Racial disparities in recommendations for surgical resection of primary brain tumours: a registry-based cohort analysis

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Summary

Background Disparities in treatment and outcomes disproportionately affect minority ethnic and racial populations in many surgical fields. Although substantial research in racial disparities has focused on outcomes, little is known about how surgeon recommendations can be influenced by patient race. The aim of this study was to investigate racial and socioeconomic disparities in the surgical management of primary brain tumors.

Methods In this registry-based cohort study, we used data from the Surveillance, Epidemiology, and End Results (SEER) database (1975–2016) and the American College of Surgeons National Cancer Database (NCDB) in the USA for independent analysis. Adults (aged ≥20 years) with a new diagnosis of meningioma, glioblastoma, pituitary adenoma, vestibular schwannoma, astrocytoma, and oligodendroglioma, with information on tumour size and surgical recommendation were included in the analysis. The primary outcome of this study was the odds of a surgeon recommending against surgical resection at diagnosis of primary brain neoplasms. This outcome was determined using multivariable logistic regression with clinical, demographic, and socioeconomic factors.

Findings This study included US national data from the SEER (1975–2016) and NCDB (2004–17) databases of adults with a new diagnosis of meningioma (SEER n=63 674; NCDB n=222 673), glioblastoma (n=35 258; n=104 047), pituitary adenoma (n=27 506; n=87 772), vestibular schwannoma (n=11 525; n=30 745), astrocytoma (n=5402; n=10 631), and oligodendroglioma (n=3977; n=9187). Independent of clinical and demographic factors, including insurance status and rural–urban continuum code, Black patients had significantly higher odds of recommendation against surgical resection of meningioma (adjusted odds ratio 1·13, 95% CI 1·06–1·21, p<0·0001), glioblastoma (1·14, 1·01–1·28, p=0·038), pituitary adenoma (1·13, 1·05–1·22, p<0·0001), and vestibular schwannoma (1·48, 1·19–1·84, p<0·0001) when compared with White patients in the SEER dataset. Additionally, patients of unknown race had significantly higher odds of recommendation against surgical resection for pituitary adenoma (1·80, 1·41–2·30, p<0·0001) and vestibular schwannoma (1·49, 1·10–2·04, p=0·011). Performing a validation analysis using the NCDB dataset confirmed these significant results for Black patients with meningioma (1·18, 1·14–1·22, p<0·0001), glioblastoma (1·19, 1·12–1·28, p<0·0001), pituitary adenoma (1·21, 1·16–1·25, p<0·0001), and vestibular schwannoma (1·19, 1·04–1·35, p=0·0085), and indicated and indicated that the findings are independent of patient comorbidities. When further restricted to the most recent decade in SEER, these inequities held true for Black patients, except those with glioblastoma (meningioma [1·18, 1·08–1·28, p<0·0001], pituitary adenoma [1·20, 1·09–1·31, p<0·0001], and vestibular schwannoma [1·54, 1·16–2·04, p=0·0031]).

Interpretation Racial disparities in surgery recommendations in the USA exist for patients with primary brain tumours, independent of potential confounders including clinical, demographic, and select socioeconomic factors. Further studies are needed to understand drivers of this bias and enhance equality in surgical care.

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Introduction

Racial disparities in health care have persisted since the beginning of modern medicine, from the Tuskegee syphilis studies in 1932 to continued racial divides in all-cause mortality rates, hospital complications, and cancer survival in the modern era.[1–3] Multiple contributions to inequality exist along a patient's health-care trajectory including access, affordability, and the patient–physician relationship. Inequity in surgical care is commonly attributed to patient-specific factors (eg, race, insurance, and socioeconomic status), systemic factors (eg, facility resources and experience), and provider-specific factors (eg, implicit bias).[4] Research into the role of implicit bias (unconscious assumptions of groups of individuals) in surgical decision making has been growing but remains challenging, due in part to the difficulty in its measurement and in isolating its effect from socioeconomic and clinical contributors. There is now increasing awareness of the intricate interplay that exists within the historical, financial, cultural, and personal context surrounding these decisions. Previous studies have suggested that non-White patients are both offered and choose surgical treatment for lung cancer less often than White patients, suggesting that further understanding of the context of

Research in context

Evidence before this study

Racial inequities have been described in several surgical fields, with research primarily focusing on surgical morbidity and overall mortality. We searched the MEDLINE, Embase, MedRxiv, and bioRxiv databases from Jan 1, 1995, to April 22, 2021, using the search terms ("Racial disparity" or "Racial inequity") and ("Surgery", "Surgical outcomes", or "Surgical management"). Studies were restricted to those in English or with English translations available. Case reports and meta-analyses were excluded from the search. Previously published relevant studies were reviewed, and 20 additional systematic reviews covering a variety of surgical fields were identified. Research, predominantly in the most recent decade, has revealed inequities in survival outcomes in neurosurgery and other surgical fields, and in the resulting operative and post-operative morbidity in neuro-oncological and other oncological conditions, but scarce data exists assessing the initial access to, and recommendation for, surgery itself.

Added value of this study

This registry-based cohort study improves on previous approaches to identifying surgical inequity in two important ways. First, this study assesses racial disparities in surgery with a primary outcome measure that focuses on the initial management of the patient: the surgeon's recommendation for or against tumour resection. Second, this work accounts for common contributors to racial inequity in health care, including patient-specific, systemic, and provider-specific factors, by using multivariable logistic regression using variables from two large US national databases. These variables include comorbidities, patient race and ethnicity, insurance status, and the rural and urban composition of the region of treatment, in addition to clinical and demographic variables. This provides control for socioeconomic and systemic contributors that were often not accounted for in previous studies.

Implications of all the available evidence

We identified significant racial disparities in surgical recommendations for patients with primary brain tumours, with physicians recommending against surgical resection significantly more often for Black patients than for White patients in the glioblastoma, meningioma, pituitary adenoma, and vestibular schwannoma subgroups. These findings are independent of clinical, demographic, and select socioeconomic and systemic variables. Previous studies have found disparities in morbidity and mortality outcomes in various surgical subspecialties. Taken together, these findings highlight previously unrecognised racial inequities in both management and outcomes of primary brain tumours, indicating a need for increased effort to rectify these health-care disparities.

surgical decision making is imperative.[5,6] Furthermore, surgeon awareness of racial and ethnic disparities might be lower than expected and extend across surgical subspecialties.[7,8] The recent refocus on racial disparities in the USA, in the setting of increasing diversity in the population, is intensifying the urgency of identifying areas of improvement to achieve fairness in surgical care.

