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Adult glioblastoma in England: Incidence, treatment, and outcomes with novel population-based strata

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ABSTRACT

Introduction: Malignant brain tumours are the leading cause of cancer death in the under 40's and they have the highest average-years of life lost. England has a long-running system for national cancer data collection. In this work we present data on incidence, treatment and survival in all adult glioblastoma patients in England diagnosed between 2013 and 2018.

Methods: GlioCova uses a linked pseudo-anonymised data set of all adult patients in England diagnosed with a primary brain tumour between 2013 and 2018. We identified all patients with a glioblastoma (GBM) based on ICD-10 diagnosis and tumour morphology.

Results: In the 6-year period of the study (2013–2018 inclusive), 15,181 patients were diagnosed with a GBM in England. The national age-standardised incidence was 4.98 adult glioblastoma patients per 100,000 per year, with men having a higher incidence than women (6.3 and 3.8 respectively). Overall, 79 % of patients received treatment (76 % female vs. 81 % male, $p = 0.22$), with younger patients more likely to be treated than older patients. Median overall survival was 16 months in those receiving aggressive treatment, but 7 months in the whole cohort. 21 % of patients received no treatment, and 17 % of patients underwent surgery or biopsy alone.

Conclusion: Age-adjusted incidence of GBM is stable, although absolute numbers are rising, and prognosis remains poor. Only 29 % of patients receive aggressive multi-modality treatment, and we suggest that taking a population-level approach to GBM reveals significant areas for improvement.

1. Introduction

Approximately 12,000 people are diagnosed every year with a primary brain tumour in the UK, and nearly 350 000 worldwide [1] with a significant increase in numbers over the last 30 years [2]. Although commoner in older patients [3], malignant brain tumours are the leading cause of cancer death in the under 40's and they have the highest average-years of life lost [4,5].

Glioblastoma (GBM) is the commonest malignant brain tumour in adults. Historically defined based on characteristic histological findings,

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the recent WHO classification includes both histological and molecular findings [6]. Even with aggressive multi-modality treatment (surgery, radiotherapy and chemotherapy) median survival is 15 months, with median progression-free survival of 4–6 months [7]. Initial therapy is maximal debulking surgery (where feasible), followed by concurrent chemo-radiotherapy and adjuvant chemotherapy, using Temozolomide. At relapse, treatment may include further surgery, but is most likely to consist of different chemotherapy, typically based around Lomustine (CCNU). Treatment choices are heavily dependent on patient fitness, and older patients may have shorter courses of chemo-radiotherapy, or single modality treatment [8]. Even in clinical trials, less than 60 % of patients receive treatment at relapse [7,9].

Little is known about patterns of care for GBM at a national level. Although there is data on incidence, detailed data on care and outcomes is generally restricted to single centres and the outcomes of clinical trials. Since clinical trial enrolment is low (<10 % of patients), there is very little work that takes a comprehensive view of a population-level approach to GBM. This has significant implications for assessing service need, variation in care and planning research.

The constituent nations of the United Kingdom each have slightly different cancer data arrangement. England has a long-running, robust system of national cancer data collection. It collects patient-level data monthly from English NHS providers, focusing on secondary care, and includes data on patient demographics, treatment (surgery, radiotherapy and chemotherapy), in-patient and outpatient care and imaging [10]. (See appendix Datasets used for details). Diagnoses are recorded using ICD-10, and procedures using OPCS [11,12]. Social deprivation is measured using the Indices of Multiple Deprivation (IMD) which integrate data income, employment, education, health, crime, barriers to housing and services, and living environment and are made available for groups of 1500 households [13]. There has been a recent move towards place-based care with the development of 'Integrated Care Systems' (ICS) which cover a population of 1.5–3.5 m patients.

The GlioCova project [14] brings together data, analysts, patients, carers, professionals and charities to understand the care of adult brain tumour patients in England. In this work we present data on incidence, treatment and survival in all adult glioblastoma patients in England diagnosed between 2013 and 2018. We report variation in care and outcomes between different patient groups, and report rates and patterns of treatment for relapsed disease and hospital admission.

2. Methods

GlioCova uses a linked pseudo-anonymised data set of all adult patients in England diagnosed with a primary brain tumour between 2013 and 2018 extracted on 10th August 2020, with mortality data (= survival) censored in October 2022. It contains data on more than 50,000 patients along with all the treatments, hospital appointments and admissions, demographics, diagnoses, patient experience and mortality data [15]. Work is guided by both an Expert Advisory Group (Appendix Expert Advisory group) and a patient & user group. The project has REC approval (REC reference: 16/YH/0213) and all analysis is conducted in a secure computing environment.

