Quantitative EASL: 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 enhancement (European Association for the Study of the Liver, EASL) on MRI is an accepted method to assess response to TACE (1).

The EASL criteria (2), evaluates response to treatment based on changes in tumor enhancement. 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, tumor enhancement becomes heterogeneous (3). This makes the current method of tumor response assessment difficult after TACE. Furthermore, the EASL criteria is applied to one representative axial slice of the tumor. As a result, different slice selection can lead to totally different response assessments. In EASL, the percent enhancement is made based on visual inspection and often grouped into quartiles (1). This assessment can be particularly inaccurate if the enhancement percentage is at a threshold between two quartiles.

Our hypothesis is that a semiautomatic quantitative tumor enhancement assessment can greatly improve the existing tumor response method (EASL). Our goal is to demonstrate that hepatic tumor enhancement pattern 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 1) semi-automatic tumor segmentation to determine enhancement for the entire tumor volume, and 2) reporting a quantitative measure of tumor viability as a % of enhancing tumor volume. We propose that this measure would be called quantitative EASL (qEASL).
Methods and Materials

In four patients with hepatocellular carcinoma and imaged using contrast enhanced MRI before and 1 month after drug-eluting beads treatment, qEASL was calculated as follows: 1) A semi-automatic 3D tumor segmentation was performed on the 20 second contrast enhanced scan. 2) The pre-contrast scan was subtracted from the 20 second scan to remove background enhancement. 3) The 3D segmented volume region from #1 was applied to #2. 4) From #2, average enhancement values were obtained from 10x10x10 pixels regions of interest (ROIs) representing normal liver parenchyma. 5) Viable tumor was defined as areas in #3 where the enhancement was more than that of the normal parenchyma ROI found in #4. 6) Based on #5, the volume of viable tumor was measured and expressed as qEASL in cm$^3$. 7) The viable tumor was also defined as a % of the total tumor volume and expressed as qEASL in %. A color map was overlayed on the 20 second scans to show volumetric and regional tumor enhancement heterogeneity. Colored regions of the segmented tumor are where there is more enhancement than healthy liver tissue. The color map for each patient was normalized to the maximum enhancement in the entire tumor of the pre-DEB-TACE scan. This ensured that the post-treatment color map used the same scale for comparison with the pre-treatment color bar. In the color bar, red represented maximum enhancement (viable tumor) and blue represented minimum enhancement (treated/non-viable tumor).
Results

Heterogeneity within tumors can be seen in quantitative color maps (Figures 1-4). The red areas show increased enhancement, while the blue areas demonstrate areas of decreased enhancement. The majority of the tumor volume for all pre-treatment MRI cases enhanced more than healthy liver tissue. This volumetric enhancement was expressed as a percentage of total tumor volume. qEASL pre-TACE was 76.1±19.3% and 24.2±14.9% post-TACE. The tumor volumes enhancing more than the healthy tissue before treatment were: 819.9, 115.5, 97.1, and 12.2 cm$^3$ for patient cases 1 through 4. After treatment, the enhancing volumes were: 558.9, 4.9, 31.6, and 1.2 cm$^3$, respectively. qEASL was able to measure the enhancement for the entire tumor volume and provide a quantitative result.
Fig. 1: qEASL pre- and post-DEB-TACE. Note the heterogeneity in tumor enhancement as seen on the color maps. Much of the viable tumor (yellow and red) became less enhanced after DEB-TACE and appears as blue in the post-treatment color map. The tumor viability % is a specific quantitative value representing the percent of the entire tumor volume showing enhancement more than healthy liver tissue. The color bar per patient case is normalized to the maximum enhancement measured in the pre-DEB-TACE tumor volume.

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Fig. 2

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Fig. 3
Fig. 4

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Conclusion

The major finding of our study is that tumor enhancement pattern measurements in a time efficient manner on a voxel-by-voxel basis is possible, giving a true 3D volumetric assessment. qEASL was obtained by the enhancement value comparison of segmented tumor volume to the normal parenchymal liver enhancement. Comparison to previous MRI examinations is also possible. In conclusion, our study showed that a semiautomatic quantitative tumor enhancement (qEASL) 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


