Original Article

Evaluation of the potential impact of reconstruction method on dyssynchrony parameters derived by phase analysis of gated-SPECT MPI: Comparison of two quantitative software

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ABSTRACT

Introduction: Gated SPECT myocardial perfusion scanning has new capabilities in addition to its main applications such as left ventricular dyssynchrony using phase analysis. Phase analysis has been investigated through various software including Emory Cardiac Toolbox (ECTb) and Quantitative Gated SPECT (QGS). The aim of this study is to evaluate the effect of reconstruction parameters on dyssynchrony indices including phase histogram bandwidth (PHB) and phase standard deviation (PSD) derived from two different software packages.

Methods: In this study three groups of patients including 47 patients with normal findings 53 patients with Left bundle branch block (LBBB) and 47 patients with heart failure (HF) (including gated studies with 8 or 16 frames). All studies were analyzed by both ECTb and QGS software and reconstructed by both FBP and OSEM reconstruction methods. Then, the PHB and PSD were compared between these methods in separate patient groups.

Results: Comparison of two reconstruction methods in ECTb and QGS software showed no statistical difference for mean PHB and PSD parameters except for PHB in HF patients that analyzed with ECTb and obtained by 8 frame. On the other hand, the comparison of two software (QGS and ECTb) showed significant difference for both PHB and PSD, although, the correlation of two software was acceptable and significant.

Conclusion: The present study showed that the method of cardiac scan reconstruction had no significant effect on the ranges of dyssynchrony parameters obtained from phase analysis. However, the type of software used for phase analysis, significantly affect the PHB and PSD.

Key words: Phase analysis; Dyssynchorony; Myocardial perfusion scan

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INTRODUCTION

The prevalence and incidence of heart failure (HF) in the world is increasing and even close to the epidemic criteria. Around 23 million people worldwide have HF. Any condition that leads to a change in the structure or function of the left ventricle can make a person susceptible to HF [1]. In 20 to 30% of cases of HF with low ejection fraction (EF), the underlying cause is unclear whether they are idiopathic, dilated, or non-ischemic cardiomyopathy. Several types of conduction disorder are commonly seen in association with chronic HF. Abnormal conduction abnormalities such as the left bundle branch block (LBBB), by altering the timing and pattern of ventricular contraction, can make the dysfunctional heart more vulnerable to mechanical abnormalities. These mechanical manifestations as a result of abnormal ventricular conduction are collectively referred to as ventricular dyssynchrony [1]. In addition to decreasing the heart's ability to pump blood, ventricular dyssynchrony is associated with increased mortality in HF patients [1].

Gated single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) is widely used to validate myocardial perfusion and function [2, 3]. This method can be performed with different stress methods, imaging protocols and radiopharmaceuticals. With the advent of imaging technology, new and useful capabilities such as left ventricular dyssynchrony using phase analysis have been emerged in addition to its main applications [4-8]. Phase analysis is based on regional count changes during a cardiac cycle resulting from the partial volume effect that indicates a linear relationship with myocardial thickness [4]. In phase analysis, two parameters, phase histogram bandwidth (PHB) and phase standard deviation (PSD) can be calculated. The PHB is equivalent to the bandwidth of the histogram, which comprises 95% of the 3D samples, and the PSD is the standard deviation of the phase angles obtained [4]. Although these parameters are calculated by the software and have high reproducibility, various technical factors, such as reconstruction method, the time resolution of gated study, and the type of software used, can influence these values [9-12]. In this study, we intended to examine the influence of reconstruction method on phase parameters of two software packages in patients with different amount of dyssynchrony.

METHODS

Patients

In this retrospective study, three groups of patients with different degrees of dyssynchrony were selected: group 1(normal) consists of patients with normal perfusion defined as summed stress score (SSS) ≤ 3 and EF >50%, group 2 (LBBB) includes patients with LBBB criteria in the baseline electrocardiogram (ECG) diagnosed by an expert cardiologist and without any fixed perfusion defect on scan, and group 3 (HF) includes patients with severe HF ,defined as EF ≤ 35% in gated study, and multiple fixed perfusion defects in the scan. In all patients scan findings and parameters were qualified by a nuclear medicine specialist and in the presence of interfering artifact such as GI activity and gating errors the patient was excluded. The patients were selected during a 6 months' period, when in the first 3 months, 8-frame gated acquisition was performed and during the 2nd 3 months, 16-frame gated acquisition was done. Then, demographic information, echocardiographic, electrocardiographic and patient characteristics were recorded in the relevant checklist, if there was complete data and the scan quality were confirmed, the patient was included in the study.