Patient cohort: We identified all patients with a glioblastoma (GBM) based on ICD-10 diagnosis and tumour morphology (Appendix Patient cohort for details). We excluded patients who had a diagnosis of more than one brain tumour diagnosed at different timepoints (multifocal disease was treated as a single diagnosis). We extracted, processed and analysed their treatments, admissions and mortality data.

Incidence: England has a comprehensive system of cancer and death registration. Thus, data on cancer incidence and survival are comprehensive, and represent a whole population cohort. For reference, the population of England during the years of the study was 54,988,465 (from 53,918,686 in 2013–55,924,528 in 2018) with age-sex distributions available [17]. We used standard techniques to calculate the crude incidence [18] and the annual European age standardised incidences rates per 100,000 population [19] for age-specific cohorts. We standardised against the 1976 reference population to allow comparison with previous work and against the 2013 reference population to give a more accurate assessment of age-standardised incidence. To calculate age-and ethnicity-specific incidence, we matched the adult population in England to the patient population in Gliocova using data and ethnic groups published by the Office for National Statistics (ONS) [17,16,20] (see Appendix Complementary tables). Patients with an unknown ethnicity were removed from the analyses of ethnicity-specific incidence. We measured deprivation using the IMD quintile. To calculate care across a notional ICS population, we assumed that an ICS had a population of 2 m, with a nationally representative age-sex distribution [21].

Selection of treatments: We identified OPCS codes that corresponded to brain or spine biopsy or surgery. We reviewed these with a multi-disciplinary group of 10 clinical staff and NHSD approved clinical coders from multiple centres in a two-stage modified Delphi process [22,23]. Codes were included if approved by at least 6 people, including one clinical coder. The final list of procedures included 101 codes to describe surgery and 87 for biopsy (Appendix Selection of appropriate major resection and biopsy Codes). For radiotherapy and chemotherapy treatments, we selected only patients who received a treatment for a brain or spinal tumour (Appendix Selection of appropriate radiotherapy treatments Codes) and excluded non-brain or spine tumour related treatments. We used HES data to examine inpatient admissions from a month before diagnosis. We removed stays of over 180 days, and where stays consisted of an admission, discharge and readmission within 2 days, we grouped as one stay.

Survival analyses: Survival was calculated by the Kaplan-Meier method and the p-values for the difference in group survival were calculated by the standard version of the multivariate log-rank tests. Survival is recorded as time to death from any cause and may not have occurred because of the cancer diagnosis.

Statistical analysis: We used the Chi-square test for difference in proportions and the *t*-test to compare the difference between two groups. A difference was considered statistically significant when the p-value was < 0.05, or when the 95 % confidence intervals did not overlap. Python version 3.10, SQLite3 version 3 and R version 4.2.1 were used to conduct the analyses [24–26].

2.1. Treatment pathways

We defined groups of treatments to make it easier to report types and sequences of treatments patients received post-diagnosis. We defined 'resection' as surgical debulking (not biopsy); 'surgery' as patients as having either resection or biopsy; 'radical radiotherapy' as any treatment of equal or more than 40 Gy; 'palliative radiotherapy' as any treatment of less than 40 Gy; 'chemo-radiotherapy' as having radical radiotherapy with concomitant chemotherapy or trial agent; 'adjuvant chemotherapy' as receiving chemotherapy or trial agent within 14–84 days post-radiotherapy; 'palliative chemotherapy' as having chemotherapy at least three months post-diagnosis with no intervening treatment. We defined patients receiving TMZ as those who had Temozolomide, at any dose or regimen; we defined those having CCNU-based chemotherapy as those having any chemotherapy that contained Lomustine.

We further grouped patients into four different strata: 'aggressive', 'intermediate', 'surgery only' and 'no treatment'. 'Aggressive' treatment was defined as first-line treatment with surgery followed by radical radiotherapy (within 90 days of surgery) and at least one cycle of chemotherapy. Within that, 'Maximal' treatment was defined as those who had aggressive treatment but specifically had resection rather than biopsy. 'Intermediate' treatment was any combination of surgery and radiotherapy or chemotherapy, either alone or together, that did not meet the definition for 'aggressive' treatment. 'Surgery only' was for patients who underwent surgery but no further treatment. We defined 'no treatment' as patients with a record of a brain tumour diagnosis in

the cancer registry, but with no record of having surgery, biopsy, radiotherapy or chemotherapy.

