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 ensure process to maintain the traceability of data correctly by positron emission tomography (PET) systems. Patient administration of 18F-fluoro-deoxy glucose is increasingly delivered by automated infusion. Its accuracy and traceability measurement need verification. In addition, it was observed that the reproducible SUV displayed in PET and the treatment planning system (TPS) may cause geographic variations 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 referring to the reference dose calibrator traceable to a primary standard. The SUV values were converted in TPS using the in-house SQA clinical tool to be displayed as in PET, to allow radiologists to rely on the correct SUV values shown on the TPS and to improve the quality of care for patients in clinical procedures.

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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 target volume 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 a st is highly correlated to the tumor. [2] Nevertheless, the specific SUV threshold-based TVD and the variability in methodology across centers decrease the widely used SUV reliability. [3] Therefore, a standardized traceability 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 to be considered.

SUV (S) [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 delineation 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 SUV value serves as a 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 consider the SUV values.

SUV is calculated as shown in equation 1.

\[
SUV = \frac{Activity}{Volume} \times \frac{1}{1000} \times \frac{1}{1000}
\]

where \( Activity \) is the radioactivity concentration in any volume of interest and \( Volume \) is the total amount of radioactivity administered to the patient.

In this study, the lack of a traceable calibration system for 18F 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 impossible. The accuracy of SUV for diagnostic and therapeutic procedures. “SUV traceable” is the SUV of an accurate measurement of the SUV traced to primary standards for a structure at a given time by definition and shown as SUV traceable. In this study, moreover, the traceability of the SUV 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 traceable AIS will provide the correct SUV in our hospital. If it is our standard procedure to inject patients with AIS; therefore, the SUV figures in our TPS need to be standardized and streamlined. The SUV 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 Communication in Medicine (DICOM) 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 display SUV correct TVD.

Materials and Methods

Dose calibrator calibration

PET/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 Technology (NIST) methodology presented by Montgomery [8] and also employed concepts used in National Physical Laboratory (NPL) and Australian Standard Laboratory (ASL) works previously presented. All cross-calibrate 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 highlights the NIST properties of the dose calibrator which propagates its reliability directly to AIS, PET scanner’s SUV, TPS, and clinical reporting of SUV.

Automated infusion systems calibration

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

AIS gas primed with saline for air removal from all lines before injection. It then samples a small amount of 18 F activity concentration knowledge the total vial weight 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 remaining waste through the waste line.

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

\[
A_{\text{patient}} = A_{\text{injection}} - A_{\text{waste}} \tag{2}
\]
where \( A(\text{patient}) \) represents the radioactivity administered to the patient, \( A(\text{sample}) \) is the tested concentration, activity measured by internal dose calibrator, and \( A(\text{top up}) \) is the amount required to make \( A(\text{waste}) \) represents the amount disposed of in the fovea of the patient.

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 significant received radioactivity to the patient (up to 20%). However, through several parts and software upgrades, the improvements were brought to within acceptable limits of %3 cross-referring dose.

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

The outcome was satisfactory as shown in Table 1. The percentage difference (P%) between the prescribed and measured activity with the reference dose calibrator was within the advised cross-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 instructions to calibrate the SUV baseline using SUV phantom, for CT PET instrumentation normalization. A 1:1 ratio of the activity 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; hence 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, 2.5, and 8 ml filled with a mixture of fluoro-deoxy-glucose. The change in CIRS phantom was to alter the medial from SUV assessment in PET/CT. The CIRS phantom was scanned using 3D PET standard body protocol identified in PET/CT images and the SUVs were calculated. The estimated values were identified to that of measured SUVs using the image processing tools available in the PET/CT. A circular region of each spherical structure in PET using CT1 as a guide. These image files were transferred to the Pinnacle TPS for further image processing and target delineation. It was however observed that Pinnacle is an accurate and consistent 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 ref 6.

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.

\[ U = (m \times SV + b) / (3) \]

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 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 level 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 PDI, 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 protocol of a 18 F-FDG with the NIST standard was demonstrated in this section (Table 2)

The detailed information regarding the DICOM tags used in Pinnacle and their values in DICOM header for each PET insert employed by the CIRS phantom as a radiotherapy structure is provided in Table 2, explained in Table 5, explaining Rescale Unit, Rescale Slope, SUV Scale Factor and Activity Concentration Scale Factor (Table 5)

A flow chart 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 require 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 18 F SUV calculated reference source is shown in a distribution chart in Figure 3, where the precision and frequency of dose calibrator 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 inadvertent 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 require such, and their impact 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 SUV 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 ensure 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 no 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 metric in SUV, we believe it is worthwhile to consider assess of different vendors' combinations of PET/CT console and TPS similar to this study.

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

**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, and consistent, quantitative analysis of their disease progress, treatment, and follow-ups [6][7][8]

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Conflicts of interest

There are no conflicts of interest.
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