

THE ESTIMATION OF GLOMERULAR FILTRATION RATE (GFR) FOR RENAL SPLIT FUNCTION WITH ^{99m}Tc -DTPA

Alamgir Hossain^{1*}, Bedarul Islam², Chanchal K. Ckaki³, Samirun Kumar Shaha⁴, Shariful I. Chowdhury⁵

^{*1,2,3}Department of Physics, University of Rajshahi, Rajshahi-6205, Bangladesh

⁴Pabna University of Science & Technology

⁵Institute of Nuclear Medicine and Allied Sciences, Rajshahi, Bangladesh

Correspondence Author: -

E-mail: alamgir_ru07@yahoo.com

Abstract: -

Introduction: To study the variation of kidney counts, uptake and Glomerular filtration rate with renal split function, 27 patient's renogram data were taken. Therefore, to investigate of glomerular filtration rate (GFR) for renal split function with ^{99m}Tc -DTPA.

Procedures: The injected dose was calibrated by the dose calibrator. About 3mCi ^{99m}Tc with DTPA are taken into the syringe. With the help of gamma camera, the pre syringe counts (in Kcpm units) and post syringe counts (Kcpm units) are measured. From the value of pre syringe counts and post syringe counts, the net injected counts are measured. Then the patient is placed on the imaging beds and the detector of the gamma camera is placed on the suitable position. The gamma rays are counted by the detector of the gamma camera, in which emits from the kidney of the patients and the display unit shows the curve time versus counts per minute, Renal split function, uptake, Glomerular filtration rate, kidney depth, and time of maximum counts for left and right kidney respectively by automated software (Easy soft-Semence signature series) program.

Results: The renal split function were investigated in the range of (89.99~22.4) % for left kidney and also (99.6~6.377) % for right kidney. It was found that the range of uptake (%), (8.019~2.2236) % for left kidney and (7.765~1.19) % for right kidney. The GFR were found in the range of (72.4~20.4) ml/min for left kidney and also (70.9~3.937) for right kidney.

Conclusion: The GFR was linear relationship with renal split functions but linearly decreased with patient's age. For majority patients, the calculated value of GFR were (20-30) (ml/min) and (40-50) (ml/min) in left and right kidney respectively. Therefore, majority patient was affected in cardiovascular disease (CVD).

Keyword's: - Renal split function • glomerular filtration rate • ^{99m}Tc - DTPA



INTRODUCTION

In Tc-99m-DTPA renography, the glomerular filtration rate (GFR) is calculated without blood or urine sampling [1]. Several techniques have been applied in clinical practice, because of technical simplicity and requirement for less time for the patients. The method (Gate) introduced by Gates [2] has been most common in the routine setting. Although the diagnostic accuracy of the gamma camera methods is debated, [3–11] the program is provided as a software package by manufacturers in commercially available computer systems dedicated for nuclear medicine.

The GFR can also be calculated from serum creatinine using the Cockcroft-Gault equation [12] (CG). In Gates and CG, 24-hour creatinine clearance was chosen as a reference. The equations for predicting the GFR are based on the linear relationship of the renal uptake of Tc-99m-DTPA in the Gates and serum creatinine in the CG. A plasma sample clearance method following a single injection of radioactive marker has been proved accurate for quantification of renal function [13–16].

Technetium-99m-Diethylene Triamine Penta Acetic acid (99mTc-DTPA) is a chelating agent which was introduced into renal nuclear medicine in 1970. 99mTc-DTPA is the least expensive renal radiopharmaceutical. It is cleared by the glomerulus and can be used to measure glomerular filtration rate (GFR), [17]. The extraction fraction (the percentage of the agent extracted with each pass through the kidney) of 99mTc-DTPA is approximately 20%; for this reason, in patients with impaired renal function this radiopharmaceutical may not be as useful as those with higher extraction efficiencies such as 99mTc-mercaptoacetyl triglycine (MAG3) and iodine-131 or iodine-123 orthoiodohippurate (OIH) [18].

