Original Research Paper

Volume - 16 | Issue - 05 | May - 2026 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Radio-Diagnosis

A COMPARATIVE STUDY TO EVALUATE THE ROLE OF RENAL DOPPLER AND SHEAR WAVE ELASTOGRAPHY IN DIABETIC NEPHROPATHY

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ABSTRACT **Background:** Diabetes mellitus is a leading cause of chronic kidney failure. Diabetic nephropathy is characterized by progressive glomerular damage and declining kidney function. Urine microalbuminuria estimation remains the standard diagnostic approach but its reliability is compromised by factors such as blood glucose levels and blood pressure variations. Recent advances like Shear Wave Elastography (SWE) quantifies the tissue stiffness and measures alterations in renal parenchymal elasticity. In this study, we aim to explore the diagnostic potential of renal doppler ultrasonography and shear wave elastography in detecting diabetic nephropathy. **Methods:** A comparative cross-sectional study was undertaken on two groups of participants involving 50 individuals each. Cases comprised of 50 patients diagnosed with type 2 diabetes mellitus for more than 5 years and controls were normal individuals with normal renal function. Study involved the department of Radiodiagnosis, Medicine, Endocrinology and Nephrology at Mahatma Gandhi Medical college and Hospital, Jaipur. Kidney damage was evaluated by Doppler ultrasound and ARFI Elastography by assessing the Resistive index and shear modulus value. **Results:** The changes which were evaluated were intrarenal Resistive Index and renal parenchymal elasticity using ARFI elastography quantified through shear modulus (Young modulus). Both RI and YM showed positive correlation with clinical parameters like Egfr, HbA1c and urinary protein. **Conclusion:** The evaluated changes like intrarenal Resistive Index and Renal parenchymal elasticity (Young's Modulus) were significantly altered in patients with diabetic nephropathy compared to healthy controls. Thus, non-invasive modalities like Elastography could be considered as promising markers for early identification of diabetic nephropathy.

KEYWORDS : Diabetic Nephropathy, Resistive Index, Young's Modulus, ARFI.

INTRODUCTION

The prevalence of diabetic nephropathy among Indian subjects of Type 2 Diabetes Mellitus based on various studies is 5–9 %.[1] It is recognized as the most frequent cause of chronic kidney disease in India like in the western world. [2]

It is usually diagnosed by micro albuminuria and progressive reduction in GFR. Micro albuminuria is defined as 30 to 300 mg of albumin in 24 hours urine is usually not detected by conventional methods[3]. The sensitivity and specificity of micro albuminuria for the early diagnosis of diabetic nephropathy is low.[4]

The role of ultrasonography in diabetic nephropathy has been limited to grey-scale ultrasound imaging for renal size and echotexture, changes which are seen late in the disease course. Renal hemodynamic changes are detectable on Doppler sonography in the early stages, although studies show that it is less specific.[5]

Shear wave elastography is a novel and non-invasive modality for quantitative tissue elasticity assessment[6].

This study was done to show role of both color doppler and shear wave elastography in diagnosing diabetic nephropathy specially in early stages.

MATERIAL AND METHODS

This comparative cross-sectional study was conducted at Mahatma Gandhi Medical College and Hospital, Jaipur, involving the departments of Radiodiagnosis, Medicine, Endocrinology, and Nephrology between April 2023 to October 2024 using Wipro GE Logiq P9 R3 ultrasound system, equipped with Doppler and ARFI elastography capabilities.

Total 100 subjects were included in the study after taking informed consent and approval from ethical committee of institution. Total 50 patients with history of Type 2 diabetes mellitus for more than 5 years were included as patients and another 50 patients presenting to the department of radiology for ultrasound with normal serum creatinine, blood sugar and not suffering from any condition affecting the kidney were included as controls. Obese patients, hypertensive patients with long standing hypertension > 5 yrs prior to detection of diabetes, patients with obstructive uropathy and coexistent renal diseases or anomalies were excluded from study.

For all cases the age, sex, duration of diabetes, history and duration of hypertension were noted and current blood pressure was recorded. For all controls the age, sex and blood pressure were recorded. Only normotensive subjects were chosen. Grey scale ultrasound was performed in each patient for both kidneys. Both kidneys were assessed for renal size, shape, position, echogenicity, and presence of any calculi, hydronephrosis or any features which exclude the subject from the study. Color doppler was done in each patient for both kidneys. The segmental arteries were identified and six waveforms from the arteries of the upper, middle, and lower poles of each kidney were obtained. Average Resistive Index (RI) for both kidneys was calculated. Shear wave elastography was performed in each patient for both kidneys. The Region of Interest (ROI) cursor was placed over 3 cortical regions of each kidney and at least 2 measurements were taken from each region. Renal sinuses and capsules were excluded. Mean of quantitative values for both kidneys were calculated.

