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Original Article

Importance of the Diastolic Flow Reversal Parameters on Quantitation of Aortic Regurgitation

Sedat Kalkan[1], Süleyman Çağan Efe[2], Zeki Şimşek[2], Ali Karagöz[2], Ulaankhuu Batgerel[3], Can Yücel Karabay[4]

[1]Department of Cardiology, Pendik State Hospital, İstanbul, Turkey

[2]Department of Cardiology, Koşuyolu Kartal Heart Training and Research Hospital, Istanbul, Turkey

[3]Department of Cardiology, Acıbadem Kadıköy Hospital, İstanbul, Turkey

[4]Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Research and Training Hospital, İstanbul, Turkey

ABSTRACT

Objective: Aortic regurgitation (AR) is one of the common cardiac valve diseases in the world. Grading the severity of chronic AR is quite critical. Despite the several clinical and echocardiographic data used, AR quantitation still remains challenging today. Findings obtained from the previous studies suggest that not only the duration of the retrograde flow but also the speed of the retrograde flow and diastolic velocity time integral (dVTI) may be associated with the AR grade. In our study, we aim to investigate the relationship and importance of the diastolic flow reversal parameters in the aorta with the grading of aortic regurgitation.

Method: The study is designed as a single-center observational study for the evaluation of dVTI and end-diastolic flow velocity (EDFV) parameters in AR grading. A total of 93 patients were included in our study after exclusion criteria. Patients were divided according to the aortic regurgitation degree into three groups as mild (n = 33), moderate (n = 21), or severe (n = 39). Echocardiographic acquisitions were done. Pulse wave velocity measurements were recorded in the descending aorta by positioning ultrasound rays parallel to the flow in the aorta and EDFV and dVTI parameters were determined.

Result: According to echocardiographic measurements; between the groups; dVTI in the mild, moderate and severe AR groups were (8.5 ± 2.4, 12.8 ± 5.8, 17.4 ± 6.2 cm, respectively, $P < .001$), and EDFV in the mild, moderate, and severe AR groups were (0.11 ± 0.11, 0.10 ± 0.11, and 0.24 ± 0.13 m/s, respectively, $P < .001$), statistically significant different.

Conclusion: In the light of the data obtained in our study, echocardiographic evaluation of the diastolic flow reversal profile in the descending aorta in patients with chronic AR and dVTI and EDFV measurements can contribute to AR grading.

Keywords: Aortic Valve Insufficiency, Heart Valve Diseases, Diagnostic Imaging, aortic valve diseases

INTRODUCTION

Aortic regurgitation (AR) is one of the common cardiac valve diseases in the world. Although there are many factors in AR etiology, valve degeneration and annuloaortic ectasia are the most common causes. Rheumatic heart disease protects its importance as etiological reason in developing countries.[1,2]

Echocardiography is the key method for the diagnosis of AR. Echocardiography may suggest opinions on several issues such as etiological factor, valve and aortic structure, bicuspid/tricuspid valve discrimination, grade of insufficiency, and ventricular dimensions.

Grading the severity of chronic AR is quite critical as it gives ideas about prognosis and determines the follow-up periods of the patients and more importantly, the timing for surgery required to be performed prior to the development of left ventricular (LV) dysfunction. Despite the several clinical and echocardiographic data used, AR quantitation still remains challenging today.

Several parameters (effective regurgitant orifice area, regurgitant volume, Jet/left ventricular outflow tract ratio, vena contracta, holodiastolic flow reversal, LV dilatation, and AR pressure half time [PHT]) obtained through two-dimensional (2D) echocardiography are used in quantitation.

