Journal of Medical Physics

ORIGINAL ARTICLE
Year : 2016 | **Volume** : 41 | **Issue** : 4 | **Page** : 240--245

A method to obtain correct standard uptake values in Pinnacle treatment planning system for target volume delineation

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Abstract

Standardized uptake value (SUV) is an advanced tool for quantitative tumor identification and metabolic target volume delineation (TVD) in diagnostic and therapeutic settings. It is thus important to es process to maintain the traceability of data correctly by positron emission tomography (PET) systems. Patient administration of ^{18} fluoro-deoxy-glucose is increasingly delivered by automated infusion s is used, its accuracy and traceability measurement need verification. In addition, it was observed that the unreproducible SUV displayed in PET and the treatment planning system (TPS) may cause gr oncologists for TVD. This concern may complicate the correlation of TVD on PET and TPS and their clinical reporting. The SUV traceability was established from the PET system to AIS. Its accuracy w referencing to the reference dose calibrator traceable to a primary standard. The SUV values were converted in TPS using the in-house «DQ»clinical tool«DQ» to be identical as in PET, to allow radiati confidently. The outcome of this study enables the clinical groups to rely on the correct SUV values displayed on the TPS and to improve the quality of care for patients in clinical procedures.

How to cite this article:
Salehzahi F, Tse J, Lee J, Selvaraj J. A method to obtain correct standard uptake values in Pinnacle treatment planning system for target volume delineation.J Med Phys 2016;41:240-245

How to cite this URL:
Salehzahi F, Tse J, Lee J, Selvaraj J. A method to obtain correct standard uptake values in Pinnacle treatment planning system for target volume delineation. J Med Phys [serial online] 2016 [cited 201
Available from: http://www.jmp.org.in/text.asp?2016/41/4/240/195188

Full Text

Introduction

The standardized uptake value (SUV) is a useful metric for quantitative analysis of positron emission tomography (PET) images, especially for tumor identification and cancer staging. SUV-based targe also shown to have significantly reduced interobserver variations. [1] Moreover, SUV can be used for "dose painting" or delivering differential doses within the target volume as it is highly correlated to t the tumor. [2] Nevertheless, center-specific absolute SUV threshold based TVD and the variability in methodology across centers decrease the widely used SUV reliability. [3] Therefore, a standardizec radioactivity traceable to primary standards is highly preferred; the assaying uncertainty of devices also influences the accuracy of the final SUV values in treatment planning system (TPS) and needs t such issues, a multidisciplinary team of scientists and clinicians is required. [4]

SUV [5],[6] by definition is a measurement of the uptake in a tumor normalized by radioactivity distributed within the whole volume (i.e., patient). It is an advanced tool for tumor identification and deline values associated with the tumor type of interest. Incorrect SUV has the potential to taint the integrity of clinical report as the multidisciplinary teams may find the quantitative values unreliable. The outc quantitative parameter to use for therapy and diagnosis. Tumor segmentation methods are employed to report a clinical outcome using metabolic target volume; however, it is recommended to always uptake value (SUV max). [6],[7],[8],[9]

SUV is calculated as shown in equation 1.

[INLINE:1]

where Act vol is the radioactivity concentration in any volume of interest and Act admin is the total amount of radioactivity administered to the patient.

In this study, the lack of a traceable calibration system for 18 F was identified. This issue, however, is often neglected in diagnostic and therapy health-care centers despite using multiple clinical device The traceability to reference instruments would then become a requirement for ensuring the accuracy of SUV for diagnostic and therapeutic procedures. "SUV traceable" is the SUV of an accurate mea primary standard for a structure at any given time by definition and shown as SUV traceable, in this study. Moreover, the traceability of the systems shall be maintained across the range of instruments quantitatively calculating the 18 F activity directly, or indirectly. Thus, using automated infusion system (AIS) was deemed important, to be verified by cross-calibrating its internal dose calibrator to the r traceable AIS will provide the correct SUV in our hospital. It is our standard procedure to inject patients with AIS; therefore, the SUV figures in our TPS need to be standardized and streamlined. The S preliminary assessment of AIS, which was found to be non-traceable and unreliable. The findings were reported to the vendor when further service and upgrades on AIS proved to be beneficial where optimized.

