Measurements of left ventricular dimensions and function using Steady-State Free Precession Imaging: comparison with Turbo Gradient Echo Imaging

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Introduction

The concept of Steady-State Free Precession Imaging was introduced in 1986 (1) under the acronym FISP (Fast Imaging with Steady Precession) and following further developments TrueFISP (2). Recently, there has been renewed interest in Steady-State Free Precession Imaging in cardiac MRI and is becoming widely available under a variety of acronyms (TrueFISP, BFFE = Balanced Fast Field Echo, FIESTA = Fast Imaging Employing Steady-state Acquisition). This work was carried out using a BFFE sequence and we will subsequently use this acronym. BFFE offers considerable potential advantages for cardiac MR imaging. Acquisition times are substantially shorter compared with standard gradient echo techniques. The blood/myocardium contrast is substantially higher and is less dependent on blood flow as it depends mainly on the T1/T2 properties of tissue. One of the main applications of BFFE will be the assessment of ventricular dimensions and function from short-axis cine images. Here, the better blood/myocardial contrast should improve the delineation of the endocardial borders and trabeculation as well as the contrast in apical slices. However, the significant differences in the image properties could lead to substantially different estimations of cardiac dimensions compared with conventional gradient echo measurements. The purpose of this study was to compare measurements of global and regional left ventricular dimensions between BFFE and a standard Turbo Gradient Echo acquisition sequence.

Methods

Fourty-one consecutive patients (13 left ventricular hypertrophy, 10 dilated cardiomyopathy, 18 normal cardiac dimensions) were studied on a 1.5T Philips ACS NT system (Philips Medical Systems, Best, The Netherlands) with Master gradients (amplitude 30mT/m, slew rate 150mT/m/ms). ECG gated, breath-hold, multi-slice multi-phase data sets covering the left ventricle in 10-12short axis slices were acquired using a Turbo Gradient Echo sequence (Turbo Field Echo =TFE: TR 8.1, TE 4.9, Flip angle 35°, approximately 12 sec acquisition time/slice) and a BFFE sequence (TR 3.34, TE 1.67, Flip angle 55°, approximately 5 sec acquisition time/slice). Slice thickness was 6mm with 4mm gap for both scans. Analysis was performed offline on a Sun workstation with MASS software (Medis, Leiden, The Netherlands). Endocardial and epicardial contours were drawn manually by two experienced observers. End-diastolic volume (EDV), end-systolic volume (ESV), Ejection fraction (EF), Stroke volume (SV) and left ventricular mass (LVM) were determined using conventional methods. End-diastolic (EDWT) and end-systolic wall thickness (ESWT) was measured and diastolic to systolic wall-thickening in % (WTh) and wall motion (WM) calculated using the centreline method. BFFE and TFE measurements were compared. In a subgroup analysis results of the three groups of subjects (normal, dilated, hypertrophied ventricle) were compared. Intra- and interobserver variabilities were assessed. Data is expressed as mean +/- SD and was compared using Bland-Altman analysis and a paired t-test.

Results

Figure 1 shows representative corresponding images acquired with BFFE (left) and TFE (right). BFFE measurements of EDV and ESV were significantly higher than TFE measurements while EDWT, ESWT, LVM and EF were significantly lower (Tables 1 and 2). SV, WTh and WM did not differ significantly. The observed differences were similar in the three groups of subjects. Intra- and interobserver variabilities were less than 5% for all measurements and were lower for BFFE measurements (not significant).

Discussion

This study demonstrates significant differences in measurements of ventricular dimensions and function between BFFE and conventional Turbo Gradient Echo Imaging. These differences are largely due to lower wall thickness measurements on BFFE. They are consistent and reproducible in subjects with normal, dilated and hypertrophied ventricles. The main reason for the observed results is likely to be the improved contrast between blood and myocardium with BFFE. In Turbo Gradient Echo, slow blood flow at the endocardial border and between trabeculation provides poor signal and can be mistaken for myocardium. In BFFE the visualisation of trabeculation is improved and may lead to positioning of the endocardial contours more towards the myocardium. This would explain lower EDWT, ESWT, LVM and higher EDV and ESV. The calculated parameters SV and EF and the functional parameters (WTh and WM) showed substantially smaller differences, in keeping with a systematic reduction in measurements of wall thickness throughout the cardiac cycle. Other inherent differences in the two sequences and imaging artefacts specific to each sequence could also have contributed to the observed differences.

In conclusion, steady-state free precession imaging results in significantly different measurements of LV dimensions compared with Turbo Gradient Echo MRI. This has to be considered in the interpretation of results, definition of normal values and in particular in long-term patient follow up.

References

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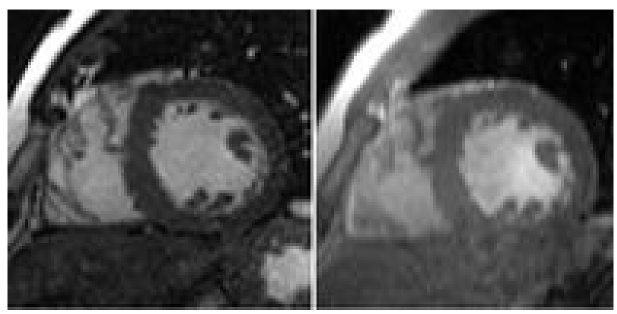

Figure 1. Corresponding BFFE (left) and TFE (right) diastolic images of a midventricular short axis slice

Table 1: TFE versus BFFE measurements

	EDV	ESV	SV	EF	LVM
TFE (SD)	163.2 (76.5)	69.8 (71.1)	94.9 (22.4)	63.8 (16.0)	155.7 (45.4)
BFFE (SD)	177.6 (79.3)	82.0 (79.9)	95.6 (21.8)	60.1 (16.9)	134.2 (40.7)
Difference (%)	-14.4 (8.8%)	-12.2 (17.8%)	0.7 (0.7%)	3.8 (5.9%)	21.5 (13.8)
p-value	<0.0001	<0.0001	0.69	<0.0001	<0.0001

Table 2: TFE versus BFFE measurements

	EDWT	ESWT	WTh	WM
TFE (SD)	9.2 (1.8)	14.8 (3.1)	64.8 (26.5)	8.4 (2.4)
BFFE (SD)	7.8 (1.8)	12.7 (3.3)	69.7 (30.1)	8.2 (2.6)
Difference (%)	1.4 (15.2%)	2.1 (14.2%)	-4.9 (7.6%)	0.1 (2.4%)
p-value	<0.0001	<0.0001	0.26	0.23