Retrograde diastolic flow in the aorta is observed in most of the patients with chronic AR. The duration, peak speed, end-diastolic flow velocity (EDFV), and diastolic velocity time integral (dVTI) measurements of the flow reversal observed in the aorta have been addressed in certain studies and have been

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ORCID iDs of the authors: S.K. 0000-0002-4202-2932; S.C.E. 0000-0002-6067-6841; Z.Ş. 0000-0001-5594-420X; A.K. 0000-0002-0438-2021; U.B. 0000-0001-7371-5355; C.Y.K. 0000-0002-9653-9048

Corresponding Author: Sedat Kalkan **E-mail:** drsedatkalkan@gmail.com

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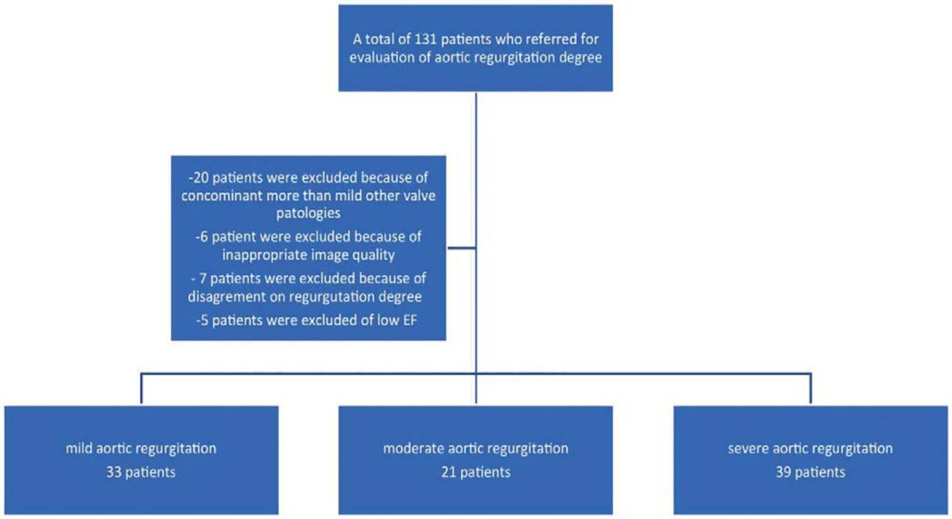
Figure 1. Flow diagram of study patients.



suggested that they can be a guide for aortic insufficiency grading.[3–5]

"Holodiastolic flow reversal" which is defined as retrograde flow seen in the aorta throughout the whole diastole is one of the important parameters used in the advanced assessment of AR. Findings obtained from the previous studies suggest that not only the duration of the retrograde flow but also the speed of the retrograde flow, and dVTI may be associated with the AR grade. In our study, we aim to investigate the relationship and importance of the diastolic flow reversal parameters in the aorta with the grading of aortic regurgitation.

METHODOLOGY

Study Protocol

The study is designed as a single-center observational study for the evaluation of dVTI and EDFV parameters in AR grading and the local ethics committee approval (22.09.2020/3) was obtained. All AR patients who apply to the echocardiography laboratory of our hospital within 6 months and meet the exclusion and inclusion criteria were included in the study sequentially. All patients were informed about the study and their consents were obtained. A total of 131 patients were evaluated in our study. Of these, 20 patients were excluded from the study due to accompanying additional valve pathology, 6 patients were excluded due to inadequate image quality, 5 patients were excluded since their EF value was detected under 50%, and 7 patients were excluded due to the conflict of the experts evaluating on insufficiency grade. In addition, 93 patients were included in our study after exclusion criteria (Figure 1). Patients were divided according to the aortic regurgitation degree into three groups as mild (n = 33), moderate (n = 21), or severe (n = 39). Patients with acute AR or decompensated valvular failure, other concomitant valvular disease of more than mild in severity, chronic pulmonary obstructive disease, previous cardiac or valve surgery, reduced left ventricular ejection fraction (LVEF; ≤50%), known ischemic heart disease, atrial fibrillation, and inadequate echocardiographic data for 2D-speckle tracking echocardiography analysis were excluded. The study population chart was shown in Figure 1.

Main Points

- Aortic regurgitation (AR) is one of the common cardiac valve diseases in the world and grading the severity of chronic AR is quite critical.
- Despite the several clinical and echocardiographic data used, AR quantitation still remains challenging today.
- Main findings of our study are diastolic flow reversal end-diastolic flow velocity in the aorta is higher and different in severe AR compared to mild and moderate AR and diastolic velocity time integral increases linearly with the AR grade and is different between AR patient groups.
- In the light of the data obtained in our study, diastolic flow reversal profile in the aorta can be a guide in addition to the current parameters in AR grading.

