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The Impact of Diabetes Mellitus on the Renal Parenchyma Measurements: ACT Based Study

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Abstract:
Objective: *In order to establish some preliminary data of our population, we determined the Computerized Tomography (CT) for evaluation the kidney dimensions in individuals with known Diabetic Nephropathy. We evaluated whether the diabetes can affect the renal measurements.*
Methods: *In Multidetector Computerized Tomography thin-slice (MDCTs) scans of 300 kidneys in 150 Sudanese patients (50 Diabetes subjects and 100 as control) the study was performed. The kidney length, width, medulla and cortical width, medulla and cortical CT Hounsfield (HU), and the renal parenchymal thickness on CT scans were measured through upper calyx; renal pelvis; and lower calyx levels and were registered in (mm) for both kidneys. The measurements were done for both control and diabetes groups. The possible influencing diabetic effects that can be visualized were recorded from a measurement data set. For measurements, axes were adjusted individually in axial and coronal planes.*
Results: *Kidneys were found to be significantly changed for some parameters in diabetic patients when compared to the normal control group. A positive linear relationship was found between the right and left kidney width and the duration of diabetes.*
Conclusions: *The possible mechanisms for the kidney measurements changes were highlighted for Sudanese population.*
Keywords: *CT, renal parenchyma measurements, Diabetes*

I. Introduction

One third of patients with diabetes have kidney damage [1]. The screening of Chronic Kidney Disease (CKD) in patients with diabetes is based on the Albumin excretion rate and the estimated Glomerular Filtration Rate (GFR) [2]. Other phenomena occur earlier in the course of diabetic nephropathy, including glomerular hyperfiltration [3,4], renal hypertrophy [5], and renal histologic lesions [6], but their assessment is not suitable: renal biopsies are invasive, GFR determinations are expensive and GFR estimations are not useful for diagnosis of hyperfiltration [7,8].A noninvasive tool for the detection of even subtle renal changes that suggest the presence of diabetic nephropathy, would therefore be highly needed. Imaging modalities are generally not considered very helpful, particularly in the early stages. [9,10,11] On the other hand; ultrasonography (US) commonly is used to screen and measure the kidney and allows non-invasive renal imaging and it is recommended for the first line evaluation of CKD. [12]In comparison with an intravenous pyelogram, US is more accurate and suffers neither from the geometric magnification of X-ray, nor from a possible increase in kidney size by osmotic diuresis through iodinated contrast material [13]. Reports on kidney measurements in patients with diabetes mellitus have been for the most part infrequent .[14,15,16]The report of Mogensen et al.[17] documented enlarged kidneys by radiography, but did so only early in diabetes. Studies on kidney length and size have also been made by means of Computerized Tomography (CT) [18] and Magnetic Resonance Imaging (MRI) [19]. Magnetic resonance imaging (MRI) has increasingly been used as a monitor of renal anatomy and function in a variety of experimental and clinical situations. The usefulness of MRI as a non-invasive monitor of renal changes has already been proven in acute and chronic renal failure [20-29]

Although (US) is the primary method of choice for examining the kidneys, spiral CT was preferred because on the one hand, some parameters were not measurable by ultrasound, and on the other hand, individual reformatting in all dimensions with resolutions up to the sub-millimeter range could be made from the volume data sets retrospectively, allowing to anticipate exceedingly precise measurements. Depending on the contrast medium phase, it is possible to delineate the renal structures and collecting system exactly and assess the surrounding organs precisely. [30] In addition to the assessment of coronal reformatting, the most reliable method of determining the kidney length [31] sagittal reformatting was used. The thin slice, multidetectors gives this modality the acknowledged results.

The purpose of this study is to confirm the finding of enlarged kidneys in diabetics using CT scanning as well as to evaluate any possible relationship between kidneys measurements and the duration of diabetes .No data are available in our Departments concerning kidney measurements in the course of diabetes or upon any relationship with the duration of diabetes in Sudanese patients.

II. Materials And Methods

2.1 Materials:

Neusoft multi-slice CT Scanner System Model: NeuViz 128, Volt: 3N-380/400v, Power: 90KVA (120 kV, 40MA) (5 mm slice) in complex of general Omer Sawi was performed, Antalya Medical Center (5 mm slice) and Modern Medical Center.

2.2 Population of the study:

The population of this study consisted of two groups of patient, those with normal kidneys free from any pathology as control group, group two were patients diagnosed as having diabetic nephropathy (nephropatia diabetic). The study includes both genders with their age ranged from 10 years to 70years old.

