Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://doi.org/10.21608/zumj.2024.234154.2873 Volume 30, Issue 1.7, Oct. 2024, Supplement Issue
Manuscript ID: ZUMJ-2307-2820 (R1) Doi: 10.21608/ZUMJ.2023.221791.2820
ORIGINAL ARTICLE

Assessment of Valvular Heart Diseases Using Cardiac Magnetic Resonance Imaging "CMRI"

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Submit Date 08-07-2023
Revise Date 15-07-2023
Accept Date 19-07-2023

ABSTRACT

Background: Cardiac magnetic resonance (CMR) is developing highly efficient imaging tools to detect different types of heart disease. Recently, valvular heart disease (VHD) hasincreased due to an aging population, so CMR is handy in the assessment of all 4 heart valves. **Objectives:** This study aims to assess cardiac valvular lesions and their severity using CMR and to establisha clinical protocol for our unit. **Methods:** This single-centercross-sectional study included 24 patients (19 males and 5 females) their ages ranged from 1 to 74 years. Included patients are patients with cardiac valvular diseases according to the clinical susceptibility and Echo results. CMR protocol included: localizers, short axis cine,2 chambers cine, 3 chambers cine, 4 chambers cine, LVOT, RVOT, Q flow aorta /pulmonary, Q flow mitral /tricuspid, LGE if required in selected cases. **Results:** Concerning the Aortic valve, cMRI detected 10 cases out of 24 (41 %) showed aortic valvular lesions while echo detected only 2 cases of them (8 %). Concerning the Mitral valve, cMRI detected 15 cases out of 24 (62 %) showed mitral valvular lesions while echo detected only 11 cases of them (46 %).**Conclusions:** CMR is an efficient technique in the evaluation of VHD because it provides major additional value, such as the capacity to image all parts of the heart and a complete approach to both valve lesions and ventricles. Direct measurement of valve stenosis, measurement of regurgitation, aortic and pulmonary flows, precise ventricular volumes, and myocardial evaluation are all part of this.

Keywords: valvular heart disease; Cardiac magnetic resonance; CMR; VHD

INTRODUCTION

Cardiac magnetic resonance (CMR) is a flexible imaging technology that contributes significantly to the diagnosis of valvular heart disease (VHD). Although it is best recognized for myocardial imaging (particularly in valve disease), it also enables excellent evaluation of all four heart valves, with certain unique benefits such as a free choice of picture planes and accurate flow and volumetric quantification [1].

The use of CMR for evaluating VHD has various advantages; providing unobstructed heart and valve views. In addition, there is no need for ionizing radiation and contrast injection to assess the severity of VHD [2].

VHD is frequent and rising in prevalence in an aging population. CMR is best recognized for myocardial imaging, it also enables excellent evaluation of all four heart valves [3].

Concerning valve stenosis, CMR gives direct planimetry of the valve orifice from an image taken through the valve tips at peak opening; this is a dependable technique utilized for all valve stenosis [4].

Regurge jets are frequently detected on cine images of valve regurgitation. Mild leaks typically exhibit narrow jets, while severe regurgitation with little turbulence may not be visualized, especially throughout the pulmonary valve [1].

This study aims to assess cardiac valvular lesions and its severity by CMR aiming to establisha clinical protocol for our unit.

METHODS

This single-center cross-sectional study was carried out at the Radio-diagnosis Department, Zagazig University Hospitals. All the patients were referred from the Cardiology Department of Zagazig University Hospitals from period June to December 2022, The study included 24 patients (19 males and 5 females) whose ages ranged from 1 year to 74 years old. Patients with cardiac valvular diseases according to the clinical susceptibility and Echo results were included in the current study. Patients with contraindications to MRI examination (implanted pacemakers or other cardiac devices, ocular implants, aneurysmal clips, claustrophobia, renal impairment, and poor image quality) were excluded.

All patients were subjected to general history taking, general examination, and cardiological examination (Carried out by our colleagues in the cardiology Department), all patients were suspected clinically to suffer from cardiac valvular diseases were referred to undergo cMRI assessment. Informed consent has been taken from all participants of the study, as part ofthe Declaration of Helsinki which is a statement of ethical principles for medical research involving human subjects.

Cardiological imaging technique:

The following examinations were done for all the patients; Cardiac magnetic resonance (CMR) (Philips Achieva MRI 1.5T) including; **l**ocalizers**,** Short axis cine**,** 2 chambers cine**,** 3 chambers cine**,** 4 chambers cine**,** LVOT**,** RVOT**,** Q flow aorta /pulmonary**,** Q flow mitral /tricuspid, and LGE if required in selected cases.All imaging results were revised.