To make matters more challenging, it was further observed that Pinnacle™ (Philips Medical Systems, CA, USA) TPS was unable to interpret the SUV correctly from the Digital Imaging and Communica images corresponding to a traceable PET.

Therefore, the objective of this study was to disseminate the SUV traceability of an established, calibrated PET instrumentation that is traceable to primary standards, and to develop a method to displa TPS for accurate TVD.

Materials and Methods

Dose calibrator calibration

The PET/computed tomography (CT) scanner model used in this study was the Philips Gemini TF (Generation 3). It was calibrated and made traceable to National Institute of Standards and Technolo methodology presented by Montgomery [9] and also employed concepts used in National Physical Laboratory [10] and Australian Standard Laboratory [11] works previously presented. All cross calibra NIST-traceable solid 68 Ge source as a 18 F surrogate. The traceability of the PET/CT to NIST and its relationship to clinical reporting in imaging and TPS is demonstrated in [Figure 1], which highlight link the NIST properties of the dose calibrator which propagates its reliability directly to AIS, PET scanner's SUV, TPS, and clinical reporting of SUV.{Figure 1}

Automated infusion systems calibration

The AIS comprises of a vial pig, suction needle, dispensing line and coil, an injection line, a disposal line, an internal dose calibrator, and a saline bag.

AIS gets primed with saline for air removal from all lines before injection. It then samples a small amount of 18 F activity concentration knowing the total vial volume and its calibrated activity entered at the sample in its internal dose calibrator system. Once it passes the concentration test, it draws up the rest of the activity to top-up the required amount as prescribed. Next, it adds saline of approximat Once it injects the patient with activity, it disposes of the remnant waste through the waste line.

The net activity injected by the AIS is therefore defined with the following equation.

A (patient) = (A[sample] + A[top.up] − A(waste) (2)

where A(patient) represents the radioactivity administered to the patient, A(sample) is the tested concentration activity measured by internal dose calibrator, and A(top.up) is the amount required to ma
A(waste) represents the amount disposed of in the leftover of the line of injection.

Observations were made to monitor the accuracy and consistency of the AIS at the time of commissioning and spanning over three annual quality assessments. It was noticed that there were significa
the received radioactivities to the patient (up to 20%). However, through several parts and software upgrades, the improvements were brought to within acceptable limits of 3% cross-referencing dose

A consistency test was conducted for a 50 ml syringe, where it was used to collect the AIS's patient injections, to cross-calibrate the internal dose calibrator of the infusing system and the reference do
assessed using randomly selected radioactivities for injections in the range of 37-200 MBq of 18 F.

The outcome was satisfactory as shown in [Table 1]. The percentage difference (PD%) between the prescribed and measured activity with the reference dose calibrator was within the advised cross-re
reference and the field instrument traceability <3%. [10],[11]{Table 1}

PET/CT scanner calibration

The Philips SUV phantom was used according to manufacturer's instruction to calibrate the SUV baseline using SUV phantom, for clinical PET instrumentation normalization. A 1:1 ratio of the radioact
was measured and compared to that of dose calibrator using the built-in software. The SUV calibration ensured that the PET/CT scanner has a 1:1 relationship to NIST traceable reference source; hen
traceable. [10],[11] The phantom was filled using a manual injection method assayed in the reference dose calibrator.

SUV cross-calibration

A Computerized Imaging Reference Systems (CIRS) Dynamic Thorax Phantom Model-008A was employed with PET inserts to use spherical structures of various volumes viz. 0.5, 2.0, and 8.0 ml fille
of fluoro-deoxy-glucose. The change in CIRS phantom use was to alter the medium from SUV assessment in PET/CT. The CIRS phantom was scanned using a clinical PET/CT standard body protocol
were identified in PET/CT images and the SUVs were calculated. The calculated values were identical to that of measured SUVs using the image processing tools available in the PET/CT. A circular re
each spherical structure in PET using CT as a guide. These image files were transferred to Pinnacle TPS, for further image processing and target delineation. It was however observed that Pinnacle er
concentration but not the actual SUVs as shown on PET/CT. A scripting tool was developed in-house, to overcome this problem. The relevant DICOM tags for the interpretation of SUV are given in refe

The Pinnacle TPS displays the pixel values or activity concentration calculated from the stored pixel values and its associated DICOM tags as shown in equation 3.

