Assiut Univ. J. of Physics *Printed ISSN 1687-4900*
48(1), pp1-13 (2019)

ESTIMATION OF PRACTICAL DOSIMETRY AND EXPOSURE PARAMETERS FOR PATIENTS UNDERGOING DIFFERENT IMAGING MODALITIES FOR RENAL DIAGNOSIS

Nourhan M. Elsoudy*, Hossam Mahmoud Yassien, Lamiaa Mahmoud Abd Elazeez***, Hazem Abo Zeid Youssef**** and Mohamed El-Azab Farid***

**Physics Department, Faculty of Science, Assiut University, Assiut, Egypt*
***Nuclear Medicine Unit, Al-Kasr Al-Ainy, Faculty of Medicine, Cairo University, Cairo, Egypt*
****Nuclear Medicine Unit, Assiut University Hospital, Faculty of medicine, Assiut University, Assiut, Egypt*
*****Radiology Department, Faculty of medicine, Assiut University, Assiut, Egypt*

Corresponding author: (Nourhan M. Elsoudy) Tel.: +201092378824; E-mail address: Norhan_elsaoudy@yahoo.com

Received: 6/2/2019 **Accepted:** 25/3/2019 **Available Online:** 7/7/2019

Imaging of the renal system is done with different procedures depending mainly on clinical symptoms and signs. Renal Scintigraphy and Urography provides physicians by useful detailed information. However, it is the responsibility of radiologist and technologist to determine scanning technique factor that provides balance between image quality and radiation dose and helps in keeping patient radiation exposure as lowest as possible. The present study was intended to evaluate patient radiation dose for nuclear medicine using Technetium-99m DTPA dynamic renal scan and Computed Tomography Urography (CTU). This study was conducted in Assiut University. Machines used for renal scan were Orbiter Gamma camera dual head and CT machine. Effective doses were estimated using conversion factors. Patient results radiation dose values for DTPA renal scan were Dose Length Product (DLP) (61.34 mGy-cm) and Effective dose (0.92 mSv). Patient radiation dose values for CTU were DLP (753.19 mGy-cm) and Effective dose (11.29 mSv).

Key words: Renal Scintigraphy, Computed Tomography, Effective dose.

INTRODUCTION

One of the common diseases worldwide is renal system disorders. Different imaging techniques were used for the management of the patient disorders. CTU and Renal Scintigraphy are widely used to evaluate the function of kidneys. During the procedures, the patients are exposed to radiation dose due to the injection of radiotracer. Different types of renal scans are used to examine different aspects of the kidneys and kidney functioning. However, all of these procedures involve the injection of a radiotracer, as it has a significant radiation exposure to kidneys and bladder. In addition, some patients may be young, i.e. more radiosensitive than adults. Therefore, measuring and minimizing the patient doses are crucial.

Imaging of the renal system is done with different techniques depending mainly upon clinical symptoms and signs. Renal Scan images in Nuclear Medicine (NM) are made by the delivery of fluid into kidneys via bloodstream, concentration of wastes in the kidney and excretion or flow from the kidneys through the ureters and filling the bladder. Technetium-99m DTPA is the radiopharmaceutical used in dynamic renal scan, which is performed to look at the blood supply, kidney function and urine excretion from the kidneys. The test can find out what percentage each kidney contributes to the total kidney function. A DTPA Scan may also be undertaken to evaluate the renal tubular function, perfusion endovascular hypertension (high blood pressure in the arteries of the kidneys) due to renal artery stenosis (narrowness of the arteries that take blood to the kidneys) and urinary tract obstruction. (1) Computerized tomography scans use a combination of x-rays and computer technology to create three-dimensional (3-D) images. A CT scan may include the injection of contrast medium, and the images are interpreted by a radiologist; anesthesia is not needed. CT scans can show stones in the urinary tract, obstructions, infections, cysts, tumors, and traumatic injuries. (2)

