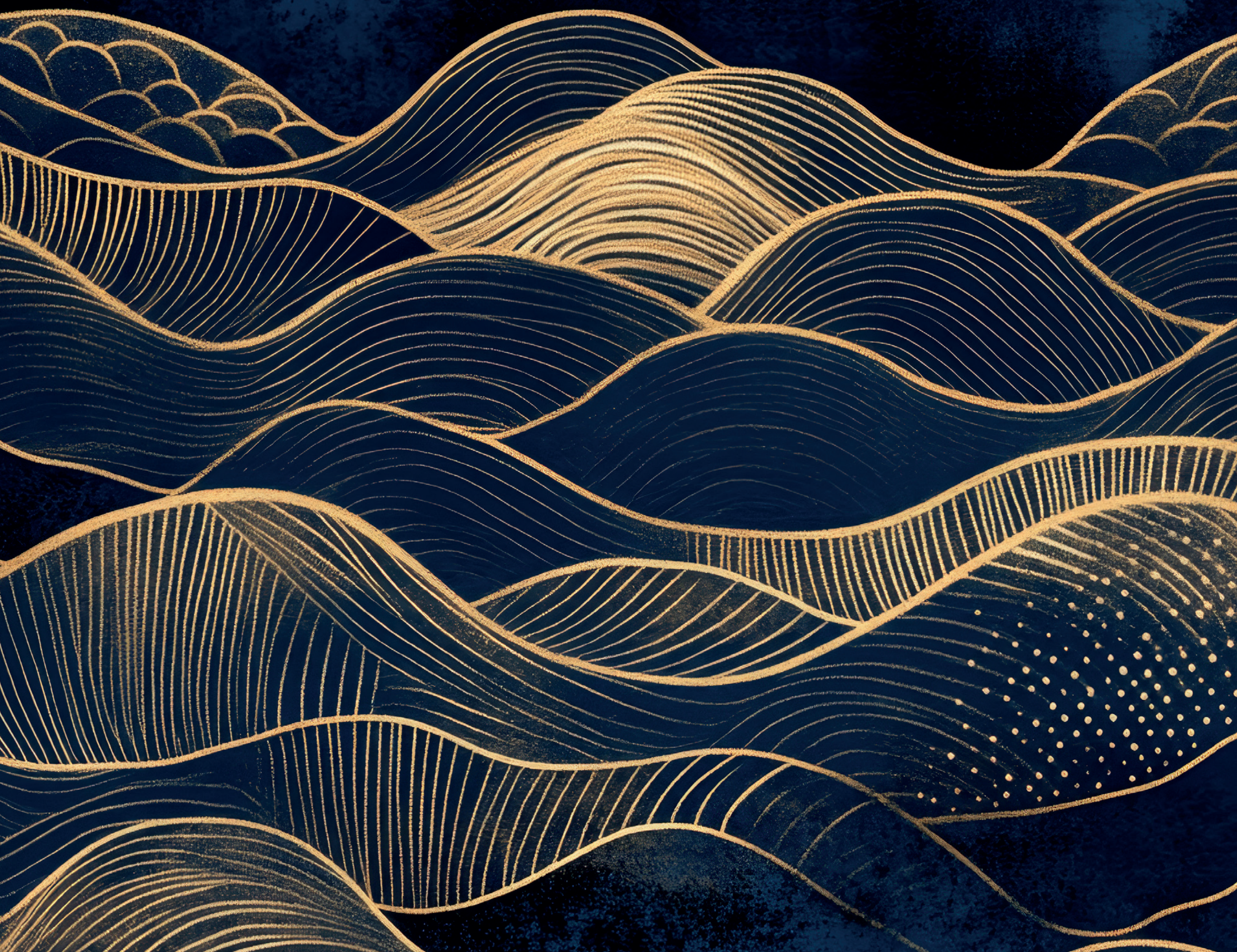
Methodology matters: characterization of glioma through advanced MR imaging

Schmitz Abecassis, B.

10 References



1. Pellerino A, Caccese M, Padovan M, Cerretti G, Lombardi G. Epidemiology, risk factors, and prognostic factors of gliomas. *Clin Transl Imaging*. 2022;10(5):467-475. doi:10.1007/s40336-022-00489-6
2. Jäkel S, Dimou L. Glial cells and their function in the adult brain: A journey through the history of their ablation. *Front Cell Neurosci*. 2017;11(February):1-17. doi:10.3389/fncel.2017.00024
3. Bachiller S, Jiménez-Ferrer I, Paulus A, et al. Microglia in neurological diseases: A road map to brain-disease dependent-inflammatory response. *Front Cell Neurosci*. 2018;12(December):1-17. doi:10.3389/fncel.2018.00488
4. Deng S, Gan L, Liu C, et al. Roles of Ependymal Cells in the Physiology and Pathology of the Central Nervous System. *Aging Dis*. 2023;14(2):468-483. doi:10.14336/AD.2022.0826-1
5. Norden AD, Drappatz J, Wen PY. Malignant gliomas in adults. *Blue Books of Neurology*. 2010;36:99-120. doi:10.1016/B978-0-7506-7516-1.00005-0
6. Teng C, Zhu Y, Li Y, et al. Recurrence- and Malignant Progression-Associated Biomarkers in Low-Grade Gliomas and Their Roles in Immunotherapy. *Front Immunol*. 2022;13(May):1-18. doi:10.3389/fimmu.2022.899710
7. Sadetzki S, Bruchim R, Oberman B, et al. Description of selected characteristics of familial glioma patients-Results from the Gliogene Consortium. *Eur J Cancer*. 2013;49(6):1335-1345. doi:10.1016/j.ejca.2012.11.009
8. Neglia JP, Robison LL, Stovall M, et al. New primary neoplasms of the central nervous system in survivors of childhood cancer: A report from the childhood cancer survivor study. *J Natl Cancer Inst*. 2006;98(21):1528-1537. doi:10.1093/jnci/djj411
9. Inskip PD, Sigurdson AJ, Veiga L, et al. Radiation-related new primary solid cancers in the childhood cancer survivor study: Comparative radiation dose response and modification of treatment effects. *Int J Radiat Oncol Biol Phys*. 2016;94(4):800-807. doi:10.1016/j.ijrobp.2015.11.046
10. Louis DN, Perry A, Wesseling P, et al. The 2021 WHO classification of tumors of the central nervous system: A summary. *Neuro Oncol*. 2021;23(8):1231-1251. doi:10.1093/neuonc/noab106
11. Lee JH, Wee CW. Treatment of Adult Gliomas: A Current Update. *Brain & Neurorehabilitation*. 2022;15(3). doi:10.12786/bn.2022.15.e24
12. van der Weide HL, Kramer MCA, Scandurra D, et al. Proton therapy for selected low grade glioma patients in the Netherlands. *Radiotherapy and Oncology*. 2021;154:283-290. doi:10.1016/j.radonc.2020.11.004
13. Thust SC, Heiland S, Falini A, et al. Glioma imaging in Europe: A survey of 220 centres and recommendations for best clinical practice. *Eur Radiol*. 2018;28(8):3306-3317. doi:10.1007/s00330-018-5314-5
14. Zhang L, Min Z, Tang M, Chen S, Lei X, Zhang X. The utility of diffusion MRI with quantitative ADC measurements for differentiating high-grade from low-grade cerebral gliomas: Evidence from a meta-analysis. *J Neurol Sci*. 2017;373:9-15. doi:10.1016/j.jns.2016.12.008
15. Smits M. MRI biomarkers in neuro-oncology. *Nat Rev Neurol*. 2021;17(8):486-500. doi:10.1038/s41582-021-00510-y
16. Hirschler L, Sollmann N, Schmitz-Abecassis B, et al. Advanced MR Techniques for Preoperative Glioma Characterization: Part 1. *Journal of Magnetic Resonance Imaging*. Published online 2023:1-21. doi:10.1002/jmri.28662
17. Hangel G, Schmitz-Abecassis B, Sollmann N, et al. Advanced MR Techniques for Preoperative Glioma Characterization: Part 2. *Journal of Magnetic Resonance Imaging*. 2023;57(6):1676-1695. doi:10.1002/jmri.28663
18. Henriksen OM, del Mar Álvarez-Torres M, Figueiredo P, et al. High-Grade Glioma Treatment Response Monitoring Biomarkers: A Position Statement on the Evidence Supporting the Use of Advanced MRI Techniques in the Clinic, and the Latest Bench-to-Bedside Developments. Part 1: Perfusion and Diffusion Techniques. *Front Oncol*. 2022;12(March):1-27. doi:10.3389/fonc.2022.810263
19. Booth TC, Wiegers EC, Warnert EAH, et al. High-Grade Glioma Treatment Response Monitoring Biomarkers: A Position Statement on the Evidence Supporting the Use of Advanced MRI Techniques in the Clinic, and the

