

Characterization of Kidneys in Diabetic Patients using Doppler Ultrasonography

Tagread Ahmed Abd Alla Elmahi

Faculty Of Radiological and Nuclear Medicine Science, National Ribat University, Khartoum – Sudan.

Mohammed Nooraldeen Yousif Abdullah

Faculty Of Radiological and Nuclear Medicine Science, National Ribat University, Khartoum – Sudan.

Ahmed Abdelrahim Mohammed Ibrahim

Faculty Of Radiology Science and Medical Imaging, Alzaiemalazhari University, Khartoum, Sudan.

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Abstract: Diabetes mellitus (DM) is a disease characterized by a high blood sugar and a concomitant excretion of glucose in the urine. It usually caused by an insufficient insulin secretion by the pancreas. The effects of (DM) include long-term damage, dysfunction and failure of various organs. DM is the number one cause of kidney disease, present in high number of all cases! This is something that needs urgent attention, the way diabetes causes kidney disease is threefold. So Doppler ultrasound (US) considered as a good tool in assessing the kidneys of diabetic patients. A descriptive cross section study performed on a group of 100 diabetic patients (cases group) in comparison to 50 non-diabetics (controls group), Sudanese population. Aimed to assess morphologic and hemodynamics changes in diabetic patients' kidneys using different major US machines, with curve linear 3.5 MHz probe. Renal US were monitored, data was presented in percentage between patients age, gender, C/M ratio, length and width of kidneys, DM duration, peak systolic (PSV), end diastolic (EDV) and resistive index (RI) of both renal arteries. US finding analysis and its correlated to DM duration were discussed, then statistically the result were analyzed. Concluded that Doppler sonography have potential role in the early identification of morphologic and hemodynamic renal changes in diabetic patients.

Keywords: Diabetes Mellitus (DM) – Renal - Doppler ultrasound

Introduction:

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, nerves, heart, and blood vessels. ⁽¹⁾

Diabetes is a chronic, metabolic disease characterized by elevated levels of blood glucose (or blood sugar), which leads over time to heart attack, stroke, blindness, kidney failure and lower limb amputation. The most common is type 2 diabetes, usually in adults, which occurs when the body becomes resistant to insulin or doesn't make enough insulin. ⁽²⁾

Diabetic kidney disease (DKD) is one of the most common complications of diabetes; prevalence is increasing steeply along with the diabetes epidemic. It is a leading cause of end stage kidney disease (ESKD) in developed countries. It is usually a clinical diagnosis made based on the presence of albuminuria and/or reduced estimated glomerular filtration rate (GFR) in the absence of signs or

symptoms of other primary causes of kidney damage.⁽³⁾ According to the Centers Disease Control (CDC), diabetes is the most common cause of ESRD. In 2011, about 26 million people in the U.S. were reported to have diabetes, and more than 200,000 people with ESRD due to diabetes were either on chronic renal dialysis or had a kidney transplant. Both type 1 and type 2 diabetes can lead to diabetic nephropathy, although type 1 is more likely to lead to ESRD.⁽⁴⁾

Diabetes is a serious threat to population health. The World Health Organization (WHO) estimated the total burden of deaths from high blood glucose. About 422 million people worldwide have diabetes, the majority living in low-and middle-income countries, and 1.5 million deaths are directly attributed to diabetes each year. Both the number of cases and the prevalence of diabetes have been steadily increasing over the past few decades. Between 2000 and 2016, there was a 5% increase in premature mortality from diabetes. In 2019, diabetes was the ninth leading cause of death with an estimated 1.5 million deaths directly caused by diabetes.⁽⁵⁾

Ultrasound is one of the most used imagistic examinations in nephrology. In order to establish a precise diagnosis in acute or chronic kidney disease, renal ultrasound has become the standard imaging modality in the investigation of kidneys because it offers excellent anatomic detail, requires no special preparation of patients. It is readily available and does not expose the patient to radiation or contrast agent.⁽⁶⁾

Objective: To characterize the diabetic mellitus effect on the kidney morphology and renal artery flow in order to predict early impact of diabetes, for early diagnosis and management.

