Renal hemodynamics and deoxygenation in transient renal artery occluded rats evaluated with USPIO perfusion and BOLD imaging

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Introduction

Mild or severe renal arterial occlusion is a phenomenon occasionally observed in daily clinical practice, potentially leading to renal ischemia and a general degration of renal function. Secondly, closing the blood flow to the kidneys is additionally occurred during kidney transplantation procedures. However, the exact physiological effects of these conditions on renal blood perfusion as well as the renal oxygen handling are poorly understood. The objectives of this study were therefore to measure the lateral changes of renal blood perfusion in rats subjected to transient unilateral arterial occlusion (TUAO), and in addition, to measure the consequences of this disease on the intrarenal oxygenation.

Methods

Experimental studies were performed using five adolescent Wistar rats (~250 g). The left renal artery was exposed through a flank incision and acute TUAO for 45 min was achieved by placing a ligature around the renal artery. MRI was performed 3 days after the surgical procedure. Magnetic resonance imaging was performed with a Philips Intera 1.5 T clinical system. To avoid movements of the kidneys during free breathing, an in-house-made plastic holder was used to block the movements of the kidneys and isolate them from bowel loops while avoiding compression of the parenchyma and renal vessels [1]. BOLD MRI was acquired in order to obtain specific information on the renal oxygen concentration. A double-echo gradient-echo sequence was used to determine R2*, which has been shown to be a good marker for level of tissue oxygenation. Using a TE of 8 and 25 ms in combination with a 35° flip angle and a TR=110 ms resulted in heavily 1/R2* weighted images. The number of data averages was 16, slice thickness = 2 mm, field-of-view = 13×10 cm, and the acquisition and reconstruction matrix was 256×256. Perfusion weighted imaging was employed using a dynamic susceptibility weighted fast low-angle shot (FLASH) sequence. Approximately 10 s after start of data acquisition, a single bolus of USPIO (Sinerem®; Guerbet, Paris, France) was administered rapidly in less than one second, which corresponded to a dose of 90 µmol Fe/kg. A dynamic series of 120 images was obtained using the following sequence parameters: TR/TE/flip angle = 12 ms /4 ms /9°. All post-processing analyses were performed on a pixel-by-pixel level. The R2* values were calculated by applying a Levenberg-Marquard fitting algorithm to a monoexponential model. Because of the intravascularity of the contrast agent, the dynamic signal intensity in the tissue was approximated to be dependent only on the susceptibility effect due to the large large magnetic moment and a high dipolar relaxivity. Calculations of relative renal blood flow (RBF), relative renal blood volume (BV) and mean transit time (MTT) were based on the singular value decomposition (SVD) algorithm and the central volume principle [2].

Results

Figures below demonstrated the cortical and medullary R2*, MTT, RBV and RBF in the ipsilateral and contralateral TUAO rat kidneys. Main findings were: 1) ipsilateral medullary R2* was likewise decreased as compared with contralateral medullary R2*, 2) both ipsilateral cortical and medullary MTT was increased, 3) no ipsilateral vs contralateral RBV difference was observed, and 4) in the cortex and in the medulla, the ipsilateral rRBF was markedly decreased as compared with contralateral rRBF.

Discussion

This study demonstrated that rapid dynamic MRI bolus administration of USPIO revealed a considerable difference in the renal tissue deoxygenation level and renal hemodynamic parameters of blood. The latter was conducted using the deconvolution approach with resulting values in accordance to those presented from studies based on radionuclides. The higher oxygenation level measured within the ipsilateral medulla (decreased R2*), whereas the blood flow was decreased, is probably related to a lower reabsorption load within the ipsilateral kidney. However, there remain several issues to be solved, for example the fact that hemotocrit may not be constant in all parts of the kidney and the water exchange problems related to the water diffusion from intra- to extravascular space.

References

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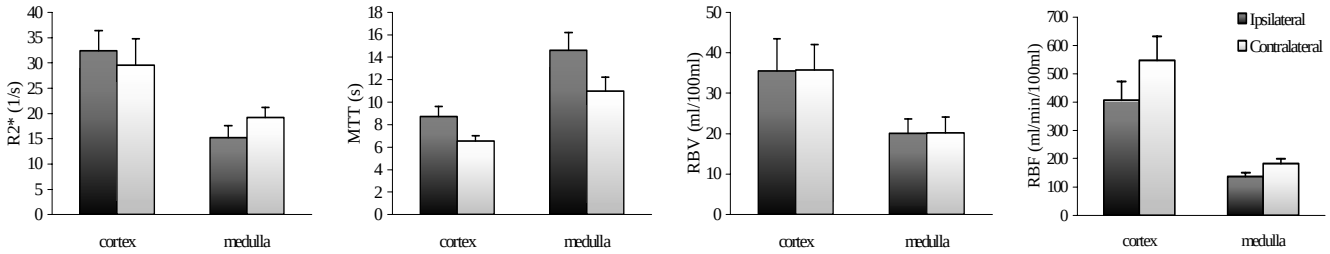

Figure. The cortical and medullary deoxygenation level (R2*), mean transit time (MTT), relative renal blood volume (RBV) and relative renal blood flow (RBF) in the ipsilateral and contralateral transient renal artery occluded rat kidneys.