

Assessment of the individual renal function in chronic unilateral renal obstruction using functional CT as compared to ^{99m}Tc -DTPA renal scan

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ABSTRACT

Introduction: The selection of optimal treatment of obstructive nephropathy requires information about the functional status of each kidney. Nuclear renal scanning objectively measure differential renal function, multiple studies have demonstrated the role of assessment of renal perfusion and GFR with triphasic CT. The aim of this study is to assess the role of CT based on renal parenchymal volume measurement in assessment of individual renal function compared to ^{99m}Tc -DTPA renal scan in patients with unilateral renal obstruction.

Methods: During the indicated time interval, 42 patients with chronic unilateral obstruction; the percentage of the individual renal functions by ^{99m}Tc -DTPA and by CT were assessed.

Results: The percentage of the individual renal functions as estimated by ^{99m}Tc -DTPA in obstructed kidneys ranged from 0% to 40.43% (13.22), while by CT is in range from 0 to 36.68% (15.52). The correlation between percent renal function by ^{99m}Tc -DTPA renal scan and percent renal volume by CT were assessed in obstructed kidneys and there were statistically significant relationship ($r = 0.877$, $P < 0.0001$).

Conclusion: CT scan can be used as an integrated modality to assess the functional and morphological status of unilateral chronic renal obstruction, however ^{99m}Tc -DTPA renal scan is a safe choice with less radiation exposure, further comparative studies are needed to assess the role of CT-based parenchymal volume in evaluation of individual renal functions in patients with acute obstruction, bilateral nephropathy and renal impairment.

Key words: Unilateral chronic renal obstruction; DTPA renal scan; Functional CT

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INTRODUCTION

Obstructive nephrouropathy is one of most common urological disorders. The plan of management is based on precise assessment of both renoureteral units and accurate estimation of the renal function. Obstructive nephrouropathy is very rarely symmetrical, and the selection of optimal treatment requires information about the functional status of each kidney as well as knowledge of the total renal function [1]. Quantitative assessment of relative individual renal function is a major role of radionuclide renography. Individual kidney function influences the clinical judgment with regard to assessment of therapy [2].

Different radiopharmaceuticals were used in nuclear renal scanning [3]. ^{99m}Tc -DTPA is used for glomerular filtration rate (GFR) evaluation because no tubular secretion or re-absorption is observed but it is completely filtered by the glomerulus. In ^{99m}Tc -DTPA renography, the GFR is calculated without blood or urine sampling. The Gate method is the most common method used in the routine setting. The simplicity of the Gates method, its cost-effectiveness and relative repetitiveness of results in an individual "case to case" study convinced us to implement the modified protocol into routine practice [4]. The accuracy of this methods was comparable to that reported for creatinine clearance, the most commonly used estimate of the GFR in current clinical practice [5].

Diuretic renography used to differentiate the dilated non obstructed collecting system from dilated system with urodynamically significant obstruction as well as to assess functional and urodynamic results [5].

Conventional radiographic contrast techniques give valuable information about the anatomical structure of the kidneys and collecting systems. However, they provide only qualitative information on differential renal function. There are different methods to evaluate the renal function like computed tomography (CT)-estimated GFR. The hydronephrotic obstructed kidney loses volume as it parenchyma atrophies and loses function. So, the residual parenchymal volume can be measured by multi-slices helical CT scan [6].

In recent years, multiple studies have demonstrated a clear role for utilizing CT to assess renal perfusion and GFR with triphasic CT. CT measures contrast medium quantitatively, with high spatial resolution by subtracting unenhanced from enhanced CT scans. CT has promising role in assessment of the functional parameters such as perfusion [7].

The golden standard to determine differential renal function is the nuclear imaging. Non-invasive method carry less hazards and the need for a reliable

noninvasive method for studying individual kidney function is important [8].