Split renal function (SRF), differential renal function, or relative kidney function can be expressed as a percent of total renal function. In determination of Split renal function (SRF), various methods, such as radionuclide methods, triphasic computed tomography (CT), magnetic resonance imaging (MR) and ultrasound Doppler techniques, etc. can be used [19–21]. SRF is traditionally measured by radionuclide renal scintigraphies, using different tracers [19]. 99mTc-dimercaptosuccinic acid (99mTc-DMSA) is an agent that is actively taken up by the proximal and distal renal tubular cells, directly from the peritubular vessels, and accumulates in the renal cortex [22].

This modality is primarily used for imaging functioning cortical mass and individual renal function [23]. It is the most reliable method for assessing chronic cortical scarring [24]. 99mTc-diethylenetriaminepentacetate (99mTcDTPA) is an agent that is freely filterable at the glomerulus, but it is neither secreted nor resorbed by the kidney tubules. This method is used to measure total and individual kidney functions. By using the gamma camera technique, glomerular filtration rate (GFR) is calculated for each kidney [25].

99mTc-mercaptoacetyl triglycine (99mTc-MAG3) is a renal plasma flow agent almost exclusively excreted by secretion in the proximal tubules and not reabsorbed by the renal tubules. This agent is good for evaluation of renal tubular function [25]. Using a procedure similar to 99mTc-DTPA scintigraphy, dynamic imaging by gamma camera is obtained. Effective renal plasma flow (ERPF), reflecting kidney function, is calculated for each kidney [26]. The purpose of the study was to investigate of glomerular filtration rate (GFR) for renal split function with ^{99m}Tc-DTPA.

Methods

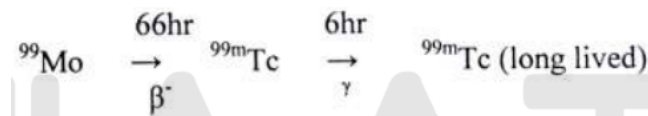
Radiopharmaceutical

In nuclear medicine technique, very small amount of suitable radiopharmaceutical is administered orally or intravenously, which accumulated preferentially in certain organs of the patient. Gamma rays from the desired organ can be detected and image can be obtained by using rectilinear scanner or scintillation camera. Imaging or function tests of different organs are possible by using proper compound tagged with appropriate radioisotope. In fact this is the basis of nuclear medicine technique. However, all radioisotopes are not suitable for imaging. In fact a very few of more than 1100 radioisotopes are used for clinical purposes. The suitability of a radioisotope to be tagged with a compound is simply called the radiopharmaceutical [27].

^{99m}Tc Radiopharmaceutical

Technetium-99m (99mTc) is widely used in radiopharmaceutical preparations due to its excellent physical and chemical properties. In fact, more than 80% of all radiopharmaceuticals used in diagnostic nuclear medicine are based on this short-lived radionuclide, which is obtained by elution of a 99Mo/99mTc generator system that is available in any radio pharmacy and nuclear medicine facility. 99mTc decays with a half-life of 6 h by isomeric transition and emission of 140.5-keV gamma radiation. Large amounts of radioactivity may be used with the single-photon emission computed tomography (SPECT) technology, producing high-contrast images with the gamma camera. In fact, the energy window of the gamma camera is optimized to 140.5keV (110–220keV). 99mTc is eluted from the generator as a pertechnetate anion. It has been demonstrated that heptavalent technetium must be reduced to a lower valence state in order to be chemically reactive for labeling. Most 99mTc pharmaceuticals comprise complexes of 99mTc at various oxidation states (I–V). The preparation of 99mTc pharmaceuticals is greatly facilitated by the availability of commercial cold kits containing the chemical ingredients as a lyophilized formulation ready for labeling with 99mTc-pertechnetate [28]. The 99mTc generation process is as follows [27] :

Although ^{99m}Tc is not stable, its half-life is so long (2.14×10^5 yr) that it can be considered stable from practical point of view and it does not have any adverse effect on human body. It can be produced in the laboratory from the parent radionuclide ⁹⁹Mo, which has a reasonably long half-life (66hr).



