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Novel Cardiac MRI Techniques in Coarctation of Aorta-Is Echo Friend or Foe?

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Abstract

Purpose: Measurement of the pressure gradients, using Phase-Contrast MRI and assessment of associated cardiac lesions/valvular affections in patients with coarctation of aorta and mapping of collaterals, with subsequent comparison of MRI findings with echocardiographic findings.

Methods: The study cohort comprised of 20 successive patients with coarctation of aorta who experienced echocardiography and cardiac-MRI between July 2018 to July 2020. Cardiac-MRI and echocardiography findings were compared with the criterion standardized by multi-team discussion, CCA, and operative findings (where ever available).

Results: Twenty patients twelve were males (60 percent) and eight were females (40 percent) with a mean age of 17 years (range from 0.019 to 60 years). The site of coarctation of aorta was accurately delineated in 85% of cases by Echo and in 100% of cases by MRI. Mild, moderate, and severe coarctation of aorta was detected in 10%, 25%, and 55% of patients respectively. Significant collateralization was detected in 55% of severe and 60% of moderate cases of coarctation of aorta with a moderate level of agreement between echocardiography and cardiac-MRI findings (kappa value of 0.459) and Pearson's correlation coefficient of 0.823. ASD, VSD, PDA, BAV, LVH, and PAH was detected in 9%, 16%, 10%, 10%, 29%, and 26% of cases.

Conclusion: MRI has been a regular exam for assessment of aortic coarctation complementing and extending the findings of echocardiography. Furthermore, MRI aortic arch measurements are comparable with the anatomic measurements, especially to show related tubular hypoplasia. Besides the severity of coarctation of aorta, MRI can aid in the evaluation of collateral circulation and better delineation of associated anomalies which constitutes a corner-stone in pre-operative evaluation algorithm in cases of COA: “coarctation of aorta”.

Keywords: PWV: Pulse wave velocity; VENC: Encoding Velocity; TTE: Trans-Thoracic Echocardiography; COA: Coarctation of Aorta; MTD: Multi-Team Discussion; TRUFI: True Fast Imaging with steady-state free precession

Introduction

The COA is a luminal narrowing of a short section of the aorta [1]. COA signifies amongst the most frequent congenital cardiac lesions and accounts for 5% to 10% of all congenital heart disorder cases. Congenital heart disorder, although rare, with the incidence of 8 per 1000 births, has increased in prevalence due to the success of surgical and medical management in childhood. Coarctation is more common in males, M:F ratio of 2-3:1.

There are two types of coarctation of aorta: -

I. Adult type-stenosis of the short segment (post-ductal and periductal)

II. Juvenile -the diffuse type (preductal tubular hypoplasia)

Aortic arch interruption is the extreme disease variant [2]. The interruption may occur at 3 sites: -

I. Type A distal to the left subclavian artery.

II. Type B between the subclavian artery and left common carotid.

III. Type C between the left common carotid artery and innominate artery.

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Coarctation is a condition that very commonly escapes early diagnosis and as the detection is delayed, treatment is delayed. This may cause heart attacks and early deaths as a result of the rise in coarctation with a delay in treatment [3]. A Death is caused by aorta rupture (approximately 25%), cardiac insufficiency (approximately 20%), infective endocarditis or aortitis (approximately 20%), intracranial hemorrhage (approximately 10%), and heart rupture (around 1%) [4].

Keeping in view the above constraints and the fact that early diagnosis of coarctation is vital, various tools, both clinical, as well as, the diagnosis of the disease using methods of radiological imaging. From ascertaining by pressure differences by sphygmomanometric between upper and lower extremities and clinical signs such as cardiac murmurs, the diagnostic armamentarium for coarctation of aorta has evolved; however imaging modalities have widened our insight about the exact mapping of this condition.

Doppler echocardiography is the first imaging method utilized to show the location as well as coarctation of aorta severity and for the estimation of pressure gradients across the narrowed segment, however, a limited acoustic window used in Doppler echocardiography will lead to non-consistent outcomes, although an exact evaluation of the aortic anatomy and the related malformations is needed prior to surgical repair.

The lack of reproducibility and consistency in Doppler echocardiography paved the way for cardiac MRI to be known as a stronger non-invasive imaging modality for the COA evaluation. Cardiac MRI provides better morphologic and hemodynamic assessment with results being in good correlation to that obtained by conventional angiography. Cardiac MR can accurately delineate the site, degree, and the narrowing extent, some related aortic arch tubular hypoplasia as well as collateral pathways.

