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Original Research Article

Role of renal doppler ultrasonography in evaluating renal haemodynamics in diabetic patients and its correlation with laboratory parameters (Serum HbA1C and Serum Creatinine)

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ABSTRACT

Background: Due to high prevalence of Diabetes Mellitus in India, Diabetic nephropathy is on the rise. Diabetic Nephropathy is the leading cause of End stage renal disease and the major factor responsible for renal transplantation. Grey scale ultrasound can detect morphologic renal parenchymal changes late in the disease but the functional haemodynamic changes can be detected early on, by the means of doppler indices such as Resistive Index (RI) and Pulsatility Index (PI). Hence, application of renal doppler can aid in the diagnosis of early nephropathic changes to allow early medical intervention, therefore improving disease prognosis.
Methods: Renal doppler ultrasonography was performed in 64 diabetic individuals, in the main renal artery and at the interlobar arteries of both kidneys in the upper pole, interpolar region, and lower pole. RI and PI were obtained for each artery and averaged. The correlation between the Mean RI and Mean PI, each with HbA1c and serum creatinine was checked for every patient using relevant statistical tests.
Results: Mean RI and PI in study participants were above the normal range. RI and PI both showed a statistically significant positive correlation with serum creatinine, HbA1c as well as the age of the patient and duration of diabetes mellitus ($p<0.001$).
Conclusions: Evaluation of renal doppler indices while correlating them with laboratory parameters can help slow disease progression. The patient can be provided with medical intervention at the early stage on detection of altered renal indices, hence reducing morbidity and mortality and significantly improving disease prognosis and outcome.

Keywords: Diabetic nephropathy, Pulsatility index, Renal doppler, Resistive index

INTRODUCTION

India is 2nd most commonly affected country in terms of Diabetes Mellitus (DM) after China currently affecting approximately 8.9 percent of people aged 20 to 79 years in India. At the moment, India accounts for one in every six adults in the world who has diabetes.[1] Individuals suffering from Type 2 DM are at high risk of vascular complications such as Nephropathy, Retinopathy, Neuropathy, and cardiovascular comorbidities.[3] Diabetic Nephropathy, seen in approximately 1/3rd of diabetic patients is the leading cause of End Stage Renal Disease (ESRD) and the major factor responsible for renal transplantation. Multiple pathophysiological entities are contributing towards the development of Diabetic Nephropathy, haemodynamic alterations being a major contributor. [4] Diabetic Nephropathy is the leading cause of mortality and morbidity in diabetic patients and hence

early detection and control of the progress of the disease are of paramount importance. Imaging modalities like Ultrasonography and Doppler tracing have played a pivotal role in detecting renal parenchymal and haemodynamic changes and have hence provided very essential diagnostic and prognostic information. By the means of renal doppler indices like the Pulsatility Index (PI) and the Resistive index (RI), the idea about the microvascular bed of the Glomerulus can be ascertained with fair accuracy as physical changes in the microvascular bed is preceded by haemodynamic changes. These doppler indices can be utilized to detect early changes, track disease progression, and also monitor the response to treatment. This can alert the treating physician to initiate medical intervention at the earliest, hence leading to effective management and ultimately improving the disease prognosis.

The objective of this study was to ascertain the role of renal Doppler ultrasound in evaluating renal haemodynamics in patients suffering from Type 2 Diabetes Mellitus and to correlate the renal doppler findings with HbA1c and serum creatinine levels.

METHODS

This was hospital-based cross-sectional study conducted in the Department of Radiology, FAAMCH, Barpeta, Assam. The study was carried out for a period of 1 year from September 2021 to August 2022.

Inclusion criteria

All known cases of Type 2 Diabetes Mellitus of age > 30 years referred to the Department of Radiology, FAAMCH, Barpeta for renal doppler ultrasonography.

Exclusion criteria

Patients with Type 1 Diabetes Mellitus, patients with non-diabetic cause of kidney disease, obstructive kidney disease, patients with a history of renal surgery, patients under dialysis, patients with Glomerular or Tubulointerstitial disease, kidneys with congenital anomaly (Horse-shoe kidney, ectopic kidneys, vascular anomalies- AV malformation, renal artery aneurysm, renal artery stenosis) and patients with severe cardiac and respiratory comorbidities.