Data surrounding disparities within neurosurgery are limited to those focusing on the relationship between race, income, and health-care access and how these influence patient outcomes.[9,10] In the most common brain malignancies including glioblastoma, astrocytoma, and oligodendroglioma, initial treatment with surgery is the standard of care and crucial to maximise survival.[11–15] In the most common benign brain tumours, including meningiomas, pituitary adenomas, and vestibular schwannomas, symptoms and growth are the most likely indications for recommending intervention to prevent neurological morbidity.[16–18] Prompt and appropriate surgical management of primary brain tumours is imperative to improve long-term outcomes in these conditions with high potential for morbidity and mortality.

In the most recent decade, research has focused on how disparities influence patient outcomes in neurosurgery. In contrast, little is known about racial and socioeconomic factors that might influence a physician's recommendation for surgery. Given the central role of surgery in the management of neuro-oncological diseases, we sought to understand the relationship between patient-specific factors and a recommendation for surgery. Herein, we investigate racial and socioeconomic disparities in surgery recommendation for primary brain tumours using two large national databases to allow for cross-validation for robustness.

For more on **SEER** see https://seer.cancer.gov/

Methods

Study design and participants

In this registry-based cohort analysis, we used data from the Surveillance, Epidemiology, and End Results (SEER) database (1975–2016, SEER Registry 18 Custom Data) as well as the American College of Surgeons National Cancer Database (NCDB, 2004–17)[19] in the USA for independent analyses. SEER Registry 18 reports cancer incidence and survival data from representative, population-based cancer registries encompassing roughly 28% of the US population. Each registry was selected based on its ability to maintain a high quality cancer reporting system and for their epidemiologically substantial population subgroups. The population covered by SEER is comparable to the general US population with regard to measures of poverty and education. Data in SEER is provided from both hospital and clinical settings. NCDB is a clinical oncology database from over 1500 Commission on Cancer-accredited hospital registries, representing over 70% of newly diagnosed cases nationally. Commission on

Cancer-accredited hospitals are larger and located more often in urban geographical areas. Patients were included in this study if they had a diagnosis, according to the third edition of the International Classification of Diseases for Oncology (ICD-O-3) histology code, associated with meningioma, glioblastoma, pituitary adenoma, vestibular schwannoma, astrocytoma, or oligodendroglioma. Only patients older than 20 years were included. Patients were excluded if they had unknown data regarding tumour size, metastatic status, or surgery recommendation. Patients were also excluded if their tumours were initially identified by autopsy.

Predetermined demographic and clinical variables included were age at diagnosis, sex (male or female), race and origin as per NCDB and SEER databases (non-Hispanic White, Hispanic [all races], non-Hispanic American Indian or Alaskan Native, non-Hispanic Asian or Pacific Islander, non-Hispanic Black, or unknown), and tumour size, histological classification, grade, and primary site. NCDB data varied from SEER in that race was reported without information on Hispanic origin. NCDB reports the Charlson-Deyo Comorbidity Index (CCI) that is not present in SEER. Resulting disease management and outcome variables included cancer-directed surgery. Cancer-directed surgery information was grouped according to whether the surgeon recommended surgery or not, independent of whether the procedure occurred. For example, a patient whose cancer directed surgery status was recommended but not performed was grouped into the surgery recommended group. Surgery recommendations are coded only for surgical procedures at the primary site intended to remove the tissue. Therapeutic procedures such as drain or shunt placement, as well as biopsies that are not intended to leave "only microscopic margins" are not coded as surgery recommendations in the databases.[20,21] Recommendations for radiation were not considered a recommendation for surgical resection.

SEER registries are required by individual state law, and supported by the Cancer Registries Amendment Act, to collect data on all people who are diagnosed with cancer and who, at the time of diagnosis, are residents of the geographical area covered by the SEER registry. All malignant histologies are reportable as well as benign primary intracranial or central nervous system (CNS) tumours. The NCDB population consists of patients who received some element of their cancer care (treatment or diagnosis) at a cancer programme that is accredited by the Commission on Cancer. Patients who did not receive care but interacted with a physician at a Commission on Cancer facility are not reported to the NCDB. Eligible patients include those diagnosed with most in situ or invasive primary tumours. Benign tumors are reported to the NCDB if they occur within the CNS.

As both SEER and NCDB databases are publicly available with de-identified data, no written consent or ethical approval were necessary for this study.

	n	Univariable		Multivariable	
		Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Meningioma (n=63 674)					
Age at diagnosis	..	1·05 (1·05–1·05)	<0·0001	1·05 (1·05–1·05)	<0·0001
Sex					
Male	16 587	Ref	Ref	..	..
Female	47 087	1·40 (1·35–1·45)	<0·0001	..	..
Race and origin*					
White	43 779	Ref	Ref	Ref	Ref
Hispanic (all races)	6893	0·62 (0·59–0·66)	<0·0001	0·86 (0·81–0·92)	<0·0001
American Indian or Alaskan Native	344	0·68 (0·55–0·84)	0·0003	0·81 (0·62–1·06)	0·13
Asian or Pacific Islander	4915	0·73 (0·68–0·77)	<0·0001	0·95 (0·88–1·03)	0·20
Black	7297	0·86 (0·82–0·91)	<0·0001	1·20 (1·12–1·27)	<0·0001
Unknown	446	0·94 (0·78–1·14)	<0·0001	1·29 (1·02–1·62)	0·035
Tumour size	63 674	0·94 (0·93–0·94)	<0·0001	0·93 (0·93–0·93)	<0·0001
Tumour site					
Cranial	61 480	Ref	Ref	Ref	Ref
Spinal	2194	0·18 (0·16–0·20)	<0·0001	0·07 (0·06–0·07)	<0·0001
WHO classification					
Grade I or not otherwise specified	60 645	Ref	..	Ref	..
Grade II	2549	0·05 (0·04–0·05)	<0·0001	0·10 (0·09–0·12)	<0·0001
Grade III	480	0·03 (0·02–0·05)	<0·0001	0·09 (0·05–0·13)	<0·0001
Glioblastoma multiforme (n=35 258)					
Age at diagnosis	..	1·04 (1·04–1·04)	<0·0001	1·04 (1·04–1·04)	<0·0001
Sex					
Male	20 395	Ref	Ref	..	..
Female	14 863	1·09 (1·04–1·15)	<0·0001	..	..
Race and origin*					
White	28 686	Ref	Ref	Ref	Ref
Hispanic (all races)	3192	1·01 (0·93–1·11)	0·79	1·19 (1·08–1·30)	0·0025
American Indian or Alaskan Native	118	0·81 (0·49–1·27)	0·37	1·01 (0·61–1·61)	0·95
Asian or Pacific Islander	1495	1·16 (1·02–1·31)	0·021	1·27 (1·12–1·44)	0·0021
Black	1737	1·01 (0·89–1·13)	0·93	1·16 (1·02–1·30)	0·018
Unknown	30	1·60 (0·69–3·38)	0·24	1·48 (0·63–3·21)	0·34
Tumour size	35 258	1·00 (1·00–1·00)	0·17	..	..
Pituitary adenoma (n=27 506)					
Age at diagnosis	..	0·99 (0·99–0·99)	<0·0001	1·00 (1·00–1·01)	0·031
Sex					
Male	12 454	Ref	Ref	Ref	Ref
Female	15 052	1·70 (1·62–1·78)	<0·0001	1·23 (1·17–1·30)	<0·0001
Race and origin*					
White	14 845	Ref	Ref	Ref	Ref
Hispanic (all races)	4968	0·86 (0·81–0·92)	<0·0001	0·95 (0·88–1·02)	0·12
American Indian or Alaskan Native	273	1·15 (0·90–1·46)	0·26	1·03 (0·79–1·34)	0·84
Asian or Pacific Islander	2232	0·79 (0·72–0·87)	<0·0001	0·85 (0·77–0·93)	<0·007
Black	4806	1·03 (0·97–1·10)	0·32	1·19 (1·11–1·28)	<0·0001

