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Research article

Renal cortical volume: High correlation with pre- and post-operative renal function in living kidney donors

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ABSTRACT

Background: CT volumetry has previously been proposed as an alternative to scintigraphy for the evaluation of pre-donation split renal function and the prediction of post-donation renal function in living kidney donors. The aim of our study was to retrospectively assess the relevance of three CT volumetry techniques for estimating pre-donation kidney function and predicting the risk for chronic kidney disease (CKD) at 1-year post-nephrectomy in a French cohort of living donors using isotopic measures of kidney function.

Methods: Kidney volume was quantified pre-donation for 105 donors using three methods total parenchymal three-dimensional renal volume (3DRV), total parenchymal renal volume contouring (RVCt), and renal cortical volume (RCoV). Subjects also had a 51Cr-EDTA scintigraphy to measure glomerular filtration rate (mGFR) pre-donation and 1-year after donation. For each volume, we tested for association with mGFR using univariate regression models, and computed receiver operating characteristics analyses to assess their predictive potential of post-donation CKD.

Results: Our population was composed of healthy subjects, who were predominantly female (69%) with a median age at donation of 51yo. Median mGFR was 102 mL/min/1.73 m^2 at pre-donation and 66 mL/min/1.73 m^2 1-year after nephrectomy. The pre-donation median volume of the preserved kidney was 156 cm^3, 163 cm^3 and 99 cm^3 for the 3DRV, RVCt and RCoV methods respectively, with a high correlation observed between each technique ($R > 0.84$). For all methods, total kidney volume was significantly associated with pre-donation mGFR ($P < 0.001$). Preserved kidney volume was also strongly correlated with post-donation mGFR ($P < 0.0001$), with the strongest correlation observed for RCoV ($R = 0.60$ *vs.* $R = 0.39$ and $R = 0.51$ for 3DRV and RVCt, respectively). Finally, the RCoV method yielded the best predictive value of 1-year post-donation CKD (AUC = 0.80 *vs.* AUC = 0.76 and 0.70 for RVCt and 3DRV, respectively).

Conclusions: In our cohort of healthy donors with measured kidney function, cortical volumetry (RCoV) appears as the best volumetric technique to use as a surrogate to scintigraphy for estimating pre-donation split renal function and predicting post-donation renal outcomes.

1. Introduction

Kidney transplantation is currently the renal replacement therapeutic option for end-stage kidney disease offering the best quality of life and the lower mortality rate [1,2]. Living kidney donation, in addition to responding to the shortage of grafts, improves the short and long-term survival of grafts and recipients. Risks associated with kidney donation have been extensively investigated and are considered to be very low as long as a careful comprehensive medical evaluation has been performed. Perioperative mortality, without being null, is very

Abbreviations: CT, computed tomography; 3DRV, total parenchymal three-dimensional volume; RVCt, total parenchymal renal volume contouring; RCoV, renal cortical volume; 51Cr-EDTA, Chrome-51 EthyleneDiamineTetraAcetic acid; mGFR, measured glomerular filtration rate; eGFR, estimated glomerular filtration rate; SRF, split renal function; CKD, chronic kidney disease

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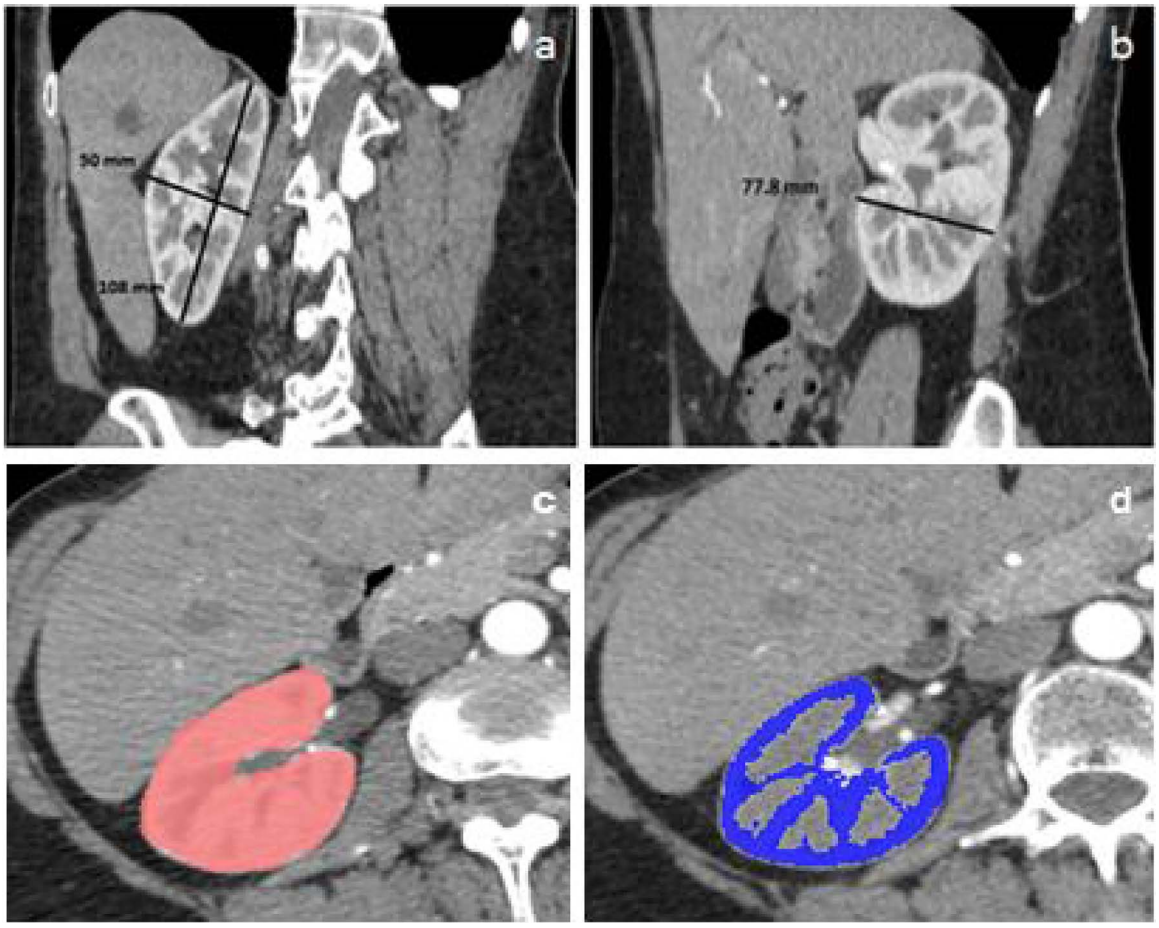

