# Relative Perfusion and Glomerular Filtration Rate: Integrating Doppler and Scintigraphy Findings in Renal Evaluation

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## ABSTRACT

Various imaging tools are utilized for the quantitative assessment of renal function in clinical practice. Integration of Doppler ultrasonography and renal scintigraphy might be invaluable for different aspects of renal evaluation. However, the relationship between these modalities remains incompletely defined. In this prospective observational study, multiple linear regression analyses were performed to evaluate the predictive value of Doppler parameters and scintigraphy derived estimations in both kidneys. For the right kidney, glomerular filtration rate was significantly predicted by resistive index ($\beta = -0.448$, $p = 0.036$) and relative perfusion ($\beta = 0.535$, $p = 0.001$), with an overall model fit of $R^2 = 0.533$ ($p = 0.001$). For the left kidney, glomerular filtration rate was strongly predicted by relative perfusion ($\beta = 0.787$, $p < 0.001$), with an overall model fit of $R^2 = 0.700$ ($p < 0.001$). In conclusion, Doppler indices alone do not reliably predict renal perfusion, underscoring the complementary rather than interchangeable role of Doppler and scintigraphy. Integrated use of both modalities enhances renal functional assessment and may improve diagnostic accuracy in patients with suspected renal impairment.

***Keywords:*** Renal perfusion, glomerular filtration rate, renal doppler, renal scintigraphy

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## INTRODUCTION

A key component of clinical nephrology and urology is accurate assessment of renal function, which directs diagnosis, treatment choices, and long-term patient care. Doppler ultrasonography and nuclear medicine scintigraphy are two commonly used imaging modalities that provide different but complementary insights. Hemodynamic measures such as resistive index (RI), end diastolic velocity (EDV), and peak systolic velocity (PSV) can be obtained non-invasively using Doppler ultrasonography. These indices show the dynamics of renal blood flow and vascular resistance; RI in particular has been suggested as a sign of compromised renal function (1, 2).

Scintigraphy, in contrast, provides quantitative measurements of glomerular filtration rate (GFR) and relative perfusion, allowing for the direct evaluation of renal function and contribution (3). Although scintigraphy is the gold standard for assessing split renal function, frequent use may be limited by its cost, availability, and radiation hazard (4).

Associations between RI and renal dysfunction have been reported in earlier research (5, 6), but few investigations have systematically compared Doppler indices with scintigraphy outcomes using regression analysis across both kidneys. The present study was designed to address this knowledge gap by evaluating the relationship between Doppler parameters (PSV, EDV, and RI) and scintigraphy derived measures of renal function (GFR) and relative perfusion. The purpose of this work is to clarify the complementary functions of Doppler ultrasonography and scintigraphy in renal evaluation and to ascertain whether Doppler indices independently predict renal function and perfusion.

## PATIENTS AND METHODS

This was a prospective observational study conducted at Institute of Nuclear Medicine & Allied Sciences (INMAS), Mitford and INMAS Suhrawardy, Dhaka between July 2025 and January 2026. A total of thirty adult patients referred for DTPA renogram to evaluate the renal function were enrolled. Clinical indications included varying levels of urinary obstruction, chronic kidney disease, pre-transplant evaluation etc. Any patient with solitary or ectopic kidney was excluded from the study.

After proper history taking, counselling and explanation of the procedure, informed consent was taken from each subject. Prior to the renogram, ultrasound of kidney and urinary bladder were done documenting both greyscale and doppler findings. First, in Greyscale long and short axis imaging of both kidneys was done to determine the size, location, and echotexture, presence of any focal abnormality, and corticomedullary differentiation. Then Peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) were measured from proximal, mid, and distal segments of bilateral renal arteries, and arithmetic means were calculated. All examinations were performed by a single observer, with more than 10 years of expertise. Renal scintigraphy was performed using Tc 99m DTPA for estimation of GFR, split function and relative perfusion following usual protocol. Imaging was acquired on Mediso AnyScan SPECT machine and processed with InterView™ Software.

Following tracer injection, high-temporal-resolution frames were acquired during the initial transit phase. Regions of interest (ROIs) were manually delineated over each kidney and the abdominal aorta to define input and output functions. Time–activity curves (TACs) were automatically generated for each ROI, and the first-pass portion of the curves was extracted. The software integrated counts under the initial peaks and normalized them against the aortic input curve to derive relative perfusion indices. Perfusion ratios were expressed as the percentage contribution of each kidney to total renal blood flow. Curve-fitting error metrics were reviewed to ensure quality control, and ROIs were adjusted if motion or overlap artifacts were suspected. This standardized workflow provided reproducible quantification of relative renal perfusion, complementing subsequent uptake and excretory phase analyses, as well as GFR estimation by Gates method.

