Brain Cancer Survival:

Understanding Factors Contributing to Survival of Patients Using SEER Data

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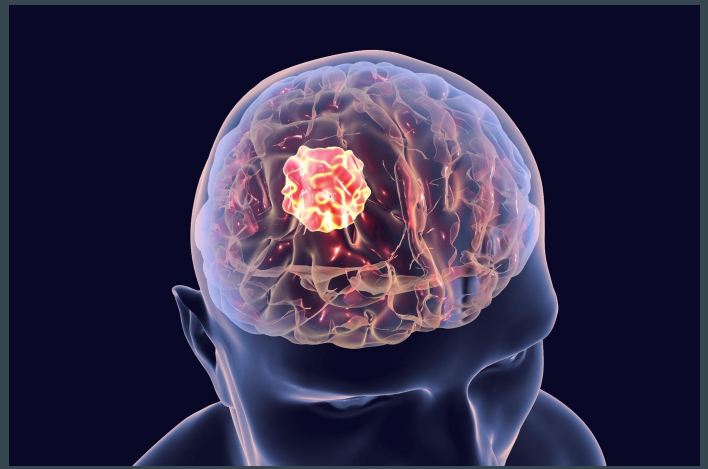
Introduction/Motivation

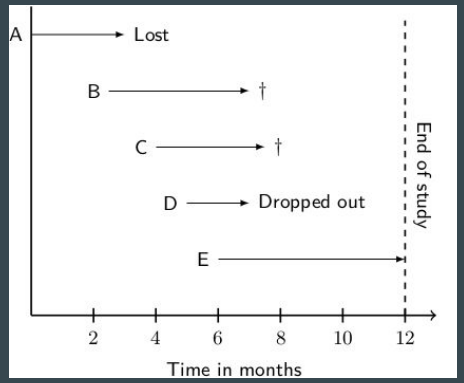
- Cancer is the #2 leading cause of death in the US.
- Cancer treatment is complex and highly individualized.
- Brain cancer is one of the hardest varieties to treat.
- Surveillance, Epidemiology, and End Results (SEER) Program
    - Large dataset of anonymized cancer listings
    - Compiled from several cancer registries
    - Covers 42% of US population
    - 1975-present
    - Tracks a large number of covariates including:
        - Demographics
        - Tumor characteristics
        - Diagnostic results
        - And much more!

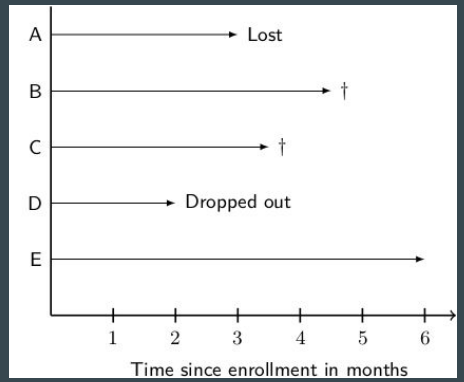


Survival Analysis

- Goal: predict survival S(t) as a function of time
  - Key distinctions from standard multivariate regression:
    - Censoring: lost to follow-up or end of study
    - Censoring ⇒ time dependence
- Methods:
  - Kaplan-Meier estimator
    - Survival estimates from raw data (no fitting required)
  - Multivariate Cox regression
    - Survival estimates account for covariates
    - Central assumption: survival functions are proportional throughout time