Defining new lines of treatment: We counted patients as receiving a new line of treatment when their chemotherapy drug changed (e.g., Temozolomide then CCNU-based chemotherapy) or when they received any new treatment at least 3 months after their last treatment (e.g. Starting chemotherapy 4 months after completing some previous treatment) and when they switched modality, except in the case of patients with first-line 'aggressive' treatment.

3. Results

In the 6-year period of the study (2013–2018 inclusive), 15,294 patients were diagnosed with a Glioblastoma (GBM) in England. We excluded 113 patients who had another diagnosis of brain tumours beside glioblastoma. Our final analytical cohort consisted of 15,181 patients. There were an average of 2530 new cases per year with a median (IQR) age of 66 years (56−73), and 60 % were male. (Appendix - Table 4). About half of the patients were from least deprived areas (Indices of Multiple Deprivation (IMD) quintiles 1 and 2), Appendix - Table 3, $p < 0.01$).

Incidence: The crude incidence was 5.85 per 100 000 per year. Adjusting for the age-sex distribution in the population using the 2013 population the national age-standardised incidence was 4.98, with men having a higher incidence than women (6.3 and 3.8 respectively). Age-specific standardised incidence showed an incidence peak for both men and women between 70 and 74 years old at 20.5 and 12.1 respectively. People from 'other' ethnic groups (i.e., Arab, Turkish groups and any other ethnic group) and from a 'white' ethnic group had the highest incidence (respectively 8.9 and 6.1), whereas people from mixed ethnic group and black ethnic group had an incidence of less than 2 (Appendix - Table 6). At an ICS level, we would expect each ICS to see 100 adult glioblastoma patients per year. Standardising against the 1976 age-sex population gave an age-sex standardised incidence of 3.67.(Fig. 1)

Diagnosis: Almost all GBM occurred in the brain, rather than the spine (Table 7). The most common sites in the brain were frontal, (28 %), temporal (26 %) and parietal lobes (16 %). Lesions in the cerebellum, brain stem, ventricle, and spinal cord each accounted for less than 1 % of patients (Appendix - Table 10). Most (77 %) patients had a histological diagnosis, with variation by age: 94 % for patients aged between 18 and 69, but less than 34 % for patients over 70. (Fig. 2).

3.1. Treatment patterns

Overall, 79 % of patients were treated (76 % female vs. 81 % male, $p = 0.22$), with younger patients more likely to be treated than older patients (>95 % of patients aged between 18 and 49 at diagnosis, versus <15 % of patients over 80). Most of the patients received a combination of surgery and radiotherapy whereas less than 50 patients had chemotherapy only. A thousand patients received both radiotherapy and SACT with no surgical intervention. Approximately 1400 patients underwent resection, and 1233 biopsy, with no further treatment (Fig. 3, Appendix - Table 9 and Table 11).

Of those treated, 11,383 patients (95 %) underwent surgery of whom 7065 patients (62 %) received radical radiotherapy within three months of surgery, and 4534 patients (40 %) were prescribed concomitant chemotherapy, almost all (4523) using Temozolomide or trial drug.

Overall, 4534 (30 %) patients were in the aggressive treatment stratum, of whom most (3751; 25 %) had maximal treatment. A further 4878 were in the intermediate treatment stratum, 2554 were in the surgery alone stratum, and 3197 were no treatment stratum.

Relapsed disease: 3417 patients received second-line treatment. Of those, most (65 %) had received aggressive first-line therapy. Of the 4534 patients receiving aggressive first-line therapy, 1342 had second-line chemotherapy, with 620 having a re-resection before starting second line chemotherapy (889 CCNU; 389 TMZ). 126 patients had re-irradiation as a second line treatment. Median time between starting first-line and second-line therapy was 8 months (IQR 8: 5–13). Median time between second- and third-line therapy was 3 months (IQR 5: 1–6).

3.2. Survival

Median survival was 7 months, and survival rates at 1, 2 and 5-year were 33 %, 13 % and 4 % respectively. There was no significant difference in survival between male and female ($p = 0.41$). However, survival was significantly worse in older patients: median survival was 19 months in those aged 20 – 44, 10 months in those aged 45–69 and 4 months in patients aged > 70 (Fig. 6, $p < 0.005$).

