Iraqi Journal of Physics, 2025 *Vol.23, No.1, PP. 31-37*
https://doi.org/10.30723/ijp.v23i1.1316 *P-ISSN: 2070-4003*
E-ISSN: 2664-5548

Evaluation of the Effective Dose for the Technologists Working in a PET/CT Department in Iraqi Hospitals

Zeena Kadhum Hasan[1a*] and Samar Omran Issa[1b]
[1]*Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq*
[a*]Corresponding author: samar.o@sc.uobaghdad.edu.iq

Abstract
Nuclear medicine makes considerable use of radioisotopes. Enhancing safe practice and promoting radiation protection measures in the radiology department is greatly aided by the analysis of occupational doses received by medical radiation workers, particularly nuclear medicine staff who deal with radioisotopes. The current study sought to establish the most effective dose of F-FDG^{18} for PET/CT department personnel. An electronic dosimeter measured the whole-body doses received by technologists during 3 months between March 2024 and May 2024 in two PET/CT departments for eight medical staff, three at Al-Andalus hospital and five at Al-Kawthar hospital. In the Al-Andalus hospital PET/CT department, the mean whole-body dose for technologists (1, 2, 3) was (0.19±0.23, 0.055±0.035, and 0.045±0.021) mSv, respectively. At Al-Kawthar hospital, the average whole-body dosages to technologists (1, 2, 3, 4, and 5) were (0.053 ± 0.005, 0.053 ± 0.005, 0.05 ± 0.01, 0.05 ± 0.01, 0.056 ± 0.015) mSv, respectively. Although the individual doses are under the permissible limits, the increased workload would necessitate greater staff doses. As a result, both facilities must endeavor to examine their operating procedures and lower their radiation dose.

Article Info.

Keywords:
PET/CT, Radiation, Whole Body, Exposure, Effective Dose.

Article history:
Received: Jun. 15,2024
Revised: Nov. 15, 2024
Accepted: Nov. 29,2024
Published:Mar.01,2025

1. Introduction
Positron emission tomography with computed tomography (PET/CT) is a non-invasive medical imaging technique that uses nuclear medicine to provide valuable diagnostic data on the internal organ’s function structure and morphological alterations of internal organs [1-4]. Moreover, it possesses a wide array of applications in cardiology and neurology. The primary radiotracer employed is the radiolabeled glucose analogue fluorine-18 (^{18}F) fluorodeoxyglucose (^{18}F-FDG), which is frequently utilized for evaluating glucose metabolism [5-7].

The half-life of ^{18}F is 109 minutes, and its positron emission energy is 630 keV. An escalation in the patient load during PET procedures could potentially lead to heightened radiation exposure for personnel involved in patient care. ^{18}F (511 keV) emits annihilation radiation of exceptionally high energy, which causes a greater whole-body dosage to be administered to personnel, specifically technologists and nurses [8-11].

Therefore, it is necessary to implement efficient shielding measures to effectively regulate and minimize the staff's exposure to radiation from ^{18}F. In addition, the measured radiation dose is directly proportional to the source activity level and the duration of an individual's exposure to it. The duration of each stage in PET imaging varies depending on the technician and is also affected by the patient's condition. The radiation exposure received by the technician is markedly greater when a patient necessitates complete assistance as opposed to a patient who is capable of ambulation [12-15]. Biological repercussions are associated with the occupational exposure of nuclear medicine (NM) personnel, and these effects worsen with duration and burden. Prolonged exposure to low levels of ionizing radiation increases the likelihood of developing long-term consequences, which could manifest several years after the initial exposure. Research has indicated that there is an increased risk of cancer [16], chromosomal abnormalities, and cytogenetic damage among NM laborers. Consequently, for governments and international organizations to assess radiation hazards and develop protective measures, it is critical to calculate radiation doses for radiation personnel [17].

There are multiple strategies to reduce radiation exposure for staff members. An essential strategy is to instruct them in fundamental radiation principles, including maintaining a safe distance from the radiation source or patient [18], completing procedures effectively, and using shielding (such as protected dispensers) whenever possible. In order to reduce the amount of occupational exposure in PET imaging, staff members might be allocated to various duties in a rotational manner, thus guaranteeing that they do not come into close contact with the radioactive source. Furthermore, the utilization of semi-automated or fully automated injectors, as well as the implementation of video and audio surveillance and efficient communication with patients receiving injections, might additionally mitigate the potential hazards [19, 20].

