Radiation Dosimetry of Whole-Body Dual-Tracer ^{18}F-FDG and ^{11}C-Acetate PET/CT for Hepatocellular Carcinoma

Dan Liu[1], Pek-Lan Khong[1], Yiming Gao[2], Usman Mahmood[3], Brian Quinn[3], Jean St. Germain[3], X. George Xu[2], and Lawrence T. Dauer[3,4]

[1]Department of Diagnostic Radiology, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong, China; [2]Department of Mechanical, Aerospace, and Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, New York; [3]Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, New York; and [4]Department of Radiology, Memorial Sloan Kettering Cancer Center, New York, New York

Combined whole-body dual-tracer (^{18}F-FDG and ^{11}C-acetate) PET/CT is increasingly used for staging hepatocellular carcinoma, with only limited studies investigating the radiation dosimetry data of these scans. The aim of the study was to characterize the radiation dosimetry of combined whole-body dual-tracer PET/CT protocols. **Methods:** Consecutive adult patients with hepatocellular carcinoma who underwent whole-body dual-tracer PET/CT scans were retrospectively reviewed with institutional review board approval. OLINDA/EXM 1.1 was used to estimate patient-specific internal dose exposure in each organ. Biokinetic models for ^{18}F-FDG and ^{11}C-acetate as provided by ICRP (International Commission on Radiological Protection) publication 106 were used. Standard reference phantoms were modified to more closely represent patient-specific organ mass. With patient-specific parameters, organ equivalent doses from each CT series were estimated using VirtualDose. Dosimetry capabilities for tube current modulation protocols were applied by integrating with the latest anatomic realistic models. Effective dose was calculated using ICRP publication 103 tissue-weighting coefficients for adult male and female, respectively. **Results:** Fourteen scans were evaluated (12 men, 2 women; mean age ± SD, 60 ± 19.48 y). The patient-specific effective dose from ^{18}F-FDG and ^{11}C-acetate was 6.08 ± 1.49 and 1.56 ± 0.47 mSv, respectively, for male patients and 6.62 ± 1.38 and 1.79 ± 0.12 mSV, respectively, for female patients. The patient-specific effective dose of the CT component, which comprised 2 noncontrast whole-body scans, to male and female patients was 21.20 ± 8.94 and 14.79 ± 3.35 mSv, respectively. Thus, the total effective doses of the combined whole-body dual-tracer PET/CT studies for male and female patients were 28.84 ± 10.18 and 23.19 ± 4.61 mSv, respectively. **Conclusion:** Patient-specific parameters allow for more accurate estimation of organ equivalent doses. Considering the substantial radiation dose incurred, judicious medical justification is required with every whole-body dual-tracer PET/CT referral. Although radiation risks may have less impact for the population with cancer because of their reduced life expectancy, the information is of interest and relevant for both justification, to evaluate risk/benefit, and protocol optimization.

Key Words: PET/CT; dual tracer; CT; radiation exposure; effective dose

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PET/CT has become an indispensable imaging modality for the diagnosis, staging, and monitoring of therapy response of a broad range of diseases in adult patients (*1,2*). Despite the significant clinical benefits provided by PET/CT, the relatively high radiation exposure of patients has prompted a heightened concern from the radiology community and regulatory bodies. PET imaging is one of the more challenging areas of radiation protection in medicine as a result of its combination with CT. In this light, quantification of the potential risk from radiation exposure forms a core responsibility for the PET/CT community. As an important aspect in evaluating the use of PET/CT scanning in medical practice, accurate dosimetry can help in the assessment of procedure justification (i.e., benefit greater than risk) (*3*).

Hepatocellular carcinoma (HCC) is 1 of the top 3 causes of cancer death in many Asian countries. The disease is also believed to be showing an upward trend in America because of the increasing frequency of hepatitis C viral infection (*4*). Accurate staging of HCC is a prerequisite in selecting the optimal treatment and to determine the prognosis. Diagnostic staging before treatment relies on imaging evaluation, primarily using either contrast-enhanced CT or MRI.

