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Machine Learning for survival prediction after brain tumor stereotactic radiosurgery.

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ADMINISTRATIVE INFORMATION

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Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 13 May 2026 and was last updated on 13 May 2026.

INTRODUCTION

Review question / Objective The review aims to summarise existing research on machine learning models developed for survival prediction in patients with brain tumours treated with stereotactic radiosurgery (SRS). It aims to identify and describe studies that develop or validate such models in SRS-treated cohorts, including their populations, tumour types, data sources, predictors and modelling strategies. It further aims to synthesise reported measures of predictive performance, focusing on discrimination (e.g. AUC, C-index). Using PROBAST, the review aims to appraise risk of bias and applicability, and, where data allow, to pool model performance estimates, explore sources of heterogeneity and areas where further methodological and clinical research is needed.

Rationale Stereotactic radiosurgery (SRS) is a key treatment modality for patients with brain tumours.

However, survival after SRS is highly heterogeneous, and accurate prognostication is crucial for treatment selection, patient counselling and trial stratification. Traditional prognostic tools (e.g. RPA, GPA and their variants) and conventional regression models offer only moderate discrimination and were not designed to exploit high-dimensional clinical, imaging and molecular data routinely available in contemporary practice.

Machine learning (ML) methods can model complex, non-linear relationships and integrate diverse predictors. In recent years, several research groups have proposed ML-based survival models specifically in cohorts treated with SRS, but these models remain largely exploratory and are not yet used routinely in clinical decision-making. The evidence is fragmented: studies differ in tumour types, inclusion criteria, input features, algorithms, validation strategies and reported performance metrics, making it difficult to judge their comparative value or readiness for translation.

This review aims to systematically identify and summarise ML models developed to predict survival in patients undergoing SRS, compare their reported performance and map the most consistently informative clinical, radiological and molecular predictors.

Condition being studied Brain tumors.

METHODS

Search strategy The core search combines four concept

groups using AND operators:

Concept 1 – Artificial Intelligence / Machine Learning: "data science" OR "artificial intelligence" OR

"machine learning" OR "AI" OR "ML" OR "reinforcement learning" OR "deep learning" OR "supervised

learning" OR "unsupervised learning" OR "cognitive computing" OR "neural network*" OR "convolutional

neural network*" OR "algorithm*" OR "predictive modeling" OR "computer-assisted"

Concept 2 – Stereotactic Radiosurgery: "stereotactic radiosurgery" OR "SRS" OR "Gamma Knife" OR

"CyberKnife" OR "LINAC" OR "LINAC-based radiosurgery" OR "Linear Accelerator radiosurgery"

Concept 3 – Brain Tumors: "brain tumo*" OR "brain oncolog*" OR "brain cancer*" OR "brain neoplasm*" OR

"intracranial*" OR "glioma*" OR "meningioma*" OR "astrocytoma*" OR "medulloblastoma*" OR "brain

metastasis*" OR "primary brain tumor*" OR "cerebral tumor*" OR "cerebral neoplasm*" OR "neoplasia" OR

"brain lesion*" OR "brain mass*" OR "central nervous system tumor*" OR

Concept 4 – Outcomes / Imaging: "planning" OR "optimization" OR "delineation" OR "segmentation" OR

"contouring" OR "treatment precision" OR "CT" OR "MRI" OR "dose" OR "dosimetry" OR "imag*" OR

"detection" OR "outcome" OR "prediction" OR "pattern recognition" OR "survival*" OR "mortalit*" OR

"risk*" OR

Database-specific implementation:

PubMed: The keyword combination was entered without field tags. PubMed's default Automatic Term

Mapping was used, which expands search terms across relevant fields and MeSH headings.

Scopus: The search was restricted to titles and abstracts using the TITLE-ABS field tag: TITLE-ABS((Concept 1) AND (Concept 2) AND (Concept 3) AND (Concept 4)).

Embase (via Ovid): The keyword combination was searched using the .mp. multi-purpose field tag.

Participant or population Patients with intrinsic brain tumors who have undergone stereotactic radiosurgery (including Gamma Knife, CyberKnife, or LINAC-based SRS), with no restrictions on age, sex, primary cancer site, or country.

Intervention Stereotactic radiosurgery (SRS) for brain tumors, including Gamma Knife, CyberKnife, and LINAC-based systems, in the context of machine learning-based survival prediction models.

Comparator Not applicable. This review did not require a comparator intervention. Where available, studies comparing machine learning models with conventional prognostic indices or statistical models were described narratively.

Study designs to be included Original studies evaluating machine learning models for survival prediction after stereotactic radiosurgery in brain tumor patients.

Eligibility criteria Studies are eligible if they are peer-reviewed original human studies published in English that evaluate machine learning models for survival prediction in patients with brain tumors treated with stereotactic radiosurgery (including Gamma Knife, CyberKnife, or LINAC-based SRS). Studies must report survival-related predictive performance. We exclude non-original articles, case reports, conference abstracts, commentaries, letters, book chapters, studies published before 2010, studies not focused on brain tumors, and studies in which machine learning-based survival prediction is not the primary outcome.

Information sources Electronic searches are conducted in PubMed, Scopus, and Embase (Ovid). Only published studies are sought. No grey literature, trial registers, or author contact are used.

Main outcome(s) The main outcome is overall survival after stereotactic radiosurgery. The principal effect measures are model discrimination metrics, reported either at specific time points or over follow-up. For quantitative synthesis, the primary meta-analytic outcome is AUC for 1-year overall survival prediction when sufficiently comparable data are available.

Data management Search results are exported from the databases, merged, and de-duplicated before screening. Study selection, extracted variables, and risk-of-bias assessments are recorded in structured tables prepared by the review team. Data extraction is performed independently by two reviewers, with discrepancies resolved through discussion and consensus.

Quality assessment / Risk of bias analysis Risk of bias is assessed using the PROBAST tool (Prediction model Risk Of Bias ASsessment Tool). Two reviewers assess each included study independently across the four PROBAST domains: participants, predictors, outcome, and analysis. Any discrepancies are resolved through discussion and consensus.

Strategy of data synthesis Findings are synthesized narratively across all included studies, with structured summary tables describing study populations, tumor types, predictors, machine learning approaches, validation methods, and reported performance metrics. Quantitative synthesis is performed when studies report sufficiently comparable discrimination measures for a similar outcome and time point. For the primary meta-analysis, AUC values for 1-year overall survival prediction are pooled using a random-effects model. Heterogeneity is assessed statistically, and subgroup analysis is performed where appropriate when clinically comparable studies are available. Metrics such as sensitivity, specificity, and accuracy are described narratively when reporting is too heterogeneous for meaningful pooling.

Subgroup analysis Where sufficient comparable data are available, subgroup analyses are performed by tumor type.

Sensitivity analysis Sensitivity analysis is conducted by restricting the meta-analysis to studies including patients with brain metastases. This also serves as a small-study sensitivity analysis, because excluding studies with sample sizes below 30 yields the same subset.

Language restriction Only studies published in English are included.

Country(ies) involved United Kingdom.

Keywords Stereotactic radiosurgery; brain tumor; brain metastases; glioma; machine learning; survival prediction; overall survival; prognostic model; radiosurgery outcomes.

Contributions of each author

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