Doppler Echocardiographic Evaluation of Patients after Aortic Coarctation Repair

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Abstract

Objective- We aimed to evaluate the accuracy of Doppler echocardiography indices in patients with significant recoarctation of the aorta (ReCoA).

Methods- Thirty-nine consecutive patients (11 females) post-surgical repair of aortic coarctation were included in the study. All the patients underwent complete Doppler echocardiography and clinical evaluation and peak systolic instantaneous pressure gradient (PPG), mean pressure gradient, velocity time integral (VTI) in the descending thoracic aorta, acceleration time (AT), ejection time (ET), and AT/ET of the coarctation repair site were measured. All the patients underwent CT angiography; and in case of significant ReCoA, cardiac catheterization was done.

Results- Measured values of ET, AT, AT/ET, and VTI at the repair site and VTI in the descending thoracic aorta were significantly greater in the patients with ReCoA. The average difference between the echocardiographic and angiographic systolic PPG was 16 mmHg. The presence of Doppler PPG greater than 35 mmHg, VTI in the descending thoracic aorta more than 40cm, and AT at the repair site of more than 135 msec had high sensitivity and specificity for the diagnosis of significant ReCoA. Five (0.42) patients with recoarctation had significant hypertension; compared to 7 (0.26) patients without recoarctation (P-value =0.32).

Conclusion- After coarctation repair, Doppler PPG should be interpreted with caution but considering other Doppler indices, Doppler echocardiography is a practical and accurate screening method for an evaluation of significant ReCoA, with a low threshold for invasive of aorta investigation if the Doppler PPG in the descending aorta exceeds 35mmHg ***(Iranian Heart Journal 2009; 10 (2):25-30).***

Key words: Doppler ■ echocardiography ■ coarctation

Coarctation of the aorta (CoA), which is typically a discrete stenosis of the proximal thoracic aorta, occurs in approximately 6-8% of patients with congenital heart disease (CHD).[1] It varies considerably in its anatomy, physiology, clinical presentation, treatment options, and outcomes.
By adulthood it has usually been recognized and repaired, so patients are at risk for several important complications, including aortic recoarctation (ReCoA).
These patients after CoA repair require life-long follow-up. ReCoA is not uncommon and rates range from 8% to 54%, depending on the definition.[1,2]
The diagnosis is not as easy as native CoA. It is an important cause of morbidity after CoA repair,

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which induces or aggravates hypertension, left ventricular mass, coronary artery disease, and heart failure. Treatment for CoA may be achieved by surgical operation or by catheter intervention.
ReCoA or residual stenosis may occur with all known surgical techniques: no single technique appears to be superior to the others.[3] A significant coarctation will produce a peak gradient of at least 30mmHg on continuous wave (CW) Doppler through the descending aorta, and a diastolic tail (forward flow continuing in diastole) beyond the CoA. After coarctectomy, local loss of distensibility is noted in addition to mild anatomic narrowing. Much controversy exists about the reliability of 2-dimensional (2D) and Doppler study in evaluating the severity of ReCoA. MRI is the gold standard imaging method, but Doppler echocardiography has been suggested as the best screening test.[4,5] Doppler ultrasound has become an established technique for the assessment of obstructive lesions, but pressure gradients derived from Doppler in patients with CoA may be less reliable than similar calculations for valve stenosis.[6-9] CW Doppler echocardiography may significantly overestimate or underestimate the pressure drop after the repair of coarctation and it should be interpreted with caution in individual patients.[6,10] There are many factors that can influence the pressure gradient across a CoA such as cardiac output, heart rate, collateral circulation, length and shape of the obstruction, complex flow dynamics in the aortic arch, inability to measure flow velocity immediately proximal to the site of the surgical repair, local scar stiffness, and increase of Doppler peak velocities after coarctectomy. The aim of this study was to evaluate the accuracy of different Doppler echocardiography indices in patients with significant ReCoA.

Methods

In total, 39 consecutive patients post-surgical repair or balloon angioplasty of aortic coarctation were included. Patients with complex CoA, any degree of aortic stenosis, and more than mild aortic regurgitation were excluded. A full clinical evaluation and echocardiographic study was performed with a commercially available echocardiography machine (Vivid 3, GE Ultrasound, Horten, Norway) and instantaneous Doppler peak pressure gradient (PPG), mean systolic pressure gradient (Fig. 1), velocity time integral (VTI) in the descending thoracic aorta, acceleration time (AT, time from beginning to peak of the Doppler signal), ejection time (ET), and AT/ET of the coarctation repair site (Fig. 2, a,b) were measured by continuous wave Doppler study using a simplified Bernoulli equation.