$$S(t\,|X) = S_0(t)\exp\left(X^T\beta\right)$$

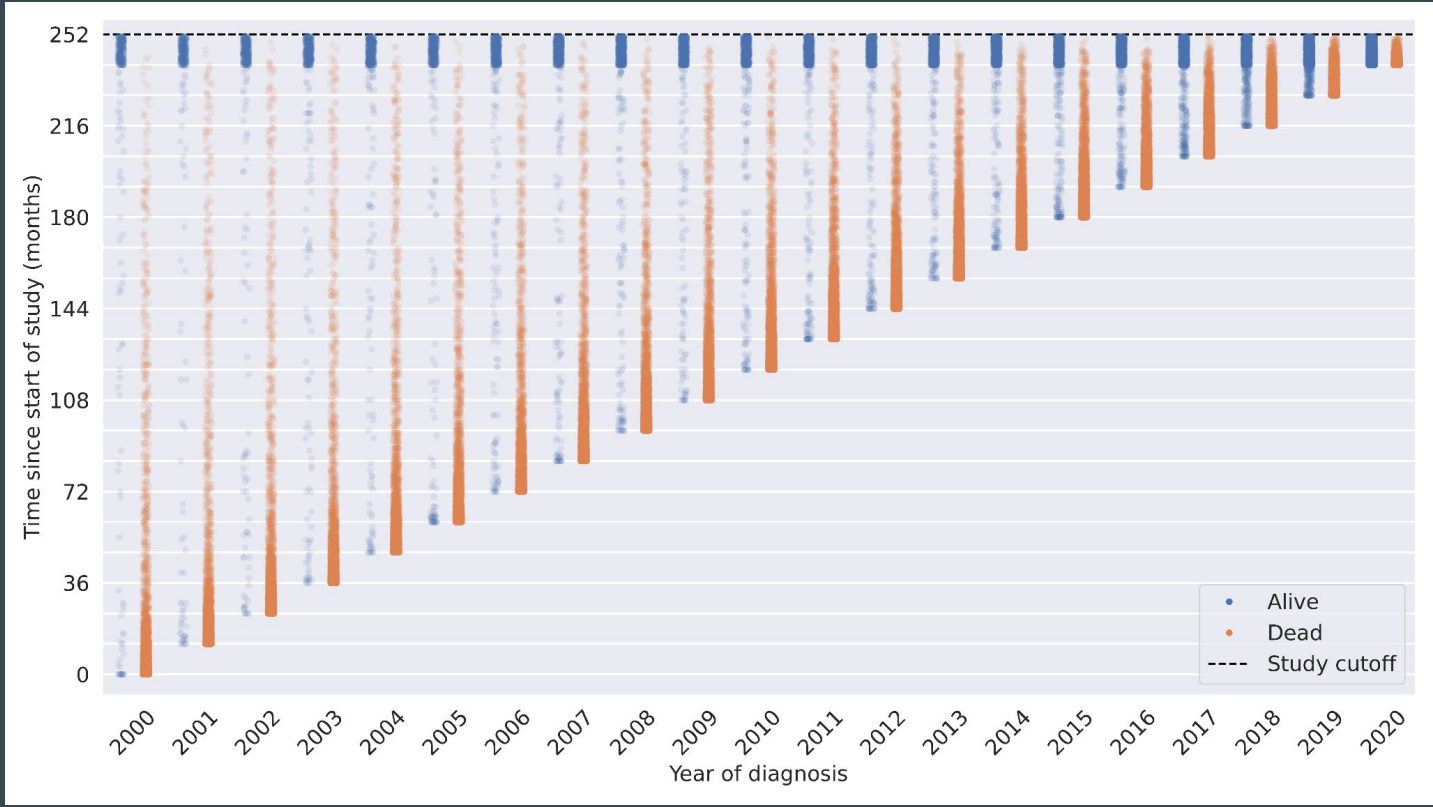




Data Collection

- Analyzed the SEER 17 database (Nov. 2022 submission)
  - Covers ~26.5% of the US population based on a 2020 population census
  - Includes cases documented between 2000 and 2020
  - 9,208,295 total tumor records
- Used the SEER*Stat software package for data collection
- Extracted case info and survival data for all 76,327 brain tumor entries
- Restricted the study cohort to patients with a single tumor ⇒ 74,332 cases

Data Collection



Data Preprocessing & Feature Engineering

- Redundant features in SEER database
- Selected a subset of all features to work with
- Fill missing values & add features to track them
- Most categories are categorical (i.e., demographics, diagnostic encodings)
  - One-hot encoding creates many features.
  - We drop categories that are too rare.
- Automatically drop features with high correlations to other features
- 111 features after preprocessing

Model Training

- Used the lifelines survival analysis library
- Model scoring via partial log-likelihood
  - Depends on the censoring pattern
  - Generalizes maximum likelihood estimation to survival analysis
- Employ L1 and L2 regularization to improve training performance & stability
- 3-fold cross-validation of regularization hyperparameters
- Stratification using age standards for survival analysis
- Assess goodness-of-fit via the concordance index (c-index)
- Model performance: c-index = 0.726

Results

Covariate	Hazard Ratio	Lower 95% CI	Upper 95% CI	p-value
Glioblastoma	1.636	1.580	1.694	<0.0005
"Months from diagnosis to treatment" data missing	1.252	1.236	1.268	<0.0005
ICD-O-3 Code: 9421	0.864	0.830	0.899	<0.0005
ICD-O-3 Code: 9064	0.897	0.872	0.923	<0.0005
Localized tumor	0.906	0.889	0.923	<0.0005
Year of diagnosis	0.917	0.890	0.945	<0.0005
Oligodendroglioma, IDH-mutant & 1 p/19q co-deleted	0.920	0.880	0.963	<0.0005
Primary Site: Cerebrum	1.084	1.073	1.095	<0.0005
Diffuse astrocytoma and anaplastic astrocytoma	1.080	1.049	1.111	<0.0005
ICD-O-3 Code: 8000	1.079	1.062	1.095	<0.0005
ICD-O-3 Code: 9450	0.930	0.909	0.951	<0.0005
Diffuse astrocytoma, IDH-mutant	0.930	0.903	0.957	<0.0005
Other astrocytic tumor	0.930	0.895	0.966	<0.0005
Ependymal tumor	0.932	0.861	1.009	0.084
Summary Stage: Regional/Not otherwise specified	1.073	1.058	1.088	<0.0005
ICD-O-3 Code: 9401	1.070	1.053	1.087	<0.0005
Tumor Grade I (Well differentiated)	0.937	0.925	0.949	<0.0005
Tumor Grade II (Moderately differentiated)	0.938	0.926	0.949	<0.0005
ICD-O-3 Code: 9391	0.938	0.873	1.008	0.082
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Prediction: a glioblastoma diagnosis is associated with a 64% higher risk of death