Treatment had a significant association with survival ($p < 0.005$) (Fig. 8). Patients in the aggressive treatment stratum had a median survival of 16 months (1-year OS: 65.8 %; 2-year OS: 27.8 %); those who had maximal had a median survival of 17 months (1-year OS: 69.8 %; 2-year OS: 30 %). Those in the intermediate therapy stratum had a median survival of 9 months and a 1-year OS of 35.9 % (Fig. 8). Those in the surgery alone (N = 2554) or no treatment (N = 3197) strata had a median survival of 2 months.

Patients in the aggressive treatment stratum had a median survival of 16 months with age at diagnosis having a significant impact on the survival ($p < 0.005$): Of those in the aggressive treatment stratum, patients aged between 25 and 29 at diagnosis living longer (median

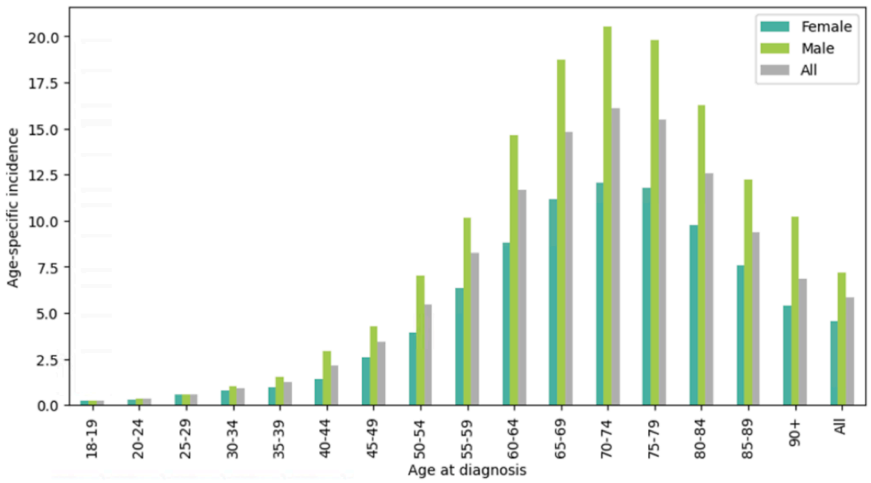

Fig. 1. Crude age-specific incidence by sex.

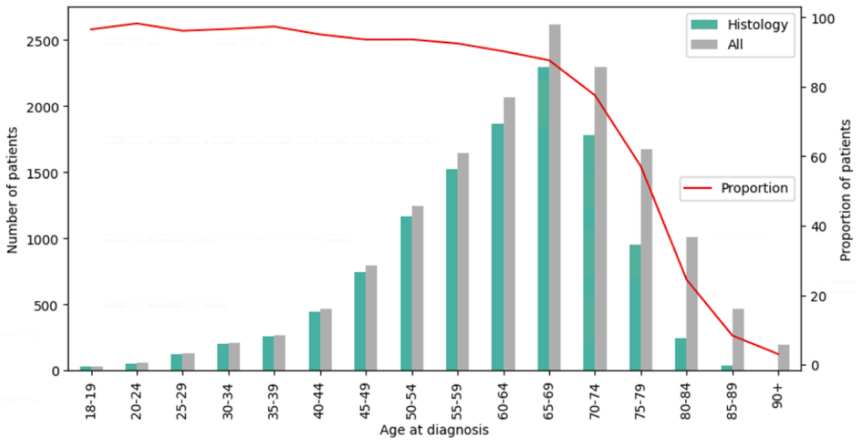

Fig. 2. Proportion and raw number of patients who had a histological confirmation of their diagnosis.

