# *In vivo* Cardiac cine $^{23}$Na MRI in rats

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**Background**

Absolute tissue sodium concentration is elevated in myocardial infarction and has been suggested as a biomarker for cell viability [1]. Sodium MRI is challenging due to relatively low $^{23}$Na concentrations in biological tissues, low NMR sensitivity and the short $T_2$ of the $^{23}$Na nucleus. On the other hand, the relatively short longitudinal relaxation time ($T_1$) of the $^{23}$Na nucleus (~30 ms), allows quantitative imaging with short repetition times (TR). Untriggered $^{23}$Na chemical shift imaging (CSI) was previously used for imaging of isolated perfused rat hearts [2]. For imaging of the *in vivo* heart, however, ECG-triggering is required to minimize image blurring due to cardiac motion, which poses restrictions on TR.

**Objectives**

To implement and test a new $^{23}$Na chemical shift imaging method for imaging of the *in vivo* rat heart during several different phases of the cardiac cycle with sufficient spatial resolution.

**Methods**

Female Sprague-Dawley rats (220-260g, n=6) were scanned in an Agilent 7T DirectDrive MRI scanner. Short-axis ECG-triggered/respiration-gated cine $^{1}$H MRI was performed using a gradient echo sequence with 128 x 128 matrix, 40 x 40 mm field of view for functional assessment and anatomical reference. 2D acquisition-weighted $^{23}$Na CSI was done using a home-built 30-mm Ø $^{23}$Na surface coil in transceiver mode. ECG-triggered $^{23}$Na images were acquired with a 40 x 40 matrix, 40 x 40 mm field of view and 3.5 mm slice thickness, TR 1 R-R interval (~180 ms) either at only 1 phase during the cardiac cycle (end-diastolic or end-systolic) or up to 6 phases (cine version, effective TR 30 ms) equally distributed over the cardiac cycle. The flip angle was adjusted for maximum signal per unit of time (90° for the conventional CSI and 68° for the cine CSI sequence with 6 phases). The total acquisition time was ~70 min. The CSI data was reconstructed using in-house written software and analysed using jMRUI (http://www.mrui.uab.es/).

**Results**

Figure 1 shows short-axis $^{1}$H (left), corresponding $^{23}$Na (middle) and overlay images at end-diastole (top row) and end-systole (bottom row). The myocardium as well as the left and right ventricle of the heart are clearly visible (figure 1). The $^{23}$Na myocardium/blood signal ratio was 0.46 ± 0.05, which is in good agreement with the reported value of 0.45 [3]. Using the cine version of the CSI sequence, several frames of the cardiac cycle could be recorded with reduced TR (~30ms) but similar image quality (myocardium/blood signal ratio: 0.44 ± 0.07 (figure 2)). The SNR of the cine CSI sequence was 38% lower than that of the standard CSI sequence as expected with this combination of TR and flip angle.

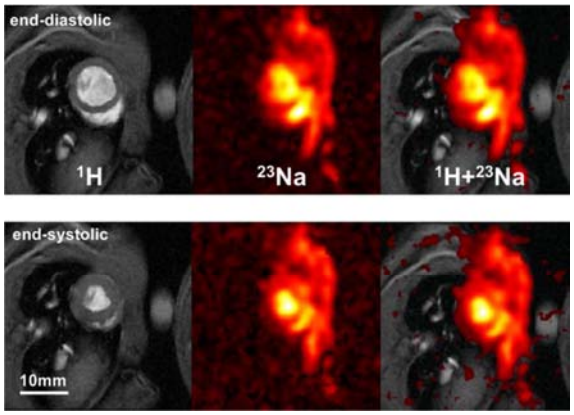


***Figure 1.*** *ECG-triggered $^{1}$H (left), $^{23}$Na CSI (middle) and overlay (right) images of a rat heart.*

**Discussion and conclusions**

To our knowledge, these are the first reported *in vivo* rat cardiac $^{23}$Na MR images. The CSI sequence can be used to acquire one or several phases during the cardiac cycle as shown above, but also in the multi-slice mode to cover multiple slices through the heart. When used in combination with a $^{23}$Na shift reagent, the sequence potentially allows for discrimination of intra- and extracellular Na signals, because the frequency information is preserved as opposed to other types of MRI sequences like ultra-short TE. This method offers a new tool for studying myocardial ion homeostasis *in vivo* and may be of interest for different areas of cardiovascular disease, e.g. myocardial infarction, myocardial hypertrophy, but could also be used to study other organs like kidney, liver or tumours.

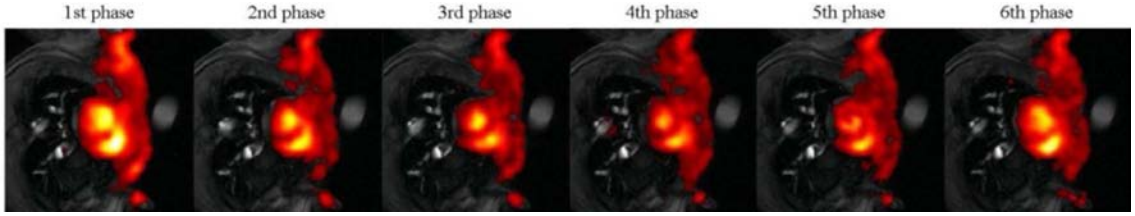


***Figure 2****. Cine $^{23}$Na CSI of different phases during the cardiac cycle, 30 ms apart, overlaid on $^{1}$H images.*

**References** [1] Kim RJ et al. Circulation 1999, 100(2):185-92. [2] Jansen MA et al. Circulation. 2004 Nov 30;110(22):3457-64. [3] Neuberger T et al. MAGMA 2004, 17:196-200.