Man vs. Machine: Validation of the qualitative imaging feature set VASARI using volumetric analysis by 3-D Slicer of the TCGA GBM Dataset

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BACKGROUND

Glioblastoma (GBM) was the first tumor to undergo comprehensive genetic analysis as part of the NCIs The Cancer Genome Atlas (TCGA). Clinical images were subsequently collected in The Cancer Imaging Archive (TCIA) to augment this genomic repository. While automated volumetric analysis is likely more precise, the current tooling available to support such analysis (e.g. 3D-SLICER, MIPAV, etc) requires a significant amount of domain expertise. Thus, volumetric analysis remains difficult in clinical practice, and qualitative assessments of imaging features are still critical, particularly if they have clinical relevance. The purpose of this study was to assess the correlation between semi-quantitative image (human-generated) features generated by the current gold-standard (i.e. neuroradiologists) against quantitative imaging volumetric measurements (machine-aided).

MATERIALS & METHODS

Neuroradiology Data: FLAIR and T1 weighted images for corresponding patients in the TCGA GBM archive was obtained from TCIA, a publically accessible neuroimaging data portal.

Qualitative Feature Segmentation: Each image was downloaded to a DICOM workstation and independently assessed by at least 3 neuroradiologists who recorded a set of 30 imaging features describing the size, location, and morphology of the tumor. To perform a systematic evaluation of these images, a set of qualitative imaging features (the VASARI feature set) along with complete corresponding guidelines was used. For each tumor, radiologists reviewed a series of images which included a T1 weighted axial image both before and after gadolinium contrast administration as well as an axial T2 FLAIR image.

The entire VASARI feature set consists of over 30 features. For purposes of this study, we focused on the segmentation results for three key features. Raters were instructed on the scoring guidelines and generated categorical based estimates of the following tumor compartments: proportion of total abnormality as visualized on the T2 FLAIR image that showed contrast enhancement, proportion showing no-contrast enhancement, proportion appearing to be necrotic tissue, and proportion appearing to be edematous tissue.

For each of the three imaging features for each patient, a consensus score was tabulated from the combined scores from the radiologists. This score reflected the rating that the majority of the radiologists chose. If there was a tie, the score reflected the random selection of the rating.

Quantitative Feature Segmentation: In parallel, we also performed volumetric analysis using the 3-D Slicer platform to quantitatively measure actual volumes of each individual region. This methodology involves the manual segmentation of each relevant image feature on several MRI sequences. The FLAIR-volume, contrast-enhancing region, and necrotic core were independently segmented and verified by a trained neuroradiologist (RRC).

MATERIALS & METHODS

Qualitative Feature Segmentation

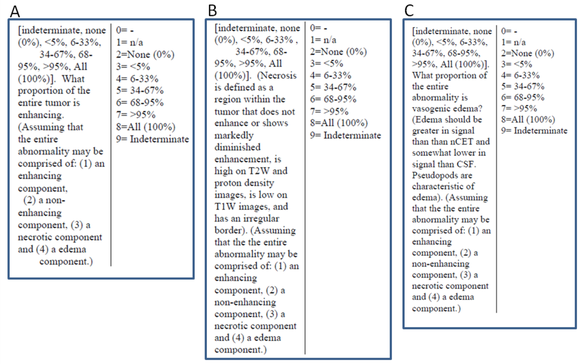

Figure 1: Subset of features scored by neuroradiologist team. Complete scoring guidelines are indicated for imaging features proportion Contrast Enhancing (A), proportion Necrotic (B), and proportion Edema (C).

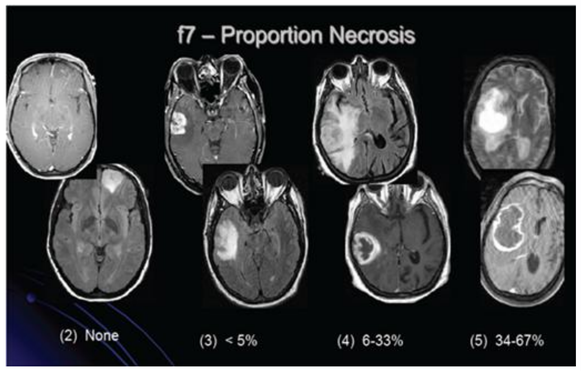

Figure 2: Example of proportion necrosis image feature scoring according to VASARI guidelines above. Necrosis is defined as the area within the total abnormality that does not enhance or that shows markedly diminished enhancement.

