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Correlation of PET/CT Standardized Uptake Value Measurements Between Dedicated Workstations and a PACS-Integrated Workstation System

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Purpose: **This study was conducted to evaluate the clinical utility of a Positron Emission Tomography/Computed Tomography (PET/CT) analysis module of a picture archiving communication system (PACS) workstation in comparison to a dedicated PET/CT interpretation workstation.** ***Materials and Methods:*** **The study included 32 consecutive patients referred for an [^{18}F] Fluro-2-Deoxy-D-Glucose (^{18}F-FDG) PET/CT at our institution. Images were reviewed at dedicated PET/CT and at PACS-integrated workstations. Mean standardized uptake values (SUVs) were calculated for the liver and the lung. Maximum SUVs were recorded for the bladder and an index lesion with the highest FDG uptake. The time spent for SUV measurements was recorded. Correlation of the SUV measurements was calculated with the Pearson coefficient.** ***Results:*** **Pearson coefficients between the workstations ranged from 0.96 to 0.99 for bladder and lesion maximum SUVs. For liver and lung average SUVs, the coefficients varied from 0.53 to 0.98. The mean time spent to perform the four SUV measurements was 122.6 s for the dedicated workstations and 134.6 s for the PACS-integrated system.** ***Conclusion:*** **The correlation of SUV measurements between dedicated PET/CT and PACS-integrated workstations is very good, especially for maximum SUVs. For routine reading of PET/CT scans, a PACS workstation with a PET/CT analysis module offers an excellent alternative to the use of a dedicated PET/CT workstation.**

KEY WORDS: PET/CT, PACS, workstation, SUV

INTRODUCTION

Nuclear medicine and radiology are rapidly becoming more closely aligned predominantly as a result of the deployment of integrated positron emission tomography/computed tomography (PET/CT) and single photon emission computed tomography-computed tomography (SPECT/CT) devices. This shift in emphasis from purely functional to integrated anatomic and functional imaging has implications for the practice of nuclear medicine beyond the localization of sites of abnormal uptake of a tracer.

PET imaging is by its very nature quantitative and the commonest quantitative measure quoted in PET/CT reports is the standardized uptake value (SUV).[1] The word "standardized" in the term SUV reflects the mathematical corrections that are made for differences in injected dose, as well as the size of the patient to allow for intra- and interpatient comparisons of regional uptake of radiotracer. The SUV maximum (SUVmax) is the highest voxel value within a region of interest (ROI), and is therefore independent of the size of the ROI, whereas the SUV average (SUVavg) is the mean uptake value of all voxels within an ROI (and therefore is not ROI size independent). SUVmax values are typically used for abnormal lesions, whereas SUVavg values are best used for organ based uptake assessment. We have demonstrated that SUV values are important predictors

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of outcome in thoracic malignancies such as mesothelioma, and lung and esophageal cancers.[2,3]

Given the importance we place on the SUV parameter, we sought to test the correlation between the SUV when calculated on a dedicated PET/CT workstation and an image analysis module (AWS Volume Viewer Plus®) available and integrated into the GE Centricity® Picture Archiving and Communication System (PACS) software package, to see if a clinician could perform PET/CT image analysis on a single PACS workstation without having to also deploy dedicated PET/CT analysis workstations specific for any particular acquisition device.

MATERIAL AND METHODS

Patients

The study included 32 consecutive patients (16 men and 16 women; mean age, 57.7 years) referred for an [^{18}F]Fluro-2-Deoxy-D-Glucose (^{18}F-FDG) PET/CT at our institution, for clinical evaluation of known or suspected cancer, from July 1 to July 7, 2005. Two additional patients studied with C-11 and I-124 (studied on the GE Discovery LS) were added, to ensure there that was no unexpected error introduced related to half-life. After discussion with the local Institutional Review Board (IRB), this work was considered of an operational nature and therefore did not require IRB oversight or approval.

