

# Factors influencing image quality with 3D self-navigated whole heart CMR imaging in patients with congenital heart disease

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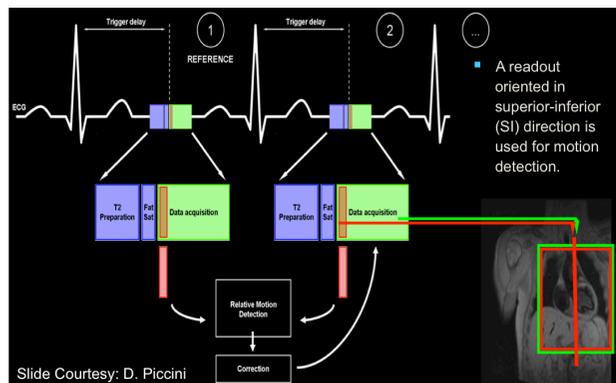
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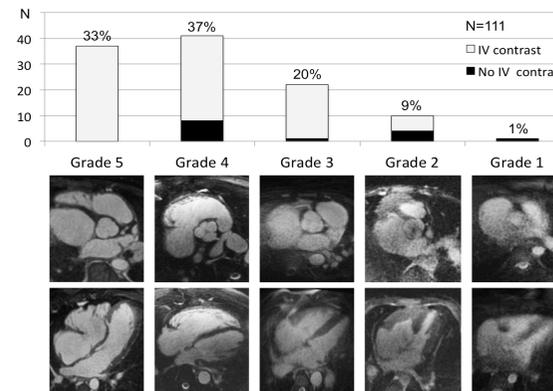
**Introduction:** For the morphological assessment of complex congenital heart disease (CHD) 3D free-breathing cardiac MR (CMR) is a potential option. A new sequence with direct self-navigation on the heart has recently been developed (Piccini D. Radiology 2014). Our aim was to identify the factors associated with low image quality in order to further improve this sequence.

**Methods:** All patients with CHD aged >2y and referred for clinical CMR were considered for inclusion. On a 1.5T-MRI scanner (Magnetom AERA, Siemens Healthcare) a self-navigated acquisition was performed during free breathing with respiratory navigation in the superior-inferior direction only (12'417-15'050 radial read-outs sampled over 377-953 heartbeats depending on heart rate (HR), all lines accepted for reconstruction) providing isotropic 3D image data with a resolution of 1x1x1mm<sup>3</sup> (Figure 1). Image quality was graded using a 5-grade scale where 5=excellent quality, 4=mild blurring only, 3=moderate blurring but completely diagnostic dataset, 2=insufficient quality with marked blurring and only partially diagnostic information and 1=non-diagnostic dataset (Figure 2). Patients and protocol-related factors associated with insufficient image quality were identified using stepwise multivariate logistic regression.

**Results:** In 144 consecutive patients the pulse sequence was not applied for logistical reasons (time constraint) in 33 patients resulting in 111 patients (55% male, age 23±12y) for analysis (44% with complex malformation; 69% with previous surgery). IV contrast (0.2 mmol/kg Gadobutrol) was used in 87%. Scan duration was 9.5±3.1min, HR was 75±16bpm. Image quality was graded as given in Figure 2. Factors significantly associated with poor image quality (grade 1 or 2 vs grades 4 and 5) were younger age, lower ejection fraction (EF) of the systemic ventricle, higher HR and the absence of contrast injection (Table). Overall, a diagnostic quality could be obtained in 94% in the contrast-enhanced 3D acquisitions, of which 77% were of good to excellent quality.



**Figure 1:** Principle of 3D data acquisition using respiratory self-navigation: the position of the heart silhouette in the superior-inferior axis is detected at the beginning of each imaging segment and the change in position due to respiratory motion is corrected inline by adding a phase shift before the data are entered into the k-space. No data is rejected providing a 100% scan efficiency.



**Figure 2:** Image quality obtained with 3D free-breathing self-navigated whole-heart MRI. Overall diagnostic quality was obtained in 90% and good to excellent quality in 70%. When IV contrast was used, these numbers increased to 94% and 77%, respectively

	Bivariate logistic regression				Multivariate logistic regression			
	OR	p	95% - confidence interval		OR	p	95% - confidence interval	
Age	0.98	ns	0.92	1.04	0.89	<0.05	0.8	0.99
Heart rate (bpm)	1.07	<0.01	1.02	1.12	1.11	<0.01	1.03	1.2
Height (cm)	0.97	<0.05	0.95	0.99				
Weight (kg)	0.96	<0.05	0.93	0.99				
EF (%)	5.8 x 10 <sup>-6</sup>	<0.01	1.3 x 10 <sup>-9</sup>	0.03	1.2 x 10 <sup>-10</sup>	<0.01	2.7 x 10 <sup>-17</sup>	6 x 10 <sup>-4</sup>
Complex malformation	4.26	<0.05	1.05	17.35				
Surgical correction	0.31	0.07	0.08	1.11				
Acquisition window	0.96	<0.05	0.92	0.99				
Scan duration (s)	1.16	0.09	0.98	0.38				
Use of IV contrast	0.14	<0.01	0.03	0.55	0.007	<0.01	0.0004	0.15

**Table:** Results of the bivariate and of the stepwise multivariate logistic regression to identify factors associated with poor image quality (quality grades 1-2 vs grades 4-5). Young age, high heart rate, lower ejection fraction of the systemic ventricle and the absence of contrast injection were independently associated with poor image quality

**Conclusion:** In a consecutive large patient population with CHD, contrast-enhanced 3D self-navigated CMR provided diagnostic datasets in 94% of patients. Further developments should aim to improve respiratory tracking in small infants, in patients with reduced EF, and in those with irregular breathing patterns, including development of motion correction algorithms compensating heart motion in all 3 directions of space or selective removal of k-space profiles that originate from respiratory outlier positions of the diaphragm. The injection of contrast as a slow infusion or the use of intravascular contrast media may be advantageous