The Ultrasound Journal

ORIGINAL ARTICLE

Open Access

# Ultrasound versus magnetic resonance imaging for calculating total kidney volume in patients with ADPKD: a real-world data analysis

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## Abstract

**Background and objectives** This study aimed to compare Total kidney volume (TKV) measurements using US-ellipsoid (US-EL) and MRI-ellipsoid (MRI-EL) in patients with autosomal-dominant-polycystic-kidney-disease (ADPKD). It also evaluated whether the agreement between right (RKV) and left (LKV) kidney volume measurements differed.

**Methods** Retrospective analysis of a prospective data-base that included consecutive patients diagnosed with ADPKD. Total kidney volumes by 3D-US-EL were compared with those by MRI-EL. Bland–Altman-plots, Passing–Bablok-regression, and the concordance-correlation-coefficient (CCC) were used to compare right (RKV), left (LKV), and TKV measurements.

**Results** Thirty-two ADPKD patients, 14(43.7%) women, were included. Mean measured (mGFR) and estimated (eGFR) glomerular-filtration-rate (GFR) were 86.5 ± 23.9 mL/min and 78.9 ± 23.6 mL/min, respectively. Compared with MRI-EL, TKV (Mean difference: −85.9 ± 825.6 mL; 95%CI −498.5 to 326.7 mL; p = 0.6787), RKV (Mean difference: −58.5 ± 507.7 mL; 95%CI −312.2 to 195.2 mL; p = 0.6466), and LKV (Mean difference: −27.4 ± 413.5 mL; 95%CI −234.1 to 179.2 mL; p = 0.7918) were lower with US-EL than with MRI-EL, although without significant differences. According to Passing and Bablok-regression analysis, the Spearman correlation-coefficient was 0.96 (95%CI 0.92 to 0.98); 0.91 (95%CI 0.82 to 0.96), and 0.94 (95%CI 0.87 to 0.97) in the RKV, LKV, and TKV, respectively; p < 0.0001 each, respectively. CCC of RKV, LKV, and TKV measurements were 0.95, 0.89, and 0.94, respectively. The mGFR and eGFR showed statistically significant negative correlations with TKV measured by both MRI-EL (p = 0.0281 and p = 0.0054, respectively) and US-EL (p = p = 0.0332 and p = 0.0040, respectively).

**Conclusions** This study found that ultrasound-based ellipsoid kidney volume measurements strongly correlated with MRI-based measurements, suggesting that ultrasound is a reliable, accessible alternative for assessing kidney volume, particularly when MRI is unavailable.

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**Keywords** ADPKD, Kidney volume, Ultrasonography, Magnetic resonance imaging, Glomerular filtration rate, Disease progression

## Introduction

Autosomal dominant polycystic kidney disease (ADPKD) is the most common inherited renal disorder worldwide, characterized by the progressive formation of numerous cysts that compress the renal parenchyma, ultimately leading to end-stage renal disease (ESRD) in adulthood [1–4]. The disease arises from mutations in the PKD1 or PKD2 genes, with PKD1 mutations being more common and associated with earlier onset and more severe clinical manifestations compared to PKD2 mutations [4–6]. This genetic variability can complicate diagnosis, especially in younger patients with milder symptoms [5, 6].

Traditional markers of kidney function, such as serum creatinine, estimated glomerular filtration rate (eGFR), and creatinine clearance, are not reliable for assessing disease severity or progression in ADPKD. These parameters typically remain within normal ranges until the disease reaches advanced stages [6–8]. In contrast, findings from the Consortium for Radiologic Imaging Study of Polycystic Kidney Disease (CRISP) highlight total kidney volume (TKV) as a key biomarker. TKV in ADPKD increases in a quasi-exponential manner throughout adulthood, with an average annual growth rate of 5%, although individual variability is substantial [9]. Recognizing its predictive value, both the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA) have endorsed TKV as a prognostic biomarker for identifying patients at high risk of progression, facilitating inclusion in clinical trials [7, 9, 10].

The gold standard for TKV measurement involves magnetic resonance imaging (MRI) or computed tomography (CT) with manual segmentation, a labor-intensive and resource-intensive process requiring radiological expertise [11–13]. In contrast, ultrasound (US) offers a more accessible and cost-effective alternative. Using the ellipsoid formula (US-EL), kidney volume can be approximated by measuring three orthogonal axes, though this method is considered less precise [14]. Additionally, the availability of three-dimensional (3D) ultrasound in many tertiary care centers provides a promising tool for volumetric assessments and has shown potential for TKV quantification in non-ADPKD populations [15, 16].

The current study aimed to compare the agreement of TKV measurements assessed by US-EL versus (vs) MRI-ellipsoid in patients with ADPKD. Additionally, we also compared the volume measurements of the right (RKV) and left (LKV) kidneys individually for evaluating whether the degree of agreement differed between both kidneys.

## Methods

### Study design

This study was a retrospective analysis of a prospective database involving consecutive patients diagnosed with ADPKD, who were followed by the out-patient clinical office at the third-level University Hospital of Gran Canaria Doctor Negrín (HUGCDN) (Las Palmas de Gran Canaria, Spain).

All participants provided informed consent in accordance with a predetermined study protocol that received approval from the Ethics Committee of HUGCDN (Protocol VO 05-2017; Review Board approval: 170071; May 2017). This research adhered to the principles established in the Good Clinical Practice/International Council for Harmonization Guidelines, the Declaration of Helsinki, and all pertinent country-specific regulations governing clinical research, emphasizing the highest level of individual protection.

To maintain anonymity, any potentially identifiable information was either encrypted or removed from the dataset.

### Study patients

This study included patients > 18 years of age who were diagnosed with ADPKD based on ultrasound-3D or MRI criteria [17, 18], clinically stable [19], without acute kidney injury, and had an eGFR, assessed with the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula, > 60 mL/min. In addition, patients had to have not indicate active infectious diseases or cardiovascular events within the 3 months preceding study enrollment.

Patients with a history of iodine allergy, contraindications for undergoing MRI, active malignancies, uremia or impending dialysis, severe psychiatric disorders, or those who were pregnant or breastfeeding were excluded from the study.