After the 1980s, MR: "Magnetic Resonance" imagers have employed quantitative flow estimation, and its ability was recognized since 1960. With the capacity of MR imaging units and the decreased time required to cardiac-study outcomes, more and more signs are emerging as a significant source of quantitative function information in cardiac MR imaging to use phase-contrast fluid measurements.

"Phase-Contrast Magnetic Resonance Imaging" (PC-MRI) is a popular method for obtaining quantitative blood flow data. Cardiovascular MR imaging uses of this procedure are expanding. Phase's contrast may be measured either in a breath holder or during natural respiration, depending on the available series.

Cardiovascular magnetic resonance uses strong magnetic fields with non-ionizing radiation to make images in response to the energy input from target molecules of the radio wave [5]. Different tissue properties may be emphasized and quantified by changing the input signal and generating images [5]. The calculation of the speed could be quantified utilizing approaches of phase contrast based upon the assumption that the blood moving through the magnet field results in a phase change relative to the speed [6]. A cine may be generated by the acquisition of several speed maps over the complete heart cycle, displaying the speed shifts over a time period and then the vessel region may measure the blood flow [6]. Similar to echocardiography, the measurements of speed and flux are used for blood transportation in the aorta and are useful in disorders like COA with benefits of complete thorax coverage and highly accurate flow quantification for collateral localization [7].

Investigations have also shown the potential to replace gradient-echo PC imaging with SSFP, with the benefit of reducing the imaging period when Pulse Wave Velocity (PMV) is also determined by PC imaging [8].

Cardiac MR may show the presence of the narrowing and with PC imaging, evaluate both the pressure gradient in the coarctation and measure the collateral flow throughout the thorax [7] and choose those who require surgical repair. MR 4D flow imaging has been demonstrated in patients with coarctation as a technique for quantification of collateral flow [9]. The 4D flow was also shown to correctly assess peak-to-peak pressure gradients in comparison to invasive catheterization with advanced post-processing techniques [10]. Moreover, non-invasive imaging may control postoperatively the suitability of the correction and serially control for complications like aneurysm or restenosis formation [7] or negative remodeling of the aorta because of arch shape [11].

Materials and Methods

Our prospective research was conducted from July 2018 for a period of over 2 years with a study cohort comprising of 20 patients out of which 12 were males (60 percent) with 8 were females (40 percent) with a mean age of 17 years (range from 0.019 to 60 years). Patients underwent cardiac MRI procedure preceded by echocardiographic assessment, either for confirmation of indeterminate echocardiography findings, or better delineation of morphological constraints, assessment of collateral circulation, and associated anomalies/valvular affections.

Inclusion criteria

All those patients who were labeled as having coarctation of aorta on the echocardiographic findings basis.

Exclusion criteria

Patients diagnosed with coarctation of aorta on echocardiography but having some contraindication for the cardiac-MRI (e.g., heavy metal foreign bodies, non-MR compatible pacemakers/metallic prosthesis) (Image 1).

The technique of echocardiography and cardiac-MRI

Echocardiography was carried out using an iE33 xmatrix Echocardiography Device (Philips, m Amsterdam, The Netherlands) by a sonographer with at least 5 to 10 years of ultrasound cardiac diagnosis experience. A four-chamber apical view was performed with echocardiography i.e., a right ventricular outflow tract view, a left ventricular long-axis view, using apical, parasternal, sub-xiphoid, and suprasternal approaches.

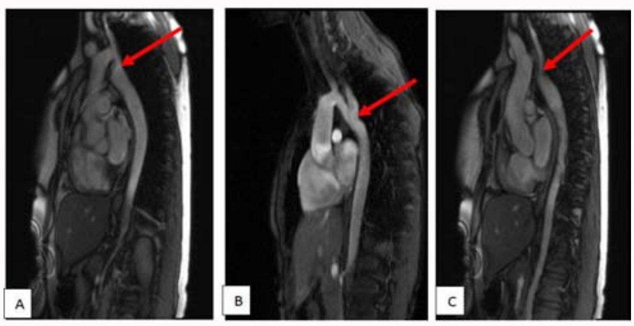

Image 1: MR cine images in oblique sagittal in systolic phase showing coarctation site (arrows) with mild [A], moderate [B], as well as severe [C] coarctation.