2.3 Design of the study:

This study is analytic study of a case control type deals with CT scan pattern of diabetic nephropathy.

2.4 Sample size and type:

In this study, 300 kidneys (right and left) of 150 patients were examined. The study population was selected from the age groups starting from 10 up to 70 years old according to the availability as a sample of diabetic cases. Meanwhile, the samples of the study after the data collection they were (female 77, and male 73).19 were of type (1) diabetes and 28 were of type (2) diabetes and 3 patients were under good glucose control.

2.5 Place and duration of the study:

The study population consisted of patients who referred to the CT scan department for CT abdomen; each patient was examined with CT (MDCT) scan by a qualified technologist. During the period spanned from August 2014 up to August 2016 In Sudan at (El Rabat National hospital, Omdurman hospital, Modern Medical Center, and Antalya Medical Center.

2-6 Methods of data analysis:

Methods used for measurements were: axial, coronal single image, coronal multi image of 150 patients referred for abdomen CT scans were included in the study. Both kidneys were investigated and had been studied. Multi-slice CT was used in this research because by the obtained coronal and axial cuts, the actual length of kidney can be obtained easily. After that CT images were stored in computer disk and were viewed by the Radiant, DICOM viewer Digital imaging and communication on medical in computer to selected the coronal images that suit the criteria of research population then uploaded into the computer based software Interactive Data Language (IDL) . The image were read by IDL the first order were extracted from Multi-slice CT A non contrast to obtain coronal, axial and sagittal cuts, to Measure the renal parenchymal thickness (PT) on CT scans through A, upper calyx; B, renal pelvis; and C, lower calyx levels. PT was measured at four locations: anterior (a), posterior (p), medial (c), and lateral (d), at right angles to each other and oriented such that a-b paralleled the renal vessels. The CT No (HU) of cortex and medulla was also measured. And also Multi-slice CT with contrast was used to obtain axial cuts, to measure the cortex a medulla.

2-7 Methods of data collection

2.7.1Technique

CT scans were performed including protocol of axial images from the xiphoid process covers all abdominal area and pelvic down to pubic bone with patient in supine position, head first. The images were made at 100/120 kV and 60/80 MAs, with 5 mm slice thickness reformat 1.2mm. Reconstruction used 5mm to obtain coronal views. Light diet for 6 hr was preparation for patients, contrast used Iodine 75ml for normal patients and 70ml for diabetic patients. Mathematical calculations of the attenuation of the CT X-ray beam allow quantitative evaluation of the relative density of structures (Hounsfield units), and it is through these “CT numbers” that much unique diagnostic information of the urinary tract is gained. [32] With rapid scanning and contrast bolus timing, several sequential phases of opacification within the kidney can be delineated by CT including coticomedullary, nephrographic, and excretory phase. The cortico medullary phase was seen when scanning is performed during the first 20 to 90 seconds after contrast administration and represents the early

preferential blood flow to the renal cortex however, small masses could be missed during this phase, being obscured within the unenhanced renal medulla. [32]
Subsequently, contrast begins to pass into the distal collecting tubules within the renal medulla, resulting in a more homogeneous opacification of the renal parenchyma, termed the CT nephrographic phase. This generally occurs around 2 to4 minutes after contrast medium injection.Finally, the excretory phase is seen when contrast opacifies the collecting system. Each different disease processes and thus various scanning protocols are used to evaluate the kidneys depending on the indication. One of the major recent advances in imaging has been the ability to noninvasively evaluate the vascular system, and thin-section early CT images accurately demonstrate the main arterial and venous structures of the kidney. [32]

2-8 Ethical approval

The ethical approval was granted from the radiology departments; which include commitment of no disclose any information concerning the patient identification as well as consent from the patients. Informed consent was obtained from every patient prior to the examination.

III. Results

Table 1: The right and left kidneys length, width ,cortex and medulla measurements, CT number (HU) for cortex and medulla in the two studied groups (normal and diabetes), presented as mean and standard deviation and p-value.