### Glomerular filtration rate (GFR)

#### *Measured GFR (mGFR)*

On the day of the study visit (baseline), a 5 mL intravenous injection of iohexol solution (Omnipaque 300, GE Healthcare) was given over a 2-min period. Iohexol concentrations were measured using dried blood spot (DBS) samples, which were then sent to the UniversityHospital

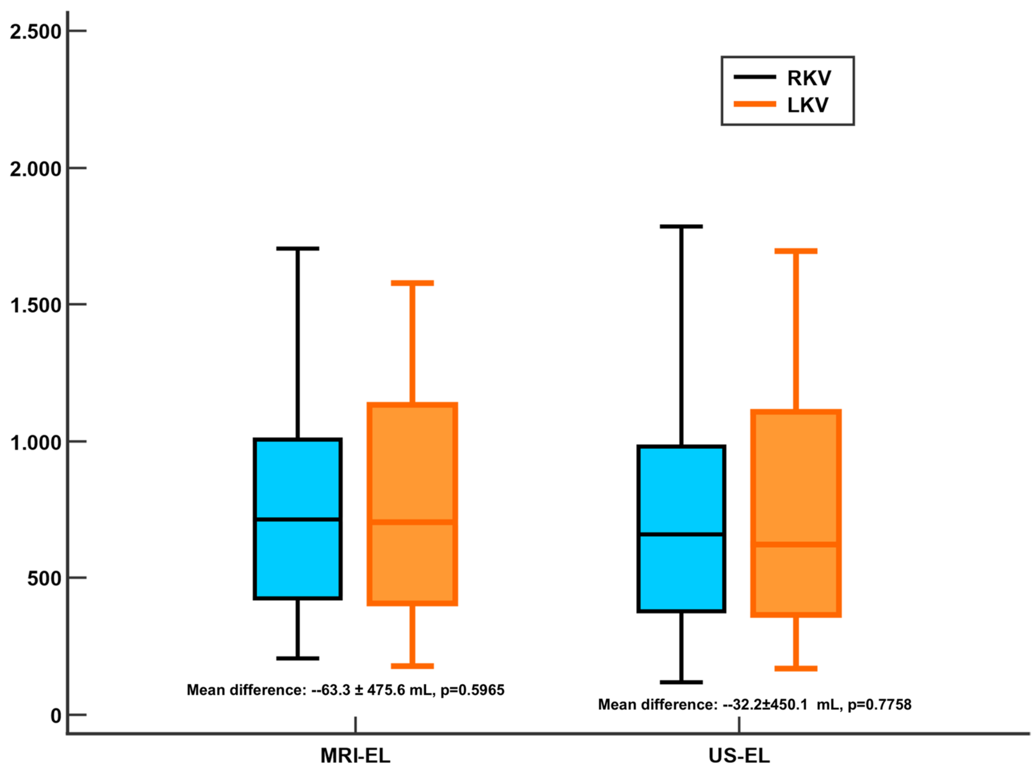


**Fig. 1** Box and whisker evaluating the difference between the right (RKV) (blue) and left (LKV) (Orange) kidney volumes assessed by magnetic resonance imaging ellipsoid (MRI-EL) and ultrasound ellipsoid (US-EL)

of Canarias, La Laguna (Tenerife, Spain) for analysis [20]. Plasma clearance of iohexol was calculated using the method outlined by Krutzé et al. [21].

### *Estimated GRF*

Simultaneously to the clearance of iohexol, the CKD-EPI formula [22] was used to calculate eGFR.

### Ultrasound-3D kidney imaging

Ultrasound examinations were conducted individually for each kidney utilizing a Aplio 500 US device (Canon Medical Systems Corporation, Tokyo, Japan), with 3.5 MHz mechanical convex D transducer. If the borders of the kidney were not fully captured within the imaging display, the lengths were measured using a panoramic function, also known as extended field of view ultrasound.

TKV by ultrasound-ellipsoid was assessed using the ellipsoid formula:

$$Volume = \frac{\pi}{6} * (Heigth * Width * Length)$$

The transducer was positioned in a longitudinal orientation along the upper pole of the kidney and then moved in a linear fashion down to the lower pole; the software subsequently dynamically "stitches" the images acquired during the transducer's movement. All scans were evaluated by the same radiologist (CRHS) who was blinded to the clinical information of the participants.

The ellipsoid volume calculation utilized sagittal length (mm), coronal length (mm), width (mm), and depth (mm) measurements obtained from the MRI, according to the following formula [23]:

$$Volume = \frac{\pi}{6} * (Heigth * Width * Length)$$

No contrast material was used in any of the patients.

All MRI were analyzed by the same radiologist (LOR) who was blinded to both the clinical information of the participants and the ultrasound data.

The ultrasound-3D and MRI examinations were performed independently, with a maximum time between them of 9 months.

### Statistical analysis

Statistical analysis was conducted using MedCalc® Statistical Software version 23.0.2 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2024).

The Shapiro–Wilk test was employed to evaluate the normality of quantitative variables.

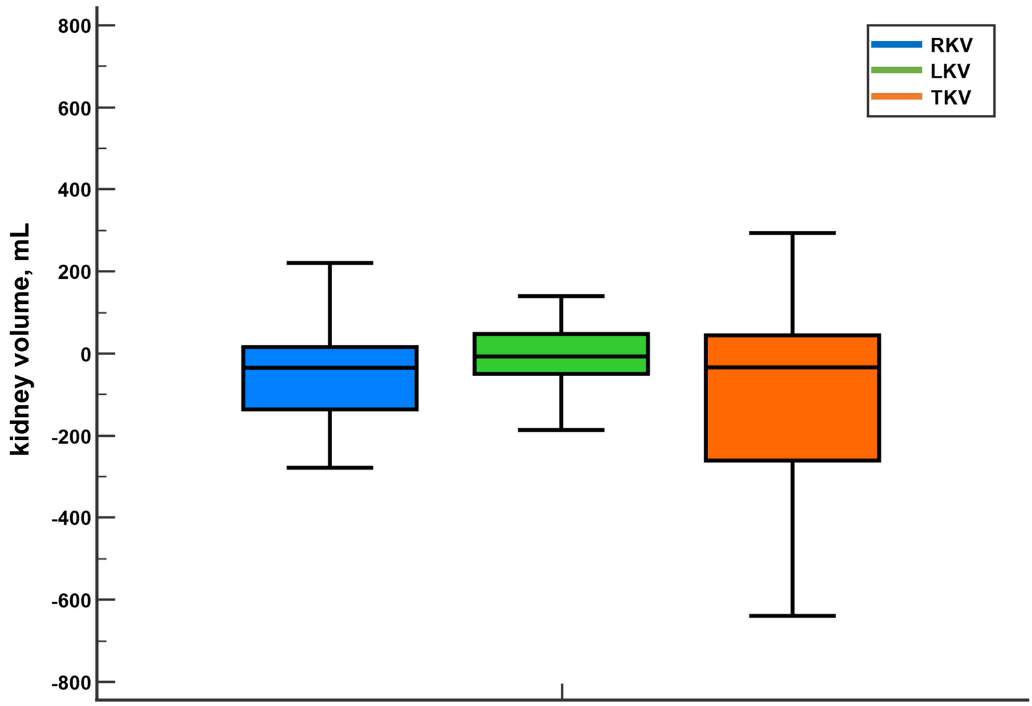


**Fig. 2** Box and whisker evaluating the difference between magnetic resonance imaging ellipsoid (MRI-EL) and ultrasound ellipsoid (US-EL) in the right (blue), left (green), and total (orange) kidney volume. Right kidney volume (RKV): Mean difference: −58.5 ± 507.7 mL, p = 0.6466. Left kidney volume (LKV): Mean difference: −27.4 ± 407.5 mL, p = 0.7918. Total kidney volume: Mean difference: −85.9 ± 825.6 mL, p = 0.6787

