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The effective dose result of ^{18}F-FDG PET-CT paediatric patients

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Abstract. Paediatric patient received high exposure from both CT and PET examination. Automatic Exposure Control (AEC) is important in CT dose reduction. This study aimed to compare the effective dose obtained from PET-CT scanner with and without the use of AEC function. In this study, 68 patients underwent PET-CT examination without the use of AEC function, while 25 patients used the AEC function during the examination. Patients involved in this study were between 2 to 15 years old with varies of malignancies and epilepsy diseases.The effective dose obtained from PET and CT examinations was calculated based on recommendation from International Commission on Radiological Protection (ICRP) Publication 106 and ICRP publication 102. The outcome of this study shows that the radiation dose was reduced up to 20% with the use of AEC function. The mean average of effective dose result obtained from PET and CT examinations without the use of AEC and AEC function were found to be as 6.67 mSv, 6.77 mSv, 6.03mSv and 4.96 mSv respectively. Where total effective dose result of PET-CT with non-AEC and AEC were found to be 13.44 mSv and 10.99 mSv respectively. Conclusion of this study is, the installation of AEC function in PET-CT machine does play important role in CT dose reduction especially for paediatric patient.

1. Introduction

Children are more sensitive to ionising radiation which lead to carcinogenic effect rather than adult [1]. Awareness on ionising radiation risk potential to the paediatric patient who undergo PET-CT examination had increased attention from medical lines [2,3]. The PET-CT machine become useful tools in diagnostic, staging, monitoring response to therapy and various type of malignancies [6-10]. The combination of CT and PET scanners, gives information on anatomy and metabolic information respectively. The scanned PET-CT images is more clear rather than a single scan of CT or PET scanner and it helps physician to make decision on further treatment for the patient [11]. There is a demand on the use of PET-CT scan due to its benefits. However, the disadvantage of these technologies is patients who undergo PET-CT examination will expose to dual radiation generated by both CT and PET scanners [12].

As an alternative solution to this radiation risk issue, the technique of Automatic Exposure Control (AEC) function was introduced in PET-CT imaging. It is mainly focused in reducing the CT dose exposure during the scanning procedure. AEC is based on tissue density where imaging parameters such as tube current and voltage were adjusted automatically to the patient's tissue thickness. Determination of whole-body effective dose is one of the important parameters to prove that the AEC can reduce the radiation dose to minimum level as required by the regulations. Many studies done on comparison of PET-CT effective dose between the PET-CT machine which installed with AEC function and without AEC function.

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Effective dose as defined in ICRP Publication 60 [13] is referred to a quantity of weighted sum of equivalent doses to all relevant tissues and organ. CT estimation dose can be derived from other CT dose indicator such as CT Dose Index (CTDI) or Dose Length Product (DLP) [1]. On the other hand, PET dose estimation uses dose coefficient provided by International Commissional Radiological Protection (ICRP) 106 [14]. Radiopharmaceutical of ^{18}F-FDG is well known and widely use in clinical PET imaging. It produced by the bombardment from the cyclotron [12].

2. Materials and Methodology

This retrospective study involved 68 paediatric patients (4 females and 54 males) that were referred to undergo PET-CT examination without the use of Automatic Exposure Control (AEC) technique. 25 patients (9 females and 16 males) underwent the PET-CT examination with the use of AEC technique. Both group of paediatric patients were scanned with the same paediatric imaging protocol. The patients age involved in this study were in the range from 2-15 years and suspected malignancies disease such as Hodgkins Lymphoma, DLBCL, cancer and epilepsy. The patients underwent a standard clinical PET-CT scan procedure in the National Cancer Institute from the beginning of the consultation until received a complete of PET-CT images.

The calculation of PET-CT effective dose includes both internal and external exposure as provided in ICRP publication 102, 103 and 106. The internal radiation exposure referred to the exposure emitted from radiopharmaceuticals ^{18}F-FDG. The ^{18}F-FDG is a positron emitters with beta energies of 240 keV and gamma 511 keV. The internal exposure to patients was computed based on equation (1) [12, 17].

$$D_T = A \times \Gamma_T^{FDG} \tag{1}$$

where D_T is the absorbed doses to a tissue or organ, T, A is the activity (MBq) of ^{18}F-FDG administered to the patient and Γ_T^{FDG} is dose coefficient provided by ICRP 106 for a variety of organs and tissues of the adult MIRD phantom [12,17]

The effective dose, E received by patients were evaluated based on equation (2).

