Pulsed-Wave Doppler Recordings in the Proximal Descending Aorta in Patients with Chronic Aortic Regurgitation: Insights from Cardiovascular Magnetic Resonance

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Background: The pulsed-wave Doppler recording in the descending aorta (PWD_{DAO}) is one of the parameters used in grading aortic regurgitation (AR) severity. The aim of the present study was to investigate the assessment of chronic AR by PWD_{DAO} with insights from cardiovascular magnetic resonance (CMR).

Methods: This prospective study comprised 40 patients investigated with echocardiography and CMR within 4 hours either prior to valve surgery (n = 23) or as part of their follow-up (n = 17) due to moderate or severe AR. End-diastolic flow velocity (EDFV) and the diastolic velocity time integral (dVTI) were measured. The appearance of diastolic forward flow (DFF) was noted. Phase-contrast flow rate curves were obtained in the DAO.

Results: Twenty-five patients had severe and eight had moderate AR by echocardiography (seven were indeterminate). The EDFV was below the recommended threshold (>20 cm/sec) in 13 patients (52%) with severe AR. Lowering the EDFV threshold (>13 cm/sec) and with a dVTI threshold >13 cm showed negative likelihood ratios of 0.27 and 0.09, respectively. Detection of DFF with PWD_{DAO} identified a nonuniform velocity profile by CMR with positive and negative likelihood ratios of 7.0 and 0.19, respectively. The relation between EDFV and DAO regurgitant volume (DAO-$RVol_{CMR}$) was strong in patients without (R = 0.88) and weak in patients with DFF (R = 0.49). The DAO-$RVol_{CMR}$ as a percent of the total $RVol_{CMR}$ decreased with increasing ascending aorta (AAO) size and increased with increasing AR severity.

Conclusions: Our findings suggest that PWD_{DAO} provides semiquantitative parameters useful to assess chronic AR severity. The limitations are related to nonuniform velocity contour and variable degree of lower body contribution, which depends on AR severity but also on the AAO size. (J Am Soc Echocardiogr 2017;■:■-■.)

Keywords: Aortic regurgitation, Pulsed-wave Doppler, Descending aorta, Cardiovascular magnetic resonance

A comprehensive transthoracic echocardiography investigation is a cornerstone in the management of patients with valvular heart disease.[1] Grading of aortic regurgitation (AR) severity by echocardiography is known to be difficult and is achieved by an "integrative approach" using several qualitative, semiquantitative, and quantitative parameters.[2,3] There are basically three contributors to the regurgitant volume (RVol) in AR: (1) the lower body, (2) the upper body, and (3) the systolic volume expansion of the ascending aorta (AAO) and aortic arch (Windkessel effect). The contribution from the lower body has been used in echocardiography for the grading of AR severity during the past four decades based on the concept that the diastolic backward flow (DBF) in the proximal descending aorta (DAO) mirrors the RVol. Typically, the normal flow profile in the proximal DAO consists of an early diastolic flow reversal followed by mid-diastolic forward flow (DFF). In patients with chronic AR, the diastolic flow reversal is more prominent and becomes holodiastolic in moderate or severe AR.[4-6] The velocity integrals in diastole (dVTI) and systole (sVTI) are surrogates for the volume passing thorough the vessel at the level of measurement. Previously, investigators used the ratio between dVTI and sVTI obtained by either continuous Doppler[4] or pulsed-wave Doppler (PWD) for assessment of AR severity.[5] Later, the end-diastolic flow velocity (EDFV) was introduced as a useful

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Conflicts of Interest: None.