The aim of this study is to assess the potential role of CT based renal parenchymal volume measurement in assessment of the individual renal function compared to ^{99m}Tc -DTPA renal scan in patient with unilateral obstruction.

METHODS

Forty two patients with unilateral obstructive nephrouropathy were included in our study; this is a prospective comparative study, performed between Dec 2011 and March 2013. Patients referred to our nuclear medicine department with questionable unilateral obstruction and the available clinical data, laboratory investigations including serum creatinine level, as well as pervious investigations includes plain X-ray of the abdomen (PUT)/ ultrasonography and intravenous urography (IVU) were collected; when this provisional diagnosis confirmed by ^{99m}Tc -DTPA renal scan. All these patients subjected to 32 slices helical CT scan. The exclusion criteria from this study were included, those with creatinine > 2 mg/dl and acute obstruction.

Diuretic ^{99m}Tc -DTPA renography was performed to all patients by (Dual heads gamma camera, Philips Bright view). The used technique includes intravenous administration of ^{99m}Tc -DTPA (Doses adjusted to each patient according to the weight and age), and acquisition of dynamic 15-60 second posterior renal images for 20 minutes, Furosemide, 0.5 mg/kg (1 mg/kg for children) with a maximum dose of 40 mg, was administered intravenously at the middle of the dynamic study. The initial sets of images were used for evaluating differential renal functions. The images obtained after administration of furosemide are used for quantitative analysis of post-diuresis clearance of the radiopharmaceutical from the dilated collecting systems. Regions of interest, including the entire dilated collecting systems, were drawn and a background subtracted time-activity curve is generated. Additional posterior static images after 2 hours were also acquired.

Triphasic CT examination were performed to the entire study group, the volume estimation software comes preinstalled with 32 slice helical CT scan (GE medical system). The three dimensional (3D) tools that was available in this software package have "add object" function that was used to build 3D virtual representation of the kidneys depending on the arterial phase images. After enhancement we select manually small area of renal parenchyma to allow the software to identify the remaining surrounding renal parenchyma that have similar voxel values which was added into the volume voxel to create the 3D renal

volume. The extra parenchymal structures like renal pelvis, vessels were excluded. The final 3D model of each kidney was compared with the cross sectional images to ensure that only the renal parenchyma was included and sometimes it was necessary to use the cutting tool to free the margins of kidney from adjacent structures. The right and left percent renal volume was calculated by dividing right and left volumes respectively by the combined right and left renal volume.

This percent renal volume was compared with percent renal function determined by ^{99m}Tc-DTPA renal scan. The statistical method for correlations between percent renal volume and percent renal function is Pearson coefficient which was used for all cases. The Bland Altman plots graphically portrayed the mean difference and variability between both measurement techniques. Statistical analyses were performed using SPSS version 16 (SPSS Inc., Chicago Il) and MedCalc for Windows, version 9.1.0.1 (MedCalc Software, Mariakerke, Belgium); *p*-values, 0.05 are considered statistically significant.

RESULTS

During the indicated time interval, 42 patients fulfilled the selection criteria and any patient with high serum creatinine level above creatinine > 2 mg/dl or acute obstruction was excluded from the study. The demographic distribution was as the follow; 20 (47.62%) were male, and 22(52.38%) were female (mean age; 32; age range, 2–68 years).

All patients had unilateral obstruction; 26 on the left side and 16 on the right side, controversy the non obstructed kidneys were 42 (16 at the right side and 26 on the right kidney), [Figure 1](#).

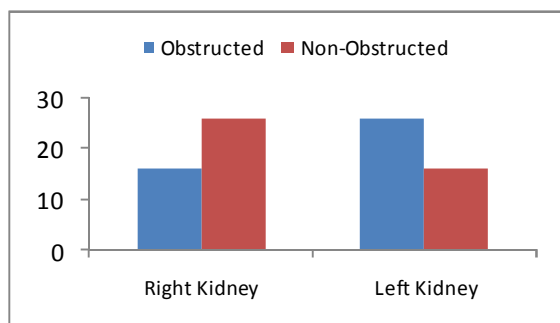


Fig 1. The distribution of obstructed and non-obstructed unites in the study groups.

