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CORRELATION ANALYSIS OF RENAL SCAN AND VOLUMETRIC PERFUSION CT IN THE ASSESSMENT OF LIVING KIDNEY DONORS

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Objective: to evaluate the correlation between renal scan (RSc) and volumetric multislice computed tomography (perfusion CT) in living kidney donors, with the goal of identifying interchangeable functional parameters and optimizing the preoperative assessment of split renal function. **Materials and methods.** The study included 54 living kidney donors (totaling 108 kidneys). Split renal function was assessed using RSc with 99mTc-mercaptoacetyltriglycine (MAG3) and contrast-enhanced volumetric MSCT. Key parameters from nephroscintigraphy included renal plasma flow (RPF), time to maximum tracer accumulation (Tmax), and excretion half-life (T½). Single-photon emission computed tomography (SPECT) analysis included arterial flow (AF), blood volume (BV), extraction fraction (FE), and indexed extraction fraction (IFE). Correlation between modalities was analyzed using Pearson's correlation coefficient and Bland–Altman plots. **Results.** Significant correlations were observed between RSc and volumetric MCT parameters. A strong negative correlation was found between Tmax and AF ($r = -0.75$, $p < 0.001$), indicating an inverse relationship between blood flow velocity and renal filtration capacity. Similarly, T½ showed a negative correlation with FE ($r = -0.75$, $p < 0.01$), suggesting that a shorter tracer half-life corresponds to more efficient renal extraction. A strong positive correlation between RPF and IFE ($r = 0.79$, $p < 0.001$) supports the feasibility of using indexed CT perfusion as a surrogate for assessing RPF. Bland-Altman analysis showed that differences between the two diagnostic methods remained within clinically acceptable limits, confirming their potential interchangeability in preoperative donor assessment. **Conclusion.** The study demonstrates the potential for partial interchangeability between RSc and volumetric CT perfusion in the preoperative assessment of kidney donors. While CT perfusion offers superior accuracy in assessing renal blood flow, nephroscintigraphy remains the method of choice for evaluating excretory function. The combined use of both modalities improves diagnostic accuracy and kidney donor selection, thereby improving the safety of kidney transplant programs.

Keywords: split renal function, nephroscintigraphy, volumetric CT perfusion, kidney donation, renal perfusion, functional diagnostics.

INTRODUCTION

Related kidney transplantation is one of the key treatment options for patients with end-stage chronic kidney disease (CKD). A critical step in this process is the selection of the most suitable donor kidney, which requires a detailed assessment of its separate function.

Split renal function refers to the relative contribution of each individual kidney to the overall renal function, often expressed as a fraction of the total activity of both kidneys. This assessment provides important information on the presence or absence of functional symmetry and serves as a decisive parameter in donor selection [1, 2].

According to current clinical guidelines, if the difference in functional contribution between the two kidneys is less than 10%, the donor retains the kidney with the higher function. However, if the difference exceeds 10%, the individual is not recommended as a donor, since significant asymmetry in kidney function may adversely affect long-term health after nephrectomy [3, 4].

At present, several methods are used in clinical practice to assess split kidney function, with renal scan (renal scintigraphy) and volumetric multislice computed tomography (CT perfusion) being the most widely used [5, 6]. According to Grenier et al. (2015) and Zhang et al. (2017), perfusion CT enables highly accurate evaluation of renal blood flow [7, 8]. In contrast, O'Connor et al. (2014) reported that renal scan provides a more precise assessment of renal excretory function, particularly in patients with nephropathy [9, 10].

A renal scan is based on the use of radiopharmaceuticals and allows for assessment of the kinetics of tracer passage through the kidneys. Key parameters include renal plasma flow (RPF), time to maximum tracer accumulation (Tmax), and excretion half-life (T½) [11, 12]. By comparison, CT perfusion provides detailed in-

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sight into renal hemodynamics, including arterial flow (AF), blood volume (BV), extraction fraction (FE), and indexed extraction fraction (IFE), the latter being especially valuable in accounting for individual anatomical variability [13, 14].

Despite the widespread use of these techniques, the degree of correlation between their parameters and the possibility of interchangeability remain unresolved. Some studies suggest that CT angiography may, in certain cases, substitute for radionuclide techniques in evaluating renal blood flow [15, 16]. Conversely, other authors emphasize that renal scintigraphy provides a more accurate measure of excretory function in patients with concomitant renal pathology [17, 18].