The National Committee of Radiation Protection (NCRP) proposed in 1987 that the concept of radiation risk is introduced when evaluating safety in the nuclear practice, as is done in many other practices. Accordingly, the assumption was made that the risk of stochastic effect after exposure to low levels of ionizing radiation follows the no threshold dose effect linear relationship. The use of such radiations was recognized as acceptable because the benefits outweighed the risks. It also stated that, to reduce the probability of stochastic effects, the policy of (as low as reasonably achievable (ALARA) must be implemented in industries using ionizing radiations. For patients, the risk of a nuclear medicine procedure is considered acceptable because the procedure does provide a benefit in terms of diagnostic value followed by the potential for a successful treatment of a properly diagnosed illness (3). On the other side one of the most significant potential risks to patient who is examined with diagnostic CT is an increased probability of cancer due to the radiation exposure from x-ray. This risk is known as a stochastic effect. A stochastic effect is defined as one in which the probability of occurrence, rather than severity of the effect, is proportional to the radiation dose. Stochastic effects have no threshold dose. In general, radiation doses from diagnostic x-ray imaging exams are considered to be low and there is still a question as to whether sufficient evidence exists that establishes a risk of cancer at these low doses. Nevertheless, in clinical practice current radiation protection standards assume that there is no threshold dose below which the risk of cancer induction is zero. This linear non-threshold model, substantiated in the report by the Committee on the Biological Effects of ionizing Radiation, is used most often in medical applications when considering radiation risk to patients. Even though this model asserts that even the smallest radiation dose poses some finite risk, the linear threshold model states that there is a threshold dose below which the risk of cancer induction is zero. Although it is difficult to prove that there is no threshold dose, the linear non threshold model is the most conservative one describing radiation risk. The probability of cancer induction, a stochastic effect defined previously, is the risk associated with x-ray exposure from CT radiation produces non-threshold effects or deterministic effects. These are effects in which there is usually an associated threshold. For non-stochastic effects, the severity of the effect is proportional to the radiation dose. Examples of non-stochastic (tissue reactions) effects are Erythema and cataract induction. The dose associated with a CT exam below is well below the threshold for these non-stochastic effects. (4)

The radiation risk from a single CT examination is generally considered small. However, compared to other diagnostic x-ray imaging procedures, the doses patients receive from a single CT exam are higher. There are several reasons for this. In CT, the x-ray tube rotates around the patient, not just a projection of radiography in which the x-ray tube exposes the patient from a single projection. This can lead to a substantially higher dose from CT to a specific region of the body or to a critical organ compared to conventional radiography. In addition many CT protocols, including CT urography require multiple acquisitions. These lead to an increased absorbed dose by the patient and consequently an increased radiation risk compared to a single CT acquisition. Last,, CT is being used in medical practice much more frequently than in the past, and CT contributes more medical radiation exposure to population than any other imaging procedure. (5)

MATERIAL AND METHODS

All measurements were carried out in nuclear medicine unit, South Egypt Cancer Institute, Assiut University, and Assiut University Hospital. Data estimated in the period of June 2016 up to August 2017. A total of 271 patients referred to South Egypt Cancer Institute at Assiut University and Assiut University Hospital. The work performed to evaluate the Effective dose for 56 patients undergoing DTPA renal scan and 215 patients CT scan.

Instrumentations

Measurement of renal function is used to make critical clinical management decisions and, as such, their reliability needs to be quality assured. Gamma cameras are used for renal scintigraphy which contains energy discriminators that allow only those photons within a specified energy range to be recorded (incidental change in photopeak during a Dynamic Renal Scan).

Gamma camera scanning was performed in South Egypt Cancer institute by using Symbia™ T Series by Siemens Company (6) and CT scanning was performed in Assiut University Hospital by using CT Market. GE Model: Bright Speed Elite 16 Slices. The Bright Speed Elite Select allows 16 fps reconstruction with IQ Enhance (IQE) allowing faster pitch scanning covering more anatomy. Built on GE’s Light speed VCT (Volara DAS, Xtream FX) technology with a more compact footprint, the Bright Speed Series provides high quality images across a wide range of clinical applications. (7)

Dose Measurements

(a) Dose Calibrator: All nuclide data are entered via the custom keyboard that includes 9 user-definable keys. Four reference sources are stored in memory and are automatically decay-corrected for today’s time and date. Its space efficient design allows for a large, easy to read display. Calibration date: March 2016, March 2017.