Gated-SPECT MPI

Gated SPECT imaging for stress and rest conditions was performed approximately 15-90 min after intravenous injection of 15-20 mCi of Tc99m-sestamibi into the patient, by dual-head gamma camera (CorCam DDD), in 180˚ arch, with starting angle of 135 (RAO) to -45 (LAO) Matrix size was 64 × 64 with 32 projections of 25 seconds with 16 or 8-frame gating, performed in forward fixed temporal resolution forward gating. Images were reconstructed by both filtered back projection (Butterworth filter; cutoff = 0.45, and order = 5) and ordered subset expected maximization (OSEM) (iteration: 4 and sub set: 6 in quantitative gated SPECT (QGS) software and iteration: 2 and sub set: 10 in Emory cardiac toolbox (ECTb) software as manufacture preferences for each software). Other data on perfusion and left ventricular function were also extracted. Perfusion and function parameters as well as phase analysis indices including PHB and PSD were derived from both Emory Cardiac Toolbox (ECTb) and QGS software.

Quantitative software packages

ECTb Software: Since phase analysis in myocardial perfusion scan was first introduced in ECTb software, most studies in this field have used this software to calculate phase analysis. The software uses a cylindrical-spherical hybrid model for initial sampling. Based on the polar map obtained for each of the gated image frames for more than 600 regions in the myocardium Fourier transform and harmonic approximation are performed, and finally the phase of each of the diagrams obtained for the different regions of the myocardium the histogram is displayed. The obtained phase is proportional to the time delay until the onset of contraction of the area and is used to quantify left ventricular homogeneity or heterogeneity in thickening [13].

QGS Software: Newer versions of the QGS software from the Cedars-Sinai Center are also capable of phase analysis. This software, for each of the short-axis images in different gated frames, use the threshold limit and match the mid myocardial surface with an elliptical default model and then determine the endocardial and epicardial levels based on a percentage of the standard deviation of the guassian graph of each mid myocardial point [13].

Statistical analysis

Statistical analysis was performed using SPSS software. Kolmogorov-Smirnov analysis was used for data normality analysis. Then Wilcoxon test was used to compare parameters between two methods of reconstruction and between two software in different groups. Comparison between groups (normal, LBBB and HF) was done by Kruskal-Wallis method. Correlation coefficient between two software was also analyzed by Spearman's correlation coefficient test. Correlation charts of two software were also plotted using SPSS software.

RESULTS

In this study, three groups of patients including 47 patients with normal perfusion findings (26 patients with 8 frames and 21 patients with 16 frames), 53 patients with LBBB (30 patients with 8 frames and 23 patients with 16 frames) and 47 patients with HF and multiple defects (28 patients with 8 frames and 19 patients with 16 frames) were enrolled. The scans of all these patients were reconstructed by both OSEM and FBP, and then were analyzed with QGS and ECTb software. Samples of phase analysis results of QGS and ECTb software are illustrated in Figure 1 for three patients.

ECTb software

Comparison of two reconstruction methods showed that PHB and PSD parameters were not affected by the type of reconstruction except for PHB parameter in the group of patients with HF who were imaged in 8 frames. However, in the HF group, which was imaged with 16 frames, the use of the two reconstruction methods did not show a significant difference. These results are shown in the Table 1.

QGS software

Comparison of OSEM and FBP for the QGS dyssynchrony parameters also showed that both PHB and PSD parameters were not affected by the reconstruction method in all groups (Table 2).

