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Evaluation of Glomerular Filtration Rate using ^{99m}Tc-DTPA Renal Scintigraphy

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Abstract: ***The evaluation of glomerular filtration rate GFR by using renal Scintigraphy with enhancement of gamma camera system using 99mTc-DTPA (185MBq) has been carried out among 149 patients of multi renal diseases and 48 as a control group with age between 20-80 year. The collected data was the age versus GFR, weight versus GFR, height versus GFR and the normal GFR, in addition to the general distribution of the sample based on the gender. Regarding GFR, the study reveals that: the predominant mean of GFR was 82.5 ml/min among the age group of 20-30 years old and the maximum GFR was 85.2 ml/min among the age group of 30-40 years old. The researchers also found that the relationship between the age and GFR is an inverse relationship demonstrated by the following equation ( ), The results also reveal that the maximum mean of GFR is 86 ml/min, which is found among the weight group of 90-100 Kg, while the minimum GFR which is 81.5 ml/min was among the weight group of 40-50 Kg, indicating that the GFR increases as the weight increase. And the normal GFR among the Sudanese people in the range of 84 – 85.9 ml/min, the study also shows that the common people encountered at hospitals complaining of renal problems were having the weight between 40-70 Kg. The analysis of the study also reveals that the height has a poor relationship with GFR that could be demonstrated in a form of the following equation. The ultimate goal of the study is that the normal GFR which has been determine by gamma camera method is 85.5+/-14.2 ml\min with an accuracy equal to 85.5% showing some advantages such as simple achieved accuracy, less time consuming, low radiation hazards, simplicity and non-invasive method relative to Single Injection Two Plasma methods SITPM which determined by Jacobson in 1985 with an accuracy equal to 84.75+/-16.63 ml/min.***

Keywords: GFR, ^{99mTc}-DTPA, Gamma Camera

1. Introduction

Glomerular filtration rate GFR is widely regarded as one of the best methods for determining the renal function with reference to the normal one (Males: 70 ± 14 mL/min/m2 - Females: 60 ± 10 mL/min/m2) (8). The accurate measurement of the Glomerular filtration rate is therefore considered as an important parameter in diagnosing the kidney function and as an early alarming for renal disease and malfunction (12). Also could be used for evaluating the effect of different therapies, adjusting the doses of various drugs and ensuring that the potential kidney donors have normal renal function (4) and (7). The Radionuclide evaluation of renal function dated back to 1950. Early studies with radiotracer and external probe deckle system that produce no image but only a time activity histogram showing uptake and execration of renal radiopharmaceutical (2). The imaging with a gamma camera and computer system are introduced (1950) and the renal function can be evaluated. For selective organ imaging several radiopharmaceuticals are available now days as well as for renal study as invivo and invitro, from which valuable information about the renal morphology and physiology such as Glomerular filtration rate can be conveniently obtained in anon invasive manner. The GFR calculation can be carried out from the rate of clearance of tracer activity from the plasma following a single injection of a suitable radiopharmaceutical as long the radiopharmaceutical is excreted slowly by Glomerular filtration and not bound to plasma protein or to any other component of blood or other tissue. GFR can be calculated simply by dividing the administered dose by integral of plasma time activity curve (13). Another method have been proposed in which the Glomerular filtration rate estimated from only one or two plasma sample. These have all based on Tc99m di-ethylene-tri-amine-pent-acetic acid (DTPA) the work of Jacobsson (9). There is a problem of Tc99m (DTPA) for quantitative measurement, because of variable degree of protein, 1985 and revised accepted in Aug. 2, 1985 by Charlos D (6), Nuclear Medicine University in Alabama. That problem was not addressed by Jacobsson. In present study we employ Tc99m DTPA with explicit measurement and correction for protein binding and simultaneous use of yttrium 169. Determining Glomerular membranes integrity is a prime in the assessment of the kidney function. The measurement of Glomerular filtration is based on renal clearance which fundamental to the diagnosis of the renal Glomerular pathology for measurement of drug therapy and in chronic renal failure. The use of radionuclide in clearance studies has simplified the evolution of renal function particularly GFR in man and animals (11). The ease with which gamma emitting radio nuclides can be quantified has led to the frequent use of radionuclide for clearance studies in clinical practice. Application of radionuclide procedure has proved to be effective and evolutions of real disorders.

2. Materials and Method

This was a prospective study carried out in nuclear medicine department, Radiation and Isotopes Center of Khartoum (RICK), the study include 197patients whom attend to the department for routine renal dynamic scan. Both males and females included with different ages (20-80) year.