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Abbreviations

2D-PC = Two-dimensional phase-contrast

AAO = Ascending aorta

AR = Aortic regurgitation

CMR = Cardiovascular magnetic resonance

DAO = Descending aorta

DAO-RVol$_{CMR}$ = Regurgitant volume in the descending aorta

DBF = Diastolic backward flow

DFF = Diastolic forward flow

dVTI = Diastolic velocity time integral

ECG = Electrocardiogram

EDFV = End-diastolic flow velocity

LVEDVindex = Left ventricular end-diastolic volume indexed to body surface area

PC = Phase-contrast

PC-FRC = Phase-contrast flow rate curve

PWD = Pulsed-wave Doppler

PWD$_{DAO}$ = Pulsed-wave Doppler recording in the descending aorta

RF = Regurgitant fraction

ROC = Receiver operator characteristic curve

RVol = Regurgitant volume

STJ = Sinotubular junction

sVTI = Systolic velocity time integral

index in the assessment of AR severity.[6] The good diagnostic performance of the VTI ratio and EDFV in identifying severe AR is based on studies using angiography with a four-point scale as reference.[4-6] Angiography is no longer considered as the gold standard, and echocardiographic grading of regurgitation severity is performed instead using a three-point scale.[1-3] The diagnostic usefulness of the PWD in the DAO (PWD$_{DAO}$) is a matter of debate. In the recent European recommendations, EDFV is considered a semiquantitative parameter, and a threshold indicating severe AR is defined (>20 cm/sec).[2] On the other hand, the American Society of Echocardiography recommendations consider PWD$_{DAO}$ a qualitative parameter by emphasizing that a prominent holodiastolic flow reversal indicates severe AR.[7] In our clinical experience, patients with severe AR can have relatively low EDFVs, and we observe that the spectral Doppler curve in diastole can have both backward and forward flow velocities, indicating complex flow. This finding questions the concept of a uniform flow profile in the DAO in patients with AR.[8] Furthermore, dilatation of the AAO is a frequent finding in patients with AR, and it is conceivable that this might influence the contribution from the Windkessel effect and the relation between the PWD$_{DAO}$ findings and the RVol. In the present study we hypothesized that (1) a nonuniform velocity profile influences the relation between PWD$_{DAO}$ findings and AR severity and (2) the size of the AAO influences the contribution from the lower body in patients with AR. To study this we used cardiovascular magnetic resonance (CMR), since this method has unique abilities compared with angiography as it can quantify flow with high accuracy and low variability and can provide information on the spatial distribution of velocity and the complexity of flow across the vessel area.[9-11] The overall aim of the present study was to investigate the assessment of chronic AR severity by PWD$_{DAO}$ with insights from CMR.

METHODS

Study Population

This prospective study comprised 40 patients with AR who were either investigated prior to valve surgery ($n = 23$) or as part of their follow-up due to moderate ($n = 14$) or severe regurgitation ($n = 3$). The indication for surgery was based on clinical assessment and the grading of severity by echocardiography without knowledge of the CMR findings. We did not include patients with acute AR in the study. All patients included had chronic AR, and those who underwent surgery were hemodynamically stable and did not have AR due to aortic dissection or acute endocarditis. Image acquisition, analysis, and grading of regurgitation severity were performed according to current 2017 American Society of Echocardiography guidelines.[7] Patients with four or more specific criteria (flail leaflet, vena contracta > 6 mm, central jet with >65% of left ventricular outflow tract, pressure half-time < 200 msec, prominent holodiastolic flow reversal in the DAO, and enlarged left ventricle defined as left ventricular end-diastolic volume indexed to body surface area [LVEDVindex] > 2 SD) were considered to have severe AR. Quantitative methods were used whenever possible in patients with two to three specific criteria. Patients with RVol$_{ECHO}$ ≥ 60 mL or regurgitant orifice area ≥ 0.3 cm^2 were considered to have severe AR as well as patients with three specific criteria and RVol$_{ECHO}$ 45-59 mL or regurgitant orifice area 0.20-0.29 cm^2. The RVol$_{ECHO}$ and regurgitant orifice area were obtained using the color Doppler flow convergence method.[12] Echocardiography and CMR were performed within 4 hours. Exclusion criteria were moderate or more than moderate regurgitation in any other valve, presence of a cardiac shunt, any other form of significant cardiac disease, and irregular heart rhythm.

The study was conducted according to the Declaration of Helsinki. The Regional Ethics Review Board in Gothenburg gave ethical approval for the study protocol, and written informed consent was obtained from all participants.

Echocardiography

The echocardiographic investigation was performed using a commercially available imaging system (Vivid E9, GE Healthcare, Milwaukee, WI). Image analysis was performed using EchoPAC (GE Healthcare). End diastole and end systole were defined visually as the frames with the largest and smallest left ventricular cavities. Left ventricular volumes were acquired using the apical four- and two-chamber view according to the biplane method of disks to determine the end-diastolic and end-systolic volume.[13] The PWD$_{DAO}$ was performed without a low-velocity filter, and the sample volume (2.5 mm) was positioned distal to the origin of the left subclavian artery. The EDFV was measured at the time point corresponding to the electrocardiogram's (ECG's) R-wave (Figure 1). The recordings where classified as either having only backward flow or both backward and forward flow during diastole. The dVTI and sVTI were measured from the outer contour of the velocity envelope (Figure 1), and the VTI ratio was calculated ((dVTI/sVTI) × 100). Dimensions of the left ventricular outflow tract, aortic root, and proximal part of the AAO was obtained from a parasternal long-axis view. The AAO was also investigated with the patient on the right side and the transducer on the right side of the sternum. The EDFV measurements were performed on three consecutive RR intervals. All echocardiographic analyses were performed in a blinded manner to CMR.

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