J Ultrasound. 2024 Nov 4. doi: 10.1007/s40477-024-00961-1. Online ahead of print.

Contrast-enhanced ultrasound can differentiate the level of glioma infiltration and correlate it with biological behavior: a study based on local pathology

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PMID: 39489864 DOI: 10.1007/s40477-024-00961-1

Abstract

Purpose: The objective of this study is to assess the diagnostic efficacy of contrast-enhanced ultrasound (CEUS) in determining the level of glioma infiltration and to investigate its correlation with pathological markers.

Methods: A prospective study involving 16 adult glioma patients was conducted. Preoperative US-(Magnetic Resonance)MR fusion imaging was utilized for tumor infiltration localization, while CEUS was employed to assess hemodynamic alterations. Parameters such as peak intensity (PI), rise time (RT), time to peak (TTP), and area under the curve (AUC) were measured. Utilizing contralateral normal brain tissue as the reference standard. The Kruskal-Wallis H-test was conducted to compare CEUS and pathological parameters (significance level, $p < 0.05$; bonferroni correction) among tumor margins, infiltration zones, and normal tissues, as well as between low-grade glioma (LGG) and high-grade glioma (HGG) within the infiltration zone, based on whole slide pathological images analysis. Spearman correlation analysis was employed to determine the correlation coefficient between hemodynamics and pathology. Receiver operating characteristic (ROC) curves were drawn to evaluate the performance of CEUS in tumor classification.

Results: From tumor margin to normal tissue, PI, AUC, Ki67, EGFR, and 1p/19q showed a significant decreasing trend, while TTP, IDH-1, and MGMT gradually increased. RT was lower at the tumor margin but did not show statistically significant differences. In the infiltration zones, there was a significant increase in parameters such as PI, normalized PI (Nor_PI), AUC, and Ki67 from LGG to HGG, while RT, Nor_RT, TTP, Nor_TTP, IDH-1, and MGMT significantly decreased. Nor_AUC and EGFR increased but were not significant, and 1p/19q decreased but was not significant. RT and Nor_TTP were independent risk factors for distinguishing between LGG and HGG in the infiltration zone, with a combined diagnostic efficacy ROC of 0.891. The sensitivity reached 96.64% and the specificity reached 82.35%. There was a significant correlation between hemodynamic indicators and pathological indicators. CEUS can effectively differentiate levels of infiltration zones, which correlates with their biological behavior, with RT + Nor_TTP showing particularly highest diagnostic efficacy.

Conclusion: These findings contribute to improving the accuracy of diagnosing infiltration zones and provide essential biological insights for subsequent treatments.

Keywords: Contrast-enhanced ultrasound; Glioma; Infiltration; Molecular pathology; Whole-slide pathological images.