A total of 64 patients (34 male and 30 female) suffering from Type 2 Diabetes Mellitus who were referred to the Department of Radiology between September 2021 and August 2022 for renal doppler ultrasonography who gave consent were included in the study.

Informed consent was taken and the procedure was explained in detail to the patient. A thorough case history was taken followed by a complete general and physical examination.

Following that, keeping the patient in a supine position, using a 3.5MHz curvilinear probe by Samsung RS80A machine via trans-abdominal route, both kidneys were visualized in their long axis one after the other. Right or left lateral decubitus positions were utilized when needed for optimal visualization of kidneys.

Greyscale imaging

Both right and left kidneys were visualized along the longest length using grey-scale ultrasound mode and any gross abnormalities, vascular malformations, and presence of calculus were ruled out.

Spectral and colour doppler evaluation

Main renal artery was evaluated first, followed by intrarenal interlobar arteries of the upper pole, interpolar region, and lower pole of both kidneys (the right kidney was evaluated first, followed by the left kidney), patient was asked to hold their breath, Doppler scan was performed at the lowest possible angle of insonation (<60 degrees)

Total 8 RI and 8 PI (one each from the Right main renal artery, left main renal artery, 3 from interlobar arteries from the upper pole, interpolar region, and lower pole of the right kidney and 3 from interlobar arteries from the upper pole, interpolar region and lower pole of left kidney) were obtained. Mean RI and PI were calculated and used for statistical analysis.

For each patient, the RI and PI values were recorded only when at least 3 consecutive waveforms with similar appearance were obtained.

Statistical analysis

Data obtained were first entered into the Microsoft Excel Spreadsheet of MS office 2019 version. Tables, bar diagrams, and pie charts were used to describe the descriptive data. Statistical tests such as the Chi-square test, Pearson correlation test, and ANOVA test were used for the statistical analysis of data. p-value of <0.05 was considered to be statistically significant.

RESULTS

This was a cross-sectional study performed for a year (September 2021 to August 2022) in the Department of Radiology at Fakhruddin Ali Ahmed medical college and hospital, Barpeta, Assam. 64 patients suffering from Type 2 diabetes mellitus, above the age of 30 years, fulfilling the inclusion and exclusion criteria, and who gave consent were enrolled in the study.

Renal doppler findings (RI and PI) were correlated with the age of patients, duration of diabetes mellitus as well as Serum creatinine and HbA1c levels. Statistical tests like chi square test, ANOVA test and Pearson correlation

tests were used to analyse the association between the variables.The participants were in the age group ranging from 31-84 years. Majority of the study participants belonged to 50-<60 years age group (n=18, 28.1%) (Figure 1) with average age being 56.5 years.

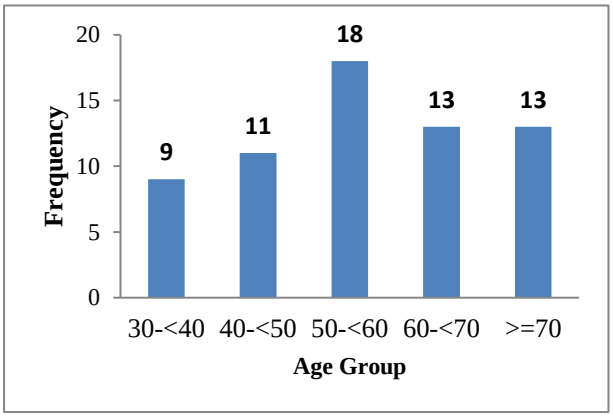

Figure 1: Age distribution of the study participants.

The majority of the study population were males (n= 34, 53.1%), whereas females comprised 46.9% of the study population (n=30).

Among the study participants, the majority of the patients have had diabetes mellitus for less than 6 years duration (n=22, 34.4), and the least number of patients in >36 years duration (n=3, 4.7%). The average duration of diabetes mellitus = 14.04 years (Table 1).

Table 1: Distribution of study participants according to duration of diabetes mellitus

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Duration (Years)	Frequency	Percent
0-6	22	34.4
6-12	12	18.8
12-18	11	17.2
18-24	6	9.4
24-30	6	9.4
30-36	4	6.3
>36	3	4.7
Total	64	100

Majority of the patients (n=28, 44%) had HbA1c in the range of (7.5-9.0). 27% of the study population (n=17) had HbA1c in the range of (6.5-7.4), 17% of the study participants (n=11) had HbA1c above 9.0 and only 12% of the participants (n=8) had normal HbA1c levels (<6.4).