Besides CT and MRI, both ^{18}F-FDG and ^{11}C-acetate PET imaging have demonstrated a certain degree of capacity to detect and stage HCC (*5–9*). Because of the mutual complementarity based on tumor cellular differentiation, in the past few years, the combined use of these 2 tracers has been reported to increase the overall sensitivity for the detection of primary and metastatic HCC (*5–7,9*), which suggest that dual-tracer PET/CT is an improved comprehensive modality compared with single-tracer ^{18}F-FDG PET.

However, whole-body dual-tracer PET/CT incurs an increased radiation burden to patients compared with a single-tracer PET/CT examination. Because these 2 biochemical probes are widely used in PET/CT studies of malignancy metabolism in humans, estimation of whole-body absorbed doses due to the intravenous administration of ^{18}F-FDG or ^{11}C-acetate and radiation exposure

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For correspondence or reprints contact either of the following:
Lawrence T. Dauer, Department of Medical Physics, Box 84, Memorial Sloan Kettering Cancer Center, 1275 York Ave., New York, NY 10065.
E-mail: dauerl@mskcc.org
Pek-Lan Khong, Department of Diagnostic Radiology, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Room 406, Block K, Queen Mary Hospital, Hong Kong, China.
E-mail: plkhong@hku.hk
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from CT have been reported previously (*10–12*). To our knowledge, there are limited studies investigating the radiation dosimetry data of whole-body dual-tracer PET/CT scans for HCC, especially combined with a 1-stop triple-phase contrast-enhanced diagnostic CT of the liver that is performed in our institution. Referral for dual-tracer PET/CT studies must be justified in each case as a first general principle of radiological protection (*13*). Optimization, or ensuring that the diagnostic information is as high as reasonably achievable while maintaining radiation doses as low as reasonably achievable, is the second general principle in radiologic protection according to ICRP (International Commission on Radiological Protection) (*14*). It was, therefore, the aim of the present study to characterize the radiation dosimetry of whole-body dual-tracer PET/CT protocols so as to aid the evaluation of risk/benefit for justification and protocol optimization in the clinical work-up of HCC patients.

MATERIALS AND METHODS

Study Population

Institutional review board approval with waiver of patient informed consent was obtained to perform a retrospective study of clinically indicated pretreatment whole-body dual-tracer (^{18}F-FDG and ^{11}C-acetate) PET/CT scans obtained for HCC patients at Queen Mary Hospital, a national tertiary referral center in Hong Kong, from November 2014 through February 2015. Consecutive adult patients who had undergone dual-tracer PET/CT for HCC were recruited, and patient data including age, sex, weight, height, and body mass index (BMI) were reviewed. For each PET series performed, the amounts of ^{18}F-FDG and ^{11}C-acetate administered were obtained from the medical records. At our institution, both the ^{18}F-FDG and the acetate dose administered were adjusted for patient body weight (7.4 MBq/kg for ^{11}C-acetate, 4.8 MBq/kg for ^{18}F-FDG).

The following CT parameters for each series were extracted from the DICOM headers for organ equivalent dose and effective dose calculation: scanner make and model, kVp, mA, beam collimation, rotation time, and pitch. The CT scanner used in the PET/CT machine (Discovery PET/CT; GE Healthcare) was a 64-detector CT scanner with tube current modulation capabilities.