Materials and methods: A descriptive cross-sectional study, deal with Doppler ultrasonography findings for renal artery (PSV, EDV and RI) in DM patients conducted in Sudan at Omdurman, Almanagil and Alnihoud hospitals - Ultrasound units. After Obtaining Hospital Ethics Committee approval, during the period from May to August 2021.100 diabetic patients (67 males and 33 females), type I (8%) and type II (92%), aged between 18-82 years were included as cases group and 50 non-diabetic patients matching their age as controls group. Patients with renal congenital anomalies, renal tract obstruction, malignant tumor and renal failure were excluded.

Gray scale and Doppler ultrasound (PSV, EDV and RI) were performed for all patients. Equipped by major US machines including Doppler software, using High-frequency Trance Abdominal (TA) curve linear transducer 3.5 MHZ, with a favorable body habitus, patients fasting a minimum of 6 hours before the examination to limit bowel gas.

Both kidneys were assessed in the transverse and coronal plane. Optimal patient positioning varies; supine and lateral decubitus positions often suffice, although oblique and occasionally prone positioning may be necessary (e.g., obese patients). Doppler setting adjusted for maximal detection of slow flow using the highest possible transducer frequency, relatively small color area of interest, low pulse repetition frequency and low wall filter. Small sample volume of the interloper artery was planned and an insonating angle of 60 degree or less are needed.

Variables including: patient’s age, gender, C/M ratio, length and width of kidney, diabetic duration, and Doppler parameters (PSV, EDV RI).

All data were tested for normality of distribution by visual comparison, as well as by visual evaluation of a statistical package for social sciences (SPSS) comparing each distribution with duration of disease.

Results:

Table (4.1) Demographic characters of the study groups (Cases and Controls group)

| Demographic characters | | DM | | Control group | | P- value |
|------------------------|--------|-----------|------|---------------|------|----------|
| | | Frequency | % | Frequency | % | |
| Gender | Female | 33 | 33.0 | 15 | 30.0 | 0.853 |
| | Male | 67 | 67.0 | 35 | 70.0 | |
| Age group / years | 18-40 | 15 | 15.0 | 26 | 52.0 | <0.001 |
| | 41-60 | 50 | 50.0 | 17 | 34.0 | |
| | 61-80 | 33 | 33.0 | 7 | 14.0 | |

| | | | | | | |
|------------------|--------------|-----|-------|-------|-------|--|
| | More than 80 | 2 | 2.0 | 0 | 0 | |
| Duration / years | 1-10 | 68 | 68.0 | - | - | |
| | 11-20 | 28 | 28.0 | - | - | |
| | More than 20 | 4 | 4.0 | - | - | |
| Type | DM type I | 8 | 8.0 | - | - | |
| | DM type II | 92 | 92.0 | - | - | |
| Total | Total | 100 | 100.0 | 100.0 | 100.0 | |