The objective of this study is to assess the level of radiation exposure experienced by Nuclear Medicine professionals working in PET/CT in Iraq, specifically in terms of whole-body effective dose. Additionally, the study seeks to evaluate the effectiveness of dose reduction methods, such as optimizing routine working practices.

2. Materials and Methods

The study included 8 medical staff (7 males and 1 female), aged between 31 and 45 years, working at (center A, Al-Andalus hospital) in Baghdad, Iraq, and (center B, Al-Kawthar hospital) in Basra, Iraq. The study was conducted over 3 months in each center from March 2024 until May 2024, both centers handling ^{18}F-labeled radiopharmaceuticals.

During an interview in the uptake chamber, the staff nurse commences the daily workflow by greeting the patients and conducting assessments of their body mass, elevation, and glucose levels. The technologist then conducts a brief verification of vital information (such as the patient's fasting state and most recent chemotherapy/radiotherapy treatment). A technologist describes each phase of the examination to the patient. Utilizing the autoinjector, the staff technologist inserts a peripheral intravenous (IV) line to administrate the ^{18}F-FDG. After encased in a lead syringe shield, the syringe is transported to the injection chamber in a shielded box. The injection lasts between 30 and 60 minutes.

Subsequently, the patient is directed to assume a supine position on the bed or reclining chair for one hour. Throughout this period, the patient's condition is observed through a closed-circuit television system located in the nursing stations. After the patient has received the injection, the door to the uptake room is shut, and a sign is placed to indicate that the room is occupied. This is done to prevent housekeepers and other paramedical staff from unintentionally entering the room. Before the scan, the patient is directed to void their bladder using the toilet in the uptake room over an intercom system connected to the nursing station. Subsequently, the PET/CT technologist will escort the patient to the scanning room.

Additional radiation safety precautions were taken during PET scanner installation. The scanning room was enclosed by high-density double brick walls. Lead glass windows (1.5 mm lead equivalent) were inserted between the scanner and console rooms. Lead containers were used to move syringes from the hot lab to the injecting chamber. Finally, patients were monitored remotely using a video monitor in the injection/uptake room and another in the scanning room. To determine the equivalent dosage from external exposure, all staff members in Al- Andalus hospital wore instadose badges in the upper pocket of their overalls.

Whole-body instadose readouts equated to one month's cumulative dose measurements, as required by country regulations [21].

Whole-body exposure measurement was performed at Al-kawthar hospital using a silicon diode detector inserted in the coat's top left pocket. Each worker carried a single dosimeter throughout the FDG PET/CT trial. The radiation doses obtained by each worker were measured directly from the dosimeter.

During this investigation, each staff member's behaviors were watched and documented. The following data were collected: staff time spent and distance from the radioactive source, the syringe holding the radiopharmaceutical, or the injected patient, as well as patient data on administered activity and status.

2. 1. Technical Parameters for PET/CT

The studies were conducted in center A using a specialized discovery IQ PET/CT scanner (GE Healthcare, Milwaukee, WI, USA). Patients had PET/CT imaging 45-90 minutes following the injection of FDG. First, a topogram was taken during PET-CT acquisition from the base of the skull to the mid-thigh. The exposure factors used were 30 mA and 140 kVp. This was followed by a spiral CT with exposure factors of 350 mA and 140 kV. Finally, a 3D PET acquisition was performed with bed positions lasting 1-4 minutes, depending on the true count rate from the patient. The overall duration of the PET-CT scan for the entire body ranges from 15 to 20 minutes.

At center B, the discovery IQ PET/CT scanner (manufactured by GE2 healthcare in Milwaukee, WI, USA) is available. Patients had PET/CT imaging 45-90 minutes following the injection of FDG. First, a topogram was taken during PET-CT acquisition from the base of the skull to the mid-thigh. The exposure factors used were 30 mA and 140 kVp. This was followed by a spiral CT scan with exposure factors of 350 mA and 140 kV. Finally, a 3D PET acquisition was performed, with bed positions lasting 1-4 minutes, depending on the true count rate from the patient. The overall duration of acquiring the entire body PET-CT scan ranges from 15 to 20 minutes.

