PARTIAL VOLUME CORRECTION IN PET: A SINGLE CORRECTION METHOD APPLIED FOR MULTIPLE SOURCE TO BACKGROUND RATIOS

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Introduction

With the importance of PET for therapy response assessment and determining prognosis, methods are needed to generate quantitative statistics that accurately reflect true activity levels. Difficulties can arise in implementing partial volume correction (PVC) methods due to inaccurate tumor volumes and the wide range of tumor to background ratios that occur clinically. We have created a PVC method based on homogeneous activity in spheres, using our gradient-based PET segmentation technique, PET Edge, for size approximation, which will equal or underestimate SUV in the clinical situation.

Method and Materials

PET scans were acquired on a GE DLS scanner for spherical phantoms with fillable spheres emulating clinical conditions of activity levels, acquisition and reconstruction. Phantom studies were acquired with C-11 background and F-18 in the spheres to obtain contrast levels ranging from 5:1 to 70:1. The spheres, radii 5mm, 6.5mm, 8.5mm, 11mm, 14mm and 18.5mm, were segmented using PET Edge *(see Segmentation)*. A single exponential curve was fit to the maximum activities to produce a correction factor based on gradient-based segmentation radius with the maximum value in the largest phantom serving as ground truth.

Segmentation

The gradient-based segmentation technique used for this purpose was shown in a previous work *(1)* to be robust to multiple source-to-background ratios (SBR), sphere sizes, and cameras. It was also shown to be more accurate than the constant threshold technique of 37% of max *(2)*. Subsequent validation was performed using Monte Carlo lung phantoms that simulated realistic clinical PET data demonstrating greater accuracy of PET Edge compared to constant thresholds from 20-50% and manual segmentation *(3,4)*.

Results

Using this PVC method, the error in maximum SUV is significantly reduced for all phantom sizes between 5mm and 14mm at $p < 0.01$ using a paired t-test *(see Table 1)*. The most substantial differences were for the smaller phantoms, and again no important trends were noticed based on SBR *(see Table 2)*. There was a slight increase in the distribution of percent errors after SUV correction, so accuracy was gained with a slight penalty in precision. The maximum percent error after PVC was an under-estimation in maximum SUV of 28.7%.

Table 1
Errors By Phantom Size

Radius	Uncorrected Error	PVC Corrected Error
5.0mm	-70.8% (2.6%)	-13.6% (17.7%)
6.5mm	-54.3% (4.5%)	8.0% (10.8%)
8.5mm	-31.5% (3.7%)	1.0% (10.0%)
11.0mm	-10.0% (6.0%)	-2.0% (7.3%)
14.0mm	-2.1% (2.3%)	-1.5% (2.5%)

Table 2
Errors by Source to Background Ratio

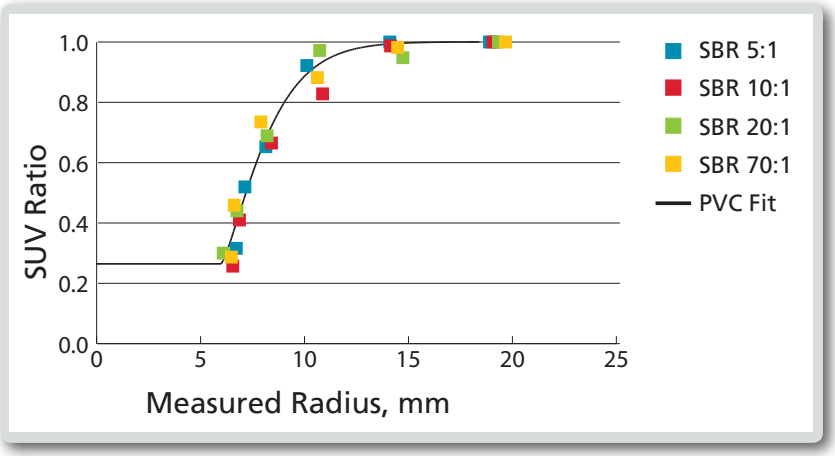
SBR	Uncorrected Error	PVC Corrected Error
5:1	-32.0% (28.3%)	-2.9% (10.6%)
10:1	-37.0% (29.8%)	-10.6% (10.9%)
20:1	-33.9% (29.6%)	4.1% (6.8%)
70:1	-33.1% (29.0%)	2.9% (15.5%)

Data Fitting

The maximum SUV ratio vs. segmentation radius was fit using an exponential of the form:

$y = 1 - ae^{-\beta(x-6)^{1.3}}$ where $a = 0.736$ and $\beta = 0.307$. This resulted in an R^2 of 0.8909. Corrections can be performed for segmentations of radius 6mm and higher. Because of a slight bias in the gradient-based segmentation no segmentations were less than 6mm in radius. In the clinical scenario, the correction would be constant for segmentations with radii of less than 6mm. There was no systematic trend between the curves for correcting based on SBR which suggests that the single correction can be used for any SBR between those studied here. The PVC fit and measured data are shown in *Figure 1*.

Figure 1
SUV Ratio vs Radius



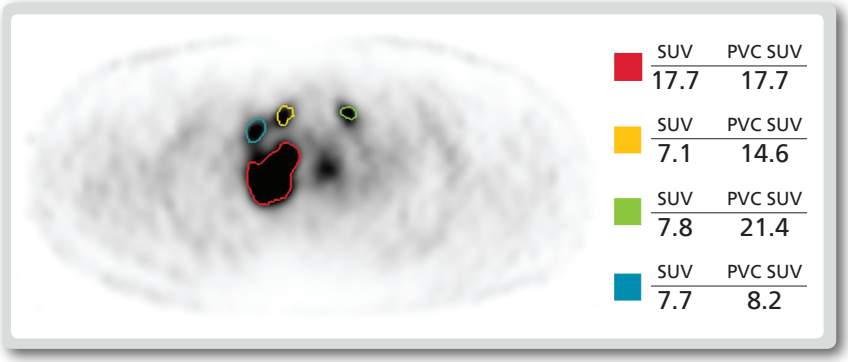
Bias

Uncorrected PET has a distinct bias to under-estimate maximum SUV for spheres approaching the resolution of the image (*Table 1*). This method of PVC minimizes the bias without risk of systematic bias of over-correction in the clinical situation (*Table 2*). Since this method is based on uniform activity and spherical phantoms, any non-uniformity or non-sphericity will cause an under-estimation in maximum SUV which is important.

Conclusions

The PVC method provides a means for more closely reflecting the true activity levels of tumors resulting in more accurate quantitative assessments. This has the potential to provide more accurate determinations of quantitative activity for assessing response to therapy and prognosis. Monte Carlo simulations will help to determine accuracy for different tumor shapes and activity distributions.

Figure 2
Effect of Partial Volume Correction - Clinical Example



Patient with Lymphoma. Note the significant recovery in uptake for the very small tumors (e.g. green contour with equivalent sphere diameter 1.3 cm) whereas the tumor with the red contour is large enough (equivalent sphere diameter of 4.6cm) that it is not significantly affected by the partial volume effect.

Future Directions

This study was performed on images acquired from a single camera. In another study *(1)*, we demonstrated segmentation accuracy for spherical phantoms imaged on a variety of PET cameras and reconstructed with a variety of algorithms. We will extend this current study to multiple cameras and reconstruction algorithms. Each scenario will require a separate PVC correction because of the impact of image resolution on partial volume effect. Additionally, correlating this PVC correction with clinical outcomes will be valuable in evaluating its prognostic usefulness.

References

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