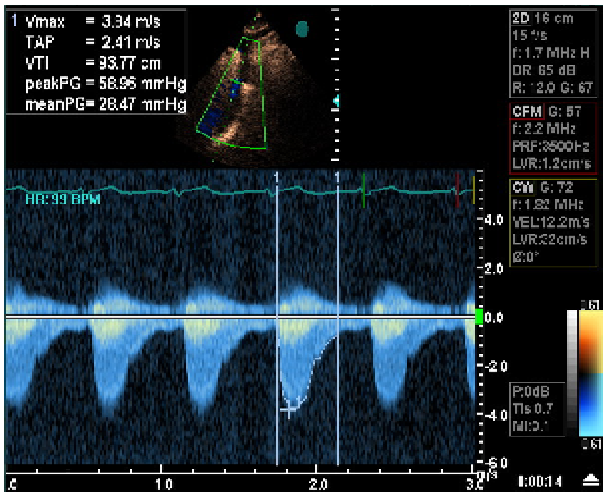
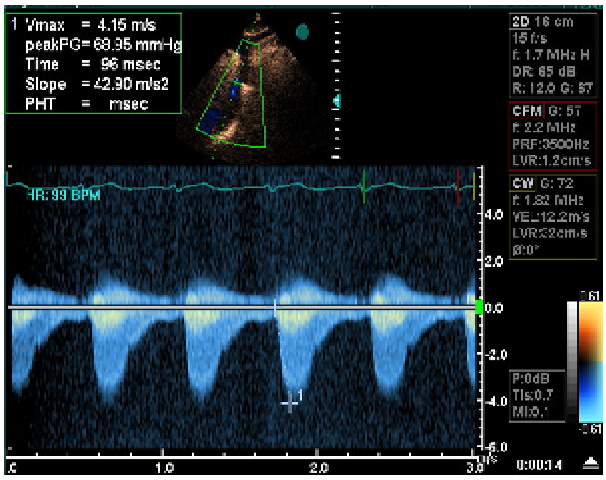


Fig. 1. Peak systolic pressure gradient (PPG), mean systolic pressure gradient, and velocity time integral (VTI) in the descending thoracic aorta by CW Doppler study

In the abdominal aorta, the presence or absence of holodiastolic forward flow was evaluated by pulse wave Doppler study (Fig. 3).

All the patients underwent CT angiography. It has been suggested that CT scans and MRI are similarly useful for the non-invasive evaluation of the thoracic aorta in patients with coarctation of the aorta.[11,12] The significance of ReCoA was defined by the CoA index less than 45% (the cross-sectional area of the obstruction was compared with the area of the abdominal aorta as an index of obstruction); and for the patients with CoA index less than 45%, cardiac catheterization was performed.



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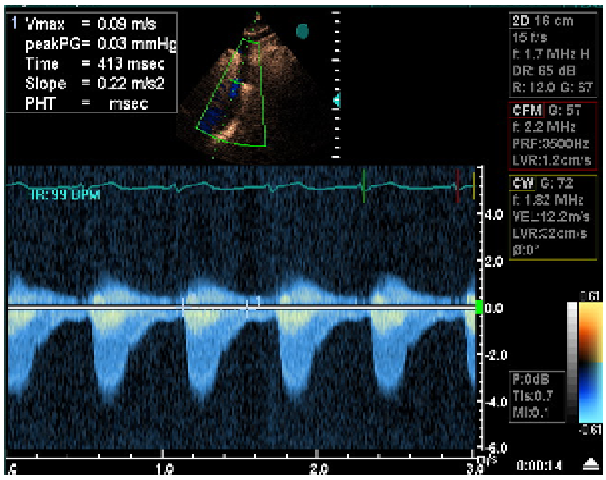

B

Fig. 2a, 2b. Acceleration time (time to peak velocity), systolic ejection time (ET) and AT/ET at coarctation repair site