Image protocol:

1- Localizers: axial, coronal, sagittal, black blood, false (pseudo) 2 chambers, 4 chambers, and short axis view).
2- Steady-state free precision (SSFP) cine images of:

a. Two chambers long axis view: from a line drawn parallel to the ventricular septum and pass through the cardiac apex.
b. Three chambers long axis view: on SAX view a line is drawn slicing arota and passing through the center of the left ventricle as well as left atrium, on 4 CH we make sure that angle through the right ventricle is not too oblique and not cutting into parts of the left ventricle.
c. Four chamber long axis view: on the 2 CH

view a line is drawn passing through both cardiac apex and center of the mitral valve.

3- Phase contrast velocity encoding (VENC) images at the level of aorta and pulmonary valves are obtained; as Velocity-encoding gradients are used to generate a phase shift in magnetic resonance phase contrast imaging proportional to the velocity of moving protons that can be used to depict and measure the velocity of spins and thus flow.
4- Late gadolinium enhancement (LGE) in required cases (10 cases) as they suffer from dilated cardiomyopathy (DCM) hypertrophic cardiomyopathy (HOCM) to detect myometrial enhancement
5- Left ventricular function: EF, COP, ESV, EDV, and SV are obtained from a cine short axis sequence with marking epicardium and endocardium.
6- Right ventricular function: EF, COP, ESV, EDV, and SV are obtained from a cine short axis sequence with marking endocardium.
7- Pulmonary Q-flow: RF, SV (Qp), and pressure gradient are detected by marking the pulmonary valve.
8- Aorta Q-flow: RF, SV (Qs) and pressure gradient are detected by marking the aortic valve.

Imaging analysis and interpretation

Left and Right Ventricular Stroke Volumes

Standard volumetric assessment of LV and RV function is done using SSFP imaging, which gives accurate measurements of LV and RV systolic and diastolic dimensions and volumes, stroke volume, and ejection fraction; these can be interpreted both as absolute and indexed and standardized based on body surface area.

Forward Flow: Aortic and Pulmonary Artery Flow

Phase contrast imaging applications of gradient pulses induce phase shifts in moving protons that are directly proportional to their velocity along the direction of the gradient. Phase contrast is capable of measuring velocities, and thus flows, in the "through plane" orientation. The imaging plane is acquired perpendicular to the desired vessel. This technique allows measurement of blood flow in vessels and is particularly suited to measuring flow in the ascending aorta and the main pulmonary artery.

Mitral valve: indirect method is used; subtracting aortic flow assessed by velocity mapping from left ventricular SV assessed by cine imaging.

Tricuspid valve: indirect method is used; subtracting pulmonary flow assessed by velocity mapping from right ventricular SV assessed by cine imaging.

All the following diseases were assessed

Infective endocarditis, tetralogy of Fallot, parachute-like valve, bicuspid aortic valve, ebstein anomaly grade II, myocarditis.

ECHO: is the gold standard technique to assess valvular heart disease, clinical decisions depend on echo results, it is a safe and non-invasive technique, it has great importance in cardiac examination, it is done using an ultrasound machine and echo prope (1.5 to 7.5 MHz).

Disadvantages of ECHO: It is an operator-dependent technique, also patients may feel some discomfort as the ultrasound wand pushes against their chest as firmness is needed to create good pictures of the heart.

ETHICAL APPROVAL

This study was done after taking approval from the Institutional Research Board Committee IRB of the Faculty of Medicine,

Zagazig University. An informed consent from parents was provided.

STATISTICAL ANALYSIS

Data were checked, entered, and analyzed using SPSS version 25 for data processing. Data were expressed as numbers and percentages for qualitative variables and mean ± standard deviation (SD) for quantitative ones. Frequency and percentage were used to describe categorical data, which were then compared using the chi-square test. Youden index was used to assess the diagnostic accuracy of CMR using echo results as a gold standard, $P<0.05$ will be used to determine the level of significance.

RESULTS

The average age of the studied group was (29.9±21.5), the range was from 1 to 74 years, less than half of them (41.7%) were in the age groups from 1 to 18 years and from 35 to 55 years. Regarding sex, more than three-fourths of them (79.2%) were males, and (20.8%) were females.(Table 1).

The isolated valvular affection regarding congenital and acquired heart disease was illustrated in Table (2) Mitral valve was most common affected valve in all cases (100%). congenital diseases causing combined valve lesion, tetralogy of fallot was the disease that affected all valves at same time while VSD spared tricuspid valve.