$$E = \sum_T W_T \times D_T = A \times \sum_T W_T \times \Gamma_T^{FDG} = A \times \Gamma_T^{FDG} \tag{2}$$

where Γ_T^{FDG} = 56uSv/MBq dose coefficient for the effective dose F18-FDG (age 2-5 years), Γ_T^{FDG} = 37uSv/MBq dose coefficient for the effective dose F18-FDG (age 6-10 years), Γ_T^{FDG} = 24uSv/MBq dose coefficient for the effective dose F18-FDG (age 11-15 years), W_T tissue weighting factors ($\sum_T W_T$=1) given in ICRP Publication 103 [16]

Assessment of external radiation exposure to the patients was obtained from CT imaging. Based on ICRP publication 102 [18], the external radiation exposure was evaluated based on CT Dose Index (CTDI) and Dose Length Product (DLP). The CTDI is defined as dose profile for a single-slice along a line parallel to the axis of rotation divided by the nominal thickness [19-20].

While determination of external exposure to the patient is basically from the CT scan that generates the x-ray. As referred to ICRP publication 102 [18], external exposure will determine using the CT Dose Index (CTDI) and Dose Length Product (DLP) value which can obtained direct from screen computer scan.

The effective dose, E for external exposure was then calculated according to equation (3) [18]

$$E = k \times DLP \tag{3}$$

where k is coefficient based on empirical weighting factor, which functional of the anatomical region scanned (mSv.mGy^{-1}.cm^{-1}) in ICRP 102 [18] and k=0.015 for trunk.

3. Results and Discussions

A summary of patient's information data and standard clinical whole-body ^{18}F-FDG scan parameters used at National Cancer Institute, Putrajaya Malaysia was presented in Table 1. The average patient body weight and height was 30.43 kg, 38.27 kg and 130.99 cm and 149.99 cm for the case without the use of AEC and with the use of AEC function in PET-CT examination.

Table 1. Summary of patient's information and whole-body PET-CT scan parameters

Case study	Gender	Body weight (kg)	Height (cm)	Tube Current (mAs)	Voltage (kV)	Pitch
68 (without the use of AEC)	14 females 54 males	30.43	130.99	80	120	1.75
25 (with the use of AEC)	9 females 16 males	38.27	149.99	50-100	140	1.25

For machine equipped with AEC function, the CT parameter like tube current, tube voltage and pitch settings was varies between 50-100 mAs, 140 kVp and 1.25 while fixed amount of 80 mAs, 120 kVp and 1.75 for PET-CT machine without AEC function. CT parameter settings such as tube current were adjusted automatically based on patient's tissue density because of installation of AEC function.

Table 2 shows the comparison result between PET-CT effective dose using the AEC function and without the use of AEC function within age categorisation. Based on ICRP publication 106, the paediatric patients who received radiopharmaceutical ^{18}F-FDG was categorised into 4 groups: 0-1 year, 2-5 years, 6-10 years and 11-15 years. The activity dose administered was based on patients' body weight where 5 MBq/kg and 6 MBq/kg was injected to patients who underwent the treatment with and without the use of AEC functions. The dose administered to patients was slightly different due to the use of AEC function.

Table 2. Comparison of PET-CT effective dose result

Age (y)	Case Study (n)		Weight (kg)		Administered Activity (MBq)		PET Effective Dose (mSv)		CT Effective Dose (mGy)		Total PET-CT Effective Dose	
	W/o AEC	With AEC	W/o AEC	With AEC	W/o AEC	With AEC	W/o AEC	With AEC	W/o AEC	With AEC	W/o AEC	With AEC
0-1	0	0	0	0	0	0	0	0	0	0	0	0
2-5	9	5	14.56	21.10	113.74	105.52	6.37	5.90	3.50	2.64	9.87	8.14
6-10	23	9	24.57	27.31	178.22	136.54	6.59	5.05	5.23	3.08	11.82	8.13
11-15	36	11	38.14	55.62	240.67	286.29	5.78	6.87	6.69	7.62	12.87	14.49

Figure 1 shows the comparison of PET-CT whole-body effective dose to patient by age categorisation between underwent PET-CT machine equipped with AEC function and without the use of AEC function. Patient underwent a single PET-CT examination in a day.