(Table 1 continues on next page)

	n	Univariable		Multivariable	
		Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
(Continued from previous page)					
Unknown	382	2·16 (1·73–2·70)	<0·0001	1·92 (1·51–2·46)	<0·0001
Tumour size	27 506	0·93 (0·93–0·93)	0·0031	0·93 (0·93–0·94)	<0·0001
Vestibular schwannoma (n=11 525)					
Age at diagnosis	..	1·06 (1·05–1·06)	<0·0001	1·06 (1·05–1·06)	<0·0001
Sex					
Male	5526	Ref	Ref	..	..
Female	5999	0·96 (0·89–1·03)	0·26	..	..
Race and origin*					
White	8599	Ref	Ref	Ref	Ref
Hispanic (all races)	1106	0·78 (0·69–0·88)	0·0001	1·06 (0·93–1·22)	0·38
American Indian or Alaskan Native	81	1·09 (0·70–1·72)	0·69	1·16 (0·72–1·89)	0·54
Asian or Pacific Islander	1067	0·87 (0·77–0·99)	0·036	1·11 (0·96–1·28)	0·15
Black	454	1·30 (1·07–1·59)	0·0077	1·56 (1·26–1·93)	<0·0001
Unknown	218	1·41 (1·06–1·87)	0·018	1·56 (1·15–2·12)	0·0045
Tumour size	11 525	0·96 (0·96–0·96)	<0·0001	0·97 (0·96–0·97)	<0·0001
Astrocytoma (n=5402)					
Age at diagnosis	..	1·03 (1·03–1·04)	<0·0001	1·03 (1·03–1·04)	<0·0001
Sex					
Male	3064	Ref	Ref	..	..
Female	2338	1·16 (1·03–1·31)	0·014	..	..
Race and origin*					
White	4034	Ref	Ref	..	..
Hispanic (all races)	698	0·73 (0·60–0·89)	0·0015	..	..
American Indian or Alaskan Native	36	0·62 (0·25–1·33)	0·25	..	..
Asian or Pacific Islander	260	1·11 (0·84–1·46)	0·45	..	..
Black	342	1·07 (0·84–1·36)	0·60	..	..
Unknown	32	1·53 (0·72–3·09)	0·25	..	..
Tumour size	5402	0·99 (0·99–1·00)	<0·0001	0·99 (0·99–1·00)	<0·0001
WHO classification					
Grade I	429	Ref	Ref	Ref	Ref
Grade II	1387	1·45 (1·11–1·90)	0·0068	1·38 (1·05–1·82)	0·023
Grade III	835	2·05 (1·56–2·72)	<0·0001	1·35 (1·01–1·81)	0·043
Unknown	2751	1·59 (1·24–2·06)	0·0003	1·37 (1·06–1·78)	0·018
Oligodendroglioma (n=3977)					
Age at diagnosis	..	1·02 (1·02–1·03)	<0·0001	1·03 (1·02–1·03)	<0·0001
Sex					
Male	2243	Ref	Ref	..	..
Female	1734	1·10 (0·91–1·32)	0·32	..	..
Race and origin*					
White	2973	Ref	Ref	..	..
Hispanic (all races)	532	0·94 (0·71–1·23)	0·66	..	..
American Indian or Alaskan Native	30	1·31 (0·44–3·16)	0·59	..	..
Asian or Pacific Islander	263	1·04 (0·71–1·48)	0·85	..	..
Black	165	0·90 (0·54–1·42)	0·67	..	..
Unknown	14	0·50 (0·03–2·53)	0·51	..	..

(Table 1 continues on next page)

Procedures

Meningiomas were identified by the ICD-O-3 histological grouping for meningioma. Subtypes were further split into their corresponding WHO classification for analysis. Because of potential differences in treatment approach, patients were grouped into cranial and spinal subgroups according to their topographical code. Patients without tumour site information were removed.

Glioblastomas were identified by ICD-O-3 histology codes 9440 and 9441 corresponding to glioblastoma and giant cell glioblastoma, respectively. Data entries that were analysed were further restricted to those explicitly stated to be grade IV neoplasms.

Pituitary adenomas were identified by ICD-O-3 histology code 8140 (benign adenoma) or 8272 (pituitary adenoma), and primary site topography code C75.1, pituitary gland. Prolactinomas, ICD-O-3 code 8271, were explicitly excluded in this selection due to non-surgical treatment options.

Vestibular schwannomas were identified by ICD-O-3 histology code 9560 and primary site topography code C72.4, acoustic nerve.

ICD-O-3 histological grouping for astrocytoma was used to identify patients. Histological classification and identified grade were used to group patients by WHO grade. Patients who were identified as grade IV were removed due to the potential to overlap with the glioblastoma group.

Oligodendrogliomas were identified by ICD-O-3 histology codes 9450 (oligodendroglioma) and 9451 (anaplastic oligodendroglioma). Because the histology name includes the grading system, grade was not included in analysis.

The primary outcome assessed was the odds of a surgeon recommending against surgical resection on diagnosis of these previously stated tumours in adult patients.

