Effect of the site of background region of interest on renogram results

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Abstract In studying kidneys uptake, perfusion and excretion of tracer following intravenous injection during the imaging process by gamma camera, a frame is recorded each 15sec. for 19 minutes (76 frames) which form the renogram. In the renogram, kidneys, bladder and appropriate blood background area can be defined as regions of interest to derive the time-activity curves. Time activity curves are normalized to correct the number of pixels in kidney and background areas of interest. The contribution from uptake in tissues over and underlying the kidney form unwanted background that should be removed prior to accurate estimation of relative renal uptake. Each kidney's normalized background time activity curve is then subtracted from the corresponding normalized kidney time activity curve. This procedure has been applied to the renograms of 100 cases who examined in urology and nephrology center (80 patients suffering from renal disorders, and 20 donors for renal transplantation) to study The effect of changing the site of background region of interest on renogram results. The 80 patients suffering from renal disorders are divided into two groups. In the first 40 patients group, the background was drawn manually and automatically. By comparing the two techniques, it is found that the values of physical parameters ($T_{1/2}$, contribution% and GFR) in manual method are better than in the automatic method. The 20 donors are divided into two groups.The same steps have been applied to first 10 donors group which also showed that the manual method is better than automatic method.In the second 40 patients group, the background was manually drawn near and far from ROI. By comparing the two sites, it is found that the far sites (areas of less activity) is better than the near sites. The same steps have been applied to the second 10 donors which also showed that the far sites is better than the near sites. In conclusion, the manual method is better than the automatic method. The best site for background ROI is perirenal far site.

Index Terms— background region of interest, renogram results, renogram processing.

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1 Introduction

The first step in any nuclear medicine diagnostic imaging study involves the administration of a radiopharmaceutical to a patient [1]. A radiopharmaceutical is a chemical combination of a radionuclide and a pharmaceutical. A radionuclide is an unstable isotope of an element which emits radiation to achieve stability. If this radiation is in the form of gamma rays, it can be detected by a nuclear medicine gamma camera [2]. The radiopharmaceutical is injected intravenously and frame are collected at 15-s intervals for 19 min to form frames (images) which can be displayed on the screen [3]. A sequence of gamma camera images which follow the passage of a radiotracer through the kidneys constitutes a renogram [4].The kidneys, the bladder and appropriate blood background area can be defined as regions of interest to derive time-activity curves [5]. since ^{99m}Tc-DTPA is diffusible and not significantly protein bound in plasma, it rapidly enters the extravascular space following injection [6].therefore, the curve derived from a kidney region of interest (i.e. the raw renogram) contains a "background" contribution from uptake in tissues over and underlying the kidney that should be removed prior to estimation of relative renal uptake or function [7].

The background curve is used to subtract a background contribution from each kidney curve. The resulting curve is the renogram [8] with the glomular filtration rate (GFR) of each kidney, split function (differential GFR), t_{peak} (time from injection to time of maximum count rate), and $T_{1/2}$ (the half emptying time) were obtained [9].

For consistency of display, it is helpful to scale each kidney curve to percent of administered activity [8].
The normal renogram curve (Fig. 1a) shows three distinct phases: (1) the initial rapid rise as tracer is delivered to the kidney, (2) a peak region during cortical transit of tracer (60 seconds to appearance of pelvicaliceal activity), and (3) a prompt decline in activity as tracer is excreted into the collecting system. In the setting of obstruction or impaired renal function, the curve plateaus in the third phase of the renogram will appear as in (Fig. 1b), where it will continues to rise, or only slowly falls [10].
The purpose of this work is to study the effect of site of background region of interest (ROI) on renogram results by choosing the site of background ROI wheter it is near or far from the kidney in case of manually or automatically chosen background ROI.

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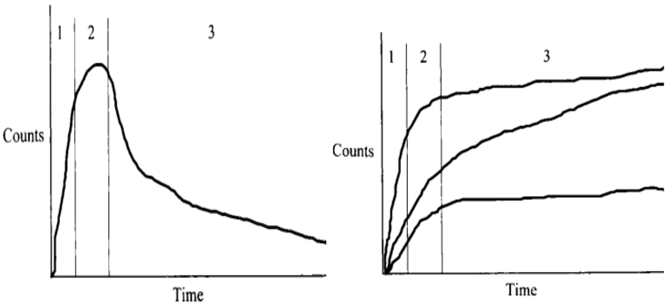