Latest Bench-to-Bedside Developments. Part 2: Spectroscopy, Chemical Exchange Saturation,. *Front Oncol*. 2022;11(February):1-22. doi:10.3389/fonc.2021.811425

20. Hanahan D. Hallmarks of Cancer: New Dimensions. *Cancer Discov*. 2022;12(1):31-46. doi:10.1158/2159-8290. CD-21-1059
21. Schmainda KM, Rand SD, Joseph AM, et al. Characterization of a first-pass gradient-echo spin-echo method to predict brain tumor grade and angiogenesis. *American Journal of Neuroradiology*. 2004;25(9):1524-1532.
22. McCullough BJ, Ader V, Aguedan B, et al. Preoperative relative cerebral blood volume analysis in gliomas predicts survival and mitigates risk of biopsy sampling error. *J Neurooncol*. 2018;136(1):181-188. doi:10.1007/s11060-017-2642-2
23. Lu J, Li X, Li H. Perfusion parameters derived from MRI for preoperative prediction of IDH mutation and MGMT promoter methylation status in glioblastomas. *Magn Reson Imaging*. 2021;83(April):189-195. doi:10.1016/j.mri.2021.09.005
24. Connelly JM, Prah MA, Santos-Pinheiro F, Mueller W, Cochran E, Schmainda KM. Magnetic Resonance Imaging Mapping of Brain Tumor Burden: Clinical Implications for Neurosurgical Management: Case Report. *Neurosurgery Open*. 2021;2(4):2-5. doi:10.1093/neuopn/okab029
25. Taylor C, Ekert JO, Sefcikova V, Fersht N, Samandouras G. Discriminators of pseudoprogression and true progression in high-grade gliomas: A systematic review and meta-analysis. *Sci Rep*. 2022;12(1):1-12. doi:10.1038/s41598-022-16726-x
26. Soldozy S, Galindo J, Snyder H, et al. Clinical utility of arterial spin labeling imaging in disorders of the nervous system. *Neurosurg Focus*. 2019;47(6):1-10. doi:10.3171/2019.9.FOCUS19567
27. Falk Delgado A, De Luca F, Van Westen D, Falk Delgado A. Arterial spin labeling MR imaging for differentiation between high- and low-grade glioma - A meta-analysis. *Neuro Oncol*. 2018;20(11):1450-1461. doi:10.1093/neuonc/noy095
28. Abdel Razek AAK, Talaat M, El-Serougy L, Gaballa G, Abdelsalam M. Clinical Applications of Arterial Spin Labeling in Brain Tumors. *J Comput Assist Tomogr*. 2019;43(4):525-532. doi:10.1097/RCT.0000000000000873
29. Yoo RE, Yun TJ, Hwang I, et al. Arterial spin labeling perfusion-weighted imaging aids in prediction of molecular biomarkers and survival in glioblastomas. *Eur Radiol*. 2020;30(2):1202-1211. doi:10.1007/s00330-019-06379-2
30. Jovanovic M, Radenkovic S, Stosic-Opincal T, et al. Differentiation between progression and pseudoprogression by arterial spin labeling MRI in patients with glioblastoma multiforme. *Journal of BUON*. 2017;22(4):1061-1067.
31. Wang Q, Zhang H, Zhang JS, et al. The diagnostic performance of magnetic resonance spectroscopy in differentiating high-from low-grade gliomas: A systematic review and meta-analysis. *Eur Radiol*. 2016;26(8):2670-2684. doi:10.1007/s00330-015-4046-z
32. Suh CH, Kim HS, Jung SC, Choi CG, Kim SJ. 2-Hydroxyglutarate MR spectroscopy for prediction of isocitrate dehydrogenase mutant glioma: A systemic review and meta-analysis using individual patient data. *Neuro Oncol*. 2018;20(12):1573-1583. doi:10.1093/neuonc/noy113
33. Vinogradov E, Sherry AD, Lenkinski RE. CEST: From basic principles to applications, challenges and opportunities. *Journal of Magnetic Resonance*. 2013;229:155-172. doi:10.1016/j.jmr.2012.11.024
34. Ugurbil K. Magnetic resonance imaging at ultrahigh fields. *IEEE Trans Biomed Eng*. 2014;61(5):1364-1379. doi:10.1109/TBME.2014.2313619
35. Shaffer A, Kwok SS, Naik A, et al. Ultra-High-Field MRI in the Diagnosis and Management of Gliomas: A Systematic Review. *Front Neurol*. 2022;13(April):1-11. doi:10.3389/fneur.2022.857825
36. Trattnig S, Springer E, Bogner W, et al. Key clinical benefits of neuroimaging at 7 T Europe PMC Funders Group. *Neuroimage*. 2018;168:477-489. doi:10.1016/j.neuroimage.2016.11.031.Key
37. Regnery S, Knowles BR, Paech D, et al. High-resolution FLAIR MRI at 7 Tesla for treatment planning in

glioblastoma patients. *Radiotherapy and Oncology*. 2019;130:180-184. doi:10.1016/j.radonc.2018.08.002

38. Radbruch A, Eidel O, Wiestler B, et al. Quantification of tumor vessels in glioblastoma patients using time-of-flight angiography at 7 Tesla: A feasibility study. *PLoS One*. 2014;9(11):1-13. doi:10.1371/journal.pone.0110727

39. Zhou J, Zijl PCM van. Chemical exchange saturation transfer imaging and spectroscopy. *Prog Nucl Magn Reson Spectrosc*. 2006;48(2-3):109-136. doi:10.1016/j.pnmrs.2006.01.001

40. Paech D, Zaiss M, Meissner JE, et al. Nuclear overhauser enhancement mediated chemical exchange saturation transfer imaging at 7 tesla in glioblastoma patients. *PLoS One*. 2014;9(8):3-9. doi:10.1371/journal.pone.0104181

41. Zaiss M, Windschuh J, Goerke S, et al. Downfield-NOE-suppressed amide-CEST-MRI at 7 Tesla provides a unique contrast in human glioblastoma. *Magn Reson Med*. 2017;77(1):196-208. doi:10.1002/mrm.26100