The present study was designed to analyze correlations between the principal parameters of renal scan and CT perfusion in living kidney donors. The objective was to identify interchangeable indicators and to evaluate their clinical significance for optimizing the preoperative assessment of split kidney function.

MATERIALS AND METHODS

The study included 54 living kidney donors, providing a total dataset of 108 kidneys. All participants underwent a standardized diagnostic work-up that incorporated both renal scintigraphy and perfusion CT analysis.

Renal scan was performed using a Siemens Symbia T16 gamma camera with ^99mTc-mercaptoacetyltriglycine (MAG3) as the radiopharmaceutical. MAG3 was selected due to its high excretory capacity and widespread use in the assessment of RPF and excretory function.

The following key indicators of renal function were evaluated renal scan: Tmax (time from the injection of MAG3 to when the highest amount of activity is detected in the kidneys, reflecting how quickly the tracer is filtered by the kidneys and distributed within the renal cortex); T½ (the time required for renal clearance of MAG3 from peak activity, characterizing the efficiency of excretory function); RPF (the volume of plasma passing through the kidney per unit time, expressed in mL/min/m^2 of body surface area).

In addition, relative kidney function was assessed by normalizing renal scintigraphy parameters to the total functional contribution of both kidneys. This calculation was based on RPF, as MAG3 is predominantly excreted via tubular secretion, making it more sensitive to renal blood flow changes compared with other radiopharmaceuticals.

The use of MAG3 allowed for a more accurate assessment of renal excretory function, particularly in patients with potential dysfunction, as its clearance correlates closely with effective RPF and tubular secretion. This makes it an indispensable tool for detecting even subtle abnormalities in renal function among potential donors.

To determine the relative functional contribution of the right and left kidneys, renal scan data were normalized to the total functional activity of both kidneys. The relative contribution of each individual kidney was calculated using the following standard formula:

$$\text{Relative kidney contribution (\%)} = \frac{\text{Function of individual kidney}}{\text{Function of both kidneys}} \times 100.$$

Initially, individual renal scintigraphy parameters were measured, including drug accumulation level, filtration rate, and RPF. The total functional contribution of both kidneys was then determined by summing the corresponding values for the right and left kidneys. Finally, the relative contribution of each kidney was calculated as a percentage, using the ratio of the functional activity of a single kidney to the total activity of both kidneys, multiplied by 100.

For example, if the RPF of the right kidney is 225 mL/min and that of the left kidney is 275 mL/min, the total RPF is 500 mL/min. Accordingly, the relative contribution of the right kidney is: (225/500) × 100 = 45%, and the relative contribution of the left kidney is: (275/500) × 100 = 55%.

Various indicators can be used to calculate the relative functional contribution of each kidney. Among them, RPF is most frequently applied, as it directly reflects the volume of blood passing through each kidney. Additional parameters, such as the level of radioisotope accumulation and its excretion rate, are also informative, as they characterize filtration and excretory processes. Assessing relative contribution is particularly important in donor selection, as it helps determine functional symmetry and identify significant asymmetry, which may indicate underlying pathology.

Perfusion measurements were performed using a 320-slice Aquilion ONE spiral CT scanner (Canon Medical Systems, Japan). Scans were obtained with a slice thickness of 0.5 mm in soft tissue reconstruction mode. The protocol was optimized to minimize radiation exposure, using a tube voltage of 100 kV and an exposure of 60 mAs, which was sufficient for dynamic studies with a maximum coverage width of 160 mm along the Z-axis. Additional parameters included collimator dimensions of 0.5×320 mm, a matrix of 512×512, a field of view (FOV) of 320–350 mm, and a tube rotation time of 0.275 s.

This technique enabled quantitative assessment of renal hemodynamics through contrast-enhanced dynamic scanning, which recorded temporal changes in renal tissue density.

Prior to the examination, all patients underwent standard preparation, which included preliminary hydration when necessary to minimize the risk of contrast-induced nephropathy. A clinical evaluation was also performed to rule out potential contraindications, such as allergy to iodine-containing contrast agents.

An iodine-containing contrast agent (iodhexol, iodine concentration 350 mg/mL) was used for perfusion studies. The contrast medium was administered via a peripheral venous catheter using an automatic injector at a rate of 5 mL/s. The total volume of contrast was calculated individually according to body weight, with a minimum dose of 0.5 mL/kg.