Radioisotope renography

Radioisotope renography is a form of kidney imaging involving radioisotopes. The two most common radiolabelled pharmaceutical agents used are $^{99\text{m}}\text{Tc}$ -MAG3 (Mercaptoacetyltriglycine) and $^{99\text{m}}\text{Tc}$ -DTPA (Diethylene Triamine Pentacetic Acid). Some other radiolabelled pharmaceuticals are EC (Ethyl Cysteine) and ^{131}I -Iodine labelled OIH (Ortho Iodo Hippurate). MAG3 is by far a better diagnostic agent than Tc- $^{99\text{m}}$ -DTPA, particularly in neonates, patients with impaired function, patients with impaired function, and patients with suspected obstruction. The MAG3 clearance is highly correlated with the effective renal plasma flow (ERPF), and the MAG3 clearance can be used as an independent measure of renal function. After intravenous administration, about 40-50% of the MAG3 in the blood is extracted by the proximal tubules with each pass through the kidneys; the proximal tubules then secrete the MAG3 into the tubular lumen. DTPA is the second most commonly used renal radiopharmaceutical in the United States, primarily because it is the least expensive. Tc- $^{99\text{m}}$ -DTPA is filtered by the glomerulus and may be used to measure the glomerular filtration rate (GFR). The extraction fraction of DTPA is approximately 20%, less than half that of MAG3 [27]. However, EC is preferred when the serum Creatinine is high.

Preparation

The kit contents the lyophilized ingredients in a multidose vial. Labeling is performed by adding 2-10ml of $^{99\text{m}}\text{Tc}$ eluate containing up to 11.1GBq under aseptic conditions. After sterile sodium $^{99\text{m}}\text{Tc}$ -pertechnetate has been added to the vial, the powder is dissolved by inverting the vial. The reaction is allowed to proceed at room temperature, instructions should be followed. $^{99\text{m}}\text{Tc}$ diethylenetriaminepentaacetate (DTPA) complex is a sterile, pyrogen-free, clear colorless solution suitable for intravenous injection. The pH should be between 4.0 and 7.5 [2831].

This is an interaction in which an incident gamma photon loses enough energy to an atomic electron to cause its ejection, with the remainder of the original photon's energy emitted as a new, lower energy gamma photon whose emission direction is different from that of the incident gamma photon, hence the term "scattering". The probability of Compton scattering decreases with increasing photon energy. Compton scattering is thought to be the principal absorption mechanism for gamma rays in the intermediate energy range 100 keV to 10 MeV. Compton scattering is relatively independent of the atomic number of the absorbing material, which is why very dense materials like lead are only modestly better shields, on a per weight basis, than are less dense materials.

Imaging techniques using gamma cameras

Scintigraphy ("scint") is the use of gamma cameras to capture emitted radiation from internal radioisotopes to create two-dimensional [32] images. SPECT (single photon emission computed tomography) imaging, as used in nuclear cardiac stress testing, is performed using gamma cameras. Usually one, two or three detectors or heads, are slowly rotated around the patient's torso.

Multi-headed gamma cameras can also be used for Positron emission tomography scanning, provided that their hardware and software can be configured to detect 'coincidences' (near simultaneous events on 2 different heads). Gamma camera PET is markedly inferior to PET imaging with a purpose designed PET scanner, as the scintillator crystal has poor sensitivity for the high-energy annihilation photons, and the detector area is significantly smaller. However, given the low cost of a gamma camera and its additional flexibility compared to a dedicated PET scanner, this technique is useful where the expense and resource implications of a PET scanner cannot be justified [33].

Patient preparation

The experiment were carried out in the centre for Nuclear Medicine and Ultrasound, Rajshahi using Gamma camera. In order to evaluation the variation of glomerular filtration rate, uptake and counts per minute with renal function, 27 patients were taken under our study.

