppler mapping for eccentric jets, proximal flow convergence may overestimate the regurgitant flow in a flail mitral valve (13,23,24). The FCR method has been applied to prosthetic valve regurgitation by Bargiggia and associates(13). In this study, color Doppler visualization of the FCR was demonstrated as a reliable method in the diagnosis of paraprosthetic valve regurgitation with a 95% accuracy in patients with MR > grade 2 in angiography. However, the correlation between regurgitant volume and regurgitation grade was not searched in this study. Similarly, we were able to detect a FCR in 100% of the patients with MR > grade 2 in angiography. Because FCR method has some advantages for the evaluation of paraprosthetic valve regurgitation, this high sensitivity is not surprising. These advantages include: 1) Unlike color Doppler mapping, FCR is constituted by laminar flow and highly accurate spatial resolution of color Doppler makes it an ideal technique for the investigation of organized laminar flows. 2) Since FCR is located on the ventricular side of the paraprosthetic valve, closer to the transducer, theoretically, it should be unaffected by flow masking phenomena. 3) Since it is located in the high-pressure chamber, upstream from the orifice, FCR would be independent of the direction of the jet, which can make the visualization of the jet area difficult (11-13).

In an in vitro study, Vandervoort and associates have used regurgitant orifice area (ROA) as a parameter to assess valvular insufficiency. In this study, it was found that an effective ROA of<10 mm^2 corresponds to a mild mitral regurgitant lesion with a mean RSV of 10.2±4.2 cm^3 and ROA>30 mm^2 corresponds to a severe mitral regurgitant lesion with a mean RSV of 67.6±15.9 cm^3. They also concluded that RSV> 50 mm3 can confirm the presence of severe MR. In the other previous studies, although a positive correlation between calculated RSV and the severity of MR has been found, a consensus has not been reached for a corresponding MR grade according to an estimated RSV. In our study, it was observed that calculated RSVs cumulated at certain levels in patients with paraprosthetic regurgitation and a mean calculated RSV of 69.9±7.83 cm^3 was obtained in severe mitral regurgitant lesions.

VCW is also another alternative for routinely used techniques. First described by Triboillay and associates (28), VCW was considered as the narrowest central flow region of mitral regurgitant jet. This technique has been easily recognized and used by many centers due to its independence from hemodynamic and technical variables and high diagnostic sensitivity for eccentric jets over color Doppler mapping (29,32). Regurgitant orifice area, transvalvular gradient and systolic duration have been well-known parameters to obtain RSV and to assess the severity of MR. Nevertheless, ROA is the most important parameter for the assessment of MR (30). VCW, which is in fact the measurement of ROA with the use of color Doppler has been proven to be independent from hemodynamic variables by in vitro studies (29). A correlation between VCW and RSV obtained from both angiography and echocardiography has also been shown by in vivo studies (15,28). Similar to our observation, low interobserver variability has been reported as another advantage of vena contracta width (31,32).

Although FCR is a quantitative and sensitive method for assessment of MR severity, it has some disadvantages such as: 1) requires special technical equipment, experienced personnel and longer time 2) is unreliable for grade I MR 3) overestimates the regurgitation flow in eccentric jets and flail mitral valve. However, VCW does not have those disadvantages (32). In the previous studies, it has been concluded that a VCW >0.5 cm associates with severe MR (31-33). In our study, in patients with severe MR, mean VCW was 0.54±0.11 cm; this observation confirms the previous studies. We concluded that the measurements of RSV> 55 mm^3 and VCW> 0.51 cm can confirm the presence of severe paraprosthetic MR and necessitate re-operation.

Study Limitations

In this study, angiography and color Doppler mapping techniques were used to confirm the severity of MR found by FCR and VCW methods. Both angiography and color Doppler mapping techniques are semi-quantitative and have imperfect reference standard for quantitating MR (19,34). However, their results were correlated with the results obtained from the methods used in this study. In several studies, FCR has been reported as a sensitive method for differential diagnosis between paravalvular and transvalvular regurgitation. We were not able to confirm paravalvular regurgitation in most of the patients other than six patients with severe MR who underwent re-operation. With currently available devices, long-axis diameter of the vena contracta is not always representative for the cross section of the whole orifice (15) while FCR may overestimate the regurgitation flow in eccentric jets (24). In the future, improved data will be provided by 3-D reconstruction technique. Regurgitant area varies during systole (36). Our aim was to minimize this problem by using the mean of three subsequent measurements. However, to obtain a more accurate value performing some more measurements may be advisable.

CONCLUSION

Our data revealed that both FCR and VCW were sensitive methods for the assessment of the severity of paraprostetic mitral regurgitation and there was a perfect correlation between these methods. However, VCW seemed advantageous because it does not require special technical equipment, experienced personnel and longer time. Using these methods together may improve the accuracy of the assessment of mitral regurgitation in patients with a prosthetic mitral valve.

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