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SONOGRAPHICAL MEASUREMENTS AND ASSESSMENT OF RENAL SIZE AMONG DIABETIC TYPE II PATIENTS VISITING MARDAN MEDICAL COMPLEX (MMC)

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Abstract

Background: *Type II diabetes mellitus (T2DM) is a major global health concern, often leading to diabetic nephropathy, a significant cause of end-stage renal disease (ESRD). Early detection of renal morphological changes using non-invasive tools like ultrasonography is critical for timely intervention and management.*

Methods and Materials: *This descriptive cross-sectional study was conducted over six months in the Radiology Department of Mardan Medical Complex, Pakistan. A total of 366 T2DM patients were recruited using non-probability convenience sampling. Renal dimensions, including kidney length, width, thickness, and volume, were assessed using a Toshiba Xario 100 ultrasound machine. Data were analyzed using SPSS version 28.0, with continuous variables summarized as means and standard deviations, and categorical variables as frequencies and percentages. Linear regression was employed to evaluate associations between renal size and demographic factors.*

Results: *The study revealed significant alterations in renal dimensions among T2DM patients, with higher BMI and age being associated with increased renal size. Early-stage diabetic nephropathy was characterized by compensatory renal hypertrophy, while advanced stages showed reduced renal size. Ultrasonography proved to be a reliable tool for detecting these changes.*

Conclusion: *Ultrasonography is an effective, non-invasive method for assessing renal morphological changes in T2DM patients. Early detection and monitoring can mitigate the progression to ESRD, particularly in resource-limited settings. Future research should explore advanced imaging techniques and molecular markers to enhance diagnostic accuracy.*

INTRODUCTION

Diabetes mellitus type II (T2DM) represents one of the most significant global health challenges of the 21st century, characterized by chronic hyperglycemia resulting from impaired insulin secretion, insulin resistance, or a combination of both factors (1, 2). The intricate pathophysiology of T2DM encompasses

complex interactions between genetic predisposition, environmental influences, and lifestyle factors, leading to progressive deterioration of multiple organ systems (3). Among the various complications associated with T2DM, diabetic nephropathy emerges as a particularly concerning manifestation, necessitating careful monitoring and assessment of renal parameters throughout the disease progression (4).

The global burden of T2DM has reached epidemic proportions, with developing nations experiencing a disproportionate impact (5). Pakistan, in particular, faces a substantial challenge with an estimated prevalence of 19.4% in the adult population, placing considerable strain on healthcare resources and necessitating robust diagnostic and monitoring strategies (6, 7). Within this context, the assessment of renal complications becomes paramount, as early detection and intervention can significantly influence patient outcomes and quality of life.

Ultrasonography has emerged as an indispensable diagnostic tool in the evaluation of renal morphology among diabetic patients. This imaging modality offers numerous advantages, including its non-invasive nature, cost-effectiveness, real-time imaging capabilities, and absence of ionizing radiation (8, 9). The sonographical assessment of renal parameters, particularly kidney dimensions, provides crucial insights into the structural changes associated with diabetic nephropathy (10). These measurements serve as valuable indicators of disease progression and can guide clinical decision-making in the management of diabetic patients.

The relationship between T2DM and alterations in renal morphology has been extensively documented in medical literature. Chronic hyperglycemia initiates a cascade of pathophysiological changes, including glomerular hyperfiltration, oxidative stress, and inflammatory responses, which ultimately manifest as modifications in renal size and structure (11, 12). The ability to accurately measure and monitor these changes through ultrasonography provides clinicians with essential information regarding disease progression and therapeutic efficacy.

Mardan Medical Complex (MMC), situated in the Khyber Pakhtunkhwa province of Pakistan, serves as a crucial tertiary care facility catering to a diverse patient population. The strategic location and comprehensive healthcare services of MMC provide an ideal setting for investigating the relationship between T2DM and renal morphological parameters in the local population. This research initiative aims to establish standardized sonographical measurements of renal dimensions among Type II diabetic patients presenting at MMC, thereby contributing to the development of region-specific reference values and clinical protocols.

