Focused Ultrasonic Propulsion of Kidney Stones

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Abstract

Introduction: Our research group is studying a noninvasive transcutaneous ultrasound device to expel small kidney stones or residual post-treatment stone fragments from the kidney.^{1–3} The purpose of this study was to evaluate the efficacy and safety of ultrasonic propulsion in a live porcine model.

Materials and Methods: In domestic female swine (50–60 kg), human stones (calcium oxalate monohydrate) and metalized glass beads (2–8 mm) were ureteroscopically implanted.⁴ Target stones and beads were placed in the lower half of the kidney and a reference bead was placed in the upper pole. Ultrasonic propulsion was achieved through a single ultrasound system that allowed targeting, stone propulsion, and ultrasound imaging using a Philips HDI C5-2 commercial imaging transducer and a Verasonics diagnostic ultrasound platform. Stone propulsion was achieved through the delivery of 1-second bursts of focused, ultrasound pulses, which consist of 250 finely focused pulses 0.1 milliseconds in duration. Stone propulsion was then observed using fluoroscopy, ultrasound, and visually with the ureteroscope. The kidneys were then perfusion-fixed with glutaraldehyde, embedded in paraffin, sectioned, and stained. Samples were histologically scored for injury by a blinded independent expert. Using the same pulsing scheme, while varying acoustic intensities, an injury threshold and patterns of injury were determined in additional pigs.^{5,6}

Results: Stones were successfully implanted in 14 kidneys. Overall, 17 of 26 (65)% stones/beads were moved the entire distance to the renal pelvis, ureteropelvic junction (UPJ), or proximal ureter. The average procedure time for successfully repositioned stones was 14.2 ± 7.9 minutes with 23 ± 16 push bursts. No gross or histologic damage was identified from the ultrasound propulsion procedure. Under this pulsing scheme, a maximum exposure of 2400 W/cm^2 was delivered during each treatment. An intensity threshold of $16,620 \text{ W/cm}^2$ was determined at which, above this level, tissue injury consistent with emulsification, necrosis, and hemorrhage appeared to be dose dependent.

Conclusions: Ultrasonic propulsion is effective with most stones being relocated to the renal pelvis, UPJ, or proximal ureter in a timely fashion. The procedure appears safe with no evidence of injury. The acoustic intensities delivered at maximum treatment settings are well below the threshold at which injury is observed. The angle and alignment of directional force are the most critical factors determining the efficacy of stone propulsion. We are now pursuing FDA approval for a human feasibility study.

No competing financial interests exist.

Runtime of video: 5 mins 44 secs

Acknowledgments: This work was supported by NIH DK43881, DK092197, NSBRI through NASA NCC 9–58, the Coulter Foundation, and the University of Washington. This material is the result of work supported by resources from the VA Puget Sound Health Care System, Seattle, Washington. We are very grateful for the help of a large team at the University of Washington and the Consortium for Shock Waves in Medicine, which we cannot list in detail.

Cite this video

Mathew D. Sorensen, Michael R. Bailey, Ryan S. Hsi, Bryan W. Cunitz, Julianna Simon, Yak-Nam Wang, Barbrina L. Dunmire, Marla Paun, Frank Starr, Wei Lu, Andrew P. Evan, Jonathan D. Harper, Focused Ultrasonic Propulsion of Kidney Stones, J Endourol Part B Videourology. 2013, DOI: 10.1089/vid.2013.0057.

References

1. Shah A, Harper JD, Cunitz BW, et al. Focused ultrasound to expel calculi from the kidney. *J Urol* 2012;187:739–743.
2. Bailey M, Wang YN, Simon JC, et al. Acoustic radiation force to reposition kidney stones. *J Acoust Soc Am* 2013;133:3279.
3. Harper JD, Sorensen MD, Cunitz BW, et al. Focused ultrasound to expel calculi from the kidney: safety and efficacy of a clinical prototype device. *J Urol* 2013;190:1090–1095.
4. Sorensen MD, Bailey M, Hsi RS, et al. Focused Ultrasonic Propulsion of Kidney Stones: Review and update of preclinical technology. *J Endourol* 2013;27:1183–1186.
5. Wang, YN. Ultrasound intensity to propel stones from the kidney is below the threshold for renal injury. *Acoustical Society of America international meeting*. Montreal, Quebec, Canada 2013.
6. Wang YN, Simon JC, Cunitz BW, et al. Determination of tissue injury thresholds from ultrasound in a porcine kidney model. *J Acoust Soc Am* 2013;133:3411.

Original Publication Date: 2013