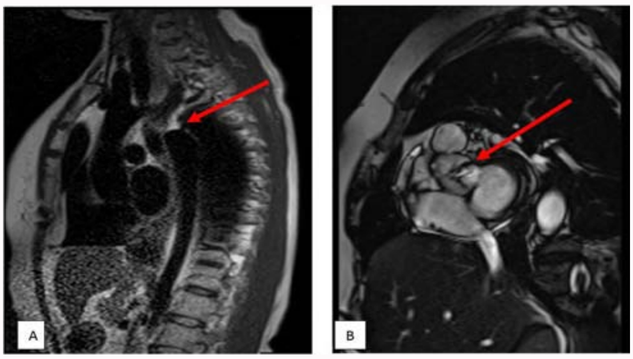

Image 2: MR spin-echo image demonstrating tight coarctation (arrow) on oblique sagittal plane [A]. MR cine image (short-axis view) showing the bicuspid aortic valve in a patient with COA (arrow) [B].

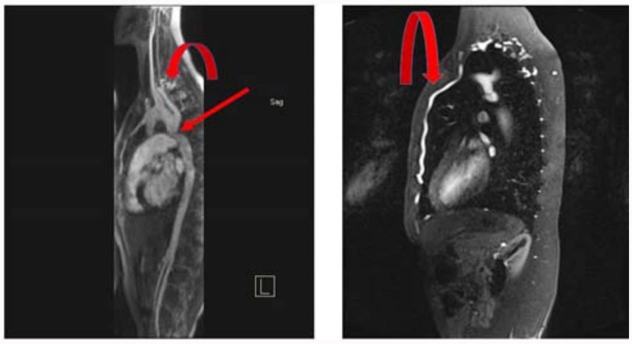

Image 3: The best methods of imaging and showing the aortic coarctation (arrow) in the thoracic aorta are gadolinium strengthened MR angiography. They are also optimal for showing the collateral flow (curved arrow).

Subsequently, these patients were subjected to a phase-contrast MRI study utilizing a 1.5-T MRI scanner ("Siemens Medical System, Erlangen, Germany") (Image 2).

Patients with coarctation of aorta were studied using HASTE: "Half Fourier Acquisition Single Shot Turbo Spin Echo" sequences, TRUFI with Steady-State Free Precession sequences, and MR angiography in multiple planes to get an optimal parasagittal view of the coarctation segment. The use of Propofol (Diprivan) in continuous infusion with the aid of the anesthesiologist allowed for quick and deep sedation with fast recovery in children under the age of 6. The MR compatible device was used to test the ECG signal, respiratory curve as well as oxygen saturation.

The axial plane was originally made up of ECG-gated multi-slice spin-echo or fast spin-echo black blood images. Then there were attained 2 extra planes, the coronal & oblique sagittal that included the aortic arch. The breath-keeping turbo spin-echo black blood series with parallel acquisition procedure has changed this sequence in adults along with older children to reduce the scanning period at the same spatial resolution. Depending on the patient's heart size, slice thickness was ranging from 3 mm to 10 mm.

The big matrix, including 256 × 512 in the read-direction, was used in younger patients such that spatial precision without prolonged time was improved.

Cine-MR imaging was then made using the previously described segmented Gradient-Echo (GE) pulse sequences [12], bFFE: "balanced Fast Field Echo sequences". 16 to 25 cardiac cycle frames have been shown in a cine loop that allowed a dynamic method. All of these examples are done using an oblique sagittal plane that includes the aortic arch, in certain instances, on the aortic isthmus an oblique coronal plane cantered. Diastolic images were analyzed for the narrowing corresponded to the coarctation. To display the flow gap owed to turbulence and low acceleration within the usual high signal pressure of the blood pool at and below the coarctation, attention has been focused on systemic photographs.

In our study, phase -contrast MR with properly adjusted encoding velocity was done at: -

I. At two levels below the coarctation segment:

a) Immediately inferior to the level of coarctation segment, and

b) At the level of distal aorta.