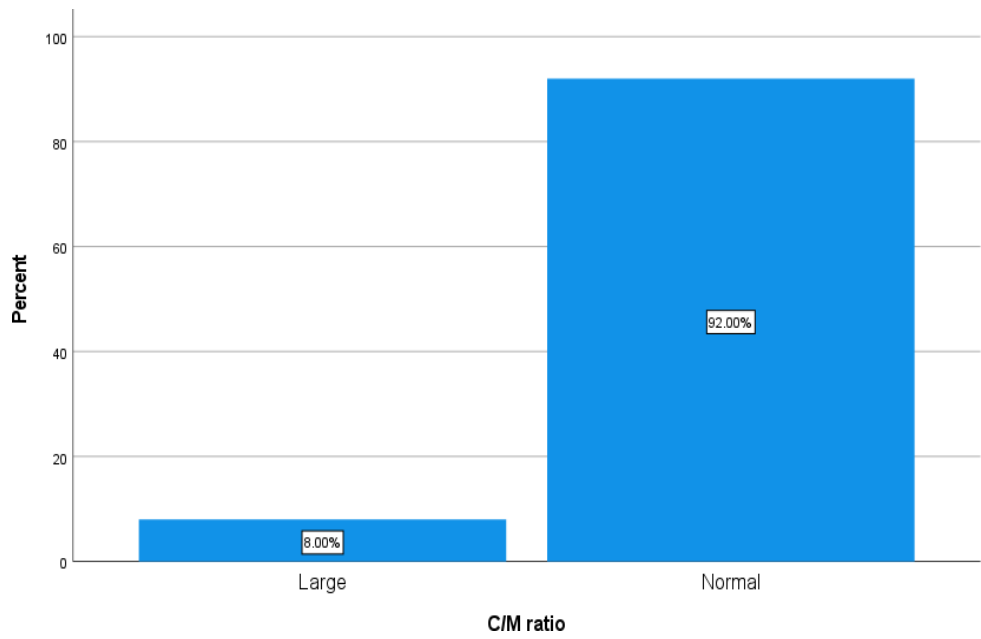


Figure (4.1) Frequency distribution of C/M ratio in DM group

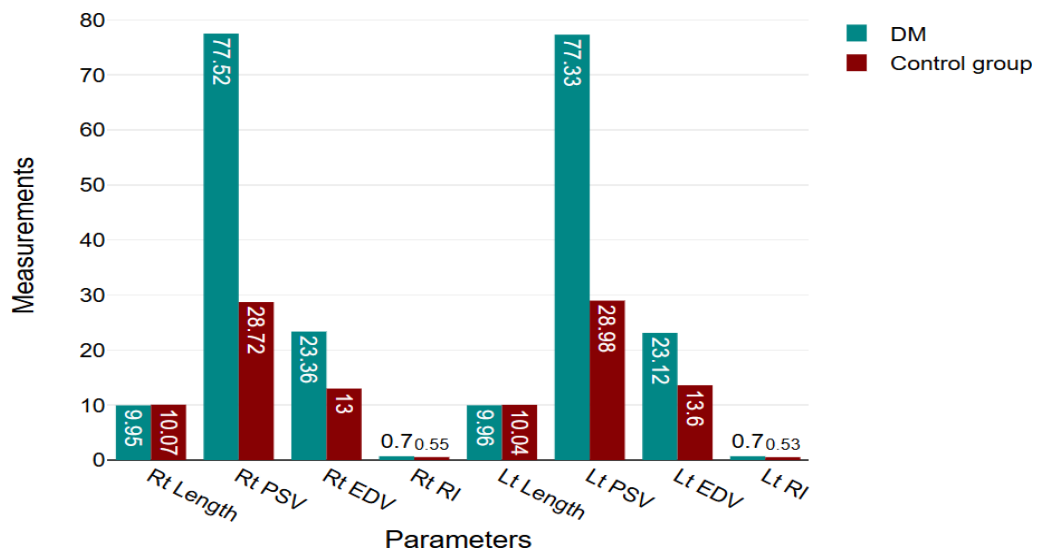


Figure (4.2) Plot box shows mean measurement among the study groups

Table (4.2) Compare mean length measurement and Doppler parameters (PSV, EDV, RI) of the kidneys in cases group with duration of DM (One-way Anova)

| Duration group | | Rt-L | Rt-PS | Rt-ED | Rt-RI | Lt-L | Lt-PS | Lt-ED | Lt-RI |
|----------------|----------|-------|-------|--------|--------|--------|-------|--------|--------|
| <10 | Mean | 0.199 | 4.669 | 23.156 | .6900 | 10.207 | 4.844 | 22.962 | .6932 |
| | Std. Dev | .8900 | 11.50 | 6.1566 | .06421 | .8771 | 11.53 | 5.6987 | .05984 |
| 1-20 | Mean | 9.457 | 2.821 | 23.850 | .7143 | 9.493 | 1.725 | 23.479 | .7157 |
| | Std. Dev | .6741 | .8781 | 6.0284 | .05196 | .6599 | .0727 | 6.2799 | .05770 |
| More than 20 | Mean | 9.050 | 8.750 | 23.300 | .7400 | 9.025 | 8.700 | 23.225 | .7400 |
| | Std. Dev | .6557 | .9293 | 8.2595 | .09129 | .6449 | .7509 | 8.3216 | .09129 |
| Total | Mean | 9.945 | 7.515 | 23.356 | .6988 | 9.960 | 7.325 | 23.117 | .7014 |
| | Std. Dev | .9038 | 11.43 | 6.1423 | .06299 | .8894 | 11.33 | 5.9064 | .06122 |
| F-values | | 0.001 | 0.001 | 0.883 | 0.093 | <0.001 | 0.002 | 0.928 | 0.114 |