Dual-Tracer PET/CT and Contrast CT Protocols

All patients fasted for at least 6 h, and the blood glucose concentration was determined before the injection of PET radiopharmaceuticals (all had glucose levels of < 8 mmol/L). ^{11}C-acetate was administered intravenously; 11 min after the administration of ^{11}C-acetate, a noncontrast limited whole-body CT (from the cerebellum to the pubic symphysis) followed by PET data acquisition was obtained. About 15 min after the completion of ^{11}C-acetate imaging, ^{18}F-FDG was injected intravenously. Another noncontrast limited whole-body CT followed by PET data acquisition began at 60 min after ^{18}F-FDG administration. This comprised a typical dual-tracer PET/CT scan (protocol A). In our clinical practice, we offered 2 other protocols, which we also evaluated: one with additional initial acetate scans at 2 min after administration of ^{11}C-acetate, with a standard unenhanced abdomen CT scan to improve specificity (protocol B), and another with additional triple-phase contrast-enhanced protocol for dynamic evaluation of the liver (protocol C) (protocol details are provided in Supplemental Table 1 [supplemental materials are available at http://jnm.snmjournals.org]). The CT protocol was 120 kV, auto-mA, pitch of 0.98, and rotation time of 0.5 s.

Internal Radiation-Absorbed Dose Assessment

The OLINDA/EXM code (version 1.1; Vanderbilt University) was used to determine the organ equivalent dose and effective dose from each PET series with patient-specific parameters (*15*). The code allows for the modification of standard reference phantoms to more closely represent patient-specific factors—for the present study, such as patient weight and corresponding organ mass. We used the standard anthropomorphic models as well as models modified to represent patients' weight and height (i.e., organ sizes of the phantom models used by OLINDA were modified to reflect the patient-specific mass of the organ as described by Marine et al. and Clark et al. (*16–18*)). Biokinetic models for ^{18}F-FDG and ^{11}C-acetate as provided by ICRP publication 106 (*19*) were used. Modified adult male and adult female models in OLINDA's phantom library were used to generate patient-specific organ equivalent dose, and then tissue-weighting factors from ICRP publication 103 (*3*) were used to generate patient-specific effective dose conversion factor (mSv/MBq). These factors were multiplied by injected activity (MBq) for each PET study to obtain an estimation of effective dose.

Absorbed doses D_T to a tissue or organ T resulting from intravenous administration of an activity A of ^{18}F-FDG and ^{11}C-acetate were also estimated by means of dose coefficients $\Gamma^{FDG}{}_T$ and $\Gamma^{ACT}{}_T$ provided by ICRP publication 106 (*19*) for a variety of organs and tissues of the adult hermaphrodite MIRD phantom. The formula for effective dose estimation is described in ICRP 103 (*3*).

External Radiation-Absorbed Dose Assessment

With patient-specific weight and scan parameters, organ equivalent dose and effective dose from each CT series were estimated using the VirtualDose (*20*), which has a comprehensive organ equivalent dose database derived from Monte Carlo calculations (using the Monte Carlo N Particle system v2.6 code) involving a suite of modules for CT, cone-beam CT, and PET/CT dose reporting, BMI-adjustable anatomically realistic patient phantoms, and multidetector CT scanners with tube current modulation (TCM) protocols and PET/CT protocols. VirtualDose allows users to specify the scanner type and scanning parameters. Moreover, dosimetry capabilities for TCM protocols were applied by integrating a dose information extraction function module, which could extract dose (e.g., CT dose index, dose–length product), CT scanner (e.g., kVp, mAs, scan region, scan protocol), and patient (weight, age, sex, etc.) information from the DICOM file headers. The patient-specific parameter information obtained was used as inputs into VirtualDose, as were start and stop locations of the series, which were interactively selected using a diagram of the anatomically realistic phantoms provided, to calculate the organ dose and effective dose for the specific patients. Limited whole-body effective dose in mSv were then calculated for each CT series for each patient using the latest ICRP publication 103 tissue-weighting coefficients (*3*), which were consistent with the conversion factors for PET.

For comparison, effective dose from CT examination was also estimated by a generic shortcut method using dose–length product and k coefficients from the ICRP publication 110 (*21*).

Statistical Analysis

Descriptive and summary statistics were performed with a spreadsheet application (Excel 2007; Microsoft).