Radionuclide GFR value obtained by using gamma camera involve all 197 subjects male to female ratio and ages between. The samples include patients of renal diseases and control group of healthy persons. All patients had previously undergone clinical staging by physical examination. Primary data collected from patient files, and their dynamic radionuclide renal scan with Tc99m-DTPA on certain period of time. All subjects well hydrated, 0.5-1 liter of water 30 mint before the study. Their weight and height will measure for the kidney depth measure normalized GFR. And void bladder prior the imaging in gamma camera based method. Planer Gamma Camera model (Nucline spirit (DHV) variable angle dual head SPECT and whole body DH -503066-VO) acquisition parameter acquired for renal dynamic study which includes: - Low energy general purpose collimator, and - Full and empty syringes are counted under the camera before and after the acquisition to measure the net dose injected to the patients after subtracted the value of empty springs from the value of full syringe. The obtained GFR was from an injection of the sample and control group by Tc-^{99m}Tc-DTPA as 185MBq (5mci). After the preparation of the dose, subject directed to void prior the study acquisition. Then they line down over the camera in supine position on the examination table, the kidney area center in the camera field of view center , subject instruct to keep non movement during acquisition time . Dynamic study requires that radiopharmaceutical to inject as bolus and the dose deliver in as small volume as possible. The acquisition starts immediately at time of injection. After the predetermine time is finish, the data which are collect process for the GFR calculation. When drawing region of interest over the kidneys, subsequent summed frames that display in the screen simultaneously during processing observe for motion correction.

Kidney region: the kidney area of interest exactly outlines. Pelvic, ureters are avoiding interest draw just under the lower pole of the kidney, ureters area carried. The clinical program includes gate method for clearance (GFR) calculation based on gamma camera image sequence, without plasma sample apply. The posterior view image of the kidneys summed during the third minute after injection is use. Region of interest are drown around each kidney and common background area.

After a background subtraction the kidney activity are correct for attenuation using Tennesseans formula for the kidney depth correction. Present uptake of the injection dose is calculated in each kidney, after correction for radioactive decay. Experimental formula is use to estimate the clearance from the fractional uptake.

3. Results and Discussion

A total of 149 patients were considered as the sample of the study out of 197 total study sample. The ratio of male to female was 85/64 respectively. Their age rang was 20-90 years old, while the control group consists of 48 persons with male to female ratio of 29/19.

The results in Figure (1) reveal that the predominant mean of GFR is 82.5 ml/min were among the age group of 20-30 years old, while the maximum GFR 85.2 ml/min was found among the age group of 30-40 years old, After the age of 30, glomerular filtration and renal blood flow rates decline in a linear fashion, so that values in octogenarian are only half to two thirds those measured in young adults (Sharon, 1985). While the minimum GFR 76.8 ml/min was for the age group of 40-50 years old this due to the declining of GFR by ageing. However the following results in Figure (2) showed the relationship between age and GFR which has reversible relation and could be demonstrated by the following equation , where y refer to GFR in ml/min and x refer to age in years. Decreased GFR in the elderly is dependent predictor of adverse outcomes, such as death and cardiovascular disease CVD. Also among elderly people, decreased GFR requires adjustment in drug dosages, as in patients with chronic kidney disease CKD (5).

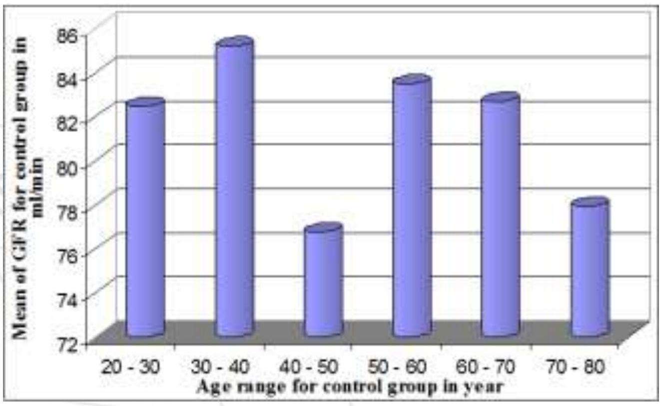

Figure 1: illustrate the relationship between the ages of the control group and mean of GFR investigated by gamma camera method during the year 2009 in (RICK).