Continuous variables were presented as means and standard deviations (SDs), while non-normally distributed variables were reported as medians and interquartile ranges. Categorical variables were expressed as percentages along with 95% confidence intervals (95% CIs). To compare RKV, LKV, and TKV measurements Bland–Altman plots, Passing–Bablok regression, and the concordance correlation coefficient were used.

From the Bland–Altman plots, biases were calculated as the mean percentage differences from zero; a bias > 0.05 indicated no difference in the mean value of two measurement methods.

Passing and Bablok regression analysis was employed to evaluate the concordance between the MRI-EL and US-EL imaging methods for measuring RKV, LKV, and TKV. This non-parametric statistical approach is particularly effective for assessing the agreement between two analytical methods, providing insight into any systematic differences or proportional biases that may exist. If 95% CI for slope includes value one, it can be concluded that there is no significant difference between obtained slope value and value one and there is no proportional difference between two methods [24, 25].

To evaluate agreement between US-EL and MRI-EL, we calculated Lin's concordance correlation coefficient (CCC) for the individual and TKV volumes [26, 27]. CCC values range between 0 and 1 and can be interpreted as follows: < 0.9 indicates poor agreement, ≥ 0.90 to ≤ 0.95 reflects moderate agreement, values > 0.95 to ≤ 0.99 represent substantial agreement, and values > 0.99 indicate almost perfect agreement [27].

## Results

### Baseline demographic, clinical, and analytical characteristics

This study included 32 ADPKD patients, 14 (43.7%) women and 18 (56.2%) men, with a mean age of 42.0 ± 15.8 years. Mean measured glomerular filtration rate (mGFR), assessed by plasma clearance of iohexol, was 86.5 ± 23.9 mL/min; while estimated GFR (eGFR) assessed by CKD-EPI formula was 78.9 ± 23.6 mL/min. Mean body mass index (BMI) was 24.6 ± 3.7 kg/m$^2$.

The US-El study found no differences between RKV (mean volume: 757.6 ± 485.5 mL; 95%CI 582.5 mL to 932.6 mL) and LKV (mean volume: 725.4 ± 411.7 mL; 95%CI 577.0 mL to 873.8 mL) measurements (mean difference: −32.2 ± 450.1 mL; 95%CI −257.1 mL to 192.7 mL; p = 0.7758). Similarly, MRI-EL demonstrated no significant differences in the measurements of RKV (mean volume: 816.1 ± 529.0 mL; 95% CI 625.3 mL to 1006.8 mL) and LKV (mean volume: 752.8 ± 415.3 mL;

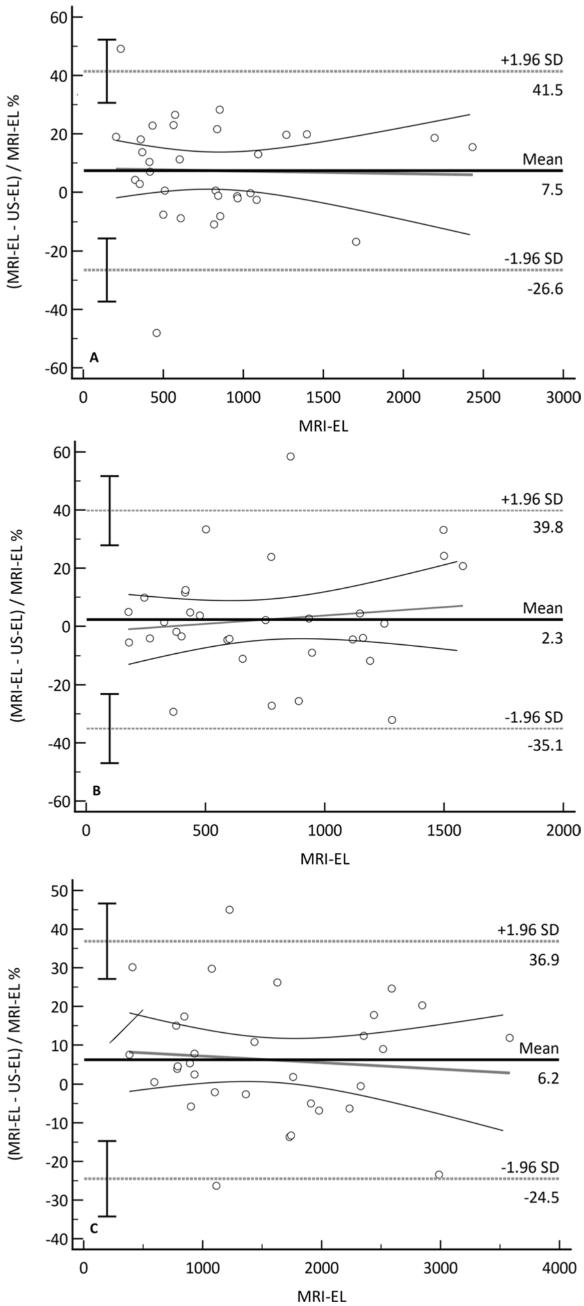


**Fig. 3** Bland–Altman plots showing within-patient differences of right kidney volume (**A**), left kidney volume (**B**), and total kidney volume (TKV) (**C**) measured by ultrasound ellipsoid (US-EL) in comparison with magnetic resonance imaging ellipsoid (MRI-EL) (reference standard). The solid black line represents the mean percentage difference (bias). The grey dotted lines are the 95% limits of agreement. The black dotted line is the slope of the bias with the 95%CI. Mean slope RKV: −0.00; 95% CI −0.01 to 0.01, p = 0.8874. Mean slope LKV: 0.01; 95% CI −0.01 to 0.02, p = 0.4885. Mean slope TKV: −0.00; 95% CI −0.01 to 0.01, p = 0.6270. These results indicate that the measurement bias was independent of kidney volume, and the agreement between the imaging modalities remained consistent across all volume ranges

95% CI 603.1 mL to 902.5 mL) (mean difference: −63.3 ± 475.6 mL; 95%CI −300.9 mL to 174.4 mL; p = 0.5965) (Fig. 1).

