Original Investigation

Fully Automated Segmentation of Polycystic Kidneys From Noncontrast Computed Tomography: A Feasibility Study and Preliminary Results

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Rationale and Objectives: Total kidney volume is an important biomarker for the evaluation of autosomal dominant polycystic kidney disease progression. In this study, we present a novel approach for automated segmentation of polycystic kidneys from non–contrast-enhanced computed tomography (CT) images.

Materials and Methods: Non–contrast-enhanced CT images were acquired from 21 patients with a diagnosis of autosomal dominant polycystic kidney disease. Kidney volumes obtained from the fully automated method were compared to volumes obtained by manual segmentation and evaluated using linear regression and Bland-Altman analyses. Dice coefficient was used for performance evaluation.

Results: Kidney volumes from the automated method well correlated with the ones obtained by manual segmentation. Bland-Altman analysis showed a low percentage bias (–0.3%) and narrow limits of agreements (11.0%). The overlap between the three-dimensional kidney surfaces obtained with our approach and by manual tracing, expressed in terms of Dice coefficient, showed good agreement (0.91 ± 0.02).

Conclusions: This preliminary study showed the proposed fully automated method for renal volume assessment is feasible, exhibiting how a correct use of biomedical image processing may allow polycystic kidney segmentation also in non–contrast-enhanced CT. Further investigation on a larger dataset is needed to confirm the robustness of the presented approach.

Key Words: Autosomal dominant polycystic kidney disease; computed tomography; kidney volume.

INTRODUCTION

Autosomal dominant polycystic kidney disease (ADPKD) is an inherited disorder that is characterized by the development and growth of cysts in both kidneys. Despite a progressive enlargement of the kidneys as a consequence of cyst expansion, especially at the first stages of the disease, the renal function is still preserved. For this reason, common renal function parameters such as the glomerular filtration rate are inadequate for the evaluation of disease progression. Nowadays, total kidney volume (TKV) is considered as the most important biomarker of disease progression (1,2) and is widely used in clinical trials for the evaluation of the efficacy of new pharmacologic therapies (3–5).

The Consortium for Radiological Imaging Studies of Polycystic Kidney Disease (CRISP) recommends the use of three-dimensional (3D) imaging for an accurate and reproducible assessment of TKV. Both magnetic resonance imaging (MRI) and computed tomography (CT) provide reliable measurements of TKV (6–9). CT may require the use of a potentially nephrotoxic contrast medium and exposes the patient to ionizing radiation. However, CT imaging systems are widely available with respect to MRI systems, also in small centers, and CT imaging is straightforward and fast.

Kidney segmentation in CT is trivial because of the low contrast in the images and because the whole pixel information is constrained in a narrow range of bins. Common techniques for kidney volume estimation are manual tracing and stereology (ie, marking grid points superimposed to the image) (10). Although these techniques are widely used, they require human interaction, are time-consuming, and in the case of stereology, the result depends on grid cell spacing. In recent

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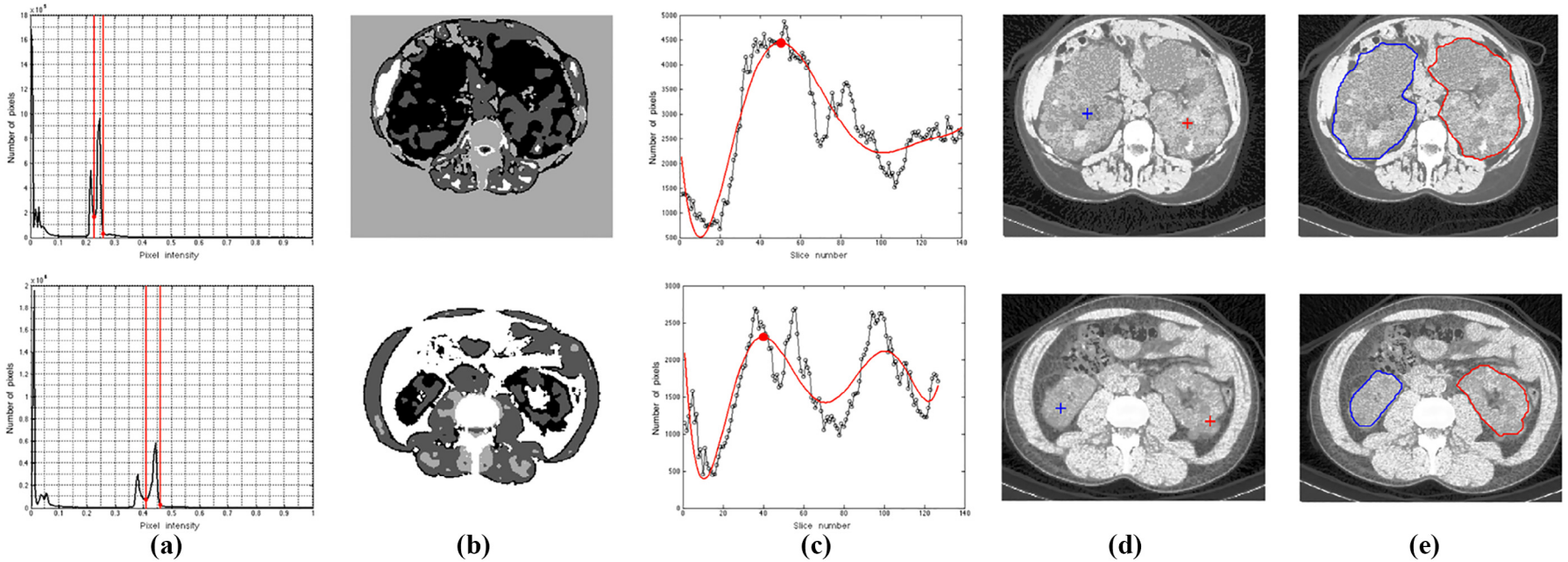

Figure 1. Description of the workflow and results in two different patients. (**a**) Histogram analysis of the three-dimensional volume and detection of the pixel range (*red vertical lines*). (**b**) Result of the three-dimensional clustering in a single slice. Each cluster is represented using a different *gray*-level intensity (*white*, *light gray*, *dark gray*, and *black*). (**c**) Pixel distribution associated with the lowest pixel intensity clusters (*dark gray* and *black*); the fitting curve and the selected slice corresponding to the maximum number of pixels are shown using the *red line* and the *red dot*. (**d**) Detection of the kidney regions on the previously selected slice. (**e**) Final segmentation of the kidneys. (Color version of figure is available online.)