The causes of hydronephrotic obstruction was pelvi-ureteric junction obstruction in 8 cases, ureteric calculus in 18 cases, renal obstructing calculi in 14

cases and lower ureteric stricture in 2 case, ([Figure 2](#)).

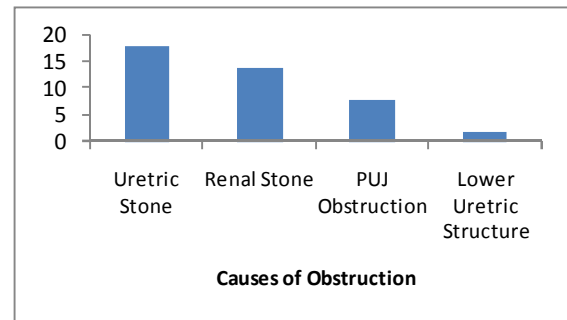


Fig 2. Causes of renal obstruction in the study group.

The range of serum creatinine among all the study population was 0.5-1.5 mg/dl (0.81).

The range of estimated GFR by ^{99m}Tc-DTPA in the hydronephrotic obstructed kidneys was between 0 and 42.43 mg/dl (12.56) and in the contra lateral non obstructed kidneys ranged between 31.2 and 59.4 mg/dl (43.1). The parenchymal volume as estimated by multislices helical CT scan in obstructed renal units are in the range of 0-157.1 cc (39.65) and in non obstructed kidneys was 94.2-267cc (142.41).

The percentage of the individual renal functions in the hydronephrotic obstructed kidneys (42 kidneys) as estimated by ^{99m}Tc-DTPA ranged ranges 0%-40.43% (13.22) and in non obstructed kidneys ranges from 59.57 to 100% (86.87). The percent renal volume estimated by multi slices CT scan in obstructed unit ranges from 0 to 36.68% (15.52) and in the contra lateral none obstructed kidneys ranges from 60.43 to 100% (84.25).

The correlation between percent renal function estimated by ^{99m}Tc-DTPA renal and percent renal volume estimated by multi-slices CT were assessed in obstructed kidneys and there were statistically significant relationship. ($r=0.877$; $P<0.0001$), ([Figure 3](#)).

Statistically strong correlation between percent renal function estimated by ^{99m}Tc-DTPA renal and percent renal volume estimated by multi slices CT scan in non-obstructed renal units ($r = 0.873$, $P < 0.0001$) were also found, ([Figure 4](#)).

Finally, significant correlation was found between percent renal function estimated by ^{99m}Tc-DTPA renal and percent renal volume estimated by multi-slice CT scan on combining both obstructed and non obstructed kidneys ($r = 0.983$, $P < 0.0001$), ([Figure 5](#)).

The Bland–Altman data ([Table 1](#); [Figure 6, 7](#)) show the correlation between renal function by ^{99m}Tc-

DTPA renal scan and CT scan at both obstructed and non obstructed kidneys.

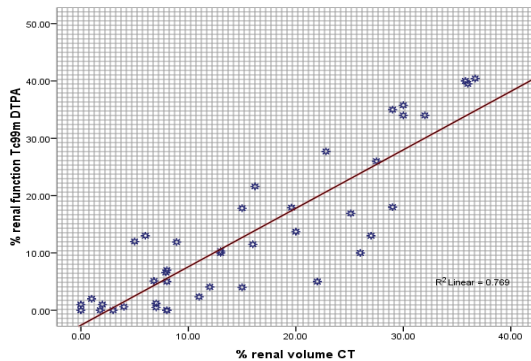


Fig 3. Positive correlation between % renal volume and % renal function in obstructed renal units.

