

# An Efficient Approach for Quantification of Aortic Regurgitation Using Proximal Isovelocity Surface Area Method

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**Abstract-**The proximal isovelocity surface area measurement, also called as the "flow convergence" method, can be used in echocardiography to estimate the area of an orifice through which blood flows. It has a lot of applications, but this paper focuses only on its use in the quantitative evaluation of aortic regurgitation. Proximal isovelocity surface area has been anticipated as a quantitative method to evaluate the severity of aortic regurgitation. In this paper, we present an effective approach based on an Image processing techniques which can accurately quantify the effective regurgitates orifice area (EROA) in aortic regurgitation by using the Doppler Echocardiography image with the aid of proximal isovelocity surface area. In the pre-processing stage, the color Doppler echocardiography image with RGB color space has been subjected to Wiener filtering. Subsequently it has been quantized with the aid of color quantization by using NBS/ISCC color space, which has made the quantification of aortic regurgitation color Doppler echocardiography image more accurate. Moreover that, the proximal isovelocity surface area (PISA) method is employed for calculation of quantitative parameters such as effective regurgitant orifice (ERO), Regurgitant volume, Regurgitant Fraction and more of aortic regurgitation (AR). The proximal flow convergence method has been exploited to quantify valvular regurgitation by the analysis of the converging flow field proximal to assess the mildness, severity and eccentricity of an aortic regurgitant lesion. Experimental evaluation on the commonly accessible dataset illustrates the enhanced performance of the proposed effective approach for the quantification of aortic regurgitation.

**Keywords-** Doppler Echocardiography; Valvular Regurgitation; Aortic Regurgitation (AR); Aortic Regurgitation (AR); Regurgitant Volume ( $R_{Vo}$ ); Regurgitant Fraction (RF); Effective Regurgitant Orifice (ERO); Proximal Isovelocity Surface Area (PISA); Wiener Filtering; Color Quantization; NBS/ISCC Color Space.

## I. INTRODUCTION

With advancement of technology and rising exploitation of Doppler echocardiography over recent decades facilitate the detection and characterization of regurgitant valvular heart disease [1]. Doppler echocardiography as a noninvasive method is advanced for detection of cardiac response to physiologic maneuvers. Doppler echocardiography has been used to obtain estimates of the prevalence of valvular regurgitation in small, selected groups, composed chiefly of normal volunteers [2]. Supplementary studies evaluated, whether the prevalence of valvular regurgitation was associated to age in small groups of apparently normal subjects. However, most of these

studies predated the exercise of color Doppler echocardiography, which has improved the accuracy and sensitivity for the detection of valvular regurgitation [3]. Valvular regurgitation can be used to determine indirectly, semiquantitatively, and quantitatively by Doppler echocardiography. Indirect indicators of important valvular regurgitation comprise of increased forward flow velocities, increased intensity of the regurgitant Doppler signal, and flow reversals. Valvular regurgitation can be used to estimate semiquantitatively by jet area ratios. Quantitative measurements of valvular regurgitation include calculation of regurgitant volumes, regurgitant fractions, and the effective regurgitant orifice area [4]. Here we engaged the quantitative evaluation of aortic regurgitation (AR) based on a comprehensive consumption of color Doppler echocardiography. Aortic insufficiency (AI), also termed as aortic regurgitation (AR), is the diastolic flow of blood from the aorta into the left ventricle. Regurgitation is because of incompetence of the aortic valve or any disorder of the valvular apparatus (e.g., leaflets, annulus of the aorta) resulting in diastolic flow of blood into the left ventricular chamber. AR force a rigorous amount overload to the left ventricle (LV) which results in dilation, eccentric hypertrophy and eventually loss of function [5]. Aortic valve is an integral part of aorta with tubular-like structure. The valve apparatus consists of three distinct leaflets with definitive passive motion during systole and diastole. Due to relatively high systolic and diastolic pressure the aortic valve is confronted with a relatively high mechanical stress and, in terms of morphology, a consideration is to be made of the relation to origin of the coronary arteries. The movement of the tube during systole and diastole is very inadequate in all directions [6]. Most of all valuable parameters is derived from echocardiography followed by MR imaging or contrast aortography. In addition to these, the key considerations are the diameters of the aortic valve orifice and of the adjoining segment of the ascending aorta. A comprehensive assessment of valvular incompetence ruins as a vital goal in clinical cardiology now days. Assessment of the degree of regurgitation is paramount to clinical decision-making in patients with aortic regurgitation (AR), because patients with severe AR frequently need surgical treatment [7]. Semiquantitative grading of AR with color and spectral Doppler echocardiography or with angiography is extensively used, but both techniques are hindered by certain specific limitations. Invasive and Noninvasive quantitative