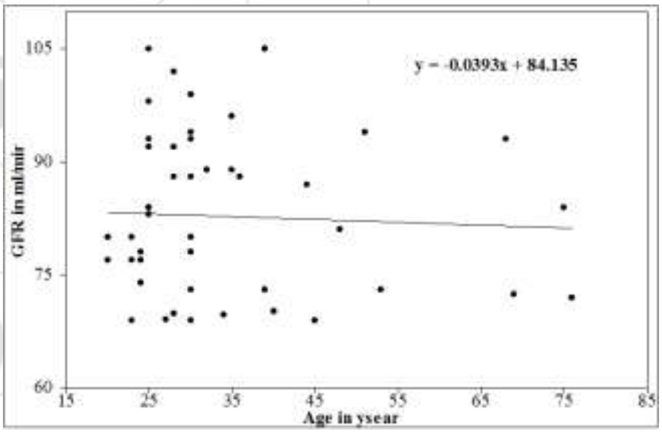

Figure 2: shows the relationship between the GFR and Age among the control group

From table 1 and Figure 3 the data shows the weight of control group versus the mean of GFR. The results reveal that the maximum mean of GFR is ml/min, which is found among the weight group of 90-100 Kg, while the minimum GFR which is 81.5 ml/min was among the weight group of 40-50 Kg , indicating that the GFR increases as the weight increase, which assume to be due to an increment of arterial pressure among the obese and over weighted people, this fact was approved by Must et al, (14); and Adelman et al, (1), they stated that: as the weight increased will leads to increment of systemic arterial pressure, high renal plasma flow, increased GFR which in turn leads to elevate trans-capillary hydro-static pressure gradient, resulting in hyper filtration, these physiologic abnormalities could cause nephritic syndrome and renal failure or glumerulo-megaly that lead to glomerular damage. The researchers also found the predominant mean of GFR was 84.0 and 85.9 ml/min among the weight group of 50-60 and 60-70 Kg respectively, indicating that the normal GFR among the Sudanese people in the range of 84 – 85.9 ml/min which fall in the range of standard GFR stated by Jacobsson et al, (9) in which they found that the normal mean GFR was ml/min.

The researchers deduce that there is a relationship between the weight and GFR which has been shown in Figure (5.6). The relationship between weight and GFR has shown a linear proportional relationship which could be demonstrated by equation, where x refer to weight in Kg and y refer to GFR in ml/min.

Table 1: shows the relationship between the GFR and Age among the control group

Weight for control group in Kg	frequency	Percentage	Mean GFR ml/min
40 – 50	11	22.91	81.5
50 – 60	13	27.08	85
60 - 70	13	27.08	85
70 - 80	5	10.41	85.6
80 - 90	5	10.41	85.8
90 - 100	1	2.08	86
Total	48	100	

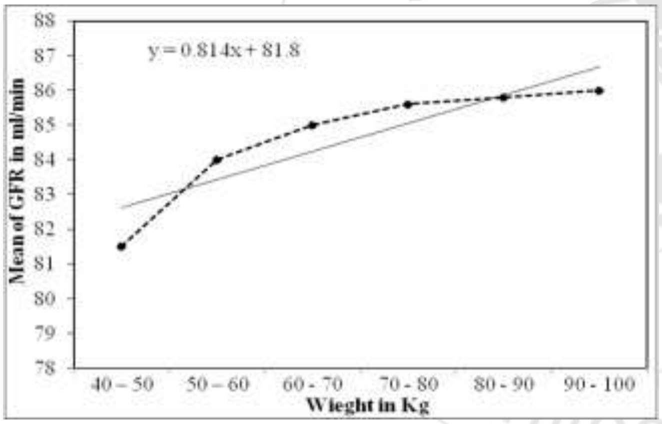

Figure 3 shows the relationship between weight and GFR among the control group

Out of the control group sample, the weight group of 50-60 and 60-70 Kg represented the predominant members among the sample and the weight group range of 40-50 Kg comes in the second order. This result indicating that the common people encountered at hospitals were having the weight between 40-70 Kg.

Table 2 showed the height of control group and their mean of GFR. Out of this table, only the height groups of 155-160, 165-170 and 185-190 cm show high GFR at 89.7, 89.6 and 89.0 ml\min respectively, while the others height groups appear as random scattered data with no relationship to height, this study is in agreement with Jamie et al, (10). However the GFR for children has a relationship with height and could be represented by Schwartz formula, (15).

Where k is a constant that depends on muscle mass, which itself varies with a child's age. In first year of life, for pre-term babies K= 0.33 (3) and for full-term infants K= 0.45 (16). For infants between ages of 1 and 12 years, K= 0.55 (15).

The relationship between GFR and height although it is so poor, however the plotting in a form of scattering correlation point shows that there is relationship which could be demonstrated by the following equation:
where y refers to GFR and x refers to height as shown in Figure (4).

