Fully MR-guided selective renal embolization techniques

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Introduction: For conservative treatment of focal kidney malignancies, minimally invasive transcatheter embolization may be employed. Exemplary treatments are the embolization of renal masses, embolization of renal angiomyolipoma[1], or the irradiation of renal tumors[2] with radioactive microspheres (similar to the selective internal radiation therapy (SIRT) of liver tumors[3]). For a successful treatment, accurate positioning of the catheter and evaluation of the therapy are essential. It can be argued that the use MRI may be advantageous for these applications, more than the currently used X-ray techniques. First, if the catheter is positioned under MR guidance, the X-ray dose is reduced (or absent), which is especially relevant during treatment of children. Second, MR contrast agents are less nephrotoxic than X-ray contrast agents, which is specifically a benefit for kidney patients. Third, MRI allows the depiction of soft tissue (tumor, anatomy) and the acquisition of functional information (perfusion, flow), which facilitates the evaluation of treatments. In this study, we demonstrate the feasibility of a real-time fully MR-guided superselective catheterization of the kidneys and illustrate the potential of MRI for guidance and evaluation of the procedure by simulating embolization procedures in parts of in vivo kidneys of two pigs.

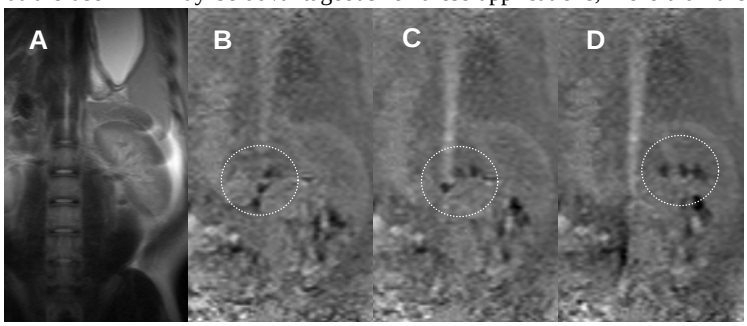

Figure 1: *Example of the real-time MR guided catheterization of the left renal arteries. (a) Anatomy, (b-d) Subsequent tracking images (created by subtraction from a baseline image). Markers on the catheter are indicated by the white circles. TE=4.6 msec, slice 30 mm.*

Method: *Catheterization:* For the superselective positioning of the catheter, a passive tracking technique was employed that allowed a real-time depiction of three paramagnetic markers (dysprosium oxide) that were mounted on a 4F headhunter catheter. The frame rate of the tracking sequences was increased by segmented EPI and parallel imaging (SENSE), up to 20 frames per second. *Microspheres*: the microspheres that were injected were either made of poly(L-lactic) acid, loaded with non-activated holmium (HoMS)[3], size 20-50 μm, or made of alginate without loading of holmium (300 μm). The alginate spheres were manufactured using a jet-cutter technique[4]. *Angiography & Embolization*: Shortly before administration of the microspheres, anatomic images (T_1-SE, T_2-SE, T_2*-GE) were made and time-resolved selective angiography was employed (60 mm slice, TR/TE/flip = 4.3/1.3/40°, diluted Magnevist (15%)). After super-selective catheterization, angiography was repeated. Then, without repositioning the catheter, a 100 ml saline flush was given, followed by the injection of the microspheres: 200 mg of HoMS or 0.05 ml of alignate spheres. The injection of the HoMS was monitored with a dynamic T_2*-w GE sequence (TR/TE/flip = 12/4.6/15°, 2.2 sec per dynamic). After administration of the spheres, the catheter was withdrawn and selective angiography of the complete kidney was repeated, as was the anatomic series.