Among the study participants, the majority of the participants (n= 34, 53.1%) had normal serum creatinine levels and 46.9% (n=30) had high serum creatinine.

The majority of the patients (n=50, 78.1%) had elevated renal Resistive Index, whereas only 21.9% (n=14) had normal renal Resistive Index (Figure 2). The mean resistive index in this study was 0.750 ± 0.079 SD which was above the cut-off value of 0.7.

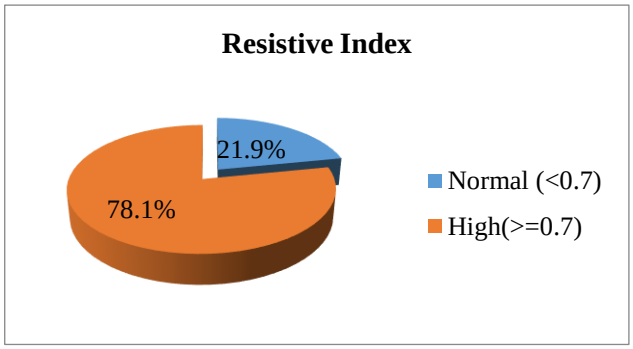

Figure 2: Distribution of study population according to Resistive Index

Among the study participants, the majority of the patients (n=46, 71.9%) had elevated renal Pulsatility Index, whereas only 28.1% (n=18) had normal renal Pulsatility index (Figure 3). Mean Pulsatility index found in our study was (1.641±0.215 SD) which was above the cut-off value of 1.56 taken for this study.

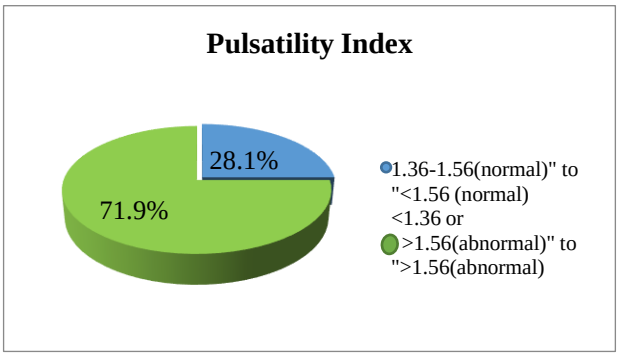

Figure 3: Distribution of study population according to the Pulsatility index.

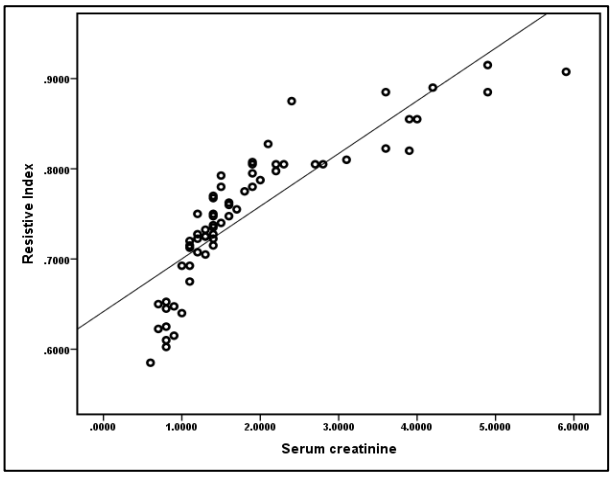

Figure 4: Scatter graph showing a positive correlation between resistive index and serum creatinine.

On Chi-Square test, a statistically significant association was found between Mean Resistive Index and Mean Pulsatility Index with the Age of the study participants ($p<0.001$) and the duration of Diabetes Mellitus ($p<0.001$).

It was observed in our study that 58.8% of diabetic patients with normal serum creatinine had a high resistive index and 100% of diabetic patients with high serum creatinine had an elevated resistive index. In our study, Pearson product-moment correlation was run to determine the relationship between Resistive Index (Mean RI) and serum creatinine. There was a strong, positive correlation between Resistive Index and serum creatinine, which was found to be statistically significant ($r = .859$, $p<0.001$) (Figure 4).