Statistical Analysis

The mean resistive index and shear modulus for each stage of diabetic nephropathy was obtained. The resistive index and shear modulus values for each stage of diabetic nephropathy were compared separately with the values for the controls using student t tests and p values obtained for significance. The differences in shear wave values and resistive index between controls and cases in five different stages of diabetic nephropathy were analysed using one way ANOVA tests and p values were obtained. p value <0.001 was considered statistically significant.

The statistical measures of performance of resistive index and shear modulus were assessed by calculating the sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio for various cut offs of resistive index and shear modulus. Cut off value with highest accuracy was identified and receiver operating characteristic (ROC) curves was generated.

RESULTS

A total of 50 controls and 50 patients with diabetic nephropathy (cases) were included in the study. Among the controls and cases, the mean age was 55.64 ± 14.92 years and 57.86 ± 14.48 years respectively.

For controls the mean resistive index (RI) of the kidneys was 0.55 ± 0.02. The mean shear modulus of the kidneys for the controls was 4.43

± 0.77 kPa. A progressive increase in the resistive index as well as the shear modulus of the kidneys was found in the controls with increase in age and this was statistically significant ($p < 0.001$).

For cases, the mean resistive index of the kidneys was 0.74 ± 0.06. The mean shear modulus of the kidneys for the cases was 13.82 ± 8.24. For each case, the estimated GFR calculated from the serum creatinine value using the modified MDRD equation. Then cases were divided into chronic kidney disease stages I to V based on the eGFR values. The resistive index as well as the shear modulus of the cases were also found to statistically significantly correlate with the stage of diabetic nephropathy based on the eGFR value ($p < 0.001$).

Table1: Mean Resistive Index of the Cases for Each Stage of Diabetic Nephropathy

Stage of CKD	RESISTIVE INDEX (Mean ± SD)	RANGE
Normal	0.55±0.02	0.51 - 0.66
I	0.67±0.02	0.65 - 0.72
II	0.72±0.03	0.66 - 0.77
III	0.73±0.03	0.68 - 0.77
IV	0.76±0.04	0.69 - 0.82
V	0.78±0.04	0.7 - 0.83

A progressive increase in the Resistive Index with advancing stages of diabetic nephropathy, showing a statistically significant difference across all stages ($P < 0.001$). The data suggest that RI is closely associated with the severity of renal impairment

Table2: Mean Shear Modulus of Cases for Each Stage of Diabetic Nephropathy

Stage of CKD	Young Modulus (Mean ± SD) (kPa)	Range
Normal	4.43±0.77	2.73-7.17
I	11.58±1.46	10.54-12.61
II	8.28±2.68	5.5-10.84
III	10.62±1.82	7.97-12.79
IV	9.48±2.16	4.3-12.09
V	9.28±2.04	4.4-12.2

Across the stages of diabetic nephropathy, a significant difference in Young's Modulus ($P < 0.001$) for all stages. These findings suggest that tissue stiffness increases sharply in early diabetic nephropathy and remains elevated through later stages.

Statistical Measure of Performance

Using a Resistive Index cutoff of 0.63 provides excellent diagnostic performance, with 97% accuracy, 96% sensitivity, and 98% specificity. The positive and negative predictive values are also high (98% and 96%, respectively). The positive likelihood ratio of 48 and negative likelihood ratio of 0.041 indicate strong ability to confirm or exclude diabetic nephropathy, making RI a reliable diagnostic tool at this threshold.

Table3: Statistical Measures of Performance for Resistive Index at Cut off 0.63

Accuracy	0.97
Sensitivity	0.96
Specificity	0.98
Positive Predictive Value	0.98
Negative Predictive Value	0.96
Positive Likelihood Ratio	48
Negative Likelihood Ratio	0.041

At a Young's Modulus cutoff of 4.9 kPa, the test achieves good diagnostic performance with 83% accuracy, 96% sensitivity, and 90% specificity. The positive predictive value is approximately 90.6%, and the negative predictive value is about 95.7%. The positive likelihood ratio of 9.6 and negative likelihood ratio of 0.044 indicate a strong ability to both confirm and exclude diabetic nephropathy, making Young's Modulus a reliable marker at this cutoff.

