Original Article

Reduction of Radiation Exposure to Patients and Professionals by Reducing the Administered Activity of 18F-Fluorodeoxyglucose in a Positron-emission Tomography/Computed Tomography Study

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Abstract

Aim: With increased clinical indications for positron-emission tomography/computed tomography (PET/CT) and repeated PET/CT scans, there is a need to reduce the radiation burden to the patient, professionals as well as public. This requires a redefining of the workflow and the 18-F-fluorodeoxyglucose (18F-FDG) administered activity. The objective of our study is to observe the impact of strike out reduction of administered activity on the radiation exposure to personnel and public, as well as the absorbed dose to the patient with no compromise on image quality by increasing the image acquisition time. **Materials and Methods:** Nineteen patients evaluated in this study (11 males, 8 females) were put into two groups, namely, A and B. Patients in Group A (n = 10) were administered with 18F-FDG equivalent to the recommended dose (7–8 MBq/kg body weight) whereas patients in Group B (n = 9) were administered with 18F-FDG equivalent to half the recommended dose (3–4MBq/kg body weight). The exposure rates from the patients at the body surface and 100 cm distance were measured immediately and 1 h postinjection. **Results:** The average surface dose rate and 100 cm dose rate of the adult patients immediately postinjection for patients of Group A were 0.94 ± 0.19 mSv/h and 0.057 ± 0.007 mSv/h, and for Group B were 0.34 ± 0.24 mSv/h and 0.031 ± 0.01 mSv/h. **Conclusion:** This study suggests that reduction in injected 18F-FDG activity reduces the radiation exposure rate from the patient, absorbed dose to the patient with reportable image quality.

Keywords: *18-F-fluorodeoxyglucose, positron-emission tomography/computed tomography, radiation exposure*

Introduction

Positron emission tomography/computed tomography (PET/CT) provides functional information corroborating anatomic details. With increasing clinical indications for PET/CT scans in oncology, the patient undergoes PET/CT multiple times at various stages of the disease management, such as initial staging, interim response, treatment response, and follow-ups.[1-4] This has also increased the risk of radiation exposure to the patient, professional and public. Hence, judicious administration of radiopharmaceuticals and proper confinement of patient during the uptake period becomes important to reduce radiation burden to the patient and professionals. Over the years, since the advent of PET/CT scanners, there have been several advancements in instrumentation as well as image reconstruction algorithms. With increased use of time of flight (TOF) PET scanners, the increased sensitivity and better spatial resolution can result in a reduction of injected dose and at the same time maintain good image quality with comparable imaging time.[5] The objective of our study, therefore, was to assess the reduction in radiation burden by reducing the injected dose, however, maintaining the image quality by increasing the acquisition time on non-TOF PET/CT system.

Materials and Methods

This study was approved by Institutional Ethics Committee. We evaluated 19 patients in this study (11 males, 8 females). All the patients except one weighed <80 kg. All patients' age, height, and weight were taken just before injection with relevant history including date of last menstrual cycle and breastfeeding, where relevant. All pregnant and diabetic patients were excluded from the study.

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Groups

The patients were put into two groups, namely, A and B. Patients in Group A (n = 12) were administered with 18-F-fluorodeoxyglucose (18F-FDG) equivalent to the recommended dose (7–8 MBq/kg body weight) whereas patients in Group B (n = 10) were administered with 18F-FDG equivalent to half the recommended dose (3–4 MBq/kg body weight).

Positron-emission tomography/computed tomography facility

The typical layout of a PET/CT facility is as suggested by the atomic energy regulatory board (AERB) as described by Tandon[6] PET/CT facility in our hospital has provision for 3 postdose waiting areas as described by Jha *et al*.[7]

Radioactive dose administration

The patients were made to change to hospital robe and given instruction on sitting quietly and calmly postinjection. 18F-FDG activity was dispensed with respect to the patient's weight and the Group allotted and measured using dose calibrator (CRC-15PET, Capintec Inc., USA). The administered dose and time were noted in the datasheet. These patients were seated in their respective postdose administration waiting areas. During the waiting period, the patients were advised to drink approximately a liter of water mixed with oral contrast and instructed to void in the radioactive toilet.

Exposure rate measurements

RAM GAM 1 ROTEM INDUSTRIES survey meter (Model no.: BAK-2070) used for this study has GM tube with an accuracy of ±15% and an energy response accuracy of ±20% between 50 keV and 1.3MeV. The measurement range of this detector was from 0.5 µSv/h to 9999 µSv/h. The average exposure rate of the patient, at the body surface and 100 cm was measured immediately postinjection and at 1 h postinjection by a technologist or the RSO.