42. Paech D, Windschuh J, Oberhollenzer J, et al. Assessing the predictability of IDH mutation and MGMT methylation status in glioma patients using relaxation-compensated multipool CEST MRI at 7.0 T. *Neuro Oncol*. 2018;20(12):1661-1671. doi:10.1093/neuonc/noy073

43. Heo HY, Jones CK, Hua J, et al. Whole-brain amide proton transfer (APT) and nuclear overhauser enhancement (NOE) imaging in glioma patients using low-power steady-state pulsed chemical exchange saturation transfer (CEST) imaging at 7T. *Journal of Magnetic Resonance Imaging*. 2016;44(1):41-50. doi:10.1002/jmri.25108

44. Dreher C, Oberhollenzer J, Meissner JE, et al. Chemical exchange saturation transfer (CEST) signal intensity at 7T MRI of WHO IV° gliomas is dependent on the anatomic location. *Journal of Magnetic Resonance Imaging*. 2019;49(3):777-785. doi:10.1002/jmri.26215

45. Neal A, Moffat BA, Stein JM, et al. Glutamate weighted imaging contrast in gliomas with 7 Tesla magnetic resonance imaging. *Neuroimage Clin*. 2019;22(June 2018):101694. doi:10.1016/j.nicl.2019.101694

46. Meissner JE, Korzowski A, Regnery S, et al. Early response assessment of glioma patients to definitive chemoradiotherapy using chemical exchange saturation transfer imaging at 7 T. *Journal of Magnetic Resonance Imaging*. 2019;50(4):1268-1277. doi:10.1002/jmri.26702

47. Paech D, Burth S, Windschuh J, et al. Nuclear overhauser enhancement imaging of glioblastoma at 7 Tesla: Region specific correlation with apparent diffusion coefficient and histology. *PLoS One*. 2015;10(3):1-16. doi:10.1371/journal.pone.0121220

48. Van Zijl PCM, Yadav NN. Chemical exchange saturation transfer (CEST): What is in a name and what isn't? *Magn Reson Med*. 2011;65(4):927-948. doi:10.1002/mrm.22761

49. van Zijl PCM, Lam WW, Xu J, Knutsson L, Stanisz GJ. Magnetization Transfer Contrast and Chemical Exchange Saturation Transfer MRI. Features and analysis of the field-dependent saturation spectrum. *Neuroimage*. 2018;168(April 2017):222-241. doi:10.1016/j.neuroimage.2017.04.045

50. Zu Z, Louie EA, Lin EC, et al. Chemical exchange rotation transfer imaging of intermediate-exchanging amines at 2 ppm. *NMR Biomed*. 2017;30(10):1-12. doi:10.1002/nbm.3756

51. Xu X, Sehgal AA, Yadav NN, et al. d-glucose weighted chemical exchange saturation transfer (glucoCEST)-based dynamic glucose enhanced (DGE) MRI at 3T: early experience in healthy volunteers and brain tumor patients. *Magn Reson Med*. 2020;84(1):247-262. doi:10.1002/mrm.28124

52. Goldenberg JM, Pagel MD. Assessments of tumor metabolism with CEST MRI. *NMR Biomed*. 2019;32(10):1-12. doi:10.1002/nbm.3943

53. Togao O, Yoshiura T, Keupp J, et al. Amide proton transfer imaging of adult diffuse gliomas: Correlation with histopathological grades. *Neuro Oncol*. 2014;16(3):441-448. doi:10.1093/neuonc/not158

54. Zhang J, Zhu W, Tain R, Zhou XJ, Cai K. Improved Differentiation of Low-Grade and High-Grade Gliomas and Detection of Tumor Proliferation Using APT Contrast Fitted from Z-Spectrum. *Mol Imaging Biol*. 2018;20(4):623-631. doi:10.1007/s11307-017-1154-y

55. Jiang S, Wen Z, Ahn SS, et al. Applications of chemical exchange saturation transfer magnetic resonance imaging

in identifying genetic markers in gliomas. *NMR Biomed*. 2023;36(6):1-15. doi:10.1002/nbm.4731

56. Su C, Xu S, Lin D, et al. Multi-parametric Z-spectral MRI may have a good performance for glioma stratification in clinical patients. *Eur Radiol*. Published online 2021. doi:10.1007/s00330-021-08175-3
57. Warnert EAH, Wood TC, Incekara F, et al. Mapping tumour heterogeneity with pulsed 3D CEST MRI in non-enhancing glioma at 3 T. *Magnetic Resonance Materials in Physics, Biology and Medicine*. 2021;(0123456789). doi:10.1007/s10334-021-00911-6
58. Jiang S, Eberhart CG, Lim M, et al. Identifying recurrent malignant glioma after treatment using amide proton transfer-weighted MR imaging: A validation study with image-guided stereotactic biopsy. *Clinical Cancer Research*. 2019;25(2):552-561. doi:10.1158/1078-0432.CCR-18-1233
59. Zhou J, Zaiss M, Knutsson L, et al. Review and consensus recommendations on clinical APT-weighted imaging approaches at 3T: Application to brain tumors. *Magn Reson Med*. 2022;88(2):546-574. doi:10.1002/mrm.29241
60. Herz K, Lindig T, Deshmane A, et al. T1ρ-based dynamic glucose-enhanced (DGEρ) MRI at 3 T: method development and early clinical experience in the human brain. *Magn Reson Med*. 2019;82(5):1832-1847. doi:10.1002/mrm.27857
61. Mcvicar N, Li AX, Meakin SO, Bartha R. Imaging chemical exchange saturation transfer (CEST) effects following tumor-selective acidification using lonidamine. *NMR Biomed*. 2015;28(5):566-575. doi:10.1002/nbm.3287
62. Yao J, Tan CHP, Schlossman J, et al. pH-weighted amine chemical exchange saturation transfer echoplanar imaging (CEST-EPI) as a potential early biomarker for bevacizumab failure in recurrent glioblastoma. *J Neurooncol*. 2019;142(3):587-595. doi:10.1007/s11060-019-03132-z
63. Cai K, Singh A, Poptani H, et al. CEST signal at 2ppm (CEST at 2ppm) from Z-spectral fitting correlates with creatine distribution in brain tumor. *NMR Biomed*. 2015;28(1):1-8. doi:10.1002/nbm.3216
64. Cai K, Tain RW, Zhou XJ, et al. Creatine CEST MRI for Differentiating Gliomas with Different Degrees of Aggressiveness. *Mol Imaging Biol*. 2017;19(2):225-232. doi:10.1007/s11307-016-0995-0
65. Dou W, Lin CYE, Ding H, et al. Chemical exchange saturation transfer magnetic resonance imaging and its main and potential applications in pre-clinical and clinical studies. *Quant Imaging Med Surg*. 2019;9(10):1747-1766. doi:10.21037/qims.2019.10.03
66. Khlebnikov V, van der Kemp WJM, Hoogduin H, Klomp DWJ, Prompers JJ. Analysis of chemical exchange saturation transfer contributions from brain metabolites to the Z-spectra at various field strengths and pH. *Sci Rep*. 2019;9(1):1-11. doi:10.1038/s41598-018-37295-y
67. Zhou J. Amide Proton Transfer Imaging of the Human Brain. *Methods Mol Biol*. 2011;711(711):227-237. doi:10.1007/978-1-61737-992-5_10
68. Xu X, Yadav NN, Zeng H, et al. Magnetization transfer contrast-suppressed imaging of amide proton transfer and relayed nuclear overhauser enhancement chemical exchange saturation transfer effects in the human brain at 7T. *Magn Reson Med*. 2016;75(1):88-96. doi:10.1002/mrm.25990
69. Xu J, Yadav NN, Bar-Shir A, et al. Variable delay multi-pulse train for fast chemical exchange saturation transfer and relayed-nuclear overhauser enhancement MRI. *Magn Reson Med*. 2014;71(5):1798-1812. doi:10.1002/mrm.24850
70. Haris M, Nanga RPR, Singh A, et al. Exchange rates of creatine kinase metabolites: Feasibility of imaging creatine by chemical exchange saturation transfer MRI. *NMR Biomed*. 2012;25(11):1305-1309. doi:10.1002/nbm.2792
71. Zhou J, Payen JF, Wilson DA, Traystman RJ, Van Zijl PCM. Using the amide proton signals of intracellular proteins and peptides to detect pH effects in MRI. *Nat Med*. 2003;9(8):1085-1090. doi:10.1038/nm907
72. Heo HY, Han Z, Jiang S, Schär M, van Zijl PCM, Zhou J. Quantifying amide proton exchange rate and concentration in chemical exchange saturation transfer imaging of the human brain. *Neuroimage*. 2019;189(December 2017):202-213. doi:10.1016/j.neuroimage.2019.01.034

