Echocardiography and MR evaluation of aortic coarctation and recoarctation-influence of aortic arch deformity and isthmic tortuosity

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Abstract. *Objective:* Peak systolic velocity measured by echocardiography (ECHO) and velocity-encoded magnetic resonance (venc MR) and consequently converted gradients are influenced by several conditions. One of these is the tortuosity of the vessel. The purpose of this study was to determine the feasibility and accuracy of echocardiography and venc MR in gradient measurement over the aortic isthmus in the case of aortic arch deformity and aortic isthmus tortuosity.

Background: Aortic coarctation is a narrowing in the descending aorta at the insertion site of the ductus arteriosus Botalli (DAB). Pseudocoarctation as well as kinking at the site of aortic isthmus or postoperative aortic arch deformity influences the hemodynamic in the descending aorta.

Patients and methods: 16 patients were included in the study (6 females, 10 males; mean age 18 years; range 8-37 years). 14 patients came in with diagnosis of simple aortic coactation, 1 had aortic coarctation in association with double outlet right ventricle and one with Taussig-Bing anomaly. 14 patients had aortic coarctation surgically repaired in the past. Peak systolic velocities over the aortic isthmus were measured and converted to gradients using ECHO and venc MR and consequently were compared with MR angiography (MRAG) as a standard method. Stenosis measurement and tortuosity of each vessel were analyzed on MRAG.

Results: Gradient estimation by ECHO correlated well with gradient measurement on venc MR (r=0.73, P=0.01). Specificity of venc MR was 0.75. All included ECHO measurements were false positive. The limits of agreement between measurements by venc MR and ECHO were from 1.23 to 33.39, which confirm the lack of agreement between-above-mentioned methods.

Conclusion: In the case of aortic arch deformity or isthmic tortuosity MR evaluation of aortic isthmus, including venc MR and MR angiography is more feasible for determination of the aortic coarctation or recoarctation compare to gradient measurement using echocardiography. Fig. 4, Tab. 1, Online full text (Free, PDF) www.cardiology.sk

Key words: aortic coarctation – pseudocoarctation – aortic arch deformity – gradient measurement

Aortic coarctation is a narrowing in the descending aorta at the insertion site of the ductus arteriosus Botalli (DAB). Pseudocoarctation of the aorta is a rare congenital anomaly consisting of redundancy of the aortic arch (1). It is characterized by one or more stenoses of the descending thoracic aorta immediately distal to the origin of the left subclavian artery. This condition is differentiated from true coarctation of the aorta by the absence of significant hemodynamic obstruction; the stenosis instead produces elongation of the aorta. Pseudocoarctation is usually asymptomatic and benign,

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Figure 1 Sagital view MIP reconstruction of TWIST MRAG shows gothic type aortic arch deformity in 17 year-old female patient after aortic coarctation repair

Figure 2 Sagital view MIP reconstruction of TWIST MRAG shows crenel type aortic arch deformity in 37 year-old female patient after aortic coarctation repair

but aneurysmal dilatations may develop in the affected areas and must be monitored and treated (2). MRAG appearance of pseudocoarctation resembles the shape of the number 3. Besides pseudocoactation, other deformations could also influence the hemodynamic in the descending aorta, including kinking at the area of aortic isthmus and postsurgical changes of aortic arch. A gothic or crenel type of aortic arch **(figure 1, figure 2)** could be recognized after surgical repair of aortic coarctation (3). Coarctation can be diagnosed invasively, by interventional angiography and noninvasively with CT angiography (CTAG), echocardiography or MR. Due to lack of ionizing radiation and availability, ECHO is the most common method used in daily practice. MR, though hardly accessible and expensive, has the advantage of complex evaluation of narrowing, gradient measurement, evaluation of collateral circulation and heart function with determination of associated lesions. The aim of this study is to confirm that the accuracy of ECHO measured gradients are influenced by the above-mentioned vessel deformities to a higher degree when compared to venc MR. Furthermore, MR evaluation is a complex method and is able to give more information, including MRAG, quantification of collateral flow circulation and other functional parameters in one setting.

