Estimation of Radiation Dosimetry for some Common SPECT-CT Exams

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Abstract: Single photon emission computed tomography associated to X ray computed tomography (SPECT-CT) is a nuclear medicine tomographic imaging technique which improves diagnostic accuracy for particular clinical indications due to the possible attenuation and/or scatter correction of the SPECT functional images and the availability of helpful anatomic information. However, the introduction of CT in the nuclear diagnostic process results in a significant increase of the patient dose. Ideally is to establish sufficient image quality for a specific diagnostic task with the lowest effective dose to the patient in order to reduce stochastic effects. Indication of SPECT-CT should be made to adhere to the "As Low as Reasonably Achievable (ALARA)" principle and ensure that the patient is not subjected to unnecessarily high levels of radiation.

In this study, we evaluate effective doses received during some standard nuclear medicine exams from 100 patients who underwent SPECT-CT in our department and analyze parameters involved in variation of these doses according to the literature data.

Keywords: Single photon emission computed tomography (SPECT), X ray computed tomography (CT), Dosimetry, nuclear medicine.

INTRODUCTION

Single photon emission computed tomography associated to X ray computed tomography (SPECT-CT) is a nuclear medicine tomographic imaging technique which improves diagnostic accuracy for particular clinical indications due to the possible attenuation and/or scatter correction of the SPECT functional images and the availability of helpful anatomic information [1]. According to literature data SPECT-CT compared to SPECT alone causes more radiation to the patient which is not sufficient to cause deterministic effects. For SPECT effective dose depends on administered activity and patient's age. In fact the average radiopharmaceutical effective dose varies from varies from tens to thousands of mSv for some nuclear medicine exams [2]. However, the introduction of CT in nuclear diagnostic process results in a significant increase of the patient dose. In general, effective dose (E) for CT examinations can be higher than most other diagnostic imaging modalities [3]. Some authors have questioned the need to reduce doses particularly in children [4, 5]. A considerable choice of CT user-selectable exposure factors results in a significant variation in CT dose to the patient. In addition, in a nuclear medicine facility devoid of CT technologists, there could potentially be limited knowledge of CT techniques, clinical applications, and associated dose consequences [6]. This study aims to evaluate effective doses received during some standard nuclear medicine exams with SPECT-CT and to analyze parameters involved in variation of these doses.

METHODS

Patient data from a dual-headed SPECT unit with an integrated 2-slice CT scanner (Symbia T E-Cam, SiemensMedical Systems, Erlangen, Germany) is presented in this study.

The CT parameters used were: tube current of 30 - 90 mAs, slice thickness of 3–5 mm, and tube voltage of 110-130 kV.

Data from 272 scans of common nuclear medicine procedures (^{123}I-MIBG, ^{99m}Tc-MIBI parathyroid, [111] In-octreotide, ^{131}I post therapy scan and ^{99m}Tc-MDP bone scan) comprising 100 patients between 20 and 83 years old (mean age: 56 years), were presented in this study.

For each patient the CT was acquired immediately after SPECT; the patient being kept in the same position to minimize offsets due to movement and allow proper registration on fused imaging. The contribution of total effective dose imparted by the nuclear tracers

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Table 1:   Factors for DPL/Effective Dose Conversion Over Various Body Regions and Patient Ages [9]

Region of body	Effective dose per DLP (mSv (mGy cm)$^{-1}$) by ag				
	0 year old	1 year old	5 year old	10 year old	Adult
Head and neck	0,013	0,0085	0,0057	0,0042	0,0031
Head	0,011	0,0067	0,0040	0,0032	0,0021
Neck	0,017	0,012	0,011	0,0079	0,0059
Chest	0,039	0,026	0,018	0,013	0,014
Abdomen and pelvis	0,049	0,030	0,020	0,015	0,015
Trunk	0,044	0,028	0,019	0,014	0,015

for each patient was calculated by multiplying the average administered activity for all patients by the "effective dose per unit administered activity" conversion factors listed in the International Commission on Radiological Protection (ICRP) Publication 53 [5] and 80 [7, 8].

The effective dose from the CT portion of the examination is estimated from the product of the dose length product (DLP) and a body-region-specific conversion factor, *k* (mSv mGy^{-1} cm^{-1}), which take into account the varying biological sensitivities of different organs as given in Table **1** [9]. DLP is a patient-specific value determined by the scan length and the acquisition parameters; it represents the total amount of radiation delivered in the acquisition.

The CT scan was acquired immediately following completion of the SPECT study with the patient in the same position to minimize motion errors.

RESULTS AND DISCUSSION

The total effective dose received by each patient for SPECT-CT examination represents the sum of the effective dose induced by radiotracer administered to patient and effective dose induced by CT portion, according to the ICRP 80 recommendations [8]. Our results displayed on Tables **2** and **3** show that the average effective dose varies according to type of the exam: 1926,9 mSv for ^{131}I-post therapeutic scans, 5.4 mSv for ^{123}I-MIBG scans and 4,2 mSv for bone scans. The percentage increase of effective dose by the inclusion of the CT is about 125% for ^{123}I-MIBG scans, 83 % for bone scans, whereas it is negligible in case of treatment with [131]I (0.15%).