Following contrast administration, a dynamic series of scans was performed to capture temporal changes in renal tissue density. Scans were acquired at intervals of 30–90 seconds, with a slice thickness of 3–5 mm, yielding a total of 20–30 series per study. Density values of the cortical and medullary layers of the kidneys were expressed in Hounsfield units (HU) and used to construct time–density curves.

Post-processing of imaging data was performed using VITREA software (Canon Medical Systems, Japan), which enabled the calculation of renal perfusion parameters. The Patlak model was applied to analyze the linear portion of the contrast accumulation curve, providing accurate estimates of extraction fraction (FE) and blood volume (BV). Arterial flow (AF) was calculated using a standard dynamic perfusion model based on the initial rate of density increase.

AF was defined as the volume of blood passing through 100 g of kidney tissue per minute and was calculated from the slope of the initial section of the contrast enhancement curve. BV represented the total volume of circulating blood in 100 ml of kidney tissue, providing an estimate of vascular filling of the parenchyma. FE and IFE were derived from analysis of contrast accumulation and clearance, reflecting the efficiency of renal filtration.

The IFE was additionally calculated to account for individual anatomical variability. For this purpose, the volume of the renal cortex – the primary site of filtration and excretion – was measured, and the FE was normalized to cortical volume. This adjustment provided a more precise and comparable index of renal functional activity across different patients.

IFE provided an additional level of normalization of renal filtration parameters, eliminating the influence of kidney size differences, particularly when comparing the right and left kidneys. This was especially important in donor selection, as IFE allowed for an objective evaluation of excretory function independent of anatomical variations. The obtained data allowed not only assessment of the functional state of the kidneys, but also analysis of their relative contribution – an essential factor in choosing the donor organ. The correlations identified between renal scan indicators and CT perfusion parameters confirmed the feasibility of applying these methods in the comprehensive evaluation of renal function.

STATISTICAL ANALYSIS

Correlation analysis was performed using Pearson's correlation coefficient to examine the relationships between renal scan indicators (Tmax, T½, RPF) and CT perfusion parameters (AF, BV, FE, IFE). The analysis was aimed at identifying linear associations between parameters reflecting renal perfusion and functional characteristics. Statistical significance was set at $p < 0.05$.

Additionally, a Bland–Altman analysis was conducted to assess the degree of agreement between renal scan and CT perfusion measurements. This method was applied to compare differences in measurements of Tmax, T½, and RPF (renal scan data) with AF, FE, and BV (CT perfusion data), in order to identify systematic biases and establish limits of agreement between the two diagnostic approaches. The analysis enabled evaluation of the reproducibility and potential interchangeability of results obtained by these different research methods.

RESULTS AND DISCUSSION

The analysis of the relationship between functional parameters derived from renal scintigraphy and perfusion CT revealed statistically significant correlations, supporting the physiological link between renal perfusion and filtration.

A negative correlation was observed between the time to maximum tracer accumulation (Tmax) and arterial flow (AF) ($r = –0.75$, $p < 0.001$). This finding indicates that higher arterial blood flow is associated with a shorter time to peak drug concentration, reflecting the dependence of isotope uptake rate on renal tissue perfusion.

Similarly, a negative correlation was found between drug half-life (T½) and extraction fraction (FE) ($r = –0.75$, $p < 0.01$). This result confirms that higher extraction capacity facilitates faster clearance of the tracer, while lower extraction efficiency prolongs drug elimination.

The relationship between RPF and IFE showed a strong positive correlation ($r = 0.79$, $p < 0.001$). The recalculation of FE values for the cortical volume significantly improved reproducibility and provided a more objective evaluation of renal filtration capacity, minimizing the influence of anatomical variability (Table 1).

Table 1

Correlation between renal scintigraphy and perfusion CT

Renal scan index	CT perfusion index	Correlation coefficient (r)	p-value
Tmax	AF	–0.75	p < 0.001
T½	FE	–0.75	p < 0.01
RPF	IFE	0.81	p < 0.01

A Bland–Altman analysis was performed to further assess the agreement between renal scintigraphy and perfusion CT. Comparison of Tmax and AF showed limits of agreement ranging from –15% to +18%, with a mean difference not exceeding 3%, supporting their interchangeability for the assessment of renal blood flow in the absence of significant vascular pathology. The comparison of T½ and FE revealed a narrower range of discrepancies (–10% to +12%), indicating strong consistency between these parameters. Similarly, the average difference between RPF and IFE was only 1.5%, with limits of agreement between –8% and +9%, confirming their functional equivalence.