Tricuspid valve was most common affected valve in nearly 75% of cases, also both HCM & DCM were the most affecting diseases respectively. Less than half of the studied group (41.7%) didn't have mitral valve regurge, (4.1%, 25.0% & 29.2%) had trivial, mild and moderate valve regurge respectively (Table 3).

Four cases had systolic anterior motion (16.7%) of the studied group while one case (4.1%) had Infective endocarditis (fig.2) and another case (4.1%) had Parachute-like valve (fig.1). One-fourth of the studied group (25%) had moderate and another one-fourth had mild regurge followed by trivial regurge which was only among (12.5%) of the studied group (Table 4).

The CMR can detect 2 cases with aortic valve lesions from a total of 3 cases by ECHO with (66.7%) sensitivity and exclude 14 normal persons with false-negative one (61.9% specificity). The accuracy of CMR for the detection of aortic valve lesions as compared to ECHO (the gold standard) is (62.5%). The CMR can detect 11 cases with tricuspid valve lesions from 15 cases by ECHO with (68.8%) sensitivity and exclude 4 normal persons with five false-negative cases (50.0% specificity). The accuracy of CMR for the detection of tricuspid valve lesions as compared to ECHO (the gold standard) is (62.5%). The CMR can detect 11 cases with mitral valve lesions from 15 cases by ECHO with (84.6%) sensitivity and exclude 7 normal persons with two false-negative cases (63.6% specificity). The accuracy of CMR for the detection of mitral valve lesions as compared to ECHO (the gold standard) is (75.0%). the right ventricle was least affected chamber (12.5%), also impaired systolic function was most common complication in 37.5% of cases (Table 5).

Table 1. Demographic characteristics, complaints, and mitral and aortic valve involvements of the studied group.

Demographic data	The studied group	
	No=(24)	%
Age (years) Mean ± SD Median (Range)	 29.9±21.5 35 (1-74)	
Age (years)		
1-18 years	10	41.7%
18-35 years	2	8.3%
35-55 years	10	41.7%
55-75 years	2	8.3%
Sex		
Male	19	79.2%
Female	5	20.8%

Table 2. Isolated valvular affection according to congenital disease.

Congenital heart disease									
Isolated valvular lesion		**Bicuspid valve**		**Truncus arteriosis**		**Parachute like valve**		**Ebstein G II**	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Aortic valve	**stenosis**	1	20%	--	--	--	--	--	--
	regurge	--	--	1	20%	--	--	--	--
Pulmonary valve	**stenosis**	--	--	--	--	--	--	--	--
	regurge	--	--	--	--	--	--	--	--
Mitral valve	**stenosis**	--	--	--	--	--	--	--	--
	regurge	--	--	--	--	1	20%	--	--
Tricuspid valve	**stenosis**	--	--	--	--	--	--	--	--
	regurge	--	--	1	20%	--	--	2	40%
Acquired Heart Disease									
Isolated valvular lesion		**Infective Endocarditis**		**Renal transplant**		**Myocarditis**			
		No.	**%**	**No.**	**%**	**No.**	**%**		
Aortic valve	Stenosis	1	33%	1	33%	--	--		
	Regurge	1	33%	1	33%	--	--		
Pulmonary valve	stenosis	--	--	--	--	--	--		
	regurge	--	--	--	--	--	--		
Mitral valve	stenosis	--	--	--	--	--	--		
	regurge	1	33%	1	33%	1	33%		
Tricuspid valve	stenosis	--	--	--	--	--	--		
	regurge	--	--	--	--	1	33%		

Table 3. Combined valvular affection according to acquired disease.

Acquired heart disease											
Combined Valvular lesion		**Amylodosis**		**Dilated cardiomyopathy**		**Hypertrophied cardiomyopathy**		**Non-compaction LV**		**Right ventricular dilatation**	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Aortic valve	**stenosis**	--	--	--	--	2	16%	--	--	--	--
	regurge	--	--	4	33%	3	25%	--	--	--	--
Pulmonary valve	**stenosis**	--	--	--	--	--	--	--	--	--	--
	regurge	--	--	1	8%	--	--	2	16%	--	--
Mitral valve	**stenosis**	--	--	--	--	--	--	--	--	--	--
	regurge	1	8%	2	16%	4	33%%	3	25%	--	--
Tricuspid valve	**stenosis**	--	--	--	--	--	--	--	--	--	--
	regurge	1	8%	3	25%	2	16%	2	16%	1	8%

