Original article

Impact of the Point Spread Function on Maximum Standardized Uptake Value Measurements in Patients with Pulmonary Cancer

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Abstract

Maximum standardized uptake value (SUVmax) from fluorodeoxyglucose (FDG) positron emission tomography (PET) scans is a semi quantitative measure that is increasingly used in the clinical practice for diagnostic and therapeutic response assessment purposes. Technological advances such as the implementation of the point spread function (PSF) in the reconstruction algorithm have led to higher signal to noise ratio and increased spatial resolution. The impact on SUVmax measurements has not been studied in clinical setting. We studied the impact of PSF on SUVmax in 30 consecutive lung cancer patients. SUVmax values were measured on PET-computed tomography (CT) scans reconstructed iteratively with and without PSF (respectively high-definition [HD] and non-HD). HD SUVmax values were significantly higher than non-HD SUVmax. There was excellent correlation between HD and non-HD values. Details of reconstruction and PSF implementation in particular have important consequences on SUV values. Nuclear Medicine physicians and radiologists should be aware of the reconstruction parameters of PET-CT scans when they report or rely on SUV measurements.

Keywords: Fluorodeoxyglucose positron emission tomography-computed tomography, lung cancer, maximum standardized uptake value, point spread function, quantification

Introduction

Positron emission tomography (PET) imaging has seen a tremendous growth in usage in the past 15 years. It is currently widely used with fluorodeoxyglucose (FDG) for staging and therapy response assessment in a large range of malignancies, such as lung, lymphoma, head and neck, and colorectal. Promising applications and development in the oncology, neurology, dementia and cardiology fields and the increasing use of non-FDG tracers will drive a continuous growth of the number of PET/computed tomography (CT) scans performed in the next decade. Standardized uptake value (SUV) is a semi-quantitative measure widely used in PET studies. SUV reflects the quantity of radiotracer within a tissue, normalized with injected activity and patient weight. SUV and other related semi-quantification measurements are increasingly used by clinicians to determine patient management. For instance SUV thresholds are used to differentiate benign from malignant lung nodules,[1] as a prognostic marker in non-small cell lung cancer[2] and the decrease in SUV between pre- and post-therapeutic scans is used to determine whether a patient with diffuse large B-cell lymphoma is responding to therapy.[1,3] Recent technological and software advances such as time-of-flight PET and the implementation of the point spread function (PSF) to algorithm reconstructions have brought increased spatial resolution and higher signal to noise ratio. The PSF describes the response of an imaging system to a point source or point object. The implementation of the PSF in reconstruction

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algorithms has shown increased contrast recovery in phantom studies and neurological and oncological studies in patients and an improvement in image quality in patient studies.[4] The Siemens Biograph PET/CT scanner (Siemens, Knoxville, Tennessee, USA) comes with the Syngo interpretation and reporting software (Siemens, Knoxville, Tennessee, USA). It includes a TrueX reconstruction option incorporating the PSF and is used in clinical routine. The consequences of PSF implementation on SUV measurements in clinical routine in patients with malignancies has not been widely assessed or validated and needs clarification.

We have studied the impact of PSF implementation in an iterative reconstruction algorithm on maximum standardized uptake value (SUVmax) measurements in 30 consecutive patients with lung cancer.

Patients and Methods

Patients

Thirty consecutive lung cancer patients were referred to our institution for initial staging with PET-CT between August and December 2008. All were included retrospectively in this study.

Positron emission tomography-computed tomography

Acquisitions were performed on a Siemens Biograph 6 PET-CT. Two different iterative reconstructions were performed for each patient with the Syngo software:

- A standard ordered subsets expectation maximization (OSEM) iterative reconstruction without implementation of the PSF, called non-high-definition (HD). Reconstruction parameters were iterative reconstruction with 4 iterations, 8 subsets, Gaussian filter with FWHM of 5 mm, zoom 1 and image size 168
- An OSEM iterative reconstruction implementing the PSF, called HD reconstruction. Reconstruction parameters were: iterative reconstruction with 3 iterations, 21 subsets, all pass filter, zoom 1 and image size 168.[5]