## Comparison of kidney volume measurements assessed by US-EL vs MRI-EL

Compared with MRI-EL (reference standard), kidney volumes measured with ultrasound-3D were smaller than those measured with MRI. These differences were more pronounced in the TKV (Mean difference: −85.9 ± 825.6 mL; 95%CI −498.5 to 326.7 mL; p = 0.6787), followed by RKV (Mean difference: −58.5 ± 507.7 mL; 95%CI −312.2 to 195.2 mL; p = 0.6466), and LKV (Mean difference: −27.4 ± 413.5 mL; 95%CI −234.1 to 179.2 mL; p = 0.7918); although in no case were these differences statistically significant (Fig. 2).

US-EL displayed a systematic bias in RKV measurements (p = 0.0211) and TKV measurements (p = 0.0328) but not in LKV measurements (p = 0.4927) (Fig. 3, Table 1).

Analyses of the within-patient percentage volume difference as a function of volume showed that bias remained relatively consistent across all measured volumes. The mean slopes were not statistically different from zero, indicating no significant variation with volume [RKV: −0.00; 95% CI −0.01 to 0.01, p = 0.8874; LKV: 0.01; 95% CI −0.01 to 0.02, p = 0.4885; Total kidney volume (TKV): −0.00; 95% CI −0.01 to 0.01, p = 0.6270]. Bland–Altman analysis revealed that the mean slopes were not significantly different from zero, indicating that there was no substantial variation in the bias with respect to volume (Fig. 3).

The results comparing RKV, LKV, and TKV between MRI-EL and US-EL, using Passing and Bablok regression analysis, are shown in Fig. 4 and Table 2.

The Spearman correlation coefficient was 0.96 (95%CI 0.92 to 0.98); 0.91 (95%CI 0.82 to 0.96), and 0.94 (95%CI 0.87 to 0.97) in the RKV, LKV, and TKV, respectively; p < 0.0001 each, respectively (Fig. 4 and Table 2).

These results suggested that the measurement bias did not exhibit a dependency on kidney volume, and the agreement between the imaging modalities was consistent across the entire range of volumes.

CCC of RKV, LKV, and TKV measurements were 0.95, 0.89, and 0.94, respectively (Table 3).

Figures 5 and 6 illustrate cases of patients with ADPKD, comparing the US-EL measurements with those obtained from MRI-EL.

**Table 1** Systematic bias in ultrasound ellipsoid (US-EL) measurements of right kidney volume, left kidney volume, and total kidney volume (TKV) compared to the reference standard of magnetic resonance imaging ellipsoid (MRI-EL)

| Volume | Mean (95%CI) bias, % | Limit (95%CI), % | | P ($H_0$: Mean = 0) |
|---|---|---|---|---|
| | | Lower | Upper | |
| Right | 7.5 (1.2 to 13.7) | − 26.6 (− 37.4 to − 15.8) | 41.5 (30.7 to 52.3) | 0.0211 |
| Left | 2.3 (-4.5 to 9.2) | − 35.1 (− 47.0 to − 23.2) | 39.8 (27.9 to 51.7) | 0.4927 |
| TKV | 6.2 (0.5 to 11.8) | − 24.5 (− 34.3 to − 14.8) | 36.9 (27.1 to 46.6) | 0.0328 |

### Relationship between measured glomerular filtration rate and total kidney volume

A total of 26 subjects had mGFR data available at the time of MRI-EL and US-EL.

The mGFR showed a statistically significant negative correlation with TKV measured by both MRI-EL (slope: −0.014; 95%CI −0.027 to −0.001; $p = 0.0281$) and US-EL (slope: −0.015; 95%CI −0.028 to −0.001; $p = 0.0332$) (Figure S1).

### Relationship between estimated glomerular filtration rate and total kidney volume

A total of 26 patients had eGFR data available at the time of MRI-EL and US-EL examinations.

The eGFR demonstrated a statistically significant inverse correlation with TKV as measured by both MRI-EL (slope: −0.017; 95% CI −0.029 to −0.006; $p = 0.0054$) and US-EL (slope: −0.019; 95% CI −0.031 to −0.007; $p = 0.0040$) (Figure S2).

## Discussion

The results of the current study found a strong correlation between MRI-EL and US-EL. Blant–Altmant analysis showed low biases in all the measurements. These biases were more pronounced in RKV (7.5%, $p = 0.0211$) and TKV measurements (6.2%, $p = 0.0328$), while were very low in the LKV measurements (2.3%, $p = 0.4927$). It should be noted that if the p-value is less than 0.05, it indicates the presence of a consistent bias, but this does not automatically imply that the methods are not comparable. As noted by Bland and Altman [28], a consistent bias can be easily corrected, if needed, by subtracting the mean difference from the measurements obtained by the US-EL method. Furthermore, it is important to highlight that these differences are independent of renal volume, as the mean slopes did not significantly deviate from zero.

In addition, Passing–Bablok regression analysis comparing MRI-EL and US-EL found strong correlation in RKV (95% CI for intercept −123.6 to 42.1 and for slope 0.83 to 1.16; $\rho = 0.96$), LKV (95% CI for intercept −84.6 to 35.8 and for slope 0.88 to 1.16; $\rho = 0.91$), and TKV (95% CI for intercept −184.9 to 84.0 and for slope 0.85 to 1.15; $\rho = 0.94$). These results clearly indicated that both methods were interchangeable.

Finally, kidney volume concordance between MRI-EL and US-EL, assessed by CCC, found a good agreement in RKV (0.95) and TKV (0.94), but slightly lower concordance in LKV (0.89).

One possible explanation is the different anatomical relationships of the two kidneys. For example, the anatomical proximity of the liver to the right kidney often results in acoustic shadowing during ultrasound examinations. Furthermore, the presence of polycystic liver disease, which is the most common extrarenal manifestation of ADPKD, might influence both imaging and measurements accuracy [29]. In addition, healthy liver parenchyma shows homogeneous echo texture and similar echogenicity compared to the right kidney, which might potentially impact on imaging and measurements [30]. In

(See figure on next page.)