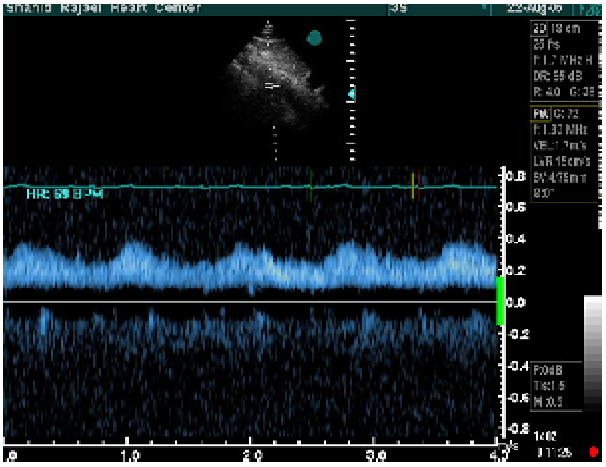

Fig. 3. Abdominal aortic pulsed wave Doppler signal showing holodiastolic antegrade flow

Statistical Analysis

The data were described by mean ± standard deviation for the quantitative and counts (%) for the qualitative variables. The quantitative data were compared between the study subgroups using the Mann-Whitney U-test. Sensitivity, specificity, and likelihood ratio for positive and negative test results were computed as indices for diagnostic accuracy. SPSS 15 for Windows (SPSS Corporation, Chicago, Illinois) was used for statistical analysis.

Results

Background data

Thirty-nine patients (11 females; mean age 14±7.3 years, range: 4 to 30 years) were evaluated. Fourteen patients were treated by balloon angioplasty, 19 by surgical repair, and 6 patients by both surgery and balloon angioplasty. The patients were evaluated after a median period of 5±8.7 years after CoA repair (range from 1 to 20 years). Twelve patients had significant ReCoA. The presence of holodiastolic antegrade flow in the abdominal Doppler flow study showed no significant

difference in patients with and without significant ReCoA. There was no significant correlation between hypertension and ReCoA. Five (0.42) patients with ReCoA had hypertension compared to 7 (0.26) patients without ReCoA (P-value =0.32).

Echocardiographic examination

The results of echocardiographic indices and the comparisons between the patients with or without recoarctation are presented in Table I. All the measured indices but two showed significant differences between the two groups of patients (all P- values ≤ 0.05). There was no significant association between VTI in the ascending aorta and recoarctation (P-value = 0.53), and between peak pressure gradient / mean pressure gradient and ReCoA (P-value= 0.54). The average difference between the echocardiographic instantaneous Doppler PPG and catheter-derived pressure gradients was 16 mmHg. The measured values of ejection time, acceleration time, acceleration time / ejection time, and VTI at the repair site were significantly greater in the patients with ReCoA. In contrast, the relative indices (VTI in the ascending aorta / VTI in the descending aorta, and VTI in the ascending aorta / VTI at the repaired site) had lesser values in these patients (Table I).

Table I. Comparison of echocardiographic indices between the patients with and without significant re-coarctation

	Re-coarctation (n = 12)	No Re-coarctation (n = 27)	P-value
Ejection Time *msec*	355 ± 66.2	277 ± 48.7	< 0.001
Acceleration Time *msec*	151 ± 23.3	92 ± 39.2	< 0.001
Acceleration Time / Ejection Time	0.43 ± 0.05	0.33 ± 0.11	0.001
VTI in Repaired Site	87.2 ± 22.13	40.5 ± 14.28	< 0.001
VTI in Ascending Aorta	27.3 ± 9.99	25.1 ± 9.78	0.53
VTI in Descending Aorta	57.6 ± 17.40	29.9 ± 10.92	< 0.001
VTI in Ascending Aorta / VTI in Descending Aorta	0.49 ± 0.17	0.87 ± 0.27	< 0.001
VTI in Ascending Aorta / VTI at Repair Site	0.32 ± 0.13	0.62 ± 0.21	< 0.001
VTI in Descending Aorta / VTI at repair site	0.66 ± 0.09	0.75 ± 0.14	0.05
Peak Gradient / Mean Gradient	2.1 ± 0.33	2.1 ± 0.50	0.54

VTI: velocity time integral

Diagnostic accuracy of echocardiographic Indices

Sensitivity, specificity, and positive and negative likelihood ratios for the different echocardiographic indices were compared to the results of angiography as the gold standard (Table II). Instantaneous Doppler PPG more than 35 mmHg had a sensitivity of 0.75 and specificity of 1.00, VTI in the descending aorta of more than 40cm had a sensitivity of 0.91 and specificity of 0.96, and acceleration time (AT) at the repair site more than 135 msec had a sensitivity of 0.81 and specificity of 0.96 for significant ReCoA.

