In Vivo Potassium (^{39}K) MRI of the Human Heart at 7.0 Tesla: Feasibility Study

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Target audience: Imaging scientists, clinical scientists, radiologists and experts interested in in vivo ^{39}K MRI

Introduction

Assessment and monitoring of viability of myocardial tissue is of profound clinical relevance and of prognostic value after an ischemic event[1]. Potassium (K^+) is the most abundant intracellular ion and plays a major role in myocardial physiology and viability[2,3]. The sensitivity gain of ultrahigh field MR ($B_0 \geq 7T$) provides an opportunity to probe the K^+ content of myocardial tissue in vivo with a spatial resolution and total acquisition time which could be acceptable for clinical applications. The goal of this study is to demonstrate the feasibility of in vivo ^{39}K MRI of the human heart at 7.0 Tesla. For this purpose preliminary in vivo ^{39}K/^{1}H images obtained from a healthy volunteer are presented.

Methods

^{39}K/^{1}H images were obtained using a customized RF coil. The RF coil design includes two sections: a flat posterior section and a curved anterior section to conform to an average human torso. Each section contains a large loop (270x280mm) element tuned to resonant frequency of ^{39}K and two smaller loop elements (220x200mm) tailored for ^{1}H MRI (Figure 1). The ^{39}K loops were connected and driven in the Helmholtz mode. The ^{1}H loops were driven in quadrature via a power splitter. In vivo datasets were acquired with a 7.0 T whole-body system (Magnetom, Siemens, Erlangen, Germany). ^{39}K imaging of a healthy male volunteer (age 27 years, BMI = 25 kg/m^2) was conducted using 3D-DAPR imaging technique (TR/TE = 30/0.7 ms, N_{proj} = 20.000, N_{avg}=3, total scan time = 30 min). Anatomical reference images were acquired using a gradient echo imaging technique: TR/TE = 6.6/3.3ms; acquisition time = 3 s.

Results

For ^{39}K MRI of the heart an isotropic spatial resolution of (14.6 x 14.6 x 14.6) mm^3 was achieved within total scan time of 30 min. Based on qualitative assessment, ^{39}K images of the upper torso showed an acceptable signal-to-noise ratio for the heart and the thorax and back muscles (Figure 2). ^{39}K signal from the muscles appears to be stronger than that from the heart because of the proximity of this tissue to the ^{39}K loops and due to partial volume effects.

Discussion and Conclusion

This work demonstrates that *in vivo* ^{39}K MRI of the human heart at 7.0 Tesla is feasible. The nominal spatial resolution of (14.6 x 14.6 x 14.6) mm^3 reported here is very much encouraging. All of the results were acquired under free breathing conditions; no cardiac triggering, cardiac gating or respiratory gating techniques were used in this study. To take the preliminary results shown here to the next level we will focus on the optimization of the imaging techniques used for ^{39}K. We also anticipate the acquisition of high spatial resolution ^{1}H images which will provide *a priori* knowledge for the reconstruction of the low resolution ^{39}K data sets. This approach will support the correction of partial volume effects intrinsic to the low spatial resolution ^{39}K data sets.

References

1. Parrish TB, et al., Theoretical Basis for Sodium and Potassium MRI of the Human Heart at 1.5 T, MRM 1997; 2. Carmeliet E., Cardiac Ionic Currents and Acute Ischemia: From Channels to Arrythmias, Physiological Reviews, 1999; 3. Haddy FJ, et al., Role of potassium in regulating blood flow and blood pressure, Am J Physiol Integr Comp Physiol, 2006

Figures

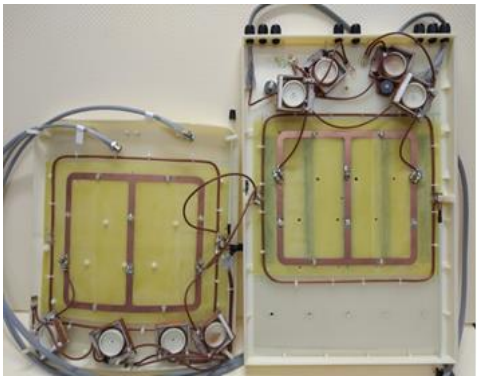

Figure 1: Anterior (left) and posterior part (right) of the RF coil which was used for ^{39}K/^{1}H MRI in our feasibility study.

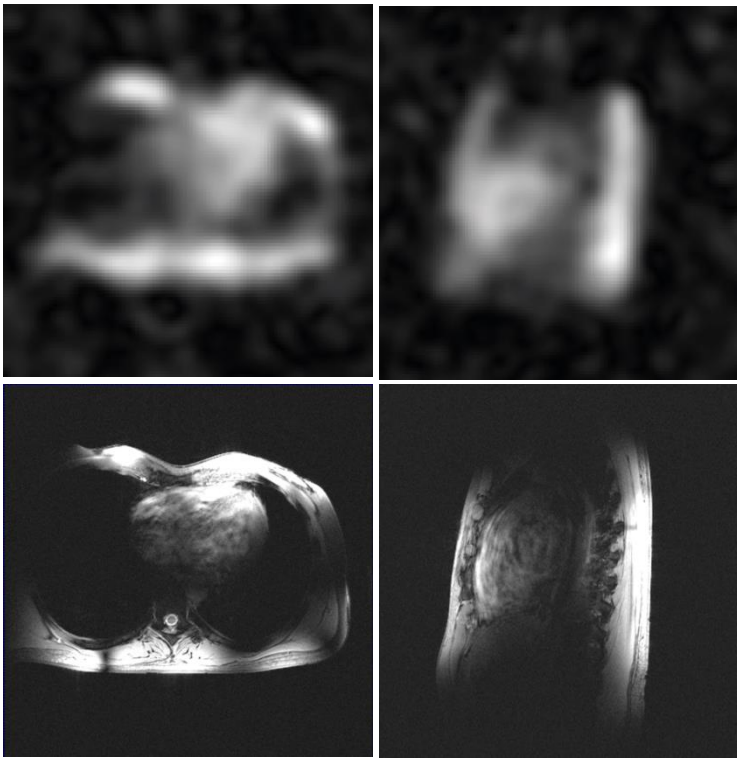

Figure 2: ^{39}K In vivo images of the human heart acquired with two loops driven in Helmholtz configuration (top row). ^{1}H images obtained with four-channel transmit/receive array (bottom row). FOV = 384 x 384 mm^2.