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Patient Dosimetry in SPECT/CT Lymphoscintigraphy Examinations

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ABSTRACT

Background: Lymphoscintigraphy imaging procedure is performed at the nuclear medicine department to evaluate sentinel lymph nodes for excisional biopsy in patients with melanoma, and to assess the use of the intraoperative gamma probe in the operating room. The objectives of this study are to evaluate the radiation dose of patients during lymphoscintigraphy SPECT/CT procedure and to estimate its radiogenic risk.

Methods: Of the thirty patients that underwent SPECT/CT in this research, 63.3 % (19 patients) and 36.7 % (11 patients) were females and males, respectively. For SPECT/CT [GE Hualun Medical Systems (Discovery NM/CT 670Pro)].

Results: The effective dose (mSv) per procedure ranges from 0.21 to 0.5 mSv, with an average dose value of 0.22 mSv. The effective dose for CT examination is 0.05 (ranging from 0.04 to 0.1 mSv per procedure). Therefore, the effective dose for CT is lower than that for SPECT by a factor of 5. This radiation risk is equivalent to 5 weeks of natural background radiation exposure.

Conclusions: The level of radiation dose place it under the category of low radiation risk for cancer, equivalent to 1 cancer case per 10^5 SPECT/CT lymphoscintigraphy procedures. Moreover, this dose is lower than previously published studies suggesting that the patients were well protected during the entire procedure.

Key words: Effective dose, SPECT/CT, Lymoscingtigraphy, Radiation risk

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INTRODUCTION

Lymphoscintigraphy imaging procedure is performed at the nuclear medicine department to evaluate sentinel lymph nodes for excisional biopsy in patients with melanoma, and to assess the use of the intraoperative gamma probe in the operating room. Patients with lymphedema are exposed to repetitive radiation exposures from hybrid and separated CT and nuclear medicine examinations. Lymphatic-edema or lymphedema is an acute debilitating disease that is often wrongly diagnosed, cured too late, or not treated at all. Lymphoma results from reduced lymphatic transport because of injury to the lymphatics, infection, or congenital abnormality [1-3]. Patients with lymphatic disease may not present with pain in mild conditions. Lymphoscintigraphy is an effective therapeutic means of diagnosing lymphatic-edema, and it can be applied mostly after the disease has been categorized. The number of cases of secondary lymphedema (breast and pelvic cancer therapy, frequent infections, injuries, or vascular surgery) is about 10 million, and the worldwide incidence of parasitic infections is about 90 million [1-3].

To effectively treat lymphedema, lymphoscintigraphy is used to understand its pathophysiology and the influence of technical factors like the choice of radiotracer, the time of injection, and the patient's activity after injection on the images [4-7].

Lymphoscintigraphy is also used to evaluate breast cancer-related lymphedema (BCRL). The procedure distinguishes normal lymphatic function from lymphedema. The perfect radiotracer for the study of the lymphatic system is one that enters the lymphatic system without any clearance through the microvascular blood circulation. ^{99m}Tc labelled with human serum albumin (HSA) shows this feature as HSA is rapidly transported into the lymphatic vessels [8-10]. The radiation dose to patients and hospital staff is one of the main concerns of lymphoscintigraphy. Alnaaimi et al. [11] reported that hospital staff may be exposed to higher radiation doses during preparation and administration of radiopharmaceuticals.

Single-photon emission computed tomography combined with X-ray computed tomography (SPECT/CT) has a vital role in improving the diagnostic precision by composite image acquisition (anatomical and functional); however it significantly increases radiation risk to patients, particularly during repetitive exposure. Therefore, the assessment of radiation risk is recommended to ensure the safety of the imaging environment. The objective of this work is to evaluate the radiation dose during SPECT/CT examination, and to estimate the cancer risk probability resulting from patient exposure.

MATERIALS AND METHODS

Imaging protocol

Patient preparation was based on individual patient's condition, but in general, no nutritional or medical treatment constraints were instituted for the procedure. The patients were instructed to be well hydrated before the SPECT/CT examination. Contrast was by a manually administered 99mTc sulfur colloid with an activity range of 18.5 MBq (0.2 mCi) to 40 MBq (1.1 mCi). In adult patients, ^{99m}Tc sulfur colloid, ^{99m}Tc human serum albumin (HSA), or ^{99m}Tc nano-colloid albumin was injected into the skin for determination of lymph node drainage in breast cancer and malignant melanoma patients.