II. At the level of coarctation segment, and

III. The level just before the coarcted segment.

In a subset of patients, 3D CEMRA was carried out after a minimal Gadolinium injection of bolus (2 ml) to assess the period the thoracic aorta has reached its contrasts. Twice, in two breath intervals, the acquisition was rendered and centered on the oblique sagittal plane encompassing the whole thoracic aorta. Every time of acquisition was 16 seconds. The dose has been 0.2 mmol per kg weight of the body and the corresponding injection volume of 3 ml/s has been gadolinium DTPA (Schering, Berlin, Germany). In a peripheral vein preferably an antecubital vein, the contrast medium was infused with an MR compatible infusion pump, flowing via the saline 20 mL. For patients under three years old, after a bolus of Propofol (Diprivan), the contrast medium was injected manually to achieve an apnea in the 32 s acquisition period. The patient was subsequently extracted from the magnet and ventilated by the anesthesiologist manually at the conclusion of the MRA sample and the spontaneous ventilation recovery period was around 5 min. The whole MR analysis took 30 min to 45 min (Image 3).

Image analysis

Image analysis included demonstrating the site, the coarctation duration, and degree, the distance to the artery of the subclavian, the correlation to aortic hypoplasia of tubular, and the existence of collateral and related malformations (Table 1).

The PC-MR images so obtained were analyzed for velocity and flow measurements using dedicated ARGUS software. The gradient across the coarcted segment was calculated using the formula: -

$$\Delta p = 4 \quad (V_{max})^2$$

{V_{max} Must has a meter's dimension per second to result in a proper pressure gradient that has the dimension of millimeters of mercury (mm Hg)}

The coarctation period was deemed small while the narrow aortic segment length was <0.5 cm and long when the narrow aortic segment length was >0.5 cm [13]. When the diameter of the transverse aortic arch ratio to distal descending aortic aorta diameter was <0.9 known as hypoplastic [14].

Data/statistical analysis

The data were analyzed by the principal investigator with advice from a statistician. For statistical research, SPSS 22.0 (IBM, Armonk, NY, USA) was used. With the multiteam discussion/CCA findings considered as the gold norm. Comparison within pressure

Table 1: Severity of coarctation of aorta.

SEVERITY	MILD	MODERATE	SEVERE
RATIO (“Diameter of the isthmic region/Distal Descending aortic diameter”)	0.9-0.6	0.6-0.4	<0.4
Pressure Gradient across coarcted segment (Δp) mmHg.	≤ 30	>30- ≤ 40	>40

Table 2: Tabulated representation of number cases mild, moderate, and severe cases detected by echocardiography, taking MRI as gold-standard for comparison.

Degree of Stenosis	ECHO (detected)	ECHO (not- detected)	PC-MRI (gold- standard)
Mild (≤ 30 mmHg)	1	1	2
Moderate (>30- ≤ 40 mmHg)	3	2	5
Severe (>40 mmHg)	8	3	11

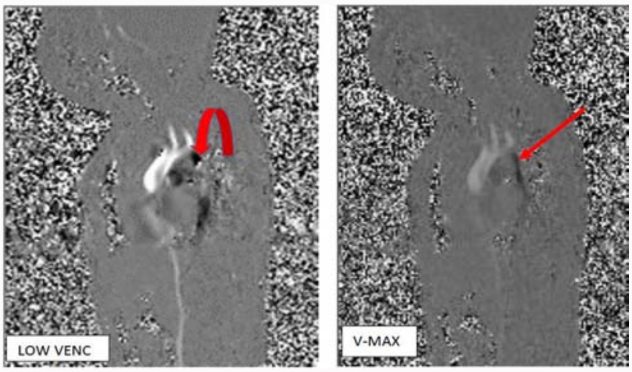

Image 4: Phase Contrast MR images in the oblique sagittal plane in a patient with severe coarctation. Phase image at low VENC demonstrates aliasing (curved arrow). With increasing VENC values there is the disappearance of aliasing at properly adjusted encoding velocity (V-MAX) within the stenotic jet (arrow).