Based on the defined cut-points, all the selected echocardiographic indices had high sensitivity and specificity for the diagnosis of recoarctation.

Table II. Diagnostic values of echocardiographic indices for detection of significant re-coarctation

	Cut-point	Se	Sp	LR+	LR-
Ejection Time *msec*	300	0.81	0.80	4.1	0.24
Acceleration Time *msec*	135	0.81	0.96	20.3	0.19
Acceleration Time / Ejection Time	0.40	0.80	0.83	4.7	0.24
VTI at Repair Site *cm*	65	0.92	0.96	23.0	0.08
VTI in Descending Aorta *cm*	40	0.91	0.96	22.8	0.09
VTI in Ascending Aorta / VTI in Descending Aorta	0.61	0.90	0.96	22.5	0.10
VTI in Ascending Aorta / VTI at Repair Site	0.42	0.90	0.96	4.1	0.24

Se: sensitivity; Sp: specificity; LR+: likelihood ratio for positive result of test; LR-: likelihood ratio for negative result of test

Discussion

In our study, we found that CW Doppler study might considerably underestimate or overestimate aortic arch pressure gradients after CoA repair. The average difference between echocardiographic instantaneous Doppler PPG and catheter-derived pressure gradients was 16 mmHg; it, therefore, seems that Doppler PPG should be interpreted with caution in this setting and alternative quantitative indices such as ET, AT, and VTI of the thoracic aorta at the repair site can be used to accurately detect the presence of significant ReCoA. Our results were close to those of the Chan et al. study, which measured pressure drop across the aortic arch simultaneously by CW Doppler and double lumen catheter in patients with CoA repair. They found wide variations ranging from +22 to -17 mmHg between these measurements.[6]

Aldousany et al.[9] proposed that after coarctectomy, the Doppler peak velocities remain elevated and even including the precoarctation velocity in the simplified Bernoulli equation, the maximal Doppler gradient still overestimates the catheter peak-to-peak gradient, although Marx and Allen[7] suggested that this discrepancy will disappear after incorporation of the proximal velocity in the Bernoulli equation.

In view of these discrepancies between Doppler PPG and catheter-derived pressure gradients, many other non-invasive Doppler indices have been proposed as markers for significant coarctation such as continuation of Doppler flow into diastole across the obstruction.[8,9-13,14] Carvalho et al.[4] proposed that the diastolic Doppler gradient was more sensitive than the systolic, and Tan et al. suggested that DV>193 cm/s and diastolic/systolic velocity ratio >0.53 had a high predictive value for severe aortic coarctation (CoAi <0.25).[16] In our study, we did not find a significant correlation between the presence of holodiastolic antegrade flow in the abdominal aorta and ReCoA, which can be explained by changes in aortic compliance and local non-distensibility at the surgical scar,[10] and delayed upstroke or prolonged time-to-peak velocity and reduced pulsatility (difference between the maximal and minimal velocities) seems more important.[17]

In the clinical setting, many methods are used to determine the severity of ReCoA, including blood pressure studies at rest and with exercise. We did not find any significant correlation between hypertension and ReCoA, which can be explained by the small number of patients with significant ReCoA and hypertension.

In our patients, instantaneous Doppler PPG more than 35mmHg had high sensitivity and specificity for significant ReCoA. In the other studies, much controversy exists about the reliability of 2D and Doppler study,[18] while Doppler echocardiography has been suggested as the best screening tool in

evaluating the severity of ReCoA.[4,5] Wendel et al. do not recommend Doppler for the evaluation of the severity of ReCoA.[19] Our study was performed on only a small number of patients with new Doppler indices, which needs more studies.

The clinical implication of our findings is that Doppler PPG more than 35mmHg with ET > 300 msec and AT> 135 msec at the CoA repair site has high sensitivity and specificity for significant ReCoA. The presence of holodiastolic antegrade flow in the abdominal aorta is not an accurate sign for significant ReCoA, but the contour of the Doppler with delayed upstroke seems more important.

The main limitation of our study is the different types of CoA repair, with small numbers of patients with significant ReCoA, and further studies are needed to confirm the accuracy of these Doppler indices.