The imaging machine used was SPECT/CT [GE Hualun Medical Systems (Discovery NM/CT 670Pro)] which is equipped with Elite NXT detector technology comprising many features such as ultrashort photomultiplier tubes (PMTs) and a very thin, sensitive layer which enables high energy resolution and high count rate. The CT system consists of 16 slice CT (Bright-Speed Elite). The machine can also acquire high-quality SPECT/CT images without affecting the image quality.

Thirty patients underwent lymphoscintigraphy for different clinical indications, as illustrated in Table 1. Lymphoscintigraphy helps to evaluate the body's lymphatic system for diseases using small amounts of radioactive materials called radiotracers that are typically injected into the bloodstream, inhaled, swallowed, or in the case of lymphoscintigraphy, injected into the skin.

The radiopharmaceutical material is injected intradermally on the patient's right and left lower extremities in the 1st and 2nd web space of each foot. The surgical procedures are undertaken immediately after the procedure. The radiotracer travels through the area being examined and gives off energy in the form of gamma rays, which are detected by a special camera and a computer to create images of the inside of the body. Because it can pinpoint molecular activity within the body, lymphoscintigraphy offers the potential to identify lymphatic disease in its earliest stages.

Table 1: Clinical indications of lymphoscintigraphy procedures.

No	Clinical indications	No	Percentage
1	Bilateral lower limb swelling	20	66.7
2	Upper limbs after surgery	3	10
3	Sentinel lymph node mapping for Melanoma	4	13.3
4	Cancer (Sarcoma, hemangioma)	3	10
	Total	30	100

Image acquisition

Anterior and posterior static images of the lower limbs were obtained immediately for a 1-hour dynamic image, and spot images were acquired 2 and 4 hours later. SPECT/CT of the pelvis and the lower limbs, including both knees were also performed.

Dynamic images of the feet were acquired for 30mins, followed by half body sweep images from the upper abdomen to the feet at 1, 2, and 43 hours. Images of the SPECT-CT of the pelvis were processed using the cinematic display of images viewed by the physician. No instructions were needed after the procedure.

Patient dosimetry

In the dosimetry tables included here, the local radiation dose has been ignored, and the effective dose has been calculated under the assumption that fifth of the administered activity (20%) absorbed consistently [12]. The reason for ignoring the local radiation dose is that deterministic effects (e.g., local skin necrosis) are not a concern for ^{99m}Tc labeled radiopharmaceuticals. All patients who underwent lymphoscintigraphy or SPECT/CT procedures for lymphedema were included in the study. Ethics and research committee at King Fahad Medical City approved the study. All data were collected retrospectively from the Picture Archive and Communication System (PACS) and patients record. The data collected were image acquisition protocol and patients' and staff's safety. Patient's data included age, body mass index (BMI(kg/m^2)), duration of lymphedema, location of disease, gender, and clinical indications. The effective doses (E) were estimated using the OLINDA software (Vanderbilt University, Nashville, USA), while the effective dose from CT was estimated using the Impact software (Saint George Hospital, London, UK).

RESULTS AND DISCUSSION

Table 2 shows the administered radiopharmaceuticals for patients during lymphoscintigraphy using a hybrid system (SPECT/CT) according to the King Fahad Medical City (KFMC) imaging protocol. The effective radiation doses during SPECT/CT lymphoscintigraphy depend on exposure parameters for the CT machines and the amount of the administered activities. Of the thirty patients that underwent SPECT/CT in this research, 63.3 % (19) and 36.7% (11) were females and males, respectively. Table 2 presents patients' characteristics (age (y), and height (m)) and the administered activity per patient. The effective dose (mSv) per procedure ranged from 0.19 to 0.41 mSv, with an average dose value of 0.22 mSv. There was no variation between administered activity and patient's effective doses according to the gender. During CT examination as a part of the SPECT/CT procedure, patients received higher doses compared to the effective doses gotten from the administration of ^{99m}Tc sulfur colloid. The average effective dose obtained from CT examination was 0.05, ranging from 0.04 to 0.1 mSv per procedure. The effective dose in CT was therefore lower than that of the SPECT procedure by a factor of 5. This was attributed to the low radiosensitivity of the lower limbs because no sensitive organs are included in the primary beam. During SPECT/CT lymphoscintigraphy examinations, the radiation dose is low compared to other SPECT/CT imaging procedures or even during separate SPECT or CT procedures. This low dose is due to the small amount of administered activity and low exposure parameters.