Postadministration of 18F-FDG, the patient was monitored for exposure rate immediately and after 1 h from head to toe at the body surface as well as at 100 cm from the body surface anteriorly and posteriorly. Maximum exposure rate at body surface as well as at 100 cm from the body was recorded.

Whole body absorbed dose to the patient

The whole body absorbed dose to the patients was estimated using MIRD whole body dose equivalent by equation 1.[8]

$$D\mathrm{wb} = (D\mathrm{u} \times A) \qquad \text{Equation 1}$$

Where,

D_{wb} = Whole body absorbed dose (mGy)

D_u = Absorbed dose per unit of administered activity (mGy/MBq)

A = Administered activity (MBq)

Imaging

All these patients were asked to void their bladder before imaging. All patients were imaged at 45 min after injection on Discovery ST PET/CT scanner, GE Medical Systems, Milwaukee, USA. The patients in Group A were imaged at one and a half min per bed position, and those in Group B were imaged at 3 min per bed position.

Image reading

All the images were transferred to the advantage workstation ADW4.3, GE Medical system, Milwaukee, USA. Identities of the scan were masked before reading. Two trained Nuclear Medicine Physicians with more than 12 years of experience reviewed the scan quality independently, and images were graded as reportable or not reportable on visual interpretation.

Results

Patient's weight in both groups and corresponding administered activity along with whole body absorbed dose to the patient are shown in the table [Table 1]. The average surface dose rate and 100 cm dose rate of the patients immediately and 1 h postinjection for both groups are shown in the table [Table 2]. Average whole body absorbed dose to the patients in Group A was 4.38 mGy, and that of Group B was 2.4 mGy [Table 2]. The average of total imaging time in Group A was 9.15 min and that of Group B was 15 min. The images acquired were assessed qualitatively on the basis of the diagnostic value of the scan independently by two experts [Figure 1]. All the scans from Group A as well as Group B were graded as reportable by both the Nuclear Medicine Physicians.

Discussion

The guidelines for tumor imaging using 18-F-FDG mentions an average injected activity in the range of 370–740 MBq.[9,10] This, however, is the dose considering the use of non-TOF PET/CT. However, with the advent of scintillation detectors such as lutetium oxyorthosilicate which are used in TOF PET scanners, there is a clear advantage of shorter dead time which allows less random and yet provide a high counting rate with better spatial resolution.[5] With such growth in technology, there was also a corresponding growth in clinical indications for PET/CT in several diseases, particularly in the field of oncological imaging.[1-4,11-15] This has thrust the need to reduce the radiation dose to the patient, professional and public. Masuda *et al*. have demonstrated in their study that increasing dose with respect to increase in body weight does not result in improved image quality without increasing imaging time.[16] de Groot *et al*. have developed linear as well as quadratic relation between the administered FDG activity, the patients' body weight, and acquisition time, and also suggested that the quadratic expression gives a

Table 1: Patient weight and corresponding administered activity and whole body absorbed dose in both groups

Group A	Height (cm)	Weight (kg)	Administered activity (MBq)	Absorbed dose (mGy)	Group B	Height (cm)	Weight (kg)	Administered activity (MBq)	Absorbed dose (mGy)
Patient 1	165	45.4	340.40	4.08	Patient 1	164	81.9	251.60	3.02
Patient 2	180	56.1	420.69	5.05	Patient 2	165	47.6	166.50	2.00
Patient 3	156	42.3	296.00	3.55	Patient 3	155	46.3	185.00	2.22
Patient 4	163	44.4	333.00	4.00	Patient 4	166	66.6	233.10	2.80
Patient 5	168	54.6	382.21	4.59	Patient 5	161	43.3	151.70	1.82
Patient 6	161	56.2	421.43	5.06	Patient 6	168	51.2	179.08	2.15
Patient 7	160	46.9	351.87	4.22	Patient 7	156	55.7	194.99	2.34
Patient 8	154	42.4	318.20	3.82	Patient 8	177	65.4	229.03	2.75
Patient 9	163	46.4	347.80	4.17	Patient 9	154	60.3	210.90	2.53
Patient 10	175	58.2	436.60	5.24					