For HbA1c, in our study, it is observed that for the Above 9.0 HbA1c group, 100% of the study participants had a high resistive index, followed by the 7.5-9.0 HbA1c group (96.4%), 6.5- 7.4 HbA1c group (70.6%) and 0% among normal HbA1c (<6.5) group.

Pearson product-moment correlation was run to determine the relationship between Resistive Index and HbA1c. A strong, positive correlation between the mean Resistive Index and HbA1c was found to be statistically significant ($r = 0.836$, $p<0.001$) (Figure 5).

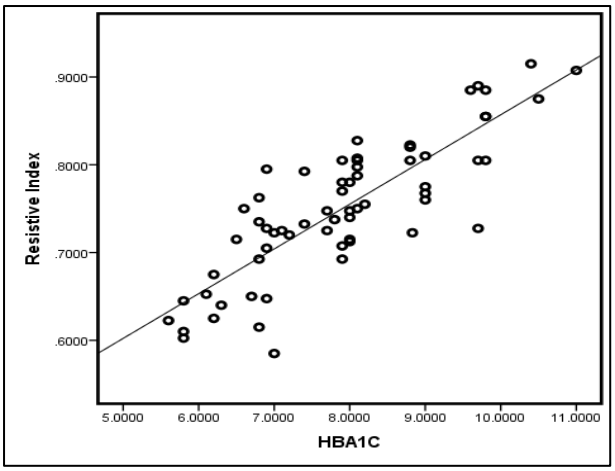

Figure 5: Scatter graph showing a positive correlation between Resistive index and HbA1c.

In our study, it was observed that 47.1% of diabetic patients with normal serum creatinine had a high Pulsatility index and 100% of diabetic patients with high serum creatinine had an elevated Pulsatility index.

Pearson product-moment correlation was run to determine the relationship between Pulsatility Index (Mean PI) and serum creatinine. There was a strong, positive correlation between PI and serum creatinine in the study population, which was found to be statistically significant ($r = 0.817$, $p<0.001$) (Figure 6).

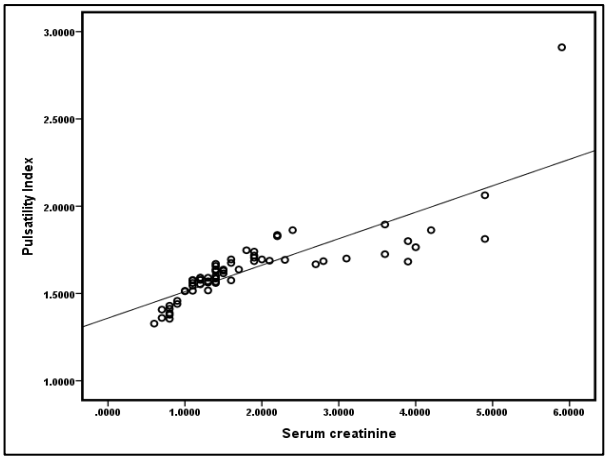

Figure 6: Scatter graph showing a positive correlation between Pulsatility Index and serum creatinine.

For HbA1c in our study, it was observed that for the Above 9.0 HbA1c group, 90.9% of the study participants had a high Pulsatility index, followed by 7.5-9.0 HbA1c group (92.9%), 6.5-7.4 HbA1c group (58.8%) and 0% among <6.5 (normal) group.

Pearson product-moment correlation was run to determine the relationship between Pulsatility Index and HbA1c. There was a positive correlation between Pulsatility Index and HbA1c, which was found to be statistically significant ($r = 0.735$, $p<0.001$) (Figure 7).

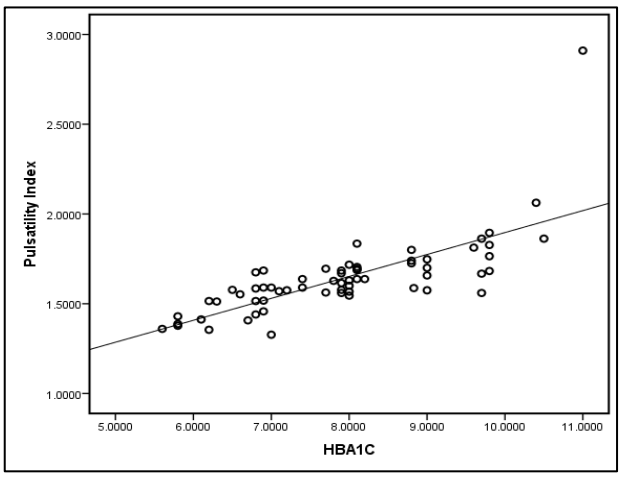

Figure 7: Scatter plot showing a positive correlation between Pulsatility Index and HbA1c.

