Arterial spin-labeled imaging of high-grade glioma

- Are Blood Flow and Blood Volume Predictors of Localized Photosensitizer Accumulation in the Brain?
- Recommendations on the use of gadolinium-based contrast agents in the diagnosis and monitoring of common adult intracranial tumours
- Congress of neurological surgeons systematic review and evidence-based guidelines for the role of imaging in newly diagnosed WHO grade II diffuse glioma in adults: update
- MRI-Based Score to Recognize Thalamic Glioma Grade in Children: Morphology, Diffusion, and Arterial-Spin-Labeling Perfusion
- Multi-Site Retrospective Analysis of Diffusion and Perfusion MRI Correlates to Glioma Characteristics Derived from Radio-Pathomic Maps
- Cerebrovascular Reactivity Mapping in Brain Tumors Based on a Breath-Hold Task Using Arterial Spin Labeling
- The cortical high-flow sign in oligodendroglioma, IDH-mutant and 1p/19q-codeleted is correlated with histological cortical vascular density
- Noninvasive blood-brain barrier integrity mapping in patients with high-grade glioma and metastasis by multi-echo time-encoded arterial spin labeling

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Arterial spin-labeled imaging of glioma

Arterial Spin-Labeled imaging is an advanced MRI technique that non-invasively measures cerebral blood flow (CBF) using magnetically labeled arterial blood water as an endogenous tracer. This technique has proven particularly useful in the evaluation of high-grade gliomas, offering insights into tumor vascularity, metabolism, and treatment response. Below are key aspects of its utility:

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Functional Insights into Tumor Pathophysiology

- **Hyperperfusion Assessment**: High-grade gliomas are characterized by neovascularization, leading to areas of increased perfusion. ASL can detect hyperperfusion, which correlates with tumor grade and aggressiveness. - **Differentiation Between Tumor and Edema**: ASL helps distinguish tumor regions (high CBF) from surrounding vasogenic edema (low CBF), improving lesion characterization.

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Clinical Applications

Tumor Diagnosis and Grading - **Grading**: High-grade gliomas (e.g., WHO grades III and IV) typically show higher perfusion values compared to low-grade gliomas due to increased angiogenesis. - **Differentiation from Non-Neoplastic Lesions**: ASL can help differentiate gliomas from non-tumorous conditions like radiation necrosis or abscesses, which may show hypoperfusion.

Prognosis

- Elevated ASL perfusion metrics, such as tumor CBF or cerebral blood volume (CBV), are associated with poor prognosis due to their correlation with angiogenic activity and potential for aggressive behavior.

Treatment Monitoring

- **Response to Therapy**: Reductions in ASL-measured perfusion after treatment may indicate a positive response. Conversely, stable or increased perfusion can suggest recurrence or treatment resistance. - **Pseudoprogression vs. True Progression**: ASL aids in distinguishing these entities, as pseudoprogression often shows lower perfusion compared to true progression.

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Advantages of ASL

- **Non-Invasive and Repeatable**: Unlike dynamic contrast-enhanced MRI or perfusion CT, ASL avoids the need for exogenous contrast agents, making it safer for patients with renal impairment or allergies to gadolinium. - **Quantitative Data**: ASL provides absolute CBF values, enabling standardized comparisons over time or between patients.

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Limitations

- **Spatial Resolution**: ASL's resolution is lower compared to other perfusion techniques, which may limit its ability to assess small lesions or heterogeneous tumors. - **Susceptibility Artifacts**: Tumors near air-filled structures (e.g., sinuses) can be challenging to evaluate due to artifacts. - **Low Signal-to-Noise Ratio (SNR)**: Achieving high-quality ASL images often requires longer acquisition times or advanced MRI sequences.

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Future Directions

- **ASL and Artificial Intelligence**: Combining ASL with machine learning algorithms may enhance glioma grading, prognosis prediction, and automated lesion segmentation. - **Hybrid Techniques**: Integrating ASL with advanced modalities like diffusion tensor imaging (DTI) or MR spectroscopy (MRS) could provide a more comprehensive understanding of tumor biology.

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ASL imaging represents a promising tool in the neuroimaging arsenal, particularly for managing high-grade gliomas. It is a valuable addition to conventional MRI, offering insights that can refine diagnostic precision, guide treatment strategies, and improve patient outcomes.

The aim of a study of Beppu et al., was to clarify whether arterial spin labeling (ASL) perfusion imaging can assess biological effects from bevacizumab (BEV) therapy as reliably as PET with 11C methionine positron emission tomography.