Experimental procedure

Clinical histories of the patient who came to select Nuclear Medicine Centre (CNMU, Rajshahi) for diagnosis were record. In Case of Renal function imagine normally $^{99\text{m}}\text{Tc}$ -DTPA were used and image is taken after a certain time when maximum number of activities accumulate to the target organ.

At first the injected dose is calibrated by the dose calibrator. About 3mCi $^{99\text{m}}\text{Tc}$ with DTPA are taken into the syringe. With the help of gamma camera, the pre syringe counts (in Kcpm units) and post syringe counts (Kcpm units) are measured. From the value of pre syringe counts and post syringe counts, the net injected counts are measured. Then the patient is placed on the imaging beds and the detector of the gamma camera is placed on the suitable position. The gamma rays are counted by the detector of the gamma camera, in which emits from the kidney of the patients and the display unit shows the curve time versus counts per minute, Renal split function, uptake, Glomerular filtration rate, kidney depth, and time of maximum counts for left and right kidney respectively by automated software (Easy soft-Semence signature series) programm.

Results

A total of 27 patients were enrolled in this study. The renal split function were investigated in the range of (89.99~22.4)% for left kidney and also (99.6~6.377)% for right kidney. It was found that the range of uptake(%), (8.019~2.2236)% for left kidney and (7.765~1.19)% for right kidney. The GFR were found in the range of (72.4~20.4) ml/min for left kidney and also (70.9~3.937) for right kidney. Therefore, there was a mean GFR range (118~60) ml/min for the study patients [Table 1].

Discussion

To study the variation of kidney counts, uptake and Glomerular filtration rate with renal split function, 27 patient's renogram data were taken. The renal split function were linearly influenced by kidney counts (CPM), uptake (%) of ^{99m}Tc -DTPA and glomerular filtration rate (GFR). The Split function versus kidney counts curves for left and right kidney are shown in Fig. 1 and Fig. 2 using Table 1. From those curve we found that the kidney counts (cpm) were increased with increasing of split function but in case of special kidney disease the kidney counts might be very low.

The split function versus uptake curve for left and right kidney are shown in Fig. 3 and Fig. 4 using Table 1. From those curve we found that the uptake (%) were linearly increased with increasing of split function. The split function versus glomerular filtration rate (GFR) curve for left and right kidney are shown in Fig. 5 and Fig. 6 using Table 1. From those curve we found that the GFR was linearly increased with increasing of split function. But from the Fig. 7, we found that the GFR was decreased with increasing patient age.

Glomerular filtration rate is usually calculated using a mathematical formula that compares a person's size, age, sex, and race to serum creatinine levels. In most healthy people, the normal GFR is 90 mL/min/1.73 m² or higher. A result of 60–89 mL/min/1.73 m² without kidney damage may be normal in some people (such as the elderly, infants). A GFR under 60 mL/min/1.73 m² may mean kidney disease—the lower the GFR number, the worse the kidney function. This number is an estimated. It may not be a good measure of kidney health in some people, such as the very young or very old, amputees, or obese people [34].

The level of GFR and its magnitude of changeover time are vital to the detection of kidney disease, and understanding its severity and making decisions about diagnosis, prognosis, and treatment Normal GFR varies according to age, sex, and body size; in young adults it is approximately 120-130 mL /min/1.73 m² and declines with age. A decrease in GFR precedes the onset of kidney failure; therefore, a persistently reduced GFR is a specific diagnostic criterion for chronic kidney disease (CKD). Below 60 mL /min/1.73 m², the prevalence of complications of CKD increases, as does the risk of cardiovascular disease (CVD) [35].