PET/CT and Image Reconstruction

Sixteen FDG PET/CT whole body image sets were recorded with a Biograph® (Siemens/CTI, Nashville, TN, USA) and 16 with the Discovery LS® (GE Healthcare, Waukesha, WI, USA) PET/CT acquisition device. Both machines consist of a combination of a spiral CT device with a full ring PET device. The Discovery uses the Advance PET device, and the Biograph uses the HR plus PET device. A low-dose CT scan, used for attenuation correction of PET emission images and for anatomic localization of PET abnormalities, was acquired first, by using the following parameters: for the Biograph, scout view with 130 kVp and 30 mA s, followed by spiral CT using effective mA s of 50, 130 kVp, scan width of 5 mm, collimation of 4 mm, and a feed/rotation of 12 mm; for the Discovery LS, scout view with 30 mA s, 120 kVp, followed by a spiral CT at 0.8 s/rotation using 80 mA s, 140 kVp, a slice thickness of 5 mm, and a 4.25-mm interval in high-sensitivity mode. PET emission images were acquired for 4 min per bed position (3D mode on the Biograph and in 2D mode on the Discovery). The total acquisition time varied between 25 and 35 min per patient. PET images were reconstructed by using iterative algorithms and attenuation correction based on the CT attenuation maps was routinely applied.

Images were acquired 64.5 ± 14.8 min (mean ± SD) after intravenous injection of 555 ± 44.4 MBq (mean ± SD) ^{18}F-FDG. Activity was scaled to body surface area for one pediatric patient.

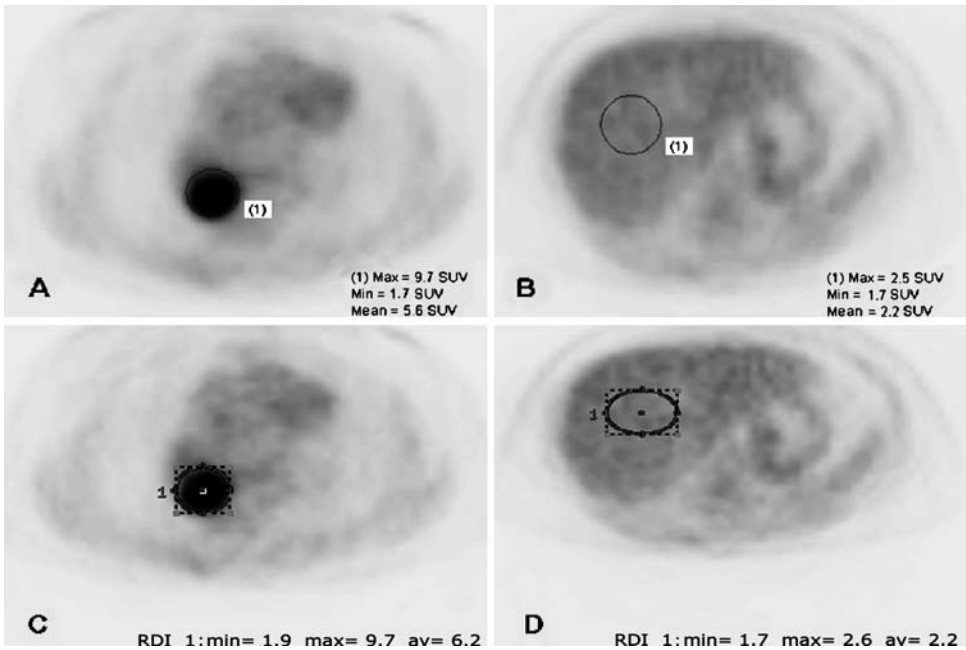

Fig 1. SUV measurements of a right lower lobe lung mass and of the liver parenchyma performed at dedicated (A–B) and AWS PACS-integrated (C–D) workstations.

Image Analysis

PET/CT images were reviewed by a radiologist at the applicable dedicated PET/CT workstations: Xeleris®-GE Healthcare, for the images acquired on the GE PET/CT scanner (16 patients), and Syngo®-Siemens/CTI for the images obtained with the Siemens PET/CT machine (16 patients). The images of the 32 studies were also reviewed, by the same radiologist, at a dedicated PACS workstation (a commercially optional extension of the GE Healthcare Centricity® PACS workstation was used, comprising AWS Volume Viewer Plus®(AWS), a commercially available module derived by GE from the preexisting GE AW suite).