Statistical analysis

RStudio version 1.3.959 and R version 4.0.2 were used for all statistical analysis. Categorical variables are presented as numbers and percentages; continuous variables are presented as mean and standard deviation. Univariable logistic regression was used to determine the odds ratio (OR) of recommendation against surgery for each variable. Multivariable logistic regression was used to determine the independent adjusted OR (aOR) of recommendation against surgery for the variables. A predetermined, backward, stepwise variable elimination was implemented, where the most insignificant independent variable was removed from the multivariable model until only variables with $p<0·05$ remained. This selection approach included predetermined variables at the initiation of backward elimination to control for covariate effects to address the specific clinical question. Follow-up analysis with the inclusion of insurance status and rural–urban continuum data, as well as with

restriction to the most recent decade were done in the same manner. A p<0·05 was considered statistically significant in all instances.

Role of the funding source

There was no funding source for this study.

Results

Patient characteristics from the SEER database are summarised in the appendix (pp 2–5). After data extraction from the SEER database, 63 674 patients with meningioma, 35 258 patients with glioblastoma, 27 506 patients with pituitary adenoma, 11 525 patients with vestibular schwannoma, 5402 patients with astrocytoma, and 3977 patients with oligodendroglioma were included in their respective analyses. Meningiomas had the highest percentage (59·5%) of patients with a recommendation against surgical resection, whereas oligodendrogliomas had the lowest percent (13·2%).

Univariable logistic regression was implemented to identify demographic and clinical characteristics associated with recommendation against surgical resection of primary brain tumours. Multivariable logistic regression identified variables that were independently associated with recommendation against surgery (table 1).

For patients with meningioma in the SEER database, based on the multivariable analysis, increased age (aOR 1·05, 95% CI 1·05–1·05, p<0·0001), patients of Black race (1·20, 1·12–1·27, p<0·0001), and patients of unknown race (1·29, 1·02–1·62, p=0·035) had statistically significantly higher odds of recommendation against surgery, independent of all included clinical or demographic variables (figure 1). For those with glioblastoma multiforme, on multivariable analysis, older age at the time of diagnosis was independently associated with statistically significantly higher odds of recommendation against surgery (aOR 1·04, 95% CI 1·04–1·04, p<0·0001). Hispanic (1·19, 1·08–1·30, p=0·0025), Asian or Pacific Islander (1·27, 1·12-1·44, p=0·0002), and Black patients (1·16, 1·02–1·30, p=0·018) had significantly higher odds of recommendation against surgical resection compared with White patients, independent of other clinical and demographic variables. In pituitary adenoma, on multivariable analysis, Black patients (aOR 1·19, 95% CI 1·11–1·28, p<0·0001) and patients of unknown race (1·92, 1·51–2·46, p<0·0001) had significantly higher odds of recommendation against surgery than White patients. Additionally, female patients (1·23, 1·17–1·30, p<0·0001) and older patients (1·00, 1·00–1·01, p=0·031) were more likely to be recommended against surgery. In patients with vestibular schwannoma, older age at diagnosis (aOR 1·06, 95% CI 1·05–1·06, p<0·0001), Black race (1·56, 1·26–1·93, p<0·0001), and unknown race (1·56, 1·15–2·12, p=0·0045) had higher odds of recommendation against surgical resection. Older age at diagnosis of astrocytoma (aOR 1·03, 95% CI 1·03–1·04, p<0·0001) was independently associated with higher odds of recommendation against surgery. Additionally, patients with tumours of WHO grade II (1·38, 1·05–1·82, p=0·023), grade III (1·35, 1·01–1·81, p=0·043), and tumours of unknown grade (1·37, 1·06–1·78, p=0·018) had higher odds of recommendation against surgery compared with grade I astrocytomas. For patients with oligodendroglioma, older age was associated with higher odds of recommendation against surgery (aOR 1·03, 95% CI 1·02–1·03, p<0·0001) on multivariable analysis. Patient characteristics from the NCDB database are summarised in the appendix (pp 6–9).

See **Online** for appendix

	n	Univariable		Multivariable	
		Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
(Continued from previous page)					
Tumour size	3977	0·99 (0·99–1·00)	0·0037	0·99 (0·99–1·00)	0·096
Histological classification					
Oligodendroglioma, not otherwise specified	2737	Ref	Ref	Ref	Ref
Oligodendroglioma, anaplastic	1240	0·53 (0·42–0·66)	<0·0001	0·48 (0·38–0·60)	<0·0001

Data are n, odds ratio (95% CI), or p value. Empty cells in the multivariable column indicate a non-significant variable that was removed from the multivariable logistic regression in accordance with the predetermined backward, stepwise, variable elimination approach. Ref groups for categorical analysis are marked accordingly. Ref=reference. *Race and origin category labels are as reported in the SEER dataset.

Table 1: **Odds of recommendation against surgery in the Surveillance, Epidemiology, and End Results database**

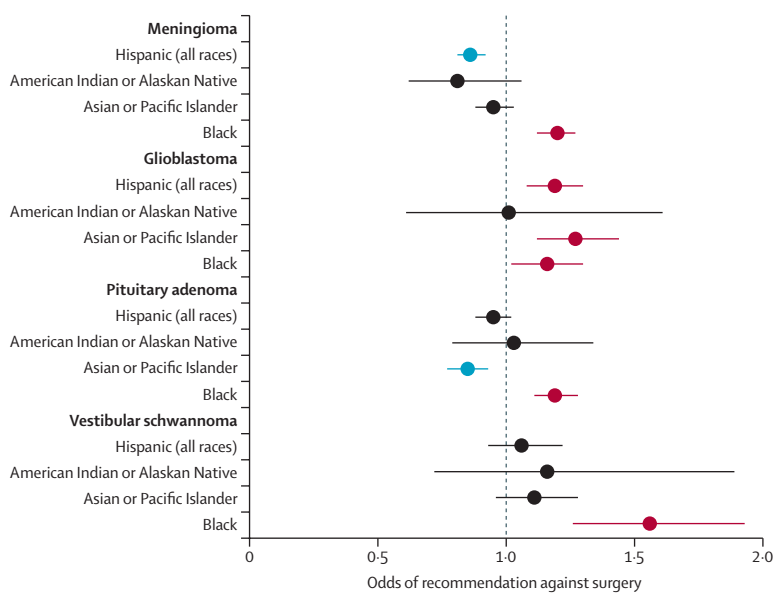

Figure 1: **Odds of recommendation against surgery compared with White patients in the SEER database**
The adjusted odds of recommendation against surgical resection of brain tumours compared with White patients in the SEER database following multivariable analysis that included clinical and demographic variables. Race and origin categories are listed as per the SEER database. SEER=Surveillance, Epidemiology, and End Results.