estimations of regurgitant volume and regurgitant fraction are accessible, but regurgitant volume and fraction depend on loading conditions. In recent times, noninvasive calculation of aortic effective regurgitant orifice (ERO), a measure of lesion severity in AR, was proposed [8]. The ERO area is a fundamental descriptor of AR; determines the consequence of AR on the left ventricle and provides information additional to the volume overload measurements such as regurgitant fraction. However, measurement of the ERO area by quantitative Doppler echocardiography is not constantly feasible, and to achieve a high degree of reliability, a combination of methods is desirable. There has been extensive interest in the proximal isovelocity surface area (PISA) method to assess the severity of valvular and congenital heart diseases. Based on the conservation of mass, the PISA method has been validated experimentally and clinically for calculating the effective orifice area in valvular regurgitation [9]. In AR, the importance regarding the concept of ERO has been underscored, and the PISA method has been pioneered in patients with AR.

The proximal isovelocity surface area (PISA) method [10-13] is based on the continuity principle and assumes that blood flow converging in the direction of a flat orifice forms hemispheric isovelocity shells. It has been revealed that the PISA method is accurate and reproducible. This method is often applied in medical science because the proximal convergence method can be easily visualized and it is the only possible method currently available. Despite of these theoretical advantages, in contrast to valvular regurgitation, the PISA method is rarely used in routine practice for the measurement of AR severity. The main objective of the current research is to present an effective approach based on an Image processing techniques which can precisely quantify the effective regurgitant orifice area (EROA) in aortic regurgitation by using the Doppler Echocardiography image with the assist of proximal isovelocity surface area. There has been substantial interest in the proximal isovelocity surface area (PISA) method to evaluate the severity of valvular and congenital heart diseases. In the pre-processing stage, the color Doppler echocardiography image with RGB color space has been subjected to Wiener filtering. Consequently it has been quantized with the support of color quantization by using NBS/ISCC color space that has made the quantification of aortic regurgitation color Doppler echocardiography image more accurate. In addition to these, the proximal isovelocity surface area (PISA) method is deployed for calculation of quantitative parameters such as Vena contracta, Regurgitant volume, Regurgitant Fraction, Effective regurgitant orifice (ERO) and more of aortic regurgitation (AR). The proximal flow convergence method has been victimized to quantify valvular regurgitation by the analysis of the converging flow field proximal to appraise the mildness, severity and eccentricity of an aortic regurgitant lesion. Correspondingly, this research provides a survey of Qualitative and quantitative parameters that are useful in rating the aortic regurgitation severity and utility, advantages and limitations

of Echocardiographic along with Doppler parameters which has been exploited in the assessment of mitral regurgitation severity. The rest of the paper is organized as follows: A brief review of the recent researches related to quantification of Aortic regurgitation is presented in Section 2. The proposed methodology for effective quantification of aortic regurgitation is presented in Section 3. The experimental results and discussion are presented in Section 4. Finally, the conclusions are summed up in Section 5.