According to our results, and literature data [10,11], combined imaging results in a significant increase of the patient dose. It is true that the introduction of CT in the nuclear diagnostic process results in a significant

Table 2:   The Average Effective Dose for the Total SPECT-CT Effective Dose for each Examination and the Percentage Increase in Effective Dose by the Inclusion of the CT

Type of study	No of patients	Average Whole body effective dose in routine nuclear medicine examinations			Average Effective dose for the CT portion of the routine nuclear medicine examinations		Average Effective dose for the total SPECT-CT effective dose for each examination
		Average Activity (MBq)	Dose per unit activity (mSv/MBq)	Average Effective dose (mSv)	Average Effective dose (mSv)	Range effective dose (mSv)	Total effective dose (mSv)
^{99m}Tc-MDP	30	740	0.0057	4.2	3.5+/-1.2	0.3-6.5	7.7
^{99m}Tc-MIBI parathy	20	925	0.009	8.3	2.3+/-0.7	1.0-3.5	10.6
[111]In-octreotide	10	185	0.054	10	2.7+/-1.3	1.9-5.4	12.7
[131]I post therapy scan	30	3700	0.52	1924	2.9+/-1.9	1.2-5.9	1926.9
^{123}I-MIBG	10	185	0.013	2.4	3.0+/-1.1	1.4-5.8	5.4

Table 3: The Percentage Increase of Effective Dose by the Inclusion of the CT

Type of Study	No of Patients	% Increase of Effective dose by the inclusion of the CT
^{99m}Tc-MDP	30	83%
^{99m}Tc-MIBI parathyroid	20	28%
^{111}In-octreotide	10	27%
^{131}I post therapy scan	30	0,15%
^{123}I-MIBG	10	125%

increase of the dose delivered to patient, however, the radiation levels are well below the threshold for the occurrence of deterministic effects. Knowing that the main risk to patients is the occurrence of cancer and that this risk increases by 4% for every Sv of total effective dose received by a patient [9], in our series, this increased risk induced by additional exposure of the CT low dose, is insignificant and does not exceed 0.02%. Taking into account the diagnostic contribution of a review SPECT- CT compared to SPECT examination alone, this "overhead" dose is justified because of the benefit to patient. However, this "additional" radiation should be optimized according to the desired objective (anatomical and / or attenuation correction) and CT parameters available on the machine. The most effective way to reduce doses received is to adapt irradiation protocols and acquisition parameters to the morphology of the patient [12].

For SPECT, the effective dose is dependent on administered activity and the patient's age. In CT, several methods are available to optimise and minimise the radiation absorbed doses [11, 13, 14]. Among the parameters which influence patient radiation dose and image quality: tube current, tube voltage, filtration, collimation, reconstruction method, reconstruction filter, slice thickness, pitch, and scanning length (Table **4**) [12]. These parameters should be optimized for each

specific examination and special efforts should be made with pediatric CT protocols [15].

The operator can monitor and modify most of them to obtain the necessary image quality with a minimal absorbed dose to the patient. Several studies have demonstrated an ability to affect radiation dose and image quality by using a lower tube voltage [16, 17]. The CT acquisition on the Symbia T were performed using a tube current modulation system, Care Dose 4D (Siemens). CARE Dose 4D assesses the size of the patient cross section being scanned and adjusts tube current relative to the reference effective milliamperage. This system have a number of potential advantages, including better control of patient radiation dose, reduced load on the x-ray tube, and the maintenance of image quality [18].

Furthermore, patient dose must be as low as compatible with the medical purpose. Practice leading to a medical exposure must be clearly justified and protection against radiation must be optimized, particularly for children. Also, quality control procedures have to be defined because of the coupling between the two devices.

Finally, it should be noted that the reduction of patient exposure in CT is not only dependent on technological innovation, but also on the training of medical and paramedical staff. In fact, users are

Table 4: CT Parameters Influencing Radiation Exposure

Radiation exposure from CT scan depends on operator dependent factors:
mAs: directly proportional to radiation dose
KVp: not lienarry proportional to dose
Pitch: inversly related to dose
Slice thickness: requires an increase in mAs
Number of scans: doubling the radiation dose
Scanning mode: step- based vs spiral technique, single-slice vs multislice

required to undergo appropriate practical training to the purpose of radiological and / or scintigraphic practices to be aware and competent in radiation protection of the patient [19].

CONCLUSION

Despite the relative increase in radiation exposure associated with SPECT-CT is generally considered acceptable; reducing the patient dose should be a constant preoccupation of prescribing physician, nuclear physician's and qualified personnel performing the act. Indication of SPECT-CT must be clearly justified and protection against radiation must be optimized, particularly for children. Also, quality control procedures have to be defined because of the coupling between the two devices.

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