Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/040309

Parameters Affecting the Quality of Renal Dynamic Scan in Nuclear Medicine Imaging

A. M. Kelany[1,2,*]

[1]Physics Department, Helwan University, Helwan, Egypt.
[2]Deanship of Preparatory Year, Umm Al-Qura University, Makkah, KSA.

Received: 17 May 2019, Revised: 19 Jul. 2019, Accepted: 23 Jul. 2019.
Published online: 1 Sep 2019.

Abstract: In the present study, thirteen centers with nine different acquisition protocols and six analysis programs were surveyed during the routine calibration for gamma camera. During this survey obtained renogram were varied widely from center to another. The curves generated from dynamic phantom can reflect the calibration status of a gamma camera. On the other hand, the data for different centers revealed that T_{max} is the most effective parameter for obtaining a good diagnosis for renal function and confirming the quality of the calibration status. The effect of region of interest on the value of T_{max} for 153 renal patients was also studied. By using good calibrated gamma camera, the ^{99m}Tc-DTPA dynamic scintigraphy was carry out in the rear view by injection intravenously as a bolus 185MBq. Two regions of interest were defined as background around the whole kidneys in comparison with cortical of kidney. T_{max} and $T_{½}$ were calculated from the time of the topmost counts to the time when renogram curve decreased to its half topmost counts. The recorded variations in $T_{½}$ and T_{max} values were due to variations in body surface area for both genders. Overweight of females suffering from obesity and fatty liver causing pressing on the right kidney which results in a significant increase in $T_{1/2}$ values comparing with that for males. A guiding protocol is constructed to assure the quality of the obtained renogram which depends mainly on the values of T_{max}. So, T_{max} is considered as an internal quality factor.

Keywords: quality of dynamic radionuclide Tc-99m DTPA and GFR.

1 Introduction

^{99m}Tc-diethylenetriamine-pentacetic acid (DTPA) is the most commercially available radiopharmaceutical for renography. Following intravenous administration, it is entirely filtered by glomeruli in the kidneys. For this reason, gamma camera uptake method with ^{99m}Tc-DTPA can be used for measurement of glomerular filtration rate, since it is simpler and less time consuming. Renal scintigraphy can provide the valuable split renal function which is not obtainable by other non-invasive measurements. The functional status of the kidneys is determined by obtaining serial images and a renogram. A renogram is simply an activity versus time curve demonstrating the passage of radiopharmaceutical through the kidneys [1,2]. In dynamic renal scans, ^{99m}Tc-diethylenetriamine-pentacetic acid (DTPA) is copiously used and it yields information about the renal blood-flow and the excretory capacity [3]. Methods such as classification and regression trees can identify the key parameters using DTPA for differentiation between non-obstructed and obstructed kidney, has the potential to serve as an intelligent support method to avoid unnecessary lasix imaging and can be applied to more complex imaging problems [4]. Phantoms have been used in order to simulate the physical structures of human organs, such as those used in computerized brain tomography. This phantom can provide a quantitative measure of kidney flow/excretion and use in different purposes in nuclear medicine. These properties of the phantom show its suitability of use for standardization and quality control of the renogram procedures by multicenter among different nuclear medicine departments [5]. With phantom, the true values of most measured parameters are well known; it closely approaches true extraction, washout, and attenuation properties and curves and the images produced are similar to those of patient studies. It is a promising tool for quality assurance and calibration of renography [6]. The relation between counts and time describes a time-activity curve (TAC). The goal of dynamic imaging in case of a renal study is to evaluate kidney function and compare left and right kidney performance. ROIs are drawn around the target organs and relative quantification is performed based on measured region of interest counts over time. Nuclear