Patients and methods

A retrospective study of patients sent for MR with suspected aortic coarctation on ECHO with threshold value of gradient for significant coarctation of 20mmHg (4) was performed. 18 patients with suspected aortic coarctation or recoarctation were sent to our department from June 6th, 2009 to July 31st, 2012. 2 patients were excluded from the study, one of them refused to have a contrast enhanced MR angiography and a second had a stent placed in the area of stenosis with artifact disabling lumen measurement on MRAG. 16 patients were finally included in the study (6 females, 10 males; mean age 18 years; range 8-37 years). 14 patients came with diagnosis of simple aortic coactation, 1 had aortic coarctation in association with double outlet right ventricle and one with Taussig-Bing anomaly. 14 patients had aortic coarctation surgically repaired **(table 1)**.

MR evaluation with standard protocol was performed in each patient. The following sequences were used in the study: free breathing velocity encoded cine MR with consequent semiautomatic evaluation of peak systolic velocities and Time-resolved Angiography with Interleaved Stochastic Trajectories (TWIST) with multiplanar reconstructions. Since ECHO quantification of stenosis was in gradients, measured

Table 1 Table shows patients from the study, CoA means coarctation, TB – Taussig-Bing anomaly and DORV is double outlet right ventricle. Values of gradient measured by venc MR and ECHO as well as size of stenosis on MRAG and type of deformities or tortuosity are included.

Diagnosis	Age	MR(mmHg)	MRAG	ECHO(mmHg)	Deformity	Surgery
CoA	21	7	0,1	20	crenel	yes
CoA	23	15	0,2	25	ghotic	yes
CoA	16	16	0,1	25	ghotic	no
CoA	37	12	0,1	25	ghotic	yes
CoA	23	19	0,2	26	ghotic	yes
TB	13	19	0,44	29	ghotic	yes
DORV/CoA	8	19	0,27	30	ghotic	yes
CoA	17	13	0,3	32	kinking	no
CoA	23	16	0,3	33	ghotic	yes
CoA	19	10	0,3	36	kinking+ghotic	yes
CoA	14	10	0,3	40	kinking+ghotic	yes
CoA	17	8	0,2	40	ghotic	yes
CoA	25	25	0,2	48	ghotic	yes
CoA	10	23	0,5	49	ghotic	yes
CoA	13	36	0,34	56	ghotic	yes
CoA	16	45	0,48	56	ghotic	yes

values of peak systolic velocity on venc MR were converted to gradient using modified Bernoulli equation: $G=4v^2$, where G is value of gradient in mmHg and v is peak systolic velocity in m/s. Correlation between MR and ECHO measured gradient was evaluated using Microsoft Excel and Systat 12 software and the Bland-Altman method (5). Consequently significance of the stenosis assigned by MR and ECHO was compared to MRAG measurements as a standard method.

Results

Very good correlation was found between MR and ECHO gradient measurements with correlation coefficient of 0.73, P=0.01 (**figure 3**). The relation between difference and average values of gradients was evaluated (5), with most of the points above 0, which suggests, that MR values of gradient in general underestimate values measured by ECHO. Even though there was a relatively strong correlation between the two methods, the limits of agreement are from 1.23 to 33.39, which confirms the lack of agreement between two methods visualized on the diagram (**figure 4**). All patients had narrowing of the aorta on MRAG below 0.6, so no hemodynamicaly significant coarctation or recoarctation was found in the studied patients (6). All patients presented with some kind of deformity either at the aortic arch or aortic isthmus on MRAG. 1 patient without surgical repair had kinking of aortic isthmus, 1 had crenel type of arch, 14 patients had gothic type of aortic arch and 2 of them had also associated kinking at the isthmus. None of the patient had increased collateral circulation assessed by velocity encoded MR. The threshold value of MR measured gradient of 20mmHg was set for significant coarctation (1). Four of

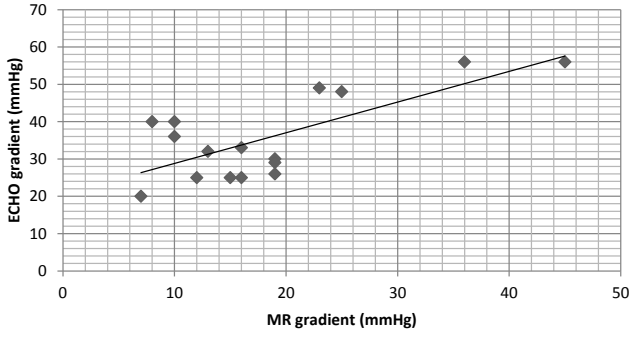

Figure 3 Graph shows correlation between ECHO and MR measured gradients on aortic isthmus-site of suspected coarctation. Good correlation was shown (R=0.74 and P=0.01).