3. Results and Discussion

Table 1 shows that the total number of patients in center A was 292 during period 1, 244 during period 2, and 263 during period 3. In center B, the number of patients was 170, 177, and 184 during periods 1, 2 and 3, respectively.

Table 1: Analysis of the workload and personnel involved in PET/CT operations at the two centers.

Period	**Centre A**			**Centre B**		
Time period (months)	1	2	3	1	2	3
Number of patients	292	244	263	170	177	184
Total number of staff analyzed, including those involved in PET/CT.	3 (1 female, and 2 males)			5 males		

Note: center A, Al- Andalus hospital, center B, Alkawthar hospital.

3. 1. Effective Whole-Body Dose

Center A, the injection activity of ^{18}F-FDG per patient ranged from (150 to 450) mCi, with an average of (272.32±102.1) mCi. The injection activity of ^{18}F-FDG per patient at center B ranged from (300 to 750) mCi, with an average of (493.47 ± 124.59) mCi. The average duration and radiation dosage per research are documented in Table 2. The average effective dose received by technologists 1, 2, and 3 at center A was 0.19

mSv, 0.055 mSv, and 0.045 mSv, respectively. These dosages were received during injection periods of 50.27 seconds, 33.49 seconds, and 30.89 seconds, respectively.

The effective dose received based on staff doses for a 3-month period was shown in Table 2 for centers A and B.

Figs. 1 and 2 show the dose values of the PET/CT staff measured with Instadose dosimeters over the 3 months in both centers.

Table 2: Staff members working with ^{18}F-FDG PET/CT procedures receive an effective whole-body dosage.

Radiation worker	No. of day/3months	Time spent (second/study)	Distance (cm)	Activity (mCi)	Effective dose (mSv)/study
Center A					
Technologist 1	51	50.27 ±11.24	31.74± 12.41	272.54 ±102.01	0.19 ± 0.23
Technologist 2	62	33.49 ± 4.900	64.45 ±15.51	272.32 ±102.1	0.055 ± 0.035
Technologist 3	60	30.89 ± 6.58	30 ± 0.0	272.32 ±102.1	0.045 ± 0.021
Center B					
Technologist 1	23	26.52 ± 7.59	23.34 ± 6.94	493.47 ± 124.59	0.053 ± 0.005
Technologist 2	23	32.73 ± 3.87	22.60 ± 6.37	493.47 ± 124.59	0.053 ± 0.005
Technologist 3	23	31.65 ± 7.42	25 ± 6.03	493.47 ± 124.59	0.05 ± 0.01
Technologist 4	23	23.39 ± 6.08	23.43 ± 6.94	493.47 ± 124.59	0.05 ± 0.01
Technologist 5	23	20.30 ± 4.91	30 ± 0.0	493.47 ± 124.59	0.056 ± 0.015

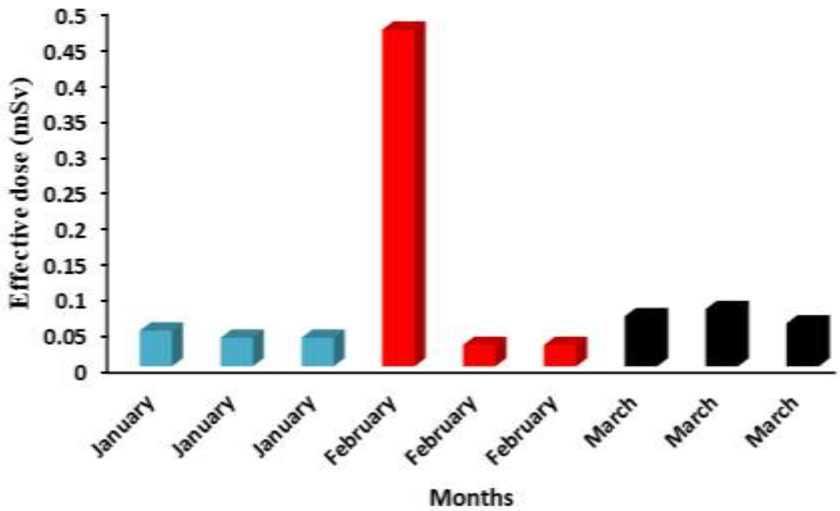

Figure 1: Dosimetric values of the medical staff in center A for a 3-month period.