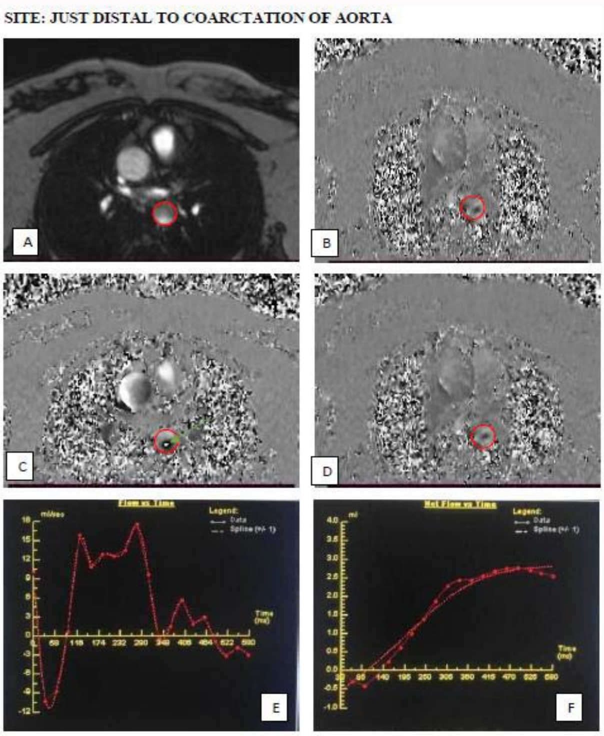

Image 5: MR Phase-contrast images obtained just distal to coarctation of aorta; Magnitude [A] and corresponding Phase image [B] with ROI marked in a red circle. MR Phase image [C] with low VENC value showing aliasing (arrow) with the disappearance of aliasing within ROI at higher values of VENC corresponding to V-MAX [D]. Graphical plots for Flow *vs.* Time [E] and Net Flow *vs.* Time [F] obtained using dedicated ARGUS software.

gradients estimates in MRI and linear regression analysis was used for echocardiography and Bland and Altman plot. Comparative analysis was also done between echocardiography, MRI, and MTD using inter-modality agreement statistical analysis (kappa values). All statistical analyses were done by the SPSS statistical software (release 23.0, SPSS Inc.; Chicago, Ill).

The study was prospective and therefore informed consent was obtained from the patients (Image 4,5).

Results

Severity of coarctation

The level of stenosis in eleven cases was extreme, moderate in five and mild in 2. Coarctation of aorta length was short/shelf-like. The site of narrowing was accurately delineated in 19 cases (distal to left subclavian artery), but the exact site of narrowing was not delineated in 1 case (due to severe hypoplasia of aortic arch) (Table 2, 3).

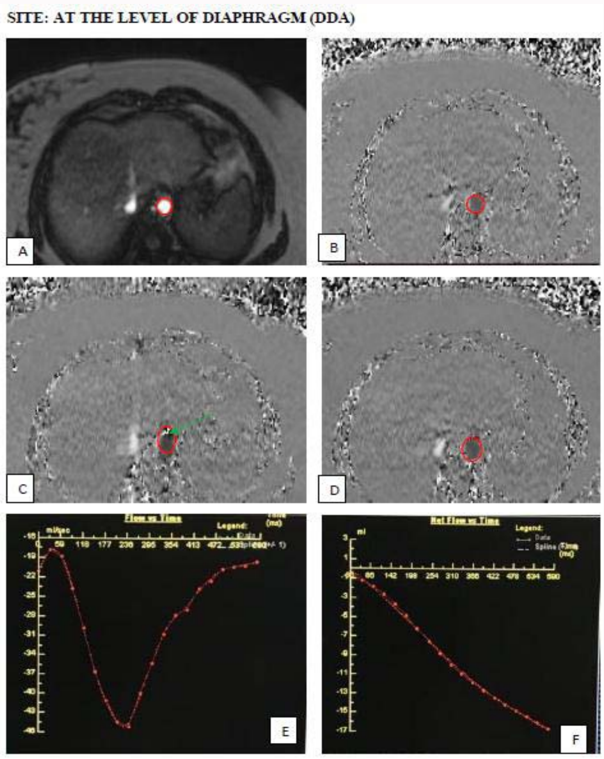

Image 6: MR Phase-contrast images found at the diaphragm level; Magnitude [A] and corresponding Phase image [B] with ROI marked in a red circle. MR Phase image [C] with low VENC value showing aliasing (arrow) with the disappearance of aliasing within ROI at higher values of VENC corresponding to V-MAX [D]. Graphical plots for Flow *vs.* Time [E] and Net Flow *vs.* Time [F] obtained using dedicated ARGUS software.

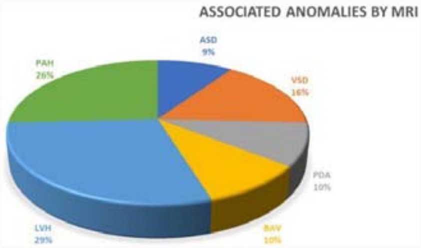

Figure 1: Pie-chart for the representation of the spectrum of associated anomalies detected by MRI.