Table (4.3) Correlation between length measurement and Doppler parameters (PSV, EDV, RI) of the kidneys in DM with duration and age

| | | Rt-L | Rt-PS | Rt-ED | Rt-RI | Lt-L | Lt-PS | Lt-ED | Lt-RI |
|----------|-----------|---------|--------|--------|--------|---------|--------|--------|--------|
| Age | Pearson r | -.485** | .430** | .278** | -.043 | -.508** | .406** | .318** | -.102 |
| | p-value | .000 | .000 | .005 | .674 | .000 | .000 | .001 | .313 |
| Duration | Pearson r | -.498** | .428** | .036 | .264** | -.507** | .394** | .025 | .260** |
| | P -value | .000 | .000 | .725 | .008 | .000 | .000 | .804 | .009 |

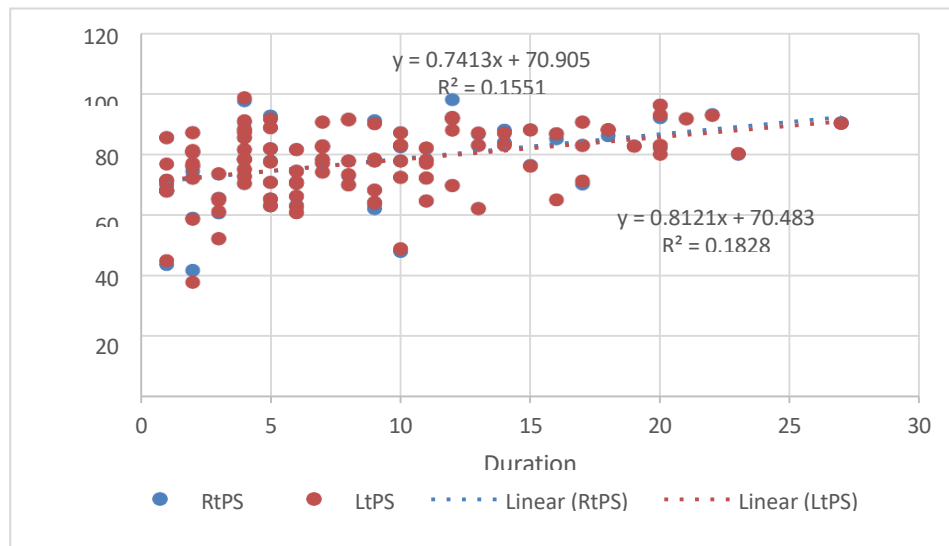


Figure (4.3) Scatter plot shows weak linear relationship between duration and PSV