*Corresponding author e-mail: kelany12@yahoo.com

medicine centers producing the best and the worst quality varied during the surveys, resulting in inaccurate values of glomerular filtration rate (GFR) in renal dynamic scan. Also, the lack of standardization and harmonization of investigation protocols plays a major role in functional image. Measuring "true" GFR is important in clinical practice, especially in particular scan **[**7**].** Currently, most of gamma cameras are equipped with a commercial program for GFR determination, manually a semi-quantitative analysis is obtained by drawing (ROI) over each kidney. Then, GFR value can be computed from the scintigraphic determination of ^{99m}Tc-DTPA uptake within the kidney [8]. The quality of renal dynamic scan in nuclear medicine imaging, as in all imaging modalities, depends on the whole investigation procedure. If any of the separate steps is unsatisfactory, the result is not reliable. Most of the steps and the facility can, and should be checked by employees of departments regularly, but this is not enough. The need for overall quality assurance by independent outside observers is taking place in medical imaging [9]. Therefore, the present work aims to optimize current routine clinical dynamic scan imaging by focusing on key components of the image formation chain: imaging instrumentation, image acquisition, image reconstruction, image evaluation and interpretation to increase clinical efficiency and improve dynamic image quality in diagnostic procedure.

2 Material and Methods

Thirteen centers of nuclear medicine all over Egypt have been conducted to identify those factors. All measurements of physical performance of the facilities were performed equally in each laboratory. Quantitative parameters were obtained according to each center's routine acquisition protocol with the surveys organized by laboratory quality. The scanning procedure has to be comparable and repeatable and it has to reflect the authentic situation in a given laboratory. Interpreters in each center gave a routine report for organ phantom image set in the dynamic renal imaging by experienced three nuclear medicine physicians. They gave the score from zero to three (poor to excellent) according to accepted characteristics, interpretation, description and the overall quality were judged separately.

Containers of phantom were filled with radioactive solution, which produce count rates close to clinical situations. The true values for time to reach maximum activity (T_{max}), time to half activity from maximum activity ($T_{1/2}$) were defined from time schedules of the simulations. Renograms contains T_{max} and $T_{1/2}$ values for both kidneys were sent to three experts (nuclear medicine specialists with over ten years' experience: one physicist and two physicians) who are familiar with the functioning of the phantom. They evaluated individually all the series blindly and scored (1–5) according to what was the informative quality of the series: display of the "analogue equivalent" images, background subtraction, display of the renogram curves and parameters. All reports were numbered, and sent to three experts (physicians with over ten years' experience and subspecialty in nuclear medicine). They scored descriptive and interpretative parts and the overall quality of the reports according to accepted criteria from zero to three (poor to excellent) and gave opinion for the quality of the reports.

In the present work renal dynamic scan for one hundred and fifty-three patients evaluated for kidney function were generated. Preoperative imaging studies included ^{99m}Tc DTPA renography as a functional study; either percutaneous contrast renal angiography, magnetic resonance angiography or computed tomography angiography were recorded for the clinical cases. The dose has to be measured in a dose calibrator that (5.0- 10.0 mCi) would be in the injection syringe. A creatinine clearance values were obtained, mean = 120 ± 38 ml/min/1.73 m^2. (Normal range is 90-140 ml/min/1.73 m^2 for males and 80-125 ml/min/1.73 m^2 for females). The mean age and SD of the subject population was 40.0 ± 10 years with a mean age of 38.0 ± 12 for males and 37.0 ± 10 for females. The mean body surface area (BSA) for males was 2.04 m^2 and for females was 1.80 m^2.

Thirty minutes before the beginning of the study, all patients were hydrated with around 300-500 ml of water. Siemens's gamma camera fitted with a low-energy all-purpose collimator will produce Images were acquired in a 128 × 128 matrix with a 10-inch field of view. Each object was imaged supine with the kidneys and bladder within the field of view. Following the intravenous injection of ^{99m}Tc DTPA at the end of the acquisition, another one post-void 2-minute image was acquired for the kidneys with the patient in the supine position and one minute frontal pre-void and post-void bladder images were also acquired to determine the residual urine volume and post-void (30 min) over maximum (post-void/max) count ratios. The Quant EM 2.0™ software was used to treat the data.

