Neuro-Oncology Advances

8(S4), vdaf231, 2026 | https://doi.org/10.1093/noajnl/vdaf231

Focused ultrasound in neuro-oncology: Realizing the promise of a noninvasive future

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The past two decades have seen a dramatic rise in innovation for the diagnosis and therapy of neuro-oncologic conditions. The central challenge remains: how do we treat brain tumors effectively without harming surrounding brain tissue. Surgery, radiotherapy, and chemotherapy—cornerstones of treatment—are all associated with toxicity to normal tissue. Stereotactic radiosurgery minimizes off-target effects through precise and conformal radiation delivery, but its use is constrained by limitations on repeated applications. Additional treatment options are urgently needed as survivorship becomes an increasingly important focus.

Focused ultrasound (FUS) is emerging as a promising noninvasive technology to address these challenges. By harnessing targeted acoustic energy, FUS enables precise, image-guided interventions that can be delivered across the intact skull in a way that was only imagined decades early by the pioneers in the field, now realized through modern advances in physics, engineering, and imaging. Ultrasound is non-ionizing, allowing the possibility of repeated application over time with minimal or no toxicity. Additionally, ultrasound transducers can be cheaply produced in comparison to other treatment modalities, facilitating future rapid expansion of the technology.

The potential applications of FUS in neuro-oncology are diverse and rapidly expanding. Among the most promising is transient blood–brain barrier (BBB) disruption, which can enhance the bioavailability of drugs with poor CNS penetration in an image-guided and spatially targeted manner. BBB or blood-tumor barrier (BTB), once disrupted, spontaneously recovers with time, creating a spatially and temporally precise window for administered therapies to pass through or biomarkers to shed out into the blood stream. FUS is also being actively investigated for its ability to facilitate liquid biopsy, enable thermal or mechanical ablation, modulation of the tumor microenvironment, and immunomodulation combined with immunotherapies.

The field is now rapidly maturing with an abundance of preclinical and translational studies, from first-in-human trials to multicenter pivotal studies. This progress was made possible by true multidisciplinary collective expertise from physicists, engineers, neurosurgeons, radiologists, medical oncologists, radiation oncologists, and neuro-oncologists. This supplement brings together leading voices in the field to highlight the breadth of ongoing research and potential implications and to chart a path forward. Contributions span from reviews of the state of the science and device development to clinical trial outcomes. Many challenges remain, from the technical to the clinical, but addressing them will come from a concerted and focused collective effort by many of the contributors to this issue.

Equally important is the patient perspective. As overall survival improves, survivorship becomes a growing reality for patients with brain tumors. There is increasing priority on treatments that preserve function, minimize toxicity, and maintain quality of life. FUS, with its noninvasive approach and capacity for repeatable, targeted interventions, holds unique promise in aligning therapeutic efficacy with these broader goals of care. FUS is no longer a futuristic concept—it is here. And it has the potential to reshape the therapeutic landscape of neuro-oncology in profound and lasting ways.

Received: September 21, 2025; accepted October 16, 2025.