Method and Material

This study employed a descriptive cross-sectional design and was conducted in the Radiology Department of Mardan Medical Complex (MMC), a tertiary care hospital located in Khyber Pakhtunkhwa, Pakistan. The study spanned a duration of approximately six months. Using OpenEpi software, the sample size was calculated to be 366 participants, based on a population size of 404,000 (Mardan population) and an anticipated frequency of 39%, with a 95% confidence interval. A non-probability convenience sampling technique was utilized to recruit participants who were readily available and met the inclusion criteria.

The inclusion criteria for the study encompassed patients with a confirmed diagnosis of type II diabetes mellitus, aged 18 years or older, with no known congenital or acquired renal disorders, such as a single kidney or previous renal surgery. Both male and female patients were included. Patients with type I diabetes, other types of diabetes, known congenital anomalies, or severe respiratory diseases were excluded from the study.

Data collection commenced following official clearance from the research committee and institutional ethical approval. Permission was obtained from the Head of the Radiology Department, and the study was coordinated with the ultrasonography department. A pre-designed questionnaire was administered to each participant undergoing renal ultrasonography. The questionnaire collected relevant demographic and clinical information, ensuring participants understood the study's objectives. Renal ultrasonography was performed using a Toshiba Xario 100 ultrasound machine with a frequency range of 5–10 MHz. The procedure adhered to institutional protocols and ethical standards.

Prior to the ultrasound examination, patients were informed about the procedure and its purpose. To ensure optimal imaging, patients were instructed to fast for a few hours and, if necessary, drink water to fill their bladder. They were also asked to remove any jewelry or clothing that could interfere with the imaging process. During the ultrasound, patients were positioned supine on the examination table, although lateral or prone positions were occasionally used for better visualization based on clinical indications. A water-based gel was applied to the abdominal area to enhance sound transmission and reduce air interference, ensuring optimal contact between the skin and the ultrasound probe. The probe was maneuvered across the abdominal region, with occasional application of pressure to obtain clearer images of hard-to-reach areas. Real-time imaging was performed to assess kidney size, thickness, volume, echogenicity, and the presence of abnormalities such as cysts, masses, or renal hypertrophy.

Data analysis was conducted using SPSS version 28.0. Continuous variables, including age, BMI, height, weight, renal size, renal thickness, renal length, renal volume, and duration of type II diabetes, were summarized using mean and standard deviation. Categorical variables, such as gender and BMI categories, were described using frequencies and percentages. Linear regression analysis was employed to evaluate the association between average renal size and continuous variables, such as age and BMI.

Results

In this study we included 366 individuals, and was categorized according to gender including 136 (37.2%) male and 230 (62.8%) females as shown in table 1. The average age was 56.1 years with a standard deviation of 12.6. 37.2% (136 individuals) were male, while 62.8% (230 individuals) were female according to the results of gender distribution. The mean height of the patients was 5.58 with a standard deviation of 0.3, and the average weight was 73.9kg with a standard deviation of 9.5. The mean body mass index (BMI) was 26.6 with a standard deviation of 3.2.

Table 1: Baseline characteristics of the patients

Characteristics		Values
Age of the patients in year, mean(±SD)		56.1(12.6)
Gender, n (%)	Male	136(37.2)
	Female	230(62.8)
Height of patients in feet, mean(±SD)		5.5(0.3)
Weight of the patients in kg, mean(±SD)		73.9(9.5)
Body mass index of the patient, mean (±SD)		26.6(3.2)

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Table 2 presents the clinical characteristics of patients with type II diabetes. The average duration of diabetes among the patients was 10.1 years with STD of 5.1. The mean blood glucose level of the patients was elevated, measuring 250.9 mg/dl with STD of 91.5. Regarding HbA1c levels, data was not available for 134 patients (36.6%), while 6 patients (1.6%) had normal levels and most patients 266 (61.7%) had high HbA1c levels. Data on urea level was not available for 214 patients (58.5%). The data available for 30 patients (8.2%) had normal urea levels. While 122 patients (33.3%) had high levels of urea. In a similar manner, creatinine levels were not available for 196 patients (54.1%), normal for 121 patients (33.1%), elevated for 47 patients (12.8%). Overall, this data indicates widespread metabolic issues among these patients, including high blood glucose level and abnormal kidney function, which can lead to serious complications.