Variables	Left Kidney	N	Mean	STDV	P-value	Right Kidney	Mean	STDV	P-value
length of kidney	Left (Normal)	100	95.73	11.40	.120	Right (Normal)	98.30	12.25	.396
	Left (DM)	50	98.77	12.11		Right (DM)	96.75	9.61	
	Total	150	97.25	11.75		Total	97.27	10.56	
width of kidney	Left (Normal)	100	42.51	5.15	.019	Right (Normal)	45.02	7.09	.000
	Left (DM)	50	44.91	7.14		Right (DM)	41.00	5.24	
	Total	151	43.32	5.98		Total	42.34	6.20	
cortex (axial)	Left (Normal)	99	5.26	.82	.000	Right (Normal)	6.17	.84	.000
	Left (DM)	51	6.12	.79		Right (DM)	5.21	.82	
	Total	150	5.55	.90		Total	5.54	.94	
medulla (axial)	Left (Normal)	100	11.21	1.68	.001	Right (Normal)	10.00	1.82	.010
	Left (DM)	50	10.11	1.97		Right (DM)	10.82	1.84	
	Total	150	10.84	1.85		Right (Normal)	10.54	1.87	
CT no cortex	Left (Normal)	100	19.18	6.23	.000	Right (DM)	29.60	4.05	.000
	Left (DM)	50	29.54	4.08		Right (Normal)	22.64	7.17	
	Total	150	22.68	7.44		Right (DM)	24.99	7.09	
CT no medulla	Left (Normal)	100	37.67	4.75	.041	Right (Normal)	36.29	3.36	.002
	Left (DM)	50	36.13	3.29		Right (DM)	37.23	4.63	
	Total	151	37.15	4.36		Total	36.91	4.25	

Table 2: The right and left kidneys upper calyx measurements, for anterior ,posterior ,medial and lateral segments in the two studied groups (normal and diabetes), presented as mean and standard deviation and p-value

Upper Calyx	Left Kidney	N	Mean	STDV	P-value	Right Kidney	Mean	STDV	P-value
Anterior (a)	Left (Normal)	100	12.00	2.60	.024	Right (Normal)	13.52	3.80	.005
	Left (DM)	50	13.13	3.35		Right (DM)	11.88	3.14	
	Total	151	12.38	2.91		Total	12.43	3.45	

Posterior (P)	Left (Normal)	100	16.11	3.95	.692	Right (Normal)	16.97	3.53	.262
	Left (DM)	50	16.38	3.95		Right (DM)	16.21	4.09	
	Total	151	16.20	3.94		Total	16.47	3.91	
Medial (C)	Left (Normal)	100	12.99	2.85	.218	Right (Normal)	13.52	2.59	.000
	Left (DM)	50	13.60	2.90		Right (DM)	11.74	2.39	
	Total	150	13.20	2.87		Total	12.34	2.59	
Lateral (D)	Left (Normal)	100	15.52	3.92	.504	Right (Normal)	17.67	15.08	.189
	Left (DM)	50	15.97	3.82		Right (DM)	15.56	3.80	
	Total	150	15.67	3.88		Total	16.27	9.29	

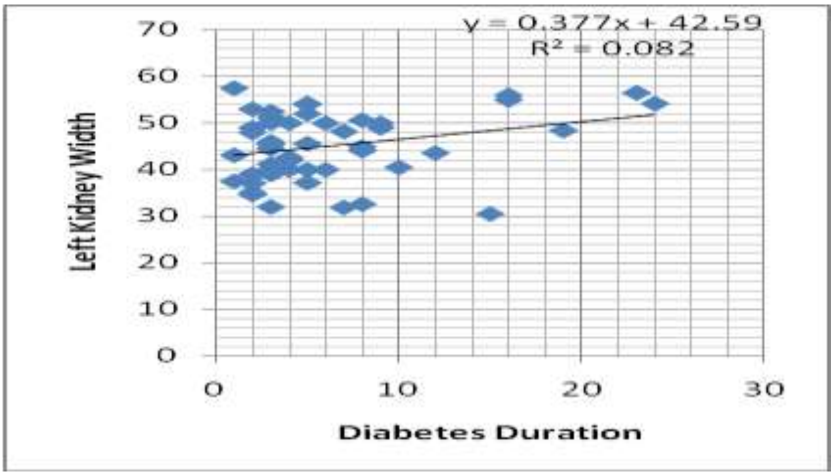
Table 3: The right and left kidneys renal pelvis measurements, for posterior, medial and lateral segments in the two studied groups (normal and diabetes), presented as mean and standard deviation and p-value

