

Evaluation of radiation risk and protection of SPECT/CT compared to SPECT alone

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Faridnejad H. Evaluation of radiation risk and protection of SPECT/CT compared to SPECT alone. *J Mic Bio Rep.* 2022;5(6):64-66.

ABSTRACT

Clinical study has been showing that Single photon emission computed tomography SPECT/CT has several advantages for diagnostic purposes compared to SPECT alone. The main reason is that this hybrid scanner provides us the anatomical and functional imaging for us, so it substantially increases radiation exposure to patients. Consequently, it is fundamental to evaluate and balance the radiation protection and diagnostic needs.

Estimating radiation dose, lifetime attributable, and cancer risk is a crucial role in considering new recommendations of the International Commission on Radiological Protection (ICRP). Based on the examination of the SPECT/CT in this study the lifetime attributable risk is less than 0.27%/0.37% for men/women older than 16 years. We want to justify the question that whether it is essential to acquire additional CT for attenuation correction for diagnostic purposes. In this case, the exposure level should not be more than the national diagnostic reference level.

Key Words: SPECT/CT; Radiation exposure; Radiation risk; Justification

INTRODUCTION

Medical imaging using systems have several advantages for clinical examination, however, using ionizing radiation always poses some risks to health especially risks related to cancer [1]. Some hybrid scanners such as emission tomography/CT or Single Photon Emission Computed Tomography (SPECT)/CT which combined with two imaging modalities have high-dose exposure. SPECT or PET provides us the functional imaging and CT anatomical imaging [2-4]. Usually, most of the SPECT/CT centers do not use the CT of the SPECT/CT individually, since because this CT is equipped on the dual modality for attenuation correction purposes. This CT technology has a high-output x-ray tube. Therefore, this technique improves clinical flexibility and dramatically increases radiation exposure to patients. So, essential to carefully balance the diagnostic needs and radiation protection requirements.

This study aims to estimate radiation doses and risks associated with SPECT and CT examinations and their results. Also, the justification of the SPECT/CT studies.

METHODOLOGY

Principles of radiation protection and evaluate the risks of ionizing radiation on human health

Examination of the SPECT/CT leads to stochastic effects such as cancer, which occur several years or days after exposure. Radiation-induced which leads to cancers cannot be recognized the only way is through epidemiological studies. For instance, studies on bombings in Hiroshima and Nagasaki provide knowledge of the relationship between radiation risk and absorbed dose and age of diagnosis. So, this kind of data can support by a multitude of smaller groups [4,5]. There are several controversies about the risk of diagnostic radiation (<100 mSv) [6]. We can use a Linear, No-Threshold (LNT) hypothesis, which tells us the risk estimates per dose unit. In this hypothesis, we should consider two assumptions first, there is no matter how radiation is small, it leads to risk. Second, the risk of dose-proportional to the dose absorbed in the tissue. Radiation protection standards are based on the LNT hypothesis, and it considers the risk evaluated of low dose and represents an upper bound [6, 7]. Regarding this issue, the recommendation for radiation protection is for obtaining required diagnostic information all procedures should be optimized to keep doses as low as reasonably achievable (ALARA) [5] (Figure 1).

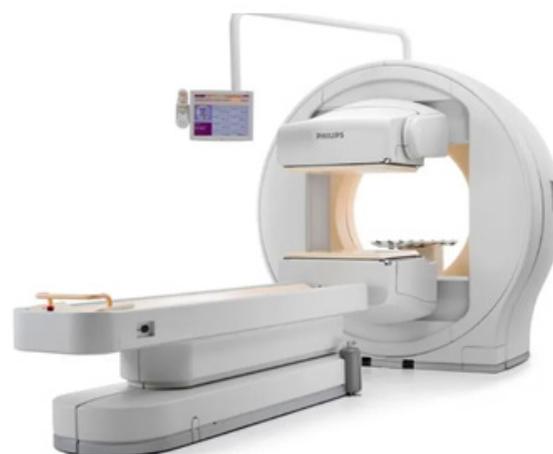


Figure 1) SPECT/CT

RESULT AND DISCUSSION

Fundamental dose quantities

In general, we must consider that the detrimental radiation effects depend on the amount of energy deposited by ionizing radiation in a sporran or tissue T. When the radiation energy absorbed in a small volume element of matter is divided by its mass, we will have fundamental physical dose quantity. Its unit is gray. Based on radiological protection purposes, the absorbed dose can be defined by the averaged over tissue and weighted by the dimensionless radiation weighting factor, WR, to reflect the difference in biological effects of radiation with a low and high Linear Energy Transfer (LET). So, the weighted dose is

$$HT=WR DT \text{ (given in the unit sievert, } Sv=1 J/kg)$$

when the ionizing radiation interacts with organs, tissues or organs are not equally sensitive. So, ICRP introduces the tissue-weighting factor, WT [8]. Examination of the SPECT/CT is one of the ununiform exposure. For the