Table 2: Mean, standard deviation and range of patient's demographic data and administered activity.

Gender	No	Age (y)	Height (cm)	Weight (kg)	Activity (mCi)	Activity (MBq)	Effective dose (mSv)
F	19	45.05 ± 16 (12-75)	154.79 ± 6 (144-162)	92 ± 25 (46-145)	0.56 ± 0.2 (0.5-1.1)	21 ± 6 (18.5- 40.7)	0.21 ± 0.01 (0.19-0.41)
M	11	40 ± 17 (12- 57)	168 ± 19 (132-181)	(105 ± 22) (61-121)	0.58 ± 0.2 (0.51.0)	21.6 ± 8 (18.5- 37)	0.22 ± 0.01 (0.19-0.4)
Overall	30	44 ± 16 (12-75)	158 ± 11 (132-181)	(95 ± 25) (46-145)	0.57 ± 0.2 (0.5-1.1)	21 ± 7 (18.5-40.7)	0.21 ± 0.01 (0.19-0.41)

From Table 3, the CT imaging protocol is based on fixed exposure parameters. The effective dose (mSv) conversion factor from DLP (mGy.cm) is comparable with the value reported by others (0.0002 mSv/DLP (mGy.cm)). The overall patient radiation dose of SPECT/CT is the summation of the effective dose due to the radiopharmaceutical material injected (^{99m}Tc sulfur colloid) for SPECT image acquisition and the effective CT dose resulting from external radiation exposure. Therefore, careful radiation dose optimization during SPECT/CT procedures will reduce the patient doses to the lowest possible level without affecting the clinical findings [13].

Table 3: CT exposure parameters and patients' doses during SPECT/CT examination.

Tube potential (kVp)	Tube current –time product (mAs)	rotation time (s)	slice thickness(mm)	pitch	CTDIvol (mGy)	DLP (mGy.cm)	Effective dose (mSv)
120	80	0.8	3.75	1.375	4.11	241.4 ± 74 (178.8-324.1)	0.05 ± 0.01 (0.04-0.1)

For this reason, the radiopharmaceutical material used and its administered activity, as well as the image acquisition and processing modalities both in SPECT and in CT must be carefully evaluated. The use of SPECT/CT lymphoscintigraphy procedures in clinical practice is important due to its ability to demonstrate the lymphatic vessel drainage patterns. Therefore, with a low dose per procedure, the surgeon can use the imaging without any increase in radiation risk. The current radiation risk from SPECT/CT is equivalent to 5 weeks of natural background radiation exposure. This places it under the category of low radiation risk for cancer, equivalent to 1 cancer case per 10^5 SPECT/CT lymphoscintigraphy procedures.

Buck et al. [14] showed that the effective dose of SPECT/CT ranged from 0.19 to 0.41 mSv using low dose imaging protocol per procedure, which is higher than the current study. However, Roach et al. [15] reported comparable values to our study, ranging from 1–2 mSv per SPECT/CT procedure. In addition, patients' effective doses (mSv) per SPECT/CT for chest, abdominopelvic, and head were reported to be 1.1, 1.3, and 0.2 mSv respectively [16]. The CT dose during SPECT/CT is within the diagnostic reference level values range that proposed by Avramova-Cholakova et al. [17] (CTDIvol=4 mGy, DLP (mGy.cm)=120 and ad mistered activity (MBq)=74).

CONCLUSIONS

In the current study, the patients' doses during SPECT/CT lymphoscintigraphy were evaluated. The patients' radiation dose from the administered activity was higher than the effective dose obtained from CT by a factor of 22.

The current radiation risk is equivalent to 5 weeks of natural background radiation exposure, which places it under low radiation risk for cancer, i.e. 1 cancer case per 10^5 SPECT/CT lymphoscintigraphy procedures. The current patient dose is lower than previously published studies, suggesting that the patients were well protected during the entire procedure.

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ETHICAL APPROVAL

Received from King Fahad Medical City.

CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

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