**Fig. 4** Comparison of right kidney volume (RKV), left kidney volume (LKV), and total kidney volume (TKV) measurements between magnetic resonance imaging using the ellipsoid formula (MRI-EL) and ultrasound with the ellipsoid formula (US-EL), analyzed using the Passing–Bablok regression method. The results are presented as scatter plots with corresponding regression lines and equations. In these equations, the intercept represents the constant measurement error, while the slope reflects the proportional measurement error. A. Right Kidney Volume (RKV): The regression line equation is $y = -40.0 + 1.0xy = -40.0 + 1.0x$, with a 95% confidence interval (CI) for the intercept of −123.6 to 42.1 and for the slope of 0.83 to 1.16, indicating strong agreement between methods. The accompanying residual plot (A*) illustrates the distribution of differences around the fitted regression line. B. Left Kidney Volume (LKV): The regression line equation is $y = -16.6 + 1.0xy = -16.6 + 1.0x$, with a 95% CI for the intercept of −84.6 to 35.8 and for the slope of 0.88 to 1.16, demonstrating good agreement. The residual plot (B*) highlights the distribution of differences relative to the fitted regression line. C. Total Kidney Volume (TKV): The regression line equation is $y = -33.0 + 1.0xy = -33.0 + 1.0x$, with a 95% CI for the intercept of −184.9 to 84.0 and for the slope of 0.85 to 1.15, confirming good agreement. The residual plot (C*) depicts the differences distributed around the regression line

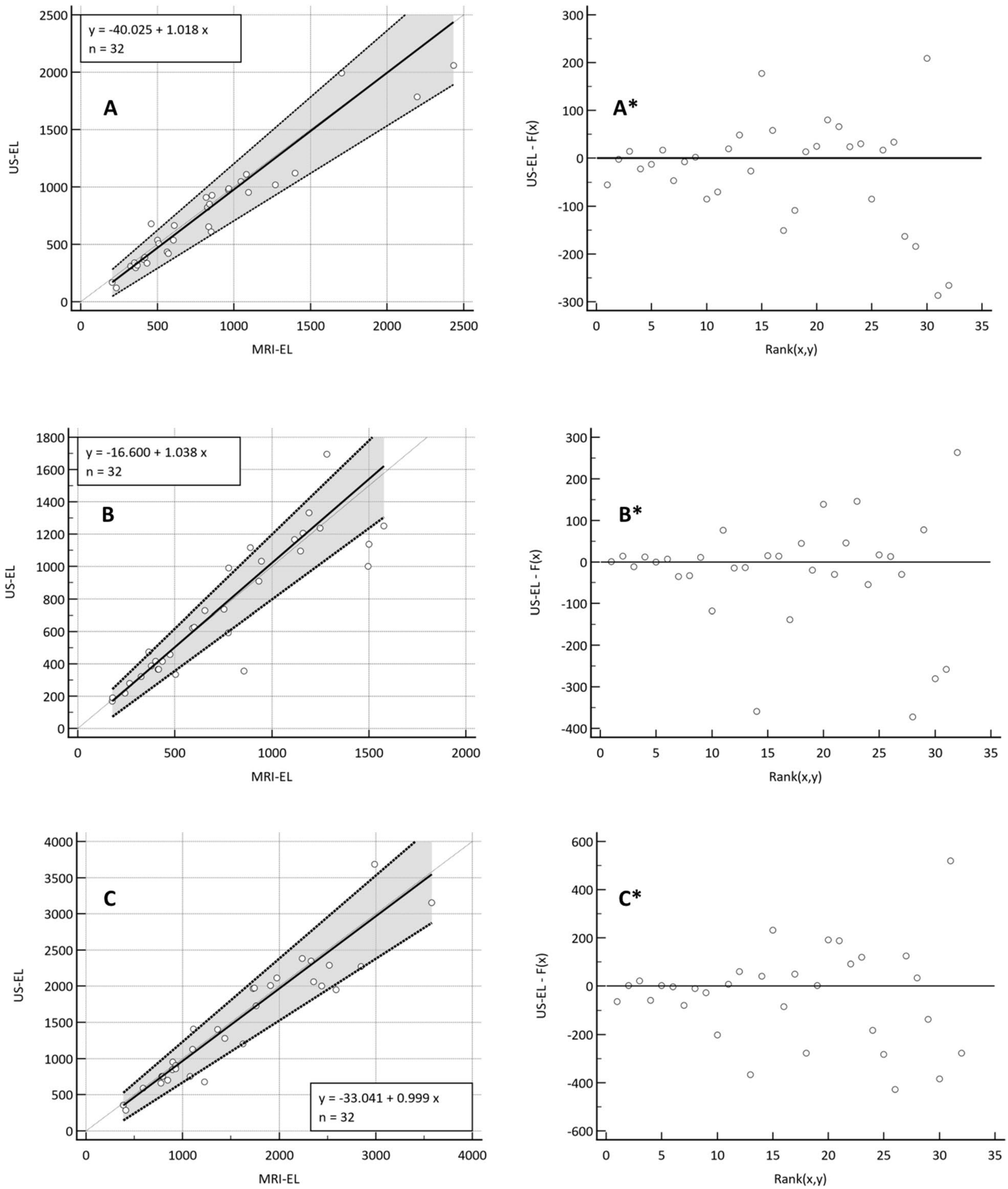


**Fig. 4** (See legend on previous page.)

contrast, the left kidney has fewer surrounding structures that cause such interference, allowing for clearer imaging and more accurate volume measurements [31].

In ADPKD, the cystic burden is most accurately represented by TKV measurements obtained via MRI. Additionally, TKV is currently the most robust predictor of future renal insufficiency in ADPKD [7, 9, 11].