Syngo®, Xeleris®, and AWS all allow simultaneous interpretation of CT, PET, and fused PET/CT image sets, as well as ROI analysis.

Similar-sized large circular ROIs, ranging from 1,000 to 1,500 mm^2, were drawn on transaxial images on the liver (central region of the right lobe), lung (basal region of the right lung), and bladder (mid portion). A fourth ROI was drawn surrounding the malignant lesion with the highest FDG uptake. Each workstation's display includes *Z* dimension localization that allowed ROIs to be placed on exactly the same transaxial slice. Figure 1 demonstrates some examples of SUV measurements performed at the dedicated and the PACS-integrated workstations.

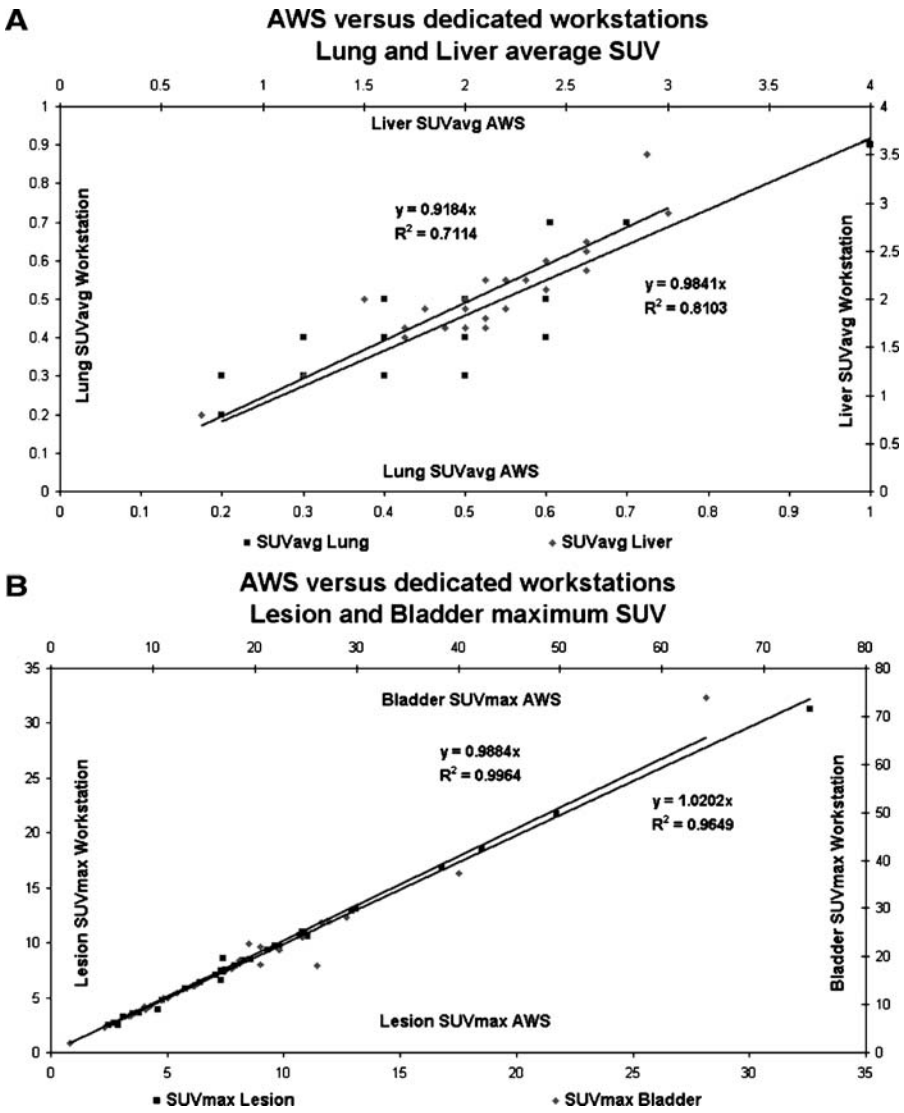

Fig 2. (A–B) Pooled correlation between the SUV measurements (average and maximum) for the AWS workstation and the GE and Siemens workstations.