All objects received a dose of 5-10 mCi (185-370 MBq) ^{99m}Tc DTPA. Dead-time losses may be remarkable when counting the higher doses, depending on the type of the using camera. For that reason, a syringe containing approximately 1 mCi (37 MBq) was counted by putting it in a syringe holder 30 cm upon the camera face. The counted syringe with 1 mCi (37MBq) over the camera and the syringe with the injected dose were also counted in the dose calibrator to produce the injected dose to counted dose ratio. The region of interest was automatically set to over each kidney using the 2-3 minute post-injection image and modified by the operator as necessary. An automated cortical region of interest was assigned using an algorithm to identify the area of renal pelvis and calyces and then deduct this area from the whole kidney region of interest to generate the cortical region of interest. A two-pixel wide perirenal background ROI was generated one pixel outside of whole kidney ROI. To measure relative uptake, the counts/pixel in the perirenal background ROI were normalized to the number of pixels in the whole kidney ROI and deduct from counts in the whole kidney ROI to determine the background-corrected counts. An automated C-shaped per renal region of interest was assigned so that the background region of interest would not overlap ureter and lead to an inappropriately high background correction when there was marked retention of activity in a ureter or enlarged renal pelvis. The counts/pixel in the C-shaped background ROI were normalized to the number of pixels in the kidney ROI and subtracted from counts in whole kidney and cortical ROIs to determine the background-corrected counts used to generate renogram.

3 Results and Discussion

External surveys have been performed for thirteen different centers distributed all over Egypt. They were judged to be standard according to investigated parameters. Centers which received the worst and the best results were always different, and also may come from the fact that some of them insufficiency certified and trained specialists and standardization. External scanning has shown that diagnostic functional imaging chain needs to be checked independently by an outside observer. Data analysis showed that there was a considerable difference in results obtained from the analysis of a set of the data obtained from the experiments. The Variation is due to the using of different data analysis techniques used and using of different acquisition protocols. Using variable protocols may explain the non-correlation of gamma camera age to qualitative results. The use of smaller patient-to-collimator distance, smaller radius of rotation, different matrix size or frame time could produce significantly better images. Accuracy of reporting is probably the most important factor for overall performance [10]. The reasons for wide variation in reported incidence may in part reflect scanning technique, equipment or methods but it is probable that the most important variables are differences in reporting of images and subsequent investigation of abnormalities. The number of different acquisition protocols for the thirteen participating centers was nine and number of different analysis programs was six. Also, there were variations in positioning of the regions of interest (ROI) for background subtraction. During the survey of routine imaging, one reference standard phantom with specifications mentioned before was used in all centers to get qualitative and quantitative data. Usually time to reach maximum activity (T_{max}) and uptake difference is calculated [11]. According to the EANM Physics Committee [12], uptake difference and T_{max} were recorded for the standard phantom in the different centers. **Fig.1 (A)** shows percentage of error in the uptake difference for patients in the different centers. It is clear that percentage error reaches up to 16%. In T_{max}, **Fig.1 (D)** Average scores of the image set and reports are presented in **Fig. 1(C)** and **1(D)** respectively. The score of the image set is from zero to five while that for the report is from zero to 3.These variations most probably on variations in analysis protocols and programs used.

