Assessment of Cardiac Function in the Rat Using an 11.75 T System with a Vertical Bore

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Introduction

High-resolution magnetic resonance (MR) imaging is uniquely suited for the accurate, non-invasive assessment of cardiovascular structure and function in rodents. Experimental scanners with high magnetic field strengths are commonly built with a vertical bore, which is well suited to perfused heart experiments. It has previously been demonstrated that there is no haemodynamic consequence of placing mice in a vertical position for MR assessment[1,2]. However the effect of placing a larger animal, such as a rat, in a vertical position is unknown. As such, we have compared the effects of horizontal versus vertical position on the cardiac function of the rat and subsequently demonstrated the ability to acquire high spatial and temporal resolution cine images using an 11.75 T MR system, enabling the accurate assessment of heart mass and function in the rat.

Methods

Haemodynamic Measurements

Five male Wistar rats (432±24 g) were anaesthetised with isoflurane and the left ventricle cannulated via the right carotid artery using a 1.4F Millar Mikro-tip cannula, specially adapted for use in the rat. Isoflurane was reduced to 1.0-1.5 % followed by a period of 15 minutes equilibration. When stable and reproducible readings were obtained, left ventricular haemodynamic indices were recorded on a Powerlab/4SP chart recorder (ADInstruments, UK) for 10 minutes in the horizontal supine position. To simulate conditions in the magnet, animals were then tilted into a vertical position (head-up) for a further 90 minutes, followed by a final 3 minutes in the horizontal position. Body temperature was maintained at 37 °C throughout.

MRI – Measurements

Three female Wistar rats (252±2 g) were anaesthetised with 2-2.5 % isoflurane. High-resolution, ECG triggered and respiration gated cine imaging was performed on a 11.75 T vertical bore MRI system (Bruker Medical, Ettlingen, Germany). The system comprised a shielded gradient system (strength 548 mT/m, risetime 160 µs – Magnex Scientific, Oxon, UK), a Bruker Avance console running Paravision™ v2.1 and a 60 mm diameter linear birdcage coil (Bruker Medical, Ettlingen, Germany). Cine imaging was performed using a gradient-echo sequence (α=15 °, TE=1.4 ms, TR=4.6 ms, NA=2), with approximately 30 frames per slice, depending on the heart rate. Imaging was performed on nine to ten short axis slices (slice thickness 1.5 mm) covering the entire long axis of the heart, giving a total scan time of approximately one hour. A FOV of 51.2×51.2 mm and a matrix size of 256×256 led to an in-plane resolution of 200×200 µm. The raw data were isotropically zero-filled by a factor of 2. Image segmentation of the left ventricular mass and volume was performed at end diastole and end systole using Scion Image™.

Results

Figure 1 shows the results of the haemodynamic studies in the horizontal position and at 10, 60 and 90 minutes after the animal was placed in a vertical position. No significant difference can be seen between the horizontal and vertical positions at any of the time points measured, indicating a normal haemodynamic profile for the rat in a vertical position for up to 90 minutes. Figure 2 shows (a) end-diastolic and (b) end-systolic images from a mid-ventricular slice. Segmentation yielded a left ventricular mass of 525±17 mg, an end-diastolic volume of 258±13 µl, an end-systolic volume of 62±10 µl and an ejection fraction of 76±3 % (Mean ± S.E.). These values are in agreement with cardiac MR measurements of the rat made in the horizontal position[3].

Discussion

We have demonstrated for the first time that haemodynamic function in the rat is not affected by adoption of a vertical position, and remains stable for up to 90 minutes. We have subsequently demonstrated the ability to assess cardiac structure and function in the rat using cine MR imaging, in a high field MR system with a vertical bore. The high field strength of the vertical bore system has enabled us to acquire images with a higher spatial and temporal resolution than has been previously demonstrated[3]. However, the move to higher field strength has been non-trivial due to technical challenges with the acquisition of ECG signals in the presence of induced signals from the motion of conducting blood in the high magnetic field. We plan to extend this work with the assessment of cardiac function in rats that are already haemodynamically compromised, for example, after myocardial infarction.

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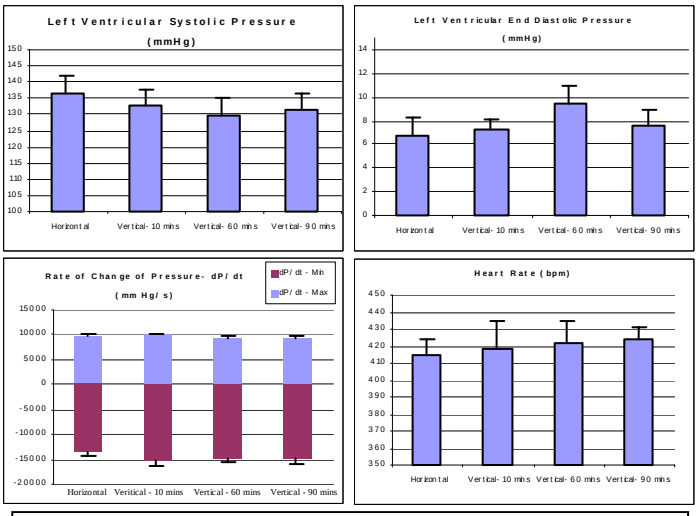

Figure 1 – (a) LVSP, (b) LVEDP, (c) dP/dt and (d) Heart Rate in Horizontal Position and at 10, 60 and 90 mins After Being Placed in the Vertical Position.

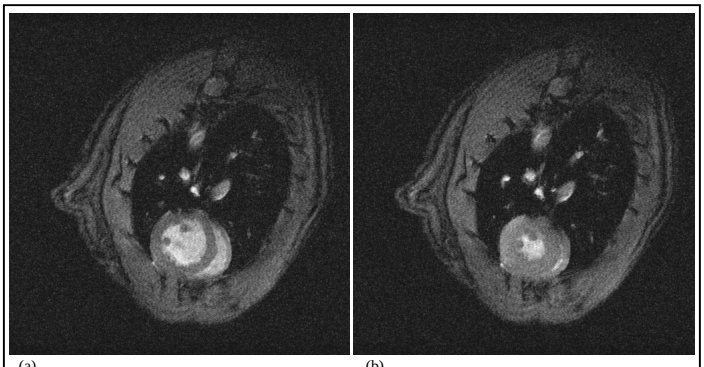

Figure 2 – (a) End Diastolic and (b) End Systolic Frames from Mid-Ventricular Short Axis Slice

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