The height of the control group and their frequency percent, this result shows that the predominant height among the sample was 170-175 cm tall, indicating that the majority of Sudanese people tall fluctuating in the range of 170 to 175 cm.

Table 2 shows the height of the control group, frequency, percentage and their mean GFR.

Height for control group in cm	Frequency	Percentage (%)	Mean GFR ml/min
150 - 155	1	2.083	88
155 - 160	4	8.33	89.7
160 - 165	6	12.5	80.11
165 - 170	3	6.25	89.6
170 - 175	22	45.83	82.8
175 - 180	8	16.6	75.6
180 - 185	3	6.25	87
185 - 190	1	2.083	89

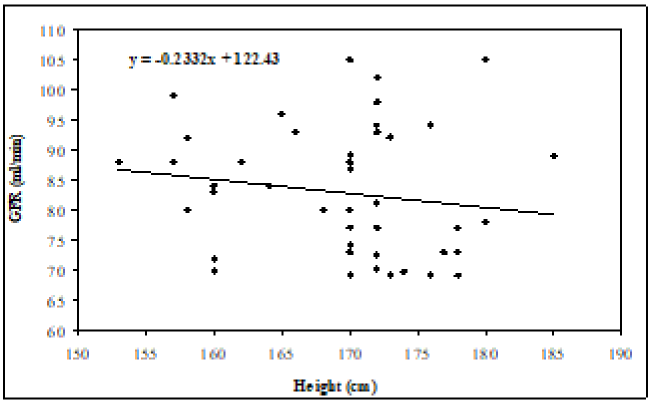

Figure 4 shows the relationship of GFR and height for the control group.

Table 3 showed the GFR for the control group and their mean of GFR in percentage. From the plotted graphs in Figure (5) reveal that the predominant GFR among the group was 70-80 and 80-90 ml\min with a frequency of 29.66% for both respectively, while the maximum mean GFR for the group was 104 ml\min. Also the study shows that the normal GFR being determine by gamma camera method is 85.5 ml\min. this results is so more acceptable and considered as more accurate relative to the SITPM which determined by Jacobson, (9) which was ml/min. From this result the accuracy of the gamma camera could be calculated from the following equation:
Where GC refer to gamma camera results.

From the above equation, gamma camera accuracy will be as follows:

Generally the determination of GFR using gamma camera method could be used instead of single injection two plasma methods (SITPM) for the achieved accuracy, less time consuming, low radiation hazards, simplicity and non-invasive method.

Table 3: Shows the GFR of control group, frequency, percentage and their mean GFR.

GFR of control group in ml/min	Frequency	Percentage (%)	Mean GFR ml/min
60 – 70	7	14.58	69.22
70 – 80	14	29.166	74.6
80 – 90	14	29.166	84.9
90 – 100	10	20.83	94.4
100 – 110	3	6.25	104

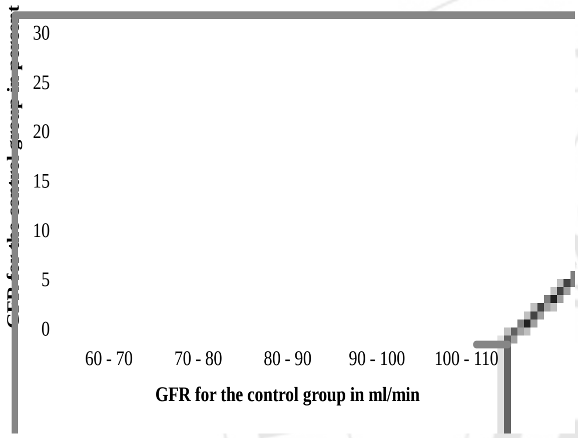

Figure 5: Shows the GFR of the control group and their frequency percentage.

The researchers also studied the GFR for multiple renal diseases patients versus the different same parameters as for control group. In this group the male represent 57.04% relative to female we assumed that the increase number of renal disease patients could be due to male habits such as smoking and alcohol.

The result reveal that the predominant mean of GFR is 36.9 ml/min among the sample, while age group of 20-30, 30-40 and 40-50 year old they show high GFR at 43.7, 43.28 and 43.3 ml/min respectively and the rest ages group showed decreasing stepwise in GFR to be ended at the minimum GFR 33.4 ml/min, such phenomena is due to effect of aging (17). Generally the results shows that the GFR fluctuating as high in the range of 40s ml/min then decrease with the age increment.

Table 4 shows the age of the patient with multiple renal diseases, frequencies, percentage and their mean of GFR.