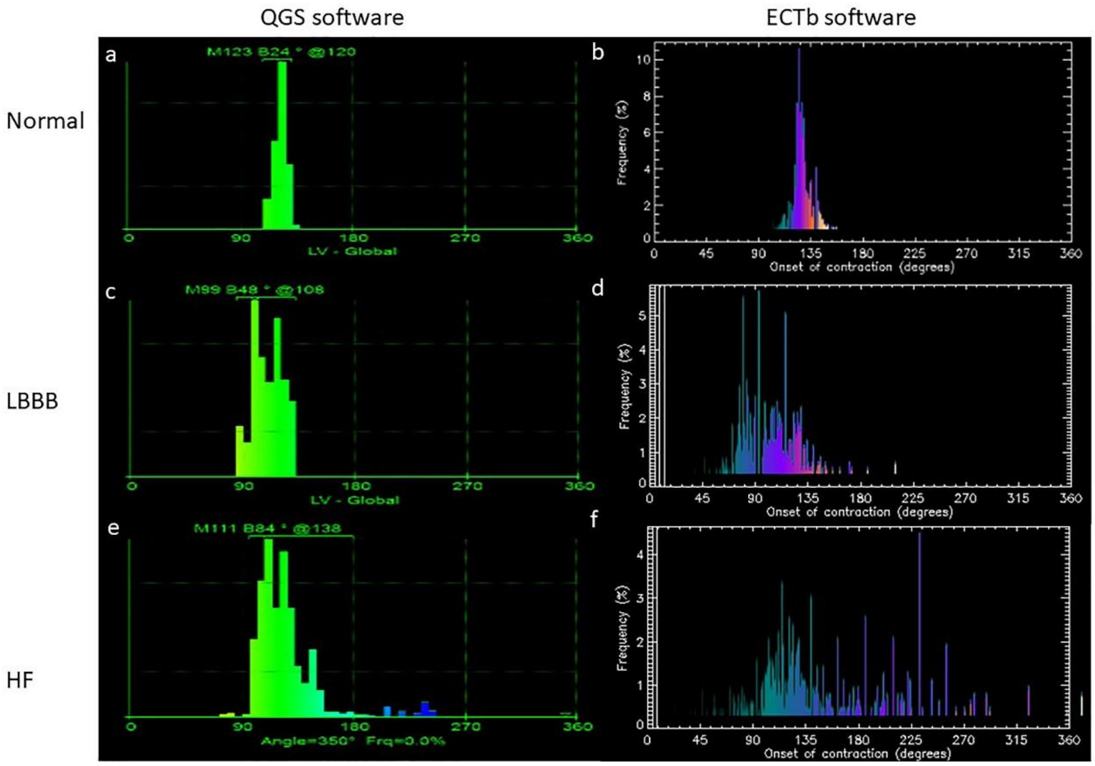

Fig 1. Phase analysis results of three patients from the three groups of normal (a, b), LBBB (c, d) and HF (e, f) with the two software packages.

Table 1: Comparison of dyssynchrony parameters derived by ECTb software between OSEM and FBP reconstruction methods in different groups.

Software	Frame	Group	FBP PSD	OSEM PSD	P-Value	FBP PHB	OSEM PHB	P-Value
ECTB	8frame	Normal	9.92 ± 3.22	9.57 ± 2.99	0.633	34.5±10.25	33.34±9.71	0.855
		LBBB	17.33±7.91	17.13±7.80	0.663	57.23±20.47	55.36±20.93	0.673
		HF	39.96±22.96	41.46±24.37	0.381	111.85±64.40	126.32±74.34	0.036
	16frame	Normal	13.47±8.18	13.84±8.85	0.875	37.31±14.42	43.47±24.11	0.616
		LBBB	24.71±23.49	22.33±12.24	0.097	60.28±31.98	66.42±31.94	0.067
		HF	36.76±23.52	36.11±23.08	0.361	113.17±73.98	124.05±77.80	0.246

Table 2: Comparison of dyssynchrony parameters derived by QGS software between OSEM and FBP reconstruction methods in different groups.

Software	Frame	Group	FBP PSD	OSEM PSD	P-Value	OSEM PHP	FBP PHP	P-Value
QGS	8frame	Normal	6.34±4.88	6.23±4.50	0.317	23.65±8.15	23.07±7.71	0.414
		LBBB	12.39±6.1	12.32±5.90	0.739	42.64±15.52	43.07±15.92	0.157
		HF	26.85±21.87	27.10±21.73	0.371	91.89±65.66	90.82±66.56	0.160
	16frame	Normal	8.04±6.89	7.85±6.70	0.102	30.95±21.43	30.85±21.23	0.317
		LBBB	11.52±6.68	11.47±6.64	0.317	43.56±19.50	43.56±18.90	1.000
		HF	19.68±16.38	19.68±16.05	1.000	72.63±59.69	69.78±59.94	0.206

Comparison of ECTb and QGS software packages

The parameters obtained from the two software packages were also compared according to each reconstruction method. As it is illustrated in Tables 3 and 4, the mean value of both PSD and PHB derived from ECTb software are significantly higher than those of QGS software in all patient groups, irrespective of the reconstruction method. This difference is independent of frame number or rate of underlying dyssynchrony.