After data extraction from the NCDB database, 222 673 patients with meningioma, 104 047 patients with glioblastoma, 87 772 patients with pituitary adenoma, 30 745 patients with vestibular schwannoma, 10 631 patients with astrocytoma, and 9187 patients with oligodendroglioma were included in their respective analyses.

	n	Univariable		Multivariable	
		Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Meningioma (n=222 673)					
Age at diagnosis	..	1·05 (1·05–1·05)	<0·0001	1·05 (1·05–1·05)	<0·0001
Sex					
Male	59 653	Ref	Ref	Ref	Ref
Female	163 020	1·35 (1·32–1·37)	<0·0001	1·05 (1·02–1·07)	<0·0001
Race and origin*					
White	182 031	Ref	Ref	Ref	Ref
American Indian or Alaskan Native	662	0·66 (0·56–0·77)	<0·0001	0·95 (0·78–1·15)	0·58
Asian or Pacific Islander	7543	0·75 (0·72–0·79)	<0·0001	0·95 (0·90–1·01)	0·095
Black	27 084	0·93 (0·90–0·95)	<0·0001	1·26 (1·22–1·30)	<0·0001
Unknown	5353	0·81 (0·77–0·86)	<0·0001	1·03 (0·96–1·10)	0·43
Tumour size	222 673	0·94 (0·94–0·94)	<0·0001	0·93 (0·93–0·93)	<0·0001
Tumour site					
Cranial	214 726	Ref	Ref	Ref	Ref
Spinal	7947	0·17 (0·16–0·18)	<0·0001	0·07 (0·06–0·07)	<0·0001
WHO classification					
Grade I or not otherwise specified	219 974	Ref	..	Ref	..
Grade II	1986	0·02 (0·02–0·03)	<0·0001	0·05 (0·04–0·06)	<0·0001
Grade III	713	0·05 (0·04–0·07)	<0·0001	0·09 (0·07–0·13)	<0·0001
CCI score					
0	160 032	Ref	Ref	Ref	Ref
1	39 627	0·97 (0·95–0·99)	0·0038	0·77 (0·75–0·79)	<0·0001
2	14 137	1·11 (1·07–1·15)	<0·0001	0·84 (0·80–0·88)	<0·0001
3	8877	1·49 (1·43–1·56)	<0·0001	1·13 (1·06–1·19)	<0·0001
Glioblastoma multiforme (n=104 047)					
Age at diagnosis	..	1·04 (1·04–1·04)	<0·0001	1·04 (1·04-1·04)	<0·0001
Sex					
Male	59 599	Ref	Ref	..	..
Female	44 448	1·12 (1·09–1·15)	<0·0001	1·05 (1·02–1·08)	0·0016
Race and origin*					
White	94 537	Ref	Ref	Ref	Ref
American Indian or Alaskan Native	199	0·88 (0·61–1·23)	0·46	1·01 (0·70–1·43)	0·95
Asian or Pacific Islander	1917	0·97 (0·87–1·08)	0·57	1·09 (0·97–1·22)	0·13
Black	5524	1·04 (0·98–1·11)	0·22	1·20 (1·13–1·29)	<0·0001
Unknown	1870	0·86 (0·77–0·96)	0·0097	0·95 (0·85–1·07)	0·43
Tumour size	104 047	1·00 (1·00–1·00)	<0·0001	1·00 (1·00–1·00)	<0·0001
CCI score					
0	72 878	Ref	Ref	Ref	Ref
1	18 215	1·17 (1·13–1·22)	<0·0001	1·02 (0·98–1·06)	0·34
2	8348	1·17 (1·11–1·23)	<0·0001	1·02 (0·97–1·08)	0·39
3	4606	1·30 (1·21–1·39)	<0·0001	1·08 (1·01–1·16)	0·027

(Table 2 continues on next page)

Univariable and multivariable regression analyses were done on patients in the NCDB dataset, using the same methodology as the SEER dataset, with the additional inclusion of CCI scores. CCI was retained in multivariable analysis regardless of significance in the regression model to control for any dependence between surgical recommendation and patient comorbidities (table 2). Black patients had significantly higher odds of recommendation against surgery compared with White patients, independent of clinical and demographic variables including comorbidity scores, in the meningioma (aOR 1·26, 95% CI 1·22–1·30, p<0·0001), glioblastoma (1·20, 1·13–1·29, p<0·0001), pituitary adenoma (1·26, 1·22–1·31, p<0·0001), vestibular schwannoma (1·30, 1·15–1·48, p<0·0001), and astrocytoma (1·29, 1·09–1·51, p=0·0021) cohorts (figure 2).

The finding that Black patients had higher odds of recommendation against surgery, independent of clinical and demographic factors, in meningioma, glioblastoma, pituitary adenoma, and vestibular schwannoma in both the SEER and NCDB datasets compared with White patients prompted further investigation into these disparities. We first explored temporal trends in the data by limiting the SEER dataset to the most recent decade (2010 or later). On repeat multivariable analysis, Black patients still had significantly higher odds of recommendation against surgery in the meningioma (aOR 1·18, 95% CI 1·08–1·28, p<0·0001), pituitary adenoma (1·20, 1·09–1·31, p<0·0001), and vestibular schwannoma (1·54, 1·16–2·04, p=0·0031) cohorts, in comparison with White patients (figure 3). This did not hold true in patients with glioblastoma, where Black patients diagnosed in 2010 or later did not have higher odds of recommendation against surgical resection (1·14, 0·93–1·38, p= 0·20).

In a second approach to test for a temporal relationship between recommendation for surgery and patient race, we included the year of diagnosis as a variable in the multivariable analysis for the SEER dataset. The results were consistent with restriction to the most recent decade in that Black patients with meningioma, pituitary adenoma, and vestibular schwannoma were significantly more likely to be recommended against surgical resection, independent of the year of diagnosis (appendix pp 10–11).

Although SEER and NCDB databases use a fundamentally distinct mechanism to collect patient data, we considered that some patients might be duplicated in both databases. To test for the effect of potential patient overlap, we did an analysis limited to two consecutive but non-overlapping time intervals to test for consistency. SEER data was restricted to patients with a year of diagnosis from 2000 to 2008 and NCDB data was restricted to patients with a year of diagnosis from 2009 to 2017. In both time-restricted databases,

Black patients had significantly higher odds of recommendation against surgery, independent of clinical and demographic factors, for meningioma, pituitary adenoma, and vestibular schwannoma (appendix pp 12–16). In the glioblastoma group, Black patients had significantly higher odds of recommendation against surgery in NCDB from 2009 to 2017 (aOR 1·27, 95% CI 1·23–1·32, p<0·0001) and in SEER from 2000 to 2008 (1·21, 1·00–1·47, p=0·046). Overall, these data corroborate the conclusion that SEER and NCDB independently show an association between Black race and recommendation against surgery in these four tumour types.