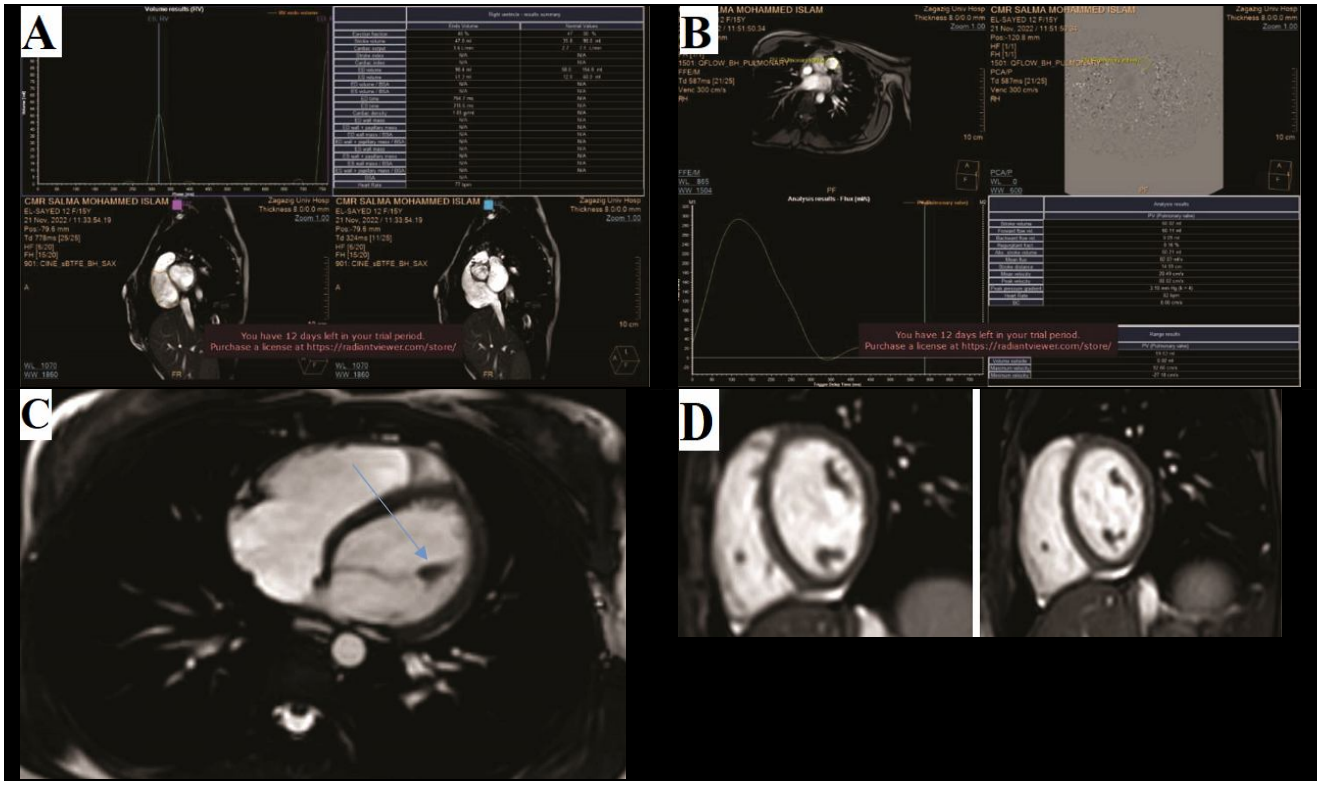
Congenital heart disease					
Combined valvular lesion		**Tetralogy Of fallot**		**Ventricular septal defect**	
		No.	**%**		**No.**
Aortic valve	stenosis	--	--	2	50%
	regurge	1	25%	--	--
Pulmonary valve	stenosis	2	50%	--	--
	regurge	1	25%	1	25%
Mitral valve	stenosis	--	--	--	--
	regurge	1	25%%	1	25%
Tricuspid valve	stenosis	--	--	--	--
	regurge	1	25%	--	--

Table 4. Mitral valve regurge and associated lesions among the studied group

	The studied group	
	No=(24)	**%**
Mitral valve regurge		
No	10	41.7%
Trivial	1	4.1%
Mild	6	25.0%
Moderate	7	29.2%
Associated lesions with mitral valve regurge		
Parachute-like valve	1	4.1%
Infective endocarditis	1	4.1%
systolic anterior motion	4	16.7%

Table 5. The diagnostic performance of CMR in regard to the ECHO as a gold standard among the studied group