Acquisition and data collection

Each patient was injected with 3.7 MBq/kg (0.1 mCi/kg) of FDG (Glucotep® Cyclopharma, Clermont-Ferrand, France) with a maximum of 370 MBq (10 mCi). Following 60 min of uptake, while resting, acquisition from the upper thighs to the skull base was performed. Six to seven bed positions with 2 min and 40 s per bed position were performed. Standard attenuation correction using CT data was performed. SUVmax were measured on HD and non-HD reconstructions for the primary tumor (T), in areas of abnormal nodal mediastinal or hilar uptake (N), in areas consistent with distant metastasis (M). SUVmax measurements were made by manually drawing a circular region of interest on the transverse view, centered on the area with the highest FDG uptake.

Statistical analysis

Maximum standardized uptake value values measured with HD and non-HD reconstruction were compared using paired t-tests, regression analysis and Bland–Altman plots of the percentage difference between the HD and non-HD reconstructions.

Results

Mean HD reconstruction SUVmax measurements were significantly higher than non-HD reconstruction measurements (paired *t*-test) for tumors [difference in mean = 3.658, $P < 0.0001$, 95% confidence interval [CI] = 2.650-4.666, Figure 1], nodes (difference in mean = 3.283, $P = 0.0009$, 95% CI = 1.644–4.921) and metastases (difference in mean = 3.721, $P < 0.0001$, 95% CI = 2.864-4.578).

There was excellent correlation between SUVmax measured with HD reconstruction and non-HD reconstruction for T [$R^2 = 0.945$, Figure 2], with slightly poorer correlation for N ($R^2 = 0.835$) and M ($R^2 = 0.782$).

Bland–Altman analysis showed that the bias of the percentage difference between the techniques was 35.4% for tumors, [95% CI = 30.6-40.1%, Figure 3], 42.4% for nodes (95% CI = 32.2-53.6%) and 49.4% for metastases (95% CI = 42.3-56.4%). For all areas, 95% limits on agreement for the percentage difference between the techniques from the average of the techniques was very wide (T: 11.8-59.0%, N: 5.8-79.8%, M: 10.4-88.4%)