RESULTS

Study Population Statistics

Of the total 14 dual-tracer PET/CT scans, 12 (85.7%) were performed on male patients, and 2 (14.3%) were performed on female patients. Subjects ranged in age from 52 to 86 y (60 $\pm$ 19.48 y). The subjects' weight ranged from 51 to 98 kg (67.57 $\pm$ 27.9 kg),

height ranged from 156 to 177 cm (165.57 ± 12.6 cm), and BMI ranged from 17.56 to 36.0 (24.58 ± 8.98) (Supplemental Table 2).

Radiation Doses

^{18}F-FDG and ^{11}C-acetate injected doses were 328.77 ± 89.78 and 481.79 ± 135.37 MBq, respectively. Patient-specific effective dose from ^{18}F-FDG and ^{11}C-acetate calculated by OLINDA were 6.08 ± 1.49 and 1.56 ± 0.47 mSv for male patients and 6.62 ± 1.38 and 1.79 ± 0.12 mSV for female patients, respectively. Effective doses estimated by the ICRP publication 106 for ^{18}F-FDG and ^{11}C-acetate for adult reference phantoms (*18,22*) were 6.25 ± 1.71 and 1.69 ± 0.47 mSv, respectively. Doses from ^{18}F PET scanning to the brain, heart, and bladder were appreciably higher than to the other organs and were 12.83, 14.52, and 44.57 mSv for male patients, respectively, and 11.58, 15.16, and 49.62 mSv for female patients, respectively (other organ doses ranged from 2.7 to 7.42 mSv for male patients and from 2.48 to 7.99 mSv for female patients). Doses from ^{11}C PET distributed primarily in the kidneys, liver, and heart were higher than the other organs and were 27.64, 7.91, and 6.28 mSv for male patients, respectively, and 29.02, 8.96, and 8.37 mSv for female patients, respectively (other organ doses ranged from 0.44 to 4.45 mSv for male patients and from 0.50 to 5.30 mSv for female patients). The measured dose coefficients, organ equivalent doses, and effective doses from ^{18}F-FDG and ^{11}C-acetate scans are listed in Supplemental Tables 3 and 4.

For the CT component, the patient-specific effective dose of a typical dual-tracer PET/CT, which comprised 2 limited whole-body noncontrast CT scans, was calculated with VirtualDose. The effective dose to male and female patients was 21.20 ± 8.94 and 14.79 ± 3.35 mSv, respectively. The CT reference phantom effective doses calculated by *k* factor from ICRP publication 110 (*21*) were 30.55 ± 10.58 and 20.73 ± 5.12 mSv for male and female patients, respectively. The CT organ equivalent doses from a typical dual-tracer PET/CT (Table 1), with an additional noncontrast abdomen CT (for initial ^{11}C-acetate PET scan) or an additional triple-phase contrast-enhanced abdomen CT, were tabulated (Supplemental Tables 5 and 6 respectively).

The total effective doses of the typical combined PET/CT studies, calculated by summing the effective doses of CT and dual-tracer PET scan, were 28.84 ± 10.18 mSv for male patients and 23.19 ± 4.61 mSv for female patients, respectively (Table 1). The total effective doses of dual-tracer PET/CT with an additional noncontrast abdomen CT and a triple-phase contrast CT are also listed in Supplemental Tables 5 and 6.

DISCUSSION

Although risk from radiation exposure to the individual may be of less impact for the population known to have cancer because of their reduced life expectancy (*23*), the information is still of importance to the evaluation of risk/benefit for justification, and relevant to protocol optimization and personnel protection (*24*). The use of ^{18}F-FDG and ^{11}C-acetate for the evaluation of patients with HCC is known to provide complementary biochemical sensitivities to identify tumor cells with various degrees of differentiation. Currently, to our best knowledge, we are not aware of published studies formally assessing radiation-absorbed dose from whole-body dual-tracer PET/CT to HCC patients. Our study assessed the dual-tracer PET/CT-based radiation dosimetry of ^{18}F-FDG and ^{11}C-acetate for all organs based on patient-specific data and the latest recommendation from ICRP publications. The derived overall effective dose from dual-tracer PET/CT scans with a mean administered ^{18}F-FDG and ^{11}C-acetate activity of 328 and 481 MBq, respectively, was calculated to be up to about 29 mSv, and up to about 57 mSv if a 1-stop triple-phase contrast-enhanced abdomen CT was included at the same setting. These results assist in evaluating justification and optimization of protection of the procedure.