		ECHO		P-value
		Diseased	Normal	
Pulmonary valve lesion				
CMR	**Diseased (6)**	1 (100.0%)	5 (21.7%)	0.07
	Normal (18)	0 (0.0%)	18 (78.3%)	
	Total (24)	1 (100.0%)	23 (100.0%)	
Aortic valve lesion				
CMR	**Diseased (10)**	2 (66.7%)	8 (38.1%)	0.9
	Normal (14)	1 (33.3%)	13 (61.9%)	
	Total (24)	3 (100.0%)	21 (100.0%)	
Tricuspid valve lesion				
CMR	**Diseased (15)**	11 (68.8%)	4 (50.0%)	0.4
	Normal (9)	5 (31.3%)	4 (50.0%)	
	Total (24)	16 (100.0%)	8 (100.0%)	
Mitral valve lesion				
CMR	**Diseased (15)**	11 (84.6%)	4 (36.4%)	**0.01***
	Normal (9)	2 (15.4%)	7 (63.6%)	
	Total (24)	13 (100.0%)	11 (100.0%)	



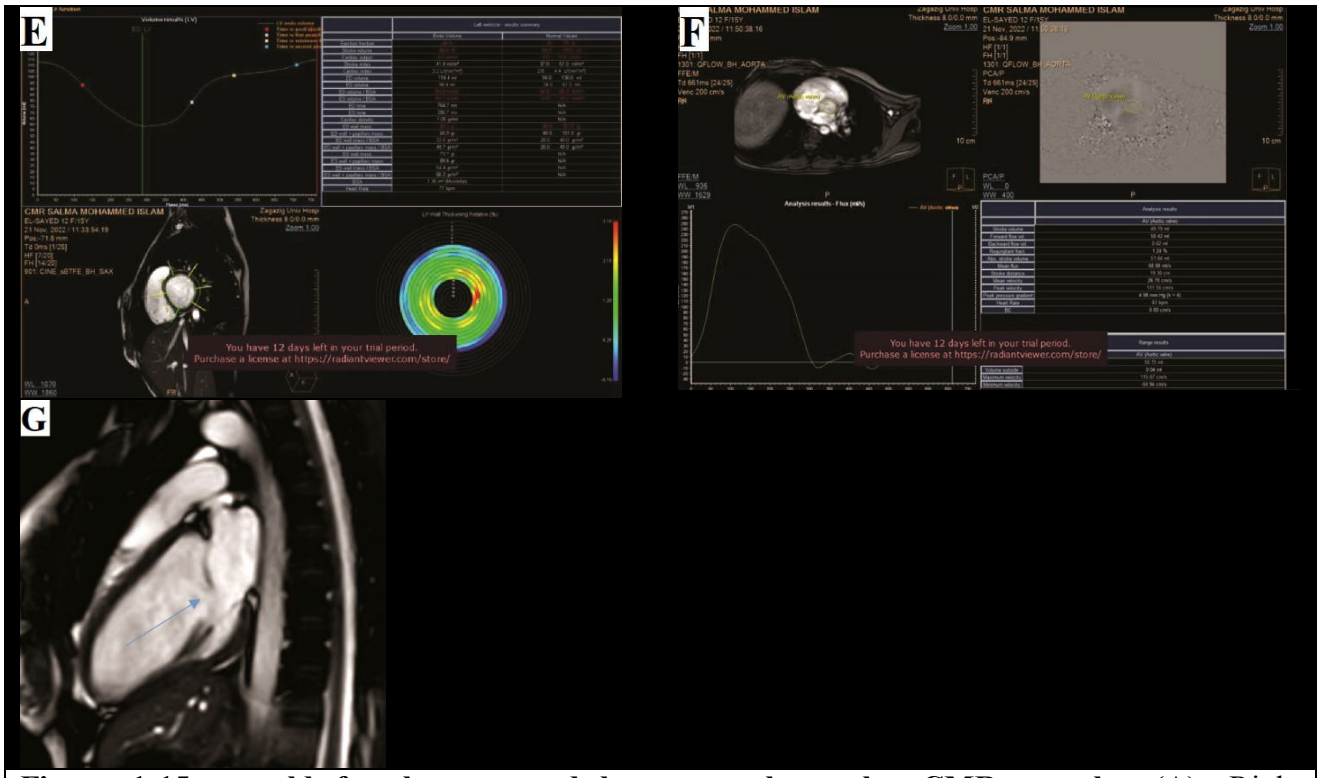
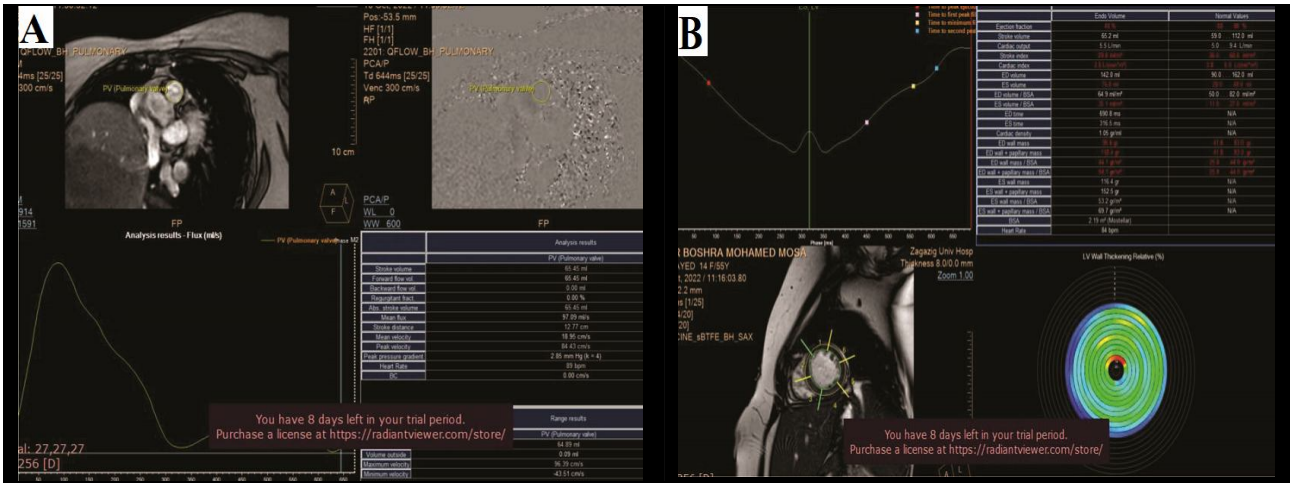