Conclusion

In most patients after CoA repair, Doppler peak velocities remain elevated; consequently, Doppler PPG should be interpreted with caution and other Doppler indices should be used as a marker of significant ReCoA, with a low threshold for invasive investigation if Doppler PPG in the descending aorta exceeds 35mmHg.

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The patient was taken to the operating room for a redo CABG, during which the adhesions were released and the epicardial vessels dissected. The LIMA was identified and divided. The LAD was just visualized only at the apex of the heart and was traced until it was found to become intramyocardial.
Due to the shortness of the LIMA, it was ligated and a new anastomosis was fashioned using an SVG on the distal portion of the LAD via the off-pump technique (OPCAB) without using cardiopulmonary bypass (CPB) (Fig. 3).

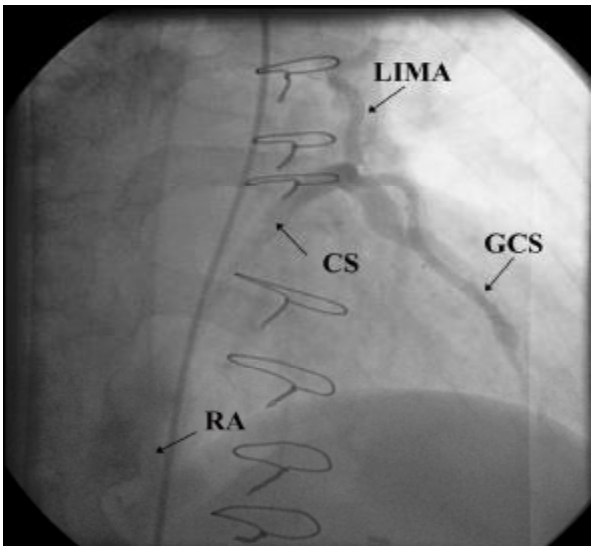
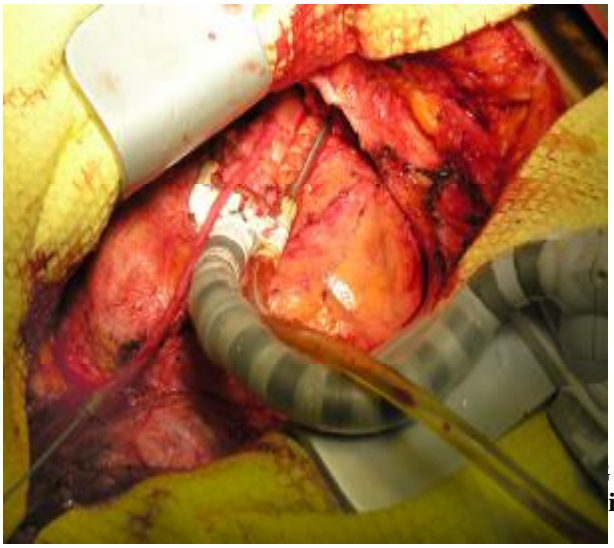


Fig. 2. Angiogram depicting patent LIMA grafted to coronary vein draining into the coronary sinus (CS).



on the distal LAD using a stabilizer device (OPCAB)

iscussion

Although errors in anastomosis during CABG are very rare, they may occur. There are some problems which may lead to anastomosis of a graft to an epicardial vein. An intramyocardial course of the target vessel and occasional difficultly in distinguishing between an artery and a vein are two common problems in cardiac surgery. Under these circumstances, several techniques can be useful in differentiating the vessels from each other.

Localization of intramyocardial vessels can often be accomplished by noting epicardial contour, accompanying epicardial venous structures, or a faint discoloration or a whitish streak within the reddish brown myocardium. When extreme difficulty is encountered in identifying a left anterior descending artery, one controversial technique that has been described is that of locating the distal LAD near the apex of the heart, where it is commonly very superficial. A small transverse arteriotomy is then created in this very distal location and a fine metal probe can be passed retrogradely into the LAD and the vessel manually palpated proximally.[1] The native artery is usually thick-walled and diseased, but veins can sometimes be thick and sclerosed.[2]

Another method is to run antegrade blood-based cardioplegia to assess the color of the blood flowing through the vessels in question. In target vessels during antegrade cardioplegia, a bright red color confirms it to be an artery.[3] During off-pump surgery with the opening of the target vessels, a bright arterial blood flow is seen and confirms it.

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