Murine Cardiac Imaging Methods at 4.7T

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INTRODUCTION: Fast cine MR imaging is required for high throughput rodent studies. We compared a recently implemented fast cine imaging protocol that overcomes some of the comparative limitations of the available 4.7 T hardware[1] to a slower technique which acquired a single line of k-space per R-wave. Left ventricular volumes and artefact levels were recorded for each method and compared.

METHODS: We imaged eleven C57 BL6/j mice between, 6-16 weeks old, with mean weight 31.1g (range 27 - 36g) on a 4.7T horizontal magnet (Magnex, UK) equipped with a 120 mT/m gradient system (Magnex, UK, AE Techron USA). Procedures were carried out in accordance with a Home Office project licence and institutional guidelines. Animals were placed prone on an in-house designed MR compatible bed which incorporated physiological monitoring (SA Instruments, USA), thermoregulation and an anaesthetic mask that delivered 0.5-3% Isoflurane in O_2. The bed also incorporated a 25 mm receive-only surface coil under the body, directly against the heart and during imaging this was positioned inside a 72 mm transmit-only coil. Image acquisitions were controlled using an EVO spectrometer (MR Solutions, UK), and were prospectively respiration and ECG gated. Gradient echo acquisitions used a 40x40 FOV, a matrix of 130x130 zero filled to 256x256 with a slice thickness of 1 mm. The "Slow" scan method acquired a single k-space line after each R-wave trigger, with *TE* =13 ms, α=45°, bandwidth = 25 kHz and 1ms gradient ramp times. Each slice was imaged with incrementing post-R-wave delays and it took approximately an hour to acquire 8 slices at 5 ms intervals, giving approximately 20 frames per cardiac cycle. "Fast" imaging used multi-slice gradient echoes with *TE*=5 ms, α=25°, bandwidth = 133 kHz and ramp times of 750 µs. The frames per cycle were determined by the number of multi-slice repetitions that fitted into one R-R wave period (in this case 7 frames, 7 slices) and the experiment was repeated *x*-times with the starting slice incremented each time to ensure all slices were imaged at all time frames[2]. Whilst 7 slices were enough to cover the left ventricle from base to apex, this technique only yielded 15 ms temporal resolution. However more frames could be added by adjusting the post R-wave delay and running the sequence again to interleave a further 7 frames. Each 7-frame, 7-slice sequence took approximately 5 mins and averaging was not necessary to achieve an acceptable SNR.
Using ImageJ (NIH, Bethesda, USA), the endocardium was manually delineated in each image to calculate the left ventricular end diastolic (EDV) and end systolic (ESV) volumes[3]. Stroke volume (SV) was calculated from their difference and ejection fraction (EF) from the ratio SV / EDV. Data from the two techniques were subjected to an independent sample, 2 tailed t-test to determine if there were significant differences. Also investigated were flow artefacts from the heart which manifested as spurious signals distributed along the phase encoding (PE) axis. To compare the two methods, an ROI was placed in the background region just outside the body and displaced along the PE axis from the heart and the average pixel intensity was divided by the standard deviation of the noise from a second ROI in an artefact-free region to give the artefact to noise ratio (ANR)[4].

RESULTS: Table 1 compares volumes recorded using the fast and slow techniques. The fast technique gives comparable ESV and EDV without any significant differences to the slow scan acquisitions ($p<0.05$). For the flow-artefact investigation, the "Fast" sequence ANR was 2.90±0.71 and for the "Slow", 6.85±2.95.

	Fast		Slow		*p* value
	Mean	SD	Mean	SD	
ESV (µl)	16.08	0.70	16.58	1.59	0.565
EDV (µl)	48.57	3.43	46.80	2.89	0.382
SV (µl)	32.49	2.82	30.21	1.82	0.113
EF (%)	66.85	1.15	64.59	2.01	0.072

Table 1: Comparison between ventricular volumes for the two sequences. Fast: *n* = 4, Slow: *n*=7

DISCUSSION: Whilst "Fast" imaging is significantly quicker compared to the single line of k-space "Slow" approach (roughly 15 mins vs 1hr for full left ventricular coverage at comparative frame rates), the images are noisier. However the reduced SNR does not significantly impact on the accuracy of left ventricular volume calculations. A second important improvement with the "Fast" sequence is the reduced flow artefacts as a result of the reduced *TE* and flip angle.

CONCLUSION: We have successfully implemented murine multi-slice, multi-phase cardiac cine imaging[2] at 4.7 T with full spatial coverage of the left ventricle in just 5 mins. The method shows reduced flow artefact (compared to the "Slow", single k-space line per R-wave method) at the expense of a reduction in SNR which, however, does not adversely impact on left ventricular volume calculations.

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