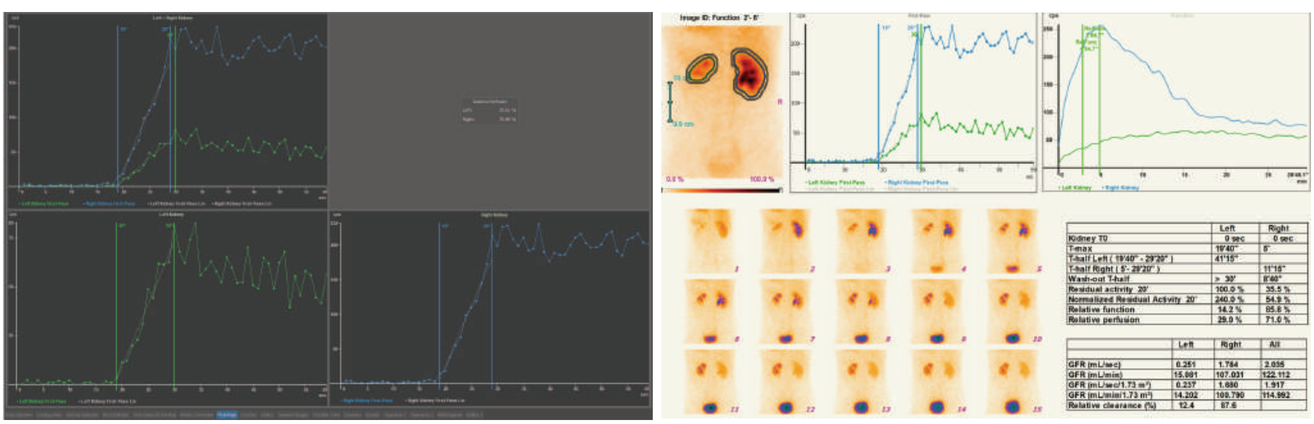

**Figure 1: Representative image of Tc-99m DTPA renogram of a 30-year-old male with smaller left kidney referred for functional evaluation. Image A shows relative perfusion estimation and image B shows summary of results with time activity curves.**

Statistical analysis was done using SPSS and Microsoft Excel. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequency and percentage. Distribution of continuous variables was assessed for normality using the Shapiro–Wilk test. Correlation analysis was done using Pearson correlation coefficient (r) for normally distributed data, and Spearman's rank correlation coefficient (ρ) for non-normally distributed data. Multiple linear regression analyses were performed to assess the predictive value of Doppler parameters and perfusion for GFR and relative perfusion. Model fit was evaluated using $R^2$ and ANOVA, and individual predictors were assessed using standardized coefficients (β) and p values. Statistical significance was set at $p < 0.05$.

## RESULTS

The study subjects were comprised of 16 females and 14 males, with ages ranging from 18 to 68 years (mean 36.6 ± 14.4 years). Nearly half of the patients (46.7%) had a history of surgical intervention.