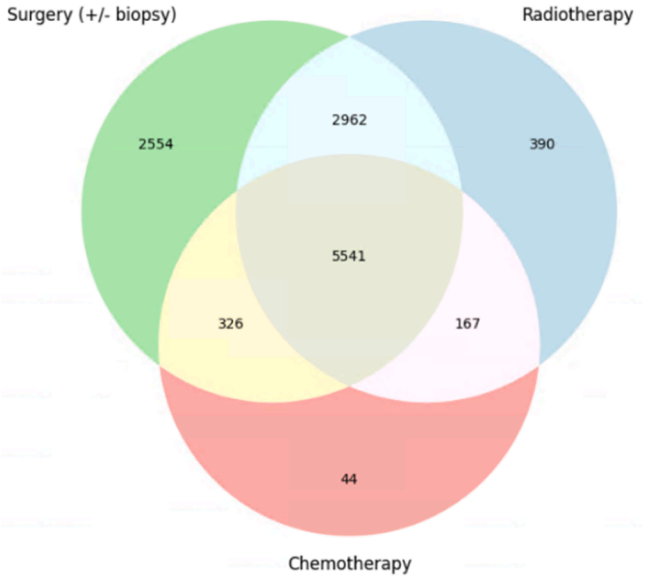

Fig. 3. Venn diagram of patients who received surgery, radiotherapy and/or chemotherapy at any time postdiagnosis.

survival: 42 months) than older patients. Patients between 35 and 49 lost approximately five months of survival every five years; patients over 60, one month every five years. There was no difference in survival between men and women in the aggressive treatment stratum (median survival of respectively 15 and 17 months).

3.3. Other care

Of the 15,181 patients, 14,799 were admitted at least once in the month before diagnosis for a total of 71,020 overnight inpatient admissions. Patients had a mean of 4.8 overnight inpatient-stays (Median = 3, IQR 3: 2–5), with a length of stay of 5.9 days (Median = 1, IQR 6: 0–6). Most patients were discharged home (N = 63,267 of admissions, 89 % of all admissions) and 3027 patients died while an in-patient (4.3 % of all admissions). 13 childbirths post-diagnosis were recorded (Appendix - Table 11). One childbirth happened in the same month of diagnosis; most patients gave birth within 29 months of diagnosis. [27]. Of the 15,181, 14,071 (93 %) had died at the time of the data extraction. Younger patients (<40 years old) were more likely to die in hospital or hospice whereas those aged over 40 were more likely to die at home or in a nursing home (Appendix - Table 14).

4. Discussion

4.1. Summary of findings

In this study, we have described a comprehensive cohort of patients

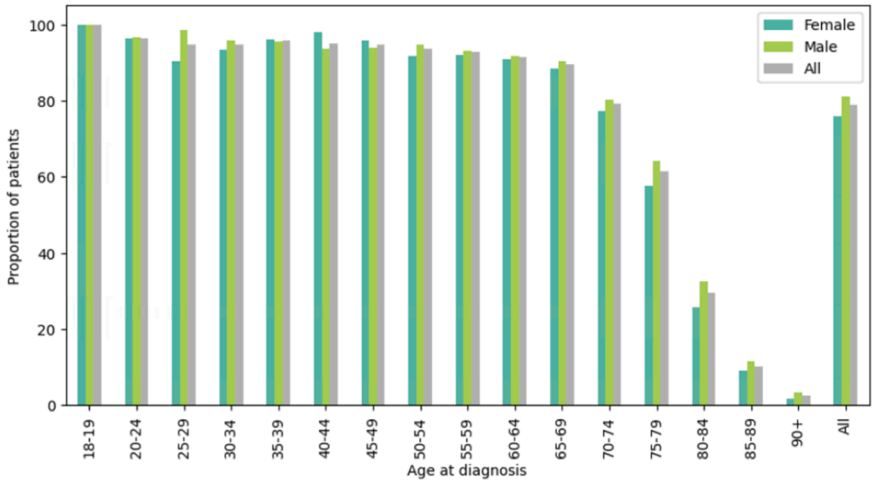

Fig. 4. Proportion of patients treated per age and sex (in %).

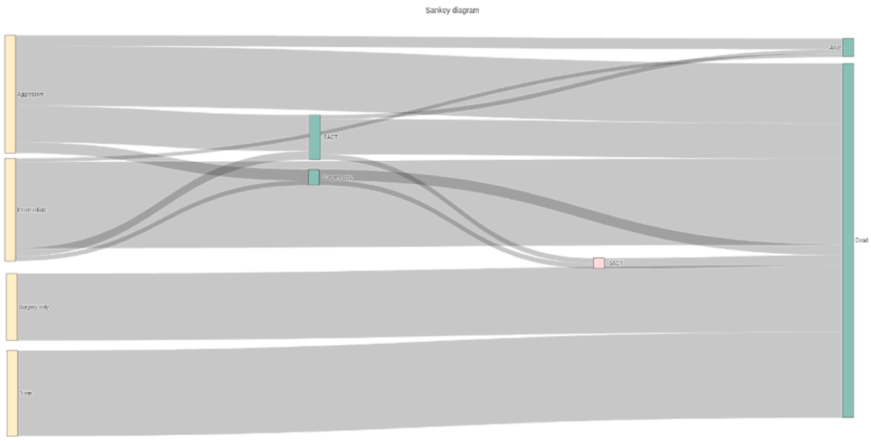

Fig. 5. Sankey diagram of the treatments received at first, second and third line of treatments.