Renal Pelvis	Left Kidney	N	Mean	STDV	P-value	Right Kidney	Mean	STDV	P-value
Posterior (P)	Left (Normal)	100	22.37	3.63	.003	Right (Normal)	21.03	3.94	.056
	Left (DM)	50	20.48	3.53		Right (DM)	22.28	3.65	
	Total	150	21.73	3.70		Total	21.85	3.79	
Medial (C)	Left (Normal)	100	13.40	3.09	.185	Right (Normal)	13.89	3.34	.309
	Left (DM)	50	14.14	3.56		Right (DM)	13.41	2.43	
	Total	150	13.65	3.26		Total	13.57	2.77	
Lateral (D)	Left (Normal)	100	14.02	2.99	.553	Right (Normal)	14.45	2.91	.836
	Left (DM)	50	14.32	2.63		Right (DM)	14.33	3.64	
	Total	150	14.12	2.87		Total	14.37	3.40	

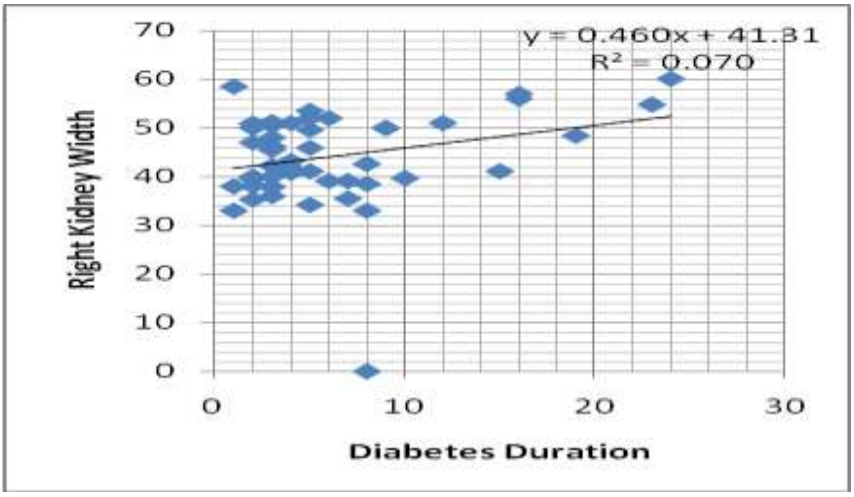
Table 4: The right and left kidneys renal pelvis measurements, for posterior ,medial and lateral segments in the two studied groups (normal and diabetes), presented as mean and standard deviation and p-value

Lower Calyx	Left Kidney	N	Mean	STDV	P-value	Right Kidney	Mean	STDV	P-value
Anterior (a)	Left (Normal)	99	10.88	2.44	.039	Right (Normal)	11.96	3.43	.564
	Left (DM)	51	11.81	2.83		Right (DM)	19.45	92.32	
	Total	150	11.20	2.61		Total	16.92	75.11	
Posterior (P)	Left (Normal)	100	18.85	3.85	.649	Right (Normal)	18.85	2.95	.487
	Left (DM)	50	18.55	3.39		Right (DM)	18.40	4.10	
	Total	151	18.75	3.69		Total	18.55	3.75	
Medial (C)	Left (Normal)	99	12.45	3.09	.002	Right (Normal)	13.76	2.89	.294
	Left (DM)	51	14.08	2.68		Right (DM)	13.15	3.61	
	Total	150	13.01	3.05		Total	13.36	3.39	
Lateral (D)	Left (Normal)	100	12.29	2.70	.005	Right (Normal)	13.35	2.46	.987
	Left (DM)	50	13.63	2.86		Right (DM)	13.35	3.51	
	Total	150	12.74	2.82		Total	13.35	3.18	

