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Original Article

Is There Concordance Between CMR and Echocardiography in Assessing Aortic Stenosis Severity?

Sepideh Jafari Naeini[1], MD; Mozhgan Parsaee[2]*, MD; Shabnam Madadi[3], MD; Zahra Hosseini[1], MD

ABSTRACT

Background: Although echocardiography has constituted the primary method of evaluating cardiac disease for many years now, using another method to complete the examination—especially in dubious situations such as calcified valvular diseases or poor echocardiography window—seems necessary. In studies in different countries, cardiac magnetic resonance imaging (CMR) has been introduced as an acceptable noninvasive complementary method for the evaluation of the severity of aortic stenosis (AS) with good reproducibility and reliable results in comparison with echocardiography.

Methods: In a cross-sectional survey in Rajaie Cardiovascular, Medical, and Research Center's CMR Department between 2009 and 2014, all patients with a diagnosis of AS were evaluated for the severity of AS in terms of peak velocity and peak gradients via both echocardiography and CMR (velocity-encoded method), and the results were analyzed by SPSS using the *t*-test and ANOVA.

Results: After the exclusion of patients with insufficient data, 26 patients were included and evaluated. There were no significant differences between the 2 groups (CMR vs. echocardiography) or between the subgroups (considering cardiovascular risk factors, ejection fraction, and valvular features).

Conclusions: CMR was comparable with echocardiography in evaluating AS severity in our study and was not inferior to echocardiography, although more studies are recommended for a more in-depth evaluation. ***(Iranian Heart Journal 2016; 17(2):38-43)***

Keywords: Aortic stenosis ▪ CMR ▪ Echocardiography ▪ Velocity-encoded method

[1] Department of Cardiology, Rajaie Cardiovascular, Medical, and Research Center, Iran University of Medical Sciences, Tehran, I.R. Iran.
[2] Department of Echocardiography Laboratory, Rajaie Cardiovascular, Medical, and Research Center, Iran University of Medical Sciences, Tehran, I.R. Iran.
[3] Department of Electrophysiology Laboratory, Rajaie Cardiovascular, Medical, and Research Center, Iran University of Medical Sciences, Tehran, I.R. Iran.

Corresponding Author: Mozhgan Parsaee, MD
E-mail: parsaeemozhgan@yahoo.com **Tel:** 02123922151

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Aortic stenosis (AS) has been the most common etiology for valve surgeries for many years.[1] Deciding to do surgery is the main issue in patients with AS. An exact evaluation of the aortic valve area is necessary for decision-making. This is made by different methods, among which echocardiography is the most common.[2]

Transthoracic echocardiography (TTE) is an easy and reliable method to evaluate the severity of valvular diseases. It is usually preferred to invasive methods such as catheterization, but it is influenced by some parameters such as the patient's poor acoustic window, annular calcifications, and inter- or intraobserver variability.[3-9] Transesophageal echocardiography (TEE), as a semi-invasive method, can enhance our knowledge about the severity of stenosis. Nonetheless, the problem is the inconvenience of this method for some patients and probably its complications. Consequently, in recent years, cardiac magnetic resonance imaging (CMR) has been introduced as a noninvasive method which can increase our information about valve morphology, aortic valve area, and concomitant valvular diseases and as a result enhance our decision-making. Velocity-encoded CMR is a relatively new method for evaluating valvular stenosis, and its efficacy has been evaluated in different trials—especially for the evaluation of the severity of mitral stenosis and AS.[1]

In the present study, we sought to compare the results of CMR and echocardiography, which is the accepted method based on the recent guidelines for the evaluation of AS.

Table 1. Selected studies validating the indices of mitral stenosis by CMR

First Author (y)	CMR Method	Reference Standard: Method	N	*r*	Mean Difference±1 SD (CMR−Other Modality)
Velocity/gradients					
Mohiaddin (1991)	$\dot{V}_{max}$	TTE: $\dot{V}_{max}$	5	…	−0.12±0.27 m/s
Kilner (1993)	$\dot{V}_{max}$	TTE: $\dot{V}_{max}$	26[†]	…	0.10±0.46 m/s
Hartiala (1993)	E velocity	TTE: E velocity	10[§]	0.68	…
	A velocity	TTE: A velocity		0.83	
Heidenreich (1995)	peak ΔP	TTE: peak ΔP	14	0.89	Vmax: 0.38±0.2 m/s
	mean ΔP	TTE: mean ΔP		0.95	(Echo−CMR)
Valve areas					
Lin (2004)	T½, T2	TTE: T½	17	0.86	0.5±0.59 cm^2
Djavidani (2005)	planimetry	TTE: T½	22	0.81	0.13±0.24 cm^2[‖]
		catheterization: Gorlin	17	0.89	0.08±0.22 cm^2[‖]
Djavidani (2006)	planimetry[**]	TTE: T½	13	0.98	0.03±0.09 cm^2[‖]
		catheterization: Gorlin	13	0.95	0.13±0.15 cm^2[‖]

n Indicates the sample size.
CMR, Cardiac magnetic resonance imaging; TTE, Transthoracic echocardiography; T½, Pressure half-time