For internal absorbed dose assessment, OLINDA/EXM was used to perform dosimetry calculations for the various body organs, which is currently unique in the field of nuclear medicine dosimetry in that it has received approval from the Food and Drug Administration to be distributed after 510(k) premarket notification (*15*). This code allows calculations for 814 radionuclides and a wide variety of adult, pediatric, and pregnant female phantoms; furthermore, it also allows users to modify organ masses in the phantoms for more patient-specific dose calculations when it may be known that an organ is larger or smaller than that assumed in the reference phantom. Moreover, organ doses calculated by OLINDA/EXM based on reference phantoms representing the average patient were found to be in good agreement with patient-specific Monte Carlo mean dose estimates (*25*). We also compared organ equivalent dose and effective dose calculated by OLINDA/EXM with those by the dose coefficients from ICRP publication 106 (*19*). The dose estimate difference between these 2 methods may be due to the dose coefficients provided in publication 106, which are computed by age- and sex-averaging, and moreover ICRP publication 106 still uses tissue-weighting factors defined in ICRP publication 60 (*26*), instead of the latest ICRP publication 103 (*3*) applied in the present study. Patient-specific organ masses were derived from previous reports on variations in the mass of different body organs in relation to stature and BMI (*16–18,27,28*). Marine et al. and Clark et al. (*16,17*) described phantoms that model different body types in a series of percentile height phantoms to evaluate how specific absorbed fractions may vary with height and weight differences across the human population. As Stabin stated (*29*), the biokinetic model used to calculate the dose is one of the major uncertainties in the evaluation of radiation doses for radiopharmaceuticals. If careful patient-specific dosimetry is performed, with attention paid to accurate measurement of individual organ volumes, many of the biokinetic model uncertainties can be minimized, and the total uncertainty in the individual dose estimate can be reduced to perhaps ±10%–20% (*29*).

With patient-specific data, the effective dose from ^{18}F-FDG PET scanning was 6.08 mSv for male and 6.62 mSv for female patients, respectively. These values are consistent with the dose estimates reported in the literature (*30–33*) and also with the dose estimates from ICRP publication 106 (*19*). The measured radiation-absorbed doses from ^{11}C-acetate PET scanning differ markedly from the previously determined estimates of Seltzer et al. (*11*). Because the dosimetry methodologies used by us and by Seltzer et al. (*11*) were different, the difference between the dose estimates obtained is mainly due to the difference in the biokinetic data used to create the kinetic models. Because the kinetic data that we used were from ICRP publication 106 (*19*), which are more complete, representing all major source organs, more accurate dosimetry estimates are likely possible. We, therefore, believe our estimates of internal doses to be reasonably accurate and to represent the best estimates of such internal absorbed doses for our HCC patient population based on the models used.

TABLE 1
Organ Equivalent Dose and Effective Dose from Typical Whole-Body Dual-Tracer PET/CT to Adult Male and Female Patients