## II. REVIEW OF RELATED RESEARCHES

A brief review of recent researches related to quantification of aortic regurgitation is depicted below. Magnetic resonance imaging was related with echocardiography and angiography in determining the regurgitant volume in patients along with aortic regurgitation which, has been offered by Thomas Wittlinger *et al.* [22]. Forty patients were taken under examination at 1.5 T. The regurgitant jet was positioned with the help of a gradient-echo sequence. Cine measurements were accomplished to calculate left ventricular function. For flow evaluation, a velocity-encoded breath-hold phase-difference magnetic resonance sequence was habituated. The degree of aortic regurgitation is computed by making use of magnetic resonance imaging agreed with that of angiography in 28 of 40 (70%) patients, and with the echocardiography result in 80%. In consequence the Correlation between calculated stroke volume by magnetic resonance cine and flow measurements was very excellent ( $r > 0.9$ ). Anne-Catherine Pouleur *et al.* [23] have presented a proximal isovelocity surface area (PISA), which has been anticipated as a quantitative method to evaluate the severity of aortic regurgitation (AR). However the accuracy of their method in patients with eccentric AR jets was unfamiliar. The objective of their study were to weigh against the accuracy of the PISA method for the quantification of AR severity in patients along with central versus eccentric AR jets and thereby to verify whether imaging from the left parasternal instead of the apical window in order to increase the accuracy of the PISA method in patients with eccentric jets. Therefore in patients with eccentric AR jets imaged from the apical window, the PISA method notably underestimated AR severity. This was no more in chaos when imaging was done from the left parasternal instead of the apical window. Quantification of aortic regurgitation (AR) using echocardiography is still thought-provoking. In spite of rheological characteristics which, has been presented by Chen Li *et al.* [24], a newly established echocardiographic method, vector flow mapping (VFM), can directly measure blood flow volume (FV). They have projected to evaluate the accuracy of VFM in the quantification of chronic AR. Thence the RegR measured by VFM, a new Doppler method that allows quantitative analysis of FV regardless of the existence of turbulent flow, is a highly reproducible parameter with good accuracy for AR quantification. Measurements of the LVOT area done using 3D-echo were highly consistent than those made using 2D-echo which is

presented by Leopoldo Pérez de Isla *et al.* [25]. The LVOT area was measured using both 2D-echo and 3D-echo, and the circularity index, using 3D-echo solely. Additionally, the severity of valvular aortic stenosis was classified using both 2D-echo and 3D-echo. Accordingly, 3D-echo may be a better technique for assessing the LVOT area. In addition, 3D-echo demonstrated that the LVOT is elliptical in form and that its size is not connected to its circularity. Besides, 3D-echo could also be helpful in distinguishing the severity of valvular aortic stenosis.

To assess the correctness of multislice computed tomography (MSCT) with 64 detector rows for determination of the aortic valve area (AVA) compared with transesophageal and transthoracic echocardiography (TEE and TTE) and cardiac catheterization (CATH) has been presented by Lembcke *et al.* [26]. AVA was resolved by planimetry on MSCT and TEE and calculated with the help of continuity equation on Doppler TTE and the Gorlin formula on CATH. Justification against both TTE and CATH exposed a superior correlation and narrower limits of agreement for MSCT than for TEE suggesting that AVA planimetry with MSCT is more consistent than with TEE.

Non-surgical management of aortic valve disease has been given extensive attention. Quite a lot of current publications have previously reported its use in clinical practice. The foremost issue is to get a considerate of the pathophysiological processes and, most importantly, extensive experimental activity. Also to testing of various animal models, technical and material aspects are also being intensively investigated. It is not comprehensible, whether the durability and applicability of this promising development will be equivalent with the standard of current cardiac surgery. Nevertheless, even the use of some models as a momentary approach serving to improve the circulatory status, not allowing safe surgery, is definitely justified. A tiny analysis of the above mentioned issue has been presented by Sochman and Peregrin [6].

### III. THE PROPOSED METHODOLOGY

One of the most important **destinations** in clinical cardiology is the quantification of severity of Aortic regurgitation and it highly mold clinical decision making. Regularly the screening for the subsistence of aortic regurgitation is preceded with the help of Color Doppler flow mapping. Numerous echocardiographic techniques have been published to enhance the quantification of valvular ineptitude. Even supposing, the primary method utilized for estimating AR severity has been found to be less accurate than its latter counterparts and as a result the proximal flow convergence method using color Doppler has been documented as a consistent and accurate quantitative approach. Here we present an effective mode for quantification of aortic regurgitant by integrating image processing techniques that accurately quantify the Effective Regurgitant Orifice Area (EROA) which reinforces the proximal isovelocity surface area (PISA) method to assess the mildness, severity and eccentricity of an aortic regurgitant lesion. Moreover here we sought to ordeal the

reliability of the PISA method for calculation of effective regurgitant orifice (ERO) of aortic regurgitation (AR). The presented approach mainly contributes two modules:

- 1) Preprocessing
- 2) Quantification using Proximal Isovelocity Surface Area (PISA)

#### A. Preprocessing

In this step, initially the color Doppler echocardiography Aortic regurgitation image is subjected to Wiener filtering, which lessens the quantity of noise present in an image by comparison with an estimation of the preferred noiseless image.