Patient age	frequency	Percentage (%)	Mean GFR
20 - 30	30	20.134	43.71
30 - 40	31	20.805	43.28
40 - 50	26	17.449	43.3
50 - 60	32	21.476	36.9
60 - 70	18	12.080	33.4
70 - 80	11	7.382	34.6
80 - 90	1	0.671	36

The result reveals that the maximum mean of GFR is 64.8 ml/min, which is found among the weight group of 110-120 Kg. Generally the data showed that as the weight increase the GFR increases and the typical equation that expresses such relationship is that: GFR=3.14w+25.1 ,
where (w) refer to weight of the patient. In this realm Must et al, (14); and Adelman et al, (1) stated that: as the increment of weight leads to increment of systemic arterial pressure, high renal plasma flow, increased GFR which in turn leads to elevate trans-capillary hydro-static pressure gradient resulting in hyper filtration, these physiologic abnormalities cause nephritic syndrome and renal failure or glumerulo-megaly that lead to glomerular damage.

The data also showed that the predominant mean of GFR was 43.2 ml/min among the weight group of 50-60 Kg.

Table 5 showed the height of patient in Kg with multiple renal diseases and their mean of GFR. Out of this table, only the height group of 180-185 cm shows high GFR at 92.84 ml/min this could be expressed due to gravity and the general relationship between height and the GFR could be expressed by the following equation: where h refer to the height of the patient. This equation reveals the proportional relationship between the height and GFR as shown in Figure 5.20, 5.21 and 5.22. This study is in agreement with the study carried out by Jamie et al, (10) in addition to such agreement also they found that the GFR for children has a relationship with height and they represented it by Schwartz formula (15):

Where k is a constant that depends on muscle mass, which itself varies with a child's age. In first year of life for pre-term babies K= 0.33 (3), for full-term infants K= 0.45 (16) and for infants between ages of 1 and 12 years K= 0.55 (15).

Table 5 shows height of the patients with, frequency, percentage and their mean of GFR

Patient Height	Frequency	Percentage (%)	Mean GFR
140 - 145	1	0.7	30
145 - 150	2	1.34	28.5
150 - 155	9	6.04	39.71
155 - 160	12	8.05	34.29
160 - 165	20	13.42	34.7
165 - 170	22	14.76	50.25
170 - 175	57	38.25	34.18
175 - 180	19	12.75	35.57
180 - 185	5	3.35	92.84
185 - 190	2	1.34	49.3
Total	149	100%	-

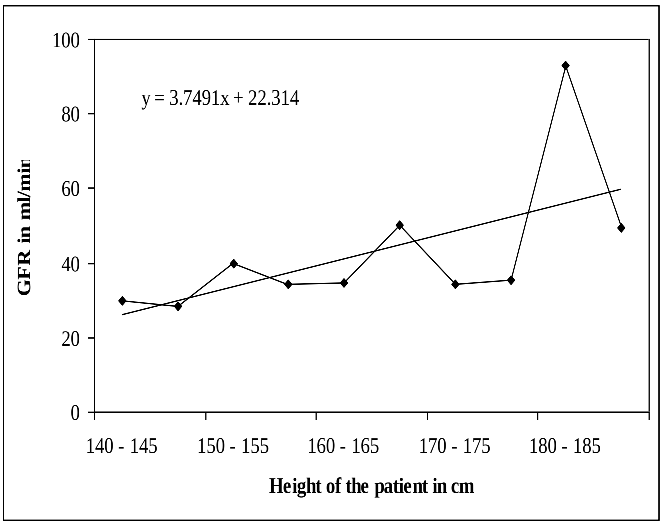

Figure 6 illustrate the relations between the height of the patients and mean GFR investigated by gamma camera during the study in (RICK).

Such results reveal that the predominant GFR among the group was 05-30.5 ml\min with a 44.29%; while the maximum mean GFR for the group was 279.2 ml\min. GFR can be increases due to hypo-proteinemia because of the reduction in plasma oncotic pressure and also could be increased due to constriction of the efferent arteriole, while the minimum GFR was 14.6 ml/min among the group of 0.5-30.5 ml/min this was due to constriction of the afferent arteriole these findings has been shown in Figures 5.23, 5.24 and 5.25. Non-steroidal anti-inflammatory drugs (NSAIDs) could prevent the production of prostaglandins, molecules which dilate the afferent arteriole. NSAIDs could therefore worsen kidney function by decreasing afferent blood flow to the Bowman's capsule (16).

4. Conclusion

From perusing the results and findings of this research we can conclude that the gamma camera method can be used instead of creatinine clearance and SITPSM to assess the GFR. • Gamma camera method could be used successfully to determine GFR. And • Determination of renal failure could be carried out by using gamma camera method depending on GFR.

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