Early Postoperative Delineation of Residual Tumor after Low-Grade Glioma Resection by Probabilistic Quantification of Diffusion-Weighted Imaging

Moritz Scherer\textsuperscript{1} M.D., Christine Jungk\textsuperscript{1} M.D., Michael Götz\textsuperscript{2} M.Sc., Philipp Kickingeder\textsuperscript{3} M.D., David Reuss\textsuperscript{4} M.D., Martin Bendszus\textsuperscript{3} M.D., Ph.D., Klaus Maier-Hein\textsuperscript{2} M.Sc., Ph.D., Andreas Unterberg\textsuperscript{1} M.D., Ph.D.

\textsuperscript{1}Department of Neurosurgery, Heidelberg University Hospital, Heidelberg, Germany
\textsuperscript{2}Devision of Medical Image Computing, German Cancer Research Center (DKFZ), Heidelberg, Germany
\textsuperscript{3}Department of Neuroradiology, Heidelberg University Hospital, Heidelberg, Germany
\textsuperscript{4}Department of Neuropathology, Heidelberg University Hospital, Heidelberg, Germany
No financial support or conflict of interest to disclose
Background:

- Postoperative tumor volume is known to determine outcome in LGG
- Early postoperative MRI has been shown to overestimate residual tumor
  - FLAIR imaging susceptible to surgical trauma:
    - Edema
    - Ischemia

Objective:
To evaluate if integration of apparent diffusion coefficient (ADC) maps into image analysis permits an accurate estimation of residual tumor also on early postoperative MRI.
Retrospective, consecutive cohort of WHO°II gliomas: n=43 primary tumor resections

Inclusion according to available postoperative MRI:

- early post-OP (<48h) -> epMRI
- FLAIR + ADC-Maps (DWI)

AND simultaneous:
- Follow-up MRI (3-6m) -> fuMRI
- FLAIR

Workflow epMRI:

Co-Registration of FLAIR and ADC

Histogram Analysis of ADC-Maps in FLAIR hyperintense areas

Comparison with follow-up MRI FLAIR

Scherer et al., JNS 2018, accepted
Residual FLAIR hyperintense tumor was manually segmented on epMRI and corresponding ADC-maps were co-registered.

Using an expectation maximization algorithm, residual tumor segments were probabilistically clustered into areas of either ischemia (1) residual tumor (2), or normal white matter (3) by fitting a mixture model of superimposed Gaussians to the ADC histogram.
Diffusion-weighted imaging-based probabilistic image segmentation

Results from clustering:

- **On epMRI**: Clustering FLAIR Hyperintensity into regions of ischemia and tumor according to ADC-histograms
- **Enables quantification of ischemia-adjusted residual tumor volume on epMRI**
Volumetric Analysis (n=43)

Mean FLAIR tumor was significantly larger on epMRI compared to fuMRI (19.4±16.5 ml vs. 8.4±10.2 ml, p<0.0001).

Clustered tumor volumes on epMRI were no longer different from the fuMRI reference (mean difference -0.8 ± 3.7 ml, p=0.16)

Repeated Measures ANOVA followed by Bonferroni’s Multiple Comparison

Scherer et al., JNS accepted, 2018
Agreement Analysis:

Follow-up MRI and Clustered epMRI tumor volumes

Correlation [Pearson $r=0.96$ (p$<0.0001$), Concordance Correlation Coefficient (CCC) 0.89 (95% CI 0.83)] and Bland-Altman analysis suggested strong agreement between clustered epMRI volumes and the fuMRI reference for residual tumor after surgery.

Scherer et al., JNS 2018, accepted
Summary & Conclusions

• Probabilistic segmentation of ADC-maps facilitates accurate assessment of residual tumor within 72h after LGG resection.

• Multiparametric image analysis detected FLAIR signal alterations attributable to surgical trauma, which led to overestimation of residual LGG on epMRI compared to fuMRI.

• The prognostic value and clinical impact of this method has to be evaluated in larger case-series in the future.

Scherer et al., JNS 2018, accepted