The Porcine Kidney as a Biological Phantom for MR ASL Perfusion Measurements

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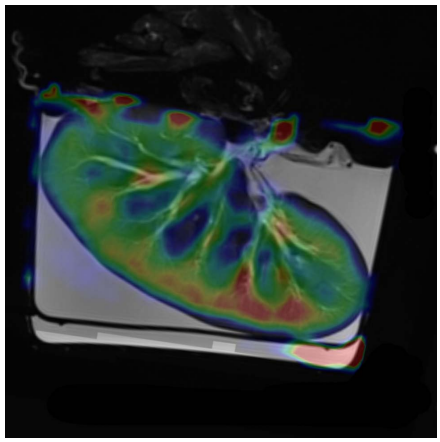
Introduction. Perfusion describes the rate of delivery of arterial blood to the parenchymal tissue and is a valuable physiological parameter for detection of ischemia and function. Most imaging modalities provide methodology for perfusion evaluation with varying degrees of accuracy and reproducibility [1], typically using a tracer in the blood or even the blood itself as in spin labeling techniques. To date, a controlled system for validation of perfusion methodology in MR has not been developed. A biologically relevant system would be needed to fully characterize perfusion methodology using the various imaging modalities. Since microvasculature is difficult to model and/or manufacture in phantom construction [2], this work describes a perfusion model for MR developed using a fixed *ex vivo* porcine kidney. Previous study using dye dilution in the *ex vivo* kidney using CT have been successful [3], which prompts this investigation into the MR behavior of an artificially perfused kidney model. For simplicity, the organ model is first evaluated using Arterial Spin Labeling (ASL) since the tracer kinetics of MR contrast agents in the model are currently unknown.

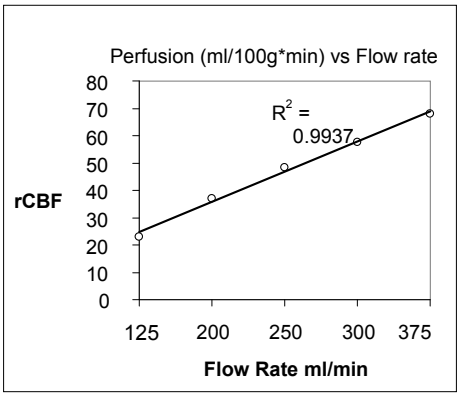
Methods. The porcine kidney is an effective biological phantom due to a dense capillary system, high rates of *in vivo* perfusion and an accessible vascular supply which is integrated easily into a flow circuit.

Sample fixation. A fresh porcine kidney was obtained from an abattoir, immediately flushed with saline and placed in a cooling box for transport. In the lab, flushing the organ with a solution of 130 ml formalin (37 %), 70 ml Phenoxethol (1 %), 320 ml water and 1000 ml ethanol (96 %) fixed the vessels, followed by 2 weeks of fixation in 5% formalin. After fixation, catheters were sutured onto the main artery and vein.

Imaging Protocol. MR imaging measurements were obtained on a 1.5T clinical system (Siemens AG, Erlangen) with the kidney submerged in an open basin. Extension tubing connected a peristaltic pump (placed outside the magnet room) to the kidney's arterial supply while the venous side was drained to basin (open circuit). Five flow rates between 125 and 375 ml/min were measured using isotonic saline 0.9% (T1 ~ 3000 ms) as the working fluid. MR structural images were acquired using a 3D, 1 mm isotropic, T2-weighted, variable flip angle sequence (SPACE). Quantitative arterial spin labeling imaging was acquired using 2D EPI and PICORE-Q2TIPS for labeling. The labeling region was placed inferior to the kidney to label the inflowing saline in the extension tubing. A 5 cm long, 7 mm diameter expansion chamber was placed inline in the tagging region to expand the bolus of labeled saline. The labeling inversion time TI2 was varied linearly with the flow rate to account for transit time changes (TI2 3000ms @125 ml/min, 190 pairs and TI2 1000 ms at 375ml/min, 70 pairs), while keeping the bolus duration TI1 fixed at 500 ms. CNR was preserved in the late TI2 images by increased averaging. Quantitative estimates of rCBF were estimated as in [4] assuming a labeling efficiency of 95% and λ of 0.9 ml/g. Six 6 mm slices covered the kidney with 3 mm in-plane resolution.



Results. Image fusion of an rCBF map with the underlying anatomy is show in Fig. 1 for an example slice at a flow rate of 200 ml/min. The results show strong correspondence of artificial perfusion signal and the cortex of the kidney in strong correlation with *in vivo* physiology. In the base T2-weighted images the intact arterial network is observed. Tagged saline which was not delivered to the kidney collects in the bottom of the basin. The artifacts above the phantom are related to EPI susceptibility artifacts. Fig. 2 displays a plot of the calculated mean rCBF (based on a common ROI analysis) versus flow rate. The trend line describes a linear response with flow rate.



Discussion. A result of the previous CT study [3] on the fixed kidney was the observation of an excellent linear relationship of the measured tissue flow values and the incoming flow rate. An aim of this work was to test if this also holds for MR as the imaging modality, which is strongly supported by the results. Another observation relative to the CT results is an underestimation of rCBF at each flow rate. This notable discrepancy could by explained both by an overestimation of the CT perfusion results due to large vessel signal contamination or the observed leakage and shunt flow of tagged blood which reduces the labeling efficiency of ASL from the assumed value of 95%.

Conclusion. The fixed ex vivo porcine kidney provides a robust biological phantom for multi-modality comparisons of perfusion imaging.

References. **1.** Wintermark M, et al. Stroke **5**:36, p83, 2005 **2.** Lorenz C, et al. MRM **19**:2, p254, 1991 **3.** Haberland U, et al. Investigative Radiology **44**:10 p 676, 2009 **4.** Wang JJ, et al. JMRI **18** p404, 2003