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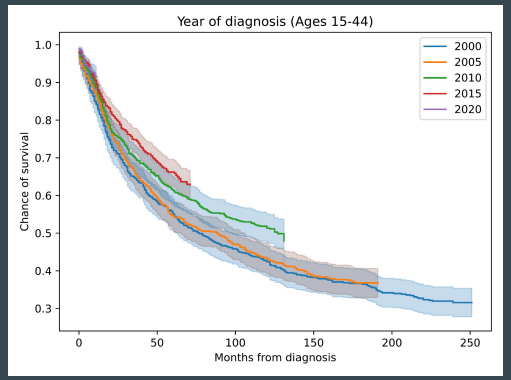
Prediction: 1p/19q co-deletion is associated with an 8% lower risk of death

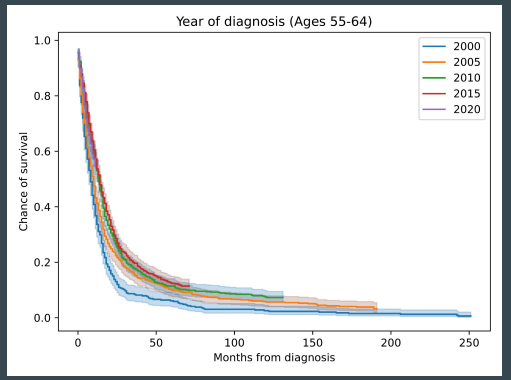
Survival adjusted for year of diagnosis

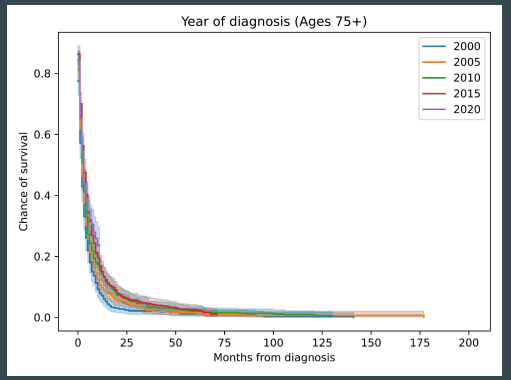
Kaplan-Meier:

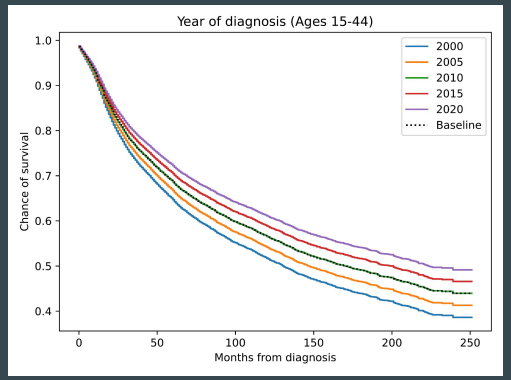
Adjust for covariates

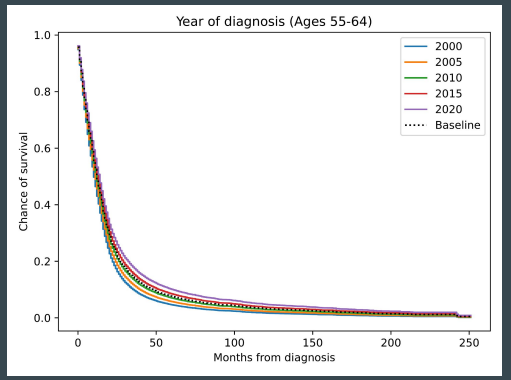
Cox regression:

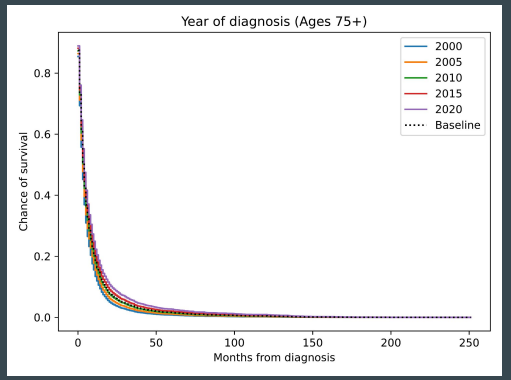












Summary & Future Work

- Analyzed brain tumor case data from the SEER cancer registry
- Predicted survival using multivariate Cox regression
- Future work:
  - Quantify proportional hazards assumption validity
  - Investigate factors that improve glioblastoma survival
  - Comparison with ensemble and deep learning methods:
    - Random survival forests
    - Survival support vector machines
    - Deep learning methods for survival analysis