**Wiener Filtering:** The Mean Squared Error optimal stationary linear filter for images despoiled by additive noise and blurring is the wiener filter. It ought to be assumed that the signal and noise processes are second-order stationary (in the random process sense), in turn to compute the wiener filter [15]. In frequency domain, the wiener filters are made use of in a regular manner. While presuming the stationary nature of the involved signals, the average squared distance between the filter output and a desired signal is reduced by computing the coefficients of a wiener filter [14], which can be consummate in the frequency domain with ease producing:

$$W(f) = (P_{DY}(f) / P_{YY}(f)) \quad (1)$$

Where  $D(f)$  is the desired signal,

$\hat{S}(f) = W(f)Y(f)$  is the wiener filter output,  $Y(f)$  the wiener filter input and  $P_{DY}(f)$ ,  $P_{YY}(f)$  are the power spectrum of  $Y(f)$  and the cross power spectrum of  $Y(f)$ ,  $D(f)$  respectively.

After that the filtered color Doppler echocardiography image is subjected to color quantization that bring down the number of dissimilar colors used in an image, generally with the intention that the new image should be as visually similar as probable to the original image.

**Color Quantization:** Color quantization is the method of decreasing the number of colors in a digital image by displacing them with a particular color selected from a palette [18]. It is extensively used nowadays as it lessens the work load of massive image data on storage and transmission bandwidth in many multimedia applications. A color-quantized image can be measured as a degraded version of the original full-color image. Color image quantization consists of two major steps:

- Creating a color map (or palette) where a small set of colors (typically 8-256 [17]) is chosen from the  $(2^{24})$  possible combinations of red, green and blue (RGB).
- Mapping each color pixel in the color image to one of the colors in the color map.

Consequently, the main motivation of color image quantization is to map the set of colors in the original color



image to a greatly smaller set of colors in the quantized image. Moreover, this mapping, as previously mentioned, should minimize the variation between the original and the quantized images [16]. In our contribution, color quantization is carried out with the assistance of NBS/ISCC color space.

Assuming the color Doppler echocardiography image as  $I_i$  where,  $0 \leq i \leq n_i - 1$ . Subsequently, to carry out the quantization, the RGB color space values of the image denoted by vectors, namely,  $I_{R_i}$ ,  $I_{G_i}$  and  $I_{B_i}$  respectively with size  $M \times N$  is resample into  $R \times R$  images (usually  $R = 192$ ). As a result that the sampled image  $S_{R_i}$ ,  $S_{G_i}$  and  $S_{B_i}$  are acquired from the color space images  $I_{R_i}$ ,  $I_{G_i}$  and  $I_{B_i}$ . Then the color quantization is executed with the help of  $S_{R_i}$ ,  $S_{G_i}$ ,  $S_{B_i}$  and color lookup table (CLUT). The matrix representation of the CLUT can be given as

$$C_{it} = \begin{pmatrix} R_0 & G_0 & B_0 \\ R_1 & G_1 & B_1 \\ R_2 & G_2 & B_2 \\ \vdots & \vdots & \vdots \\ R_{n-1} & G_{n-1} & B_{n-1} \end{pmatrix} \quad (2)$$

The CLUT is nothing other than the table which has  $n$  diverse possible colors created by various,  $R_x$ ,  $G_y$  and  $B_z$  combinations. Afterward the images of the database are color quantized by manipulating the Euclidean distance between each pixel value of the re-sampled color space images and the  $C_{it}$  value. Therefore the quantized image  $Q_i$  is acquired, which is comprised of the quantized RGB color space values  $Q_R$ ,  $Q_G$  and  $Q_B$  which is formulated as

$$Q_R(a,b) = \min \left( \sqrt{(S_R(a,b) - R_j)^2 + (S_G(a,b) - G_j)^2 + (S_B(a,b) - B_j)^2} \right) \quad (3)$$

where,  $0 < j < n - 1$ ,  $0 < a < r - 1$  and  $0 < b < r - 1$ . This is same for the quantization of other

color space images  $Q_G$  and  $Q_B$  also (i.e.  $Q_R = Q_G = Q_B$ ).