DISCUSSION

Cross-sectional study was performed for a year between September 2021 to August 2022 in the Department of Radiology at Fakhruddin Ali Ahmed medical college and hospital, Barpeta, Assam.

64 patients suffering from Type 2 diabetes mellitus, above the age of 30 years, fulfilling the inclusion and exclusion criteria, and who gave consent were enrolled in

the study. Renal doppler findings (RI and PI) were correlated with the age of patients, duration of diabetes mellitus as well as Serum creatinine and HbA1c levels. Statistical tests like chi square test, ANOVA test and Pearson correlation tests were used to analyse the association between the variables.

In this study, around 78.1% (n=50) of the study participants who had type 2 diabetes mellitus had elevated Resistive Index. The mean resistive index in this study was 0.750 ± 0.079 SD which was above the cut-off value of 0.7 (Table 2).

Table 2: Comparison of Resistive Index with other studies.

Studies	Resistive index
Platt et al.[5]	0.71±0.14
Dawha et al. [6]	0.72±0.06
Shirin et al. [7]	0.71±0.04
Our study	0.750±0.079

The findings of our study are comparable with a study conducted by Platt et al. (mean resistive index= 0.71±0.14), Dawha et al. (mean resistive index= 0.72±0.06), and Shirin et al. (mean resistive index= 0.71±0.04) who found diabetic patients to have elevated renal Resistive Index.[5-7]

It was observed in our study that 58.8% of diabetic patients with normal serum creatinine had a high resistive index and 100% of diabetic patients with high serum creatinine had an elevated resistive index. In our study a strong, positive correlation between Resistive Index and serum creatinine, which was found to be statistically significant (r =0.859, p<0.001).

This was similar to findings in the study conducted by Kim et al., Brkljacic et al., Platt et al., Sari et al., Shirin et al., and Shaw et al. where a statistically significant positive correlation was found between the renal resistive index and serum creatinine.[5-11]

From this, we can say that the Resistive index increases with an increase in serum creatinine levels. Resistive index is also noted to be elevated in 58.8% of patients with normal serum creatinine levels. This implies that Resistive index is able to detect functional changes in the kidney before the laboratory values (serum creatinine in our case) became apparent.

For HbA1c, in our study, it is observed that for the Above 9.0 HbA1c group, 100% of the study participants had a high resistive index, followed by the 7.5-9.0 HbA1c group (96.4%), 6.5- 7.4 HbA1c group (70.6%) and 0% among normal HbA1c (<6.5) group.

In our study, a strong, positive correlation between the mean Resistive Index and HbA1c was found to be statistically significant (r = 0.836, p<0.001).

In similar studies conducted by Pelliccia et al., Youssef et al., Kim et al., and Alareqi et al., the Renal resistive index showed a positive correlation with HbA1c levels which was found to be statistically significant.[12-15] From this observation, we can derive a conclusion that a higher Resistive Index is seen in patients with poorer glycaemic control and implied poorer renal status.

Renal Resistive index also showed a statistically significant positive correlation with the age of the patients (r = 0.847, p<0.001) which was comparable to the study conducted by Brkljacic et al., Ohta et al., Platt et al., Sari et al. and Dawha et al. suggesting that with an increase in age, renal resistive index increases in the diabetic population. It further implies that there is an increase in the severity of renal changes in patients with type 2 diabetes mellitus with an increase in age.[5-7,9,10]

In our study, Renal resistive index also showed a statistically significant positive correlation with the duration of diabetes mellitus among study participants(r =0.816, p<0.001). Our study's findings are consistent with those in previous similar studies by Pelliccia et al., Dawha et al., and Ishimura et al.[6,12,17] This implies that with an increase in the duration of diabetes mellitus, Resistive Index increases which suggests a significant progression of renal disease.

