Volumetric RECIST: an improved way to assess tumor response after transcatheter arterial chemoembolization (TACE)

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Purpose

Multi-phasic contrast-enhanced MRI is accepted as a gold standard for diagnosing liver tumors and assessing treatment response after locoregional therapy, especially following Transcatheter Arterial Chemo-Embolization (TACE). Measuring changes in tumor size (Response Evaluation Criteria in Solid Tumors, RECIST) on MRI is an accepted method to assess response to TACE (1).

RECIST evaluates response to treatment based on changes in tumor size (2, 3). Although this method is widely used, it has some glaring limitations when applied to TACE. TACE induces partial arterial occlusion and inhomogeneous necrosis, and as a result, changes in tumor size are inhomogeneous (4). This makes current methods of tumor response assessment difficult after TACE. Furthermore, RECIST is applied to one representative axial slice of the tumor. As a result, different slice selection can lead to totally different response assessments. Additionally, the measurements comprise the longest diameter on the specified slice and ignore the volume of the tumor.

Our hypothesis is that a semiautomatic quantitative tumor volume assessment can greatly improve the existing tumor response method (RECIST). Our goal is to demonstrate that hepatic tumor volume measurements in a time efficient manner on a voxel-by-voxel basis is possible, giving a true 3D volumetric assessment. This was done by using a semi-automatic tumor segmentation to determine tumor volume. We propose that this measure would be called quantitative volumetric RECIST (vRECIST).
Methods and Materials

A semi-automatic 3D volume segmentation employing non-Euclidean radial basis functions was used by an experienced interventional radiologist (O.P., 9 years of experience), who did not perform the DEB-TACE procedures, on the 20 second pre- and post-DEB-TACE contrast-enhanced MRIs to segment the tumors (5, 6). Briefly, this method is inspired by front-propagation theory and radial basis functions (mathematically, a function whose value depends only on the distance from the origin). Combined with non-Euclidean distances, this method allows for segmentations that follow 3D image features including straight edges and corners. This method was used because it can accurately segment in 3D, yet needs minimal user interaction. Manual segmentation requires a high level of expertise and incorporates an expert's knowledge with image features to make accurate segmentations. This semi-automatic method provides similar results but only at a fraction of user interaction time. In practice, the user identifies an initial control point. From there, the user can interactively expand or contract the 3D region of interest. Additional segmentations can be included by placing more control points. Corrections are made in the same volumetric way. The segmentation time was recorded.

In four patients with hepatocellular carcinoma and imaged using contrast enhanced MRI before and 1 month after drug-eluting beads treatment, vRECIST was calculated as follows: 1) A semi-automatic 3D tumor segmentation was performed as described above on the 20 second contrast enhanced scan. 2) The volume was directly calculated based on this segmentation. The vRECIST therapy response was calculated as the pre- minus post-vRECIST values, so a positive change value in vRECIST indicated a decrease in tumor volume after DEB-TACE. A percent change was also calculated as (pre- minus post-vRECIST) divided by pre-vRECIST.
Results

Four representative patients (Figures 1-4), 8 MRI examinations total (4 pre-DEB-TACE and 4 post-DEB-TACE), were used to visualize the segmented tumor with a patterned overlay on a representative axial slice from the 20-second scan. The 3D segmentation allowed for a volume rendering of the tumor (right most column). The tumor volumes (vRECISt) were found to be in the range of 15.9-952.0cm$^3$ and 8.0-1300.0cm$^3$ for pre- and post-DEB-TACE, respectively. Specific vRECISt values, therapy response change, and segmentation time are shown in Table 1.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Segmentation Time (sec)</th>
<th>vRECISt (cm$^3$)</th>
<th>Therapy Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Pre</td>
<td>200 90</td>
<td>952.0 1300.0</td>
<td>-348.0cm$^3$ -36.6% change</td>
</tr>
<tr>
<td>2-Pre</td>
<td>90 50</td>
<td>124.2 51.0</td>
<td>73.2cm$^3$ 58.9%</td>
</tr>
<tr>
<td>3-Pre</td>
<td>90 50</td>
<td>197.8 109.9</td>
<td>87.9cm$^3$ 44.4%</td>
</tr>
<tr>
<td>4-Pre</td>
<td>40 50</td>
<td>15.9 8.0</td>
<td>7.9cm$^3$ 49.7%</td>
</tr>
</tbody>
</table>

Table 1: vRECISt segmentation time, tumor volume, and therapy response measurements.
Fig. 1: Patient 1 vRECIST pre- and post-DEB-TACE (at the same slice levels). Note how the semi-automatic tumor segmentation (patterned overlay) aligns well with the actual tumor borders. The quantitative volumes are of the entire segmented tumor.

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**Fig. 2:** Patient 2 vRECIST results.

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**Fig. 3:** Patient 3 vRECIST results.
Fig. 4: Patient 4 vRECIST results.
Conclusion

The major finding of our study is that tumor volume measurements in a time efficient manner on a voxel-by-voxel basis is possible, giving a true 3D volumetric assessment. vRECIST was based on tumor volume size difference between pre- and post-treatment. Comparison to previous MRI examinations is also possible. In conclusion, our study showed that a semiautomatic tumor volumetric (vRECIST) assessment is feasible in a realistic time frame. This software can help the interventional radiologist plan future treatments by demonstrating the shape and location of residual tumor.
References


