Validity of the phase-contrast cardiac magnetic resonance in the estimation of the left ventricular ejection fraction

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Received 16 December 2018
Accepted 29 January 2019

Journal of Current Medical Research and Practice
September-December 2018, 3:136–139

Background

Left ventricular (LV) function is one of the most important prognostic factors for the evaluation of cardiac disorders, whether managed medically or surgically. This makes the LV ejection fraction (EF) the most frequently used clinical parameter of the LV function and gives important data that can be useful in the selection of therapy or determination of the best time for an intervention.

Aim

The aim of this study was to evaluate the validity of the phase contrast (PC) cardiac magnetic resonance (CMR) method in the estimation of LV EF.

Patients and methods

This is a prospective study performed between January 2017 and December 2018. The studied group included 10 healthy patients. All patients underwent CMR scan to evaluate EF by two methods: volumetric method which assesses stroke volume (SV) via subtraction of end-systolic volume from end-diastolic volume, and PC method which assesses the aortic (SV) through-plane PC across the aortic valve. The recorded SV were compared between the two methods.

Results

By the volumetric method, the estimated mean EF was 62.44 ± 6.61, while that estimated by the PC method was 64.34 ± 5.33, with a nonsignificant difference ($P = 0.62$) and it shows the validity of the PC method.

Conclusion

Validity of the PC CMR in the evaluation of EF as an alternative assessment method.

Keywords:

cardiac magnetic resonance imaging, ejection fraction, phase contrast

J Curr Med Res Pract 3:136–139

2357-0121

Introduction

Left ventricular (LV) function is one of the most important prognostic factors for the evaluation of cardiac disorders, whether managed medically or surgically. This makes the left ventricular ejection fraction (LVEF) the most frequently used clinical parameter of the LV function and gives important data that can be useful in the selection of therapy or determination of the best time for an intervention [1,2].

Ejection fraction (EF) is defined as 'the percentage of blood leaving the heart each time it contracts,' and it is calculated through dividing the ventricular stroke volume (SV), which is the difference between the end-diastolic volume (EDV) and the end-systolic volume (ESV), by the ventricular EDV depending on the rule of summation of disks (Simpson's method) [3]. This method is applied by most or even all modalities which are used to estimate the EF, either invasively or noninvasively, subjectively by visual estimation or objectively by quantitative methods, that is, echocardiography, MRI, computed tomography, gated equilibrium radionuclide angiography (commonly referred to as multiple gated acquisition 'MUGA' scan), and gated myocardial perfusion imaging with either single-photon emission computed tomography or PET [4].

If the LV EDV and ESV are known, the LVEF can be determined using the following equation [5]:

LVEF = stroke volume(EDV-ESV)/EDV.

In a heart with normally functioning valves, that is, in the absence of regurgitation, the blood volume entering the LV across the mitral valve will be equal to the volume exiting the LV across the aortic valve.

As a result of great amendments in hardware and software design in the last decades, MRI has claimed its role as a central player in a large variety of cardiac diseases offering unique information, especially by its unique ability to directly quantify the flow using through-plane phase-contrast (PC) velocity mapping [6].

The aim of the current study was to evaluate the validity of the PC cardiac magnetic resonance (CMR) method in the estimation of the LVEF.

Patients and methods

The study was conducted on 10 age-matched and sex-matched healthy adults with no clinically or echocardiographically detected cardiac abnormalities. Patients with known contraindication to MRI including the presence of paramagnetic surgical clips, prosthetic valves or pacemakers, severely ill patients, claustrophobic or restless patients, and patients with arrhythmia were excluded. The study was approved by the Ethics Committee of the Faculty of Medicine with reference number (17100583), Assiut University, and informed consent was obtained from all the participants in the study.

All cardiac MRI studies were performed using a 1.5 Tesla MRI system (Achieva; Philips Medical Systems, Best, The Netherlands) and a six-element phased-array receive-only coil (SENSE-cardiac coil) in the MRI Unit of the Radiology Department of Assiut University Hospitals.

Image acquisition

Cardiac MRI protocol

A standard MRI protocol was applied in all participants in the research including the following steps and pulse sequences:

(1) FFE multiplanar localizer for the planning of the imaging views.

