Can we rely on the new 1T "benchtop" systems for investigating cardiac function and viability?

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TARGET AUDIENCE

Researchers studying myocardial viability and function, pre-clinical multi-modality imaging, high-throughput imaging and screening of therapeutics

PURPOSE

To investigate the feasibility of using "benchtop" MRI to assess cardiac function and viability in experimental myocardial infarction.

INTRODUCTION

With the advent of new magnet technology, low strength permanent magnetic field "benchtop" MRI systems claim to make high-performance preclinical MRI accessible to non-specialist researchers by providing an easy to use, cryogen free, compact and cost effective alternative to high field MR systems. Here we assessed the feasibility of using 1T benchtop MRI to measure cardiac function and viability in rats acutely after myocardial infarction. Results were compared to measurements made using high field 9.4T MRI and high frequency ultrasound.

METHODS

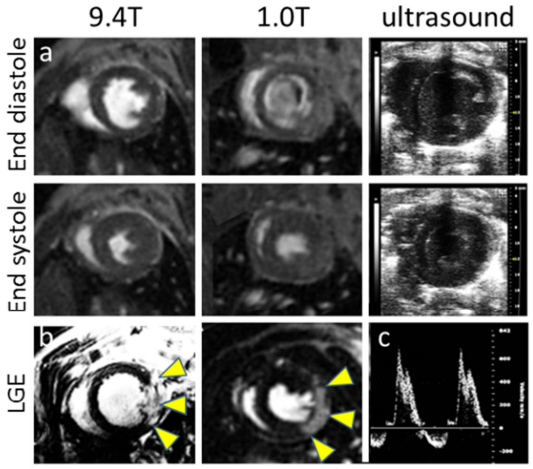
Myocardial infarction was surgically induced in 7 Wistar rats by permanent occlusion of the left anterior descending coronary artery as described [1].

Benchtop MRI was performed using a 1T Bruker ICON Scanner (Bruker BioSciences Corporation, Ettlingen, Germany) with a 44mm rat body solenoid RF coil. Cardiac and respiratory gated cineFLASH images were acquired in the true short axis to cover the entire left and right ventricles (8-10 slices, thickness 1.5mm, FOV 51.2 x 51.2 mm, matrix 128 x 128, FA 35°, TR/TE 14/4ms, cine frames 10-14, averages 2, approx acquisition time 15 min). Late gadolinium enhancement images (LGE) were acquired 15 min after i.p. injection of 0.5 mmol/kg Gd-DTPA using a single frame, multi-slice inversion recovery acquisition with the same geometry as above (FA 90°, TR/TE/TI 14/4/220ms, one phase encoding step per respiration, averages 1, approx acquisition time 2 min).

High field MRI was performed using a 9.4 T MRI system (Agilent Technologies Inc, CA, US) with a 72 mm transmit coil with a four-element receive array (Rapid Biomedical). Cardiac and respiratory gated cineFLASH images were acquired in the true short axis to cover the entire left and right ventricles (8-10 slices, thickness 1.5mm, FOV 51.2 x 51.2 mm, matrix 128 x 128, FA 15°, TR/TE 5/1.3ms, cine frames 28-35, averages 2, approx acquisition time 10 min). Late gadolinium enhancement images (LGE) were acquired 15 min after i.p. injection of 0.5 mmol/kg Gd-DTPA using a single frame, multi-slice inversion recovery acquisition (number of slices 14-16, slice thickness 1mm, FOV 51.2 x 51.2 mm, matrix 192 x 192 (FA 90°, TR/TE/TI 3.3/1.3/300-400ms, one phase encoding step per respiration, averages 1, approx acquisition time 3 min) as described [2].

Ultrasound was performed using a Vevo 2100 system with 25MHz probe (Visualsonics, Canada). Rats were anaesthetized, hair was removed from the chest and cine loops (30-37 frames) were acquired in the parasternal long axis and short axis at the base, mid and apex of the left ventricle, and pulse wave Doppler images were acquired in the apical 4 chamber view.

Image analysis for MRI data was performed using ImageJ. Volumes were calculated as the sum of all slices and infarct area was segmented after thresholding LGE images to 2 s.d. above the signal of the remote myocardium. Ultrasound images were analysed using the Visualsonics analysis package. Volumes were calculated using Simpsons rule, while LV filling parameters E & A were measured in the pulse wave Doppler acquisition. All measurements were made in triplicate.



	9.4T	1.0T	ultrasound
left ventricle			
Mass (mg)	690 ± 49	764 ± 45	860 ± 61
End diastolic volume (µl)	477 ± 25	397 ± 27	435 ± 31
End systolic volume (µl)	209 ± 16	163 ± 14	196 ± 17
Stroke volume (µl)	268 ± 25	234 ± 23	239 ± 27
Ejection fraction (%)	56 ± 3	59 ± 3	55 ± 4
Infarct size (mg)	99 ± 14	90 ± 20	-
Infarct size (% LV)	15 ± 2	12 ± 3	-
E/A	-	-	1.49 ± 0.15
right ventricle			
End diastolic volume (µl)	369 ± 35	290 ± 30	-
End systolic volume (µl)	94 ± 12	59 ± 13	-
Stroke volume (µl)	275 ± 28	231 ± 23	-
Ejection fraction (%)	75 ± 3	81 ± 3	-
Prep+acqui time (min)	24 ± 4	29 ± 3	7 ± 3*

RESULTS

High image quality and contrast was obtained in all cine acquisitions, although some signal attenuation occurred in the ultrasound images owing to rib shadows and edema from the surgical procedure (Fig 1a). LGE acquisitions gave excellent contrast between areas of infarction and viable myocardium across the whole heart (Fig1b). Doppler ultrasound allowed measurement of LV filling phases in all rats (Fig 1c). Quantitative analysis of function and viability showed no significant differences (ANOVA, $p > 0.05$) between measurements made using the three techniques (table, mean ± sem). However, it is important to note that ultrasound cannot accurately assess infarct size or right ventricular function, while MRI cannot easily assess diastolic function. Total acquisition time was shorter for the ultrasound acquisitions

DISCUSSION

Here we show that 1T benchtop MRI can assess myocardial viability as well as contraction in a rat model of myocardial infarction. Results compare well with high field MRI and US. Given that US acquisitions are considerably faster and have higher resolution than MRI it could be argued that US is a more effective choice for cine imaging than benchtop MRI. However, the ability to rapidly quantify infarct size, as well as RV function, demonstrates that this novel application of benchtop MRI can yield essential information beyond what is possible with US, providing a valuable tool for studying experimental myocardial infarction and therapy, and making cardiac MRI accessible to a wider experimental research community.

REFERENCES [1] DJ Stuckey et al. *MRM* (2008); 60:582-587. [2] AN Price et al. *JCMR* (2011); 13:4469-76.