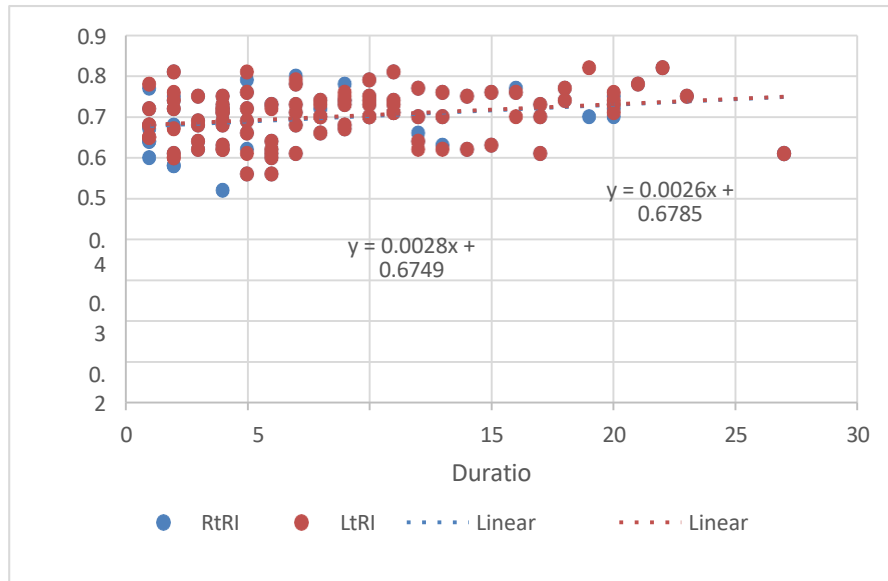


Figure (4.4) Scatter plot shows no observed relationship between duration and PSV

Table (4.4) Compare mean length and width measurement and Doppler parameters (PSV, EDV, RI) of the right kidney in DM and control group

| Right kidney | Group | Mean | Std. Deviation | Std. Error Mean | 5% CI of difference | p-value |
|--------------|---------------|--------|----------------|-----------------|---------------------|---------|
| Length | DM | 9.945 | 0.038 | 0.004 | 0.04-0.15 | .338 |
| | Control group | 10.066 | 0.186 | 0.0875 | | |
| Width | DM | 4.715 | 0.526 | 0.0653 | .15-0.43 | 0.001 |
| | Control group | 4.424 | 0.1975 | 0.0279 | | |
| RA PSV | DM | 77.515 | 11.4344 | 1.1434 | 6.2-51.3 | 0.001 |
| | Control group | 28.720 | 3.9797 | 0.5628 | | |
| RA EDV | DM | 23.356 | 6.1423 | 0.6142 | .04-11.6 | 0.001 |
| | Control group | 13.000 | 1.7496 | 0.2474 | | |
| RI | DM | 0.6988 | 0.06299 | 0.00630 | .14-0.17 | 0.001 |
| | Control group | 0.5454 | 0.04229 | 0.00598 | | |

Table (4.5) Compare mean length and width measurement and Doppler parameters (PSV, EDV, RI) of the left kidney in DM and control group

| Left kidney | Group | Mean | Std. Deviation | Std. Error Mean | 5% CI of difference | P-value |
|-------------|---------------|--------|----------------|-----------------|---------------------|---------|
| Length | DM | 9.960 | .8894 | .0889 | 0.31- -0.14 | .469 |
| | Control group | 10.042 | .4920 | .0696 | | |
| Width | DM | 4.683 | .6403 | .0644 | 2.14-0.96 | .451 |
| | Control group | 5.270 | 5.4482 | .7705 | | |
| Rt. PSV | DM | 77.325 | 11.3342 | 1.1334 | 5.10-51.50 | 0.001 |
| | Control group | 28.980 | 3.5484 | .5018 | | |
| Rt. EDV | DM | 23.117 | 5.9064 | .5906 | .24-10.78 | 0.001 |
| | Control group | 13.600 | 1.7613 | .2491 | | |
| RI | DM | .7014 | .06122 | .00612 | .15-0.18 | 0.001 |
| | Control group | .5300 | .04116 | .00582 | | |

Discussion: In The Present Study Out of 150 Cases Sub-Divided in Two Groups: 100 Cases Group and 50 patients matching their age as controls group, aged from 18-82 years, mean age was (50.5 years ±SD.) Duration from 1-27 years. The majority of Cases Group were between 41-60years including 50.00%, the most affected gender with diabetes were males (67%) (Table 1), This Result Matches To **Mohammed I Amer Bahir (2019)** ⁽⁷⁾ and **Mohammed (2014)** ⁽⁸⁾ Who reported that male gender were more affected by DM. The majority of patients had type II diabetes (92%), and most of them had a duration of disease less than 10 years were 68 (68.0%), then (10-20) were 28 (28.0%), and more than 20 years were 4 (4.0%). 92% of patients have good CMD, where 8% have poor CMD figure (4.1). This finding similar also to Study done by Mohammed (2014) ⁽¹⁸⁾ who said **there** is no deference in Echogenicity between DM and healthy participants. ⁽⁸⁾