From the Table 1 we found that the ratio between GFR and split function for left kidney is approximately equal to the ratio between GFR and split function for right kidney for every patient. Again From the Table 1, we found that the ratio between uptake and split function for left kidney is approximately equal to the ratio between uptake and split function for right kidney for every patient and the value of this ratio is approximately equal to the 0.1. The cumulative frequency of the patients are linearly increased by the uptake (%) of radiotracer ^{99m}Tc (Fig.8.11). The glomerular filtration rate (GFR) was linearly increased with renal split function but decreased with patient's age. Majority patients had received (3-6)% ^{99m}Tc -DTPA for left kidney but (0-6)% uptake ^{99m}Tc -DTPA for right kidney in this research. On the other hand, majority patient had been investigated (20-30) GFR (ml/min) for left kidney but (40-50) GFR (ml/min) was evaluated for right kidney. Therefore, majority patient were affected in cardiovascular disease (CVD).

Conclusions

Glomerular filtration rate (GFR) was affected by kidney counts (CPM), ^{99m}Tc -DTPA uptake (%) and the renal split function. The GFR was linear relationship with renal split functions but linearly decreased with patient's age. For majority patients, the calculated value of GFR were (20-30) (ml/min) and (40-50) (ml/min) in left and right kidney respectively. Therefore, majority patient were affected in cardiovascular disease (CVD). In future from this research, a doctor or a medical physicists will be able to identify that the renal function of a patient is damage or good.

Conflict of interest The author declares that he has no conflict of interest.

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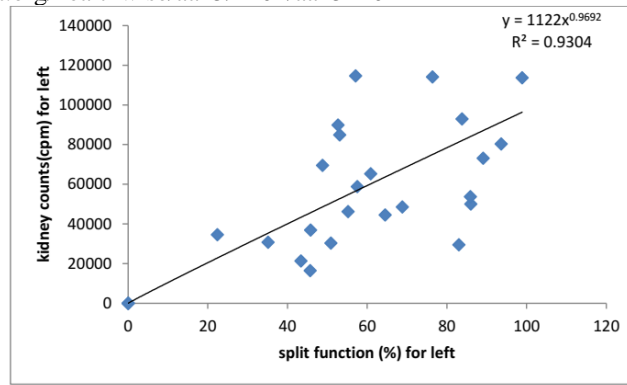


Fig. 1 Split function versus Kidney counts curve(for left kidney scan)

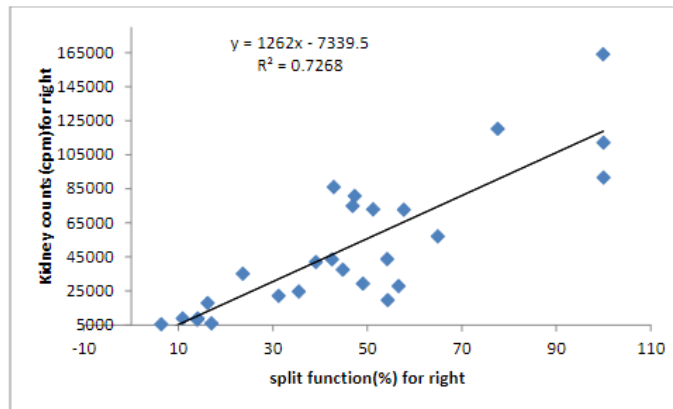


Fig. 2 Split function versus Kidney counts curve(for right kidney scan)

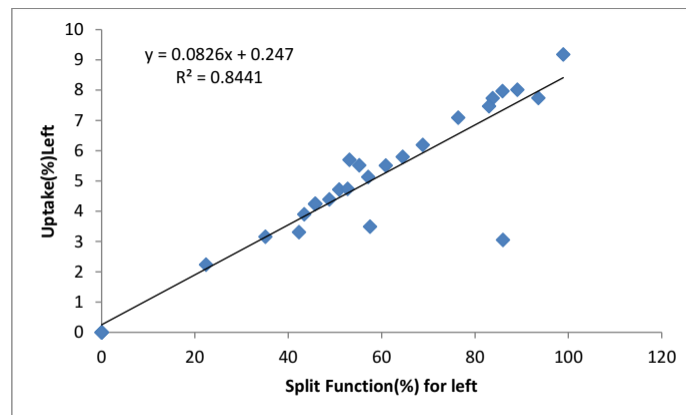


Fig. 3 Split function versus uptake curve(for left kidney scan)