Assessment of the relative functional contribution of each kidney demonstrated that CT perfusion provided higher accuracy. The mean contributions of the right and left kidneys, as determined by FE and IFE, were 49.8% (±3.2%) and 50.2% (±3.4%), respectively, confirming functional symmetry in the donor cohort. In contrast, renal scintigraphy exhibited greater interindividual variability, which may limit its precision in determining relative functional contribution (Table 2).

The findings of this study indicate that renal scan and CT perfusion parameters are partially interchangeable. AF can be reliably used in place of Tmax for assessing renal blood flow. Similarly, FE is equivalent to T½ in evaluating clearance. IFE, adjusted for renal parenchyma volume, accurately reflects RPF and can serve as its substitute in functional calculations.

The identified correlations enal scan and CT perfusion confirm the feasibility of using both techniques in comprehensive assessment of renal function. While methodological differences arise from their distinct physical principles, Bland–Altman analysis showed that measurements were consistent within clinically acceptable limits. Importantly, CT perfusion yielded a more precise determination of the relative functional contribution of each kidney compared with renal scintigraphy, which makes this method preferable for preoperative evaluation of living kidney donors.

Perfusion CT provides a highly accurate quantitative assessment of renal hemodynamics. Its key advantage lies in the ability to separately evaluate the functional state of the cortical and medullary layers and to determine the relative contribution of each kidney with high precision. The combination of anatomical detail with microcirculatory parameters makes this technique particularly valuable in the selection of living kidney donors.

Table 2

Average relative contribution of kidneys by method

Method	Right kidney (%)	Left kidney (%)	Standard deviation (SD)
CT perfusion	49.8	50.2	±3.4%
Renal scan	48.6	51.4	±5.3%

The primary limitations of CT perfusion are radiation exposure and the need for intravenous contrast material, which necessitates caution in patients at risk of contrast-induced nephropathy. Nevertheless, adherence to optimized preparation protocols and appropriate patient selection substantially reduces these risks.

Taken together, CT perfusion emerges as a promising tool for comprehensive evaluation of kidney donors. Its strong correlation with renal scan parameters supports its use as a reliable alternative for assessing renal blood flow and plasma flow.

FINDINGS

The results of the study demonstrated that renal scintigraphy and CT perfusion analysis show a high degree of correlation across several key parameters, indicating their potential partial interchangeability in clinical practice.

The time to maximum tracer accumulation (Tmax), obtained from scintigraphy, showed a strong negative correlation with arterial flow (AF) derived from CT perfusion. This relationship confirms the applicability of both parameters for evaluating renal blood flow velocity and filtration capacity (Fig. 1).

Similarly, the excretion half-life of the radiopharmaceutical (T½) measured by scintigraphy demonstrated a negative correlation with extraction fraction (FE) obtained from CT perfusion. This finding supports the conclusion that both parameters reliably reflect renal filtration and excretory activity (Fig. 2).

RPF, obtained from renal scintigraphy, revealed a strong positive correlation with BV measured by CT perfusion, indicating that these parameters can be considered equivalent for assessing renal hemodynamics (Fig. 3).

The differences between renal scan and CT perfusion values remained within clinically acceptable limits of agreement, further supporting the feasibility of using both methods to evaluate renal function. The diagrams confirm the potential of CT perfusion as an alternative to renal scan, particularly in settings where the latter is not available.

Overall, both methods provide valuable information on renal physiology, though with distinct strengths. Renal scan offers more detailed insights into filtration and excretion processes, whereas perfusion CT provides a more precise assessment of blood flow and microcirculation in the kidneys.

The following indicators have been found to be interchangeable:

– Tmax ↔ AF – for assessing renal blood flow and filtration rate;

– T½ ↔ FE – for evaluating filtration and excretion functions;
– RPF ↔ IFE – for assessing renal plasma flow and indexed extraction fraction.

When one of the methods is unavailable or contraindicated, the other can provide comparable functional data. For example, in patients with contraindications to iodine-containing contrast agents used in CT perfusion, renal scan (renal scintigraphy) remains the preferred option. Conversely, in donor evaluation, where a more detailed assessment of renal hemodynamics is required, CT perfusion is preferred.

