# Intracellular sodium MRI during acute regional myocardial ischemia and reperfusion

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## Introduction

Due to the rapid changes of intracellular [$Na^+$] ([$Na^+$]$_i$) during ischemia and reperfusion of viable myocardium, $^{23}$Na-MRI appears to be an ideal diagnostic modality for early detection of myocardial ischemia and viability. So far, data on cardiac $^{23}$Na-MRI are extremely limited and are mostly concerned with imaging of total $Na^+$. For proper interpretation, imaging of both intra- and extracellular $Na^+$ is essential. Previously, using $^{23}$Na-MR chemical shift imaging (CSI) we found a very good correlation between $Na^+_i$-image intensity at the end of global low flow ischemia and recovery of rate pressure product at the end of reperfusion of isolated rat hearts[1]. This shows that $Na^+_i$-image intensity can predict the ability of myocardial tissue to recover after ischemia. In this study, the value of intracellular sodium imaging was assessed in a model of acute regional ischemia and reperfusion.

## Methods

Data were acquired using a Bruker AVANCE 400 spectrometer. Rat hearts were perfused using a dual-perfusion cannula[2], which allowed independent perfusion of both sides of the heart. To assess the area at risk, one side of the heart was perfused with a Gd-DTPA-BMA-containing perfusate and a $T_1$-weighted $^1$H-image was acquired after 15 min. Next, the contrast agent was omitted and the shift reagent $TmDOTP^{5-}$ was included in the perfusate on both sides to separate the intra- and extracellular sodium resonance. Subsequently, acquisition-weighted $^{23}$Na-CSI (16×16, FOV 20×20 mm, slice thickness 5 mm, voxel size 7.8 µl, 5 min/scan) was performed during control perfusion, ischemia of only the left side of the heart for 40 min (flow to the other side remained unaltered) and reperfusion. At the end of the experiment, the right side of the heart was perfused with methylene blue to determine the area at risk for histology. After that, the whole heart was perfused with 1% triphenyltetrazolium chloride (TTC) to stain the viable tissue.

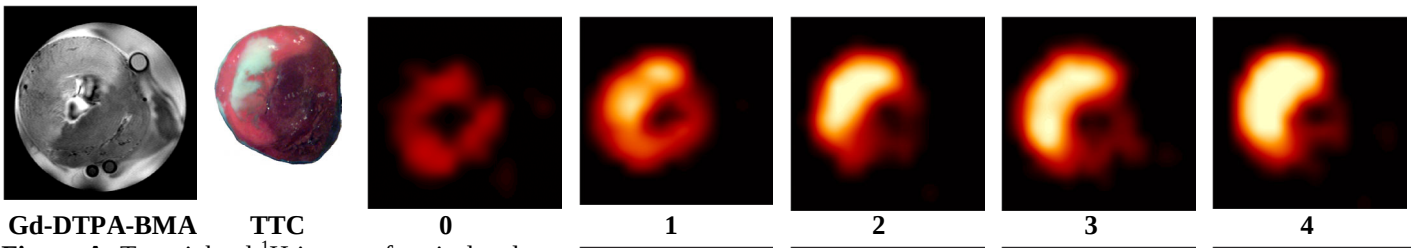


**Figure A.** $T_1$-weighted $^1$H-image of an isolated rat heart perfused with Gd only on the left side, showing the area at risk, a TTC-image showing also the infarct (white) and intracellular $^{23}$Na images during control perfusion (0), ischemia of the left side of the heart for 40 min (1-4) and reperfusion (5-8).

## Results and Discussion

Figure A shows short axis $^{23}Na_i$ images of a heart subjected to acute regional ischemia and reperfusion and the corresponding $^1$H- and TTC image. $Na^+_i$ was already visible during control perfusion. $Na_i$-image intensity increased significantly during ischemia of the left side to 345 ± 75 % while that of the right side remained unaltered. During reperfusion, $Na_i$-image intensity returned to normal in 2 of the 5 hearts. **Total** $^{23}$Na image intensity remained unaltered during the entire protocol in both sides of the heart. The area on the $Na_i$-image at the end of ischemia where $Na_i$-intensity was above 4% (% of the buffer) correlated well with the unstained area on the TTC-image (R=0.73). However, further research is necessary to confirm this finding.

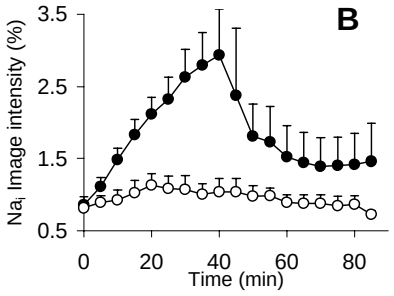


**Figure B.** Intracellular $Na^+$ image intensities relative to the buffer intensity (%) of the area at risk (closed circles) and the right coronary perfusion bed (open circles) (n=5 hearts).

## Conclusion

These data demonstrate that intracellular $^{23}$Na-CS-imaging is a promising tool for assessment of myocardial viability.

### References

1. Jansen MA and van Echteld [2003] *Proc ISMRM* 11:858
2. Avkiran M and Curtis MJ [1991] *Am J Physiol* 261: H2082–H2090