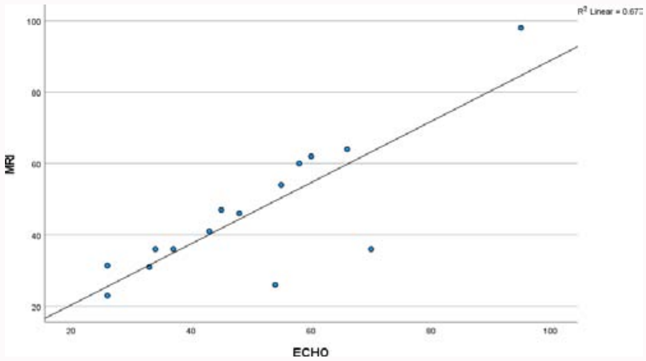

Figure 2: Comparison via linear regression study of pressure gradient estimates produced via VENC Doppler Echocardiography & MRI. The Doppler measurements are compared with MR. The graph shows that the two techniques are well correlated.

Collateral flow with respect to the severity of coarctation

Collateral circulation was found to be significant in 11 cases out of 20 cases. In 6 cases out of 11 cases (55%) with severe stenosis, collateral circulation was significant. In 3 cases out of 5 cases with moderate stenosis (60%) collateral circulation was significant.

Spectrum of associated anomaly/findings

- Tubular hypoplasia of aortic arch was observed in one case.
- PFO was seen in 2 cases.
- Shone complex was diagnosed in one case on MTD.
- One case was diagnosed with pseudo-coarctation of aorta (Δp=12 mmHg). This patient was diagnosed with Ellis-van Crevald syndrome (homozygous non-sense variation in EXON8 of EVC2 gene) (Figure 1).

Comparison of Doppler echocardiography and MRI results

Doppler echocardiography has diagnosed coarctation in 17 of the 20 patients; in three instances there was coarctation suspicion and/or "aortic arch hypoplasia". The aortic arch/site of coarctation was not well shown in three instances on echocardiography, one of which was labeled with features suspicious for coarctation of aorta on echocardiography and when subjected to PC-MRI diagnosis of pseudo-coarctation (Δp=12 mmHg) was made, which was confirmed on MTD. VENC-MRI and in 15 situations, Doppler estimates of pressure gradients were required for contrast. The pressure gradient estimates of VENC-MRI were contrasted with Doppler estimates (Figures 2, 3). The graph shows a strong connection between the two approaches with Pearson's correlation coefficient of 0.823. Doppler measurement was not feasible in 5 cases, and in 1 case MRI measurement as stated above was unlikely. It was mostly attributed to a tight stenosis/tubular aortic arch hypoplasia and the flow below the

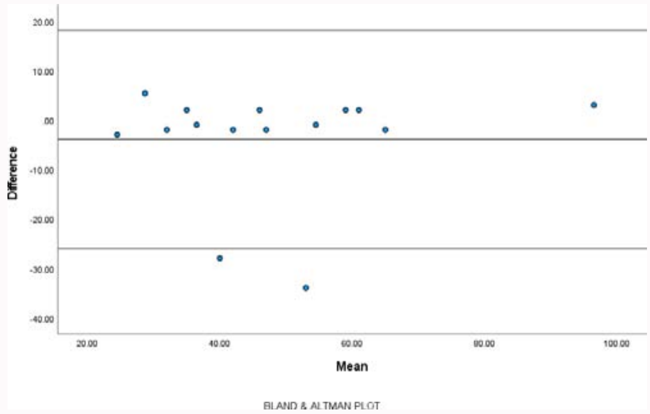

Figure 3: Difference between MRI & Doppler measurements according to the Bland and Altman approach with the average value for any pair. The central line is the mean difference; the upper and lower lines indicate the agreement limits (± 2 SD).

Table 3: Tabulated representation of a number of cases with mild, moderate, and severe coarctation of aorta by MRI (on the basis of aortic diameters).

Degree of stenosis	Number of patients(n)
Mild (0.9-0.6)	3
Moderate (0.6-0.4)	5
Severe (<0.4)	11

coarctation was preferentially directed from the large PDA.

Echocardiography and cardiac-MRI findings were compared with criteria standardized by 'MULTI TEAM DISCUSSION' which comprised of two experienced radiologists and two cardiologists. An insignificant number of patients underwent cardiac catheter angiography (Image 6).