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Received: 13-October-2022, Manuscript No. PULJMBR-22-5796; Editor assigned: 15-October-2022, Pre QC No. PULJMBR-22-5796 (PQ); Reviewed: 31-October-2022, QC No. PULJMBR-22-5796 (Q); Revised: 04-November-2022, Manuscript No. PULJMBR-22-5796 (R); Published: 20 November-2022, DOI: 10.37532/puljmb.2022.5(6).64-66



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calculation of the exposed dose, we must consider tissue weighting factors for each organ based on the following equation:

$$E = \sum_T WT.H_T \text{ with } \sum_T WT = 1$$

E (in Sv) is the effective dose. We can add and compare the probability of stochastic radiation effects to this equation.

$$CTDI_{vol} = \frac{CTDI_w}{p}$$

Because SPECT/CT examination is yielding from a different pattern of dose distribution in the body this is a reasonable way to use this. Measuring the effective dose directly is too difficult, one solution for it is dose-related quantities for radio diagnostic procedures. there are some different quantities that we can measure. For example, activity, A for radiopharmaceutical administered for nuclear medicine or Computed Tomography Dose Index (CTDI) and the Dose-Length Product (DLP) in CT. Weighted CTDI is given in Gy as the average dose inside an irradiated slice. We have to use the average dose because the dose in a slice may decrease or increase, So, the average dose is given by volume CTDI.

$$DLP = CTDI_{vol} \cdot L$$

P is the pitch factor. L is the length of the scanned organ. the typical activities of the adult in German for the SPECT radiopharmaceuticals are summarized in Table 1. Also, the values of CTDIvol, DLP, and L are summarized in Table 2.

The effective dose of the SPECT and CT examinations was calculated respectively in Tables 1 and 2. the effective doses injected into the patient's body for SPECT examinations are any amount between 2 mSv and 10 mSv. For CT examinations the effective dose was low because the irradiation tissue es had a low weighting factor, but the brain yielded the highest local dose levels CTDI vol. the values of the effective doses of the patients under the SPECT and CT and SPECT/CT examinations were determined and compared it in Table 3 [8-10].

Assessment of radiation risks to patients in SPECT/CT

Effective doses cannot be used for detail-specific investigations of individual

radiation risk [4]. For this purpose, it is necessary to use specific data characterizing the exposed individual.

We can estimate the risk of radiation exposure based on the Excess Relative Risk (ERR) or Excess Absolute Risk (EAR) models. The EAR model expresses the risk in terms of differences between the total risk and the baseline risk, but the ERR model is excess risk is proportional to the baseline risk, i.e., the risk of a person developing specific cancer in the absence of radiation. age, sex, and organ risk estimates are based on ERR or EAR models. ERR model is defined as a baseline risk the risk of that provides cancer in absence of radiation. The EAR model is the risk difference between total risk and baseline risk.

$$ar_T(e,a,s,D_T) = r_0 \cdot T(a,s) \cdot [1 + err_T(e,a,s,D_T)]$$

S is the absolute risk of a person of sex, DT is an absorbed organ dose after exposure, at age e, to develop cancer. In this equation r is the baseline rate, O excess relative rate, T and err T excess absolute rate. Lifetime attributable

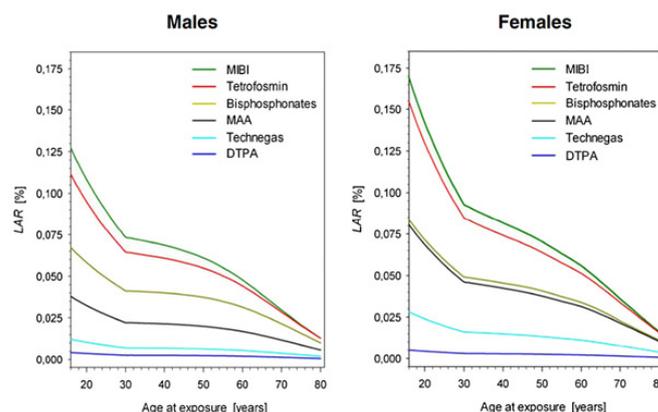


Figure 2) Values of lifetime attributable risks (10) resulting from the administration of some SPECT radiopharmaceuticals to adult male (left column) and female (right column) patients at different ages. 99mTc-labelled compounds (upper row): MIBI (800 MBq, rest), tetrofosmin (800 MBq, rest), bisphosphonates (600 MBq), MAA (160 MBq), techniques (400 MBq, 10 % lung uptake) and DTPA (950 MBq, 4 % lung uptake).

