MR-Guided Percutaneous Nephrostomy of the Non-Dilated Upper Urinary Tract in a Porcine Model

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Introduction
In the last 15 years, image-guided percutaneous nephrostomy has replaced an open surgical approach for temporary drainage of the urinary collecting system because the percutaneous technique has proved to be faster, less expensive, and less morbid. The reasons for this include the small access tract needed and the guiding modalities which demonstrate the relative positions of the needle and target as well as any intervening structures. Usually, percutaneous nephrostomy is performed under ultrasound guidance in a fluoroscopic suite. In few cases, however, CT is used instead of ultrasound for initial needle placement. The cross-sectional imaging modality is used for gaining access to the urinary collecting system, while the draining catheter is placed under fluoroscopic guidance. Using MR imaging for both steps of the intervention avoids ionizing radiation as well as the need for patient transportation (e.g., from the CT scanner to the fluoroscopy suite). We therefore sought to determine whether MR guidance during percutaneous nephrostomy of the non-dilated upper urinary tract in a porcine model is feasible and safe.

Materials and Methods
MR-guidance and monitoring of percutaneous nephrostomy was performed using a modified 0.2-T clinical C-arm imaging system (Magnetom Open, Siemens). A belt-shaped 21-cm diameter multi-turn solenoid receive-only coil was used for signal reception. Following a protocol approved by the Institutional Animal Research Committee, 4 domestic farm pigs (female, 20-25 kg) were anesthetized using a combination of acepromazine (0.25 mg/kg) and ketamine (7.5 mg/kg) by IM injection. Pentothal was administered (15 mg/kg) via IV injection to allow tracheal intubation and anesthesia was maintained using redosing of pentothal. The pigs were placed obliquely on the MR scanner table. In the last two pigs, percutaneous nephrostomy was performed bilaterally after adequate repositioning of the animals. Following axial T2-weighted turbo spin-echo imaging, gadodiamide (0.2 mmol/kg), furosemide (0.4 mg/kg), and 250 ml of physiologic saline solution were administered intravenously. The desired renal calyx was predetermined on axial T1-weighted spin echo images acquired ten minutes after administration of the diuretic agent. The target was localized relative to the skin surface using a fluid-filled syringe. An 18-gauge x 10 cm MR-compatible needle was advanced under a continuous imaging mode consisting of the repeated acquisition, reconstruction, and display of a set of three parallel 5-mm slices. Following placement of the needle tip in the predetermined calyx, the position was confirmed using a T1-weighted turbo spin-echo sequence. An angled nitinol guidewire (0.035-inch x 150 cm, flexible tip length of 3 cm), coated with an undiluted superparamagnetic iron oxide-containing contrast medium (SPIO) was inserted using Seldinger technique under MR guidance. This was followed by the dilation of the needle tract under MR monitoring (5-French x 20 cm dilator). Finally, a 4-French x 8 cm sheath was inserted, and tip position was confirmed with a T1-weighted turbo spin-echo sequence. Furthermore, a diluted SPIO solution (0.1ml Ferridex in 3 ml physiologic saline solution) was injected via the sheath under MR monitoring to confirm correct placement of the device within the urinary collecting system.

Results
Ten minutes after administration of gadodiamide and furosemide in addition to physiologic saline solution, the urinary collecting system appeared hyperintense on spin echo T1-weighted imaging with a renal calyx size not larger than 8 mm and a maximum renal length of 10 cm (9.2 ± 0.4 cm). In all cases, a calyx in the middle portion of the kidney was predetermined as the target for needle insertion. Artifact size of the 18-gauge MR-compatible needle ranged from 6 to 8 mm on gradient echo imaging, and allowed needle insertion in the predetermined target without complication in the first attempt in all six cases. On turbo spin-echo T1-weighted imaging for needle tip position confirmation, artifact size was 5 mm, but these images allowed better demarcation of the needle tip. Procedure time for MR-guided needle insertion ranged from 4 to 13 min (6 ± 4 min). After removal of the needle stylet, clear urine could be aspirated in all cases. An angled guidewire, coated with an undiluted SPIO, was inserted using coronal gradient echo imaging for guidance. The guidewire could be easily identified as a hypointense structure of about 3 mm width within the contrast-enhanced, hyperintense renal collecting system. Axial Fast Imaging with Steady-State Precession was used to confirm correct guidewire placement. After withdrawing the needle shaft, the tract was dilated in a typical manner, and a 4-French sheath was inserted over the wire. These steps of the procedure were again controlled using coronal and axial Fast Imaging with Steady-State precession. Successful sheath insertion was possible in all cases except the first. Procedure time starting with the styllet removal and ending with sheath confirmation ranged from 6 to 28 min (16 ± 9 min). In no case was additional gadodiamide injection necessary, either IV or via the nephrostomy tract. Diluted SPIO injection via the sheath confirmed physiologic flow conditions within the renal collecting system in all cases in which a sheath could be placed successfully. A urinoma smaller than 1 cm resulted in all cases, starting to develop with the removal of the needle shaft, and ending with the sheath insertion. No other complications occurred during MR-guided percutaneous nephrostomy.

Discussion
In 1998, Nolte-Ernsting et al. described their initial experimental results of MR-guided percutaneous nephrostomies of the contrast-enhanced non-dilated upper urinary tracts of three pigs (male, 42-61 kg body weight). They used a closed cylindrical 1.5-T high field system with limited access to the animal to perform their study. In contrast to Nolte-Ernsting et al., we performed our experiments on smaller pigs (about half the body weight) in an open 0.2-T system with wide access to the animals. Successful needle insertion in the predetermined target was accomplished in the first attempt in all six cases without complication. Procedure time for MR-guided needle insertion ranged from 4 to 13 min (6 ± 4 min), and was much faster than Nolte-Ernsting et al., who reported taking 30 to 40 min for planning and successful puncture of the collecting system. The extended planning and needle insertion time might be due to the cumbersome set up of repeatedly removing and repositioning the pig in a conventional cylindrical system for every step of the device insertion. The nitinol guidewire could be identified easily as a hypointense structure of about 3 mm width within the hyperintense renal collecting system. This is due to the SPIO coating, which was achieved by placing the wire tip in undiluted SPIO for ten minutes. Successful sheath insertion was possible in all cases except the first, which represented the not unexpected learning curve for a new interventional procedure. Procedure time, starting with styllet removal and ending with sheath confirmation, ranged from 6 to 28 min (16 ± 9 min). In no case was additional gadodiamide injection necessary, either IV or via the nephrostomy tract. Diluted SPIO injection via the sheath confirmed physiologic flow conditions within the renal collecting system in all cases in which a sheath could be placed successfully. A urinoma smaller than 1 cm in axial dimension resulted in all cases as the only complication; its development began with removal of the needle shaft and ended with sheath insertion. The discrepancy between the wire diameter and the width of the needle tract, especially after dilation, is responsible for urinoma development. Possible indications for MR guidance during percutaneous nephrostomy include non-dilated uropathies such as ureteral fistulas. Other indications might include undiluted ureteral strictures related to multiple parapelvic cysts or cysts in which sonographic or fluoroscopic guidance is extremely difficult (e.g., obesity, meteorism). Finally, MR imaging may be considered for guidance of endoureteral endoscopic interventional procedures.

References