Because insurance status is a barrier for care that disproportionately affects minority ethnic and racial populations, and county rural–urban status serve as a proxy for geographical access to high volume academic and private neurosurgical centres, we assessed the role each of these played in the racial disparities identified.[9,22] Insurance status of the patient, and the rural–urban continuum code for the county the patient was treated in, were extracted from SEER. Multivariable surgical recommendation analysis was repeated with the addition of these two variables. Independent of insurance status, county rural–urban continuum code, and previously discussed clinical factors, Black patients with meningioma (aOR 1·13, 95% CI 1·06–1·21, p<0·0001), glioblastoma (1·14, 1·01–1·28, p=0·038), pituitary adenoma (1·13, 1·05–1·22, p<0·0001), and vestibular schwannoma (1·48, 1·19–1·84, p<0·0001) had significantly higher odds of recommendation against surgical resection (figure 3 and appendix pp 17–20).

We did the parallel analysis using the NCDB dataset, with the inclusion of insurance status and county rural–urban continuum code. Independent of clinical and demographic variables, Black patients with meningioma (aOR 1·18, 95% CI 1·14–1·22, p<0·0001), glioblastoma (1·19, 1·12–1·28, p<0·0001), pituitary adenoma (1·21, 1·16–1·25, p<0·0001), vestibular schwannoma (1·19, 1·04–1·35, p=0·0085), and astrocytoma (1·28, 1·08–1·50, p=0·0039) still had significantly higher odds of recommendation against surgical resection (figure 3 and appendix pp 21–27).

Discussion

Recent activity surrounding racial inequality in the USA and persistent racial inequities in resources and outcomes throughout the COVID-19 pandemic have sparked increased focus on disparities within health care. In a national study of both the SEER and NCDB databases, we found that Black patients and patients of unknown race were significantly more likely to receive a recommendation against surgical resection for a number of primary brain tumours compared with White patients, independent of clinical and demographic factors including tumour characteristics, comorbidities, insurance status, and rural–urban continuum, among other variables.

Racial disparities in outcomes and mortality have been well described in a variety of surgical specialties.[23] Black patients have been shown to have higher mortality rates

	n	Univariable		Multivariable	
		Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
(Continued from previous page)					
Pituitary adenoma (n=87 772)					
Age at diagnosis	..	0·99 (0·99–0·99)	<0·0001	..	..
Sex					
Male	41 011	Ref	Ref	Ref	Ref
Female	46 761	1·64 (1·59–1·68)	<0·0001	1·27 (1·23–1·30)	<0·0001
Race and origin*					
White	63 889	Ref	Ref	Ref	Ref
American Indian or Alaskan Native	361	0·81 (0·65–1·00)	0·048	0·87 (0·70–1·09)	0·22
Asian or Pacific Islander	3280	0·82 (0·76–0·88)	<0·0001	0·83 (0·77–0·90)	<0·0001
Black	17 156	1·14 (1·10–1·18)	<0·0001	1·26 (1·22–1·31)	<0·0001
Unknown	3086	1·18 (1·10–1·27)	<0·0001	1·14 (1·06–1·23)	<0·0001
Tumour size	87 772	0·95 (0·95–0·95)	<0·0001	0·95 (0·95–0·95)	<0·0001
CCI score					
0	69 836	Ref	Ref	Ref	Ref
1	13 146	0·53 (0·51–0·55)	<0·0001	0·56 (0·54–0·58)	<0·0001
2	3182	0·76 (0·70–0·80)	<0·0001	0·82 (0·76–0·88)	<0·0001
3	1608	1·23 (1·11–1·36)	<0·0001	1·40 (1·26–1·55)	<0·0001
Vestibular schwannoma (n=30 745)					
Age at diagnosis	..	1·06 (1·05–1·06)	<0·0001	1·06 (1·05–1·06)	<0·0001
Sex					
Male	14 455	Ref	Ref	Ref	Ref
Female	16 290	0·96 (0·91–1·00)	0·059	0·92 (0·87–0·97)	0·0013
Race and origin*					
White	26 999	Ref	Ref	Ref	Ref
American Indian or Alaskan Native	79	0·54 (0·35–0·84)	0·0068	0·81 (0·49–1·33)	0·40
Asian or Pacific Islander	1071	0·73 (0·64–0·82)	<0·0001	0·89 (0·78–1·02)	0·088
Black	1367	1·10 (0·98–1·23)	0·10	1·30 (1·15–1·48)	<0·0001
Unknown	1229	1·14 (1·02–1·29)	0·026	1·29 (1·13–1·47)	0·0001
Tumour size	30 745	0·96 (0·96–0·96)	<0·0001	0·97 (0·96–0·97)	<0·0001
CCI score					
0	26 959	Ref	Ref	Ref	Ref
1	2953	0·64 (0·59–0·69)	<0·0001	0·50 (0·46–0·54)	<0·0001
2	576	0·89 (0·75–1·05)	0·16	0·59 (0·49–0·71)	<0·0001
3	257	1·11 (0·86–1·44)	0·42	0·68 (0·51–0·89)	0·0058
Astrocytoma (n=10 631)					
Age at diagnosis	..	1·04 (1·03–1·04)	<0·0001	1·04 (1·03–1·04)	<0·0001
Sex					
Male	5772	Ref	Ref	..	..
Female	4859	1·07 (0·99–1·17)	0·10	..	..
Race and origin*					
White	9189	Ref	Ref	Ref	Ref
American Indian or Alaskan Native	41	0·74 (0·33–1·48)	0·42	0·81 (0·36–1·68)	0·60

(Table 2 continues on next page)