73. Xu J, Chan KWY, Xu X, Yadav N, Liu G, van Zijl PCM. On-resonance variable delay multipulse scheme for imaging of fast-exchanging protons and semisolid macromolecules. *Magn Reson Med*. 2017;77(2):730-739. doi:10.1002/mrm.26165

74. Chen L, Xu X, Zeng H, et al. Separating fast and slow exchange transfer and magnetization transfer using off-resonance variable-delay multiple-pulse (VDMP) MRI. *Magn Reson Med*. 2018;80(4):1568-1576. doi:10.1002/mrm.27111

75. Dortch RD, Moore J, Li K, et al. Quantitative magnetization transfer imaging of human brain at 7T. *Neuroimage*. 2013;64(1):640-649. doi:10.1016/j.neuroimage.2012.08.047

76. Nehrke K, Börnert P. DREAM-a novel approach for robust, ultrafast, multislice B1 mapping. *Magn Reson Med*. 2012;68(5):1517-1526. doi:10.1002/mrm.24158

77. Lin EC, Li H, Zu Z, et al. Chemical exchange rotation transfer (CERT) on human brain at 3 Tesla. *Magn Reson Med*. 2018;80(6):2609-2617. doi:10.1002/mrm.27365

78. Smith SM. Fast robust automated brain extraction. *Hum Brain Mapp*. 2002;17(3):143-155. doi:10.1002/hbm.10062

79. Zhang Y, Brady M, Smith S. Segmentation of brain MR images through a hidden Markov random field model and the expectation-maximization algorithm. *IEEE Trans Med Imaging*. 2001;20(1):45-57. doi:10.1109/42.906424

80. Reuter M, Schmansky NJ, Rosas HD, Fischl B. Within-subject template estimation for unbiased longitudinal image analysis. *Neuroimage*. 2012;61(4):1402-1418. doi:10.1016/j.neuroimage.2012.02.084

81. Windschuh J, Zaiss M, Meissner JE, et al. Correction of B1-inhomogeneities for relaxation-compensated CEST imaging at 7T. *NMR Biomed*. 2015;28(5):529-537. doi:10.1002/nbm.3283

82. Shu Z, Xu Y, Shao Y, Pang P, Gong X. Radiomics from magnetic resonance imaging may be used to predict the progression of white matter hyperintensities and identify associated risk factors. *Eur Radiol*. 2020;30(6):3046-3058. doi:10.1007/s00330-020-06676-1

83. Chen L, Xu X, Zeng H, et al. Separating fast and slow exchange transfer and magnetization transfer using off-resonance variable-delay multiple-pulse (VDMP) MRI. *Magn Reson Med*. 2018;80(4):1568-1576. doi:10.1002/mrm.27111

84. Lee JS, Xia D, Jerschow A, Regatte RR. In vitro study of endogenous CEST agents at 3T and 7T. *Contrast Media Mol Imaging*. 2016;11(1):4-14. doi:10.1002/cmmi.1652

85. Jones CK, Huang A, Xu J, et al. Nuclear Overhauser enhancement (NOE) imaging in the human brain at 7T. *Neuroimage*. 2013;77:114-124. doi:10.1016/j.neuroimage.2013.03.047

86. Khlebnikov V, Polders D, Hendrikse J, et al. Amide proton transfer (APT) imaging of brain tumors at 7 T: The role of tissue water T1-Relaxation properties. *Magn Reson Med*. 2017;77(4):1525-1532. doi:10.1002/mrm.26232

87. Paech D, Dreher C, Regnery S, et al. Relaxation-compensated amide proton transfer (APT) MRI signal intensity is associated with survival and progression in high-grade glioma patients. *Eur Radiol*. 2019;29(9):4957-4967. doi:10.1007/s00330-019-06066-2

88. Cai K, Haris M, Singh A, et al. Magnetic Resonance Imaging of Glutamate. *Nat Med*. 2012;18(2):302-306. doi:10.1038/nm.2615.Magnetic

89. Singh A, Debnath A, Cai K, et al. Evaluating the feasibility of creatine-weighted CEST MRI in human brain at 7 T using a Z-spectral fitting approach. *NMR Biomed*. 2019;32(12):1-18. doi:10.1002/nbm.4176

90. Cai K, Singh A, Roalf DR, et al. Mapping glutamate in subcortical brain structures using high-resolution GluCEST MRI. *NMR Biomed*. 2013;26(10):1278-1284. doi:10.1002/nbm.2949

91. Khlebnikov V, Windschuh J, Siero JCW, et al. On the transmit field inhomogeneity correction of relaxation-compensated amide and NOE CEST effects at 7 T. *NMR Biomed*. 2017;30(5):1-10. doi:10.1002/nbm.3687

92. Cui J, Zu Z. Towards the molecular origin of glutamate CEST (GluCEST) imaging in rat brain. *Magn Reson Med*. 2020;83(4):1405-1417. doi:10.1002/mrm.28021

93. Haris M, Nanga RPR, Singh A, et al. Exchange rates of creatine kinase metabolites: Feasibility of imaging creatine by chemical exchange saturation transfer MRI. *NMR Biomed*. 2012;25(11):1305-1309. doi:10.1002/nbm.2792

94. Kogan F, Harris M, DeBrosse C, et al. In vivo CEST imaging of Creatine (CrCEST) in Skeletal Muscle at 3T. *Journal of Magnetic Resonance Imaging*. 2014;40(3):596-602. doi:10.1002/jmri.24412.In

95. Kogan F, Haris M, Singh A, et al. Method for high-resolution imaging of creatine in vivo using chemical exchange saturation transfer. *Magn Reson Med*. 2014;71(1):164-172. doi:10.1002/mrm.24641

96. Davis KA, Nanga RPR, Das S, et al. Glutamate imaging (GluCEST) lateralizes epileptic foci in nonlesional temporal lobe epilepsy. *Sci Transl Med*. 2015;7(309):1-8. doi:10.1126/scitranslmed.aaa7095

97. Cai K, Tain R wen, Zhou XJ, et al. Degrees of Aggressiveness. 2018;19(2):225-232. doi:10.1007/s11307-016-0995-0. Creatine