Figure 1:15-year-old female presented by syncopal attacks, CMR reveal : (A): Right ventricular function EF 40%, SV 47 ml. **(B):** Qflow pulmonary**,** no regurge, volume 80 ml. **(C):** SSFP bright blood 4CH showing parachute-like mitral valve attached to the posteromedial papillary muscle. **(D):** SFP bright blood SAX showing bifid papillary muscle. **(E):** Left ventricular function EF 47%, SV 56 ml. **(F):** Q flow aorta, no regurge, volume 49 ml, pressure gradient 4.9 mmHg. **(G):**SSFP bright blood 2CH showing parachute like mitral valve attatched to posteromedial papillary muscle **-**QP/QS: 1.6. -Mild mitral regurge (RF 11%) by indirect method. **Conclusion:**Parachute-like mitral valve with mild MR.



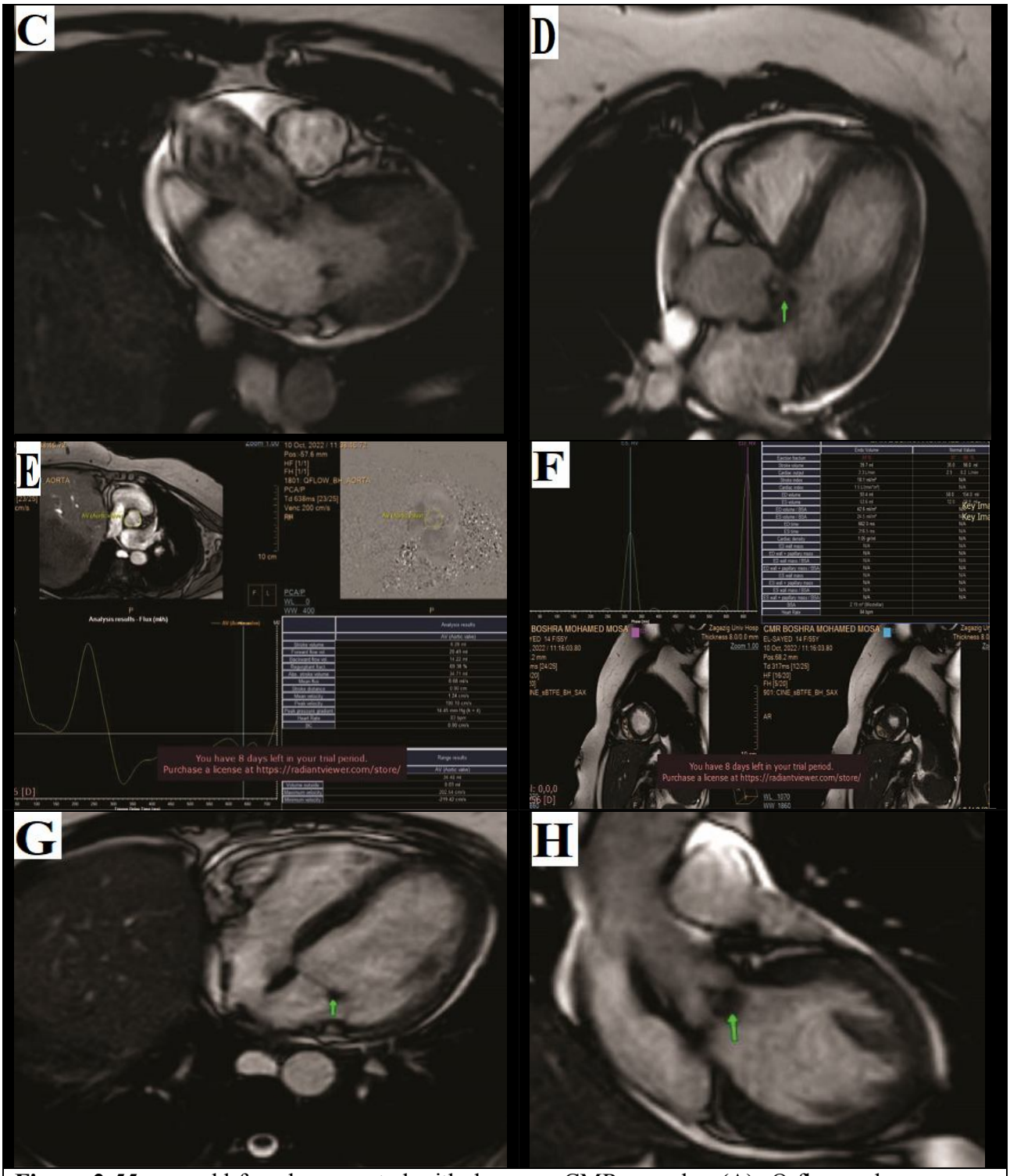


Figure 2:55-year-old female presented with dyspnea. CMR reveals**: (A):** Q flow pulmonary**,** no regurge, volume 65ml. **(B):** left ventricular function EF 46%, SV 65 ml. **(C):** SSFP bright blood 3CH showing jet of aortic valve stenosis. **(D)** SSFP bright blood 3CH showing low signal intensity soft tissue lesion arising from the ventricular surface of aortic valve leaflet. **(E):** Q flow aorta, RF 69 %, volume 42ml, pressure gradient 14 mmHg. **(F):** Right ventricular function EF 43%, SV 39.7 ml. **-**QP/QS: 1.5. **(G):** SSFP bright blood 4CH showing low signal intensity soft tissue lesion arising from the atrial surface of the mitral valve leaflet. **(H):** SSFP bright blood LVOT showing low signal intensity soft tissue lesion arising from ventricular surface of the aortic valve leaflet. -Moderate mitral regurge (RF 30%) by indirect method. -Severe aortic regurge (RF 69%) with mild stenosis (14.5mmHg), maximum velocity 202 cm/sec. **Conclusion:** Infective endocarditis of aortic and mitral valve. Impaired systolic function.

DISCUSSION