*B. Quantification using Proximal Isovelocity Surface Area*

Once the color Doppler image is preprocessed; it is then subjected to effective quantification of aortic regurgitation along with the assistance of Proximal Isovelocity Surface Area (PISA) method. The PISA method, derived from analysis of the Flow Convergence (FC) region proximal to the regurgitant orifice and from the conservation of mass, has been previously described (19 – 21). Doppler color flow images of the proximal FC of the AR were obtained from an apical long-axis view is shown in Fig. 1. In Doppler echocardiography, AR is estimated by the size of the regurgitant jet in the LV cavity, the jet width in the LV outflow tract, and the pressure half-time measured by continuous-wave Doppler. Calculation of RV or RF is also possible by echocardiography because the total stroke volume through the aortic valve must equal forward stroke volume plus RV. Based on these methods, the severity of AR was graded as mild, moderate, severe, and eccentric. The Qualitative and quantitative parameters useful in grading aortic regurgitation severity is tabulated in Table.1.

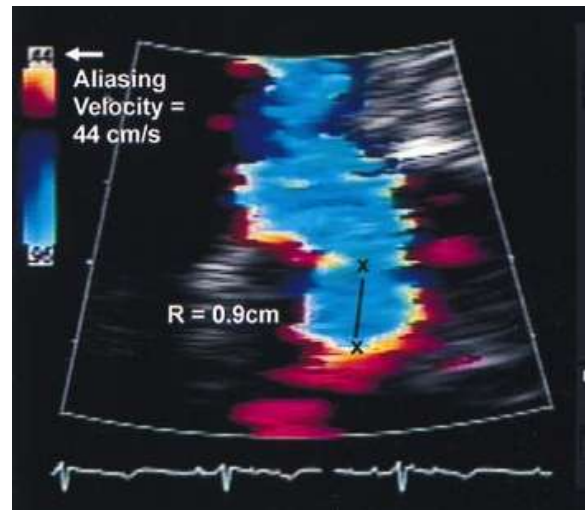


Fig. 1. Shows the Color flow Doppler imaging of the proximal FC recorded from the apical view.

Table. 1. Qualitative and quantitative parameters useful in grading aortic regurgitation severity

	Mild	Moderate	Severe
<b><u>Structural Parameters</u></b>			
LA size	Normal*	Normal or dilated	Usually dilated**
Aortic leaflets	Normal or abnormal	Normal or abnormal	Abnormal/flail, or wide coaptation defect
<b><u>Doppler Parameters</u></b>			
Jet width in LVOT-Color Flow $\xi$	Small in central jets	Intermediate	Large in central jets; variable in eccentric jets
Jet density-CW	Incomplete or faint	Dense	Dense
Jet deceleration rate-CW (PHT, ms) $\psi$	Slow>500	Medium 500-200	Steep<200
Diastolic flow reversal in descending aorta- PW	Brief, early diastolic reversal	Intermediate	Prominent holodiastolic reversal
<b><u>Quantitative Parameters <math>\phi</math></u></b>			
VC width, cm $\xi$	<0.3	0.3-0.60	>0.6
Jet width/LVOT width, % $\xi$	<25	25-45	46-64
Jet CSA/LVOT CSA, % $\xi$	<5	5-20	21-59
R Vol, ml/beat	<30	30-44	45-59
RF, %	<30	30-39	40-49
EROA, cm <sup>2</sup>	<0.10	0.10-0.19	0.20-0.29

CSA-cross sectional area; CW-continuous wave Doppler; LVOT- left ventricular outflow tract; PHT- pressure half-time; PW- pulsed wave Doppler;  $R_{Vol}$  - regurgitant volume; RF - regurgitant fraction; VC - vena contracta. \*Unless there are other reasons for LV dilation. Normal 2D measurements; LV minor axis  $\leq 2.8\text{cm/m}^2$ , LV end-diastolic volume  $\leq 82\text{ml/m}^2(2)$ .; \*\*Exception: would be acute AR, in which chambers have not had time to dilate.;  $\xi$  At a Nyquist limit of 50-60 cm/s.;  $\psi$  PHT is shortened with increasing LV diastolic pressure and vasodilator therapy, and may be lengthened in chronic adaptation to severe AR.;  $\phi$  Quantitative parameters can sub-classify the moderate regurgitation group into mild-to-moderate and moderate-to-severe regurgitation as shown