A

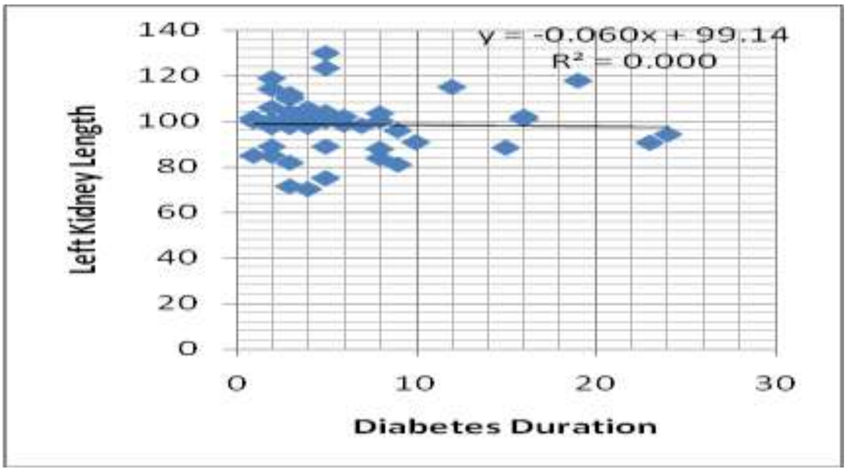


B

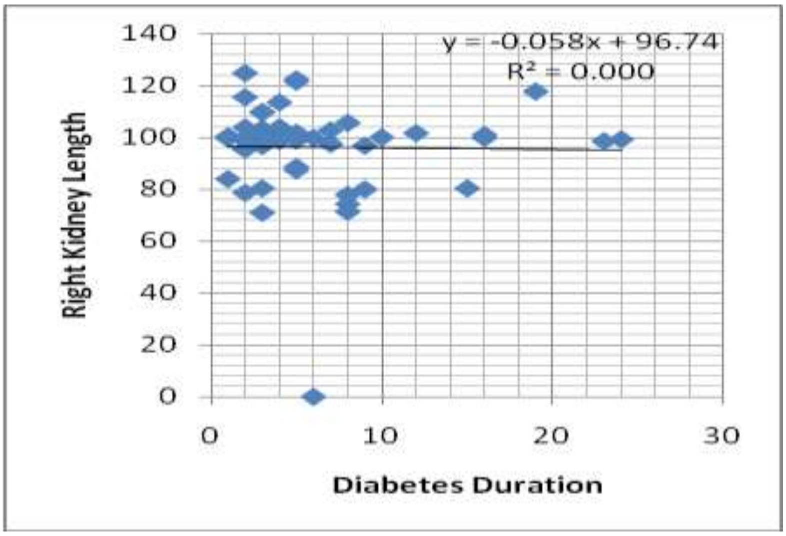


Figure(1) A: a scatter plot diagram shows the relation between the diabetes duration and left kidney width ,as the diabetes duration increased the left kidney width increased by 0.377mm starting from 42.59mm and the impact/contribution of the diabetes to do effect on the left kidney width measurement is 8%. **B:** a scatter plot diagram shows the relation between the diabetes duration and right kidney width, as the diabetes duration increased the right kidney width increased by 0.460mm starting from 41.31mm and the impact/contribution of the diabetes to do effect on the width measurement is 7%.

A



B



Figure(2) A: a scatter plot diagram shows the relation between the diabetes duration and left kidney length ,as the diabetes duration increased the left kidney length decreased by 0.063mm starting from 99.14mm and the impact/contribution of the diabetes to do effect on the left kidney length measurement is 0%. **B:** a scatter plot diagram shows the relation between the diabetes duration and right kidney length, as the diabetes duration increased the right kidney length decreased by 0.058mm starting from 96.74mm and the impact/contribution of the diabetes to do effect on the length measurement is 0%.

IV. Discussion

Renal disease is suspected to be secondary to diabetes in the clinical setting of long-standing diabetes.[33] In this current study where the renal evaluation were obtained; 19 were of type (1) diabetes and 28 were of type (2) diabetes and 3 were under good glucose control. It was mentioned that the renal hypertrophy has been noted in type 1 diabetics [34], it also exists in type 2 diabetes [35]. Since the pioneer work of Mogensen [17, 36], the high risk of large kidneys in diabetic patients has been reported frequently [37-41]. However, all these studies were on the initial stages of renal involvement. Diabetic renal hypertrophy can persist for years despite good glucose control [42,43,44].But with advanced renal insufficiency the kidneys become smaller [45] and this also occurs in diabetic patients, as reflected by the correlation between GFR and renal size as we found, in line with other authors [44,41] This late course raised the issue of whether kidney size remained a marker of progression in diabetic patients with more advanced chronic kidney disease.

Table (1) presented the measurement done for the right and left kidneys length, width, cortex and medulla, CT number (HU) for cortex and medulla in the two studied groups (normal control group and diabetes group), presented as mean and standard deviation and p-value. There are significant difference between the kidney width of the control and diabetes group for the right and left kidneys at p= 0.000 and 0.019 respectively, as well as the measurements done in the axial planes for the cortex and medulla. A significant changes were detected for both kidneys in the cortex and medulla at $p \leq 0.000$ in each 0.010 for the cortex and 0.000 for the medulla when compared with the controls.