Organ	Dose from ^{18}F-FDG and ^{11}C-acetate*		Dose from CT†		Total dose	
	Male (n = 12)	Female (n = 2)	Male (n = 12)	Female (n = 2)	Male (n = 12)	Female (n = 2)
Adrenals	6.22 ± 1.29	6.25 ± 0.74	24.96 ± 12.47	14.82 ± 2.47	31.18 ± 13.52	21.06 ± 1.73
Brain	13.27 ± 3.17	12.08 ± 2.38	1.99 ± 1.26	1.40 ± 0.35	15.26 ± 4.11	13.48 ± 2.74
Breasts	3.71 ± 0.80	3.79 ± 0.58	19.05 ± 11.44	12.51 ± 5.63	22.76 ± 12.09	16.30 ± 6.21
Gallbladder wall	3.47 ± 0.74	3.87 ± 0.50	18.30 ± 7.17	11.87 ± 0.41	21.76 ± 7.69	15.73 ± 0.09
Colon	10.35 ± 2.28	10.58 ± 1.72	20.85 ± 8.41	16.87 ± 1.71	31.20 ± 10.10	27.45 ± 3.44
Small intestine	4.93 ± 1.07	4.79 ± 0.74	20.09 ± 8.01	18.88 ± 3.01	25.02 ± 8.68	23.67 ± 3.76
Stomach wall	3.75 ± 0.81	3.92 ± 0.57	21.15 ± 8.43	14.04 ± 0.40	24.90 ± 9.05	17.96 ± 0.97
Heart wall	20.80 ± 4.31	23.53 ± 2.61	21.70 ± 9.74	14.98 ± 4.85	42.50 ± 13.06	38.51 ± 7.46
Kidneys	31.36 ± 8.57	32.60 ± 1.19	24.35 ± 9.96	14.91 ± 0.27	55.70 ± 14.33	47.51 ± 0.92
Liver	15.34 ± 3.24	16.96 ± 1.07	24.93 ± 10.03	15.89 ± 0.06	40.26 ± 12.05	32.85 ± 1.13
Lungs	6.95 ± 1.55	7.42 ± 1.25	23.17 ± 10.84	15.96 ± 4.04	30.12 ± 12.06	23.38 ± 5.30
Muscle	4.07 ± 0.89	4.09 ± 0.64	18.34 ± 8.06	14.09 ± 3.93	22.41 ± 8.76	18.18 ± 4.57
Ovaries/testes‡	4.23 ± 0.95	6.06 ± 1.04	30.32 ± 12.27	18.56 ± 6.62	34.55 ± 13.03	24.62 ± 7.66
Pancreas	8.17 ± 1.75	9.16 ± 0.45	19.32 ± 7.29	12.66 ± 0.68	27.48 ± 8.11	21.82 ± 1.13
Red marrow	4.17 ± 0.90	4.11 ± 0.64	13.92 ± 5.79	10.58 ± 2.56	18.08 ± 6.47	14.69 ± 3.20
Osteogenic cells	6.38 ± 1.40	6.32 ± 1.02	17.32 ± 7.39	13.40 ± 3.32	23.70 ± 8.48	19.71 ± 4.34
Skin	3.22 ± 0.70	3.05 ± 0.48	14.09 ± 7.30	10.32 ± 3.01	17.31 ± 7.83	13.36 ± 3.49
Spleen	5.19 ± 1.08	5.40 ± 0.70	25.65 ± 11.46	16.28 ± 0.17	30.83 ± 12.32	21.68 ± 0.87
Thymus	4.62 ± 0.99	4.92 ± 0.73	24.50 ± 9.84	16.74 ± 5.97	29.12 ± 10.49	21.66 ± 6.70
Thyroid	3.92 ± 0.87	3.61 ± 0.59	38.59 ± 28.23	23.43 ± 4.24	42.51 ± 28.78	27.04 ± 4.84
Urinary bladder wall	45.15 ± 10.94	50.20 ± 10.32	17.72 ± 6.01	20.07 ± 7.51	62.87 ± 15.50	70.27 ± 17.83
Uterus	—	6.83 ± 1.22	—	14.02 ± 1.70	—	20.85 ± 2.91
Effective dose§	7.64 ± 1.64	8.41 ± 1.26	21.20 ± 8.94	14.79 ± 3.35	28.84 ± 10.18	23.19 ± 4.61

*Patient-specific average dose calculated by OLINDA.
†Two whole-body CT doses calculated by VirtualDose.
‡Ovaries for female patients/testes for male patients.
§Effective dose estimated by ICRP publication 103.