However, the correlation coefficient analysis between the two software packages showed a good correlation between the software with correlation coefficient of >0.7 for all comparison, which was also independent of the reconstruction method. (Figure 2 and 3).

DISCUSSION

The present study showed that SPECT reconstruction method do not have a significant effect on the left ventricular dyssynchrony parameters obtained from phase analysis. A significant difference was observed only in a group of patients with HF and multiple defect perfusion, imaged with 8 frame gating and only in analysis with ECTb software. However, there is significant differences between the dyssynchrony parameters derived from different software packages.

In a study aimed at investigating the effect of image reconstruction on gated-SPECT phase analysis, 30 patients with different levels of dyssynchrony were evaluated using Cardio MD Philips instrument and data was reconstructed by FBP and MHLE methods [14]. There was no statistically significant difference between the two methods, and it was concluded that image reconstruction techniques had little effect on left ventricular dyssynchrony indices [14]. In this study patients from different groups were not studied separately and the software used was different from the software used in our study [14], whereas, our study revealed that ECTb software in patients with multiple and significant perfusion defects had limited reproducibility between the two conventional reconstruction methods, especially when imaged with 8-frame gating. Since the most common application of phase analysis is this group of patients with HF, this is particularly important in the follow-up of these patients, and emphasizes that a same reconstruction approach should be used to compare the results of phase analysis in these patients.

Table 3: Comparison of dyssynchrony parameters between the QGS and ECTb software packages, reconstructed by FBP, in different groups.

Software	Frame	Group	QGS PSD	ECTb PSD	P-Value	QGS PHB	ECTb PHB	P-Value
FBP	8frame	Normal	6.34±4.88	9.92±3.22	0.002	23.07±7.71	34.50±10.25	<0.001
		LBBB	12.39±6.1	17.64±8.11	0.003	43.07±15.92	58.1±20.94	<0.001
		HF	26.85±21.87	39.96±22.96	0.004	90.82±66.56	111.85±64.4	0.101
	16frame	Normal	8.31±7.21	13.47±8.18	0.001	31.57±22.25	37.31±14.42	0.039
		LBBB	11.42±6.85	24.71±23.49	<0.001	43.42±19.24	60.28±31.98	0.004
		HF	19.17±15.79	36.76±23.52	<0.001	68.47±59.39	113.17±73.98	0.002