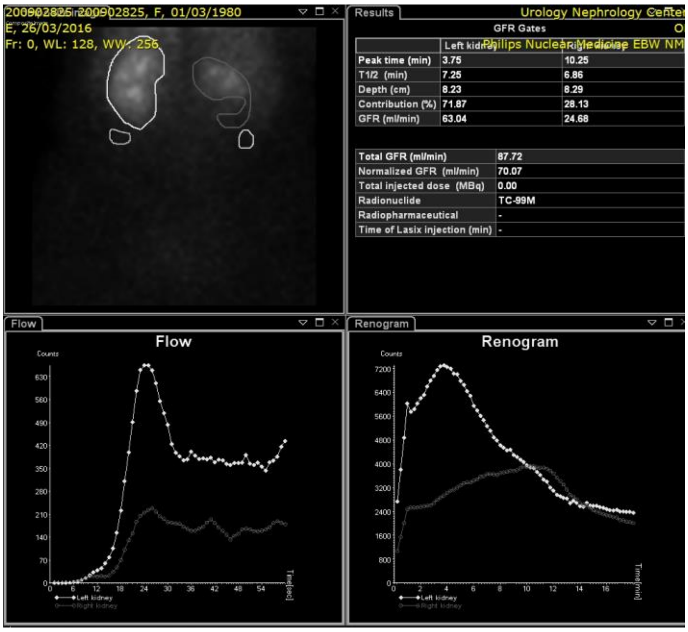
(a) (b)

Figure (1): Stylized time-activity curves. a, Normal curve showing the three renogram phases: 1=perfusion phase; 2= cortical transit phase; 3= excretion/clearance phase. b, Abnormal curves. These curves are typical for obstructive or nonobstructive dilatation with accumulation of tracer in the collecting system. Impaired renal function with cortical retention of tracer can produce a similar appearance, although the peak parenchymal activity will be lower than normal (bottom curve).

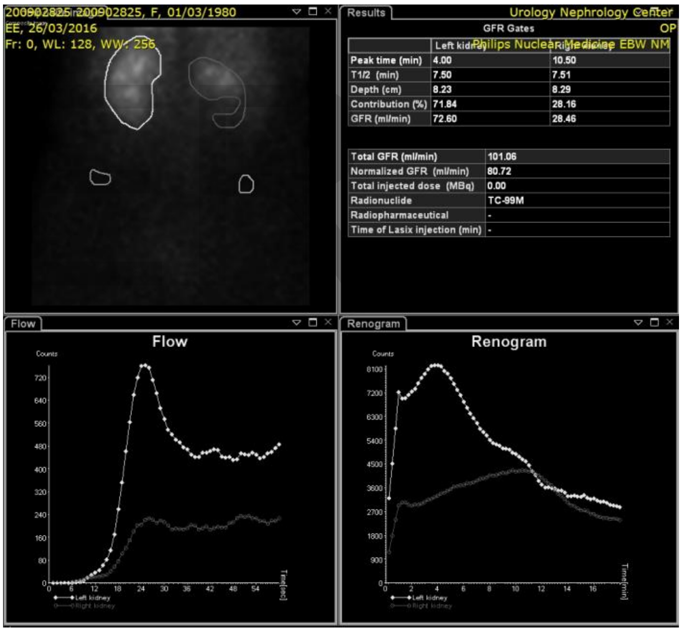
2 Subjects and Methods

In this study 80 patients suffering from renal disorders, and 20 normal cases (donors for renal transplantation) have been selected. All cases were examined in gamma camera unit at urology and nephrology center. The patients were hydrated with approximately 1-2 Liter of water 30 minutes before tracer injection. Voiding the bladder before data acquisition is important because a full bladder may affect the drainage of the pelvicalyceal system. The patient is placed in in a supine position and the camera is placed posterior to the patient under the imaging table. The prepared radiopharmaceutical, 3-5 mCi; (^{99m}Tc-DTPA), was injected intravenously. Counts of pre-injection and post-injection syringes were measured for 1minute at 30 cm from the Gamma-Camera to determine the net amounts of activity injected. A 20 % of energy of the photopeak window is centered at 140KeV for computer data acquisition. A 64 × 64 pixel matrix is used at 2 sec. /frame for one minute (30 frames /min) & 15 sec. /frame for 19 minutes (76 frames).

The appropriate areas of interest and the background areas of interest are defined for each kidney. Time activity curve is created for each area of interest over the duration of the study. Time activity curves are normalized to correct the numbers of pixels in kidney and background areas of interest. Each kidney's normalized background time activity curve is then subtracted from the corresponding normalized kidney time activity curve as illustrated in (fig. 2) & (fig. 3).