Discussion

Cardiac-MRI and echocardiographic findings were categorized under 4 headings

I. Pressure gradient evaluation across the COA.

II. Morphological assessment of the aortic malformation and measurement of aortic diameters.

III. Assessment of collateral circulation.

IV. Detection of associated anomalies.

Pressure gradient evaluation across the coarctation of aorta

Hemodynamic evaluation of COA in our study was done using pressure gradients (Δp) obtained by TTE and PC-MRI, which categorized our study into 3 categories on the basis of increased severity of stenosis (Table 2).

Echocardiography and PC-MRI were utilized for pressure gradient calculation across the COA and a good correlation was observed severe between these two diagnostic modalities using comparative statistical analysis with Pearson's correlation coefficient of 0.823 (scatter plot) and Bland and Altman plot (Figure 1, 2). Our study was complemented by a study conducted by Serif Beslic et al. in "Institute of Radiology", "Clinical Centre University", Sarajevo and a study conducted by Didier et al. [12] in the "Department of Radiology", "University Hospital of Geneva", to compare Doppler

Table 4: Tabulated representation of significant/insignificant collateral flow with respect to the severity of COA assessed by PC-MRI.

Case No.	Severity of COA (PC-MRI)	Flow (Just distal COA) l/min (A)	Flow (IN DDA at level of diaphragm) l/min(B)	Flow ratio (A/B)	Percentage change inflow (A- B)	Collateral assessment
1	Mild	0.256	1.63	0.16	537 +	Significant
2	Mild	0.637	1.37	0.46	115 +	Significant
3	Pseudo-coarctation	1.98	1.67	1.19	16-	Insignificant
4	Moderate	0.101	0.265	0.38	162 +	Significant
5	Cannot be determined		0.595			Could not be estimated
6	Moderate	0.146	0.359	0.41	146 +	Significant
7	Moderate	1.55	1.91	0.81	23 +	Insignificant
8	Severe	2.7	2.63	1.03	2.6 -	Insignificant
9	Severe	0.121	0.298	0.41	147+	Significant
10	Severe	2.21	3.39	0.65	53 +	Significant
11	Moderate	1.61	1.67	0.96	3.7 +	Insignificant
12	Severe	0.133	0.29	0.46	118+	Significant
13	Severe	2.48	1.98	1.25	20 -	Insignificant
14	Severe	1.28	2.98	0.43	132+	Significant
15	Severe	0.135	0.126	1.07	6.6-	Insignificant
16	Severe	0.163	0.143	1.14	12.3-	Insignificant
17	Severe	0.21	0.17	1.23	19-	Insignificant
18	Severe	0.168	0.29	0.76	73+	Significant
19	Moderate	1.89	2.98	0.71	58+	Significant
20	Severe	1.77	2.88	0.61	63+	Significant

Table 5: Three-tier comparative analysis was done for the comparison of the spectrum of associated anomalies detected by echocardiography, MRI, and MTD using inter-modality agreement kappa values.

Associated anomaly	ECHO-MRI		MRI-MTD		ECHO-MTD	
	Kappa Value	“Level of Agreement	Kappa Value	Level of Agreement	Kappa Value	Level of Agreement
ASD	1	Perfect	0.773	Substantial	0.773	Substantial
VSD	1	Perfect	1	Perfect	1	Perfect
PDA	0.459	Moderate	1	Perfect	0.459	Moderate
LVH	0.688	Substantial	1	Perfect	0.688	Substantial
PAH	0.545	Moderate	0.894	Perfect	0.39	Fair
BAV	0.828	Perfect	1	Perfect	0.828	Perfect

and MRI echocardiographic findings in coarctation of aorta [14,15].

Morphological assessment of aortic malformation and measurement of aortic diameters

In our study, the site of coarctation was accurately delineated in 17 patients out of 20 (distal to left subclavian artery). The length of coarctation of aorta was a short segment in 17 patients evaluated by echocardiography. In 3 patients the exact site of coarctation and length of the coarcted segment was not delineated due to poor window.

MRI was able to delineate the exact site of coarctation in 19 patients, distal to the left subclavian artery. The length of coarctation of aorta was short in 19 patients. The exact site of the coarctation of aorta and length of the coarcted segment was not delineated on MRI in 1 case owed to severe hypoplasia of the aortic arch.

In addition to the delineation of the site of coarctation, MRI was used for the measurement of aortic diameters, using these aortic diameters; the degree of stenosis was categorized into 3 categories (Table 2).