Table4: Statistical Measures of Performance for Youngs Modulus at Cutoff of 4.9

Accuracy	0.83
Sensitivity	0.96
Specificity	0.90
Positive Predictive Value	0.90.6
Negative Predictive Value	0.95.7
Positive Likelihood Ratio	9.6
Negative Likelihood Ratio	0.0444

DISCUSSION

The present study was undertaken to evaluate changes in the intrarenal resistive index (RI) and elasticity of the renal parenchyma using Acoustic Radiation Force Impulse (ARFI) elastography, quantified through shear modulus (Young's modulus), in diabetic nephropathy (DN). The findings were analysed statistically and correlated with disease severity.

Both RI and YM showed a trend of increasing values with advancing age in controls and cases, with statistically significant differences ($P < 0.001$) in almost all age groups. Between genders, no significant differences in either RI or YM were observed, highlighting that these parameters are independent of sex in diabetic nephropathy assessment.

RI increased significantly with age in both groups. Similarly, the shear modulus also increased with age among both cases and controls.

The mean RI in cases (0.74 ± 0.06) was significantly higher than in controls (0.55 ± 0.02), with statistical significance across all age groups ($P < 0.001$). This rise reflects increased intrarenal vascular resistance in diabetic nephropathy.

Shear modulus values showed similar trends. Cases exhibited a mean of 13.82 ± 8.24 kPa vs 4.43 ± 0.77 kPa in controls ($P < 0.001$). Even in the youngest age group (21–30 years), YM was higher in cases (7.1 ± 2.36) than controls (4.69 ± 0.44), though not statistically significant ($P = 0.057$), possibly due to smaller sample size.

Progressive increases in RI were observed from Stage I (0.67 ± 0.02) to Stage V (0.78 ± 0.04), indicating worsening vascular resistance with disease severity ($P < 0.001$).

Shear modulus peaked in Stage I (11.58 ± 1.46 kPa), then declined through subsequent stages, with Stage V showing 9.28 ± 2.04 kPa. This biphasic pattern may reflect early glomerulosclerosis followed by parenchymal damage and reduced perfusion in advanced disease.

Strong positive correlations were found between RI and critical clinical parameters like Egfr, HbA1c and urinary protein, Likewise, YM was also positively correlated with all three clinical parameters. These results confirm the pathophysiological basis of elastography and Doppler changes in diabetic nephropathy.

RI had higher overall diagnostic performance. Combining both tests improved specificity (96.3%) when used in an "AND" format and enhanced sensitivity (99%) when used in an "OR" format, highlighting the utility of integrated diagnostic approaches.

Limitations

There was no age matching which could confound age-related elevation in RI and YM. Due to the lack of biopsy, the gold standard confirmation was missing.

CONCLUSION

Intrarenal resistive index (RI) and renal parenchymal elasticity (Young's modulus) measured via Acoustic Radiation Force Impulse (ARFI) elastography are significantly altered in patients with diabetic nephropathy (DN) compared to healthy controls. The mean RI was significantly higher in diabetic nephropathy cases than in controls, with a progressive rise across the stages of CKD, reflecting increasing intrarenal vascular resistance. Young's modulus, which quantifies tissue stiffness, was also markedly elevated in the diabetic group, with the highest values noted in the early stages of nephropathy—suggesting early glomerulosclerosis and subclinical structural changes. Combining resistive index and Young's modulus offers a powerful, non-invasive tool for early diagnosis and staging of diabetic nephropathy, potentially guiding early therapeutic intervention and improving patient outcomes.

Figure1: Grey Mode Ultrasound of a Patient With Stage III

Diabetic Nephropathy Showing Minimal Increase in Cortical Echogenicity. Corticomedullary Differentiation is Well Maintained

Figure2: Shear Wave Elastography of the Same Patient Showing Cortical Shear Modulus of 7.75 ± 2.99 kPa Reading. The Average Shear Modulus of the Kidneys for this Patient was 7.85 kPa, Which is Much Higher than the Obtained Cut Off Value of 4.9 kPa for Diagnosis of Diabetic Nephropathy

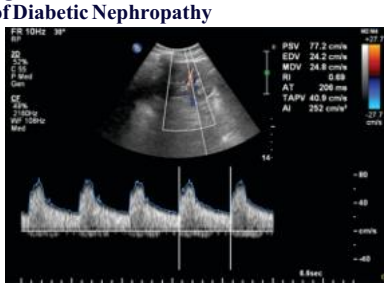

Figure3: Renal Doppler of the Same Patient Showing Resistive Index of 0.69 Reading. The Average Intrarenal Resistive Index of the Kidneys was Found to be 0.71 which is Higher than the Obtained Cut Off Value of 0.63 for the Diagnosis of Diabetic Nephropathy.

Acknowledgments

We wish to thank the staff in the department of Radiodiagnosis, Mahatma Gandhi Hospital for their support and cooperation throughout the study. All subjects were acknowledged for their participation in this research.

Conflict of Interest

None Geclared.

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