This study was made at the Radio-diagnosis Department at Zagazig University Hospitals. All the patients were referred from the Cardiology Department of Zagazig University Hospitals. We aimed to assess cardiac valvular lesions and their severity by CMR aiming for establishing a clinical protocol for our unit.

In our study, cMRI was done after performing an echo that states the presence of valvular lesions to detect the sensitivity of cMRI as it has developed as a new standardizing tool for cardiac evaluation. Processing of images was done to examine the following; Left ventricular function, Right ventricular function, Pulmonary Q-flow, Aorta Q-flow, Mitral valve, and Tricuspid valve.

Regarding pulmonary valve echo detected only mild stenosis in several patients less than those detected by CMR, in addition, CMR detected higher grades of stenosis and regurge which confirms higher sensitivity of CMR than an echo in agreement with **Ribeiro. etal,** who found that echo is less sensitive than CMR in detecting pulmonary stenosis by 62% and also it didn't detect any regurge cases in agreement with our study that echo didn't diagnose any regurge cases also regarding stenosis cases it was less sensitive than CMR in detecting them by 54% [5].

Regarding tricuspid valve echo detected only trivial regurge in less number of patients than those detected by CMR, also CMR detected higher grades of regurge that confirm higher sensitivity of CMR than echo, **Crouch. etal**, agreed with us as 52% of their study group suffered from tricuspid regurge according to echo results while CMR detected 93% of cases positive for tricuspid regurge that confirms higher sensitivity of CMR due to different grades of diseases that trivial ones couldn't be detected by echo [6].

Altiok. etal, conducted a study of tricuspid valve diseases and found echo results in diagnosing tricuspid regurge were lower than those detected by CMR in agreement with our study that echo was less sensitive by 54 % in comparison to CMR [7].