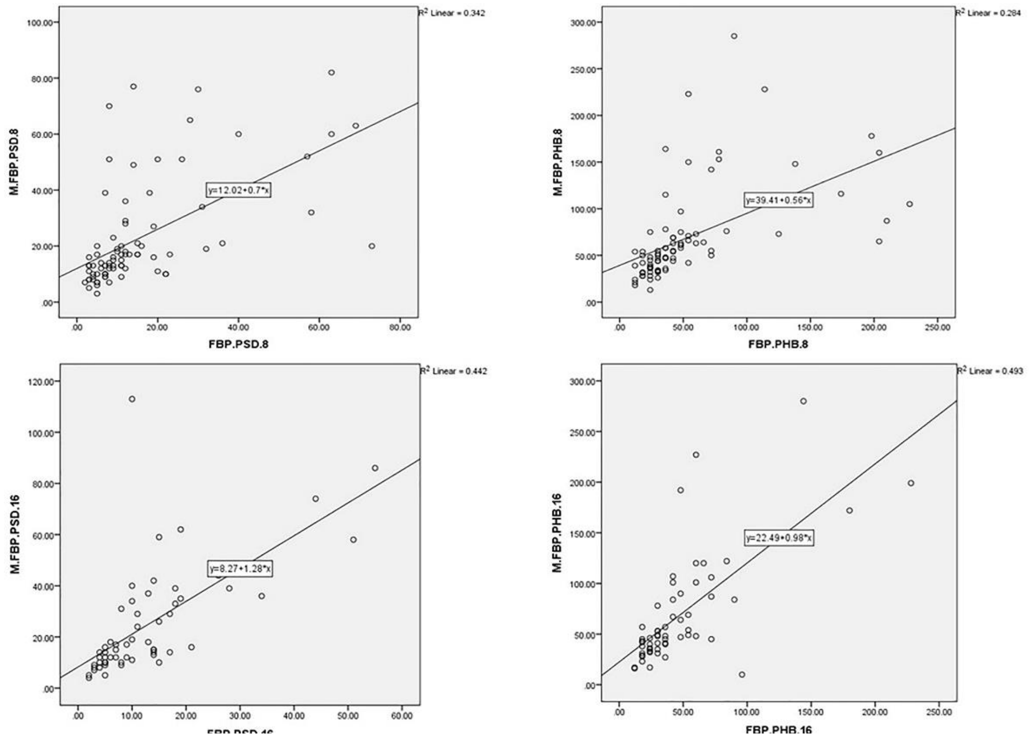

Fig 2. Correlation diagram of dyssynchrony parameters of QGS and ECTb software packages, reconstructed by FBP method in two groups of all patients with 8-and16-frames gating.

Table 4: Comparison of dyssynchrony parameters between the QGS and ECTb software packages, reconstructed by ECTb, in different groups.

Software	Frame	Group	QGS PSD	ECTb PSD	P-Value	QGS PHB	ECTb PHB	P-Value
FBP	8frame	Normal	6.23±4.9	9.57±2.99	0.002	23.65±8.15	33.34±9.71	<0.001
		LBBB	12.32±5.9	17.35±8.03	0.004	42.64±15.52	55.89±21.57	0.002
		HF	27.1±21.73	41.46±24.37	0.02	91.89±65.66	126.32±74.34	0.034
	16frame	Normal	8.1±7.01	13.84±8.58	0.001	31.68±22.46	43.47±24.11	0.005
		LBBB	11.38±6.81	22.33±1.24	<0.001	43.42±19.89	66.42±31.94	<0.001
		HF	19.29±15.6	36.11±23.08	0.004	71.64±59.18	124.05±77.80	<0.001

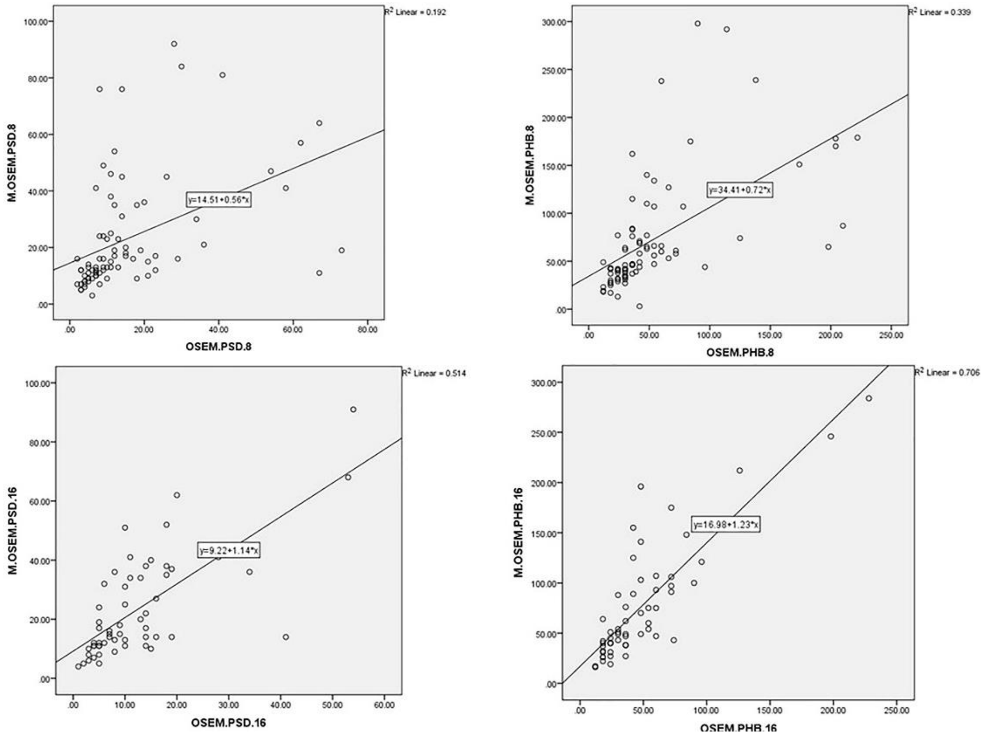

Fig 3. Correlation Diagram of dyssynchrony parameters of QGS and ECTb software packages reconstructed by OSEM method in two groups of all patients with 8-and16-frames gating.

