Impact of partial volume effect for using PET to define metabolically active tumor volume for pancreatic cancer

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Aim Correct for partial volume effect (PVE) on PET images for patients with pancreatic cancer.

Methods A voxel-by-voxel PVE correction using a recovery coefficient (RC) approach, the use of 4 different PET thresholding methods and manual delineation on 2 MRI methods.

Results SUVmax values before and after PVE correction, diameter and volumetric analysis.

Summary
What is partial volume effect (PVE)?

The term PVE represents differences in intensity values in the image, which effects images quantitatively and qualitatively, and is referred to two distinct phenomenon:

- **Size dependent 3D blurring effect** (i.e., predominant in small lesions that are < 3 times the FWHM of PET scanner).
  - This effect is pronounced with PET due to the poor spatial resolution.

- **Tissue sampling effect**
  - Affects also CT & MRI images

Soret et al., J Nucl Med, 6, 932-945 (2007)
For the RC approach:
Three phantom set-up were made using the following spheres to background ratios i.e., 8:1, 6:1, 4:1.

RC is defined using the following formula:

\[
RC = \frac{\text{measured sphere activity} - \text{measured background activity}}{\text{known sphere activity} - \text{known background activity}}
\]

Now that RC is known, the voxel-by-voxel PVE corrected activity is given by:

\[
PVE \text{ corrected activity} = \frac{\text{measured activity} - \text{background activity}}{RC} + \text{background activity}
\]
Continue – NEMA phantom

Profile analysis (PA) study: to define a cut-off value (COV) to threshold PET images. A vertical and a horizontal profile were drawn through the centre of each sphere, followed by profile analysis and mathematical interpolation along the x-axis at the FWHM value to determine sphere diameter in mm. We used a spheres to background ratio of 4:1.

The COV is given by following formula:

\[
COV\% = \left( \frac{3 \times FWHM_{PET}}{D} \right) \times \left( \frac{\text{mean Sphere activity} - \text{background}}{\text{Max Sphere activity} - \text{background}} \right) \times 100
\]

Note: The COV is point spread function (PSF) Dependent and size dependent.

Findings: RC & COV%

For sphere to background ratio of 4:1

<table>
<thead>
<tr>
<th>Sphere (D) mm</th>
<th>RC</th>
<th>COV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.15</td>
<td>81</td>
</tr>
<tr>
<td>13</td>
<td>0.26</td>
<td>62</td>
</tr>
<tr>
<td>17</td>
<td>0.47</td>
<td>48</td>
</tr>
<tr>
<td>22</td>
<td>0.68</td>
<td>37</td>
</tr>
<tr>
<td>28</td>
<td>0.83</td>
<td>28</td>
</tr>
<tr>
<td>37</td>
<td>0.85</td>
<td>22</td>
</tr>
</tbody>
</table>
**Findings: SUVmax before & after PVE correction**

<table>
<thead>
<tr>
<th>Tumor diameter on CT</th>
<th>SUVmax before PVE mean &amp; range</th>
<th>SUVmax after PVE mean &amp; range</th>
<th>RC mean &amp; range</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.9 – 5.8) cm</td>
<td>8.2 (3.9 – 13.1)</td>
<td>10.6 (6.56 – 16.37)</td>
<td>0.72 (0.58 – 0.81)</td>
</tr>
</tbody>
</table>

**Define background in patients**

- A duplicated ROI of that used on the tumor was drawn in a region inside the liver.  

- The mean and range of SUVs in the liver were 1.63 (1.2 – 2.2), 9 patients.
Pancreatic tumor on different modalities

<table>
<thead>
<tr>
<th>Diameter</th>
<th>CT with contrast</th>
<th>ADC-DW</th>
<th>DCE</th>
<th>PET SUV2.5 before corr.</th>
<th>PET SUV2.5 after corr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>1.9</td>
<td>2.31</td>
<td>1.58</td>
<td>1.61</td>
<td>1.95</td>
</tr>
</tbody>
</table>

DWI-MRI \( (b=1000 \text{ s/mm}^2) \)

ADC-DWI-MRI

DCE-MRI

PET
Findings: Tumor contours on PET using different methods

maximum diameter on CT = 1.9 cm

<table>
<thead>
<tr>
<th>Thresholding methods</th>
<th>Threshold value</th>
<th>Volume cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before corr.</td>
<td>After corr.</td>
</tr>
<tr>
<td>SUV2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>0.33</td>
<td>0.64</td>
</tr>
<tr>
<td>42%SUVmax</td>
<td>1.65</td>
<td>2.75</td>
</tr>
<tr>
<td></td>
<td>2.29</td>
<td>0.79</td>
</tr>
<tr>
<td>COV%</td>
<td>1.71</td>
<td>2.86</td>
</tr>
<tr>
<td></td>
<td>1.93</td>
<td>0.73</td>
</tr>
<tr>
<td>S/B</td>
<td>2.44</td>
<td>2.44</td>
</tr>
<tr>
<td></td>
<td>13.78</td>
<td>14.00</td>
</tr>
</tbody>
</table>
General observations:

- SUV 2.5 & S/B ratio yield larger volumes after PVE correction.
- 42% SUVMax & %COV yield smaller volumes after PVE correction.
- In all modalities, S/B ratio demonstrated the highest tumor volume except for CT.
- ADC-MRI yield volumes that sits between PET & CT.
Findings: maximum diameter on different modalities & different PET thresholding methods

General observation

- No trend was seen on maximum diameter measurements before & after PVE correction using the 4 PET thresholding methods.
Summary

- PVE yield a considerable impact on 3D tumor volume measured on PET images.
- PVE corrected PET images reveals larger volumes except for 42%SUVmax and %COV methods.
- Corrected PET images reveal a reduced volumetric difference between CT & ADC-DW MRI.
- Further studies combined with pathological specimens are required to identify the optimal PET thresholding method.