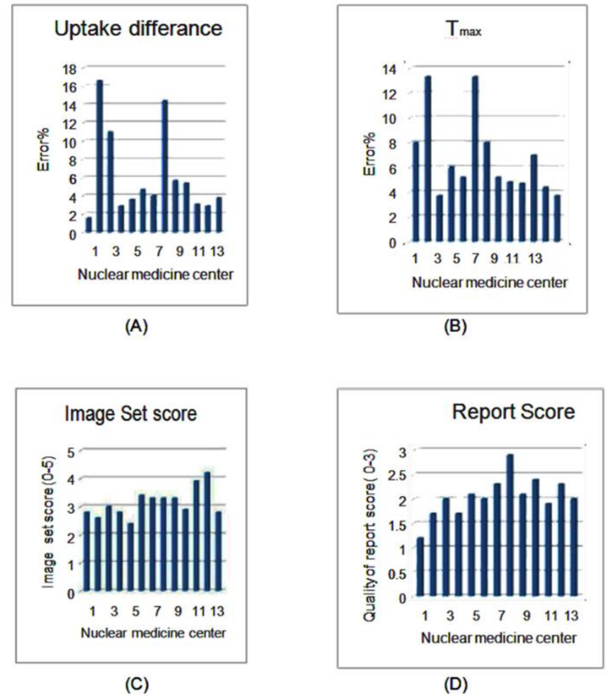

Fig.1: Uptake difference (1A), T_{max} of phantom (1B), image set score (1C) and report score (1D) recorded for patient at different centers**.**

The previous data revealed that image set score and report score have a little effect on the quality of renogram due to their dependence on human evaluation. Differences in scan quality are primarily related to differences in physician and technologist training and supervision. So, variations in uptake difference and T_{max} are considered as very sensitive parameter for evaluation of quality of renogram. Yassin et al [13] showed that renogram parameters are varied between centers due to variations in study protocol, analysis programs and human errors. The effect of region of interest on the value of T_{max} (Time belonged to maximal value of the curve generated for both kidney during radio tracer injection in renal dynamic scan was also studied. Semilunar background ROI around each kidney was defined, and was modified for inferior ROIs in the original gates according to Gates [14]. Background corrected time-activity curve was generated, and renal uptake of individual kidney was recorded from the second to the third minute after injection. GFR was automatically estimated by available computer. Manual kidney regions of interest are likely to have increased inter-observer variability; this problem is observed when manual ROIs are defined by individuals with limited experience. Variability in ROI assignments could lead to changes in quantitative variables which could be misinterpreted as clinically significant. To assist in interpretation of renogram scan post-void kidney to maximum count ratio, residual urine volume and DTPA clearance should be considered. The poorly functioning patient's kidneys images are often of low quality with poorly defined renal borders due to high background activity, especially in the liver, and a low kidney to background ratio. it comes from that, the right kidney is neighboring to and often overlie partially on the liver. The lowing uptake of the right kidney combined with increased hepatic activity can make a border definition of the right kidney [15]. The difference in Tmax value for the whole kidney and cortical (parenchymal) time–activity curves comes from the variation in the size of the relative cortical region of interest. The function of a cortical curve is to show transit time through the cortex without contaminating curve from activity in the collecting system and the cortical [16]. Klingensmith [17], showed that the amounts for these parameters created by cortical regions of interest are significantly lower than the values created with the whole kidney regions of interest. As presented in table (1) the value of Tmax and T½ are significantly lower ($p < 0.05$) than those for the whole kidney. T½ for the right kidney (using the whole kidney regions of interest) was remarkably higher in females than in males, 8.35 min against 5.75 min, respectively, but this variation was reduced when using cortical regions of interest. The mean values for cortical T½ were significantly less than those for the whole kidney, the average right cortical for right kidney (20 min/max) count ratio was 0.18 ± 0.05 and 0.19 ± 0.09 for the left one. They were both remarkably less than the whole kidney values, $p < 0.001$.

Table1: T_{max} and $T_{1/2}$ recorded for both genders by using ROI over whole and cortical methods.

T_{max} and $T_{1/2}$ values (min)	Using the whole kidney		Using cortical method	
	male	female	male	Female
T_{max} for left kidney	3.16	3.73	2.62	2.1
T_{max} for right kidney	3.57	4.35	2.57	2.30
$T_{1/2}$ for left kidney	5.36	6.26	5.44	5.10