98. Goerke S, Zaiss M, Bachert P. Characterization of creatine guanidinium proton exchange by water-exchange (WEX) spectroscopy for absolute-pH CEST imaging in vitro. *NMR Biomed*. 2014;27(5):507-518. doi:10.1002/nbm.3086

99. Zhang Z, Wang K, Park S, et al. The exchange rate of creatine CEST in mouse brain. *Magn Reson Med*. 2023;(March):1-12. doi:10.1002/mrm.29662

100. Zaiss, Moritz, Zu, Zhongliang, Xu, Junzhong, Schuenke, Patrick, Gochberg, Daniel F., Gore, John C., Ladd, Mark E., and Bachert P. A combined analytical solution for Chemical Exchange Saturation Transfer and semi-solid Magnetization Transfer Moritz. *NMR Biomed*. 2015;28(2):217-230. doi:10.1002/nbm.3237.A

101. Mueller S, Scheffler K, Zaiss M. On the interference from agar in chemical exchange saturation transfer MRI parameter optimization in model solutions. *NMR Biomed*. 2021;34(1):1-12. doi:10.1002/nbm.4403

102. Kim M, Gillen J, Landman BA, Zhou J, Van Zijl PCM. Water saturation shift referencing (WASSR) for chemical exchange saturation transfer (CEST) experiments. *Magn Reson Med*. 2009;61(6):1441-1450. doi:10.1002/mrm.21873

103. Teeuwisse WM, Brink WM, Webb AG. Quantitative assessment of the effects of high-permittivity pads in 7 Tesla MRI of the brain. *Magn Reson Med*. 2012;67(5):1285-1293. doi:10.1002/mrm.23108

104. O'Reilly TPA, Webb AG, Brink WM. Practical improvements in the design of high permittivity pads for dielectric shimming in neuroimaging at 7 T. *Journal of Magnetic Resonance*. 2016;270:108-114. doi:10.1016/j.jmr.2016.07.003

105. Singh A, Cai K, Haris M, Hariharan H, Reddy R. On B1 inhomogeneity correction of in vivo human brain glutamate chemical exchange saturation transfer contrast at 7T. *Magn Reson Med*. 2013;69(3):818-824. doi:10.1002/mrm.24290

106. Zaiss M, Windschuh J, Paech D, et al. Relaxation-compensated CEST-MRI of the human brain at 7T: Unbiased insight into NOE and amide signal changes in human glioblastoma. *Neuroimage*. 2015;112:180-188. doi:10.1016/j.neuroimage.2015.02.040

107. Provencher SW. Estimation of metabolite concentrations from localized in vivo proton NMR spectra. *Magn Reson Med*. 1993;30(6):672-679. doi:10.1002/mrm.1910300604

108. Simpson R, Devenyi GA, Jezzard P, Hennessy TJ, Near J. Advanced processing and simulation of MRS data using the FID appliance (FID-A)—An open source, MATLAB-based toolkit. *Magn Reson Med*. 2017;77(1):23-33. doi:10.1002/mrm.26091

109. Marjańska M, Auerbach EJ, Valabrègue R, Van de Moortele PF, Adriany G, Garwood M. Localized 1H NMR spectroscopy in different regions of human brain in vivo at 7T: T 2 relaxation times and concentrations of cerebral metabolites. *NMR Biomed*. 2012;25(2):332-339. doi:10.1002/nbm.1754

110. Neal A, Moffat BA, Stein JM, et al. Glutamate weighted imaging contrast in gliomas with 7 Tesla magnetic resonance imaging. *Neuroimage Clin*. 2019;22(January):101694. doi:10.1016/j.nicl.2019.101694

111. Davis KA, Nanga RPR, Das S, et al. Glutamate imaging (GluCEST) lateralizes epileptic foci in nonlesional temporal lobe epilepsy. *Sci Transl Med*. 2015;7(309):1-19. doi:10.1126/scitranslmed.aaa7095

112. Lucas A, Nanga RPR, Hadar P, et al. Mapping hippocampal glutamate in mesial temporal lobe epilepsy with glutamate weighted CEST (GluCEST) imaging. *Hum Brain Mapp*. 2022;(May 2022):549-558. doi:10.1002/hbm.26083

113. W A Belitzer KSG. PHOSPHATE ACCEPTORS IN “RESPIRA- TORY PHOSPHORYLATION” IN MUSCLE TISSUE. 1940;92(2397):536-537.

114. Li X, Lu Y, Pirzkall A, McKnight T, Nelson SJ. Analysis of the spatial characteristics of metabolic abnormalities in newly diagnosed glioma patients. *Journal of Magnetic Resonance Imaging*. 2002;16(3):229-237. doi:10.1002/jmri.10147

115. Cai K, Haris M, Singh A, et al. Magnetic resonance imaging of glutamate. *Nat Med*. 2012;18(2):302-306. doi:10.1038/nm.2615

116. Schuff N, Ezekiel F, Gamst AC, et al. Region and tissue differences of metabolites in normally aged brain using multislice 1H magnetic resonance spectroscopic imaging. *Magn Reson Med*. 2001;45(5):899-907. doi:10.1002/mrm.1119

117. Zhang XY, Xie J, Wang F, et al. Assignment of the molecular origins of CEST signals at 2 ppm in rat brain. *Magn Reson Med*. 2017;78(3):881-887. doi:10.1002/mrm.26802

118. Xu J, Chung JJ, Jin T. Chemical exchange saturation transfer imaging of creatine, phosphocreatine, and protein arginine residue in tissues. *NMR Biomed*. 2023;36(6):1-37. doi:10.1002/nbm.4671

119. Duarte JMN, Lei H, Mlynárik V, Gruetter R. The neurochemical profile quantified by in vivo 1H NMR spectroscopy. *Neuroimage*. 2012;61(2):342-362. doi:10.1016/j.neuroimage.2011.12.038

120. Cai K, Singh A, Roalf DR, et al. Mapping glutamate in subcortical brain structures using high-resolution GluCEST MRI. *NMR Biomed*. 2013;26(10):1278-1284. doi:10.1002/nbm.2949

121. Zaiß M, Schmitt B, Bachert P. Quantitative separation of CEST effect from magnetization transfer and spillover effects by Lorentzian-line-fit analysis of z-spectra. *Journal of Magnetic Resonance*. 2011;211(2):149-155. doi:10.1016/j.jmr.2011.05.001

122. Schmitz-Abecassis B, Vinogradov E, Wijnen JP, et al. The use of variable delay multipulse chemical exchange saturation transfer for separately assessing different CEST pools in the human brain at 7T. *Magn Reson Med*. 2022;87(2):872-883. doi:10.1002/mrm.29005

123. Zhang XY, Wang F, Li H, et al. Accuracy in the quantification of chemical exchange saturation transfer (CEST) and relayed nuclear Overhauser enhancement (rNOE) saturation transfer effects. *NMR Biomed*. 2017;30(7):1-14. doi:10.1002/nbm.3716

124. Cember ATJ, Nanga RPR, Reddy R. Glutamate weighted CEST (gluCEST) imaging for mapping neurometabolism: An update on the state of the art and emerging findings from in vivo applications . *NMR Biomed*. 2022;(November 2021):1-21. doi:10.1002/nbm.4780

125. Chung JJ, Jin T, Lee JH, Kim SG. Chemical exchange saturation transfer imaging of phosphocreatine in the muscle. *Magn Reson Med*. 2019;81(6):3476-3487. doi:10.1002/mrm.27655