**Table 2** Passing–Bablok regression analysis between magnetic resonance imaging ellipsoid (MRI-EL) and ultrasound ellipsoid (US-EL) in the right, left, and total kidney volume

| | Systematic differences | Proportional differences | Random differences | Linear model validity | Correlation** | |
|---|---|---|---|---|---|---|
| | Intercept (95%CI)[a] | Slope (95%CI)[a] | RSD (± 1.96 RSD interval) | Cusum test for linearity* | CC (95%CI) | p |
| RKV | − 40.0 (− 123.6 to 42.1) | 1.02 (0.83 to 1.16) | 111.2 (− 217.9 to 217.9) | 0.38 | 0.96 (0.92 to 0.98) | < 0.0001 |
| LKV | − 16.6 (− 84.6 to 35.8) | 1.04 (0.88 to 1.16) | 139.1 (− 272.7 to 272.7) | 1.00 | 0.91 (0.82 to 0.96) | < 0.0001 |
| TKV | − 33.0 (− 184.9 to 84.0) | 1.00 (0.85 to 1.15) | 204.9 (− 401.6 to 401.6) | 0.67 | 0.94 (0.87 to 0.97) | < 0.0001 |

*CI* confidence interval, *RSD* residual standard deviation, *RKV* right kidney volume, *LKV* left kidney volume, *TKV* total kidney volume

*p > 0.05 means that there is linear relationship between the two measurements and therefore the Passing–Bablok method is applicable

**Spearman rank correlation coefficient

[a] Bootstrap confidence interval (1000 iterations; random number seed: 978)

**Table 3** Concordance correlation coefficient (CCC) between magnetic resonance imaging ellipsoid (MRI-EL) and ultrasound ellipsoid (US-EL) in the right, left, and total kidney volume

| | MRI-EL (Reference) | | |
|---|---|---|---|
| | Overall study sample (n = 32) | | |
| | CCC (95%CI) | Precision* | Accuracy** |
| US-EL RKV | 0.95 (0.91 to 0.98) | 0.96 | 0.99 |
| US-EL LKV | 0.89 (0.80 to 0.95) | 0.90 | 1.00 |
| US-EL TKV | 0.94 (0.88 to 0.97) | 0.94 | 0.99 |

*CCC* concordance correlation coefficient, *CI* confidence interval, *MRI-EL* magnetic resonance imaging ellipsoid, *US-EL* ultrasound ellipsoid, *RKV* right kidney volume, *LKV* left kidney volume, *TKV* total kidney volume

*Pearson correlation coefficient

**It is a bias correction factor that measures how far the best-fit line deviates from the 45° line through the origin (i.e. a value of 1.00 means perfect concordance)

Kidney volume has been evaluated in numerous experimental and clinical studies employing various imaging techniques. MRI provides consistently reproducible measurements of kidney volume, as well as low inter- and intra-operator variability [32], while ultrasound is frequently used due to its accessibility and non-invasive nature [14–16].

While CT and MRI provide superior resolution for detecting small cysts, US remains the preferred initial method due to its accessibility, lower cost, and absence of radiation or contrast exposure. US demonstrates good reproducibility for TKV measurements, correlating well with CT, despite slightly lower accuracy and sensitivity [33]. Additionally, Advances in three-dimensional (3D) US technology have further enhanced diagnostic precision, enabling improved cyst detection and accurate volume measurements [34, 35]. Additionally, artificial intelligence (AI)-assisted 3D US systems show performance comparable to MRI, offering a promising alternative for routine clinical use [35]. These developments underscore the potential of US, particularly 3D and AI-enhanced systems, as accessible and effective tools for monitoring TKV and assessing treatment efficacy in ADPKD [33–36].

Despite being more cost-effective and readily accessible, ultrasound-derived kidney volume measurements are generally considered to be less accurate than those obtained from MRI ellipsoid analysis [34, 37]. Indeed, previous studies have found current US methods are still vulnerable to underestimation compared with MRI- and CT-based estimates [33, 34, 38, 39]. In agreement with these findings, compared with MRI-EL, US-EL displayed systematic bias for underestimating RKV, LKV, and TKV (mean bias of −7.5%, −2.3%, and −6.2%, respectively). Nevertheless, the results of our study (Passing–Bablok regression analysis) showed that the measurement of renal volumes with US-EL was interchangeable with MRI-EL. Therefore, the clinical significance of this underestimation may not be relevant. The increase in kidney size enables clinicians to identify patients experiencing rapid disease worsening, thus supporting timely intervention aimed at slowing disease progression. However, to the best of our knowledge, there is currently no data available in the literature regarding the recommended frequency for performing MRI scans.

Consistent with this hypothesis, Breysem et al. [39] proposed that while US-EL measurements tend to underestimate kidney volume, they still offer a valuable alternative to MRI for the assessment of early ADPKD.

In addition, Bhutani et al. [40] observed that TKV measurements obtained by ultrasound and MRI were comparable, particularly in kidneys of normal to moderate size (< 17 cm). This is likely attributable to the ability to capture the entire kidney within a single imaging plane. Moreover, this study also found that a single measurement of kidney length, either with US or MRI, can reliably predict the development of CKD stage 3 within an 8-year timeframe. This approach effectively reduces healthcare costs while delivering essential prognostic insights into potential outcomes and complications associated with ADPKD [40].