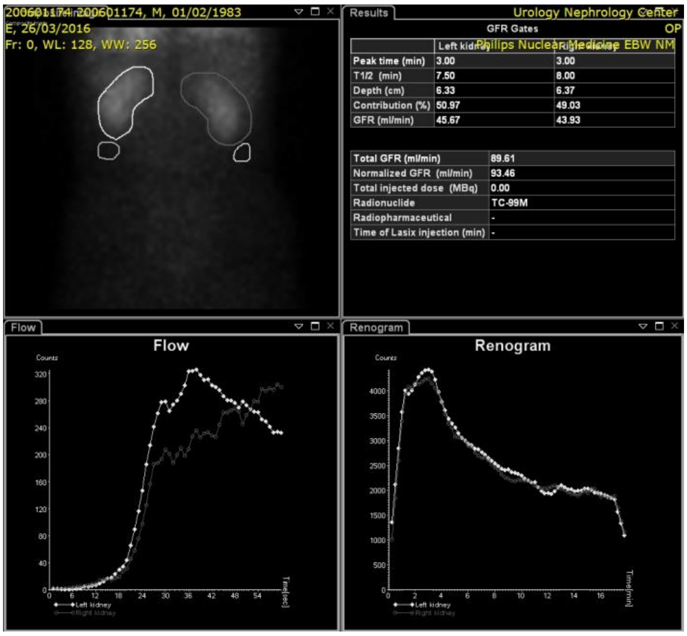


(a)

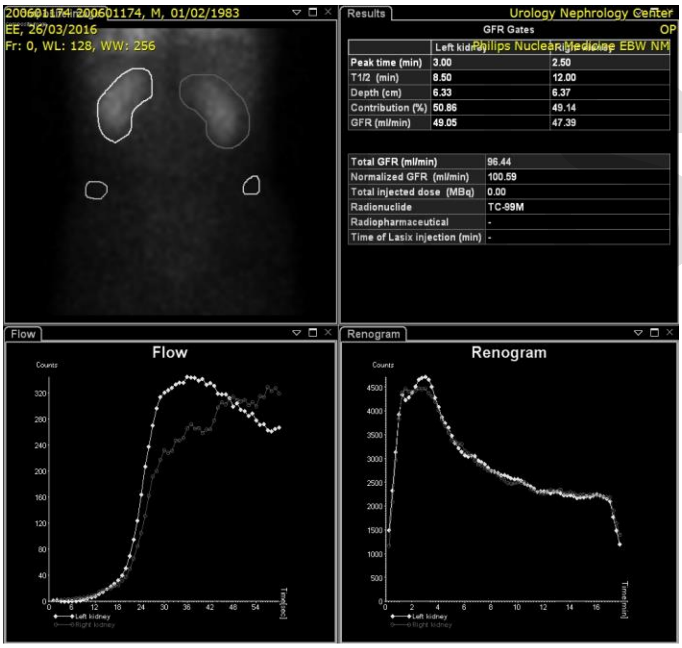


(b)

Figure (2): Regions of interest and background regions of interest near from the kidney (a) and far from the kidney (b) as defined during processing and the corresponding physical parameters and renogram curves obtained for a case with impaired kidney.



(a)



(b)

Figure (3): Regions of interest and background regions of interest near from the kidney (a) and far from the kidney (b) as defined during processing and the corresponding physical parameters and renogram curves obtained for a kidney donor case.

3 Results

The processing of the resulting images are done on the computer linked to gamma camera system for 80 patients suffering from different disorders in the kidney and 20 donors. In this study, the work has been on two groups, the first 50 cases group is divided into 40 patients suffering from different disorders in the kidney and 10 donors. During processing, an appropriate regions of interest are defined for each kidney and the background regions of interest are manually or automatically chosen for each kidney. Then, the corresponding physical parameters ($T_{1/2}$, contribution and GFR) have been obtained. By changing the site of background ROI (in case of manual and automatic) near and far from the kidney and recording the corresponding physical parameters. The data were statistically analyzed using the SPSS software (Statistical package for the social sciences).

The results of the mean and standard deviation of the physical parameters for each kidney of 40 patients in case of manual background near and far from the kidney were calculated and tabulated in table (1).

TABLE 1
The mean and standard deviation of the physical parameters for each kidney in case of manual background near and far from the kidney of 40 patients.