Regarding the duration of DM, the study found that the lowest mean value of Rt. kidney length was (9.050±.6557) cm and (9.025±6449) for Lt.one with duration of diseases (more than 20 years) and the largest length mean was (10.199±.8900) cm for Rt. Kidney and (10.207±.8771) for Lt. one cm with duration of diseases (1-10 years), with significant P-value < 0.0001. This indicates that the kidney decreased in size with the duration of the disease. This finding is similar to Study done By Omer et.al (2008) who reported that impact of duration was a reduction in size significantly ⁽⁹⁾.

The lowest mean value of Rt. PSV was 74.669±11.50 at duration of diseases (1-10 years).and the largest was (88.750 ±5.9293) at duration of diseases (more than 20 years), Lt. PSV measured lowest value (74.844±11.53) at duration of diseases (1-10 years) and the largest was (88.700 ±5.7509) at duration of diseases (more than 20 years), with significant P-value <0.0001, Table (4.2).These results showed significant relation between duration of DM with length and PSV in both kidneys. P value <0.0001), matching Mancini M. et al (2013), who said Both renal volume and RI values results in the diabetic patients were significantly higher compared to the controls ⁽¹⁰⁾

Same result shown in table (4-3) when compare length and Doppler parameters of both kidneys with age of cases group and duration of disease, with significant P – value.

When compare mean of length, width and Doppler parameters between cases and controls group: Rt. Kidney length measurement were (9.945 ±.9038)-(10.066±.6186) in DM and controls respectively, and (9.960 ±.8894)-(10.042 ±.4920) respectively for left kidneys, width measured were (4.715 ±0.6520)- (4.424±0.1975) respectively for Rt. Kidney, where it measured (4.683±0.6403)- (5.270±5.4482) respectively for left one. Doppler parameters (PSV, EDV, RI) measurements in cases and controls group were (77.515±11.4344)-(28.720±3.9797), (23.356±6.1423)-(13.000±1.7496), (0.6988±.06299) (0.5454±.04229) respectively for right

kidney, and it measured $(77.325 \pm 11.3342) - (28.980 \pm 3.5484)$, $(23.117 \pm 5.9064) - (13.600 \pm 1.7613)$, $(0.7014 \pm 0.06122) - (0.5300 \pm 0.04116)$ respectively for left one, (tables 4.4 and 4.5) which showed significant relation between cases and controls group with all Doppler parameters in both kidneys and width in Rt. one, P - value < 0.0001 , where both kidney length and width of left one showed negative significant relation P-value > 0.0001 , with 95% CI of difference for all. These results matching to Study done By Mancini. et al⁽¹⁰⁾ Who said both renal volume and RI values in the diabetic patients were significantly higher compared to the controls.

In general, there was decreased in kidney length which is equal to 0.1cm/year for diabetes duration, also there was a decreased in C/M ratio and increased in Doppler Parameters.

Conclusion: The present study concluded that there was significant difference between renal sonography of diabetes and non-diabetic patients, also there was strong correlation between renal length, width and hemodynamic changes with duration of disease. These results indicate a potential role of duplex sonography in the early identification of morphologic and hemodynamic renal changes in type 2 diabetic patients.

Recommendation: So, we recommended that assessment of renal volume and hemodynamics should be part of routine evaluation of all patients with DM at first diagnosis as well as follow-up evaluation of these patients. This may help in the early detection of any renal disorder in these patients.



Image(1): 52 years old Diabetic female patient for 2 years, Lt. kidney showed normal length, width, and normal C/M differentiation.



Image (2): color Doppler and P/W for 52 years old DM female patient 2 years in duration, Lt Kidney, Showed increased Resistance index.



Image (3): color Doppler and P/W for 28years old healthy male, It kidney, showed normal range for (PSV, EDV and RI).

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