With respect to the comparison of morphological constraints *via* delineation of site COA and length perfect correlation was observed between MRI and MTD and moderate correlation was observed between Echo and MRI findings (echocardiographic and MRI findings both were available in 17 out of 20 patients). In our study, there was a moderate correlation in terms of morphological assessment of COA *via* echocardiography and MRI which is in concordance with a study conducted by Serif Beslic et al. in the Institute of Radiology, Clinical Centre University, Sarajevo [16-18].

Evaluation of collateral circulation

Collateral circulation in our study was assessed by VENC-MRI significant collateralization was detected in 55% of severe and 60% of moderate cases with coarctation of aorta. However, 2 cases with mild coarctation of aorta also had significant collateralization (Table 4).

In exceptional situations, however, scarce collateral can be identified for close coarctations; the sum of collaterals is normally equal to the seriousness of the coarctation. Collateral circulation evidence is necessary to prevent ischemic medullary damage before surgical care. In rare instances with major coarctations, the physician uses bypass ventilation in the case of aortic cross-clamps to avoid medullary ischemia. At present, collateral circulation can be accessed *via* Three-Dimensional "Gadolinium- enhanced MRA" that demonstrates dilatation of the posterior mediastinal, cervical arteries, internal mammary as well as intercostals. The collateral circulation estimation may also be performed with VENC-MRI *via* measurement of the proximal (10 mm below under the stenosis) and the distal part (at the diaphragm) of the downward aorta. Due to collateral flow in the coarctation with hemodynamic significance, distal flow increases by 83 ± 50% compare to the total distal aorta distal in the nearest part of the lowering aorta in regular subjects. The collateral flow would be measured as the distal aorta flow, less the proximal aorta flow (Table 4). However, massive collateral sometimes reaches or just below the reduction level and this flow can affect these measurements. Measurements of aortic flow in the diaphragm may also be affected by exiting the aorta by the celiac artery. Then, VENC-MRI can also no longer be carried out if essential collaterals are seen and preserved where the severity of the stenosis is in question and where collaterals are not noticeable at a mild or moderate coarctation.

Our study was complemented by a research performed by Riehle entitled if VENC-MRI "velocity-encoded cine magnetic resonance imaging" should offer insight into collateral flow anatomy and hemodynamics for unrepaired coarctation patients [19-23].

Finally, it was wrapped up that PC-MRI is an improved diagnostic modality for collateral assessment; however, it is advocated to use VENC-MRI for collateral assessment in mild cases of COA and 3D-MRA for collateral assessment in severe cases of COA.

Detection of associated anomalies

Diagnostic spectrum of our study included coarctation of aorta (n=19), pseudo-coarctation (n=1), tubular hypoplasia of aortic arch (n=1), significant collateral circulation (n=11), ASD (n=2), VSD (n=5), PDA (n=3), BAV (n=3), LVH (n=9), PAH (n=7) (Figure 1). Three tier comparative analyses was done for the comparison of the spectrum of associated anomalies/findings detected by echocardiography, MRI and MTD using inter-modality agreement kappa values (Table 5).

To summarize, MRI proved to be a better imaging modality for delineation of associated anomalies with coarctation of the aorta as is evident from a higher level of agreement (kappa value) between MRI-MTD, particularly so in the detection of PDA and PAH.

Conclusion

Hemodynamic assessment of coarctation of aorta using PC-MRI proved to be a better diagnostic imaging modality for pressure gradient estimation throughout the coarctation of aorta than echocardiography with more consistent and reproducible results, with a moderate level of agreement (kappa value of 0.459) between PC-MRI and echocardiography findings. Moreover, assessment of collaterals and better delineation of associated anomalies/findings using MRI helped in the exact pre-operative mapping of this condition.

MRI is a common instrument for the diagnostic evolution of aortic coarctation, complementing and extending echocardiography results. PC-MRI has the benefits of high-resolution effective image processing and better hemodynamic evaluation of coarctation of aorta with less interobserver variability as compared to the echocardiographic assessment of coarctation of aorta. The diagnostic value of echocardiography is markedly degraded in patients with limited acoustic window, particularly in the pediatric age group. Aortic arch measurements with MRI are comparable with anatomic measurements, especially for the demonstration of associated tubular hypoplasia. Besides the severity of coarctation of aorta, MRI can aid in the assessment of collateral circulation and better delineation of associated anomalies/findings which constitutes an indispensable part of adequate pre- operative assessment algorithm in cases of coarctation of aorta.

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