Mean SUVs were calculated for the liver and the lung. Maximum SUVs were recorded for the bladder and the hottest lesion. The SUV was calculated as:

$$SUV = \frac{decay - corrected\ activity[kBq]/tissue\ \ volume[ml]}{injected - FDG\ \ activity[kBq]/body\ \ weight[g]}$$

The time taken to select and load the images from the patient selection menu into the workspace, draw the four ROIs, and record the data on paper was defined as the time of analysis and recorded by the radiologist for each system.

Statistical Analysis

Data were analyzed using Microsoft Excel® software. Correlation of the SUV measurements between the dedicated workstations and AWS was measured with the Pearson correlation coefficient. Three correlations were performed, one comparing Siemens images on Syngo® and AWS image analysis (n = 16), a second comparing GE images on Xeleris® and AWS image analysis (n = 16), and a third pooling all vendor specific (GE and Siemens) to AWS analysis (n = 32).

RESULTS

As far as the maximum SUVs were concerned, Pearson correlation coefficients between the workstations (dedicated and PACS-integrated) were very high. The correlation coefficients were as

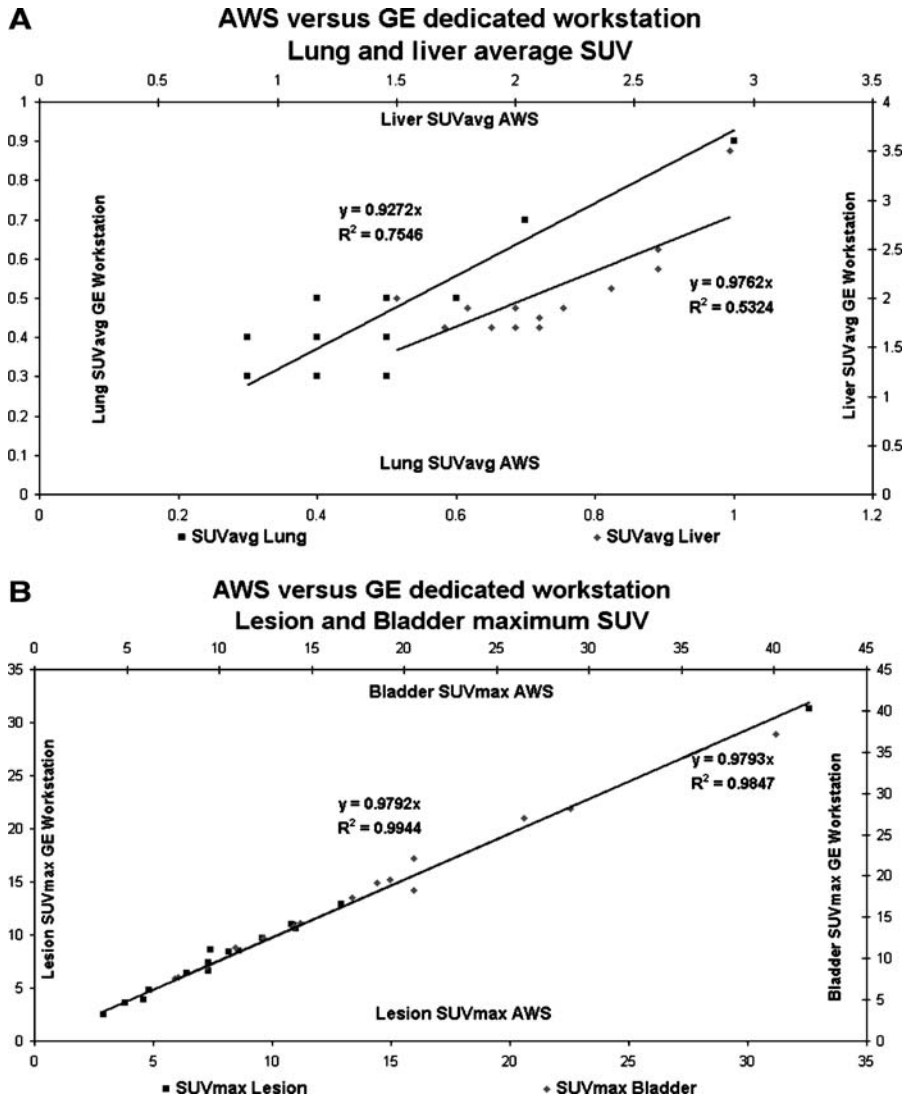

Fig 3. (A–B) Correlation between the SUV measurements (average and maximum) for the AWS workstation and the GE system.

follows: Syngo®/AWS (n = 16) 0.99 (lesion) and 0.96 (bladder); Xeleris®/AWS (n = 16) 0.99 (lesion) and 0.98 (bladder); pooled Syngo® and Xeleris®/AWS (n = 32) 0.99 for the lesion and 0.96 for the bladder.

For the average SUVs, the correlations were less strong. The correlation coefficients were as follows: Syngo®/AWS (n = 16) 0.61 (lung) and 0.98 (liver); Xeleris®/AWS (n = 16) 0.75 (lung) and 0.53 (liver); pooled Syngo® and Xeleris®/AWS (n = 32) 0.71 for the lung and 0.81 for the liver.

Figures 2, 3, and 4 illustrate the correlation of the SUV measurements between the workstations (dedicated and AWS).

The time spent to perform the SUV measurements ranged from 100 to 135 s (mean, 122.6 s; SD, 9.6) for the dedicated workstations, and from 110 to 155 s (mean, 134.6 s; SD, 12.7) for the AWS.

The analysis of the C-11 and I-124 data sets revealed no significant differences for the measurements of maximum SUVs using the Xeleris® and AWS.