Deducing hemispheric shape of the PISA, the diastolic aortic regurgitant flow  $R_{Flow}$ , is calculated as

$$R_{Flow} = 2\pi \times r^2 \times V_r \quad (4)$$

Where  $r$  the radius of the FC is measured in early diastole, and  $V_r$  is the corresponding aliasing velocity. The aortic regurgitant ERO area is then calculated as

$$ERO(PISA) = R_{Flow} / R_{Vel} \quad (5)$$

Where  $R_{Vel}$  is the maximal velocity of the aortic regurgitant jet in early diastole recorded with continuous

wave Doppler echocardiography from the apical, par apical or right parasternal transducer position. Color-flow techniques includes measurement of the maximal anteroposterior diameter (height) of the regurgitant jet at the junction of the LV outflow tract (LVOT) and the aortic annulus in parasternal long-axis view, and the maximum height of the LV outflow tract at the same location. Continuous Doppler-wave imaging of AR permits quantification of both the slope and pressure half-time.

Regurgitant volume ( $R_{Vol}$ ) which is calculated as:

$$R_{Vol} = \text{aortic flow} - \text{mitral flow} \quad (6)$$

$$\text{Aortic flow} = (D_{LVOT}^2 * 0.785)R_{Vel} \quad (7)$$

Where  $D_{LVOT}$  is the diameter of the LV outflow tract (LVOT). Regurgitant fraction ( $RF$ ) was calculated as

$RF = \frac{R_{Vol}}{\text{aortic flow}}$ . A regurgitant fraction exceeding 40% to 50 % inculcate more severe AR [27].

#### IV. EXPERIMENTAL RESULTS AND DISCUSSION

The research reveals that the effective  $EROA$  calculated on the basis of analytical study conducted on the proximal flow convergence method, displayed by color Doppler echocardiography image, which is feasible and correlates

very closely with the true effective regurgitant orifice for an assortment of different orifice. This section presents the outcome gained from the experimentation on the proposed approach for an effective quantification of aortic regurgitation from color Doppler echocardiography image. The proposed approach was implemented in Matlab (Matlab version 7.8) and it was verified on color Doppler echocardiography images accessible commonly. To employ proximal flow convergence method in the clinical setting,

we have estimated Flow rate, effective *EROA*, vena contracta width, jet width, LVOT width and more based on the analysis of the proximal flow convergence method with aortic regurgitation. The efficacious measurements of above mentioned parameters for Mild and Eccentric aortic regurgitation are sketched in the below table: 2 and the intermediate results of the proposed approach is given in Fig. 2.