The recorded difference in T_{max} and $T_{½}$ values is due to variations in body surface area for both genders. The pronounced difference in $T_{½}$ values for females comparing with that for males may be interpreted as follows: females of overweight suffering from obesity and fatty liver which cause pressing on right kidney and these results in a hyperactivity count recorded for their renal dynamic scan as shown in **Figure 2(A) and Figure 2(B).** The present results confirmed that T_{max} is an effective parameter for obtaining good diagnosis for renal function and reflect calibration status of gamma camera and can be consider as an internal quality control factor. For the best of our knowledge this is the first time to obtain such a greatest importance for the recorded values of T_{max}. Therefore, the authors check the procedure illustrated in the following chart at the participating centers. The steps mentioned in this chart represent a guiding protocol which depends mainly on the value of T_{max}. The centers check this protocol many times and considered it as a rapid and accurate method to check the quality of diagnosis in renal dynamic scan.

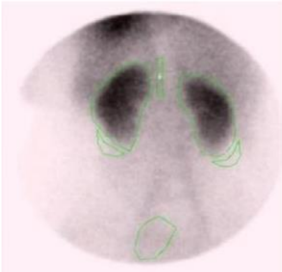

Fig. 2(A)

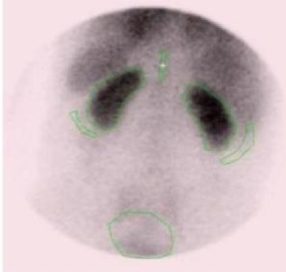

Fig. 2(B)

Representative posterior view of renal dynamic scan for average weight female (A), and female suffering from obesity (B).

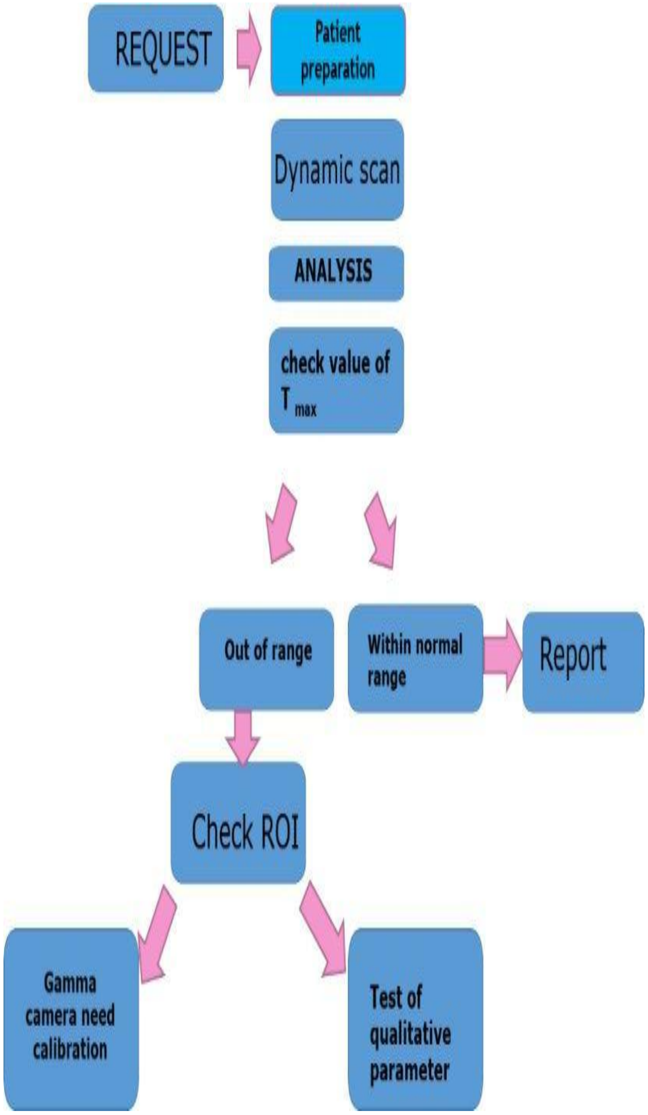

Fig.3: Guiding protocol chart**.**

4 Conclusions

External survey has shown that the whole diagnostic imaging chain needs to be checked independently by an outside observer. The calibration statuses of gamma camera depend on the internal quality control factor T_{max}. Guiding protocols which depend mainly on the value of T_{max} can assure the quality of the obtained renogram and may be considered as an important test before diagnosis in renal dynamic scan.