In addition, since there was no difference in the group of patients with HF imaged with 16 frames, it is recommended to perform phase analysis in these patients with at least 16 frames.

In one study using digital simulation, it was shown that if sufficient quantities of phase data with 8 or 16 frames were obtained, it could be as effective as 64 frames [15]. Considering tis result, the presence of areas with significantly lower uptake than usual in the given patients with HF and multiple defect perfusion in our study, might partly explain in the less reproducibility of phase analysis by 8 frame gating in these patients. The effect of count reduction was also seen in another study on the dependence of left ventricular dyssynchrony parameters on the rotation angle of the device [16]. In this study, a significant difference in the parameters obtained from two different imaging modalities (180 or 360 degrees) was observed in a number of patients who were imaged with thallium as compared to 99mTc-sestamibi [16].

In 2012, a study was conducted to evaluate the effect of radiotracer dose on the accuracy and repeatability of myocardial perfusion scan [17]. This study was performed on 54 patients with normal left ventricular perfusion and function and 54 patients with systolic HF and showed that PSD values were significantly higher in low dose resting phase in both groups of patients using two different ECTb and 4DM software regardless of stress type and BMI [17]. The current study also found that the phase analysis parameters obtained from the QGS and ECTb software packages were statistically different, independent of the type of reconstruction method, the amount of dyssynchrony, and the number of imaging frames. Thus, phase analysis at different times for same patients must be performed with the same software and the results of these two software packages cannot be directly compared. However, similar to our study, the results of the two software packages were in good correlation with each other, indicating similar diagnostic ability. In 2014, Rastgou et al. compared the QGS and ECTb software packages in a cohort of HF patients and compared the correlation of phase analysis results with Doppler echocardiography [13]. They found out that although the two software packages had significant differences in the measured PHB and PSD parameters, there is a good correlation with the echocardiographic results for both software packages. However, unlike our study, in this study, the effect of software was only evaluated in HF patients, reconstructed by FBP method.

In another study, phase analysis parameters were also evaluated by both QGS and ECTb software packages in patients with normal myocardial perfusion scan [18]. Phase analysis parameters among 138 patients without diabetes and normal LV function indices, were evaluated in both QGS and ECTb software packages [18]. Although in this study, the PHB and

PSD values were much closed between the QGS and ECTb software packages the authors stated that normal values of phase analysis parameters might be software-dependent. A study in 2017 evaluated left ventricular dyssynchrony by phase analysis of myocardial perfusion in which 4 software were compared [19]. In total, 122 patients with normal myocardial perfusion and function and 34 patients with suspected left ventricular dyssynchrony were reviewed, retrospectively. The mean PHB and PSD in all four software packages were significantly different in patients with normal perfusion and function. In this study, the diagnostic performance of each software was evaluated using ROC curve analysis, in differentiating normal group from abnormal group, which showed that although optimum cutoff values of PHB and PSD were variable depending on software type, diagnostic performance using ROC analysis was similar [19]. In another study, left ventricular dyssynchrony by phase analysis was compared between 4 software packages with ECTb as reference [20]. PHB in all three software QGS, HFV and cREPO was significantly different from ECTb software. Phase parameters showed a large variation in patients with lower EF and greater ventricular volume depending on the type of software. The authors recommended that based on the normal range of dyssynchrony parameters by the four software packages, during comparison phase analysis between different software packages, gender and EF dependency and left ventricular volume should be taken into account, indicating the need for careful comparison between different software programs [20].

There are some limitations with our study. There is a relatively small sample size in each group in our study. We could not directly compare the 8-frame and 16-frame gated-SPECT images in a same group of patients and the impact of number of gating frames needs more studies that are dedicated.

CONCLUSION

Our study suggests that same software should be used in follow-up and serial studies of patients. In addition, the reconstruction method might affect the values of dyssynchrony parameters by different software packages regarding the underlying patient disease and frame number of gating. Thus, more investigations are needed to evaluate and compare the diagnostic performance of different software packages in different clinical and technical conditions.

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