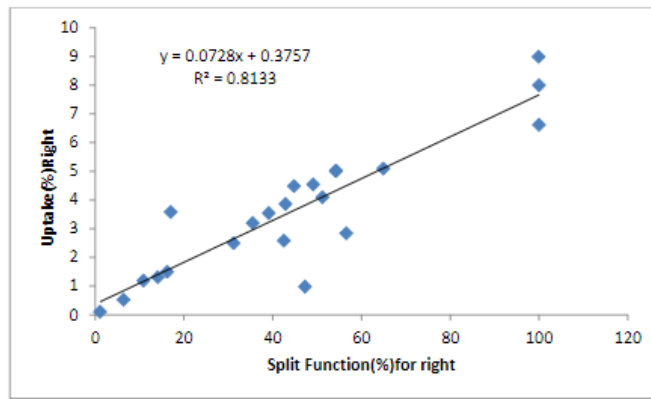


Fig. 4 Split function versus uptake curve(for right kidney scan)

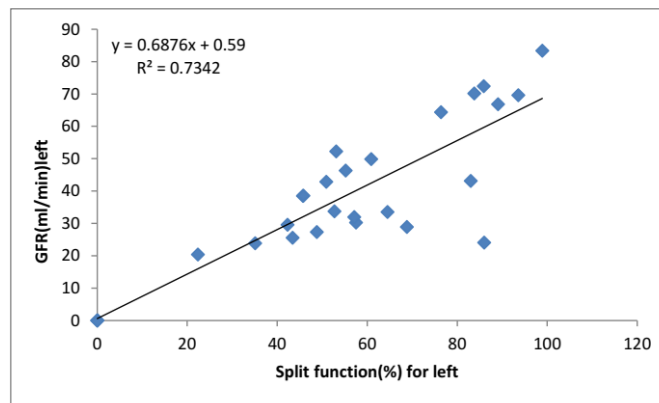


Fig. 5 Split function versus GFR curve(for left kidney scan)

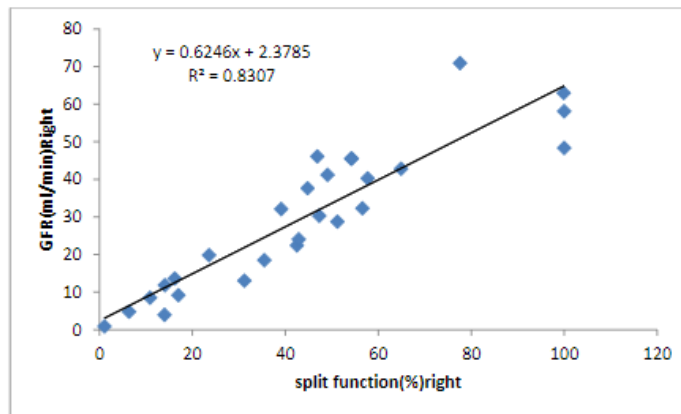


Fig. 6 Split function versus GFR curve(for right kidney scan)

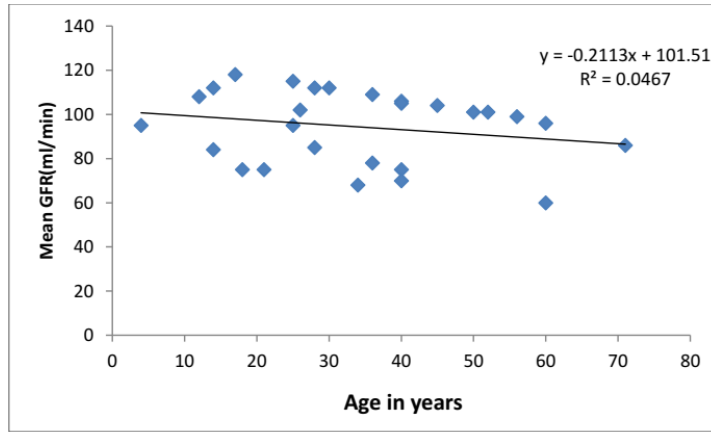


Fig. 7 Age versus mean GFR curve(for kidney scan)