Despite the high correlation, the two methods are not completely identical. The choice of an appropriate diagnostic technique should therefore be determined by the clinical objective and the patient's condition. Renal scintigraphy has lower spatial resolution for evaluating segmental blood flow, while CT perfusion provides more detailed information on local microcirculation.

The results of this study confirm the presence of interchangeable indicators between the two modalities. A comparison of our findings with the studies of Rigatelli et al. (2020) and Lim et al. (2024) further highlights the capacity of CT perfusion to provide a quantitative

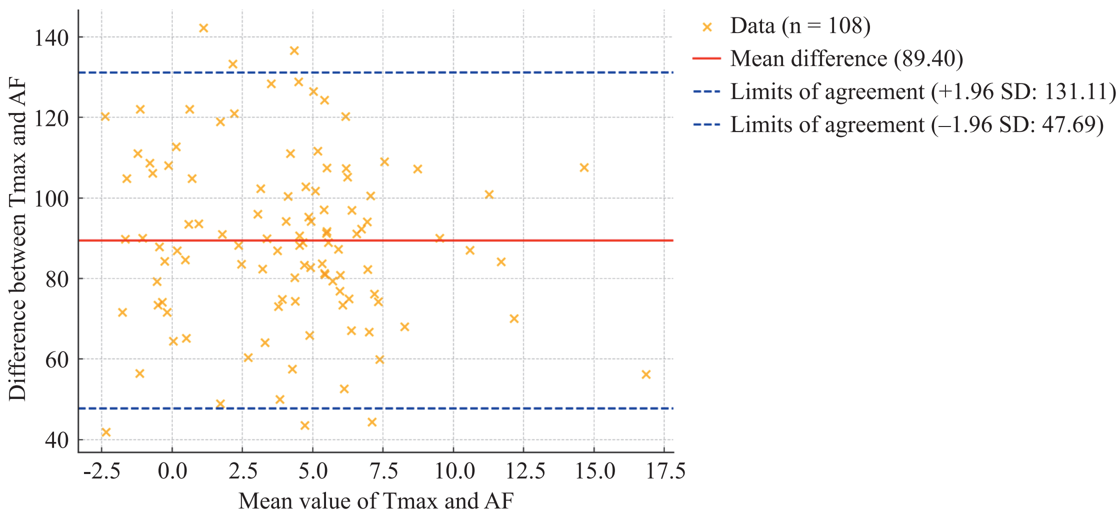

Fig. 1. Bland–Altman plot: Tmax *vs* AF (n = 108). The X-axis represents the mean of Tmax (time to maximum radiotracer accumulation from renal scan data) and AF (arterial flow from MSCT renal perfusion data). The Y-axis shows the difference between these two measurements (Tmax – AF). The red line indicates the mean difference between methods; blue lines denote the limits of agreement (±1.96 SD). The graph shows that the difference between Tmax and AF varies within the limits of agreement, confirming good reproducibility of the results. However, there is a tendency for the difference to increase with increasing AF, which may indicate individual variations in renal hemodynamics