(b) Pocket Dosimeter: Absorbed dose is measured by using pocket dosimeter (PDM-127) for patients undergoing Gamma camera scanning. The PDM-127 is excellent electronic pocket dosimeters that use a semiconductor detector which is sensitive to gamma and x-rays. Both models are battery operated and do not require a charger, separate reader or developing. The PDM-122 and PDM-127 have an automatic zero reset when the unit is turned off. The range is 20 keV and above with a measuring from 1 to 9999 μSv. Calibration date: March 2016, March 2017. (8)

RESULTS AND DISCUSSION

This section will highlight all the results of the study that deal with Clinical indication, exposure factor, and patient dosimetric data. A total of 56 patients underwent DTPA over 12 months. Patients were divided into five groups with respect to their GFR value as presented in (Table 1).

Table 1: *GFR categories for patients undergone DTPA renal Scintigraphy*

GFR categories			
Category	**Description**	**Range (9)**	**No. of patients**
G1	Normal or high	≥ 90	6
G2	Mildly decreased	60 – 89	20
G3a	Mildly to moderately decreased	45 – 59	14
G3b	Moderately to severely decreased	30 – 44	11
G4	Severely decreased	15 – 29	4
G5	Kidney failure	< 15	1

Clinical data for DTPA renal Scintigraphy were collected from 56 patients; sex (16F – 40M), age range (20 – 75), weight range (70 - 78 kg), height range (1.62 m), and BMI range (26.9 kg/m^2). Clinical data for CT were collected from 215 patients of sex (47F – 168M), and age ranged (18 – 75).

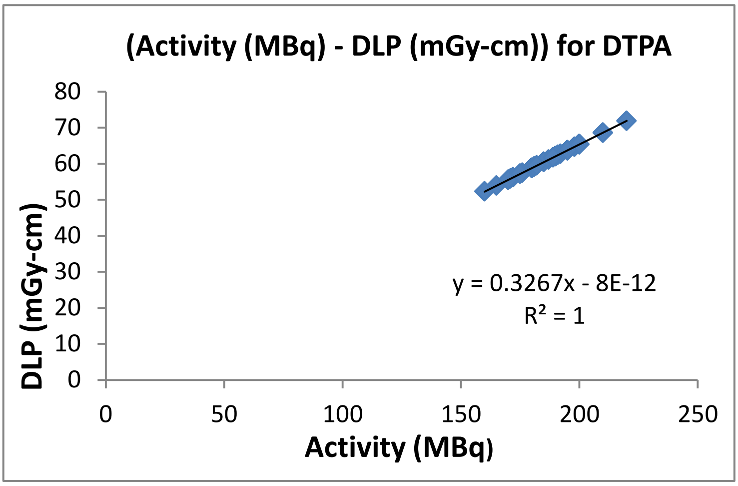

Figure 1: *Relation between DLP and Activity values for patients undergone DTPA renal Scintigraphy*