Two of our cases were diagnosed with ebsetin anomaly G II whichcauses tricuspid regurge and we agreed with **Attenhofer Jost. etal,** who found the same result in their study [8].

Regarding aortic valve echo detected only mild stenosis in several patients less than those detected by CMR, in addition, CMR detected higher grades of stenosis and regurge which confirms the higher sensitivity of CMR than echo in disagreement with **Kammerlander. etal,** as they found 34% of their cases suffered from aortic lesions either stenosis or regurge by both ECHO and CMR that is mainly because echo is operator dependent technique so fallacies are common and also grades of aortic valve disease were higher at their study could be easily detected by echo while our study has trivial cases that could be easily missed on echo [9].

Lee. etal, agreed with our study as they found that 99% of their patients have aortic valvular lesions either stenosis or regurge by CMR in comparison to 33% of cases (stenosis only) by echo and This occurs in cases lower grades of stenosis could be detected by CMR, not by echo also regurge was trivial that was missed by echo [10].

We found that aortic stenosis is the most common complication in cases of bicuspid valves in agreement with **Bohbot. etal,**who found the same in their study [11].

One of our cases suffered from truncus arteriosis that subsequently affected aortic valve regurge and also VSD was evident in agreement with **Verhaert. etal,** who has a case discussion for a case nearly similar to

ours [12].

Regarding mitral valve echo detected only trivial regurge in less number of patients than those detected by CMR, also CMR detected higher grades of regurge that confirm higher sensitivity of CMR than echo, **Urtesky. etal,** found in their studies of mitral regurge that CMR and echo findings matched in 58% of cases in partial agreement with our study that CMR and echo results match in about 73% of cases while 42% of their cases and 27% of our study group who suffered mitral regurge were diagnosed by CMR only as lower grades of regurge can't be detected by echo [13].

Sachdev. etal, found 66% of their patient suffering from mitral valve regurge are evident on both echo and CMR results in agreement with us that we found 73% of patients evident on both echo and CMR, also agreed with us in patients that were detected by CMR only they found 19% in comparison to 27% in our study [14].

One of the congenital lesions that cause mitral regurge is parachute-like morphology of the mitral valve, we and **Casavecchia. etal,** agreed about this condition at its effect on the mitral valve diagnosed by CMR [15].

Both echo and CMR agreed that valvular lesions affected males more than females and we agreed with **Orwat. etal, a** study that found valvular lesions diagnosed either by CMR or echo were predominant in males rather than females [16].

Infective endocarditis is a common disease that affects multiple valves, in our study it affected the aortic valve either by stenosis or regurge in addition to mitral regurge which agreed with **Bhuta. etal,** [17] who studied infective endocarditis cases by CMR and found results similar to us.

Also, hypertrophic cardiomyopathy is one of the diseases that affects multiple valves, in our study it causes both aortic stenosis and regurge in addition to regurge of both tricuspid and mitral valves in agreement with **Brenes. etal,** [18]who studied HOCM and found nearly same as our results.

Dilated cardiomyopathy is characterized by a regurge of all examined valves in agreement with **Francone. etal,** [19]who studied dilated cardiomyopathy valvular affection and shared some of the results with us.

Post-operative assessment of tetralogy of fallot cases showed the affection of all four valves either by stenosis or regurge (pulmonary stenosis was the predominant complication postoperative), in agreement with **Attalla. etal,** [20] found nearly the same findings in their study.

Multiple complications were encountered during our study of valvular heart lesions such as different chamber dilatation, overriding aorta, and impaired systole, **Aquaro. etal,** [21], also **Maganti. etal,** [22] agreed with us in detecting some of these complications during their study especially LV dilatation and impaired systole.

There were some limitations during our study as: unstable patients not susceptible for anesthesia, patients with implants non compatible with MRI, and patients with impaired renal function are not susceptible to contrast administration.

CONCLUSION

CMR is an efficient technique in the evaluation of VHD because it provides major additional value, such as the capacity to image all parts of the heart and a complete approach to both valve lesions and ventricles. Direct measurement of valve stenosis, measurement of regurgitation, aortic and pulmonary flows, precise ventricular volumes, and myocardial evaluation are all part of this.

CONFLICT OF INTEREST

The authors reported no potential conflict of interest.

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Citation:

Hossam, T., Zidan, E., Shehata, S., Abdelhay, R. Assessment of Valvular Heart Diseases Using Cardiac Magnetic Resonance Imaging "CMRI". *Zagazig University Medical Journal*, 2023; (4083-4095): -. doi: 10.21608/zumj.2023.221791.2820