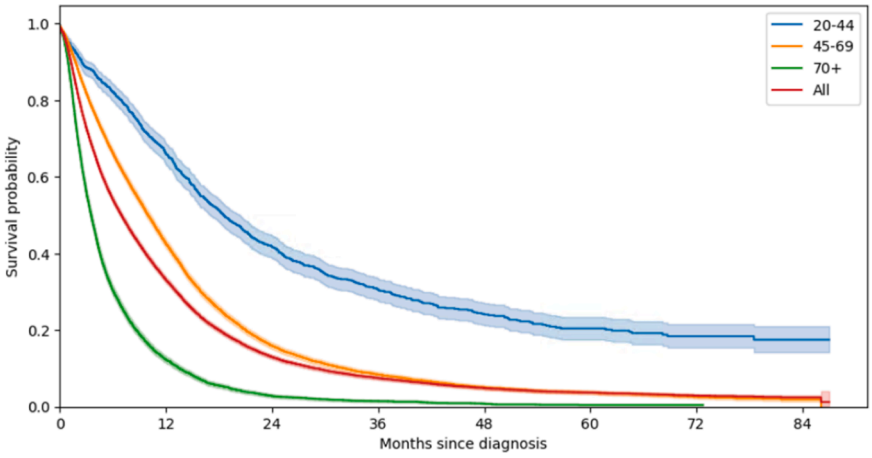

Fig. 6. Survival by age band with 95 % confidence limits calculated by the Brookmeyer-Crowley method using a complementary log-log transformation shown.

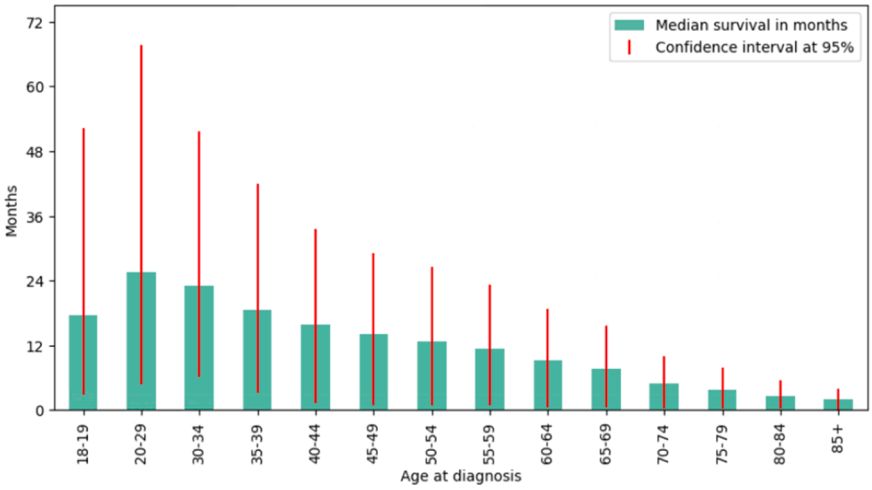

Fig. 7. Median life expectancy in months for patients with a GBM by age.

diagnosed with glioblastoma in England between 2013 and 2018. To the best of our knowledge, this is first work to do so. There are some key insights from the work: although the age-sex adjusted incidence is static, the absolute number of patients with GBM is rising as the population grows and becomes older. While 79 % of patients receive some treatment, a significant proportion of those (17 % of the total) have surgery or biopsy alone and have the same poor prognosis as the 21 % of patients who did not receive treatment. Less than a third of all patients were in the aggressive treatment stratum, and even in that group, less than a third of them receive treatment for relapsed disease. We have established clear reproducible definitions for treatments which should facilitate comparing data across countries. It represents a significant expansion and update of our previous work [28]. In comparison, other countries have limited biobanks for patients who have had surgery [29],