Currently, a few CT dose-calculation tools, including ImPACT Dose (http://www.impactscan.org/ctdosimetry.htm) (*34*), CT-Expo (Georg Stamm, http://www.sascrad.com/attachments/File/Leaflet_CT-Expo_v2_1(E).pdf) (*35*), eXposureTM (http://www.radiologysolutions.bayer.com/products/ct-dosemanagement/rep/), and methodologies (*36*), report organ doses based on their calculations of simplified stylized anatomic models that are anatomically crude but widely used for several decades for practical applications with the standard mathematic representations of the reference man (*37*) and other representative phantoms in radiation protection, nuclear medicine, and medical imaging (*38,39*). Recently, more realistic models, developed by Xu et al. (*40*), based on imaging data from human subjects, including updated anatomic information from reference data on adults and children (*18*), can be used in place of traditional stylized models for more accurate dose estimates (*41*).

The use of VirtualDose improves on existing dose calculation tools by considering the latest CT scanners based on the newer realistic models developed by Xu et al. (*40*): 25 available models, including adult male and female models of various body mass, pediatric models from newborn through adolescent, and pregnant models of 3 gestational ages. Standard CT models have been modeled and patient dose calculated using Monte Carlo radiation transport methods, with corrections applied to represent the behavior of most commonly available CT scanners. The Monte Carlo results suggest that the organ equivalent dose estimates can be different by a margin as great as 277% between our calculations and those derived from the use of earlier stylized MIRD-type phantoms (*42*). VirtualDose enabled us to assess organ equivalent dose under TCM schemes, which has now been frequently implemented in clinical body CT examinations for a decade. Quantifying the magnitude of organ dose under TCM, however, is practically challenging. The main challenge relates to the fact that the x-ray radiation is dynamically altered over the patient habitus for TCM examinations. VirtualDose provides accurate estimates of organ equivalent dose, based on

modeling change of irradiation condition and integrating it with the anatomic feature of the patients. Therefore, the use of this dose tool is expected to improve both the accuracy and the usability in reporting CT doses.

The limited whole-body CT effective dose to reference phantoms determined by k factor (0.0019 for chest-abdomen-pelvis, the ICRP publication 110) was overestimated in the present study compared with the patient-specific effective dose calculated by VirtualDose. This finding is not surprising because k factor is an age- and sex-averaged parameter, based on data averaged over many scanner makes and models; moreover, effective dose is defined by ICRP as a single parameter to reflect overall risk averaged over all ages and both sexes for a reference patient (*3*) and is not a physical parameter that can be measured, which is always computed through multiple steps and approximations. OLINDA/EXM and VirtualDose were used in the present study to calculate organ equivalent doses, and then effective doses were calculated using ICRP publication 103 tissue-weighting coefficients (*3*).

The present study is limited because it was performed for a small sample size cohort ($n = 14$) that was recruited consecutively in the first 4 mo of the implementation of such scans for a specific population with HCC in a single center. This limitation should be considered in the generalization of the conclusions. However, as noted above, a review of our results against literature values shows general consistency.

CONCLUSION

Patient-specific parameters (e.g., weight and height) identified from patient data allow for a more accurate estimate of organ equivalent doses. Consideration of actual patient-specific characteristics resulted in lower organ equivalent dose estimates than traditional reference phantoms and models. We estimated an average patient effective dose from whole-body dual-tracer PET/CT examinations of about 29 mSv. Considering the substantial radiation dose to patients compared with individual PET/CT examinations, a judicious medical justification has to be made with every whole-body dual-tracer PET/CT referral. This is especially important when its clinical utility is less well established. Although radiation risks may be of less impact for the population with cancer due to their reduced life expectancy, the information is still of importance and relevant for both justification, to evaluate risk/benefit, and protocol optimization.

DISCLOSURE

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