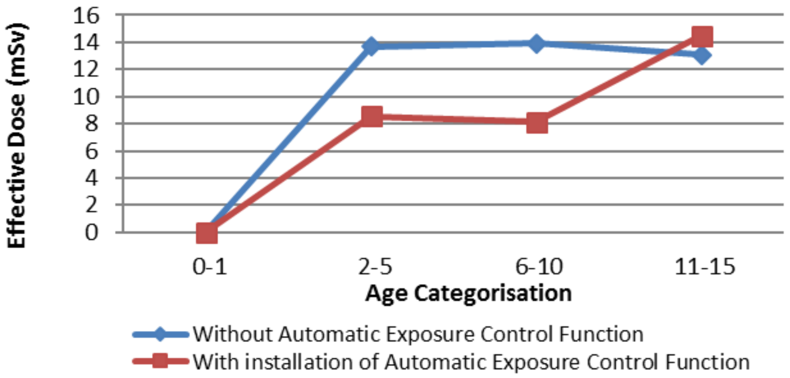

Figure 1. Comparison of PET-CT Whole-body Effective Dose to Paediatric patients based on Age categories between machine with AEC and without AEC function.

PET-CT effective dose at age of 2-5 years and 6-10 years was found to show differences between the machine equipped with AEC and without AEC function. However, findings in this study found that the effective dose for age group of 11-15years shows patient whom underwent PET-CT examination with AEC slightly high compared to without AEC function.

Figure 2 shows whole body PET-CT effective dose in paediatric patients. Results in this study found that the radiation dose exposure was reduced up to 20% to the patient who underwent PET-CT scan that with the use of AEC function. Installation of AEC software contributes to the external exposure (CT exposure), which related with the X-ray tube. Results from this studies in-line with Soni et al., [4] where CT exposure dose is lower than PET radiation dose due to low CT dose was used in the study. The CT dose is proportional to the tube current. Higher tube current will give more radiation dose to patients [4,6]. Thus, adjustment of tube current based on patient size will reduce the radiation dose to patients especially in paediatric patients [24,25]. Furthermore, other CT imaging parameters such as tube voltage, pitch, time per bed and rotation can be adjusted manually to obtain good images [22] rather than rely on AEC function only.

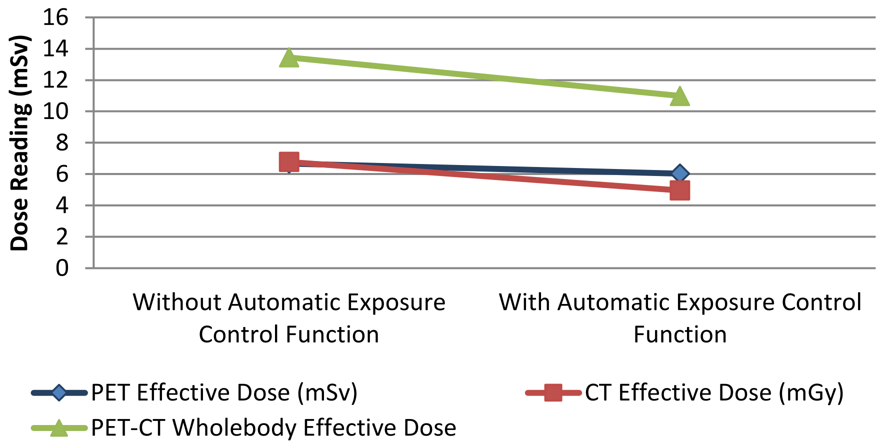

Figure 2. Comparison of PET-CT Whole-body Effective Dose

As for paediatric patient the suggested PET acquisition mode is in 3D compared from 2D [26]. With the use of 3D acquisition mode, the PET detector is managed to collect more data from the photons that travel in the body which effect from the collimations interaction compared to 2 D which the ability to gain data is less due to filter design. With this specialities, the administered dose activity to the patient can be minimise and this indirectly reduce the effective dose [28-30]. The use of 3D acquisition mode and OSEM reconstruction method is to ensure obtaining get a good quality image [26].

Patient's body mass index (BMI) also contributes to the radiation dose exposure. Patient with a small size and short received higher dose compared to bigger size patients. The reason of this is because of less water density in the body and the distance between organ to organ in small range and angle lead to have a lot of scattered radiation produced during the photons travelling with a short distance between each organs at the medium of less water compared to patient having big and tall figure [27].

4. Conclusion

The whole-body PET-CT effective dose was reduced up to 20% with the use of AEC function compared to without the use of AEC function. The AEC function is based on patient size and it related to external exposure which is CT exposure. There are other factors that can be applied to reduce the radiation dose exposure such as other CT parameter, injected administered dose, acquisition mode and scan time. Perhaps, the paediatric scan protocol shall set based on guidelines [23] that based on weight or age for the same PET-CT machine series. These will balance the unnecessary exposure especially when dealing with paediatric patient.

5. References

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