Because PET-CT is used extensively in oncology, it has become well-known all around the world [22]. This has sparked apprehension regarding the level of radiation exposure experienced by personnel participating in PET-CT operations. The individuals who are exposed are the technologists responsible for administering the injection and conducting the scanning. Consequently, this study determined the level of occupational and ambient exposure to the staff workers to guarantee that they are in a secure environment and that all the necessary measures for staff protection were correctly applied.

In this work, the patient was injected with FDG of activity between 150 and 450 mCi (average of 272.32 ± 102.1 mCi) for center A and 300 to 750 mCi (average of 493.47 ± 124.59 mCi) for center B. Technologists' radiation exposures vary due to factors such as patient condition, distance from radioactive source, presence of shielding, level of training, experience handling radioactive materials, the intensity of the provided activity, and time spent in close proximity to the source. As demonstrated by other studies, technician radiation exposure from PET/CT increases mostly when they come into touch with radioactive patients [10, 23], as outlined in Table 2. The total exposure to the body would be around 0.19 mSv if one of the technicians worked alone for 20 days a month at center A, handling around 292 PET/CT cases. For center B, the whole-body dose would be around 0.056 mSv when one of the techs keeps working alone with the highest workload (around 184 PET/CT cases during an eight-day workweek). These values are less than the ICRP-recommended limit of 20 mSv per year [24].

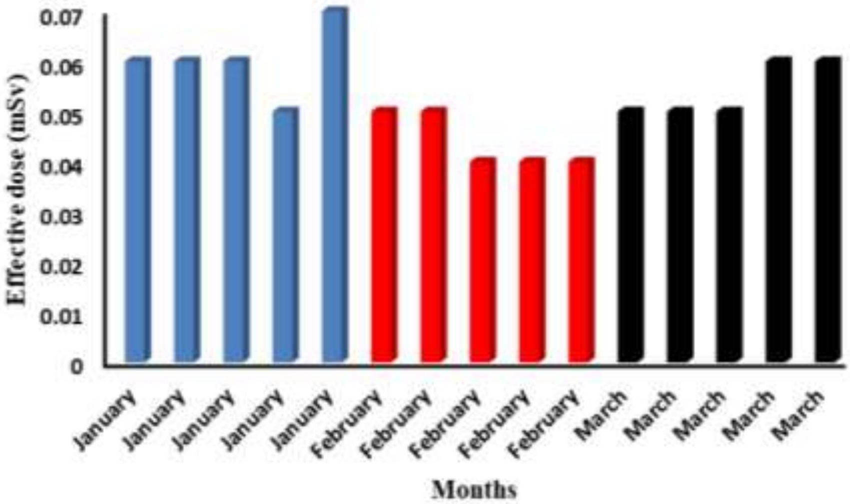

Figure 2: Dosimetric values of the medical staff in center B for a 3 month period.

Not unexpectedly, the average total radiation dose received by technologist 1 at center A was 0.19 mSv, which was higher than that of other workers. The dose for other personnel is likely to vary depending on the time they spend near a patient, ranging from 27 to 77 seconds. Higher radiation doses may necessitate increased patient care and, hence, longer contact time. The cumulative radiation dose received by a technologist during PET/CT investigations is determined by multiplying the dose rate by the duration of exposure. Multiple studies in the literature have reported whole-body doses per study, including 8.9 µSv by Zeff and Yester [24], 6.5 µSv by Benetar et al. [25], and 7.2 µSv by Biran et al. [26]. Comparing dosages between different centers is challenging due to the variety of conditions and specific elements at each PET/CT facility. These factors include patient administered doses, imaging protocol, staff performance, and facility architecture. Nevertheless, the highest amount of radiation exposure to the technologists during PET/CT procedures, as determined in this study, was 0.16 mSv at center A, which is somewhat elevated compared to the radiation dose at center B. To ensure that the workers' exposure to radiation remains within the acceptable limit, it is recommended to hire more staff when there is a plan to increase the number of patients, the number of working shifts, or the number of scanners.