The measurements increased in diabetes group for the left kidney and decreased for the right kidney for the same patients .The medulla width and CT number decreased in the left and increased in the right kidney ,this findings was in consistent with what was mentioned previously that in fact; a review of kidney size in various nephropathies studies failed to include diabetes as a cause of bilateral enlargement [45] we also justify the finding of increasing the CT number is that in renal injury, accompanied the diabetic nephropathy the glomerular permeability increased and allow plasma proteins to escape into the urine. Some of these proteins will be taken up by the proximal tubular cells, which can initiate an inflammatory response that contributes to interstitial scarring eventually leading to fibrosis due to the stimulation of collagen and fibronectin[33]. This lead to the difference in its attenuation values of the normal renal tissue .Changes were also been detected in upper, and lower calyces as well as the renal pelvis for right and left kidneys of the diabetes group when compared with the controls and the differences were significant. These were presented in tables (2,3,4)

In the upper calyx, the anterior segments for both right and left were found to be changed significantly at p=0.005, 0.024 respectively while only the medial segment is reduced significantly at p=0.000 for the right kidney .In the renal pelvis assessment, the posterior segments for both right and left were found to be changed significantly at p=0.056, 0.003 respectively. Left segment is reduced and the right is increased. In the lower calyx assessment; the anterior, medial and lateral segments for the left kidney showed significant changes at *p*=0.039, 0.002 and 0.005 respectively, while the right kidney did not show any changes in all segments when compared with the diabetes group.

The justification of the changes happened in the kidneys measurements is that early diabetes is heralded by glomerular hyperfiltration and an increase in GFR. This is believed to be related to increased cell growth and expansion in the kidneys, Long-standing hyperglycemia is known to be a significant risk factor for the development of diabetic nephropathy. Hyperglycemia may directly result in mesangial expansion and injury by an increase in the mesangial cell glucose concentration. The glomerular mesangium expands initially by cell proliferation and then by cell hypertrophy. Increased mesangial stretch and pressure can stimulate this expansion [33]

The description of the fact of the pathogens and changes; is that the first major structural change after onset of type I diabetes is enlargement of the whole kidney [34] and individual glomeruli [46].Studies work with the structural and functional natural history of diabetic nephropathy has identified the expansion of the mesangium and the reduction in peripheral capillary surface as constituting the mechanism leading to the demise in kidney function[47,48,49].It is well established that GFR is increased in early diabetes. [50,16] as well as in long-term diabetics.[16] In one study ;it has been shown that the roentgenographic kidney size is increased .Therefore the current study presented the impact of the diabetes duration on the kidneys length and width .Figure 1(A and B) and figure 2(A and B) presented the results and showed that as the diabetes duration increased the left kidney width increased by 0.377mm starting from 42.59mm and the impact/contribution of the diabetes to do effect on the left kidney width measurement is 8%. While the right kidney width increased by 0.460mm starting from 41.31mm and the impact/contribution of the diabetes to do effect on the width measurement is 7%. For the left kidney length, as the diabetes duration increased the left kidney length decreased by 0.063mm starting from 99.14mm and as the diabetes duration increased the right kidney length decreased by 0.058mm starting from 96.74mm.

The sample of the current study have diabetes duration from eight months up to 24 years .The limitation of our study is the small sample size without considering the drug used or the type of diabetes in the kidneys changes burden. Results of similar studies discuss the changes happened in the kidneys regarding the diabetes duration; they have mentioned that the majority of patients had diabetes for over fifteen years have a small and consistent decrease in kidney size as the duration of diabetes increased, and Kidneys remained enlarged in many instances in patients with diabetes of well over twenty-five years' duration.[51]

Several investigators [16,52,17] have found increased glomerular filtration rates both early [16,52]and late[17] in the course of diabetes. Mogensen et al. [16] have shown that this increased glomerular filtration rate correlates closely with the increased kidney size seen in diabetic patients.

V. Conclusion

As the Diabetic nephropathy is more prevalent among African Americans,[53,54] Sudanese population should be evaluated well. Studies showed that renal replacement therapy is starting among patients and the incidence of diabetic nephropathy increased [53] therefore it should be considered as critical. Fortunately, the rate of increase has slowed down, probably because of the adoption in clinical practice of several measures that contribute to the early diagnosis and prevention of diabetic nephropathy, which thereby decreases the progression of established renal disease therefore using imaging is important .In principle, kidney measurements can be estimated using ultrasound, MRI, intravenous pyelograms and CT, amongst others [31]. The CT predicts kidney measurements better than other modalities [31] for that reason our study used this imaging method in the evaluation of kidneys changes. The possible mechanisms for the kidney measurements changes due diabetes are argued for Sudanese population.

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