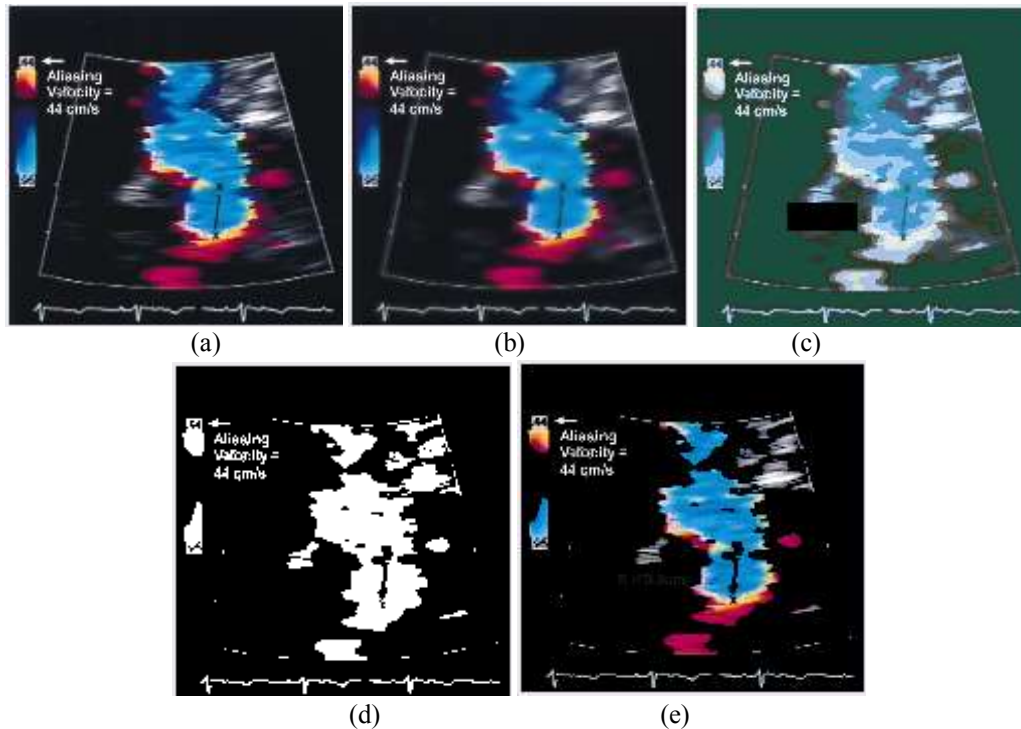


Fig. 2. Intermediate Results of the Proposed Approach (a) Input (b) Filtered Image (c) Color Quantization (d) Binary output (e) Segmented Output

Table. 2. Measured values of the above mentioned parameters of Mild and Eccentric Aortic Regurgitation.

Quantitative Parameters	Mild	Eccentric
Radius r (cm)	0.6085	1.32292
Vena Contracta Width (cm)	0.3175	0.635
Jet Width (cm)	0.9525	1.56104
LVOT width (cm)	1.2964	2.2754
Regurgitant Flow Rate (cm <sup>2</sup> )	111.6868	483.8353
EROA (cm <sup>2</sup> )	0.22337	0.96767
Aortic flow (cm <sup>3</sup> )	152.658	267.9303
R <sub>vol</sub> (cm <sup>3</sup> )	21.456	57.9303
Regurgitant Fraction (%)	0.1405	0.21621

**Discussion:**

In recent times, the PISA method, based on the conservation of mass, was verified clinically to quantify the ERO area in regurgitation. In particular, the PISA method is attractive because of its simplicity. Experimental research has recommended that the PISA method might be of value in the quantitation of AR. The ERO corresponds to the area of the vena contracta, which is less than the anatomic regurgitant area. Experimental and clinical investigations have recommended that the ERO area yields unique information on the severity of regurgitation, neither which is less dependent on hemodynamic variables nor dependent on heart rate ledge management in both academic research as well as practical applications. Recently, the aortic ERO area in AR is resolved by Doppler echocardiography invasively and noninvasively. These studies demonstrated that the ERO area is an important and clinically significant index of AR severity that contributes additional information to the regurgitant fraction. Accordingly, development of other clinically consistent noninvasive methods is necessary so that the ERO area can be obtained in all status with a combination of methods during the same Doppler echocardiographic examination, to reach a high degree of reliability in the evaluation of severity of the AR.

Main deliberation with quantitation of AR is the calculation of the mean ERO over the regurgitant phase of the cardiac cycle as a measure of lesion severity. The PISA method provides instantaneous measurements of flow and ERO. Because the regurgitant flow rate by the PISA method and the regurgitant velocity were measured simultaneously in early diastole, the calculated aortic ERO area is the early diastolic ERO. In AR the potentially dynamic nature of the regurgitant orifice area during diastole remains controversial. Despite these conjectural considerations, an important result of the present study is that in patients with

AR and appropriate FC, early diastolic measurements concomitant to peak regurgitant velocity provide a calculated ERO that correlates closely with the mean ERO measured by the reference methods, without a significant trend toward overestimation or underestimation. Consequently, the PISA method, which is reasonably feasible and highly accurate with appropriate FC, can be used in clinical practice for the quantitation of AR. Importantly, the ERO by the PISA method correlates well with other methods of assessment of the degree of AR using left ventricular volumes, angiographic grade or surgical assessment of lesion severity, further supporting the relevance of this measure in patients with AR.