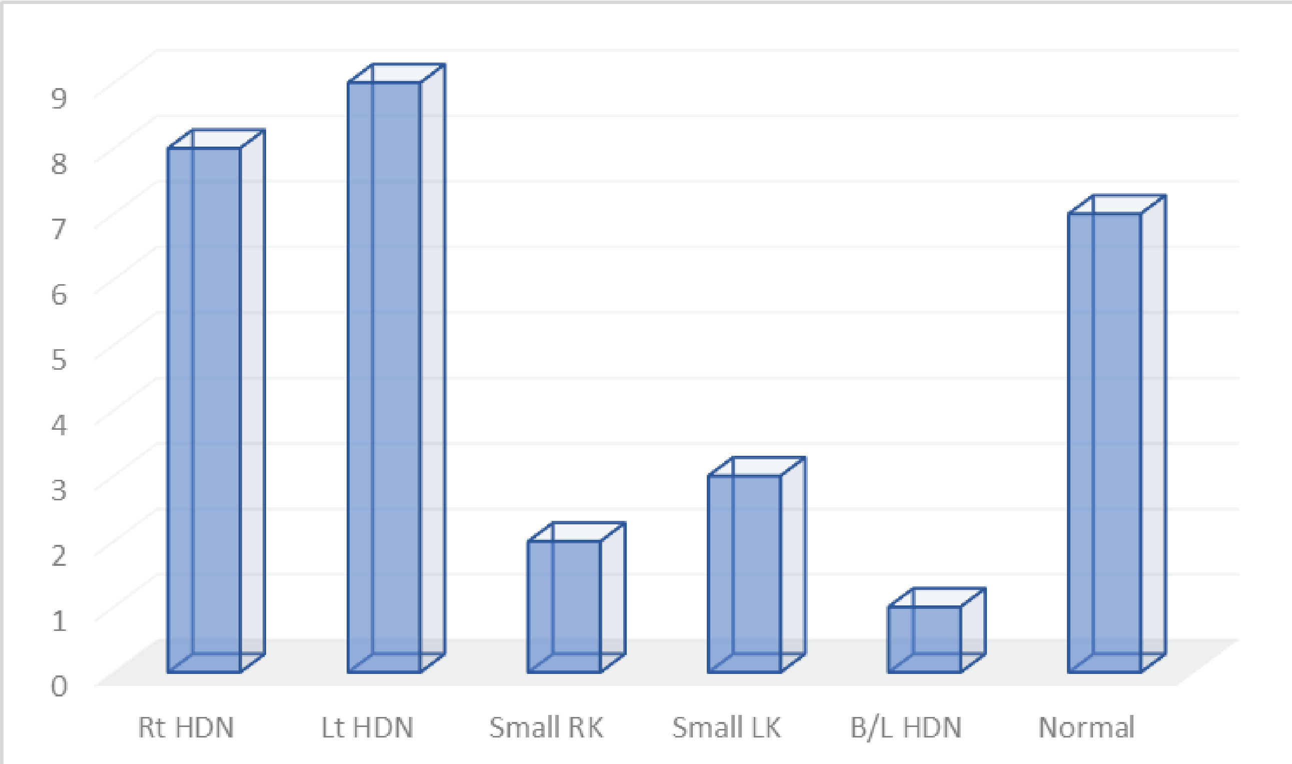


**Figure 2: Distribution of ultrasound greyscale findings of the study subjects. Pathological changes were more common on left side.**

In the case of the right kidney, a significant positive correlation was found between scintigraphy-derived parameters SF, GFR, and relative perfusion, as expected. Moreover, significant negative correlation was seen between GFR and RI. On the contrary, in the left kidney, Doppler parameters other than RI showed significant positive correlation.

Regression analysis of the right kidney revealed an $R^2$ of 0.533, indicating about 53.3% of the variation in GFR could be explained by Doppler parameters and scintigraphy-derived perfusion. Moreover, ANOVA p = 0.001 suggested the overall regression model was statistically significant. Nonetheless, the model was driven mainly by RI and perfusion, where PSV and EDV contributed numerically but were not statistically significant (Table 1).

**Table 1: Coefficients table for right kidney showing values and interpretations of each predictors of GFR**

| *Predictor* | *Beta (standardized)* | *p-value* | *Interpretation* |
|---|---|---|---|
| PSV | +0.215 | 0.423 | Not significant. PSV doesn't independently predict GFR. |
| EDV | –0.202 | 0.463 | Not significant. EDV doesn't independently predict GFR. |
| RI | –0.448 | 0.036 | Significant. Higher RI is associated with lower GFR. |
| Relative perfusion | +0.535 | 0.001 | Highly significant. Better relative perfusion strongly predicts higher GFR. |

A multiple linear regression was also conducted to assess whether Doppler parameters (PSV, EDV, RI) could predict scintigraphy-derived relative perfusion of the right kidney. The overall model was not statistically significant ($R^2 = 0.160$, $p = 0.201$), indicating that only 16% of the variance in perfusion was explained by the predictors. Individually, none of the Doppler indices reached statistical significance. PSV showed a positive but non-significant association with perfusion ($\beta = 0.410$, $p = 0.236$), while RI demonstrated a negative but non-significant trend ($\beta = –0.393$, $p = 0.135$). EDV was not associated with perfusion ($\beta = –0.145$, $p = 0.687$). These findings suggest that, unlike GFR, relative perfusion measured by scintigraphy was not reliably predicted by Doppler parameters in this cohort. Doppler indices may capture complementary aspects of renal physiology but do not substitute for perfusion assessment.

Multiple regression analysis performed to evaluate the predictive value of Doppler parameters and relative perfusion for the GFR of the left kidney showed that the overall model was highly significant ($R^2 = 0.700$, $p < 0.001$), indicating 70% of the variance in GFR was explained by the predictors. However, relative perfusion was the only significant predictor of GFR, while PSV, EDV, and RI showed numerical trends but did not reach statistical significance (Table 2).

**Table 2: Coefficients table for left kidney showing values and interpretations of each predictors of GFR**

| *Predictor* | *Beta (standardized)* | *p-value* | *Interpretation* |
|---|---|---|---|
| PSV | –0.187 | 0.396 | Negative trend, but not significant. |
| EDV | +0.282 | 0.222 | Positive trend, but not significant. |
| RI | +0.099 | 0.529 | Very weak, non-significant relationship. |
| Relative perfusion | +0.787 | 0.000 | Strong, highly significant positive predictor of GFR. |

Similarly. Multiple linear regression to assess the predictive power of Doppler parameters for relative perfusion of the left kidney revealed that the overall model was statistically significant ($R^2 = 0.308$, $p = 0.021$), and approximately 31% of the variance in perfusion was explained by the predictors. Individually, none of the Doppler indices reached statistical significance. PSV showed a positive but non-significant association with perfusion ($\beta = 0.374$, $p = 0.245$), EDV demonstrated a weak positive trend ($\beta = 0.217$, $p = 0.519$), and RI was essentially unrelated ($\beta = –0.034$, $p = 0.884$). Therefore, although the overall regression model was significant, scintigraphy-derived relative perfusion was only modestly explained by Doppler indices, reinforcing the complementary rather than interchangeable role of Doppler and scintigraphy in renal functional assessment.

