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Expert-Level Segmentation Using Deep Learning for Volumetry of ADPKD

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Autosomal dominant polycystic kidney disease (ADPKD), characterized by innumerable cysts arising in bilateral kidneys, is a hereditary chronic kidney disease that is frequently associated with irreversible renal impairment and end-stage renal disease. From the assessment of disease progression to clinical management and therapeutic trials for patients with ADPKD, quantitative image analysis plays an important role. In particular, total kidney volume (TKV) which is determined using quantitative image analysis is considered the most significant factor in assessing severity and progression of ADPKD, among various prognostic factors including sex, age, genotype, and kidney function.

TKV is commonly measured from a set of MRI images or CT images by an operator who manually traces the boundaries of kidneys slice-by-slice. Kidney areas calculated within the delineated boundaries are summed over the set of slices and multiplied by the pixel spacing and slice thickness to yield TKV. Although this manual method has been widely used in determining TKV in a number of clinical trials of ADPKD, the measurement process is onerous and time consuming. To alleviate these inefficiencies, region-growing based semi-automated segmentation techniques for kidneys and cysts were also reported, but they still required seed points from experts and the observers' perceptual supervision.

As automated measurements of TKV are highly desired, various approaches have been proposed to achieve automated segmentation of ADPKD kidneys. In particular, deep-learning methods using U-Net architecture were shown to be extremely promising and successful for a fully automated measurement of TKV to overcome the limitation of the manual approach.

In the past 5 years, remarkable advances in AI (deep learning) were made in image segmentation and quantification where AI systems were capable of surpassing human-level performance. It is highly likely and foreseeable that AI technology will enhance the quality and efficiency of the current clinical practice across many specialties and even make some activities in clinical practice obsolete. However, AI technology in the current form is not a magic bullet and is not fully mature. Rigorous quality control and evaluation are still required to integrate AI technology in daily clinical practice.

In this presentation, we will review and discuss the current state and future direction of deep-learning technology in the volumetric measurements of ADPKD kidneys.