References

[1] K Itoh, Comparison of methods for determination of glomerular filtration rate ^{99m}Tc-DTPA renography, predicted creatinine clearance method and plasma sample method. *Ann. Nucl. Med.*, **17**, 561-565, 2003.

[2] G.B. Saha, Fundamental of nuclear pharmacy, 5th edition, Instruments for Radiation Detection and Measurement., 277-278, 2004.

[3] H.M. Fahmy, H.M. Yassin, I.M. Muhammed, S. E. Mohamed and S.S. Hassan Evaluation of the Efficiency of ^{99m}Tc-DMSA as a Radiopharmaceutical in Dynamic Renal Scans. Erciyes Med. J., **40(3)**, 140-7, 2018.

[4] H. Yassin, M. El-Nagdy and A. Kelany Intelligent operation support method for detection renal obstruction by ^{99m}TcDTPA. J. Nucl. Med., 53**(1)**, 222, 2012.

[5] A.S.M. Sabbir , L. Kabasakal and I. Uslu, A dynamic renal phantom for nuclear medicine studies, American Association of Physicists in Medicine, journal of medical physics., **32(2)**, 2005.

[6] J.O. Heikkinen, New automated physical phantom for renography, J. Nucl. Med., **45**, 495–499, 2004.

[7] P. Delanaye, M. Souvignet, L. Dubourg, L. Thibaudin, N. Maillard, J.M. Krzesinski, E. Cavalier, and C. Mariat, Le dosage de l'inuline: mise au point, Ann Biol Clin (Paris)., **69(3)**, 273-284, 2011.

[8] L. Kun-Ju, H. Jia-Yann and C. Yung-Sheng, Fully Automatic Region of Interest Selection in Glomerular Filtration Rate Estimation from ^{99m}Tc-DTPA Renogram. J. Digit. Imaging., **24**, 1010–1023, 2011.

[9] A.S. Levey, L. A. Stevens, Schmid et al. A new equation to estimate glomerular filtration rate, Ann. Intern. Med., **150(9)**, 604-612, 2009.

[10] G. Hart, A UK survey of nuclear medicine imaging performance using the Trans Bone anthropomorphic phantom. Nucl. Med. Comm., **18**, 668-672, 1997.

[11] P. S. Cosgriff, Lawson, and C. C. Nimmon, Towards standardization in gamma camera renography, Nucl. Med. Commun., **13**, 580–585, 1992.

[12] E. B. Sokole & A. Płachcínska & A. Britten, Routine quality control recommendations for nuclear medicine instrumentation, Eur J Nucl Med Mol Imaging., **37**, 662–671 2010.

[13] H. Yassin, M. Ali, A. Kelany, Quality of dynamic renal scan in nuclear medicine departments in Egypt. *Eur J Nucl Med Mol. Imaging.*, **41 (2),** 656, 2014.

[14] G.F. Gates, Glomerular filtration rate: Estimation from fractional renal accumulation of ^{99m}Tc-DTPA (stannous). *AJR.*, **138**, 565–570, 1982.

[15] D White, A Houston, W Sampson and G.P. Wilkins, Intra- and interoperator variations in region-of-interest drawing and their effect on the measurement of glomerular filtration rates. *Clinical Nuclear Medicine*., **3(24)**, 177–181, 1999.

[16] A. Taylor and M.S. Kipper, The qualitative I-131 hippuran renogram: a potential problem. *Clin. Nucl. Med.*, **8**, 149–154, 1983.

[17] W.C. Klingensmith, D.E. Briggs and W.I. Smith, Technetium-99m-MAG3 renal studies: normal range and reproducibility of physiologic parameters as a function of age and sex. *J. Nucl. Med.*, **35**, 1612-1617, 1994.