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1pPAb5. Acoustic radiation force to reposition kidney stones

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Our group has introduced transcutaneous ultrasound to move kidney stones in order to expel small stones or relocate an obstructing stone to a nonobstructing location. Human stones and metalized beads (2-8 mm) were implanted ureteroscopically in kidneys of eight domestic swine. Ultrasonic propulsion was performed using a diagnostic imaging transducer and a Verasonics ultrasound platform. Stone propulsion was visualized using fluoroscopy, ultrasound, and the ureteroscope. Successful stone movement was defined as relocating a stone to the renal pelvis, ureteropelvic junction (UPJ) or proximal ureter. Three blinded experts evaluated for histologic injury in control and treatment arms. All stones were moved. 65% (17/26) of stones/beads were moved the entire distance to the renal pelvis (3), UPJ (2), or ureter (12). Average successful procedure per stone required 14±8 min and 23±16 pushes. Each push averaged 0.9 s in duration. Mean interval between pushes was 41±13 sec. No gross or histologic kidney damage was identified in six kidneys from exposure to 20 1-s pushes spaced by 33 s. Ultrasonic propulsion is effective with most stones being relocated to the renal pelvis, UPJ, or ureter. The procedure appears safe without evidence of injury. Supported by NIH DK43881, DK092197 and NSBRI through NASA NCC 9-58.

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INTRODUCTION

Our group has previously reported the ability to use noninvasive, focused ultrasound technology to move urinary tract calculi in a phantom model and subsequently in the porcine kidney.[1,2] This demonstrated proof of concept in using ultrasonic propulsion to facilitate the clearance of lower pole residual stone fragments. Several advancements and modifications have since been achieved. We now assess a new prototype device for efficacy of treatment in relocating calyceal stones to the renal pelvis, UPJ and proximal ureter in a porcine model.

METHODS

All animal studies were approved by the University of Washington Institutional Animal Care and Use Committee. Ureteroscopy was performed on 14 kidneys from eight common domestic female pigs weighing 50-60 kg under general anesthesia. A 2.5 mm silver-coated glass reference bead was endoscopically placed in an upper pole calyx using a nitinol basket. A series of 2-8 mm stones (calcium oxalate monohydrate coated in tantalum powder) or beads were implanted in interpolar or lower pole calyces for ultrasonic repositioning. Stones were coated to improve visualization under fluoroscopy. Stone position was confirmed under direct visualization by ureteroscopy and by fluoroscopy.

Stones were targeted by transcutaneous ultrasound using the same transducer used subsequently for ultrasonic propulsion to push the stone. Push bursts were delivered by touching the image of the stone on the monitor. The goal was to displace stones from their original position in a renal calyx to the renal pelvis, UPJ, or ureter. Stone motion was visualized and recorded using fluoroscopy (GE OEC 9800, GE OEC Medical Systems Inc, Salt Lake City, UT), ureteroscopic direct vision, and with the ultrasound imager in real-time. If several attempts to push the stone were unsuccessful, the probe was moved to a different angle, and targeting and treatment were repeated. If these maneuvers were unsuccessful, the pig was gently repositioned and the procedure was repeated.

RESULTS

Stones were successfully placed in 12 of 14 kidneys. Experimental time constraints along with anatomic difficulties prevented placement in two kidneys. A total of 26 natural and artificial stones were placed within interpolar and lower pole calyces (2-3 stones per kidney) as targets for relocation. All stones were visible with ultrasound and all stones exposed to ultrasonic propulsion were observed to move within the calyx. Overall, 17 of 26 (65%) stones were successfully relocated from the calyx to the renal pelvis (3), UPJ (2), or ureter (12). Two were moved out of the calyx but did not reach the renal pelvis. The remaining seven were observed to move upon exposure to push bursts, but were not dislodged from the calyx.

Average procedure time to successfully displace a stone was 14.2±7.9 min and required 23±16 push bursts. Push bursts averaged 0.9 sec in duration, with none greater than 1 sec, and were separated by a mean of 41±13 sec. Most push attempts either did not move the stone, or less commonly, the stone moved but fell back into the same calyx. In contrast, few effective pushes were necessary to result in stone clearance. In cases where the stone was inadvertently repositioned into an upper pole calyx, it was possible to push the stone back towards the UPJ.

DISCUSSION AND CONCLUSIONS

Experimental outcomes with our clinical prototype acoustic propulsion device were encouraging. All stones that were treated were observed to move, and 65% of interpolar and lower pole stones were successfully moved from the calyx to the renal pelvis, UPJ, or ureter using ultrasonic propulsion. This modality appears to be safe without any histologic evidence of renal injury. Minimal to no injury might be expected given that the acoustic pressures and energies are lower than those used currently in shock wave lithotripsy.

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