126. Chen L, Zeng H, Xu X, et al. Investigation of the contribution of total creatine to the CEST Z-spectrum of brain using a knockout mouse model. *NMR Biomed*. 2018;30(12):1-24. doi:10.1002/nbm.3834.Investigation

127. Chen L, Barker PB, Weiss RG, et al. Creatine and phosphocreatine mapping of mouse skeletal muscle by a polynomial and Lorentzian line-shape fitting CEST method. *Magn Reson Med*. 2019;81(1):69-78. doi:10.1002/mrm.27514.Creatine

128. Wermter FC, Bock C, Dreher W. Investigating GluCEST and its specificity for pH mapping at low temperatures. *NMR Biomed*. 2015;28(11):1507-1517. doi:10.1002/nbm.3416

129. Kakimoto A, Ito S, Okada H, Nishizawa S, Minoshima S, Ouchi Y. Age-related sex-specific changes in brain metabolism and morphology. *Journal of Nuclear Medicine*. 2016;57(2):221-225. doi:10.2967/jnumed.115.166439

130. Cui J, Afzal A, Zu Z. Comparative evaluation of polynomial and Lorentzian lineshape-fitted amine CEST imaging in acute ischemic stroke. *Magn Reson Med*. 2022;87(2):837-849. doi:10.1002/mrm.29030

131. Lingl JP, Wunderlich A, Goerke S, et al. The Value of APTw CEST MRI in Routine Clinical Assessment of Human Brain Tumor Patients at 3T. *Diagnostics*. 2022;12(2):1-11. doi:10.3390/diagnostics12020490

132. Zaiss M, Windschuh J, Paech D, et al. Relaxation-compensated CEST-MRI of the human brain at 7T: Unbiased insight into NOE and amide signal changes in human glioblastoma. *Neuroimage*. 2015;112:180-188. doi:10.1016/j.neuroimage.2015.02.040

133. Mancini L, Casagranda S, Gautier G, et al. CEST MRI provides amide/amine surrogate biomarkers for treatment-naïve glioma sub-typing. *Eur J Nucl Med Mol Imaging*. 2022;(0123456789). doi:10.1007/s00259-022-05676-1

134. Groothuis DR, Vick NA. Brain tumors and the blood-brain barrier. *Trends Neurosci*. 1982;5(C):232-235. doi:10.1016/0166-2236(82)90134-5

135. Kanda T, Ishii K, Kawaguchi H, Kitajima K, Takenaka D. High signal intensity in the dentate nucleus and globus pallidus on unenhanced T1-weighted MR images: Relationship with increasing cumulative dose of a gadoliniumbased contrast material. *Radiology*. 2014;270(3):834-841. doi:10.1148/radiol.13131669

136. Scott JN, Brasher PMA, Sevick RJ, Rewcastle NB, Forsyth PA. How often are nonenhancing supratentorial gliomas malignant? A population study. *Neurology*. 2002;59(6):947-949. doi:10.1212/WNL.59.6.947

137. 137. Dao Trong P, Kilian S, Jesser J, et al. Risk Estimation in Non-Enhancing Glioma: Introducing a Clinical Score. *Cancers (Basel)*. 2023;15(9):1-14. doi:10.3390/cancers15092503

138. Zaiss M, Xu J, Goerke S, et al. Inverse Z-spectrum analysis for spillover-, MT-, and T1-corrected steady-state pulsed CEST-MRI - application to pH-weighted MRI of acute stroke. *NMR Biomed*. 2014;27(3):240-252. doi:10.1002/nbm.3054

139. Schmitz-Abecassis B, Najac C, Plugge J, van Osch MJP, Ercan E. Investigation of metabolite correlates of CEST in the human brain at 7 T. *NMR Biomed*. 2024;37(5):1-13. doi:10.1002/nbm.5104

140. Lupo JM, Cha S, Chang SM, Nelson SJ. Analysis of metabolic indices in regions of abnormal perfusion in patients with high-grade glioma. *American Journal of Neuroradiology*. 2007;28(8):1455-1461. doi:10.3174/ajnr.A0586

141. Park S, Rintaro H, Kim SK, Park I. Characterization of distinctive in vivo metabolism between enhancing and non-enhancing gliomas using hyperpolarized carbon-13 mri. *Metabolites*. 2021;11(8). doi:10.3390/metabo11080504

142. Hattingen E, Raab P, Franz K, et al. Prognostic value of choline and creatine in WHO grade II gliomas. *Neuroradiology*. 2008;50(9):759-767. doi:10.1007/s00234-008-0409-3

143. Avalos LN, Luks TL, Gleason T, et al. Longitudinal MR spectroscopy to detect progression in patients with lower-grade glioma in the surveillance phase. *Neurooncol Adv*. 2022;4(1):1-9. doi:10.1093/noajnl/vdac175

144. Howe FA, Barton SJ, Cudlip SA, et al. Metabolic profiles of human brain tumors using quantitative in vivo 1H magnetic resonance spectroscopy. *Magn Reson Med*. 2003;49(2):223-232. doi:10.1002/mrm.10367

145. Hangel G, Cadrien C, Lazen P, et al. High-resolution metabolic imaging of high-grade gliomas using 7T-CRT-FID-MRSI. *Neuroimage Clin*. 2020;28(May):102433. doi:10.1016/j.nicl.2020.102433

146. Wang K, Ju L, Song Y, et al. Whole-cerebrum guanidino and amide CEST mapping at 3 T by a 3D stack-of-spirals gradient echo acquisition. *Magn Reson Med*. 2024;92(4):1456-1470. doi:10.1002/mrm.30134

147. Wang K, Huang J, Ju L, et al. Creatine mapping of the brain at 3T by CEST MRI. *Magn Reson Med*. 2024;91(1):51-60. doi:10.1002/mrm.29876

148. Chen Z, Han F, Du Y, Shi H, Zhou W. Hypoxic microenvironment in cancer: molecular mechanisms and therapeutic interventions. *Signal Transduct Target Ther*. 2023;8(1). doi:10.1038/s41392-023-01332-8

149. Harris RJ, Cloughesy TF, Liau LM, et al. PH-weighted molecular imaging of gliomas using amine chemical

exchange saturation transfer MRI. *Neuro Oncol*. 2015;17(11):1514-1524. doi:10.1093/neuonc/nov106

150. Osborn AG, Louis DN, Poussaint TY, Linscott LL, Salzman KL. The 2021 World Health Organization Classification of Tumors of the Central Nervous System: What Neuroradiologists Need to Know. *American Journal of Neuroradiology*. 2022;43(7):928-937. doi:10.3174/ajnr.A7462

151. D'Abaco GM, Kaye AH. Integrins: Molecular determinants of glioma invasion. *Journal of Clinical Neuroscience*. 2007;14(11):1041-1048. doi:10.1016/j.jocn.2007.06.019

152. Giese A, Kluwe L, Laube B, Meissner H, Berens ME, Westphal M. Migration of Human Glioma Cells on Myelin. *Neurosurgery*. Published online 1996:755-764. doi:10.1097/00006123-199604000-00026

153. Ellingson BM, Bendszus M, Boxerman J, et al. Consensus recommendations for a standardized Brain Tumor Imaging Protocol in clinical trials. *Neuro Oncol*. 2015;17(9):1188-1198. doi:10.1093/neuonc/nov095

154. Bernstock JD, Gary SE, Klinger N, et al. Standard clinical approaches and emerging modalities for glioblastoma imaging. *Neurooncol Adv*. 2022;4(1):1-19. doi:10.1093/noajnl/vdac080