Twenty-four patients with recurrent glioblastoma were examined using both ASL and C-met-PET before and 4 and 8 weeks after starting BEV treatment. Tumor-to-normal brain (T/N) ratios, fluctuations in T/N ratio, and tumor volumes were compared between ASL and C-met-PET. Accuracy of predicting patient with long progression free survival (PFS) was assessed for T/N ratios and fluctuations for ASL and C-met-PET in each phase and in each period using receiver operating characteristic curves. Between 2 groups of patients assigned by cutoff values from receiver operating characteristic curves, PFS was compared in each phase or in each period.

T/N ratios, fluctuations in ratio, and tumor volumes correlated significantly between ASL and C-met-PET at all time points and all periods. Arterial spin labeling was eligible as a predictor for long PFS only in assessment of fluctuations in T/N ratio. However, the most accurate predictors for long PFS were T/N ratio from C-met-PET at 8 weeks and the fluctuation from baseline to 4 weeks in T/N ratio from C-met-PET.

Blood flows on ASL correlated with accumulations of C-met on PET in recurrent glioblastoma under BEV treatment. Although C-met-PET offered superior accuracy for predicting patients with long PFS from time points, ASL offered reliable prediction of long PFS, provided that fluctuations in T/N ratio between consecutive scans are assessed [1)].

ASL improves the diagnostic accuracy of DSC perfusion MRI in differentiating pseudoprogression from early tumor progression [2)].

A study enrolled 60 glioblastoma patients with more than 5-mm-thick surgical cavity wall enhancement (SCWE)s as detected on contrast-enhanced MR imaging after concurrent chemoradiation therapy. Two independent readers categorized the shape and perfusion state of SCWEs as nodular or non-nodular and as having positive or negative perfusion compared with the contralateral grey matter on arterial spin labeling (ASL). The perfusion fraction on ASL within the contrast-enhancing lesion was calculated. The independent predictability of TTP was analyzed using the Kaplan-Meier method and Cox proportional hazards modelling.

The perfusion fraction was higher in the non-progression group, significantly for reader 2 (P = 0.03) and borderline significantly for reader 1 (P = 0.08). A positive perfusion state and (P = 0.02) a higher perfusion fraction of the SCWE were found to become an independent predictor of longer TTP (P = 0.001 for reader 1 and P < 0.001 for reader 2). The contrast enhancement pattern did not become a TTP predictor.

Assessment of perfusion in early post-treatment MR imaging can stratify TTP in patients with glioblastoma for adjuvant temozolomide therapy. Positive perfusion in SCWEs can become a predictor of a longer TTP [3].

Prospective observational diagnostic studies

Hemodynamic measurements such as cerebral blood flow (CBF) and cerebrovascular reactivity (CVR) can provide useful information for diagnosing and characterizing brain tumors. Previous work showed that arterial spin labeling (ASL) in combination with vasoactive stimulation enabled simultaneous non-invasive evaluation of both parameters, however, this approach had not been previously tested in tumors. This work aimed to investigate the application of this technique, using a pseudo-continuous ASL (PCASL) sequence combined with breath-holding at 3 T, to measure CBF and CVR in high-grade gliomas and metastatic lesions, and to explore differences across tumoral- - peritumoral regions and tumor types. To that end, 27 patients with brain tumors were studied. Baseline CBF and CVR were measured in the tumor, edema, and gray matter (GM) volumes of interest (VOIs). Peritumoral ipsilateral ring-shaped VOIs were also generated and mirrored to the contralateral hemisphere. Differences in baseline CBF and CVR were evaluated between contralateral and ipsilateral GM, contralateral and ipsilateral peritumoral rings, and among VOIs and tumor types. CBF in the tumor was higher in grade 4 gliomas than metastases. In grade 4 gliomas, edema had lower CBF than the tumor and contralateral GM. CVR values differed between grade 3 and grade 4 gliomas and between grade 4 and metastases. CVR values in the tumor were lower compared to the contralateral GM. Differences in CVR between contralateral and ipsilateral-ring VOIs were also found in grade 4 gliomas, presumably suggesting tumor infiltration within the peritumoral tissue. A cut-off value for CVR of 27.9%-signal-change is suggested to differentiate between grade 3 and grade 4 gliomas (specificity = 83.3%, sensitivity = 70.6%). In conclusion, CBF and CVR mapping with ASL offered insights into the perilesional environment that could help to detect infiltrative disease, particularly in grade 4 gliomas. CVR emerged as a potential biomarker to differentiate between WHO Grade 3 glioma and WHO Grade 4 glioma [4]

This study presents an innovative approach to assessing hemodynamic parameters in brain tumors and highlights the potential of CVR as a diagnostic biomarker. While promising, limitations in sample size, patient variability, and lack of validation necessitate further research. With refinement and validation, PCASL-based CVR mapping could become a valuable tool for non-invasive tumor characterization, aiding in personalized treatment planning and prognosis.

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