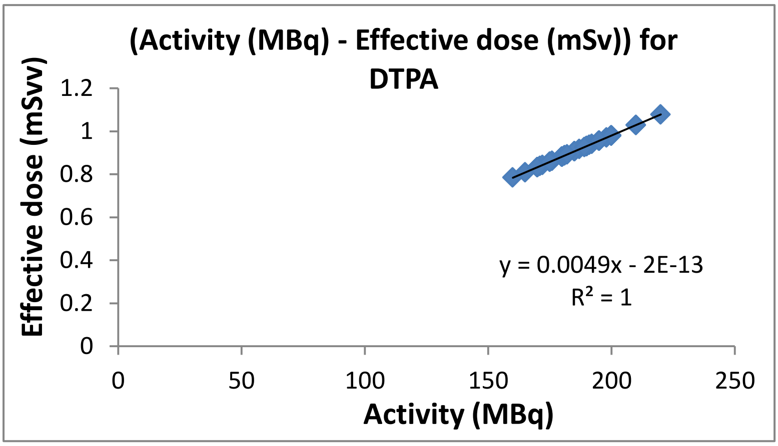

Figure 2: *Relation between Effective dose and Activity values for patients undergone DTPA renal Scintigraphy*

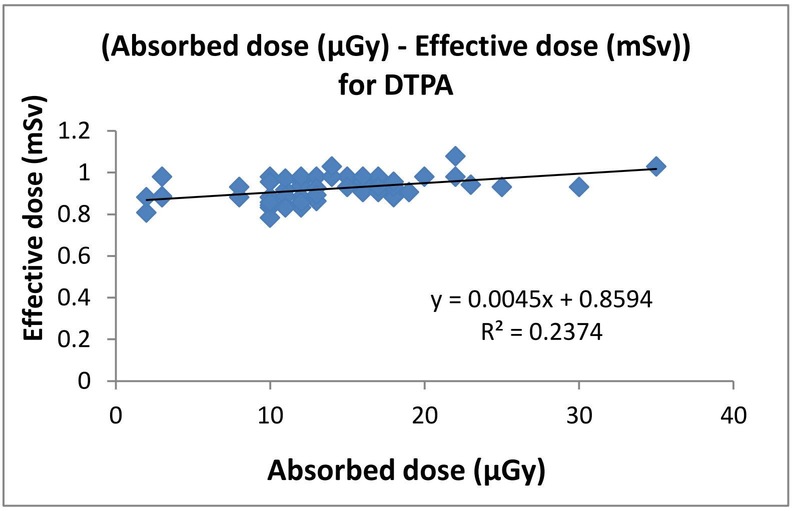

Figure 3: *Relation between Effective dose and absorbed dose for patients undergone DTPA renal Scintigraphy*

In the present study the radiation dose was evaluated for five groups of patients' undergone DTPA renal scan. DTPA renal scintigraphy is recommended as the initial screening study in patients found on IVU to have hydro-nephrosis without obvious cause (equivocal obstruction).

It is used to follow patients with managed (treated) obstructive hydro-nephrosis, and it's very sensitive technique to estimate the residual function in atrophic kidneys. Non-visualized kidneys on IVU and ultrasound can be visualized on dynamic renal scan. The kidney is considered non-functional if its split function is 10 -15% and less. The values of effective dose mean (0.92015) mSv ranged between (0.8085 – 1.078) mSv, which were relatively small radiation dose compared to the other techniques.