If not stated in the publication, the statistics were calculated from the data provided in the manuscript. If this was not performed or data were not provided, a designation of "not available" (...) was given.

†This analysis comprised 17 aortic stenoses and 9 mitral valve measurements.

**Includes 5 patients before and after balloon valvuloplasty.

Table 2. Selected studies validating the indices of aortic stenosis by CMR

First Author (y)	Principle	Reference Standard	N	*r*	Mean Difference±1SD (CMR−Echo)
Velocity/gradients					
Kilner (1993)	$\dot{V}_{max}$	TTE	26†	…	−0.10±0.46 m/s
Eichenberger (1993)	peak ΔP	TTE	15	…	2.6±13.3 mm Hg
	mean ΔP			0.96	−0.6±8.5 mm Hg
Sondergaard (1993)	$\dot{V}_{max}$	TTE	12	…	−0.88±0.91 m/s
Caruthers (2003)	peak ΔP	TTE	24	0.82	…
	mean ΔP			0.87	
Physiological valve area					
Caruthers (2003)	continuity equation	TTE	24	0.83	…
Anatomic valve area					
John (2003)	planimetry‖	TEE	40	0.96	0.02±0.08 cm^2¶
Kupfahl (2004)	planimetry	TEE	32	…	0.02±0.21 cm^2
Debl (2005)	planimetry	TEE	25	0.86	0.13±0.16 cm^2¶
Reant (2006)	planimetry	TEE	39	0.58	0.01±0.14cm^2 (Echo−CMR)
Schlosser (2007)	planimetry	TEE	32	0.82	0.15±0.13 cm^2

N Indicates the sample size.
CMR, Cardiac magnetic resonance imaging; TTE, Transthoracic echocardiography;
Peak ΔP, Peak pressure gradient; Mean ΔP, Mean pressure gradient; TEE, Transesophageal echocardiography
If not stated in the publication, the statistics were calculated from the data provided in the manuscript. If this was not performed or data were not provided, a designation of "not available" (...) was given.
†This analysis comprised 17 aortic stenoses and 9 mitral stenosis measurements.
‖Cine MRI pulse sequence was gradient echo; the other planimetry studies used an SSFP cine sequence.

METHODS

In a cross-sectional study between 2009 and 2014, after the exclusion of some patients, 26 patients fulfilling the inclusion criteria were enrolled based on their CMR and TTE results, which showed AS. We evaluated AS severity in terms of peak velocity and peak pressure gradients obtained from echocardiography (TTE alone or TTE in addition to TEE/stress echocardiography) and CMR at 1.5 T (by the velocity-encoded method) and analyzed the results using the *t*-test and ANOVA by SPSS, version 18. All CMR images were reviewed by an expert, and the data were collected. All echocardiographic results were reviewed by an echocardiography fellow.

Table 3. Echocardiographic and magnetic resonance imaging findings

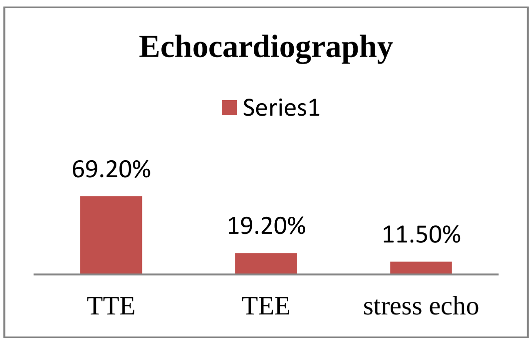
	N	Minimum	Maximum	Mean	SD
Age (y)	26	27	84	63.46	14.833
EF	26	15	60	46.15	12.830
PG	26	2.90	126.00	72.3038	33.17313
MG	26	1.60	90.00	44.8192	21.19340
AVA	16	.60	2.00	.9988	.31688
AV v max	12	2.35	5.40	3.9125	.96816
AV VTI	15	39.00	138.00	94.9333	27.16212
LVOT VTI	18	15.00	51.00	25.0556	9.45872
LVOT v max	10	.80	2.40	1.3200	.51767
ASC size	19	19	64	38.95	9.812
MRI gradient	26	9.00	153.76	48.5677	30.86125