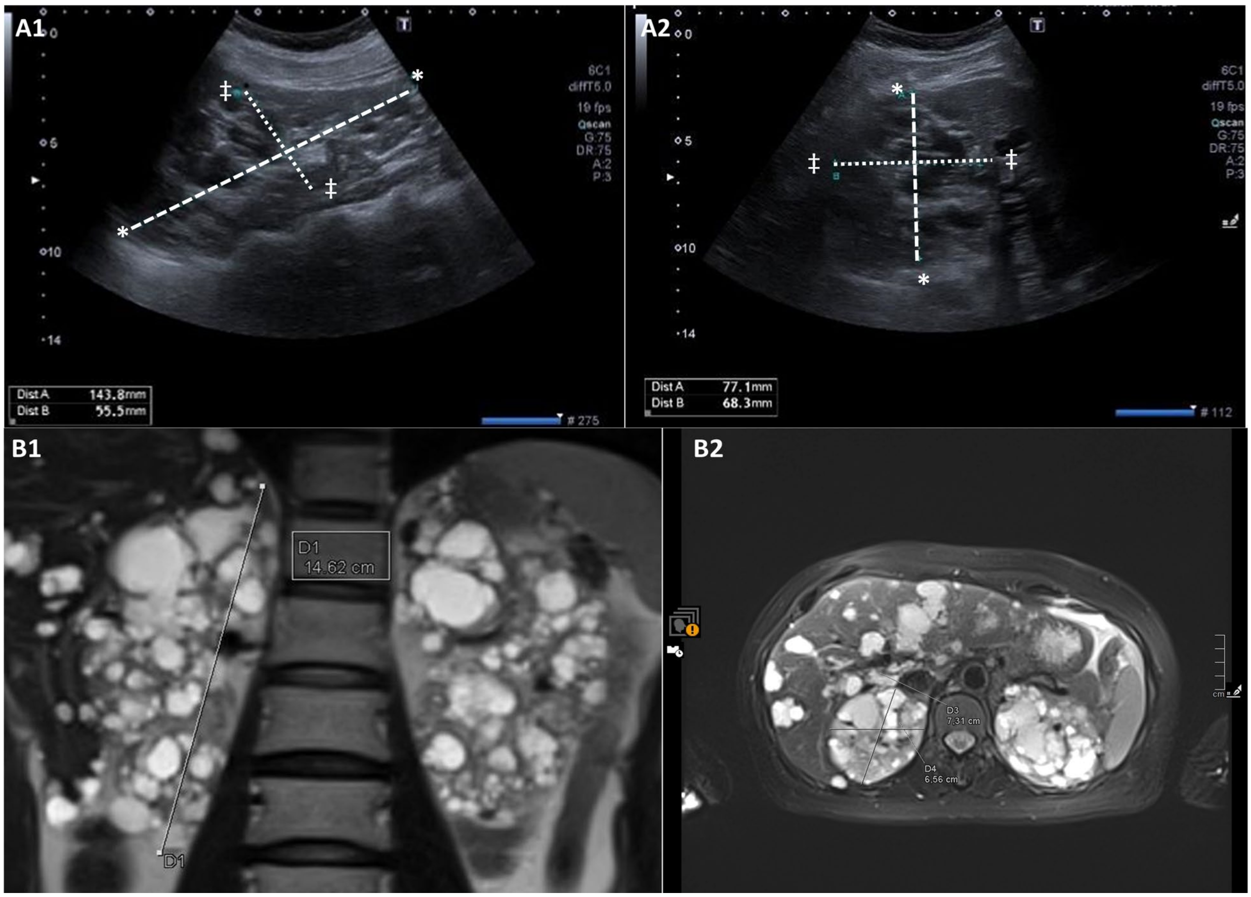


**Fig. 5** Kidney volume measurement of a 54-year-old female patient with autosomal-dominant polycystic kidney disease (ADPKD). **A** Kidney Volume Measurement Using Ultrasound. 1. Right Kidney Cranio-Caudal and Anterior–Posterior Diameters (Ellipsoid Formula). Cranio-Caudal Distance (marked * to *): 143.8 mm. Anterior–Posterior Distance (marked ‡ to ‡): 55.5 mm. 2. Right Kidney Antero-Posterior and Transverse Diameters (Ellipsoid Formula). Antero-Posterior Distance: 78.1 mm. Transverse Distance: 68.3 mm. **B** Kidney Volume Measurement Using Magnetic Resonance Imaging (MRI). 1. MRI T2 Coronal Cranio-Caudal Diameters (Ellipsoid Formula). Cranio-Caudal Distance D1: 146.2 mm. 2. MRI T2 Axial Anterior–Posterior and Transverse diameter for ellipsoid formula. Anterior–Posterior Distance D3: 73.1 mm. Transverse Distance D4: 65.6 mm

Furthermore, Braconnier et al. [41], reported a strong correlation between ultrasound-measured renal length and MRI-measured renal length in both patients with and without chronic kidney disease (CKD). However, the correlation between MRI and ultrasound measurements for kidney volume, while statistically significant, was notably weaker. Consequently, renal volume assessments should be interpreted with caution [41].

Finally, this study found an inverse correlation between renal function, either assessed by mGFR or eGFR, and TKV, regardless of the method used for determining TKV. Our findings align with those of previous studies, which have demonstrated an inverse correlation between kidney volume and renal function [7, 42–44]. However, these studies were performed evaluating renal volume with MRI, while ours used both MRI and ultrasound, finding no significant differences between both methods. These findings support the use of US-EL for determining kidney volume in clinical practice.

This study has several limitations that should be considered when interpreting its findings. A key limitation of this study is its small sample size of only 32 patients, which restricts the ability to draw generalizable conclusions and limits the broader applicability of the findings. The second major limitation is the time interval between the MRI and ultrasound examinations, which raises the possibility of kidney volume changes occurring during this period. The timing discrepancy between these imaging modalities could influence the findings, as prior research suggests that kidney condition progression is time-sensitive, potentially impacting the consistency of measurements [45]. In our specific case, this delay might be primarily attributed to limited access to MRI facilities. Nevertheless, all patients included in this study had an estimated GFR greater than 60 mL/min (CKD-EPI),