Physical Examination and Echocardiography

A complete physical examination was performed by obtaining clinical history and anamnesis from all the subjects. Demographical and clinical particulars are given in Table 1.

Transthoracic echocardiographic images were obtained using an ultrasound system, Vivid-7 (General Electric Vingmed), from the patients in the left lateral decubitus position, and these images were digitally kept for offline examination (EchoPAC version 110.0.0, GE-Vingmed). Echocardiographic acquisitions (colored, standard 2D, pulsed, and continuous-wave Doppler) were done. Standard M-mode images at a parasternal long-axis view were used to obtain the LV dimensions. Then, LV end-diastolic and end-systolic volumes were calculated using biplane Simpson's method from the apical views (two- and four-chamber).

Table 1. Demographic Features of Mild/Moderate and Severe AR Patients

	Mild (n = 33)	Moderate (n = 21)	Severe (n = 39)	*P*
Age (years)	54.9 ± 15.3	47.6 ± 18.6	40.5 ± 18.2	.006
Gender (male n, %)	12 (36.3)	12 (54.5)	25 (64.1)	.062
DM (n, %)	6 (18.1)	4 (18.1)	6 (15.3)	.939
HT (n,%)	7 (21)	9 (40.9)	8 (20.5)	.167
Smoking (n, %)	12 (36)	8 (40)	15 (37)	.326
DL (n, %)	3 (9.1)	5 (22)	6 (15.3)	.378

Abbreviations: DM: diabetes mellitus; HT: hypertension; DL: dyslipidemia.

Table 2. Echocardiographic and Diastolic Flow Reversal Features of Mild/Moderate and Severe AR Patients

	Mild (n = 33)	Moderate (n = 21)	Severe (n = 39)	*P*
Aort diastolic diameter (cm)	3.02 ± 0.57	3.25 ± 0.55	3.26 ± 0.68	.212
EDD (cm)	4,74 ± 0.43	4.86 ± 0.41	5.71 ± 0.63	<.001
ESD (cm)	3.09 ± 0.45	3.12 ± 0.37	3.7 ± 0.43	<.001
Septum	1.04 ± 0.15	1.14 ± 0.19	1.20 ± 0.25	.013
Posterior wall	1.06 ± 0.16	1.13 ± 0.22	1.25 ± 0.25	.002
EF (%)	63.2 ± 6.68	64.5 ± 6.96	62.9 ± 7.16	.691
E (cm/s)	0.5 ± 0.1	0.6 ± 0.2	0.5 ± 0.1	.89
A (cm/s)	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	.51
TAPSE (cm)	2.29 ± 0.4	2.48 ± 0.46	2.42 ± 0.6	.362
AR VC (cm)	0.32 ± 0.9	0.48 ± 0.12	0.63 ± 0.13	<.001
Jet/LVOT	0.29 ± 0.8	0.39 ± 0.11	0.49 ± 0.10	<.001
AR PHT (ms)	480.0 ± 96.2	435.4 ± 89.06	293.7 ± 97.89	<.001
dVTI (cm)	8.5 ± 2.4	12.8 ± 5.8	17.4 ± 6.2	<.001
EDFV (m/s)	0.11 ± 0.11	0.10 ± 0.11	0.24 ± 0.13	<.001

EDD, end-diastolic diameter; ESD, end systolic diameter; TAPSE, tricuspid annular plane systolic excursion; EF, ejection fraction; AR, aortic regurgitation; PHT, pressure half time; VC, vena contracta; EDFV, end-diastolic flow velocity; dVTI, diastolic VTI; LVOT, left ventricular outflow tract.

Following the aforementioned measurements, LVEF was calculated and the results were expressed with percentage.