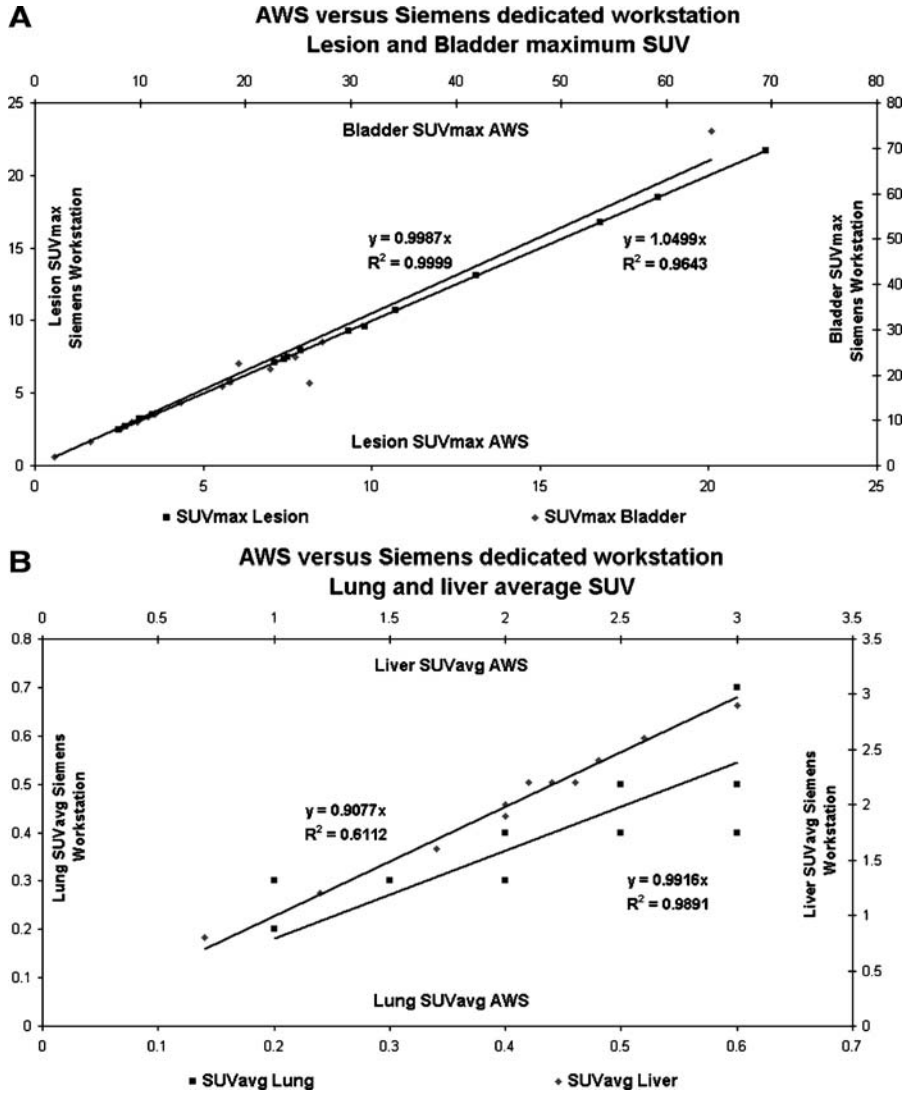

Fig 4. (A–B) Correlation between the SUV measurements (average and maximum) for the AWS workstation and the Siemens system.

DISCUSSION

PET/CT has been considered an essential imaging modality for tumor detection, staging, and treatment followup. A qualitative analysis, with visual assessment, could be sufficient for neoplasms recognition and staging.[4,5] We have shown the SUV to be a valuable predictor of prognosis in untreated thoracic patients undergoing surgery. For the evaluation of response to therapy, most physicians rely on quantitative measurements on PET scans performed at baseline and repeated following an intervention.[6] The European Organization for Research and Treatment of Cancer (EORTC) has specified that a drop of greater than 20% in the maximum SUV of a tumor on repeat imaging is likely to be clinically significant (in other words, a greater than 20% drop in SUV is associated with a better patient outcome) when evaluating the response to a therapy.[7]

The correlation between dedicated and PACS-integrated workstations was very good, for the maximum SUV. This is reassuring because it means that the PACS software module (AWS Volume Viewer) is correctly interrogating the DICOM (digital imaging and communication in medicine) header, and accurately correcting for variations in body weight and injected dose. Therefore, for the purposes of SUVmax measurements, the AWS PACS workstation could be considered interchangeable to the dedicated (Syngo® and Xeleris®) workstations.

The correlation of the mean SUV is not as good, probably as a result of human variabilities when drawing and placing the ROIs. Even small differences in an ROI size can lead to marked differences in the mean SUV, particularly in the lung where signal-to-noise ratios are low. For this reason, the reproducibility of the maximum SUV should be taken as evidence of the clinical validity of the Volume Viewer application.