U = (m × SV + b) (3)

where U is the activity concentration of each voxel, m is the rescale slope, SV is the stored pixel value, and b is the rescale intercept as defined in the DICOM standard. The value of b is set to 0 and m
Pinnacle. Thus, it is possible to retrieve the actual SUV values by modifying the rescale slope " m" in the Pinnacle TPS. This process is shown in [Figure 2].{Figure 2}

Results

The results for AIS cross-calibration with reference dose calibrator is shown in [Table 1] which displays the activity dialed on AIS, as prescribed to a patient, and displayed on printed AIS injection label,
AIS radioactivity measured by reference dose calibrator to record comparisons in PD%, for displayed and measured activities.

The SUV figures in PET and Pinnacle consoles from randomly selected patients were recorded, and their constant median ratio of 5.23 was obtained and given in [Table 2] before applying the "clinical
corresponds to Activity Concentration Scale Factor 5.222854, given in PET phantom studies listed in [Table 3].{Table 2}{Table 3}

The combined uncertainty of fluorine-18-deoxyglucose activity injected into patients using the AIS is provided in [Table 4]. Quality performance monitoring period used records from July 27, 2013, to Ju
of assaying a traceable 18 F simulated source to NIST was demonstrated in this section.{Table 4}

The detailed information regarding the DICOM tags used in Pinnacle and their values in DICOM header for each PET insert employed in the CIRS phantom as radiotherapy structure is provided in [Tat
explained in [Table 5], explaining Rescale Unit, Rescale Slope, SUV Scale Factor and Activity Concentration Scale Factor.{Table 5}

A flowchart was developed to manage the Python scripting demonstrated in [Figure 2], after studying the Pinnacle DICOM conformance and how the SUV is calculated in PET console and the requirer
PET SUV in Pinnacle. The logic of using a plugin script in Python was to enable the steps required to calculate the correct SUV in Pinnacle that is calibrated and traceable to PET.

NIST traceability of dose calibrator performance with respect to the NIST 18 F simulated reference source is shown in a distribution chart in [Figure 3], where the precision and frequency of dose calibr
highlighted.{Figure 3}

PET-fused images of CIRS Phantom with 8 mm PET insert were viewed in PET and Pinnacle consoles. After running the script, the Pinnacle SUV traceability to PET images was found to be identical.
same SUV max . The SUV traceable was thus verified as shown in [Figure 4].{Figure 4}

Discussion

This study identified two significant points. It revealed the importance of establishing and maintaining the measurement traceability of the radioactivity assaying instruments (e.g., dose calibrator and AI
accuracy would have a direct impact in the calibration of the PET/CT console and the quantitative values used for diagnostic and treatment planning purposes. Secondly, it has highlighted the inadvert
values by the planning system Pinnacle and proposed a method for correction.

SUV is often assumed by clinicians to be a standardized quantitative value, used clinically in diagnostic and therapeutic aspects of patient management. However, it was found that health centers may
requirements, and their impacts on clinical outcomes.

In this work, the need to have a national standardized SUV approach was also recognized, i.e., a national reference 18 F simulated source to be selected by Activity Standard Laboratory of Australian
Technology Organisation and circulated to all PET centers to form 18 F traceability. A national approach will assure a calibrated standardized SUV to be employed in Australia.

Further discussions on the possibility of vendor dependency of this study highlighted that other untested TPS platforms may not be reliable. Our local experience shows that the TPS Pinnacle had inco
SUV data generated from a Philips PET/CT console. Given that various PET systems may determine SUV in a different manner (e.g., using private DICOM tags) and hence the interpretation of that wo
in TPS, we believe it is worthwhile to consider assessment of different vendors' combinations of PET/CT console and TPS similar to this study.

Our physicians have already expressed interest in standardizing and using our methodology for future clinical effectiveness to liaise with two other health centers.

Their interest is due to improved clinical efficiency and reliability in SUV max figures. Work is already under progress for developing functional imaging based TVD.

Conclusions

The quantitative analysis of results based on SUV max is identical in both Pinnacle and PET processing terminals. A method to accurately define target volumes based on SUV has been implemented
traceable to images obtained on the PET console. Overall, it was demonstrated that the clinical effectiveness of our practice in diagnostic imaging and radiation oncology is considerably optimized, anc
consistent, quantitative analysis of their disease prognosis, treatment, and follow-ups. [6],[7],[8]

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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