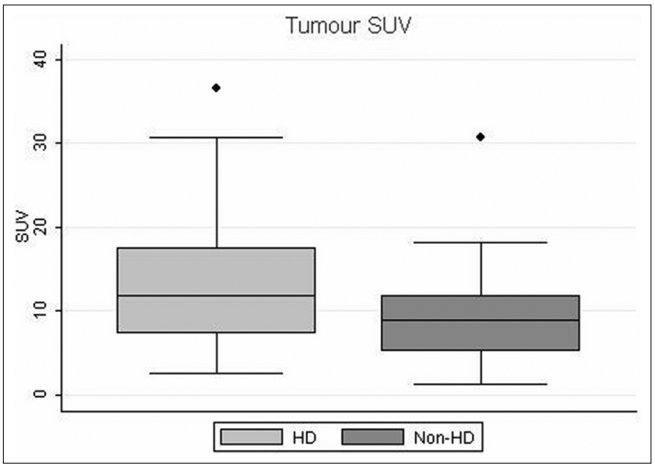

Figure 1: Comparison of tumour max SUV with HD and non-HD reconstruction

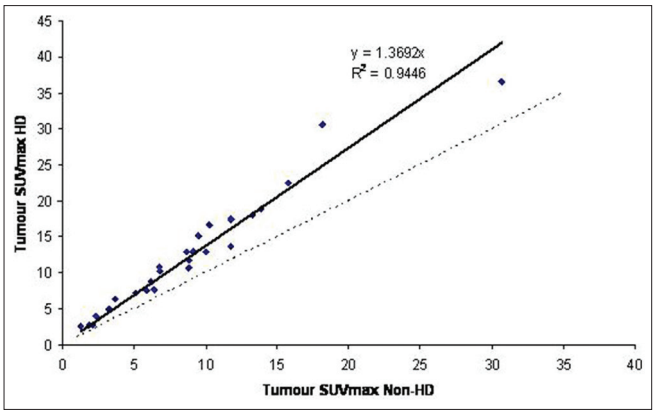

Figure 2: Correlation between tumour max SUV with HD and non-HD reconstruction

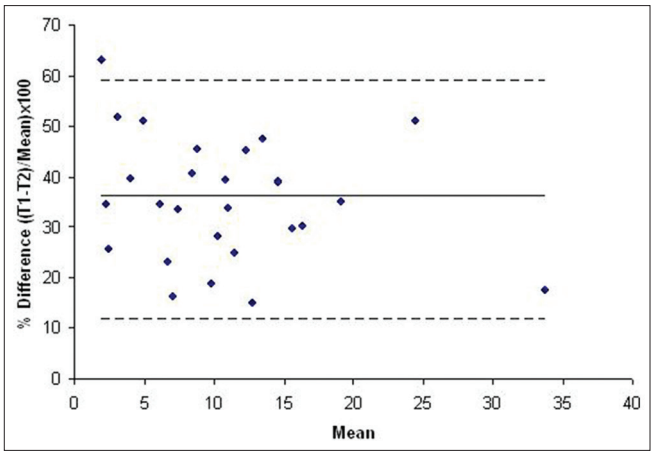

Figure 3: Bland-Altman plot for tumour max SUV for HD and non-HD reconstruction

Discussion

The integration of the PSF in the reconstruction algorithm led to significantly higher SUVmax values in 30 patients with lung cancer for the tumor, the nodes and the metastases.

There has recently been significant work toward improving image quality, increasing spatial resolution and signal to noise ratio.[6] Partial volume correction in PET has been shown to improve accuracy of SUV measurement in phantoms and patients with lung and breast malignancies.[5] However, clinical studies have been lacking. FDG PET has taken a central role in the characterization of solitary pulmonary nodules. Apostolova *et al*. have studied the combined correction of recovery effect and motion blur for SUV quantification of solitary pulmonary nodules.[7] They have found an increase in SUV of 30%. Knäusl *et al*. have studied the TrueX algorithm in phantom studies and have found an overestimation of the true activity.[8]

To the best of our knowledge, this is the first study investigating the impact of the PSF on SUV measurements in clinical routine in such a large group of patients with malignancies. SUV measurements are calculated differently by different manufacturers and Nuclear Medicine physicians and referring clinicians may not be aware of the potentially large differences the different algorithms lead to. Our study demonstrates this large difference in a selected group that reflects the lung cancer patient population in France referred to PET/CT centers as all our patients had PET/CT as part of routine clinical staging, for clinically validated indications.

Using SUV values without the knowledge of how they were obtained may have consequences for patient management. We believe that awareness of this issue is lacking in the nuclear medicine/radiologist community.

One limitation of our study is that the regions of interest (ROI) were drawn manually and that the ROI's were therefore not necessarily identical between the HD and non-HD reconstruction. We have only looked here at SUVmax and careful attention was taken at the time the ROI's were drawn to ensure that the same areas were included. Given that variability is lowest for SUVmax we believe that this limitation does not affect the results or the conclusions of the study.

Another limitation of this study was the lack of lesion/background tissue uptake comparison pre- and post-HD implementation; particularly for nodes and metastasis. We have shown HD reconstruction enhances SUVmax of lesions, but lesion/background ratio in lung cancer patients is less clearly defined and possibly could influence the conspicuity of lesion detection perhaps for nodal disease and metastasis.

In our case, we believe this issue was minimized as we focused on lung cancer primary where local background uptake due to air is generally very low.

SUV variation before and after therapy seems to be a promising prognostic tool. We have not investigated whether different reconstruction algorithms may influence SUV and this would be of interest in future studies along with observing lesion/background characteristics.

Conclusion

Implementation of the PSF significantly increases SUVmax values in patients with lung malignancies. Further work is needed on other malignancy types and on the variation of SUVmax with lesion/background characteristics before and after therapy to assess the consequences of these differences in SUV measurements.

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