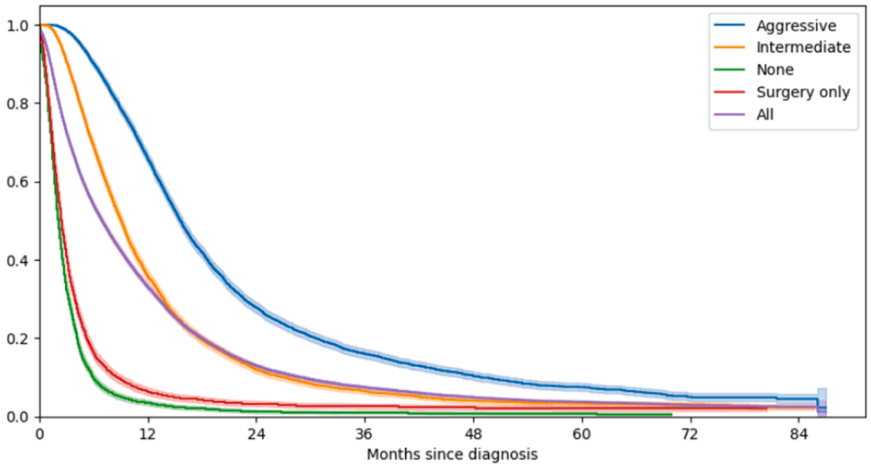

Fig. 8. Survival by the treatment(s) received.

or can report incidence data but little on treatment [30–33], or utilise a combination of five cancer registries covering a population of 25 million inhabitants in Nordic countries, which is less than half of the population in England [34,35]. This is therefore the largest comprehensive dataset currently available for analysis.

Our study offers a truly comprehensive national picture, with uniform coding and data capture; however, it has no data on quality of life, functional status or reasons for care. While our data only captures patients treated in NHS institutions, it includes those having both NHS and private treatment within NHS hospitals. While our data does not capture treatments delivered entirely in the private sector these numbers are likely to be small - reinforced by the fact that patients who are recorded as having 'no treatment' have a poor prognosis, and so are unlikely to be having significant treatment not captured in our data. Despite the time, and trials in the period since 2005, there have been very few significant advances in treatment for GBM. Median survival for those receiving aggressive therapy, who are most similar to those enrolled in clinical trials, is now 16 months, in line with more recent trial data [36,37]. While we were not able to manually review patients records, the cancer registration staff in England have a quality assurance process that includes manual review of imaging and reports. Therefore, while all summary national datasets represent a simplified view of reality, the English cancer registration data is likely to be as accurate as is possible.

The incidence is broadly similar to other studies shows broadly similar figures to other studies conducted in northern hemisphere countries. Specifically, the incidence rates per 100,000 per year were as follows: England: 4.98, Canada: 4.06 [30], Finland: 3.5 [31], France: 3.3 [29], Greece: 3.69 [32]. Comparison of variation in incidence between ethnic groups is complicated by differences in the ethnic group classifications used between North America and England [38,39]. Previous work on treatment and outcomes is limited, and uses slightly different populations: for example, the US work uses data from the National Cancer Database, which is pooled data from 1500 hospitals, and the German data excluded approximately 10 % of patients who had been diagnosed based on death certificate/ autopsy only, who would have been included our study. In other studies, the rates range between 5 % and 15 % for non-treatment and between 13 % and 15 % for surgery/biopsy only [33,40–42], which are lower than the observed rates in England. These are important caveats: sampling from secondary care, or excluding patient diagnosed only at autopsy tends to increase apparent treatment rates and survival. However, there is a suggestion that outcomes in England are worse than those in the US, Canada or Germany [39]. Half of all patients diagnosed with a GBM are from the wealthiest areas. This is in keeping with previous studies from outside the UK and is due to GBM being commoner in older patients, who tend to be wealthier [43–47]. Despite this study being based on historical data (2013–2018), there have been no significant changes in treatment since that time [9]. Of note, there was no difference in survival in those receiving aggressive treatment when analysed by sex, in contrast to smaller previous studies [37].