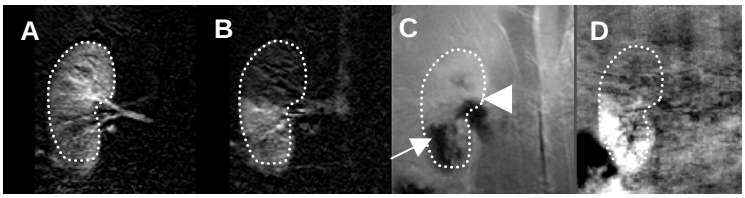

Figure 2: *Selective delivery of holmium-loaded microspheres to the right kidney of a pig. (a) Single frame of the selective angiography of the right kidney, (b) superselective angiography of the lower half of the kidney, (c) single frame of the dynamic T_2*-w GE (TE=4.6 msec) sequence showing the deposition of the paramagnetic holmium-loaded microspheres (arrow) (d) total intensity projection of the difference of multiple anatomic T_2*-w images. Background noise is created by motion of signal giving abdominal structures. Note that the collection of contrast agent in the kidney base creates a signal void in T_2*-w imaging (arrowhead).*

Results: Real-time MR guidance allowed accurate catheter positioning (Fig. 1) and good visualization of the markers on the devices, even at 20 frames per second. Deposition of the holmium-loaded microspheres was easily visualized by dynamic T_2*-w GE imaging. The region of signal loss in the anatomic series corresponded to the target region as predicted by the superselective angiography (Fig. 2). The use of the time-resolved angiography to detect the embolization by alginate spheres resulted in a good qualitative depiction of the dynamics of kidney perfusion. The target area as predicted by the superselective angiography (Fig. 3) matched the perfusion deficit after administration of the alginate spheres.

Discussion: In this study, we illustrated the techniques for a fully MR-guided selective renal embolization, which may be employed in conservative treatment of renal malignancies. The use of the full MR-guidance cancels the need for X-ray and, therefore, eliminates the X-ray dose for patients and staff. Although the current techniques allow a reliable device visualization at 20 frames/second, the used devices are still suboptimal in terms of MR safety (metal guidewire, braiding) and clinical practicability (home built markers), but that does not compromise the principle of an MR-guided catheter placement. For the microspheres, loading with a radionuclide like holmium may allow irradiation of renal tumors and holmium can be depicted in T_2*-w GE images. A disadvantage of the holmium loading of the microspheres is that the T_2* effect of holmium may interfere with contrast-enhanced T_1-w GE angiography. Finally, for the evaluation of the embolization, time-resolved contrast enhanced angiography was used, which gave good qualitative insight in the dynamics and distribution of the renal perfusion. However, the collection of contrast agent at the base of the kidney may give undesired susceptibility artifacts and in that case arterial spin labeling (ASL) techniques may also be employed for the evaluation of perfusion and/orembolization.

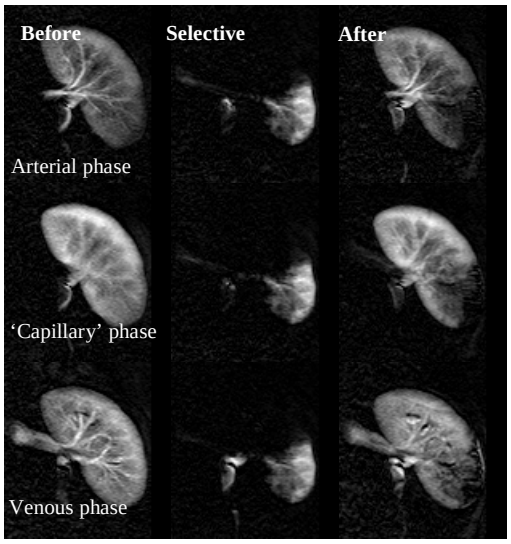

Figure 3: *Selective angiography of the left kidney before and after embolization with alginate spheres (300 μm). Superselective angiography of the lower part of the kidney indicates the target area. After embolization, selective angiography of the kidney showed a perfusion deficit (right column). Angiography was done during breath hold and at a frame rate of 1.6 fps.*

References: [1]Bissler JJ, Kidney Intl, 2004, 66: p. 924 [2]Glick RD, J.Ped.Surg.2004: 39(4): p. 522 [3]Nijsen JF, Radiology 2004, 231(2), p. 491 [4]see http://www.genialab.com