(2) Functional cine images, acquired using ECG-gated segmented k-space breath-hold balanced turbo field echo sequence in short-axis view; two-, three-, and four-chamber views; and left ventricular outflow tract (LVOT) views, all obtained during repeated breath-holds. The parameters for balanced turbo field echo sequence were as follows:

TR/TE: 2.9/1.4	FOV: 320
Phases: 30	NSA: 1
Matrix: 160×256	Bandwidth: 1225.5 Hz
Flip angle: 60°	Total scan time: 37.7 s
Slice thickness: 8 mm	Slice number: 9-11

(3) Volumetric images were acquired using a stack of nine contiguous 8 mm slices in the double-oblique LV short-axis orientation, covering the whole LV from the apex to just above the level of the base.

(4) Transaortic flow assessment (Q-flow): The transaortic flow was determined from through-plane PC images obtained with retrospective ECG synchronization, during breath-hold. A velocity of 150 cm/s was chosen for velocity encoding to avoid temporal aliasing; the phase encoding velocity was increased if aliasing was noticed.

To define the acquisition plane, the three-chamber (LVOT) and coronal LVOT views were used during systole. The section was positioned just above the opened aortic valve at the sinotubular portion.

The following parameters were used in PC.

Slice thickness: 8 mm	FOV: 320/1.6
Matrix: 128/256	Repetition time: 3.1
Echo time: 3.1	Flip angle: 12°

Images analysis

All the obtained MRIs were transferred to a computer workstation (Extended WorkSpace 2.6.3.3; Nederland B.V., Best, The Netherlands) for analysis and postprocessing.

The LVEF will be estimated using CMR by calculating the EDV through planimetry of the LV end-diastolic endocontours, and calculation of SV (the aortic forward flow volume) by PC CMR at the aortic root using the following equation:

LVEF = aortic stroke volume (phase contrast)/EDV.

So, we will compare two methods for the estimation of LVEF; the first method (volumetric method), the most commonly applied method which uses the equation

LVEF=LVSV (EDV-ESV)/EDV.

And, the second method (PC method) which uses the equation

LVEF=aorticSV (phase contrast)/EDV

Also, in order to minimize the effect of factors that may affect EF such as changes in the heart rate, blood pressure, and resting conditions we will compare the two methods by MRI examination, which were performed at the same time on the same MRI scanner.

Assessment of the LVSV and EF from volumetric short-axis images (first method: volumetric method) were done via measurement of the left ventricular (LVEDV) and ESV. Endocardial borders at the end-diastole and end-systole were manually traced using the standard system software analysis tools. Volumes were computed by a summation of the disk's method (Simpson's rule), where the sum of all slices was multiplied by the slice thickness. Subsequently, SV and EF were calculated using EDV and ESV.

Assessment of the LVSV and EF was derived from the transaortic flow volume (second method: PC method) performed by using velocity maps to determine the flow volume throughout the cardiac cycle. With the same magnitude and phase velocity maps, a region of interest is traced around the ascending aorta to determine the area of the flow, frame by frame. By multiplying the velocity (cm/s) of each pixel by the area (cm^2) of the region of interest, the instantaneous flow volume (cm^3/s) is obtained for each frame of the cardiac cycle. The instantaneous flow volume of each frame (y-axis) can be plotted against the time of the cardiac cycle (x-axis) to show the bulk flow as it relates to the cardiac cycle. When the area under the curve is integrated for systole and diastole, forward, regurgitant, and SVs can be generated. Subsequently, EF (by Q-flow) can be calculated by the equation

LVEF = aorticstroke volume (phase contrast)/EDV.

The data obtained from both methods were compared with each other.

Statistical analysis

The collected data were entered into a Microsoft Access Database and then analyzed using the statistical package for the social sciences (SPSS, version 20; IBM, Armonk, New York, USA). Continuous data are expressed as the mean ± SD or the median (range), while nominal data are expressed as frequency (percentage). The validity of the PC method was performed by measurement of the EF and assessment of the cardiac function by both volumetric CMR and PC CMR. The comparison was done between two methods using the independent-sample or Student's t-test, and the P values were considered significant if less than 0.05.