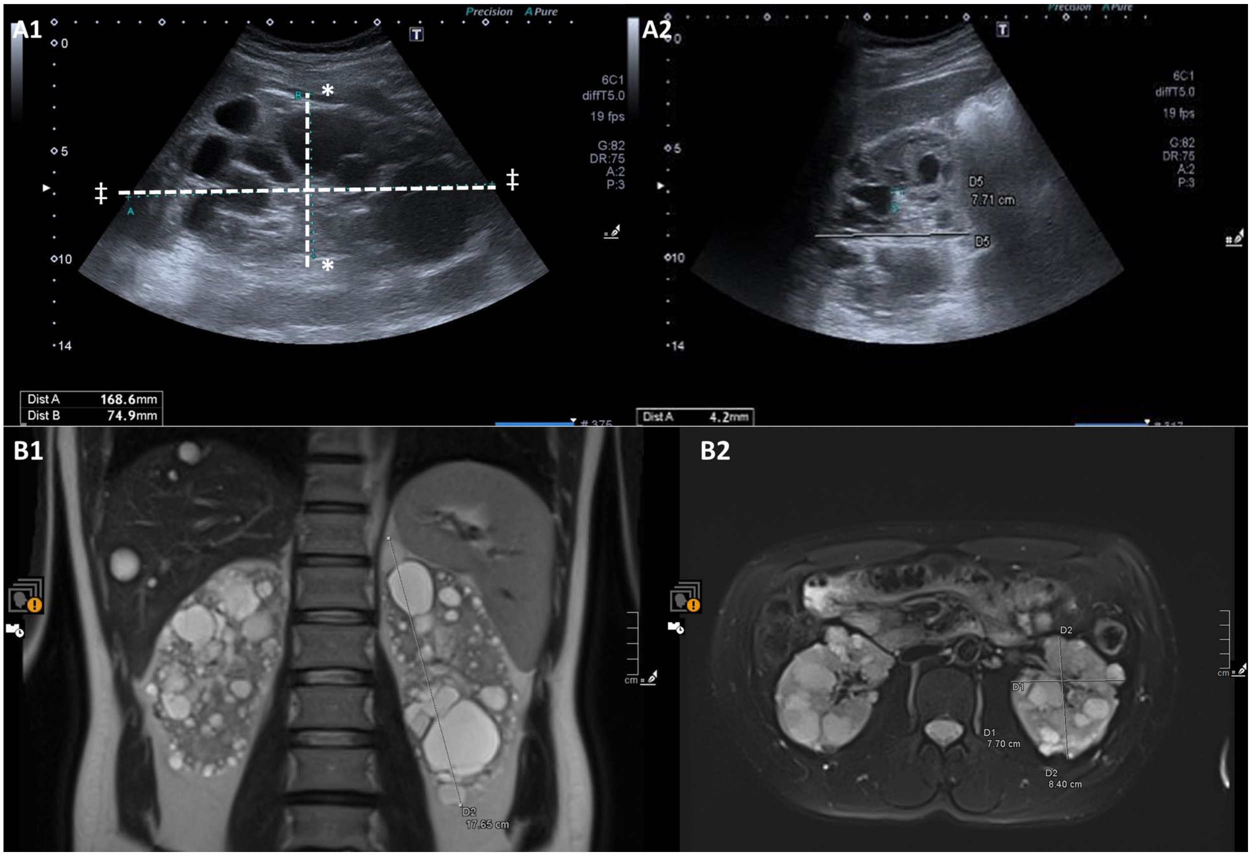


**Fig. 6** Kidney volume measurement of a 39-year-old male patient with autosomal-dominant polycystic kidney disease (ADPKD). **A** Kidney Volume Measurement Using Ultrasound. 1. Right Kidney Cranio-Caudal and Anterior–Posterior Diameters (Ellipsoid Formula). Cranio-Caudal Distance (marked * to *): 74.9.mm. Anterior–Posterior Distance (marked ‡ to ‡): 168.6 mm. 2. Right Kidney Antero-Posterior and Transverse Diameters (Ellipsoid Formula). Transverse Distance (D5): 77.1 mm. **B** Kidney Volume Measurement Using Magnetic Resonance Imaging (MRI). 1. MRI T2 Coronal Cranio-Caudal Diameters (Ellipsoid Formula). Cranio-Caudal Distance D1: 176.5 mm. 2. MRI T2 Axial Anterior–Posterior and Transverse diameter for ellipsoid formula. Anterior–Posterior Distance D2: 84.0 mm. Transverse Distance D1: 77.0 mm

indicating early-stage disease, and their clinical stability was maintained throughout the study. Notably, for most patients (18 of 32), the interval between measurements was less than 2 months, with only five patients exceeding 4 months. While renal volume changes cannot be entirely ruled out, no significant clinical alterations were observed that might have influenced the results. Another limitation is that we did not evaluate intraobserver variability of both MRI-EL and US-EL. This study was conducted by a single expert radiologist to ensure consistency and reproducibility. Although US is an operator-dependent technique, and it is advisable that radiologists undergo at least 6 months of specialized training, both techniques have shown low intraobserver variability [39, 41], although such variability may be slightly greater with US-EL [46]. In addition, US may offer other advantages such as low cost, high availability, no radiation exposure, and minimal patient discomfort. Additionally, US is quicker and less expensive than MRI (US takes between 20–30 min and the MRI between 30–50 min) [47].

The primary strength of this study lies in its execution under real-world clinical conditions, providing a more accurate reflection of how these diagnostic tools perform in routine clinical practice, outside of controlled research settings.

## Conclusions

The findings of the current study demonstrated that ultrasound-based ellipsoid kidney volume measurements (including right kidney volume, left kidney volume, and total kidney volume) showed a strong correlation with the corresponding measurements obtained via MRI-based ellipsoid assessment. This suggests that ultrasound, despite its simplicity and greater accessibility, may be considered as a reliable alternative for evaluating kidney volume in daily practice, especially in contexts where MRI may be unavailable or impractical. However, this does not imply that US-EL can be regarded as a complete substitute for MRI-EL.

It would be interesting and probably the subject of future research, to compare the clinical performance of both techniques for monitoring the course of patients with ADPKD. In addition, it might be clinically relevant to analyze the performance of both techniques for predicting the disease's progression and identifying patients at risk of experiencing accelerated disease progression, which facilitates customized monitoring and tailored treatment strategies.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13089-025-00400-0.

Supplementary Material 1. Figure S1. Linear regression analysis evaluating the relationship between measured glomerular filtration rate (mGFR) and total kidney volume (TKV) assessed by magnetic resonance imaging ellipsoid (MRI-EL) and ultrasound ellipsoid (US-EL). The shaded grey area represents the 95% confidence interval. The analysis revealed a statistically significant negative correlation between mGFR and TKV for both imaging methods. For MRI-EL, the slope was −0.014 (95% CI: −0.027 to −0.001; p=0.0281), while for US-EL, the slope was −0.015 (95% CI: −0.028 to −0.001; p=0.0332). These findings highlight an inverse relationship between mGFR and TKV, regardless of the imaging modality used.

Supplementary Material 2. Figure S2. Linear regression analysis examining the relationship between estimated glomerular filtration rate (eGFR), assessed by the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula, and total kidney volume (TKV) assessed by magnetic resonance imaging ellipsoid (MRI-EL) and ultrasound ellipsoid (US-EL). The grey-shaded region represents the 95% confidence interval. The analysis revealed a statistically significant inverse correlation between eGFR and TKV for both imaging methods. For MRI-EL, the slope was −0.017 (95% CI: −0.029 to −0.006; p = 0.0054), while for US-EL, the slope was −0.019 (95% CI: −0.031 to −0.007; p = 0.0040). These results underscore a consistent negative relationship between eGFR and TKV, regardless of the imaging modality employed.

**Acknowledgements**
To Universidad Fernando Pessoa Canarias for the regular support to the biomedical research.
Writing and editorial assistance was provided to the authors by Antonio Martinez (MD) of Ciencia y Deporte ltd.
At the time of the research, Dr Juan M Fernandez was part of the staff of the Nephrology Department of Hospital Universitario de Gran Canaria Dr. Negrín (HUGCDN), Las Palmas de Gran Canaria (Spain)

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**Funding**
Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. This research did not receive any specific grant from funding agencies.

**Availability of data and materials**
The data underlying this article will be shared on reasonable request to the corresponding author.

## Declarations

**Ethics approval and consent to participate**
The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of HUGCDN (Protocol VO 05-2017; Review Board approval: 170071; May 2017). Informed consent was obtained from all subjects involved in the study.

**Consent for publication**
Not applicable.

**Competing interests**
None of the authors have any conflict of interest to declare. Neither honoraria nor payments were made for authorship of this article. All authors declare no proprietary interest.

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Received: 30 October 2024 Accepted: 2 January 2025
Published online: 11 February 2025

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## Publisher's Note