Fig. 1. Description of the three CT renal volumetry methods. We implemented three post-processing software-based methods to measure renal volumetry in living kidney donors: total parenchymal three-dimensional volume (3DRV) using a double obliquity, length and width on a coronal view (a), thickness on a sagittal view (b); total parenchymal renal volume contouring (RVCt) on an axial view (c); and renal cortical volume (RCoV) on an axial view (d).

low [3] and equivalent to that of minor surgery. Recently, two independent studies, one American [4] and one European [5], have stressed the long-term risk for post-donation end-stage kidney disease, emphasizing the need to ameliorate the selection and safety of living donors by predicting the evolution of the remaining kidney function.

Besides the known factors such as age, sex, and obesity [6,7], pre-donation kidney function (as assessed by glomerular filtration rate or GFR) and split renal function (SRF) are major determinants of post-donation kidney function. Scintigraphy is currently the gold-standard for measuring SRF and is included in the pre-donation assessment. However, this method remains expensive, time-consuming, is not available in all hospitals (especially for low-income countries), exposes subjects to radiation, and suffers from measurement artifacts due to the imaging susceptibility to kidney depth and rotation [8,9]. Due to these limitations, computed tomography (CT) scan has been investigated as an alternate method for assessing SRF. Renal volume is indeed a parameter of great interest for estimating kidney function in healthy subjects as it reflects the nephron endowment of the donor. In addition, CT scan can be performed in routine and offers the advantage of providing additional information regarding kidney anatomy, vasculature and potential abnormalities.

Several CT volumetry techniques (ellipsoid and voxel count based) have been examined and studies reported that renal volumetry, especially cortical volumetry, was a reliable surrogate to scintigraphy for evaluation of pre-donation SRF [8,10–21]. However, only few studies have explored the use of CT volumetry to predict post-nephrectomy kidney function [10,11,18,20]. Two studies focused on a 6-month follow-up [11,20], when two other ones investigated 1-year post-donation kidney function. Limitations of these studies included small sample size for two studies (n = 34 and n = 88 [10,20], n > 100 for [11,18]), and the use of estimated GFR (eGFR) calculations derived from serum creatinine levels for assessing kidney function.

The objective of our study was to compare three CT volumetry methods to estimate pre-donation SRF and predict 1-year post-donation kidney function using for the first time isotopic measures of the donor renal function (mGFR) in 105 French living kidney donors.

2. Material and methods

2.1. Study population

One hundred and five living kidney donors were retrospectively included from 2006 to 2016. All subjects were extracted from the French clinical prospective DIVAT cohort of kidney transplantation follow-up, and provided their written consent for the exploitation of their electronic medical record for research purposes. All surgeries were performed at the University Hospital of Nantes (France). Inclusion required a Chrome-51 EthyleneDiamineTetraAcetic acid scintigraphy (^{51}Cr-EDTA) to measure pre-donation and 1-year post-donation kidney function (mGFR), and a pre-donation CT scan to measure the renal volume. Pre-donation SRF of the preserved kidney was calculated by integrating renal volume (see below) in the following equation: SRF (volume) = volume (%) × mGFR (mL/min/1.73 m^2). In addition, we collected clinical and biological data for each donor including age, sex, body-mass index (BMI), hypertension, diabetes and pre- and post-donation serum creatinine levels to estimate kidney function (eGFR) using