All measurements and evaluations performed in the study were carried out considering the guidelines of the European Society of Echocardiography. Detailed examination of the aortic root, AV, and proximal ascending aorta was performed taking into account the standard guidelines. To evaluate the AR severity, comprehensive, color, continuous, and pulsed-wave Doppler recordings were carried out considering the recommendations that included the measurement of regurgitant jet width, vena contracta width, pressure half-time, and diastolic flow reversal in the descending aorta.[6,7]

The transducer was placed in the suprasternal notch to measure the diastolic flow reversal parameters. Pulse wave velocity measurements were recorded in the descending aorta by positioning ultrasound rays parallel to the flow in the aorta. The existence of holodiastolic flow reversal, duration of diastolic flow reversal, and speed of peak and end-diastolic flow and dVTI were calculated. EDFV was determined at the peak R wave on a simultaneously recorded electrocardiogram and the EDFV measurements were performed on three consecutive RR intervals. Echocardiographic and diastolic flow reversal parameters are given in Table 2.

AR severity was fixed on by two expert cardiologists who were working in an echocardiography laboratory with more than 5 years of experience. They used conventional echocardiographic evaluation methods for deciding severity degree if both of them are in the same decision on severity degree these patients concluded in the study.

Statistical Analysis

All statistical analyses were carried out using Statistical Package for the Social Sciences (SPSS) Version 22.0. (IBM SPSS Corp.; Armonk, NY, USA).

Descriptive statistics for numerical variables are expressed as mean ± standard deviation (SD), while categorical data are reported as numerical values and percentages. The chi-square test and Fisher's exact chi-square test were used to compare categorical variables between the groups. One-way analysis of variance test was used to compare means between groups. The statistical significance was set at $P < .05$, and the confidence interval at 95%.

RESULTS

According to the AR degree, the patients were divided into three groups: mild, moderate, and severe AR. The basal variables among these groups are presented in Table 1. No statistically significant difference was noticed on parameters among the groups.

Echocardiographic and diastolic flow reversal parameters are defined in Table 2. According to these parameters, end-diastolic diameter (EDD) was detected to be 4.74 ± 0.43 cm in the mild AR group, 4.86 ± 0.41 cm in the moderate AR group and 5.71 ± 0.63 cm in the severe AR group ($P < .001$). End-systolic diameter (ESD) was detected to be 3.09 ± 0.45 cm in the mild AR group 3.12 ± 0.37 cm in the moderate AR group and 3.7 ± 0.43 cm in the severe AR group ($P < .001$). AR vena contracta (VC) was detected to be 0.3 ± 0.9 cm in the mild AR group, 0.48 ± 0.12 cm in the moderate AR group and 0.63 ± 0.13 cm ($P < .001$) in the severe AR group. AR PHT was detected to be 480.0 ± 96.2 ms in the mild AR group, 435.4 ± 89.06 ms in the moderate AR group and 293.7 ± 97.89 ms in the severe AR group with a P value <.001.

Diastolic VTI (dVTI) was detected to be 8.5 ± 2.4 cm in the mild AR group 12.8 ± 5.8 cm in the moderate AR group and 17.4 ± 6.2 cm in the severe AR group ($P < .001$). EDFV was detected to be 0.11 ± 0.11 m/s in the mild AR group, 0.10 ± 0.11 m/s in the moderate AR group and 0.24 ± 0.13 m/s in the severe AR group ($P < .001$).

DISCUSSION

Main findings of our study are as follows:

1. Diastolic flow reversal EDFV in the aorta is higher and significantly different in severe AR compared to mild and moderate AR,
2. dVTI increases linearly with the AR grade and is significantly different between the mild/moderate and severe AR patient groups,
3. Diastolic flow reversal profile in the aorta can be a guide in addition to the current parameters in AR grading.