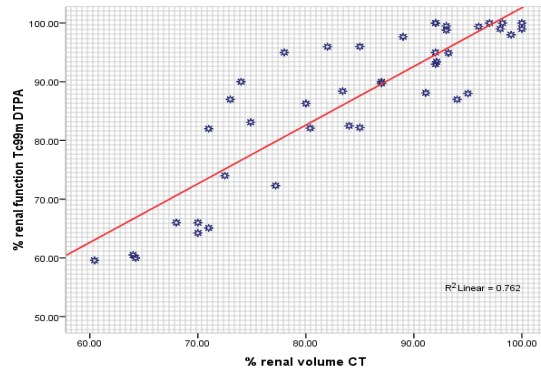


Fig 4. Positive correlation between % renal volume and % renal function in non-obstructed renal units.

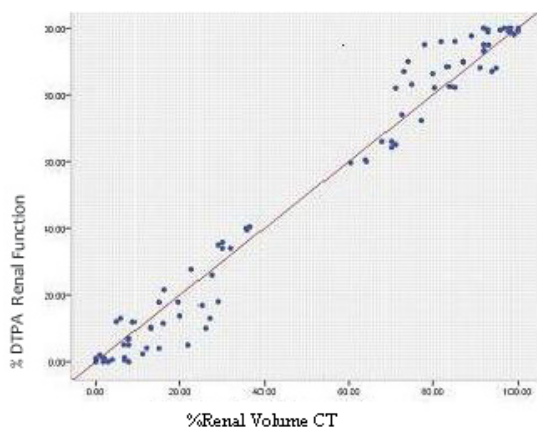


Fig 5. Correlation between percent renal function by DTPA and CT scan at both obstructed and non-obstructed kidneys.

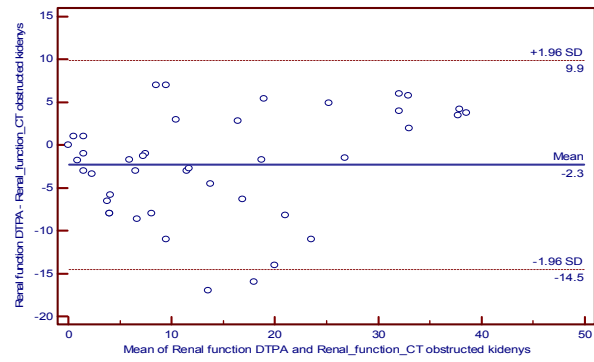


Fig 6. Bland–Altman plots for percent of renal functions by renal scan vs. renal volume by CT in obstructed kidneys SD, standard deviation.

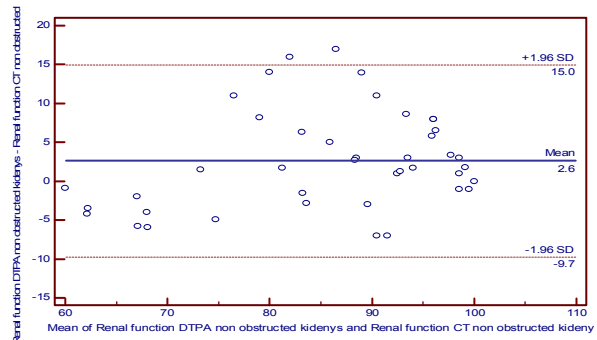


Fig 7. Bland–Altman plots for percent of renal functions by renal scan vs. renal volume by CT in non-obstructed kidneys SD, standard deviation.

DISCUSSION

Relative kidney function is an important parameter during urological decision making. Nuclear renal scanning objectively measures individual renal function, and it is considered as the imaging modality of choice for assessment of the individual function. It has several advantages, it is safe easy and feasible method for such assessment, but despite these advantages, we cannot dispense on other anatomical modalities which is essential to detect the therapeutic plane. Creatinine clearance (24 hours) evaluate the total renal function, but the major limitation of this method that it gives impression on the overall GFR unabling to assess the individual renal function which is essential for management of these obstructed units.