MANUAL PATIENTS (N=40)												
Statistics	Contribution (%)				GFR(ml/min)				$T_{1/2}$(min.)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Mean	46.63	46.75	53.37	53.25	32.81	36.89	37.71	42.23	16.8	16.29	31.52	31.77
Std. Deviation	17.66	16.83	17.66	16.83	21.99	23.68	26.14	27.68	21.43	14.05	85.72	85.58

The results of the mean and standard deviation of the physical parameters for each kidney of 40 patients in case of automatic background ROI near and far from each kidney were calculated and tabulated in table (2).

TABLE (2)
The mean and standard deviation of the physical parameters for each kidney in case of automatic background ROI near and far from each kidney of 40 patients.

AUTOMATIC PATIENTS (N=40)												
Statistics	Contribution (%)				GFR(ml/min)				(%)$T_{1/2}$(min.)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Mean	46.51	45.73	53.03	53.52	32.05	34.86	35.77	41.08	16.27	15.33	19.05	23.04
Std. Deviation	17.06	16.82	17.44	16.33	21.41	22.81	23.95	26.62	18.27	12.08	21.73	42.51

A comparison between the near sites of manual background ROI with the near sites of automatic background ROI in each physical parameters has been done through estimating the p values, as well as for the far sites. The results were tabulated in table (3).

TABLE (3)
P-values resulted from comparison of near sites in case of manual background ROI with the near sites of automatic background ROI as well as for the far sites.

P VALUE FOR PATIENTS (N=10)												
Statistics	Contribution (%)				GFR(ml/min)				$T_{1/2}$(min)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	far	near	Far	Near	Far	near	far	Near	far	near	far
P value	0	0	0.001	0	0.003	0.003	0	0	0.002	0	0.001	0

The p-values were less than 0.05 which mean that there is a significant differences between near background sites in manual and near background sites in automatic methods, as well as for far sites in assessment of physical parameters.

The same steps of processing have been done for the 10 donors. The data were statistically analyzed using the SPSS software.

The results of the mean and standard deviation of the physical parameters for each kidney of 10 donors in case of manual background near and far from the kidney were calculated and tabulated in table (4).

TABLE (4)
The mean and standard deviation of the physical parameters for each kidney in case of manual background ROI near and far from the kidney of 10 donors.

MANUAL DONORS (N=10)												
Statistics	Contribution (%)				GFR(ml/min)				$T_{1/2}$(min.)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Mean	50.9	51.02	49.09	48.98	41.31	47.43	39.8	47.97	9.33	10.5	8.6	9.53
Std. Deviation	3.11	3.07	3.11	3.07	14.89	16.04	13.62	17.3	3.78	4.28	2.79	3.41

The results of the mean and standard deviation of the physical parameters for each kidney of 10 donors in case of automatic background ROI near and far from each kidney were calculated and tabulated in table (5).

TABLE (5)
The mean and standard deviation of the physical parameters for each kidney in case of automatic background ROI near and far from each kidney of 10 donors.

AUTOMATIC DONORS (N=10)												
Statistics	Contribution (%)				GFR(ml/min)				$T_{1/2}$(min.)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Mean	51.52	50.29	48.48	49.72	40.5	47.19	39.24	45.93	9.63	10.51	8.46	10.03
Std. Deviation	2.69	3.62	2.69	3.62	13.98	15.35	14.16	18.94	3.69	4.1	2.91	3.24

A comparison between the near sites of manual background ROI with the near sites of automatic background ROI for each physical parameters has been done through estimating the p values for 10 donors, as well as for the far sites. The results were tabulated in table (6).

TABLE (6)
P-values resulted from comparison of near sites in case of manual background ROI with the near sites of automatic background ROI as well as for the far sites for 10 donors.

P VALUE FOR DONORS (N=10)												
Statistics	Contribution (%)				GFR(ml/min)				$T_{1/2}$(min.)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	far	near	Far	Near	far	Near	far	near	far	Near	Far
P value	0.023	0	0.023	0	0	0.001	0.001	0	0	0	0	0

The p-values were less than 0.05 which mean that there is a significant differences between background sites in manual and automatic methods in assessment of physical parameters.
In the second group (50 cases) divided into 40 patients suffering from different disorders in the kidney and 10 donors. The same method of processing has been done to 40 patient and 10 donors but only with manual background ROI (near and far from each kidney) to recognize the best location for the background ROI. Then, the corresponding physical parameters ($T_{1/2}$, contribution, GFR) have been recorded. The data were statistically analyzed using the SPSS software.
The results of the mean and standard deviation of the physical parameters for each kidney of 40 patients in case of near and far background from the kidney were calculated and tabulated in table (7).

TABLE (7)
The mean and standard deviation of the physical parameters for each kidney in case of manual background near and far from the kidney for 40 patients.