Table 2: Clinical characteristics of the patients

Clinical Characteristics	Values
Duration of the type II diabetes, mean(±SD)	10.1(5.1)
Blood glucose level of the patient in mg/dL, mean (±SD)	250.9(91.5)

HbA1c of the patients, n(%)	Record not available	134(36.6)
	Normal	6(1.6)
	Raised	226(61.7)
Urea of the patients in mg/dL, n(%)	Record not available	214(58.5)
	Normal	30(8.2)
	Raised	122(33.3)
Creatinine level of the patients in mg/dL, n(%)	Record rd not available	196(54.1)
	Normal	121(33.1)
	Raised	47(12.8)

Table 3 summarizes sonographic measurements of the patients. For the right kidney, the length ranges from 7.1 to 15 cm, with the mean of 10.2 (±0.9), while width ranges from 1.7 to 6.0cm, with the mean of 4.4 (±0.7). The thickness varied between 1.0 and 3.8 cm, with a mean of 2.0 (±0.7), and the volume ranged from 16 to 200 cm3,with a mean of 145.9 (±23.7). For the left kidney, the length ranges from 7.3 to 13.4 cm, with a mean of 10.5 (±0.7), while width ranges from 1.9 to 9.6 cm, with a mean of 4.6 (±0.7). The thickness varied between 1 and 3.9 cm, with a mean of 2.1 (±0.7), and the volume ranged from 19 to 240 cm3, with a mean of 167.9 (±30.8). Average across both kidney, the length ranges from 7.2 to 13 cm, with a mean of 10.3 cm (±0.8), while the width ranges from 1.8 to 20.1 cm, with a mean of 4.6 (±1.0), thickness from 1.0 to 3.9 cm, with a mean of 2.1 (±0.7), and the volume from 17.5 to 202 cm3, with a mean of 156.8 (±25.5).

Table 3: Sonographic measurements of the patients

Variables	Measurements	
	Range (min-max)	Mean (±SD)
Right kidney length in cm	7.1-15	10.2 (0.9)
Right kidney width in cm	1.7-6.0	4.4 (0.7)
Right kidney thickness in cm	1.0-3.8	2.0 (0.7)
Right kidney volume in cm3	16-200	145.9 (23.7)
Left kidney length in cm	7.3-13.4	10.5 (0.7)
Left kidney width in cm	1.9-9.6	4.6 (0.7)
Left kidney thickness in cm	1-3.9	2.1 (0.7)
Left kidney volume in cm3	19-240	167.9 (30.8)
Average kidney length in cm	7.2-13	10.3 (0.8)
Average kidney width in cm	1.8-20.1	4.6 (1.0)
Average kidney thickness in cm	1-3.9	2.1 (0.7)
Average kidney volume in cm3	17.5-202	156.8 (25.5)

Table 4 relates ultrasonographic measurements between male and female, assessing differences in size and volume. For the right kidney, males had slightly longer (10.3 cm vs. 10.1 cm, P=0.04), wider (4.6 cm vs. 4.4 cm, P=0.001), and thicker kidneys (2.3 cm vs. 1.85 cm, P<0.0001) than females. There is no significant change in the right kidney volume of both male and female (P=0.82).

For the left kidney, there is no difference in the lengths of both male and female, (10.6 cm vs. 10.5 cm, P=0.32), wider (4.8 cm vs. 4.7 cm, p=0.12), and thicker kidney (2.3 cm vs. 2.0 cm, P<0.01). Meanwhile, the volume difference was not statistically significant (P=0.42).

On average, male kidneys were thicker than females (P<0.01), while there were no significant changes in the average length, width, or volume. Overall, males have slightly longer kidney dimensions as compared to females, except for the kidney thickness, most of

the differences were small and not clinically significant.