Though the accuracy of Doppler echocardiographic methods for quantitation of regurgitation and dimension of left ventricular volumes has been questioned, reliability has been confirmed from high resolution imaging and consistent use. Possible restrictions of the PISA method, related to the assumption of a hemispheric shape of the proximal FC, have been discussed, but clinical series have demonstrated that in most cases the hemispheric assumption provides appropriate measurement of the flow rate and ERO. In addition, examination of the FC region allows identification of the cases in which the geometry of this region may invalidate the hemispheric assumption, so that they can be either corrected or classified as inappropriate. The shape of the perceived proximal FC, and thereafter the reliability of the ERO calculation, depends on the radius value, which is driven out using the selected aliasing velocity. The appropriate and individualized selection of the aliasing velocity, as done in the present study, avoids overestimation or underestimation of the flow rate. Advantages and Limitations of Echocardiographic and Doppler parameters used in the assessment of aortic regurgitation severity are depicted in table 3.

Table .3. Echocardiographic and Doppler parameters used in the evaluation of aortic regurgitation severity: Utility, advantages, and limitations

	<b>Utility/Advantages</b>	<b>Limitations</b>
<b>Structural parameters</b>		
LV size	Enlargement sensitive for chronic significant AR, important for outcomes. Normal size virtually excludes significant chronic AR.	Enlargement seen in other conditions. May be normal in acute significant AR.
Aortic cusps alterations	Simple, usually abnormal in severe AR; Flail valve denotes severe AR.	Poor accuracy, may grossly underestimate or overestimate the defect.
<b>Doppler parameters</b>		
Jet width or jet cross-sectional area in LVOT- Color Flow	Simple, very sensitive, quick screen for AR.	Expands unpredictably below the orifice. Inaccurate for eccentric jets.
Vena contracta Width	Simple, quantitative, good at identifying mild or severe AR.	Not useful for multiple AR jets. Small values; thus small error leads to large % error.

PISA method	Quantitative. Provides both lesion severity (EROA) and volume overload (Rvol).	Feasibility limited by aortic valve calcifications. Not valid for multiple jets, less accurate in eccentric jets. Provides peak flow and maximal EROA. Underestimation is possible with aortic aneurysms. Limited experience.
Flow quantitation -PW	Quantitative, valid with multiple jets and eccentric jets. Provides both lesion severity (EROA, RF) and volume overload (Rvol).	Not valid for combined MR and AR, unless pulmonic site is used.
Jet density-CW	Simple. Faint or incomplete jet compatible with mild AR.	Qualitative. Overlap between moderate and severe AR. Complementary data only.
Jet deceleration rate (PHT)-CW	Simple	Qualitative; affected by changes in LV and aortic diastolic pressures.
Diastolic flow reversal in descending aorta -PW	Simple	Depends on rigidity of aorta. Brief velocity reversal is normal

AR, Aortic regurgitation; CW, continuous wave Doppler; EROA, effective regurgitant orifice area; LV, left ventricle; LVOT, left ventricular outflow tract; MR, mitral regurgitation; PHT, pressure half-time; PW, pulsed wave Doppler; R Vol, regurgitant volume; RF, regurgitant fraction; VC, vena contracta width.

#### V. CONCLUSION

The Studies reveal that for the measurement of the EROA of AR, the PISA method has a realistic feasibility and high accuracy with appropriate FC. Further this can be applied on clinical experiments, including patients with an eccentric jet and valve prolapse. In this paper we have presented an efficient approach based on image processing techniques for effective quantification of Aortic regurgitation with the assistance of Doppler echocardiography images. A reasonably greater accuracy was acquired in the quantification of aortic regurgitation Doppler image. This is achieved due to the filtering and color quantization in the preprocessing stage. The developments in imaging technologies facilitate the following features namely accessibility of spatial distribution of the valve regurgitation immediately to progress measurements of flow convergence, vena contracta and the regurgitant which eventually leads to enhancements in the quantization of valvular regurgitation. We would conclude from our researchers that determination of cardiac output non-invasively by Doppler echocardiography with the aid of the flow convergence method is beneficial. Experimental results have been found to correlate with the several other procedures in existence for cardiac output measurement.

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