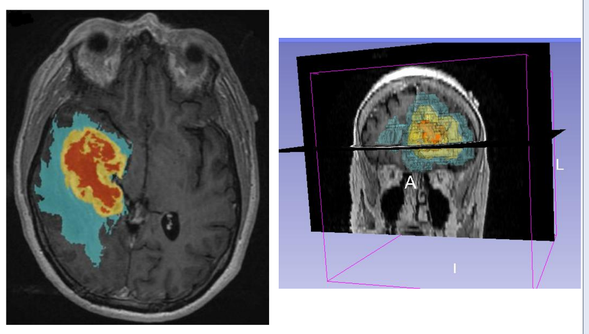

Figure 3: Visualization of quantitative volumetric segmentation methodology. Region corresponding to edema/tumor infiltration (blue) was segmented from FLAIR sequences whereas contrast enhancement (yellow) and necrosis (orange) have been segmented from T1 post contrast weighted images (reprinted with permission from Zinn *et al.*, 2011).

RESULTS

Inter-rater agreement of relevant imaging features between radiologists scores according to VASARI standard.

	Original data set		New data set	
	α estimate	95% CI	α estimate	95% CI
Proportion enhancing	0.607	(0.403, 0.749)	0.243	(0.034, 0.462)
Proportion nCET	0.428	(0.239, 0.565)	0.134	(-0.056, 0.316)
Proportion necrosis	0.511	(0.358, 0.646)	0.631	(0.337, 0.787)
Proportion edema	0.496	(0.339, 0.608)	0.504	(0.206, 0.667)
T1/FLAIR	0.422	(0.234, 0.574)	0.119	(-0.085, 0.295)
Enhancing margin thickness	0.313	(0.079, 0.548)	0.22	(-0.086, 0.509)
Diffusion	0.170	(-0.096, 0.438)	0.392	(-0.002, 0.696)
Tumor location	0.795	(0.704, 0.881)	–	–

Table 1: Inter-rater agreement for relevant imaging features. Agreement between raters is measured via Krippendorff's α. Values closer to +1 indicate higher levels of agreement.

Correlations between measurements based on VASARI measurements and measurements from machine-generated volumetric quantitative analyses.

Univariate linear regressions of the volumetric contrast enhancing portion, edema, and necrosis measurements upon the neuroradiologist-generated contrast enhancing, edema, and necrosis estimates respectively, were performed. These analyses indicated very strong correlations between the volumetric and human measurements (p-value < 0.0001 in each case).

Image Feature	β coefficient	95% CI	P-value
Proportion enhancing	0.855	0.747, 0.963	5.42e--24
Proportion nCET	0.920	0.778, 1.065	2.40e-19
Proportion necrosis	0.447	0.392, 0.503	1.64e-24
Proportion edema	1.296	1.180, 1.411	2.11e-32

Table 2: Results of univariate linear regression for agreement between VASARI measurements and measurements derived from quantitative volumetric analyses.

Quantitative volumetric measurements were also transformed into VASARI-relevant measurements and the percent agreement with the VASARI consensus scores as well as with any of the three raters was calculated. (Figure 4).

CONCLUSIONS

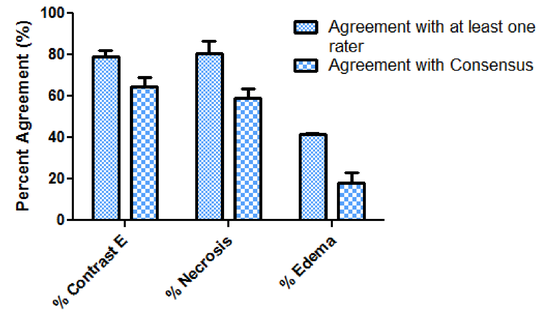

Figure 4: Subset of features scored by neuropathology core. Complete scoring guidelines are indicated for imaging features proportion Contrast Enhancing (A), proportion Necrotic (B), and proportion Edema (C).

CONCLUSIONS

This study, which included consensus reads by 3 neuroradiologists for 75 patients, indicated a high-degree of concordance between qualitative and quantitative assessment of tumor features. Given that quantitative volummetry is not performed in routine cancer clinical practice, this work suggests that clinical visual semi-quantitative estimations of tumor volume are both reproducible and valid.

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