4. Conclusions

An assessment was conducted to determine the radiation doses that nuclear medicine workers were exposed to. Based on the present procedures and amount of work, all the radiation doses that personnel got were within the acceptable limits set by the International Commission on Radiological Protection (ICRP). However, there is still a need for radiation dose optimization measures, specifically for radiographers, to decrease occupational exposure. This can be achieved by implementing suitable shielding, automating injecting equipment, and minimizing the duration of patient injections. Conversely, the study revealed a decrease in the number of workers in the field of nuclear medicine and PET/CT, along with a rise in the annual effective dosage. Continuous monitoring and evaluation of occupational radiation should be implemented to ensure the promotion of safe practices.

Conflict of Interest

All authors affirm the absence of any conflict of interest to disclose. This paper has not received any financial support from any funding entity.

References

1. A. B. Hade, S. M. Kadam, and S. I. Essa, E. European J. Phys., 277 (2023). DOI: 10.26565/2312-4334-2023-2-31.
2. A. B. Hade and S. I. Essa, E. European J. Phys., 241 (2023). DOI: 10.26565/2312-4334-2023-1-32.
3. M. R. Hasan, S. M. Kadam, and S. I. Essa, Iraqi J. Sci. **63**, 2000 (2022). DOI: 10.24996/ijs.2022.63.5.15.
4. A. B. Hade and S. I. Essa, Iraqi J. Sci. **65**, 4704 (2024). DOI: 10.24996/ijs.2024.65.8(SI).2.
5. A. Mallum, T. Mkhize, J. M. Akudugu, W. Ngwa, and M. Vorster, Diagnostics **13**, 53 (2023). DOI: 10.3390/diagnostics13010053.
6. G. J. Kelloff, J. M. Hoffman, B. Johnson, H. I. Scher, B. A. Siegel, E. Y. Cheng, B. D. Cheson, J. O'shaughnessy, K. Z. Guyton, D. A. Mankoff, L. Shankar, S. M. Larson, C. C. Sigman, R. L. Schilsky, and D. C. Sullivan, Clin. Cancer Res. **11**, 2785 (2005). DOI: 10.1158/1078-0432.CCR-04-2626.
7. H. Menon, C. Guo, V. Verma, and C. B. Simone, Ii, PET Clin. **15**, 45 (2020). DOI: 10.1016/j.cpet.2019.08.002.
8. X. Deng, J. Rong, L. Wang, N. Vasdev, L. Zhang, L. Josephson, and S. H. Liang, Angew. Chem. Int. Ed. **58**, 2580 (2019). DOI: 10.1002/anie.201805501.
9. N. S. Goud, R. K. Joshi, R. D. Bharath, and P. Kumar, European J. Med. Chem. **187**, 111979 (2020). DOI: 10.1016/j.ejmech.2019.111979.
10. Y. Wang, Q. Lin, H. Shi, and D. Cheng, Front. Chem. **10**, 1 (2022). DOI: 10.3389/fchem.2022.884517.
11. M. Al-Aamria, N. Al-Balushia, and D. Bailey, J. Med. Imag. Rad. Sci. **50**, 565 (2019). DOI: 10.1016/j.jmir.2019.05.009.
12. N. Khalili, S. S. Zakariaee, E. J. Gharebaghi, Y. Salehi, and V. Changizi, J. Med. Sign. Sens. **12**, 90 (2022). DOI: 10.4103/jmss.JMSS_45_20.
13. L. C. Pike, C. M. Thomas, T. Guerrero-Urbano, A. Michaelidou, T. Greener, E. Miles, D. Eaton, and S. F. Barrington, British J. Rad. **92**, 20190180 (2019). DOI: 10.1259/bjr.20190180.
14. C. Lapa, U. Nestle, N. L. Albert, C. Baues, A. Beer, A. Buck, V. Budach, R. Bütof, S. E. Combs, and T. Derlin, Nuklearmedizin-Nucl. Med. **60**, 326 (2021). DOI: 10.1055/a-1525-7029.
15. N. Galldiks, M. Niyazi, A. L. Grosu, M. Kocher, K.-J. Langen, I. Law, G. Minniti, M. M. Kim, C. Tsien, F. Dhermain, R. Soffietti, M. P. Mehta, M. Weller, and J.-C. Tonn, Neuro-Oncology **23**, 881 (2021). DOI: 10.1093/neuonc/noab013.
16. M. Alnaaimi, M. Alkhorayef, M. Omar, N. Abughaith, M. Alduaij, T. Salahudin, F. Alkandri, A. Sulieman, and D. A. Bradley, Rad. Phys. Chem. **140**, 233 (2017). DOI: 10.1016/j.radphyschem.2017.02.048.
17. J. H. Kim, Korean J. Pain **31**, 145 (2018). DOI: 10.3344/kjp.2018.31.3.145.
18. K. Skovorodko, M. Bareikė, A. Gudelis, and B. Gricienė, Phys. Med. European J. Med. Phys. **77**, 169 (2020). DOI: 10.1016/j.ejmp.2020.08.014.
19. W. Elshami, R. U. Erdemir, M. M. Abuzaid, B. Cavli, B. Issa, and H. O. Tekin, J. King Saud Univ. Sci. **34**, 102005 (2022). DOI: 10.1016/j.jksus.2022.102005.
20. B. Pavičar, J. Davidović, B. Petrović, G. Vuleta, S. Trivić, V. Šajinović, N. Egeljić-Mihailović, N. Todorović, and B. Predojević, Arh. Hig. Rada. Toksikol. **72**, 216 (2021). DOI: doi:10.2478/aiht-2021-72-3517.
21. A. Gallamini, C. Zwarthoed, and A. Borra, Cancers **6**, 1821 (2014). DOI: 10.3390/cancers6041821.
22. T. H. Kim, S. W. Hong, N. S. Woo, H. K. Kim, and J. H. Kim, Korean J. Pain **30**, 104 (2017). DOI: 10.3344/kjp.2017.30.2.104.
23. J. Valentin, Ann. ICRP **37**, 1 (2011).
24. B. W. Zeff and M. V. Yester, Med. Phys. **32**, 861 (2005). DOI: 10.1118/1.1869552.
25. N. A. Benatar, B. F. Cronin, and M. J. O'doherty, European J. Nucl. Med. **27**, 583 (2000). DOI: 10.1007/s002590050546.
26. T. Biran, J. Weininger, S. Malchi, R. Marciano, and R. Chisin, Heal. Phys. **87**, 539 (2004). DOI: 10.1097/01.HP.0000137180.85643.9d.