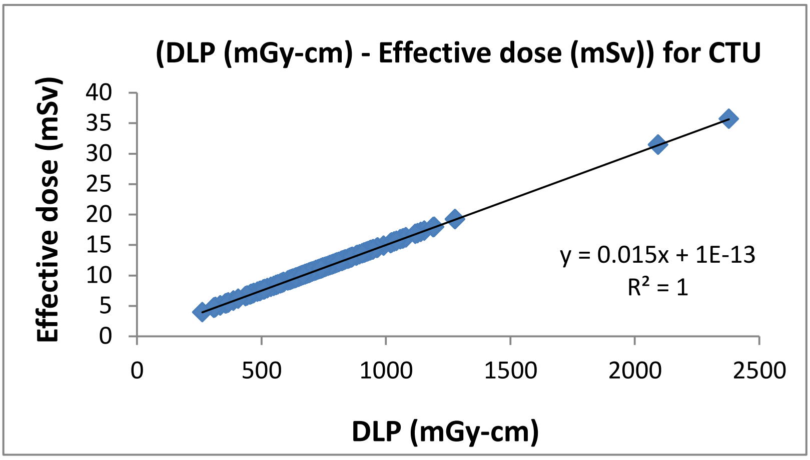

Figure 4: *Relation between Effective dose and DLP for patients undergone CTU*

The exposure parameter and dosimetric data for patients undergone CTU used within CT machine are kVp mean is 120, scanned with mAs 254, ranged (71 - 570), pitch of 0.85, beam collimation total of 3.6 mm, slice thickness of 1.5 mm, and rotation time 0.5 second. The region of scan includes the abdomen and pelvic. The parameter produced these radiation values which show the values of DLP mean (753.19296) mGy-cm and ranged between (309 - 2378) mGy-cm; CTDI mean (15.19) mGy and range between (7.16 – 48.72) mGy; and effective dose mean (11.29) mSv ranged between (3.93 – 35.67) mSv.

There were variations in the radiation dose to the patients. In general, these variations of doses are due to differences in tube voltages, number of scans, tube current and repeated scans. The exposure parameters were dependent on clinical data, regions of interest, patient weight and balance between the image quality and benefit of radiation risks. Also, there were variations in patients' radiation dose compared to the previous study due to the protocol used and the type of CT machine.

Therefore, according to this result when considering CT urography as a replacement for conventional urography, radiologists should examine the risks of CT urography as well as the benefits. One of these risks is radiation. Our results indicate that the effective dose for CT urography is 1.45 times greater than that for conventional urography.

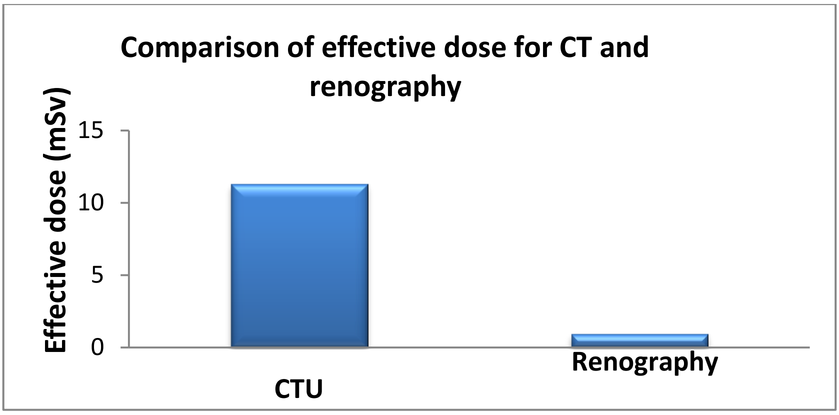

Figure 5: *Relation between Effective dose and DLP for patients undergone CTU*

Table 2: *Patient dosimetric data and exposure parameters for patients undergone CT*

mA mean	**kV mean**	**DLP mean (mGy-cm)**	**$\mathrm{CTDI_{vol}}$ mean (mGy)**	**Effective dose mean (mSv)**
254	120	753.19	15.19	11.29

Table3: *Patient dosimetric data and exposure parameters for patients undergone Renography*

DLP mean (mGy-cm)	**Absorbed dose mean (μGy)**	**Effective dose mean (mSv)**
61.34	13.41	0.92

Medical uses of radiation have grown very rapidly over the past decade, and, as of 2007, medical uses represent the largest source of exposure to the U.S. population. Most physicians have difficulty assessing the magnitude of exposure or potential risk. Effective dose provides an approximate indicator of potential detriment from ionizing radiation and should be used as one parameter in evaluating the appropriateness of examinations involving ionizing radiation. The purpose of this review is to provide a compilation of effective doses for radiologic and nuclear medicine procedures. Standard radiographic examinations have average effective doses that vary by over a factor of 1000 (0.01–10 mSv). Computed tomographic examinations tend to be in a more narrow range but have relatively high average effective doses (approximately 2–20 mSv), and average effective doses for interventional procedures usually range from 5–70 mSv. Average effective dose for most nuclear medicine procedures varies between 0.3 and 20 mSv. These doses can be compared with the average annual effective dose from background radiation of about 3 mSv. **(10)**

The comparison of effective dose (E) is estimated by anatomic region according to recommendations of International Commission on Radiological Protection (ICRP) publications 26, 60, or 103 or calculated using dose–length product (DLP) and k coefficients.

