Ultrafast ultrasound: First successful contrast agent-free imaging of complex structure of kidneys

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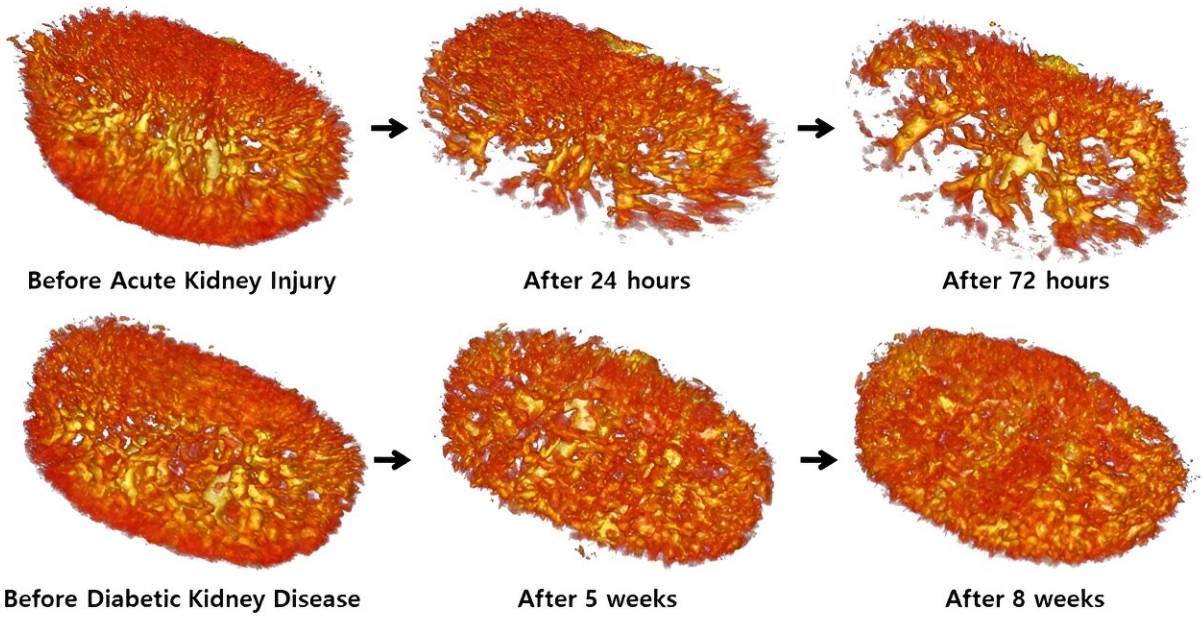

Vascular changes in acute and diabetic renal failure. Credit: POSTECH

A research team at POSTECH (Pohang University of Science and Technology) has investigated kidney diseases using ultrafast ultrasound that captures 1,000 images in just one second.

The research team has achieved imaging of the three-dimensional

microvasculature of the kidneys using ultrafast ultrasound. Their technique is gathering attention for being capable of visualizing the whole kidney microvasculature without any contrast agents. The findings are published *Advanced Science.*

The kidney plays a role in filtering waste and eliminating unwanted substances from the bloodstream. Conditions such as hypertension and diabetes can compromise this vital function, leading to kidney failure —an irreversible condition necessitating lifelong treatment through artificial hemodialysis or donor kidney transplantation.

Given the direct connection between blood perfusion in the kidneys and their filtration function, microvascular imaging can be a key indicator for both preventing and recovering from kidney failure.

Representative contemporary medical imaging methods like CT (computed tomography) and MRI (magnetic resonance imaging) have limitations in capturing fine vascular structures due to their constraints in resolution and sensitivity. Moreover, the use of contrast agents in these methods is restricted due to the potentially fatal side effects in patients with kidney disease.

In contrast, ultrasound imaging, considered safe enough for fetal monitoring, utilizes the Doppler effect to measure real-time blood flow velocity and direction without needing contrast agents.

However, the current imaging speed has limitations in capturing fine blood vessels with sufficient sensitivity. The research team has enhanced microvascular sensitivity by employing ultrafast ultrasound acquisition, capturing 1,000 frames per second, a speed over 100 times faster than conventional ultrasound imaging.

Using this technique, the researchers achieved a world-first by imaging

the entire three-dimensional vascular network of the renal artery, vein, and 167μm (micrometer) thick interlobular arteries and veins in the renal cortex without the need for a contrast agent.

Furthermore, they continuously observed renal vascular changes in an animal model induced with renal failure, performing multivariate analysis using hemodynamic and vascular morphological indicators. The results revealed a sharp decrease in renal blood flow during acute renal failure, while in the case of diabetic nephropathy, they identified chronic vascular degeneration in the kidneys accompanied by vascular distortion.

Professor Chulhong Kim explained, "The system allows us to understand the pathophysiology of diseases leading to kidney failure, enabling the observation of vascular changes before and after kidney transplantation. It has significant potential to be used to study blood circulation and functional impairment across various organs, including the digestive system, circulatory system, and cerebral nervous system."

More information: Donghyeon Oh et al, Contrast Agent-Free 3D Renal Ultrafast Doppler Imaging Reveals Vascular Dysfunction in Acute and Diabetic Kidney Diseases, *Advanced Science* (2023). DOI: 10.1002/advs.202303966

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