تقييم الجرعة الفعالة للتقنيين العاملين في قسم PET/CT في المستشفيات العراقية

زينة كاظم حسان[1] وسمر عمران عيسى[1]
[1]*قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق*

الخلاصة

يستخدم الطب النووي النظائر المشعة بشكل كبير. يتم تعزيز الممارسة الآمنة وتعزيز تدابير الحماية من الإشعاع في قسم الأشعة بشكل كبير من خلال تحليل الجرعات المهنية التي يتلقاها العاملون في الإشعاع الطبي، وخاصة موظفي الطب النووي الذين يتعاملون مع النظائر المشعة. سعت الدراسة الحالية إلى تحديد الجرعة الأكثر فعالية من (^{18}F-FDG) لموظفي قسم PET/CT. تم قياس جرعات الجسم الكاملة التي يتلقاها الفنيون بواسطة مقياس جرعات إلكتروني خلال فترة 3 أشهر بين مارس 2024 ومايو 2024. في قسمينPET/CT ، لـ 8 من الطاقم الطبي 3 في مستشفى الأندلس و5 في مستشفى الكوثر في قسم التصوير المقطعي بالإصدار البوزيتروني (PET/CT) بمستشفى الأندلس، كان متوسط جرعة الجسم بالكامل لكل التقنيين (1،2،3) (0.19±0.23، 0.055±0.035، 0.045±0.021) ملي سيفرت، على التوالي. اما في مستشفى الكوثر، كان متوسط الجرعة لكامل الجسم للتقني (1، 2، 3، 4، و5) (0.053±0.005، 0.05±0.01، 0.05±0.01، 0.056±0.015، 0.053±0.005) ملي سيفرت، على التوالي. وعلى الرغم من أن الجرعات الفردية تقع تحت الحدود المسموح بها، فإن زيادة عبء العمل سيؤدي الى اكتساب جرعات أكبر للموظفين. ونتيجة لذلك، يجب على كلا المرفقين أن يسعيا إلى فحص إجراءات التشغيل الخاصة بهما وخفض الجرعة الإشعاعية الخاصة بهما.

الكلمات المفتاحية: التصوير المقطعي بالإصدار البوزيتروني/التصوير المقطعي المحوسب، الاشعاع، كامل الجسم، التعرض ، الجرعة الفعالة.