	n	Univariable		Multivariable	
		Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
(Continued from previous page)					
Asian or Pacific Islander	250	1·19 (0·90–1·56)	0·21	1·36 (1·02–1·81)	0·034
Black	866	1·05 (0·90–1·23)	0·51	1·29 (1·09–1·51)	0·0021
Unknown	285	0·89 (0·67–1·16)	0·39	1·07 (0·80–1·41)	0·66
Tumour Size	10 631	1·00 (0·99–1·00)	<0·0001	1·00 (0·99–1·00)	0·0001
WHO classification					
Grade I	1071	Ref	Ref	Ref	Ref
Grade II	1712	1·74 (1·45–2·09)	<0·0001	1·52 (1·26–1·84)	<0·0001
Grade III	858	2·91 (2·38–3·58)	<0·0001	1·68 (1·36–2·08)	<0·0001
Unknown	6990	1·52 (1·30–1·79)	<0·0001	1·29 (1·10–1·53)	0·0025
CCI score					
0	8781	Ref	Ref	Ref	Ref
1	1234	1·30 (1·15–1·48)	<0·0001	0·91 (0·80–1·05)	0·20
2	457	1·53 (1·26–1·86)	<0·0001	0·94 (0·76–1·15)	0·54
3	159	2·25 (1·64–3·09)	<0·0001	1·20 (0·86–1·67)	0·29
Oligodendroglioma (n=9187)					
Age at diagnosis	..	1·02 (1·02–1·02)	<0·0001	1·03 (1·02–1·03)	<0·0001
Sex					
Male	5141	Ref	Ref	Ref	Ref
Female	4046	0·82 (0·73–0·93)	0·0024	0·79 (0·69–0·89)	0·0002
Race and origin*					
White	8156	Ref	Ref	..	..
American Indian or Alaskan Native	26	1·22 (0·36–3·20)	0·71	..	..
Asian or Pacific Islander	291	1·07 (0·75–1·49)	0·70	..	..
Black	483	0·86 (0·64–1·14)	0·32	..	..
Unknown	231	0·93 (0·61–1·36)	0·71	..	..
Tumour size	9187	0·99 (0·99–0·99)	<0·0001	0·99 (0·99–0·99)	<0·0001
Histological classification					
Oligodendroglioma, not otherwise specified	6126	Ref	Ref	Ref	Ref
Oligodendroglioma, anaplastic	3061	0·42 (0·36–0·49)	<0·0001	0·38 (0·32–0·44)	<0·0001
CCI score					
0	7620	Ref	Ref	..	..
1	1056	1·03 (0·85–1·24)	0·79	0·89 (0·72–1·08)	0·23
2	364	1·04 (0·75–1·40)	0·82	0·92 (0·66–1·25)	0·60
3	147	1·40 (0·89–2·13)	0·13	1·03 (0·65–1·60)	0·88

Empty cells in the multivariable column indicate a non-significant variable that was removed from the multivariable logistic regression in accordance with the predetermined backward, stepwise, variable elimination approach.
Ref groups for categorical analysis are marked accordingly. CCI=Charlson-Deyo Comorbidity Index. Ref=reference.
*Race and origin category labels are as reported in the SEER dataset.

Table 2: **Odds of recommendation against surgery in the National Cancer Database**

after common abdominal procedures, lower survival rates in transplant surgery, and higher rates of in-hospital complications and disease recurrence in multiple surgical subsets.[24] Contributors to these inequities include patient-specific, systemic, and provider-specific factors.[23] A patient's insurance status impacts both the likelihood of receiving surgery and the method of surgery recommended, as do the comorbidities of the patient population. Systemic contributors within surgery include decreased access to high-volume hospitals within urban settings.[9] Despite evidence to the contrary, a minority of US surgeons surveyed agreed that racial disparities exist in health care, and only 11% reported it within their hospital or clinic.[7] One of the most difficult factors to consider, and to investigate, is the role that provider-specific biases have in surgical disparities.[25]

Limited efforts have been carried out to define disparities that exist within the field of neurosurgery, despite the high severity and national burden of neurological disorders.[26] The studies that have been done describe worse postoperative satisfaction for Black patients undergoing spinal surgery and higher morbidity and mortality rates in both spinal surgeries and craniotomies.[10,23,27] Surgical outcomes such as morbidity and mortality are often the variables of interest in studies surrounding inequities in any field of surgical care. When disparities are found in these outcome measures, the contributing socioeconomic factors are typically investigated first, with a resulting dearth of data on discrepancies in the management of these patients. Although insurance, income, geography, and other structural inequities contribute to disparities between races, the increased identification of and ability to control for these factors has led to a limited body of work that suggests racial disparity exists within the initial management of these conditions.[28,29]

The initial management and associated outcomes of primary central nervous system tumours are dependent on a number of clinical factors, although in many instances surgical resection is considered the standard of care. Glioblastoma and lower grade gliomas, including astrocytoma and oligodendroglioma, represent cases where surgical resection is the recommended first-line treatment and is associated with longer overall survival.[11,30–32] The more recent adaptation of a standardised treatment regimen for glioblastoma in 2005 with surgery, radiotherapy, and temozolomide might have played a part in the finding that disparities in surgical recommendation for Black patients with glioblastoma did not persist when restricted to the most recent decade.[33] The decision to offer surgery for vestibular schwannoma, meningioma, and pituitary adenoma is more influenced by severity of symptoms, rate of tumour growth, and likelihood of success with alternative treatments such as radiation therapy.[17,18,34] Nevertheless, a surgical resection endows survival advantages and symptomatic relief for patients with meningiomas and can alleviate or prevent symptoms such as imbalance due to brainstem compression or visual loss in patients with vestibular schwannoma and pituitary adenomas.[35,36] It is important to note that for some tumours with unfavourable surgical anatomy, medical therapy, radiation, or both might be the preferred approach, which in this analysis could be

classified as a recommendation against surgery. An important extension of these findings will be to investigate differences in treatment modalities by race. Although further research is needed, the inequities in surgery recommendations described in this study might in part contribute to the finding of worse outcomes for Black patients with brain tumors.[37]

Notably, instances of disparities in surgical recommendations within this study were seen for other races as well. Hispanic and Asian or Pacific Islander patients had higher odds of recommendation against surgery for glioblastoma in the SEER dataset, which persisted after controlling for insurance status. This finding was not seen for Asian or Pacific Islander patients with glioblastoma in the NCDB analysis. Of the races included in these databases, only Black patients and patients of unknown race had increased odds of recommendation against surgery for a tumour type that persisted in both databases. This occurred in four tumour subsets for Black patients (meningioma, glioblastoma, pituitary adenoma, and vestibular schwannoma) and two tumour subsets for patients of unknown race (vestibular schwannoma and pituitary adenoma).

Our study has several limitations that should be addressed with future investigations. This study is limited by the variables available in the SEER and NCDB databases, which include limited patient-specific socioeconomic data as some of these factors are reported on a county or area-code level. The reporting of race and ethnicity to SEER and NCDB vary on a hospital-by-hospital basis. Race is not clearly denoted as either self-identified or provider-identified. This might have played a part in the finding of increased odds of recommendation against surgery for patients of unknown race in many of the tumours studied. Clinically, patient comorbidities that guide decisions to offer surgery are not available in SEER, although the CCI was available in NCDB. Unlike SEER, NCDB is hospital-based and thus only includes patients treated at facilities accredited by the Commission on Cancer, which might lead to under-representing or over-representing certain geographic areas. There is the potential for some patient overlap between the two databases since they are collected from distinct sources, as addressed in our follow-up analysis. Furthermore, many of the CNS tumours are more recently diagnosed based on molecular or cytogenetic profiles that are not reported in either database, which could increase heterogeneity within each diagnosis category.