Different radiopharmaceuticals such as technetium-99m dimercaptosuccinic acid (^{99m}Tc-DMSA), and ^{99m}Tc-DTPA, are commonly used, DMSA scan is usually considered as gold standard for "differential renal function" especially in the unilateral obstruction setting.

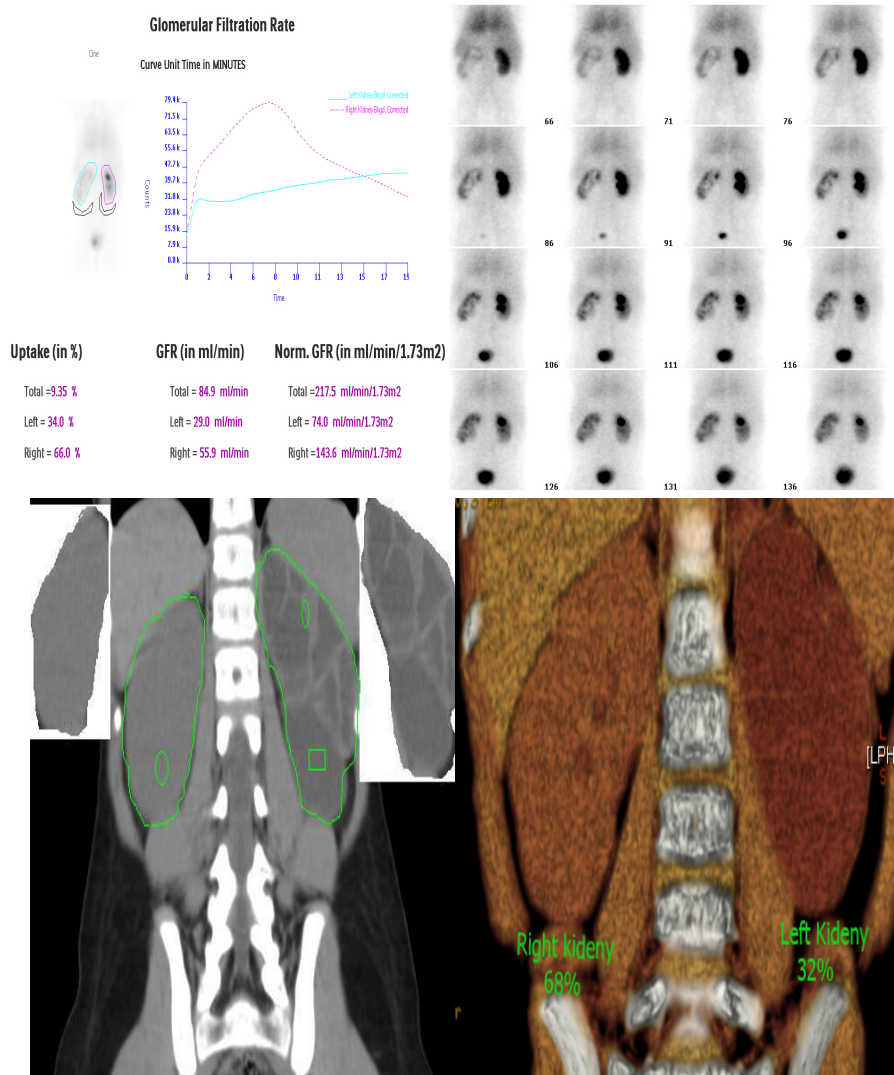


Fig 8. 4 year old girl, presented with history of left PUJ obstruction with significant hydronephrotic changes, which affect the differential renal function of the left kidney with rising up obstructive curve pattern (above figures). In volume estimation by CT we select manually (left below) small area of renal parenchyma to allow the software to identify the remaining surrounding renal parenchyma that have similar voxel values, The differential renal functions on CT (right below) were similar to that detected by renal scan.

