Even though passing a kidney stone is painful for a patient, APL-UW researchers are hoping to put technology in urology clinics to assist patients do exactly that. An ultrasound-based system may provide an office procedure to speed the natural passage of stones, doing so without exposing patients to X-ray diagnoses and lowering the incidence of potential injury from extracorporeal shockwave lithotripsy and other surgeries.

A diverse team of scientists, engineers, and students at the Center for Industrial and Medical Ultrasound has developed a system that uses commercial ultrasound components to locate stones in kidneys. It creates clear pictures of them and then applies an acoustic radiative force, repositioning stones in the kidney so they are likely to pass naturally. Ultrasonic propulsion may be used to remove small stone fragments after lithotripsy surgery or to diagnose and speed the removal of small stones before they become symptomatic.

Combined, team members have decades of research experience in lithotripsy—breaking kidney stones with shock waves—as well as high intensity focused ultrasound (HIFU)—“cooking” diseased tissue such as prostate cancer. During a laboratory experiment to break simulated kidney stones with HIFU, researchers observed stones shooting across the water bath in which they were placed. It was clear that pushing, not breaking, stones was an idea worth pursuing.
**Repositioning Stones**

In practice, the urologist scans the kidney with the ultrasound probe, zooms to a location of interest using the touch screen display, and with several ultrasound imaging techniques available including the Doppler (‘twinkle’ mode, locates the stone(s)). The radiation force is applied in the direction normal to the transducer face, the urologist manipulates the probe’s angle to direct the stone toward the kidney exit. Then a mouse-click on the screen image of the stone flashes a test pulse to reveal the location of the pulse-pulse beam to confirm alignment. When the urologist mouse-clicks a second time, the radiative force is applied and the stone is pushed. The display tracks the stone moving within the kidney. The system then returns to the stone detection and localization mode so that more pushes may be made if needed.

**Making Clearer Pictures**

Before a stone can be moved it must be seen. Two conventional ultrasound imaging modes used in urology practice are brightness (B-mode) and color flow Doppler. B-mode shows a bright reflection from kidney stones, which, compared to the surrounding tissue and fluid, are hard and reflect the acoustic energy. Doppler mode detects objects that are moving away from or toward the probe applying color in image processing makes it especially useful to detect blood flow. When imaging kidney stones, however, something in the ultrasound reflection from the stone confuses the Doppler image processing and causes the stone to display as a flickering mosaic of color.

Bioengineering doctoral student Wei Lu has conducted extensive research on the colorful ‘twinkling’ artifact returned in Doppler mode images of kidney stones. The flickering is caused by the noisy signals echoing from the stones. It is likely that the high reflectivity of the stones and their roughness, curvature, and reverberant nature make them sensitive to even slight changes in the angle of the incident wave from the ultrasound probe. Lu and the team, knowing that Doppler processing aims to eliminate noisy signals to more effectively image blood flow, set to re-engineer the image processing to accentuate such signals. Processing algorithms were created to specifically image the reflective and reverberant stones, but not motion (blood flow).

**Next Steps**

The detection and repositioning system operates at levels above regulated limits for diagnostic ultrasound. Julianna Simon, also a doctoral bioengineering student, and the team performed safety studies where they exposed porcine model kidney tissue to a series of increasing ultrasound intensities and duty cycles. Exposed tissue samples were examined microscopically to look for evidence of mechanical or thermal damage. They determined that the system propels stones effectively within safe thresholds and at no risk to kidney tissue.

Confident that their system is effective and safe, the team is conducting clinical simulations and submitting device approval applications with the Food and Drug Administration.

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- National Institutes of Health
- National Space Biomedical Research Institute
- UW Center for Commercialization
- Washington Research Foundation
- Institute of Translational Health Sciences
- W.H. Coulter Foundation

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The National Space Biomedical Research Institute knew of the team’s research in lithotripsy and funded work to develop a portable system to protect astronauts on long missions from the effects of kidney stone disease. NSBRI came to Seattle to meet with the research team and the University of Washington Center for Commercialization. C4C identified several foundations interested in promoting transition of this technology into the clinical sphere and the commercial realm. Patent applications have been filed and the current plan is to conduct a clinical trial and achieve device approval before starting up a company or licensing the technology.