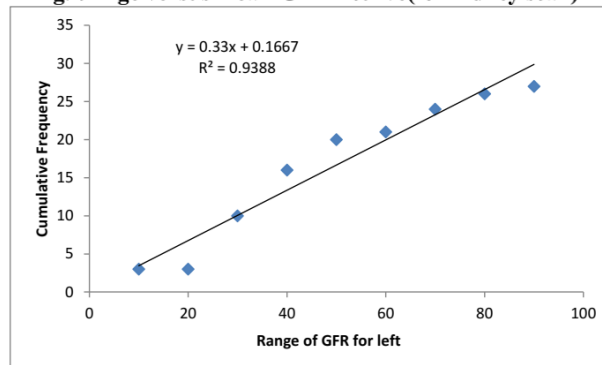


Fig. 8 Range of GFR versus cumulative frequency curve(for left kidney scan)

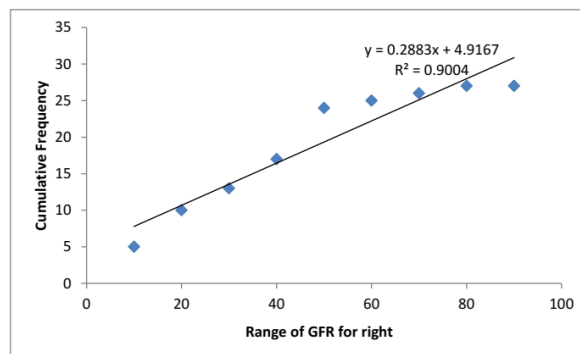


Fig. 9 Range of GFR versus cumulative frequency curve(for right kidney scan)

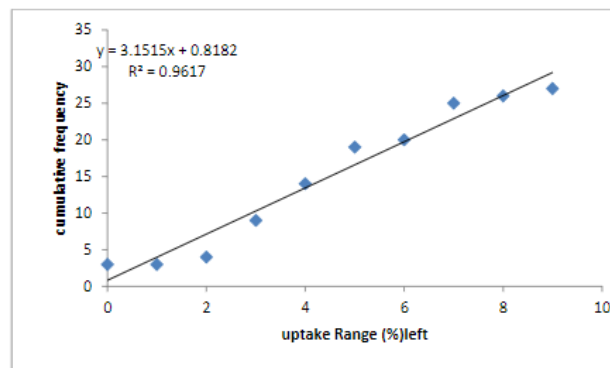


Fig. 10 Uptake range versus cumulative frequency curve(for left kidney scan)

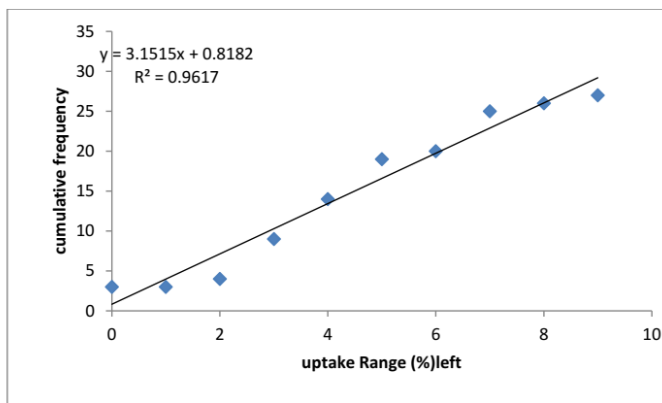


Fig. 10 Uptake range versus cumulative frequency curve(for left kidney scan)