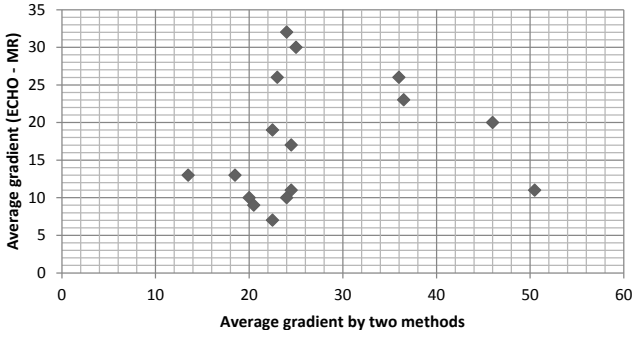

Figure 4 Graph shows correlation between difference and average values for venc MR and ECHO evaluation. The fact that the values are above the zero on y axis reflects the overestimation of ECHO compare to venc MR measurements. The limits of agreement were from 1.23 to 33.39, which confirm the lack of agreement visualized on diagram.

the 16 patients, who had the gothic type arch and history of surgical repair, had gradient measured on MR over 20mmHg, which gives MR specificity of 0.75. All of the ECHO evaluation showed gradients over 20mmHg, which is consistent of 100% with false positive measurements.

Discussion

In the population of patients with clinically suspected coarctation, the imaging evaluation method of choice is ECHO, mainly due to its accessibility and noninvasivity. However , ECHO has a few limitations including operator dependence, limitation due to patient habitus, especially in adult population and difficulties in evaluating peak systolic velocities in tortuous vessels. Tortuous vessels are known to cause difficulties with accurate duplex sonography. Velocity vector is changed over the curves and it may be impossible to obtain an accurate angle of insonation and conversely, what appears to be an adequate angle on the sonographic images is not so in reality (7). Venc MR is a well-established method for functional analysis of flow. Unlike ECHO, it is not operator dependent. Even so, it has potential disadvantages, which could cause technical difficulties and consequently inaccurate result of peak systolic velocity (8, 9). Correlation between ECHO and venc MR was relatively high, however it did not reach the correlation value of P=0.001 published by Baltes et al (10), in which study no vessel deformity was present. This fact is most probably due to imprecise gradient measurement caused by changing of flow dynamics in the deformed aortic arch and tortuous vessel. None of the patients in our study has proven coarctation on MRAG. The reason is most probably the fact that due to hard accessibility and the price of MR evaluation, only patients with uncertain diagnosis of coarctation are usually sent for MR. Low specificity of ECHO in this study results from the overestimation of peak systolic velocities with ECHO, most probably due to above mentioned hemodynamic changes. Other factors such as the influence of technique, operator and patient habitus, however, cannot be completely excluded. A velocity encoded MR evaluation of gradients with specificity of 0.75 was influenced by vessel deformities and tortuosity to lesser degree compare to ECHO. The reason for this is the fact that accuracy of venc MR is influenced by changed velocity vector as in the case of vessel deformity to a lesser degree compared to Doppler technique and morphologic vessel evaluation, and estimation of vector of blood flow through the vessel is more accurate with MR compared to ECHO.

Conclusions

In the case of aortic arch deformity or isthmic tortuosity MR evaluation of aortic isthmus, including venc MR and MR angiography, is more feasible for determination of the aortic coarctation or recoarctation compare to gradient measurement using echocardiography. Noninvasivity of MR and the ability to examine cardiac function and morphology in one setting makes it an excellent method of aortic arch evaluation, especially among the young patient population.

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