Together, these results highlight concern for unrecognised bias in treatment recommendations using two large national databases. The SEER database is a representative, population-based cancer reporting system across the USA, which limits selection bias. The NCDB encompasses over 70% of all newly diagnosed cancers in the USA further enabling a robust examination of rare tumour types. We observed similar results in our independent analyses of these two large

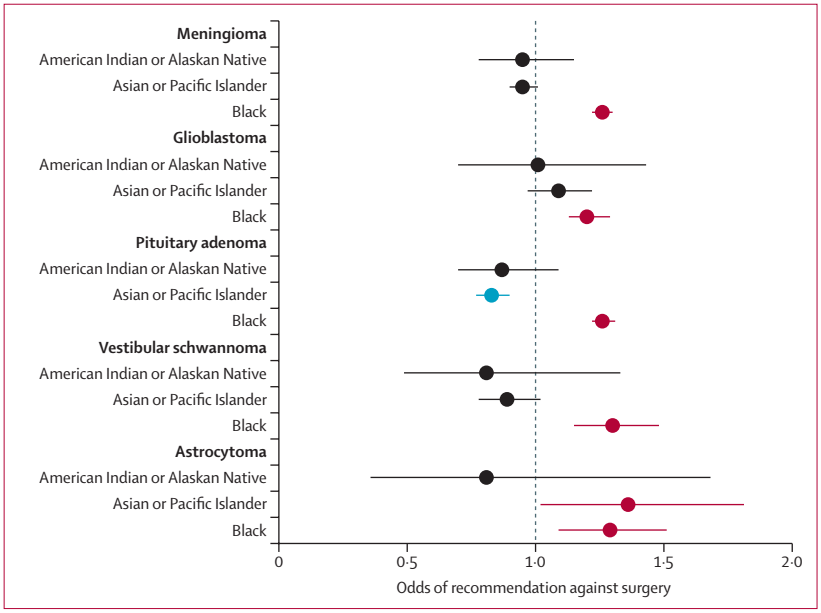

Figure 2: **Odds of recommendation against surgery compared with White patients in the National Cancer Database**

The adjusted odds of recommendation against surgical resection of brain tumours compared with White patients in the National Cancer Database following multivariable analysis that included clinical and demographic variables with the addition of a comorbidity index.

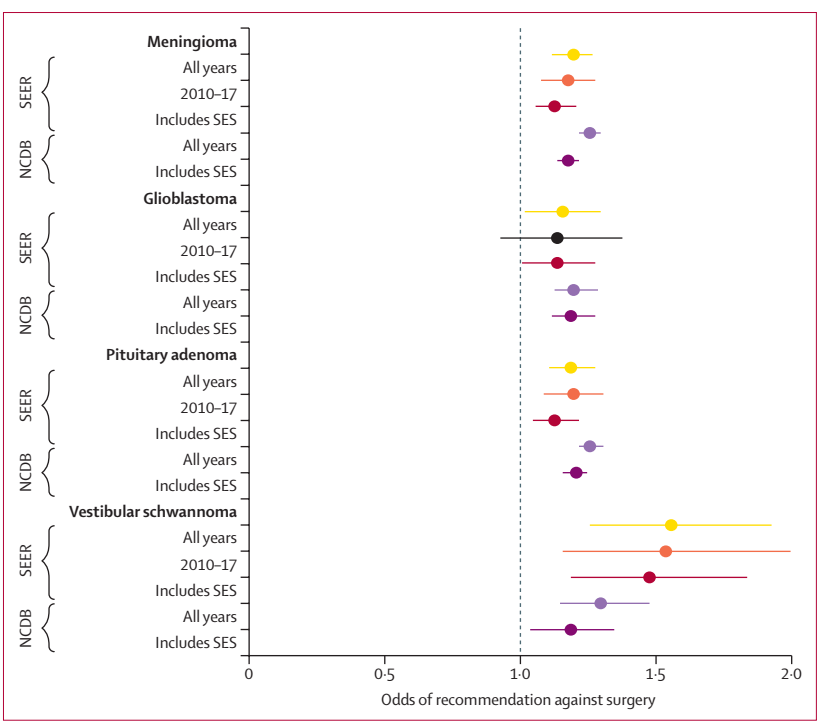

Figure 3: **Odds of recommendation against surgery for Black patients compared with White patients in the SEER and NCDB databases**

The adjusted odds of recommendation against surgical resection for Black patients compared with White patients following multivariable analysis including clinical and demographic variables, as well as markers of SES. Odds were reported for all years in the SEER database (1975–2017), for only the most recent decade (2010–17), and for all years with the inclusion of insurance status and rural–urban continuum code. Additionally, odds were reported for all years in the NCDB database (2004–17) with and without the inclusion of insurance status and rural–urban continuum code in the multivariable analysis. NCDB=National Cancer Database. SEER=Surveillance, Epidemiology, and End Results. SES=socioeconomic status.

national databases, adjusting for numerous potential confounders available within each dataset. These results provide compelling evidence that racial disparities in surgical recommendations for treatment of brain tumours are not specific to a particular neurosurgical disease, and that they are robust after adjusting for select socioeconomic, clinical, and demographic characteristics. Our observations support the concept that surgical management might be influenced by patient race, independent of socioeconomic background and insurance status.

In conclusion, through independent analyses of two large national databases, we found that Black patients were significantly more likely than White patients to receive a recommendation against surgical resection of glioblastoma, meningioma, pituitary adenoma, and vestibular schwannoma. These findings were independent of available clinical, demographic, and socioeconomic factors. This disparity did not hold for patients with the more uncommon diagnoses of oligodendroglioma and astrocytoma. These results provide a basis for future studies to gain further insight into unrecognised bias in the surgical management of neuro-oncological diseases. Crucial next steps include understanding sources for physician unconscious bias, determining the impact of such bias on patient outcomes, and identifying mechanisms to reduce bias.[25] A renewed effort to increase awareness and overcome potential biases is imperative to promote the highest-quality care to patients across all races.

Contributors

JTB, SD, ELM, and ASV were responsible for the concept and design of the study. JTB, EF, SG, and RJ acquired the data. JTB and ELM did the statistical analysis. JTB, CCC, ELM, and ASV drafted the manuscript. All authors contributed to the interpretation of the data and critical revision of the manuscript. JTB and ASV had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the analysis. All authors had the final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

For **SEER** see https://seer.cancer.gov

For **NCDB** see https://www.facs.org/quality-programs/cancer-programs/national-cancer-database/

All input data from the SEER and NCDB databases are available from their source databases. Model data and code are available on request to the corresponding author.

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