PATIENTS (N=40)												
Statistics	$T_{1/2}$(min.)				Contribution (%)				GFR(ml/min)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Mean	22.13	23.81	14.17	14.59	41.68	43.13	58.32	56.87	30.41	36.65	40.78	46.46
Std. Deviation	53.54	36.91	12.03	11.41	21.81	20.96	21.81	20.96	18.69	21.41	18.25	20.51

A comparison between the near sites of background ROI with the far sites of background ROI has been done through estimating the p-values for each case. The results were tabulated in table (8).

TABLE (8)
P-values resulted from comparison of near sites of background ROI and the far sites of background ROI.

P VALUE FOR PATIENTS						
Statistics	T1/2		Contribution (%)		GFR(ml/min)	
	Left kidney	Right kidney	Left kidney	Right kidney	Left kidney	Right kidney
P value	0.001	0.001	0	0	0.002	0.002

The p -values were less than 0.05 which mean that there is a significant differences between near and far background sites in assessment of physical parameters.

The results of the mean and standard deviation of the physical parameters for each kidney of 10 donors with near and far background from the kidney were calculated and tabulated in table (9).

TABLE (9)

The mean and standard deviation of the physical parameters for each kidney in case of manual near and far background from the kidney for 10 donors.

DONORS (N=10)												
Statistics	T1/2				Contribution (%)				GFR(ml/min)			
	Left kidney		Right kidney		Left kidney		Right kidney		Left kidney		Right kidney	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Mean	8.2	9	7.88	8.75	50.32	50.50	49.68	49.49	47.15	53.43	46.97	52.83
Std. Deviation	1.38	1.94	1.35	2.05	2.26	2.60	2.26	2.60	6.07	6.98	9.27	10.47

A comparison between the near sites of background ROI with the far sites of background ROI has been done for the 10 donors through estimating the p values. The results were tabulated in table (10).

TABLE (10)

The P-values results from the comparison of near sites of background ROI and far sites of background ROI for10 donors.

P VALUE FOR DONORS (N=10)						
Statistics	T1/2		Contribution (%)		GFR(ml/min)	
	Left kidney	Right kidney	Left kidney	Right kidney	Left kidney	Right kidney
P value	0	0.003	0.001	0.001	0	0

The p -values were less than 0.05 which mean that there is a significant differences between near and far background sites in assessment of physical parameters.

4 Discussion

Proper selection of background ROIs is important for accurate calculation of dose that reached to the kidney. It is difficult to determine the true background since there is intervening soft-tissue background both anterior and posterior to the kidney. Different methods for background selection are applied in the various nuclear medicine departments, and no universally accepted protocol exists. Regions adjacent to the kidney should be used for background subtraction [11].

In a study by Dopuda M and et al on 50 patients who were divided into two groups (21donors and 29 patients). The background activity region was drawn below the lower pole of each kidney. GFR calculated by the use of a region under the lower pole has statistically significant effect on GFR ($p < 0.0001$) [12].

Hiep T. Nguyen and et al carried a study on 23 patients and found that changing the background subtraction technique affect the calculated relative renal function and account for the observed increase in the function of the obstructed kidney, they recommend that the preferred method for calculating background subtraction to minimize error should be based on region of interest surrounding the whole kidney [13].

Middleton GW, Thomson WH and et al described a technique for accurate background subtraction in ^{99m}Tc-DTPA renography. The technique is based on a multiple regression analysis of the renal curves and separate soft tissue curves which represents background activity. It is compared for over 100 renograms, with a previously described linear regression technique, results showed that the method provides accurate background subtraction, even in very poorly functioning kidneys, so enabling relative renal filtration and excretion to be accurately estimated [14].

Moonen M and Granerus G carried a study on 21 patients and emphasize the necessity for an individual background ROI for each kidney and the need to separate extra-and intrarenal background activities before subtraction. The most accurate ROI for subtracting extra-renal tissue activity is surrounding the kidney, preferably one pixel away from the kidney and two pixels wide. Such a background ROI should be automatically drawn by the computer and normalized to the kidney area [15].

This work aimed to study the effect of site of background region of interest (ROI) on renogram results by choosing the site of background ROI wheter it is near or far from the kidney in case of manually or automatically chosen background ROI.

5 Conclusion

It is concluded from the obtained results that;

- Changing the site of background region of interest has an effect on renogram results.
- The values of physical parameter in manual method is better than the values in automatic method.
- The perirenal far site (less activity area) is the best site for the background wether it is manual or automatic.

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