EF, Ejection fraction; PG, Peak gradient; MG, Mean gradient; AVA, Aortic valve area; AV v max, Maximum velocity of the aortic valve; AV VTI, Velocity time integral of the aortic valve; LVOT VTI, Velocity time integral of left ventricular outflow tract; LVOT v max, Maximum velocity of left ventricular outflow tract; ASC, Ascending aorta

Table 4. Echocardiography

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	TTE	18	69.2	69.2	69.2
	TEE	5	19.2	19.2	88.5
	stress echo	3	11.5	11.5	100.0
Total		26	100.0	100.0	

TTE, Transthoracic echocardiography; TEE, Transesophageal echocardiography



Totally, 69.2% of the examined patients were men and 73.1% had severe AS. Also, 57.7% of the total study population had concomitant valvular diseases. Most of the reported cardiovascular risk factors were cigarette smoking (20%), followed by hypertension (16%) and dyslipidemia (16%). Only 2 patients were reported to have poor echocardiography window. There were no significant differences between the echocardiography and CMR results in the main groups or the subgroups (based on risk factors, ejection fraction, or valvular features). Given the relatively small sample size in our CMR database and the lack of appropriate coordination with the patients for performing examinations, we were obliged to curtail some parts of our analyses such as comparing the size of the ascending aorta or the severity of aortic insufficiency.

DISCUSSION

Nowadays, TTE is a common and simple method for the evaluation of valvular diseases such as AS. Nevertheless, certain limitations have led to the development of other modalities. One of these methods is CMR, which is used in a limited number of centers due to its high price and unavailability in comparison with different kinds of echocardiography. In various studies, CMR has acceptable reliability and reproducibility in comparison with other methods.[10-11]

Echocardiography has been the method of choice on the strength of its real-time capabilities, bedside availability, and lower cost for many years. Recent years have seen the emergence of new approaches to valvular heart diseases such as CMR and—especially—velocity-encoded CMR, which is cheaper and easier to perform than CMR. CMR provides information about the cardiac dimensions and functions. CMR as an alternative to echocardiography has been studied and debated in different trials. Sondergaard et al.[12] used velocity-encoded CMR to estimate the orifice area by planimetry in 12 patients and showed its good correlation with catheterization.[12-13] The optimized method for the evaluation of AS by CMR has yet to be clearly defined, however.

In echocardiography, an ultrasound beam parallel to the valve is required so as to obtain correct peak velocity envelope. This is influenced by the echocardiographer's experience in finding the best window for obtaining the highest peak velocity, which is not only time-consuming but also less reliable. In addition, it may be influenced by the patient's poor echocardiography window and unusual anatomic configurations (e.g., ectatic aorta and horizontal heart position), affecting the accuracy of Doppler beam results.[10]

Velocity-encoded CMR is based on the assumption that the flow is perpendicular to the valve plane and helps obtain images in shorter durations. Nonetheless, misalignment may decrease its accuracy and should be considered a potential error. Other probable sources of error depend on the proximity to the valve and the range of values chosen for velocity encoding. Velocity-encoded CMR shows the average velocity within a single imaging voxel. (It is typically $1 \times 1 \times 10$ mm^3 in dimension.) CMR results are also influenced by ghosting artifacts or motion artifacts, which sometimes happen.

We sought to compare CMR and TTE considering the fact that both methods have their own limitations and benefits and that CMR may be helpful in distinguishing the severity of AS in suspicious cases. Our study was a single-center study and was, as such, dependent on its facilities; consequently, its results cannot be extended to other Iranian centers. The overloading of patients in the CMR department forced us to limit our search for finding AS cases to available ones. We included all patients whose echocardiography was done by an echocardiography fellow, although it would have been more desirable had the echocardiographic examinations been performed by a specialist. The fact that we encountered problems due to overcrowdedness may have exerted an impact on the quality of the study. We missed some data such as MRI velocity-time integral and MRI ejection fraction due to the technique and retrograde features of the study.

CONCLUSIONS

Our study was in favor of the non-inferiority of CMR to echocardiography in AS cases. Be that as it may, we recommend more long-term studies with a prospective approach to gain enough data with more cases to demonstrate CMR superiority. New methods of echocardiography such as 3D can be examined in future studies.

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