Table 2: Results of dose rate and whole body absorbed dose for Groups A and B

	Group A	Group B
Average administered activity (MBq)	364.82±48.02	200.21±33.28
Average dose rate immediately postinjection		
At surface (mSv/h)	0.94±0.19	0.34±0.24
At 100 cm (mSv/h)	0.057±0.007	0.031±0.01
Average dose rate 1h postinjection		
At surface (mSv/h)	0.26±0.099	0.12±0.03
At 100 cm (mSv/h)	0.021±0.011	0.011±0.0028
Whole body absorbed dose (mGy)	4.38±0.58	2.4±0.4

better relation of the aforementioned parameters without compromising on image quality.[17] FDG PET/CT: EANM procedure guidelines for tumor imaging: version 2.0 has also adapted the de Groot *et al.* quadratic expression.[10] Wickham *et al*. have also recently suggested an expression for reduction of administered 18F-FDG activity to achieve a reduction in radiation exposure to the patient as well as professional.[18] Considering these recommendation, we empirically decided to reduce the administered activity and accordingly increase the imaging time to compensate for the reduced administered activity without compromising on image quality. In our study, we found the average reduction in administered activity to patients in Group B with respect to Group A by 55% resulted in 56% reduction in whole-body patient absorbed dose as well as 40%–50% reduction in external exposure rate eventually resulting in reduced radiation exposure to the professional and general public. However, average imaging time per patient in Group B increased by 89% in comparison with that of Group A. 89% increment in average imaging time instead of 100% in Group B as compared to that of Group A may be attributed to the difference in the height of patients in respective groups.

This study identifies the reduction of external and absorbed radiation dose to patients and personnel which

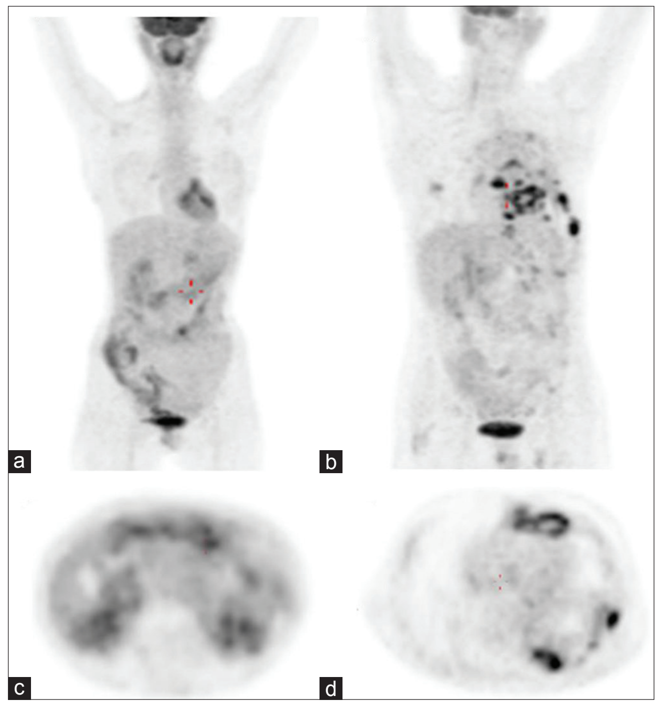

Figure 1: Whole body 18-F-fluorodeoxyglucose positron-emission tomography images (a) shows maximum intensity projection image of a patient from Group A, (b) shows maximum intensity projection image of a patient from Group B, (c) shows transaxial image of a patient from Group A and (d) shows maximum intensity projection image of a patient from Group B

may be used as a reference for modification of layout plan of a PET/CT facility. The present regulatory framework in our country to plan a layout of a PET/CT facility is based on the assumption that around 370–555 MBq FDG is injected in a routine PET/CT imaging.[7] According to regulatory norms, in a PET/CT patient waiting room, there should be at least 2 m distance along with a 230 mm RCC wall between any two 18F-FDG administered patients. However, certain modifications to this layout can be made by adhering to the regulatory norms as described by Jha *et al*.[7] Based on the workload of the department, a PET/CT facility can be planned with appropriate alterations in the area, wall thickness, and material for construction.

Image quality assessment was made purely based on the assessment by an experienced nuclear medicine physician. Although qualitatively assessment parameters could have been be objectively based on Likert scale or similar, but, this was not performed and maybe considered as one of the limitations of the study.[19]

Conclusion

Our study suggests that while reduced 18F-FDG injected activity can reduce the radiation exposure rate from the patient and absorbed dose to the patient, at the same time, reportable image quality can be produced by increasing the imaging time.

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Conflicts of interest

There are no conflicts of interest.

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