Table 1: Bland–Altman plot analysis values for comparisons between renal scan and CT in both obstructed and non-obstructed kidneys.

	Renal function & renal volume by CT in obstructed kidneys	Renal function & renal volume by CT in non-obstructed kidneys
Arithmetic mean	-2.3019	2.6210
95% CI	-4.2448 to -0.3590	0.6603 to 4.5817
P (H ₀ : Mean=0)	0.0214	0.0100
Standard deviation	6.2348	6.2919
Lower limit	-14.5222	-9.7112
95% CI	-17.8692 to -11.1752	-13.0889 to -6.3335
Upper limit	9.9184	14.9531
95% CI	6.5713 to 13.2654	11.5754 to 18.3308

CI: confidence interval; SD: standard deviation.

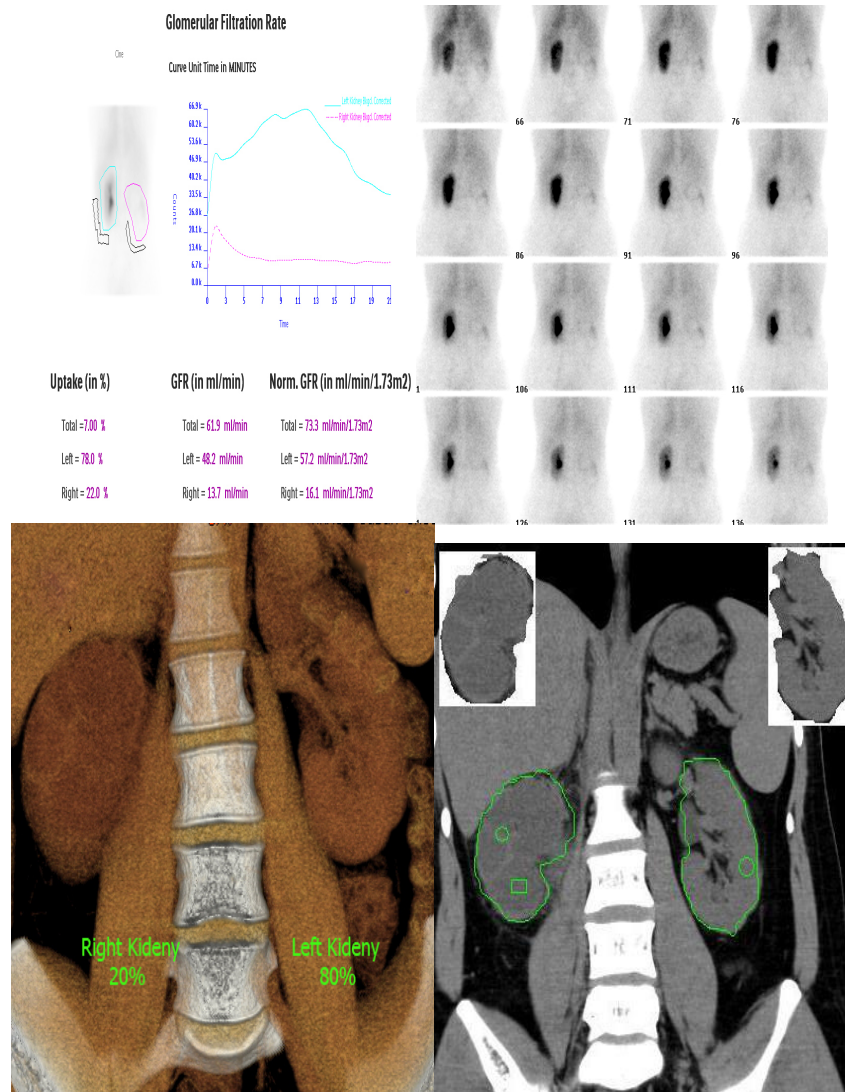


Fig 9. 59 year old male, presented with long standing right renal obstruction, with substantial low nephrons functions on renal scan (above), In volume estimation by CT (below) the individual renal function of the right kidney was 20% compared to 22 % in Tc-99m renal study.