Table 4: *Comparison of patient effective doses during DTPA Renal Scintigraphy with previous studies*

Author	**No of patients**	**effective dose mean (mSv)**
Stabin M, et al. (1992) (11)	11	3.3
Fred A. Mettler, et al. (2008)(10)	20	1.81
Present study	56	0.92

Table 5: *Comparison of patient effective doses during CTU with previous studies*

Author	**No of patients**	**effective dose mean (mSv)**
Denis Tack, et al. (2003) (12)	106	1.55
Jacqueline MZ Thomson, et al. (2001) (13)	224	5
Bong Soo Kim, et al. (2009) (14)	121	8.65
Eli N. Eikefjord, et al. (2007) (15)	119	7.7
Weldon Liu, et al. (2000) (16)	60	2.8
Present study	215	11.29

CONCLUSION

Radiography has a major role of diagnostic method in medical field. Urography provides the radiologist with useful detailed information. It is the responsibility of radiologist and technologist to determine the scanning technique factor that provides balance between image quality and radiation dose and shares in keeping patient radiation exposure at lowest as possible.

In the present study, evaluation of radiation doses form DTPA Renal Scintigraphy, computed tomography CT can vary considerably between scanners and between centers. The radiation dose in DTPA is considered low compared with most previous studies. This may be due to the amount of the administrated activity, patient size (less than normal), scanner and protocol used. Moreover, according to data obtained from CT, it was higher in comparison to the previous study.

REFERENCES

1. JP Esser (2014): Dynamic Renal Scintigraphy (part I), Meander Medical Centre, Amersfoort.

2. Arnstein P. M., Richards A. M. & Putney R. (1994): The risk from radiation exposure during operative X-ray screening in hand surgery. Journal of Hand Surgery, 19(3): 393-396.

3. Max H. Lombardi (2006): Radiation Safety in Nuclear Medicine, CRC Press, 9780849381799.

4. Shope T. B., Gagne R. M. & Johnson G. C. (1981): A method for describing the doses delivered by transmission x-ray computed tomography. Medical physics, 8(4): 488-495.

5. Rebecca Smith-Bindman, Jafi Lipson & Ralph Marcus: Radiation Dose Associated With Common Computed Tomography Examinations and the Associated Lifetime Attributable Risk of Cancer, Arch Intern Med. 2009;169(22):2078-2086.
6. Symbia™ T Series by Siemens Company: https://usa.healthcare.siemens.com/molecularimaging/xspect/symbiatseries

7. GE Healthcare BrightSpeed Elite: http://www3.gehealthcare.fr/~/media/downloads/uk/product/computed-tomography/general/gehealthcare-ct-clarity-magazine-autumn-2011.pdf

8. Capintec 2012 product catalog:https://drive.google.com/open?id=13ybSa43-b-2FXYOr8Lmk8srF8FC1rxC5

9. National kidney Foundation: https://www.kidney.org/atoz/content/gfr

10. Fred A. Mettler, Walter Huda, Terry T. Yoshizumi & Mahadevappa Mahesh (2008): Effective Doses in Radiology and Diagnostic Nuclear Medicine: A Catalog, RSNA publications.

11. Stabin M, Taylor A Jr, Eshima D & Wooter W: Radiation dosimetry for technetium-99m-MAG3, technetium-99m-DTPA, and iodine-131-OIH based on human biodistribution studies, Journal of Nuclear Medicine : Official Publication, Society of Nuclear Medicine [01 Jan 1992, 33(1):33-40].

12. Denis Tack, Stavroula Sourtzis, Isabelle Delpierre, Viviane de Maertelaer & Pierre Alain Gevenois: Low-Dose Unenhanced Multidetector CT of Patients with Suspected Renal Colic, American Journal of Roentgenology, 2003;180: 305-311. 10.2214/ajr.180.2.1800305.