## DISCUSSION

This study illustrates how scintigraphy and Doppler ultrasonography complement each other in evaluating renal function. Glomerular filtration rate (GFR) was positively associated with scintigraphy-derived perfusion, especially for the left kidney, while resistive index (RI) was a major predictor of GFR in the right kidney.

Doppler ultrasound and angiographic methods, which offer important details on vascular anatomy and hemodynamics, have historically been used to assess renal perfusion (7-9). Angiography is still the gold standard for identifying anatomical stenosis; however, Doppler-derived indices like resistive and pulsatility indices show intrarenal vascular resistance (10). Both methods have drawbacks: angiography is intrusive and does not measure functional perfusion directly, while Doppler is heavily operator-dependent and limited by patient habitus (11).

On the other hand, a non-invasive, quantitative assessment of relative renal blood flow is provided by scintigraphy-driven first-pass analysis. This is estimated by the visual or quantitative documentation of the initial bolus during its transition from the abdominal aorta to the renal arteries. This technique produces repeatable perfusion ratios between kidneys by recording tracer transit during the first frames and using region-of-interest analysis using specialized software (3, 12). However, such quantitative measurements of renal perfusion have only been significantly applied in renal transplant evaluation. Renal flow evaluation was included in potential areas of future research utilizing radionuclides in nephrourology (13). It was also cautioned that a higher than usual dose of radiotracer might be required to obtain sufficient results. A previous study identified six renogram patterns based on the relationship between uptake & perfusion and observed significant change to occur with altering kidney hemodynamics and function (12). The current work attempted to evaluate the correlation between scintigraphy-derived perfusion data and Doppler indices in non-transplanted kidneys and found a non-significant association. Rather, RI was significantly associated with GFR in the right kidney (table 1). This finding reflects the observations of several previous works stating that Doppler indices, particularly RI, represent the status of renal vascular resistance and are therefore promising in the assessment of parenchymal dysfunction (2, 14). Asymmetry of findings between both kidneys is possibly due to variability of pre-existing pathologies, e.g., a dilated pelvicalyceal system and smaller size observed more commonly on the left side (figure 2). Nonetheless, renal flow estimation through scintigraphic methods remains underexplored and warrants further research.

The Tc-99m DTPA renogram is a time-tested gold standard imaging technique for functional assessment of kidneys (3, 13). Several authors correlated renal Doppler findings and parenchymal changes as proved by histopathological or biochemical tests (15-17). A Korean study in 2015 compared Doppler ultrasonography and DTPA renogram in 79 transplanted kidneys, and statistically significant levels were only observed in resistive & pulsatility indices and GFR, but not velocities (18). Similarly, the present study did not find any significant relationship between Doppler-derived arterial velocity (PSV, EDV) and estimated GFR from renal scintigraphy (Tables 1, 2). Such limits of hemodynamic measurements in capturing functional outcomes highlight the fact that a multimodal approach is required to improve diagnosis accuracy in patients with suspected renal impairment by using scintigraphy for direct functional assessment and Doppler for insight into vascular physiology.

Limitations of this study include a small cohort with only single-center involvement. There was also a possibility of bias as multi-modality data was collected by the same observer.

## CONCLUSION

Renal scintigraphy is still a mainstay of functional imaging because it provides a quantitative evaluation of split renal function, relative perfusion, and glomerular filtration rate that Doppler ultrasonography cannot match. It is essential for clinical decision-making, especially when assessing patients for obstruction or differential renal contribution. Doppler ultrasonography also provides useful hemodynamic data, and the resistive index has a strong correlation with renal impairment. However, peak systolic velocity and end diastolic velocity did not independently predict renal function or perfusion, highlighting the limitations of relying solely on Doppler indices. Taken together, these findings highlight the complementing rather than interchangeable nature of Doppler and scintigraphy. Combining both methods improves diagnostic precision and offers a more thorough framework for renal assessment. Future studies with larger patient cohorts and longitudinal follow up are warranted to validate these findings and explore their prognostic implications across diverse clinical settings.

**Declaration of Competing Interest:** The authors declare that there are no competing interests.

**Conflict of Interest:** The authors declare no conflict of interest.

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