Model Parameter Correlation for DCE-MRI in Advanced Cervical Cancer

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Purpose

Recently it has been shown that stratifying patients by certain DCE-MRI parameters can distinguish between patients with better and poorer outcome for advanced cervical cancer. The results from Yuh et al. [1] showed the lowest 10th percentile of the RSI (Relative Signal Increase) to be the best stratifier. Recent results from Halle et al. [2] have shown the 20-30th percentile of A0pix to be the best stratifier. A number of these derived model parameters are highly correlated [3] and may thus be redundant. If such a correlation can be determined the computationally fastest and most robust approach could be chosen to enhance clinical use of these functional estimates for improving therapy.

Materials and Methods

In total 24 DCE-MRI scans in 11 different patients were included in the study. A 3T Philips Achieva was used with the following DCE protocol: 20-24 slices, 5mm slice thickness, TE/TR: 1.4ms/2.9 ms, 10° Flip Angle (FA), 2,27mm isotropic in-plane resolution. The bolus injected was 0.1 mmol/kg Dotarem at 4ml/s, followed by a 5 ml saline flush. 120 dynamics equidistantly spaced by 2.1 sec were acquired. Tumor delineation was performed by an experienced oncologist on T2W images. The models tested and parameters estimated were: the Tofts model (ktrans,std and k'trans,std), the extended Tofts model (vep,kd,extend and k'trans,extend), the Brix-Hoffman model (A0pix,ktrans,Brix and k0), the Relative Signal Increase of the first 90 seconds (RSI90) and initial Area under the Curve (iAUC90). R2 and Normalized Mutual Information (NMI) were determined for sets of parameter pairs.

Results

In Figure 1A an example of the spatial distribution of different modeling parameter is shown. A voxelwise scatterplot of the same data are shown in figure 1B. The R2 value indicates that the 91% of variability of the iAUC90 is explained by the A0pix factor if assuming a linear relation between parameters. R2 and NMI for the 24 scans for a subset of parameter are shown in table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>iAUC90/ktrans,extend</th>
<th>A0pix/ktrans,extend</th>
<th>iAUC90/A0pix</th>
<th>RSI90/A0pix</th>
<th>A0pix/RSI90</th>
<th>ktrans std</th>
<th>ktrans,extend/k0,extend</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>0.59±0.19</td>
<td>0.58±0.17</td>
<td>0.82±0.15</td>
<td>0.73±0.17</td>
<td>0.83±0.13</td>
<td>0.55±0.15</td>
<td></td>
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<tr>
<td>NMI</td>
<td>0.58±0.15</td>
<td>0.57±0.16</td>
<td>0.64±0.11</td>
<td>0.61±0.13</td>
<td>0.61±0.12</td>
<td>0.53±0.14</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

The parameters that best describe the same mechanism are iAUC90 and A0pix followed by RSI and A0pix. The latter correlation might explain the consistent results from [1] and [2]. Also worth noticing is that the often cited correlation [4] between Ktrans,std and A0pix,ktrans,Brix only reaches R2=0.55 in these tumors of advanced cervical cancer. Ktrans describes the permeability/leakage from the vessels into the interstitium and is determined mostly by the initial slope of the tissue curve. The A0pix and similarly RSI mostly describe the maximum buildup of contrast in the tissue and is related to the extracellular extravascular fraction. Both Ktrans and A0pix have been shown to correlate with hypoxia and thus radioresistance though they describe different aspects of tumor blood flow.

Conclusion

Estimation of outcome in patients with advanced cervical cancer by measuring A0pix [2] can potentially be replaced by estimating the much less computationally intensive parameter iAUC90 or RSI90. This could stimulate broader clinical use of DCE-MRI for estimating outcome in patients with advanced cervical cancer.