Table 1 Split function and Glumerolur filtration rate (GFR) measured by Gamma camera due to administration of ^{99m}Tc –DTPA for left and right kidney

Age	Split function(%)left	Split function(%)right	Kidney Counts(cpm)Left	Kidney Counts (cpm)Right	Uptake(%) Left	Uptake(%) Right	GFR(ml/min)left	GFR (ml/min) Right	Ratio between GFR And split func. (for left kidney)	Ratio between GFR and split func. (for right kidney)	Ratio between uptake and split function (for left kidney)	Ratio between uptake and split function (for right kidney)
7	22.4	77.6	34625	120246	2.236	7.765	20.4	70.9	0.911	0.913	0.099	0.100
40	42.3	57.7	533655	72706	3.311	4.511	29.6	40.3	0.699	0.698	0.078	0.078
30	76.4	23.6	114139	35164	7.092	2.185	64.4	19.8	0.842	0.838	0.092	0.093
17	53.1	46.9	84970	74904	5.700	5.025	52.3	46.1	0.985	0.983	0.107	0.107
50	86	14	50122	8176.9	3.057	0.499	24.1	3.937	0.280	0.281	0.035	0.035
25	0.039	100	36	91590	0.003	6.612	0.023	58.1	0.590	0.581	0.077	0.066
45	93.6	6.377	80413	5477.4	7.747	0.528	69.6	4.743	0.744	0.744	0.082	0.082
52	60.9	39.1	65306	42009	5.512	3.546	49.9	32.1	0.820	0.820	0.090	0.091
36	83.8	16.2	92941	17958	7.736	1.495	70.2	13.6	0.838	0.839	0.092	0.092
56	57.5	42.5	58899	43556	3.491	2.582	30.3	22.4	0.527	0.527	0.061	0.061
14	50.9	49.1	30425	29346	4.72	4.54	42.9	41.19	0.843	0.840	0.092	0.092
12	45.7	54.3	16537	19637	4.24	5.02	38.52	45.55	0.843	0.841	0.092	0.092
26	45.8	54.2	36989	43777	4.252	5.01	38.6	45.47	0.843	0.841	0.093	0.092
40	98.9	1.069	113680	1228.4	9.18	0.099	83.36	0.897	0.842	0.839	0.092	0.092
60	85.9	14.1	53830	8860.1	7.97	1.31	72.4	11.82	0.843	0.838	0.093	0.093
4	55.2	44.8	46253	37501	5.52	4.48	46.37	37.63	0.840	0.840	0.1	0.1
71	64.5	35.5	44621	24608	5.805	3.195	33.54	18.46	0.520	0.521	0.090	0.090
14	0.063	99.9	98.8	16110	0.00567	8.991	0.04	62.93	0.635	0.630	0.090	0.090
21	57.1	42.9	114729	86116	5.139	3.861	31.98	24.03	0.560	0.560	0.090	0.090
60	68.8	31.2	48638	22083	6.192	2.496	28.9	13.04	0.420	0.417	0.090	0.080
40	48.8	51.2	69610	72963	4.392	4.096	27.33	28.7	0.560	0.561	0.090	0.080
40	83	17	29548	6038	7.47	3.584	43.16	9.18	0.520	0.540	0.090	0.085
28	89.1	10.9	73202	8948	8.019	1.19	66.825	8.502	0.750	0.740	0.090	0.109
25	52.7	47.3	89863	80810	4.743	0.981	33.728	30.27	0.640	0.639	0.090	0.090
18	43.4	56.6	21386	27892	3.906	2.838	25.61	32.26	0.590	0.570	0.090	0.089
34	0.006	100	7	112197	0.00054	8	0.0042	72.3	0.700	0.723	0.090	0.080
36	35.1	64.9	30826	57039	3.159	5.093	23.87	42.83	0.680	0.670	0.090	0.080