Table 4: Gender based comparison of ultrasonographic measurements of the kidney

Variables	Male Mean (±SD)	Female Mean (±SD)	*P*-value
Right kidney length in cm	10.3(0.93)	10.1(0.92)	0.04
Right kidney width in cm	4.6(0.75)	4.4(0.69)	0.001
Right kidney thickness in cm	2.3(0.77)	1.85(0.64)	<0.001
Right kidney volume in cm^3	145.6(23.4)	146.2(24.03)	0.82
Left kidney length in cm	10.6(0.90)	10.5(0.91)	0.32
Left kidney width in cm	4.8(0.67)	4.7(0.67)	0.12
Left kidney thickness in cm	2.3(0.73)	2.0(0.64)	<0.01
Left kidney volume in cm^3	169.6(31.25)	166.9(30.66)	0.42
Average kidney length in cm	10.4(0.89)	10.3(0.81)	0.11
Average kidney width in cm	4.7(0.72)	4.6(1.91)	0.40
Average kidney thickness in cm	2.3(0.72)	1.1(0.68)	<0.01
Average kidney volume in cm^3	157.6(26.01)	156.5(25.32)	0.68

The results indicate that both age (mean 56.1 plus minus 12.6) and body mass index (mean 26.6 plus minus 3.2) are linked with the outcome ($p < 0.001$ and $p = 0.004$, respectively). But the correlations are weak ($R = 0.3$ for age and $R = 0.149$ for BMI), showing moderate relationship. Age explains 10% of outcome variability ($R^2 = 0.1$), on other hand BMI shows only ($R^2 = 0.022$). Despite their statistical importance, both variables have limited explanatory power.

Table 5: Linear Regression of Average Renal Length with age and BMI

Variables	Mean (SD)	p-value	R	R^2
Age of the patient in years	56.1 (12.6)	<0.001	0.3	0.1
Body Mass index of the patient	26.6 (3.2)	0.004	0.149	0.22

The data reveals neither age (mean 53.1 ± 12.6), nor BMI ((mean 26.7 ± 3.2) shows marked effect on the results. the p-value is far above the significance threshold, no relationship, and its correlation ($R = 0.009$) does not exist, with no explanatory power ($R^2 = 0.000$). Similarly, on the other hand BMI has p-value (0.067) and a weak positive correlation ($R = 0.096$), it just explains 0.9 % of the outcome variability ($R^2 = 0.009$).

Table 6: Linear Regression of Average Renal Width with age and BMI

Variables	Mean (SD)	p-value	R	R^2
Age of the patient in years	53.1 (12.6)	0.862	0.009	0.000

Body mass index of the patient	26.7 (3.2)	0.067	0.096	0.009

Both age (mean 56.1 ± 12.6), and BMI (mean 26.6 ± 3.2) indicate statistically important relationships with the result, with p-values of 0.048 and <0.001, respectively. On the other hand, the strength of these associations is weak and low: age has a correlation of 0.103 and shows only 1.1% of changes in the result (R^2 = 0.011), however BMI has a slightly strong and high correlation 0.171, indicating 2.9% of the variation (R^2 = 0.029). These outcomes show both variables are linked with the result their explanatory power is low and minimal.

Table 7: Linear Regression of Average Renal Thickness with age and BMI

Variables	Mean (SD)	p-value	R	R^2
Age of the patient in years	56.1 (12.6)	0.048	0.103	0.011
Body mass index of the patient	26.6 (3.2)	<0.001	0.171	0.029

Both age (mean 56.1 ± 12.6) and BMI (mean 26.7 ± 3.2) show an important relationship with the results (p <0.001). Age has a minimal positive correlation with the outcome (R = 0.177), showing only 3.1% of the variation (R^2 = 0.031). BMI also has limited positive correlation (R = 0.207), and also explains 4.3% of variation (R^2 = 0.043).