13. Jacqueline MZ Thomson, Jeffrey Glocer, Christopher Abbott & Thomas MJ Maling (2001): Computed tomography versus intravenous urography in diagnosis of acute flank pain from urolithiasis: A randomized study comparing imaging costs and radiation dose, Journal of Medical Imaging and Radiation Oncology.

14. Bong Soo Kim, Im Kyung Hwang, Yo Won Choi, Sook Namkung, Heung Cheol Kim,Woo Cheol Hwang, Kuk Myung Choi, Ji Kang Park, Tae Il Han & Weechang Kang (2009): Low-Dose and Standard-Dose Unenhanced Helical Computed Tomography for the Assessment of Acute Renal Colic: Prospective Comparative Study, Journal Acta Radiologica.

15. Eli N. Eikefjord, Frits Thorsen & Jarle Rørvik (2007): Comparison of Effective Radiation Doses in Patients Undergoing Unenhanced MDCT and Excretory Urography for Acute Flank Pain, American Journal of Roentgenology, 188: 934-939. 10.2214/AJR.06.0676.

16. Weldon Liu, Stephen J. Esler, Bryan J. Kenny, Raymond H. Goh, Andrew J. Rainbow & Giles W. Stevenson (2000): Low-Dose Nonenhanced Helical CT of Renal Colic: Assessment of Ureteric Stone Detection and Measurement of Effective Dose Equivalent, RSNA publications.

تقدير الجرعة المقاسة وعوامل التعرض للمرضى تحت تأثير أنماط تصوير مختلفة لتشخيص أمراض الكلى

نورهان محمد السعودي فخري* – حسام محمود ياسين – لمياء محمود عبدالعزيز ***- حازم أبوزيد يوسف**** – محمد العزب حسن فريد***

**قسم الفيزياء، كلية العلوم، جامعة أسيوط، مصر*
***وحدة الطب النووي، القصر العيني، كلية الطب، جامعة القاهرة، القاهرة، مصر*
****وحدة الطب النووي، مستشفى جامعة أسيوط، كلية الطب، جامعة أسيوط، أسيوط، مصر*
*****قسم الأشعة التشخيصية، كلية الطب، جامعة أسيوط، أسيوط، مصر*

توجد عدة طرق مختلفة لتصوير الجهاز البولي استنادًا إلى الأعراض والمؤشرات الطبية. يمد تصوير الكلى باستخدام الأشعة العادية والطب النووي الطبيب بمعلومات هامة، غير أنه تكمن مسئولية أخصائي الأشعة والفني في تحديد تقنية التصوير التي توازن بين جودة الصورة وأقل جرعة إشعاعية يتعرض لها المريض بقدر الإمكان. أُعدت الدراسة الحالية لتقدير الجرعة الإشعاعية للمريض المستخدمة في الطب النووي عن طريق الفحص الكلوي المتحرك DTPA باستخدام مادة تكنيشيوم-٩٩ m وباستخدام الأشعة المقطعية للكلى. أجريت هذه الدراسة بجامعة أسيوط، والأجهزة المستخدمة للفحص الكلوي هي: كاميرا أشعة جاما الدوارة ثنائية الرأس وجهاز الأشعة المقطعية. تُقدر الجرعة الفعالة باستخدام عوامل التحول. وتقدر نتائج قياس الجرعة الإشعاعية للمرضى في فحص DTPA بـ ٦١.٣ مللي جراي- سم لمحصلة الجرعة الطولية و٠.٩٢ ميللي زيفرت للجرعة الفعالة. وتقدر قيم الجرعة الإشعاعية للمرضى في فحص الأشعة المقطعية للكلى بـ ٧٥٣.١٩ مللي جراي- سم لمحصلة الجرعة الطولية و١١.٢٩ ميللي زيفرت للجرعة الفعالة.