Retrospective Triggered Free Breathing Cardiac Function with Respiratory Pencil Beam Navigators

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Introduction

Most cardiac MR examinations include a functional study of the heart for the assessment of ventricular volumes and ejection fractions. For sufficient volume coverage, 7–12 cardiac phase resolved contiguous short-axis views have to be acquired each providing 25 - 30 cardiac phases over the complete heart cycle. The standard method used today is a fast, retrospective ECG-triggered steady state free precession (SSFP) gradient echo sequence. Depending on the heart rate and the temporal and spatial resolution, the acquisition of a single slice requires 3 – 8 heart beats. For each 1 - 3 slices, an independent breathhold of 3 – 12 seconds is needed. A significant amount of patients face problems in obeying to the breathhold commands, either due to problems with holding their breath or due to hearing impairment. As for these people a fallback scenario is needed, we developed a respiratory navigator controlled sequence and compared it to the standard breathhold technique and a free breathing method which uses 4 signal averages, concerning left and right ventricular cardiac functional parameters.

Methods

Thirty consecutive patients (13 female,17 male; mean age 51+/-15) scheduled for standard CMR ischemia diagnostic at a clinical MR whole body scanner (Intera 1.5 T, Philips, the Netherlands) were enrolled in this feasibility study. In addition to the conventional retrospective triggered cine breathhold (BH) short axis (SA) protocol (SSFP cine, 1.5 x 1.5 x 8 mm, 32 cardiac phases, temporal resolution 30 ms, 10-15slices), two free-breathing SA sequences using either 4 signal averages (AVG) or a navigator approach (NAV, 8 mm acceptance window) for motion artifact reduction were performed in randomized order. Myocardial contours of ventricles were identified manually on a workstation (View forum, Philips, the Netherlands). Papillary muscles were excluded. The resulting enddiastolic and endsystolic volumes, the stroke volume and the ejection fraction were compared between the different techniques by means of paired t-test, regression and agreement analysis.

Results

The MRI imaging protocol could be completed in all patients at reasonable image quality (Fig.1). Average scan times were: BH - 86s (including breathing between subsequent BH scans); AVG 144s; NAV 60s (mean navigator efficiency 61%±13%). The individual heart rate variability was below 10% over the three subsequent acquisitions. In direct comparison to the BH acquisition, quantitative analysis shows a significant ($p<0.05$) underestimation b of the enddiastolic (EDV) and endsystolic (ESV) ventricular volumes between 2 – 13% in the free-breathing approaches. Similar values were found for the stroke volume (SV), with regression coefficients R^2 between 0.77 and 0.99. No significant differences could be found for the ejection fractions (EF).

	left ventricle								right ventricle							
	EDV		ESV		SV		EF		EDV		ESV		SV		EF	
	R^2	b [%]	R^2	b [%]	R^2	b [%]	R^2	b [%]	R^2	b [%]	R^2	b [%]	R^2	b [%]	R^2	b [%]
NAV	0.94	-9.3	0.99	-8.3	0.96	0.004	0.8	-9.8	0.85	-11	0.91	-13	0.8	0	0.77	-10
AVG	0.93	-3.2	0.96	-4.1	0.97	0.007	0.9	-2	0.95	-6	0.96	-3.3	0.92	-0.01	0.9	-7.5

Table 1: Quantitative analysis of the different investigated methods

Discussion

In direct comparison with the conventional breathhold technique, ejection fractions assessed by the free-breathing techniques do not show any significant differences. The underestimation in the volumetric assessment may be caused by the slightly reduced image sharpness in the free-breathing techniques, which causes a less distinct delineation of the myocardium and the papillary muscles. Both free-breathing techniques appear qualified for replacing the conventional approach in patients not capable of adequate breatholding.

Figure 1: Examples of typical image quality