155. Verma G, Balchandani P. Ultrahigh field MR Neuroimaging. *Topics in Magnetic Resonance Imaging*. 2019;28(3):137-144. doi:10.1097/RMR.0000000000000210

156. Verma N, Cowperthwaite MC, Burnett MG, Markey MK. Differentiating tumor recurrence from treatment necrosis: A review of neuro-oncologic imaging strategies. *Neuro Oncol*. 2013;15(5):515-534. doi:10.1093/neuonc/nos307

157. Morrison MA, Lupo JM. 7-T Magnetic Resonance Imaging in the M a n a g e m e n t o f B r a i n Tu m o r s. *Magnetic Resonance Imaging Clinics of NA*. 2021;29(1):83-102. doi:10.1016/j.mric.2020.09.007

158. Keller JA, Sigurdsson S, Klaassen K, et al. White matter hyperintensity shape is associated with long-term dementia risk. *Alzheimer's and Dementia*. 2023;(November 2022):5632-5641. doi:10.1002/alz.13345

159. Kant IMJ, Mutsaerts HJMM, van Montfort SJT, et al. The association between frailty and MRI features of cerebral small vessel disease. *Sci Rep*. 2019;9(1):1-9. doi:10.1038/s41598-019-47731-2

160. Kollia K, Maderwald S, Putzki N, et al. First clinical study on ultra-high-field MR imaging in patients with multiple sclerosis: Comparison of 1.5T and 7T. *American Journal of Neuroradiology*. 2009;30(4):699-702. doi:10.3174/ajnr.A1434

161. Chalifoux JR, Y NP, Katz JS, et al. The ability of high field strength 7-T magnetic resonance imaging to reveal previously uncharacterized brain lesions in patients with tuberous sclerosis complex. *J Neurosurg Pediatr*. 2013;11(3):268-273. doi:10.3171/2012.12.PEDS12338

162. Maruyama S, Fukunaga M, Fautz HP, Heidemann R, Sadato N. Comparison of 3T and 7T MRI for the visualization of globus pallidus sub-segments. *Sci Rep*. 2019;9(1):1-8. doi:10.1038/s41598-019-54880-x

163. Zwanenburg JJM, Hendrikse J, Visser F, Takahara T, Luijten PR. Fluid attenuated inversion recovery (FLAIR) MRI at 7.0 Tesla: Comparison with 1.5 and 3.0 Tesla. *Eur Radiol*. 2010;20(4):915-922. doi:10.1007/s00330-009-1620-2

164. Xia L, Fang C, Chen G, Sun C. Relationship between the extent of resection and the survival of patients with low-grade gliomas: A systematic review and meta-analysis. *BMC Cancer*. 2018;18(1):1-10. doi:10.1186/s12885-017-3909-x

165. Louis DN, Perry A, Wesseling P, et al. The 2021 WHO Classification of Tumors of the Central Nervous System: a summary. *Neuro Oncol*. 2021;23(8):1231-1251. doi:10.1093/neuonc/noab106

166. Sheikh S, Radivoyevitch T, Barnholtz-Sloan JS, Vogelbaum M. Long-term trends in glioblastoma survival: Implications for historical control groups in clinical trials. *Neurooncol Pract*. 2020;7(2):158-163. doi:10.1093/nop/npz046

167. Fatterpekar GM, Galheigo D, Narayana A, Johnson G, Knopp E. Treatment-related change versus tumor recurrence in high-grade gliomas: A diagnostic conundrum - Use of dynamic susceptibility contrast-enhanced (DSC) perfusion MRI. *American Journal of Roentgenology*. 2012;198(1):19-26. doi:10.2214/AJR.11.7417

168. Hansen MR, Pan E, Wilson A, et al. Post-gadolinium 3-dimensional spatial, surface, and structural characteristics of glioblastomas differentiate pseudoprogression from true tumor progression. *J Neurooncol*. 2018;139(3):731-738. doi:10.1007/s11060-018-2920-7

169. Gladwish A, Koh ES, Hoisak J, et al. Evaluation of early imaging response criteria in glioblastoma multiforme. *Radiation Oncology*. 2011;6(1):1-7. doi:10.1186/1748-717X-6-121

170. Abel R, Jones J, Mandelin P, Cen S, Pagnini P. Distinguishing Pseudoprogression From True Progression by FLAIR Volumetric Characteristics Compared to 45 Gy Isodose Volumes in Treated Glioblastoma Patients. *International Journal of Radiation Oncology*Biology*Physics*. 2012;84(3):S275. doi:10.1016/j.ijrobp.2012.07.716

171. Le Fèvre C, Constans JM, Chambrelant I, et al. Pseudoprogression versus true progression in glioblastoma patients: A multiapproach literature review. Part 2 – Radiological features and metric markers. *Crit Rev Oncol Hematol*. 2021;159(January). doi:10.1016/j.critrevonc.2021.103230

172. Wang YL, Chen S, Xiao HF, et al. Differentiation between radiation-induced brain injury and glioma recurrence using 3D pCASL and dynamic susceptibility contrast-enhanced perfusion-weighted imaging. *Radiotherapy and Oncology*. 2018;129(1):68-74. doi:10.1016/j.radonc.2018.01.009

173. Ye J, Bhagat SK, Li H, et al. Differentiation between recurrent gliomas and radiation necrosis using arterial spin labeling perfusion imaging. *Exp Ther Med*. 2016;11(6):2432-2436. doi:10.3892/etm.2016.3225

174. Choi YJ, Kim HS, Jahng GH, Kim SJ, Suh DC. Pseudoprogression in patients with glioblastoma: added value of arterial spin labeling to dynamic susceptibility contrast perfusion MR imaging. *Acta radiol*. 2013;54(4):448-454. doi:10.1177/0284185112474916

175. Rau MK, Braun C, Skardelly M, et al. Prognostic value of blood flow estimated by arterial spin labeling and dynamic susceptibility contrast-enhanced MR imaging in high-grade gliomas. *J Neurooncol*. 2014;120(3):557-566. doi:10.1007/s11060-014-1586-z

176. Ozsunar Y, Mullins ME, Kwong K, et al. Glioma Recurrence Versus Radiation Necrosis?. A Pilot Comparison of Arterial Spin-Labeled, Dynamic Susceptibility Contrast Enhanced MRI, and FDG-PET Imaging. *Acad Radiol*. 2010;17(3):282-290. doi:10.1016/j.acra.2009.10.024

177. Manning P, Daghighi S, Rajaratnam MK, et al. Differentiation of progressive disease from pseudoprogression using 3D PCASL and DSC perfusion MRI in patients with glioblastoma. *J Neurooncol*. 2020;147(3):681-690. doi:10.1007/s11060-020-03475-y

178. Chen X, Wei X, Zhang Z, Yang R, Zhu Y, Jiang X. Differentiation of true-progression from pseudoprogression in glioblastoma treated with radiation therapy and concomitant temozolomide by GLCM texture analysis of conventional MRI. *Clin Imaging*. 2015;39(5):775-780. doi:10.1016/j.clinimag.2015.04.003

179. Yan JL, Toh CH, Ko L, Wei KC, Chen PY. A neural network approach to identify glioblastoma progression phenotype from multimodal mri. *Cancers (Basel)*. 2021;13(9):1-9. doi:10.3390/cancers13092006

180. Shim KY, Chung SW, Jeong JH, et al. Radiomics-based neural network predicts recurrence patterns in glioblastoma using dynamic susceptibility contrast-enhanced MRI. *Sci Rep*. 2021;11(1):1-14. doi:10.1038/s41598-021-89218-z