Table 8: Linear Regression of Average Renal Volume with age and BMI

Variables	Mean (SD)	p-value	R	R^2
Age of the patient in years	56.1 (12.6)	<0.001	0.177	0.031
Body mass index of the patient	26.7 (3.2)	<0.001	0.207	0.043

Discussion

The findings of this study provide valuable insights into the renal morphological changes observed in patients with type II diabetes mellitus (T2DM) using sonographical measurements. The use of ultrasonography as a non-invasive and cost-effective diagnostic tool has proven to be instrumental in assessing renal dimensions, including kidney length, width, thickness, and volume, which are critical indicators of renal health. This study contributes to the growing body of evidence highlighting the importance of early detection and monitoring of diabetic nephropathy, a major complication of T2DM.

The observed alterations in renal size among the study participants align with previous research indicating that chronic hyperglycemia in T2DM patients leads to structural and functional changes in the kidneys. Studies have shown that glomerular hyperfiltration, oxidative stress, and inflammatory responses are key mechanisms driving these changes (13, 14). The increase in renal size observed in the early stages of diabetic nephropathy may reflect compensatory

hypertrophy, which eventually progresses to renal atrophy and dysfunction in advanced stages (15).

The demographic characteristics of the study population, including age, gender, and BMI, were found to influence renal dimensions. These findings are consistent with recent studies that have reported significant associations between demographic factors and kidney morphology in diabetic patients (16, 17). Higher BMI has been linked to increased renal size, likely due to the hemodynamic changes associated with obesity and insulin resistance (18). Additionally, age-related changes in renal morphology have been documented, with older individuals often exhibiting reduced renal size and function, which may compound the effects of diabetes (19, 20).

The use of a standardized ultrasonographic protocol in this study ensured the reliability and reproducibility of the measurements. The Toshiba Xario 100 ultrasound machine, with its high-frequency transducer, provided high-resolution images that facilitated accurate assessment of renal dimensions. This methodological rigor enhances the validity of the findings and underscores the utility of ultrasonography in routine clinical practice for monitoring renal health in diabetic patients (Lee et al., 2022). Furthermore, the inclusion of patient preparation protocols, such as fasting and bladder filling, ensured optimal imaging conditions, which are critical for obtaining accurate and reproducible measurements (Anderson et al., 2021).

The implications of these findings extend beyond individual patient care to broader public health strategies. Early detection of renal changes in T2DM patients can facilitate timely interventions, potentially delaying the progression to end-stage renal disease (ESRD). This is particularly relevant in resource-limited settings, such as Pakistan, where the burden of diabetes and its complications is rapidly increasing (21). The establishment of region-specific reference values for renal dimensions can aid in the development of tailored screening and management protocols, ultimately improving patient outcomes (22).

Despite its strengths, this study has several limitations that warrant consideration. The use of a non-probability convenience sampling technique may limit the generalizability of the findings to the broader population of T2DM patients. Additionally, the cross-sectional design precludes the establishment of causal relationships between T2DM and renal morphological changes. Longitudinal studies are needed to further elucidate the temporal dynamics of these changes and their clinical implications (23, 24). Moreover, the reliance on ultrasonography alone may overlook subtle renal changes that could be detected using more advanced imaging modalities, such as magnetic resonance imaging (MRI) or computed tomography (CT) (25).

Future research should also explore the potential role of molecular and genetic factors in the pathogenesis of diabetic nephropathy. Recent studies have identified several biomarkers and genetic variants associated with increased susceptibility to renal complications in T2DM patients (26). Investigating these factors could provide deeper insights into the mechanisms underlying renal changes and identify novel therapeutic targets. Additionally, the integration of artificial intelligence (AI) and machine learning algorithms into ultrasonographic analysis holds promise for enhancing the accuracy and efficiency of renal assessments (27).

Conclusion

In conclusion, this study underscores the utility of ultrasonography as a valuable tool for assessing renal dimensions in T2DM patients. The findings highlight the need for early detection and monitoring of renal changes to mitigate the burden of diabetic nephropathy. By addressing the existing gaps in knowledge and providing region-specific data, this research contributes to the understanding and management of diabetes-associated renal complications, ultimately improving patient outcomes. Future studies should build on these findings by incorporating advanced imaging techniques, exploring molecular and genetic factors, and leveraging AI-driven technologies to further enhance the assessment and management of renal health in diabetic patients.

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