Yet Yalçın et al. [9] found excellent correlation between these two methods. DTPA used in our study because it is most widely applied in the daily clinical practice in nuclear medicine departments and the dynamic study gave additional data about the perfusion, uptake, excretion of the tracer, GFR values as well and the pattern of renogram curves which are important in assessment of the degree of obstruction (Figures 8 and 9). In recent years, multiple studies have demonstrated a clear role for utilizing CT to assess renal perfusion and (GFR). Hackstein et al. [7] demonstrated that GFR can be measured accurately with triphasic CT. In their study they found a strong linear relationship between differential renal function by dynamic CT using modified Patlak graphic analysis, nuclear renal scan and 24-hour creatinine clearance. Other study by Herts et al [10], who compare the estimated GFR by CT-based parenchymal volume with GFR measurement by ¹²⁵I-

iothalamate clearance imaging, found that CT is comparable to GFR assessment by nuclear medicine methods. El-Ghar et al [11] observed that contrast enhanced spiral CT is more sensitive than IVU for identifying the cause of chronic obstructive uropathy and it is as accurate as radioisotope renal scan for calculating the total and separate kidney function. So they recommend spiral CT with contrast medium as a single radiological diagnostic modality for the assessment of patients with chronic renal obstruction and normal serum creatinine. In this study the individual renal functions were assessed by both radionuclide methods as well as multislices CT, the patient with acute obstruction and with serum creatinine above 2 mg/dL were excluded from the study group, a threshold of 2.0 mg/dL in the setting of stable chronic renal insufficiency is probably safe for most patients [12]. The morphological changes on CT are not usually sufficient enough to induce

significant alteration in the individual renal functions based on parenchymal thickness changes. Correlation between individual renal functions in both methods revealed strong relationship at both obstructed and non obstructed kidneys agreement with previous study by Feder et al. [13], who found differential renal parenchymal area measured by CT strongly correlates with differential function on ^{99m}Tc-DTPA renal scan. Morrisroe N et al. [14] found also statistically significant correlations between percent renal function and percent renal volume in all cases. It is concluded that differential renal volume measured by CT strongly correlates with differential renal function on ^{99m}Tc-DTPA for normal and chronically obstructed kidneys, But despite this strong correlation, the ability of CT to be used as an integrated radiological modality for anatomical and functional assessment in patients with unilateral renal obstructions has many limitation as the need for contrast media administration which adversely affect the renal functions and induced nephrotoxicity with sudden deterioration in renal function following the intravascular administration [12]. ^{99m}Tc-DTPA renal scan is safer and radiation exposure is much lower than other radiological modalities. The mean effective dose reported in several studies estimated at 14.8 mSv +/- 90 for CTU, and 9.7 mSv +/- 3 for IVU while in a triphasic CTU which performed in the current study is significantly higher than renal scan and ranges between 20.1 mSv and 66.3 mSv [15]. CT cannot estimate the overall GFR simply as estimated by ^{99m}Tc-DTPA with inability to be performed in renal insufficiency and false results in acute obstruction.

CONCLUSION

There is a significant correlation between the measurement of individual renal function by CT-based parenchymal volume and as estimated by ^{99m}Tc-DTPA renal scan in unilateral renal obstruction. CT can detect the anatomical details, and it may be used as an integrated modality in assessment of the functional and anatomical status of the unilateral chronically obstructed kidneys, however ^{99m}Tc-DTPA renal scan is a safe choice has no hazards of contrast on the already diseased kidneys with less radiation exposure, Further comparative studies are needed to assess the role of CT-based parenchymal volume in assessment of individual renal functions in patient with acute obstruction, bilateral nephropathy and renal impairment.

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