TABLE 1
Activities and dose values for radiopharmaceuticals used in SPECT [7]

Organ	radiopharmaceutical	hE(μSv/MB) ^a	A(MBq)	E(mSv) ^c
Brain	¹²³ I	40	180	72
Parathyroid	99 mTc-methoxyisobutyl	6.8	535	3.6
Myocardium	9 mTc-MIBI	Rest, 6.8 Stress, 5.9	970d	6
Lung	99 mTc-red blood cells	11	700	7.7
Skeleton	99 mTc-bisphosphonates	4	510	2.2
Whole body	111 In-octreotide	59	167	9.9

TABLE 2
Quantities and effective dose for fully diagnostic CT [9]

Organ	CTDI _{vol} (mGy) ^a	DLP (mGy cm) ^a	L(cm) ^a	E(mSv) ^b
Brain	57.5	697	13.5	1.4
Chest	9.9	314	33.8	5.7
Upper Abdomen	11.2	319	25.7	5.8
Abdomen	13	604	50.2	9.7
Pelvis	11.8	320	26.8	4.2

TABLE 3
Comparison of the effective doses SPECT and CT by the SPECT/CT

Organ	Present Ea(mSv)	Larkin et al.Ea(mSv)	Sharma et al.Ea(mSv)
CT			
Brain	1.3 ± 0.5	0.7 ± 0.5	0.9 ± 0.6
Chest	6.9 ± 2.6	7.4 ± 2.7	3.9 ± 2.3
Abdomen	10.6 ± 5.0	8.6 ± 4.6	25.7
Pelvis	4.9 ± 3.6	6.1 ± 2	4.6 ± 2.5
SPECT			
99mTc-biophosphonates	3.8 ± 1.1	5.4 ± 1.7	4.1 ± 1.7

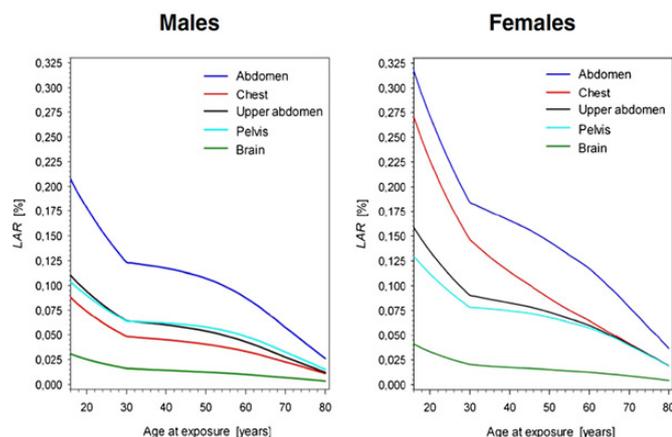


Figure 3) Lifetime attributable risks (10) for fully diagnostic single-phase CT examinations of the brain, chest, upper abdomen, abdomen, and pelvis performed at different ages in adult males (left) and female (right) patients

risk, LAR, can be calculated by summing up all T (e, a, s, DT). In this study life table data, LARs were estimated for SPECT and CT examinations considered in detail this estimation is plotted in (Figures 2 and 3) for both sex and different ages. Based on this we can determine the risk related to the SPECT/CT by the sum of the LARs that are determined separately. The result of this examination was LAR decreases for all examinations by increasing age at exposure. This result shows the lifetime baseline cancer risk for all cancers (excluding skin cancer) is about 39% for women and about 47% for men [11,12].

Justification and optimization of SPECT/CT examinations

Individual justification of the SPECT/CT for diagnostic purposes is growing and most of the studies demonstrate the benefits of this hybrid imaging technology compared to SPECT alone [2]. In general, the spectrum of the clinical shows that SPECT/CT has a major impact on the age distribution of patients. However, there are several questions regarding the benefits and risk factors of SPECT/CT to SPECT alone [7]. So, it is essential to consider the benefits and risks of it when adding CT to SPECT scan [13].

CONCLUSION

Using combined SPECT/CT will be increased the radiation exposure and risk to the patients whenever we used it alone. Consequently, it is essential to balance the two factors of radiation protection and diagnostics needs by considering the justifications and optimization. choosing the proper

examination depends on the individual situation and the physician and it plays a crucial role in justifications. SPECT/CT studies have to be optimized by adapting dose reduction from CT practice. and it should not exceed the DRLs.

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