181. Kim JY, Yoon MJ, Park JE, Choi EJ, Lee J, Kim HS. Radiomics in peritumoral non-enhancing regions: fractional anisotropy and cerebral blood volume improve prediction of local progression and overall survival in patients with glioblastoma. *Neuroradiology*. 2019;61(11):1261-1272. doi:10.1007/s00234-019-02255-4

182. Hashido T, Saito S, Ishida T. A radiomics-based comparative study on arterial spin labeling and dynamic susceptibility contrast perfusion-weighted imaging in gliomas. *Sci Rep*. 2020;10(1):1-10. doi:10.1038/s41598-020-62658-9

183. Sudre CH, Panovska-Griffiths J, Sanverdi E, et al. Machine learning assisted DSC-MRI radiomics as a tool for glioma classification by grade and mutation status. *BMC Med Inform Decis Mak*. 2020;20(1):1-14. doi:10.1186/s12911-020-01163-5

184. Jaarsma-Coes MG, Ghaznawi R, Hendrikse J, et al. MRI phenotypes of the brain are related to future stroke and mortality in patients with manifest arterial disease: The SMART-MR study. *Journal of Cerebral Blood Flow and Metabolism*. 2020;40(2):354-364. doi:10.1177/0271678X18818918

185. Le Fèvre C, Sun R, Cebula H, et al. Ellipsoid calculations versus manual tumor delineations for glioblastoma tumor volume evaluation. *Sci Rep*. 2022;12(1):1-9. doi:10.1038/s41598-022-13739-4

186. Schwartz LH, Colville JAC, Ginsberg MS, et al. Measuring tumor response and shape change on CT: Esophageal cancer as a paradigm. *Annals of Oncology*. 2006;17(6):1018-1023. doi:10.1093/annonc/mdl058

187. Van Osch MJP, Teeuwisse WM, Van Walderveen MAA, Hendrikse J, Kies DA, Van Buchem MA. Can arterial spin labeling detect white matter perfusion signal? *Magn Reson Med*. 2009;62(1):165-173. doi:10.1002/mrm.22002

188. Charrad M, Ghazzali N, Boiteau V, Niknafs A. Nbclust: An R package for determining the relevant number of clusters in a data set. *J Stat Softw*. 2014;61(6):1-36. doi:10.18637/jss.v061.i06

189. Kassambara A. Package "factoextra": Extract and Visualize the Results of Multivariate Data Analyses for R. Published online 2020.

190. Rousseeuw P, Struyf A, Hubert M, Studer M, Roudier P. "Finding Groups in Data"': Cluster Analysis Extended." Published online 2022.

191. Galili T. dendextend: An R package for visualizing, adjusting and comparing trees of hierarchical clustering. *Bioinformatics*. 2015;31(22):3718-3720. doi:10.1093/bioinformatics/btv428

192. Pallud J, Capelle L, Taillandier L, et al. Prognostic signifcance of imaging contrast enhancement for WHO grade II gliomas. *Neuro Oncol*. 2009;11(2):176-182. doi:10.1215/15228517-2008-066

193. Curtin L, Whitmire P, White H, et al. Shape matters: morphological metrics of glioblastoma imaging abnormalities as biomarkers of prognosis. *Sci Rep*. 2021;11(1):1-11. doi:10.1038/s41598-021-02495-6

194. Kant IMJ, Slooter AJC, Jaarsma-Coes M, et al. Preoperative MRI brain phenotypes are related to postoperative delirium in older individuals. *Neurobiol Aging*. 2021;101:247-255. doi:10.1016/j.neurobiolaging.2021.01.033

195. Shieh LT, Ho CH, Guo HR, Huang CC, Ho YC, Ho SY. Epidemiologic Features, Survival, and Prognostic Factors Among Patients With Different Histologic Variants of Glioblastoma: Analysis of a Nationwide Database. *Front Neurol*. 2021;12(November):1-9. doi:10.3389/fneur.2021.659921

196. Palpan Flores A, Vivancos Sanchez C, Roda JM, et al. Assessment of Pre-operative Measurements of Tumor Size by MRI Methods as Survival Predictors in Wild Type IDH Glioblastoma. *Front Oncol*. 2020;10(September):1-12. doi:10.3389/fonc.2020.01662

197. van Dijken BRJ, van Laar PJ, Smits M, Dankbaar JW, Enting RH, van der Hoorn A. Perfusion MRI in treatment evaluation of glioblastomas: Clinical relevance of current and future techniques. *Journal of Magnetic Resonance Imaging*. 2019;49(1):11-22. doi:10.1002/jmri.26306

198. Songtao Q, Lei Y, Si G, et al. IDH mutations predict longer survival and response to temozolomide in secondary glioblastoma. *Cancer Sci*. 2012;103(2):269-273. doi:10.1111/j.1349-7006.2011.02134.x

199. Dula, Adrienne N., Smith, Seth. GCJ. Application of Chemical Exchange Saturation Transfer (CEST) MRI for Endogenous Contrast at 7 Tesla. *Journal of Neuroimaging*. 2013;23(4):526-532. doi:10.1111/j.1552-6569.2012.00751.x. Application

200. Zhang Z, Wang K, Park S, et al. The exchange rate of creatine CEST in mouse brain. *Magn Reson Med*. 2023;(February):373-384. doi:10.1002/mrm.29662

201. Xu J, Chan KWY, Xu X, Yadav N, Liu G, Van Zijl PCM. On-resonance Variable Delay Multi Pulse Scheme for Imaging of Fast-exchanging Protons and semi-solid Macromolecules HHS Public Access. *Magn Reson Med*. 2017;77(2):730-739. doi:10.1002/mrm.26165

202. Liu R, Wang X, Zhao Z, et al. A comparative study of quantitative metrics in chemical exchange saturation transfer imaging for grading gliomas in adults. *Magn Reson Imaging*. 2023;96(May 2022):50-59. doi:10.1016/j.

mri.2022.11.008

203. Ozturk-Isik E, Pirzkall A, Lamborn KR, Cha S, Chang SM, Nelson SJ. Spatial characteristics of newly diagnosed grade 3 glioma assessed by magnetic resonance metabolic and diffusion tensor imaging. *Transl Oncol*. 2012;5(1):10-18. doi:10.1593/tlo.11208

204. Perera Molligoda Arachchige AS, Meuli S, Centini FR, Stomeo N, Catapano F, Politi LS. Evaluating the role of 7-Tesla magnetic resonance imaging in neurosurgery: Trends in literature since clinical approval. *World J Radiol*. 2024;16(7):274-293. doi:10.4329/wjr.v16.i7.274

205. Voormolen EH, Diederen SJH, Woerdeman P, et al. Implications of Extracranial Distortion in Ultra-High-Field Magnetic Resonance Imaging for Image-Guided Cranial Neurosurgery. *World Neurosurg*. 2019;126:e250-e258. doi:10.1016/j.wneu.2019.02.028

206. Verdugo E, Puerto I, Medina MÁ. An update on the molecular biology of glioblastoma, with clinical implications and progress in its treatment. *Cancer Commun*. 2022;42(11):1083-1111. doi:10.1002/cac2.12361

207. Quartuccio N, Laudicella R, Vento A, et al. The additional value of 18F-FDG PET and MRI in patients with glioma: A review of the literature from 2015 to 2020. *Diagnostics*. 2020;10(6). doi:10.3390/diagnostics10060357