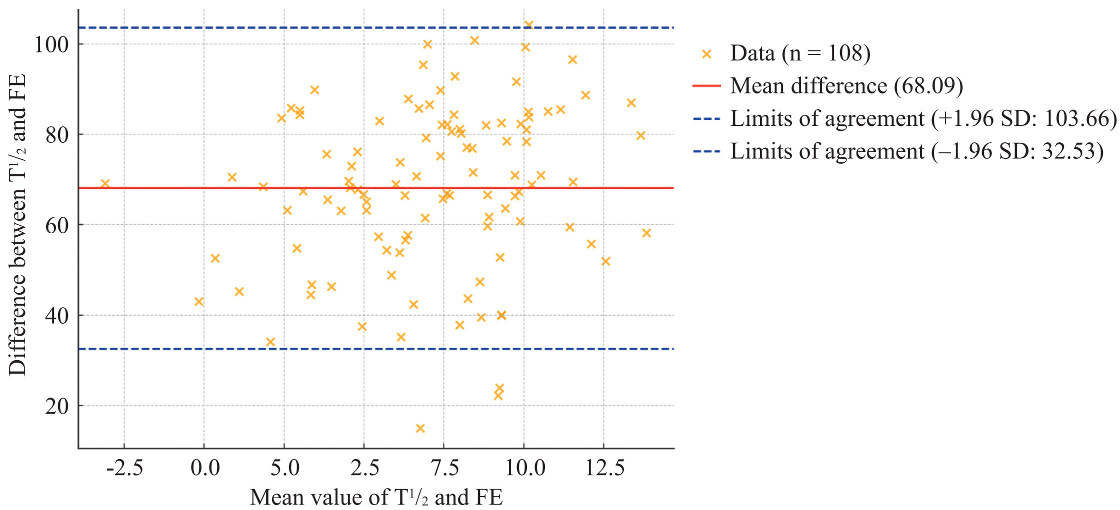

Fig. 2. Bland–Altman plot: T½ *vs* FE (n = 108). The X-axis represents the mean of T½ (radiotracer half-life from renal scan data) and FE (extraction fraction from MSCT perfusion data). The Y-axis shows the difference between T½ and FE measurements (T½ – FE). The red line indicates the mean difference; blue lines represent the limits of agreement (±1.96 SD). The plot demonstrates a high degree of agreement between T½ and FE, with most data points falling within the limits of agreement. The mean difference is close to zero, supporting the use of FE as a surrogate indicator of renal clearance dynamics

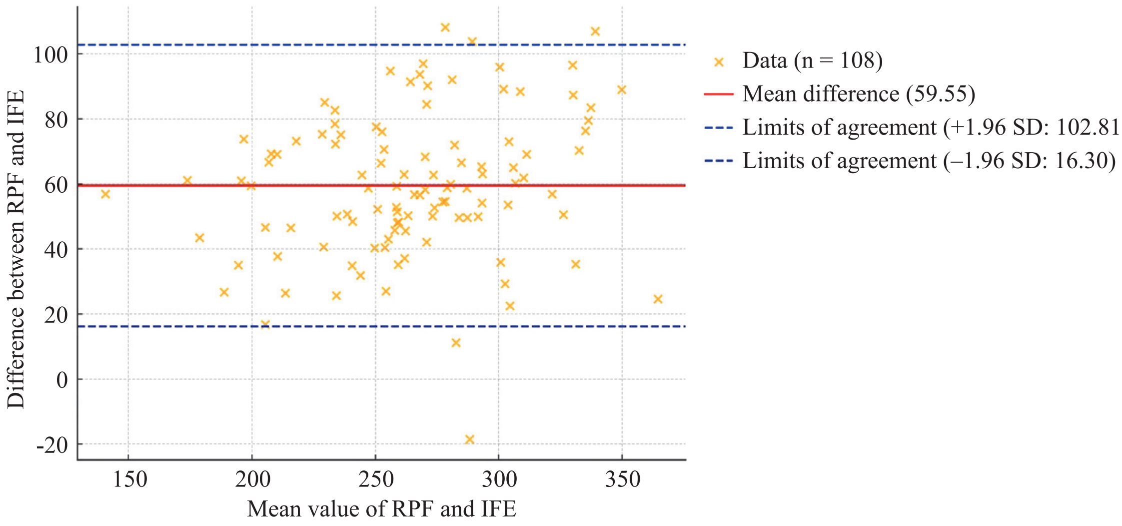

Fig. 3. Bland–Altman plot: RPF *vs* IFE (n = 108). The X-axis shows the mean values of RPF (renal plasma flow from renal scan data) and IFE (indexed extraction fraction from MSCT perfusion data). The Y-axis represents the difference between RPF and IFE measurements (RPF – IFE). The red line indicates the mean difference between methods, while the blue lines represent the limits of agreement (±1.96 standard deviations). This plot demonstrates the highest level of agreement between renal plasma flow and blood volume. The average difference is minimal, and most data points fall within the limits of agreement, supporting the strong equivalence between RPF and IFE

assessment of renal microcirculation, strengthening its role as a promising tool for preoperative evaluation and selection of donor kidneys [19, 20].

CONCLUSION

Renal scan and CT perfusion should be regarded as complementary techniques for assessing renal function. The demonstrated correlations between their key parameters support their interchangeable use depending on clinical scenario: CT perfusion provides a more precise evaluation of renal blood supply, while renal scan offers integrated indicators of filtration and excretory capacity. The choice of the appropriate method must therefore be individualized, taking into account diagnostic objectives, institutional resources, and patient condition.

Importantly, the assessment of split kidney function and use of indexed parameters such as IFE not only enhance the accuracy of donor evaluation but also contribute to improving the overall safety of kidney transplant programs.

The authors declare no conflict of interest.

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