AR grading with echocardiography is quite complex. The flow reversal in the descending aorta (in a way to reflect the amount of blood that flows back inside from the aortic valve) is directly proportional to the AR grade and remains important in AR grading as a result of the studies performed for many years. Echocardiographic parameters such as flow reversal which continues throughout the diastole, high end-diastolic flow speed, and high diastolic/systolic flow ratio were suggested as guides in AR rating.[8] Diastolic flow reversal seen in chronic AR can be observed markedly and as holodiastolic in patients with moderate/severe AR.[9]

It was determined in the previous studies that flow reversal in ascending aorta was less reliable compared to the examination of flow reversal in the descendant aorta due to the irregular flow pattern.[8] It was highlighted that early diastolic flow reversal may be affected by the aortic compliance, therefore, the flow reversal in late diastole was more reliable in AR grading.[4] Therefore, the importance of the measurements of the descending aorta increased, and EDFV was studied intensively.

In the study conducted by Tribouilloy et al.[3] published in 1991; EDFV assessed with pulse wave doppler (PWD) was suggested as a routine noninvasive parameter that may be beneficial for AR grading. It was concluded that the EDFV being above 18 cm/s may predict the moderate and severe AR. Again in another study, EDFV measured in the descending aorta was found correlated with regurgitant reaction detected in MRI.[8]

In the study conducted by Kalaycı et al.,[5] dVTI detected in the descending aorta with PWD may predict severe AR with high specificity and susceptibility. dTVI cut-off value was determined as 13.5 cm for severe AR in this study. In another study, it was concluded that EDFV and dVTI were effective in AR grading. In the same study, cut-off values for severe AR were suggested as dVTI >13 and for EDFV as >13 cm/s.[9]

The gold standard methods for AR grading are MRI and cardiac catheterization.[5] It is often not possible to assess all patients with interventional procedures such as catheterization or hard-to-reach methods such as MRI. The guidelines are suggesting the concomitant use of quantitative, semiquantitative, and quantitative echocardiographic parameters to evaluate the AR severity.[6,7] The most accurate results can be obtained with quantitative methods, but these methods are both time-consuming and have inter-observer variability.[5] Most of these methods have specific limitations and may be inadequate for AR grading alone. Nonplanar/noncircular regurgitant orifice and a thickened, calcified valve may limit the use of proximal isovelocity surface area method.[10] Increased AR grade is associated with increased LV remodeling and prolonged PHT; and PHT may be an indicator for LV filling pressure, rather than AR grade.[11] Therefore, all parameters that can be obtained with a noninvasive method such as echocardiography and contribute to AR grading are important. This situation increases the importance of parameters such as EDFV and dVTI.

The diagnostic importance of diastolic flow reversal in AR grading is also indicated in the guidelines. Recent European guideline (>20 cm/s for severe AR) recommends EDFV as a parameter to be used in grading, while American Society of Echocardiography[6] emphasizes the existence of holodiastolic flow reversal as a criterion for severe AR in its suggestions.[7]

Examining the flow reversal profile in AR may have limitations in some situations. When AR is mild, flow speed may be low or flow reversal may not be observed. Regular flow that may be seen in the aorta in congenital diseases such as patent ductus arteriosus, coarctation of aorta, or clinical situations such as aortopulmonary fistula, aortic dissection can disturb the flow reversal profile. And again in the cases of acute AR, the benefit of the evaluation of flow reversal is limited due to the rapid equalization of aortic and ventricular pressures.[3]

The results we obtained in our study show the importance of EDFV and dVTI parameters in AR grading in parallel with the previous studies. Therefore, routine evaluation of diastolic flow reversal with echocardiography, which is an easily accessible noninvasive method, may be a reasonable approach in AR grading.

The limitations of our study are that it is single-center, the number of patient population is limited, we are unable to validate the AR grade with gold standard methods and AR degree was calculated by semi-quantitative methods. Multicenter extensive studies that will be validated with a large patient population and gold standard methods will show the role of EDFV and dVTI parameters in AR grading more clearly.

CONCLUSION

In the light of the data obtained in our study, echocardiographic evaluation of the diastolic flow reversal parameters like EDFV and dVTI measured in the descending aorta can contribute to AR grading. Handling these semiquantitative parameters with other grading criteria as a whole may strengthen the prediction in AR grading.

Ethics Committee Approval: This study was approved by Ethics committee of Kartal Koşuyolu Heart Training and Research Hospital (Approval No: 22.09.2020/3).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

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