There are some distinct advantages of a PET/CT analysis package melded into a PACS workstation, including a reduction in the number of computers that need to be in an office or interpretation room. An integrated system is beneficial as direct comparisons to other prior examinations are possible irrespective of the modality, within a single package; this is a tremendous advantage and encourages comparative reviews. Archiving PET/CT studies to PACS places additional demands on the PACS in terms of image data volumes, as typically a whole-body PET/CT consists of well over 800 images, but has the advantage of centralizing archival procedures, especially in centers such as ours with two different PET/CT machines.

We found minor differences in time to perform the estimations, likely to be related to network traffic and performance as well as the configuration of the underlying workstation. An additional advantage of the particular integrated AWS PACS workstation we used is its ability to make tridimensional SUV measurements, eliminating errors of SUV measurement related to physicians' inability to identify the one image slice that contains the maximal SUV voxel.

A dedicated workstation has an additional functionality that allows users to perform ROI analysis on dynamically acquired PET/CT image sets, and therefore at least one dedicated workstation is probably needed for this purpose in those centers performing dynamic PET.

CONCLUSIONS

These results indicate that PACS-integrated workstations could be used interchangeably with dedicated workstations for routine clinical interpretation of PET/CT images without losing the capacity to accurately measure the maximum SUV. The integrated system also offers users the capability to perform volumetric SUV measurements, which should improve the reproducibility of the SUV measurements in clinical practice.

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