In our study it was found that the majority of the patients (n=46, 72%) had elevated renal Pulsatility Index. Mean Pulsatility index found in our study was (1.641±0.215 SD) which was above the cut-off value of 1.56 taken for this study.

The findings of our study are comparable with a similar study conducted by Dawha et al., Alareqi et al., Ohta et al., and Kim et al. who found diabetic patients to have elevated renal Pulsatility Index.[6,14-17]

In our study, it was observed that 47.1% of diabetic patients with normal serum creatinine had a high Pulsatility index and 100% of diabetic patients with high serum creatinine had an elevated Pulsatility index. We found out that there was a strong, positive correlation between PI and serum creatinine in the study population, which was found to be statistically significant (r = .817, p<0.001).

This was comparable to findings in the study conducted by Kim et al, Brkljacic et al, and Soyoye et al, where a statistically significant positive correlation was found between renal Pulsatility index and serum creatinine.[9,14,18]

From this, we can say that the Pulsatility index increases with an increase in serum creatinine levels. Pulsatility index is also noted to be elevated in 47.1% of patients

with normal serum creatinine levels suggesting the ability of Pulsatility Index to detect renal haemodynamic changes before laboratory parameters were apparent.

For HbA1c in our study, it was observed that for the Above 9.0 HbA1c group, 90.9% of the study participants had a high Pulsatility index, followed by 7.5-9.0 HbA1c group (92.9%), 6.5-7.4 HbA1c group (58.8%) and 0% among <6.5 (normal) group. We found a positive correlation between Pulsatility index and HbA1c, which was found to be statistically significant ($r = 0.735$, $p<0.001$).

The findings in our study were comparable to the study conducted by Alareqi et al, who found a statistically significant correlation between the two parameters.[15]

Based on the findings, we can say that better glycaemic control (lower HbA1c) is associated with better renal outcomes as predicted by the Pulsatility index and vice versa. And that in patients with poor glycaemic control (higher HbA1c), the Pulsatility index is higher suggesting poorer renal status.

Renal Pulsatility index also showed a statistically significant positive correlation with the age of the patients ($r = 0.664$, $p<0.001$) which was comparable to the study conducted by Brkljacic et al, Matsumoto et al, Ohta et al, Dawha et al, and Kim et al.[6,9,14,16,19] It suggests that with an increase in age, renal Pulsatility index increases implying that, with increasing age, there is an increase in severity of renal changes in patients of type 2 diabetes mellitus.

The renal Pulsatility index also showed a positive correlation with the duration of diabetes mellitus among study participants ($r =0.668$, $p<0.001$) which was found to be statistically significant. The finding in our study is comparable with the finding in a previously conducted similar study by Dawha et al.[6]

This implies that with an increase in the duration of diabetes mellitus, Pulsatility index increases which suggests poorer renal outcome with the progression of renal disease.

Renal Doppler showing a statistically significant age-graded increase as well as an increase with duration of diabetes mellitus suggests gradual changes occurring in renal vascular bed which can ultimately result in End Stage Renal Disease (ESRD).

Hence, the application of renal doppler indices early in the disease while correlating it with laboratory parameters can prove helpful in slowing down disease progression as well as improving disease prognosis and outcome as early intervention can be made. Any elevation in renal doppler indices even without a significant increase in laboratory parameters should alert the treating physician to provide medical intervention as soon as possible so the pace of disease progression can be slowed down.

Limitation of this study was, it was a cross sectional study, performed on small sample size. Further long-term prospective studies are recommended with larger study population so more information regarding applicability of renal doppler indices in diabetes mellitus can be obtained. Also, in this study, only laboratory parameter used were serum creatinine and HbA1c for correlational purpose. Use of other sophisticated parameters such as urinary microalbumin, albumin creatinine ratio etc. can be used for getting more insight on how RI and PI compare with the same.

CONCLUSION

Renal doppler parameters, RI, and PI are invaluable radiological tools used to assess renal vasculature in patients suffering from type 2 diabetes mellitus. In this study, RI as well as PI showed increased values above the normal range in patients suffering from type 2 diabetes mellitus and showed statistically significant positive correlation with serum creatinine and HbA1c. Ultrasonography and Doppler study being easily accessible and repeatable, it can be performed in diabetic patients with ease and hence be helpful in identifying early nephropathic changes so early medical intervention can be carried out, thus improving the disease prognosis and outcome.

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