Quantification of renal R_2* index using BOLD-MRI: reproducibility and observation of age-dependence

S. Zoula[1], L. Hofmann[2], A. Giger[1], B. Vogt[2], P. Vock[1], F. J. Frey[2], C. Boesch[3]

[1]Institute of Diagnostic Radiology, University and Inselspital, Bern, Switzerland, [2]Division of Nephrology/Hypertension, University and Inselspital, Bern, Switzerland, [3]Dept. Clinical Research, University and Inselspital, Bern, Switzerland

Introduction

The dynamics of intra-renal oxygenation was shown to be observable non-invasively in humans using BOLD-MRI [1, 2]. This type of functional MRI of the kidney has received attention for many years, however, clinical applications are still limited, most likely because of difficulties in obtaining reproducible and reliable information. The present study aimed at evaluating the reproducibility and robustness of BOLD measurements in healthy volunteers. In addition, age-dependent BOLD effects in the kidney have been observed for a range of 20 – 57 years.

Methods

Eleven healthy volunteers (8 men and 3 women; mean age: 37.2 ± 12 years) were involved in this study. Measurements were performed on a 1.5 T MR system (SONATA, Siemens, Germany) using a body coil for transmission and a phased array surface coil for reception. A modified Multi Echo Data Image Combination sequence (TR: 65 ms, TE: 6-52.31 ms, flip angle: 30°) was used to acquire 12 T_2* weighted images within a single breath-hold. For each volunteer, 3 axial and 3 coronal slices were obtained in both kidneys, and the measurements were repeated three times in each volunteer (subjects were leaving the magnet between each measurement).

R_2* maps were calculated at each pixel using IDL (Interactive Data Language, RSI, Boulder, CO, USA): the signal intensity vs. echo time data were fitted to a mono-exponential function. ROIs were selected in medulla and cortex, and a mean value of R_2* index was determined. Two different selections of ROIs were made, one with fixed size, the second one in homogeneous regions, using variable size of the ROIs and carefully avoiding vessels.

The statistical significance of the results was analyzed using MANOVA for 3 Repeated Measures and 6 factors (volunteer, medulla/cortex, large/small ROI, left/right kidney, 6 axial/coronal slice orientations), with Bonferroni adjustment for multiple comparisons (SPSS 11.0).

Results

Slice position and location as well as ROI selection did not affect BOLD measurements (Fig.1). Similarly, the results derived from left and right kidneys in the same individual revealed virtually identical results (Fig.1). Highly significant differences were evidenced between volunteers ($p < 0.001$) and between medulla and cortex ($p < 0.001$). R_2* values showed a highly significant age-dependence (Fig.2) in the medulla (R_2* = 9.63 + 0.177*age, $p < 0.001$) and a tendency to increase in the cortex (R_2* = 10.9 + 0.019*age, $p = 0.053$). Repetition of measurements showed a tendency to increasing BOLD effects with time, however, without reaching significance over all data (Fig.1). Coefficients of variance (CV) for experimental errors were 13% if the influence of all other parameters was separated by MANOVA.

Fig.1: Reproducibility of BOLD measurements (mean ± sem)

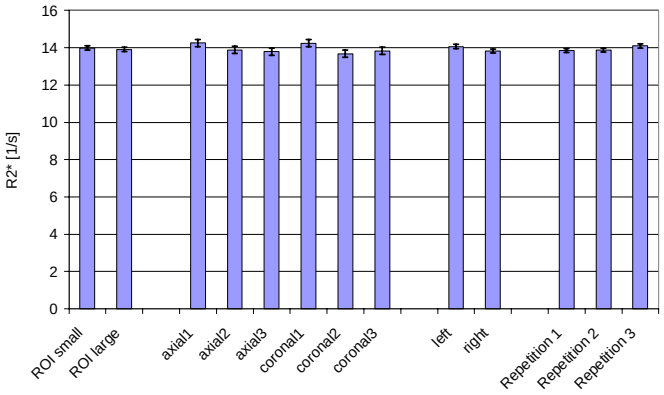
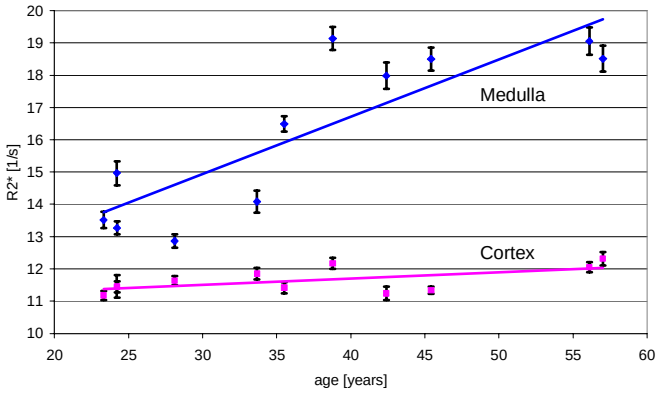


Fig. 2: Correlation of R_2* index with volunteers age (mean ± sem)



Discussion/Conclusion

Measurements of intra-renal oxygenation using the BOLD effect are reproducible with a CV of 13% and are robust, since R_2* values were independent of slice position or orientation, and of the choice of small or large ROIs. Furthermore, they are indistinguishable between left and right kidney in healthy volunteers. The results also confirm a cortico-medullary gradient of R_2* values, presumed to be due to different oxygenation levels. R_2* values in the medulla and less in the cortex increase with age. A tendency to increased BOLD effects with time, i.e., with repeated measurements, could be explained by the effect of lying in the magnet. BOLD measurements in the kidney are highly reproducible; however, age dependence [2] and a tendency to increased values with time in the magnet should be considered when studies of BOLD measurements in the kidney are designed.

References

1.Prasad, P.V., Edelman, R.R., and Epstein, F.H., Circulation, 1996. **94**(12): p. 3271.
2.Epstein, F.H. and Prasad, P., Kidney Int, 2000. **57**(5): p. 2080.