

Reproducibility of renal artery flow and BOLD ($R2^*$) in renal impaired patients

Dinah S Khatir¹, Niels H Buus¹, and Michael Pedersen²

¹Department of Nephrology, Aarhus University Hospital, Aarhus, Denmark, ²MR Research Center, Aarhus University Hospital, Aarhus, Denmark

Introduction: Hemodynamic and metabolic factors play an important role in the development of chronic kidney disease (CKD), with reduced renal blood flow accompanied by intrarenal ischemia, promoting formation of fibrosis in the renal parenchyma independent of the underlying pathology. Measurements of renal artery blood flow (RABF) is readily available using a phase-contrast velocity-sensitive MRI sequence, whereas the blood oxygenation level dependent (BOLD) sequence has proven sensitive to tissue oxygenation (according to the relationship between $R2^*$ and deoxyhaemoglobin content). However, no studies have evaluated the reproducibility of MRI-based RABF and BOLD ($R2^*$) in patients with CKD suffering from hypertension. Thus, the aims of the study were to evaluate the reproducibility of RABF and BOLD in patients with CKD grade 3 and 4 with hypertension, and to compare findings from healthy volunteers. Second, we investigated the reproducibility of intrarenal BOLD MRI in response to altered respiratory levels of oxygen.

Methods: Eleven patients diagnosed with CKD were recruited from the outpatient clinic, and nine healthy volunteers with normal kidney function and blood pressure and not receiving any medication served as controls. MRI was performed with a 1.5 T clinical system. RABF of each kidney was performed with a 2D phase-contrast gradient-echo sequence using the following parameters: $2.5 \times 2.5 \times 5 \text{ mm}^3$ voxels, field-of-view $\sim 320 \times 160 \text{ mm}^2$, TR/TE = 95 / 3.2 ms, 30° excitation flip angle, 2 averages, <128 phases (depending on heart rate), 7 segments, 100 cm/s velocity encoding. BOLD MRI was performed with a multi-echo gradient-echo sequence in the axial plane, crossing perpendicular to the two kidneys. The sequence parameters were: $3 \times 3 \times 5 \text{ mm}^3$ voxels, $\sim 250 \times 250 \text{ mm}^2$ field-of-view, TR/TE = 50 / 2,4,6,8,10,12,14 ms (for $R2^*$ mapping), 60° excitation flip angle, 250 Hz/pixel, 8 averages. After the first BOLD sequence was acquired, the participant was asked to breathe 100% oxygen for 5 min using a close fitting facemask covering the mouth and nose, after which the BOLD sequence was repeated. Participants were divided into two groups: patients and controls. For calculations, each participant was subdivided into two kidneys (right and left) with two scans (1: first and 2: second), which gave a total of 4 observations per person. Furthermore, BOLD MRI included regional data from cortex and medulla breathing, acquired during either air or 100% O_2 breathing.

Results: The plot of first against second RABF measurement showed good agreement for both groups (Fig 1). Calculated intra-class correlation (ICC) showed relatively high values (≥ 0.78) for both patients and volunteers, and calculated coefficient of variation (CV) showed low/intermediate values for patients (<13%) and low for volunteers (<8%). BOLD MRI showed that $R2^*$ values were lower in the cortex compared to the medulla in both groups. We found no systematic differences between first and second $R2^*$ measurements for left or right kidney (neither in cortex nor medulla), both in patients and healthy volunteers (Fig 2). $R2^*$ values in the cortex did not change after breathing 100% oxygen in either patients or healthy volunteers, but decreased significantly in the medulla in both groups (up to 15%). Repeated $R2^*$ measurements revealed a relatively moderate/high ICC (≥ 0.42) and low CV (≤ 0.85) for both patients and volunteers in the cortex before and after breathing 100% oxygen.

Discussion: This study showed that RABF and cortical BOLD MRI were reproducible in both healthy volunteers and patients with CKD and hypertension. Furthermore, we found that inhalation of 100% oxygen significantly increased $R2^*$ in renal medulla in both groups. RABF measurements may serve as a sensitive biomarker for hemodynamic monitoring in CKD patients suffering from hypertension. We observed that $R2^*$ reproducibility in the cortex was generally better than the medulla, where CV was low in the cortex and higher in the medulla, both before and after breathing 100% oxygen. However, care should be taken to perform $R2^*$ measurements using standardized patient positions in the scanner; otherwise, changes in magnetic susceptibility may corrupt measured $R2^*$.

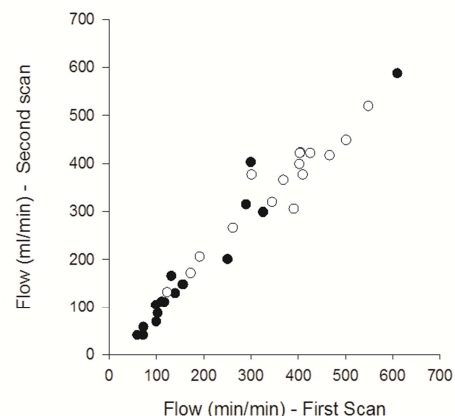


Figure 1: Scatter graph (First scan vs Second scan) of RABF in CKD patients (●) and healthy volunteers (○) for measurements of both left and right kidneys.

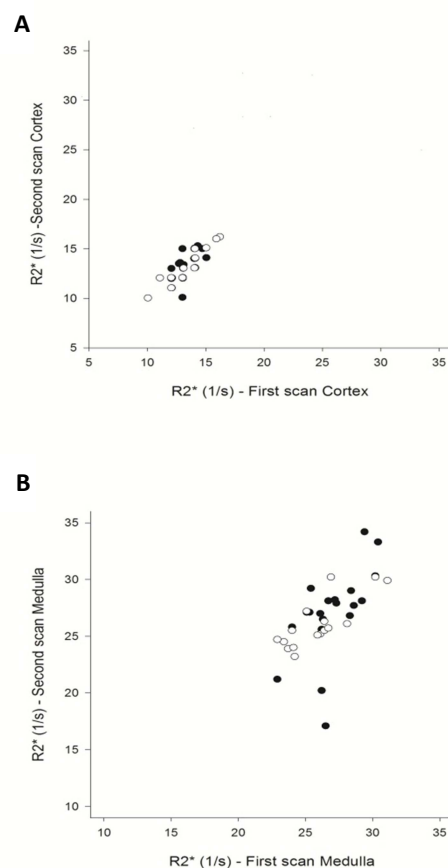


Figure 2: Scatter diagram depicting of $R2^*$ (1/s) values of first and second scan in the cortex (A) and medulla (B) in patients (●) and healthy volunteers (○).