Table 1 Demographic data of both groups

	Study group (n=10)
Age (years)	38.60±9.83
Sex	
Male	8 (80)
Female	2 (20)

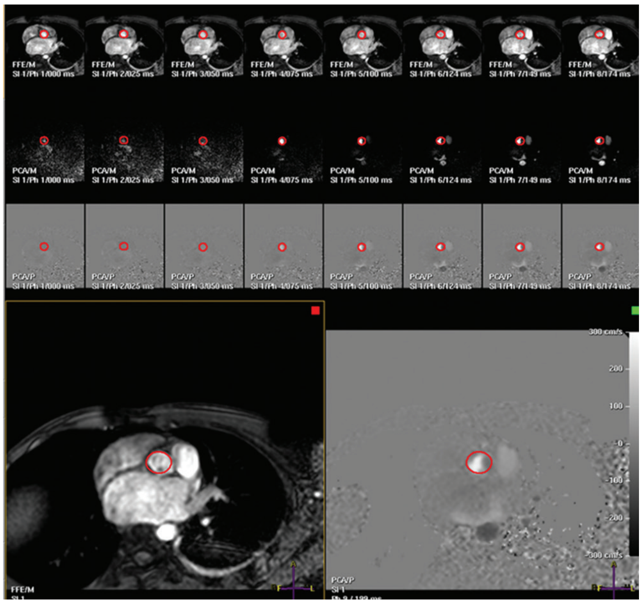
Continuous data were expressed in the form of mean±SD or frequency (percentage)

Table 2 Measurement of the ejection fraction and assessment of cardiac function by volumetric and phase-contrast cardiac magnetic resonance in the control group

	First method; volumetric method	Second method; phase contrast method	P
Ejection fraction	62.44±6.61	64.34±5.33	0.62

Continuous data were expressed in the form of mean±SD or frequency (percentage). P<0.05, significant.

Figure 1



Phase-contrast cardiac magnetic resonance of the aorta to determine the aortic stroke volume and flow; On the right is the magnitude image providing the details of the anatomy, contour and shape of the aorta and, on the left is the phase velocity map depicts the velocity and direction of the flow in each pixel.

Results

The demographic data of the study showed that the mean ± SD age of the study group was 38.60 ± 9.83 years. Most of the studied patients were men (Table 1).

According to the volumetric CMR method estimation of the mean EF, the mean SV in the study was 62.44 ± 6.61, whereas that estimated via the PC method was 64.34 ± 5.33, which was not significant (P = 0.62; Table 2 and Fig. 1).

Discussion

In this study, among the 10 healthy patients, the classic volumetric estimation of the ventricular EF showed a high degree of matching compared with the PC cardiac MRI method with a nonsignificant difference, confirming the validity of the PC method.

Prior studies have described the use of PC CMR for calculation of the valvular regurgitant volume by subtraction of the aortic forward flow calculated from PC CMR at the aortic root from the total LVSV obtained from planimetry of the LV end-diastolic and end-systolic contours [7]. To the best of our knowledge, this is the first time to estimate the LVEF via PC CMR.

Currently, there is no universally accepted 'gold standard' for measuring LVEF. Every method and modality used to measure the LVEF is subject to factors that may introduce error and variability into the calculated EF. As there is no gold standard, the choice of modality used should depend on the patient factors, local resources, other information desired from the study, and the need for follow-up measurements.

Limitations

This study shows that the cardiac MRI can accurately calculate the ventricular EF in patients with valvular heart disease. Many limitations are present in this study; some of them could be expressed through further studies, whereas others are related to the method we used. First, PC imaging was the tool used for the quantification of LV SV; this flow MRI sequence can be affected by some technical factors such as velocity offset errors, partial volume degradation, temporal blurring, and translational valve movement due to eddy currents or magnetic field inhomogeneity, and so, for better reproducibility of results, the technique needs to be standardized [8].

Conclusion

Functional assessment of the LV is important in the management planning of different heart diseases. In this study, we assessed the LV function by two methods; the first is the volumetric method while the second is by using the PC. Our results show that there is no difference between these two methods, confirming the validity of the PC method. On the other hand, this is of great help for the investigators to choose the proper available calculation method according to the patient's condition, and this should be taken into consideration in future software design as a postprocessing tool in CMR as it might help to guide management in cardiac patients.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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