The major benefit of this work is that it offers a novel insight into population-based patterns of care and outcome. This is significant because much research focuses on improving outcomes in the 30 % of patients in the aggressive treatment stratum. While this group of patients provides an obvious basis for clinical trials, it ignores the 17 % in the surgery alone stratum, and the 21 % in the no treatment stratum. We would therefore suggest that our work allows us to think about three distinct strata who need different research approaches: the 30 % having aggressive treatment, where we continue to add therapies to existing standard of care; the 32 % having intermediate treatment, for whom we may want to look at either treatment intensification or treatment substitution, or shorter courses of treatment; and the 38 % who have either surgery and no other treatment or no treatment at all, in whom different approaches, such as earlier diagnosis, pre-habilitation, pre-surgical counselling and early involvement of palliative care may be more appropriate. We underscore the importance of taking a population-based approach by noting that if we doubled the survival of those in the aggressively treated group from 16 to 32 months, the survival of the entire population would only improve from 7 to 10 months. Given that a notional ICS only has an incidence of 100 new patients/ year, single-centre audits of treatment are unlikely to be a good guide as to population-based outcomes.

5. Conclusion

We have provided an updated analysis of our previous work from 2015 [28]. We show that the age-adjusted incidence of glioblastoma has remained stable, and the overall prognosis for the entire cohort remains poor. While patients receiving aggressive treatment have outcomes that match those seen in large trials, only a small proportion of patients actually receive such treatment, and improving outcomes in this group will have limited impact on survival in the population. A significant minority of patients are undergoing surgery alone, without outcomes comparable to patients who received no treatment, and we would question the value of that surgery. Future work will focus on exploring the variation in care in more detail, and the costs associated with that variation, as well as exploring a wider range of tumours.

CRediT authorship contribution statement

Vernon Sally: Writing – review & editing, Resources, Data curation. **Gregory Jonathan J:** Writing – review & editing, Validation, Resources,

Data curation. **Dumba Maureen:** Writing – review & editing, Data curation. **Oberg Ingela:** Writing – review & editing, Data curation. **Brodbelt Andrew:** Writing – review & editing, Validation, Resources, Data curation. **Pakzad-Shahabi Lillie:** Writing – review & editing, Data curation. **Price Stephen J:** Writing – review & editing, Validation, Resources, Data curation. **Williams Matt:** Writing – review & editing, Supervision, Project administration, Methodology, Data curation, Conceptualization. **Treasure Peter:** Writing – review & editing, Validation, Resources, Methodology, Data curation. **Booth Thomas C:** Writing – review & editing, Validation, Resources, Data curation. **Basharat Jawad:** Writing – review & editing, Data curation. **Le Calvez Kerlann:** Writing – original draft, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Dadhania Seema:** Writing – review & editing, Data curation. **Mauricaite Radvile:** Writing – review & editing, Investigation, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Datasets used

The National Disease Registration Service (NDRS), now part of NHS England and previously a part of Public Health England (PHE), collects patient data monthly from English NHS providers, focusing on secondary care (inpatient and outpatient admissions, and Accident and Emergency (A&E) visits are recorded in the Hospital Episode Statistics (HES) dataset; the anti-cancer treatments, in the Systemic Anti-Cancer Therapy (SACT) data set; all the radiotherapy treatments, in RadioTherapy DataSet (RTDS); and the imaging data, in the Diagnostic Imaging Dataset (DIDs)). Patient demographics and tumour details are captured in the National Cancer Registry.

Expert Advisory group (by alphabetical order)

1. Bloomfield, David
2. Booth, Thomas
3. Bottle, Alex
4. Brodbelt, Andrew
5. Bulbeck, Helen
6. Caldano, Micah
7. Camp, Sophie
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9. Dadhania, Seema
10. Dixon, Luke
11. Droney, Joanne
12. Dumba, Maureen
13. Fontana, Gianluca
14. Gregory, Jonathan
15. Huskens, Nicky
16. Jenkinson, David
17. Kurian, Kathreena
18. Le Calvez, Kerlann
19. Mauricaite, Radvile
20. Oberg, Ingela
21. Pakzad-Shahabi, Lillie
22. Price, Stephen
23. Robinson, Clare
24. Roques, Tom
25. Smith, Joel
26. Soni, Shivani
27. Thomas, Derek
28. Treasure, Peter
29. Vernon, Sally
30. Williams, Matthew

Codes used throughout the analyses
Patient cohort

Glioblastoma tumour was defined using the International Classification of Diseases 10th Revision diagnosis codes C70-C72, ICD-O-3 morphology codes 9440–9442 and WHO grades coded as G3, G4, GX, and field left blank. Glioblastoma patients coded with a grade 3, grade 'X' or with a field left blank had a similar survival to those with a grade 4 glioblastoma. We therefore assumed those patients had been miscoded as the data is historic and predates the new WHO recommendations.

Selection of appropriate radiotherapy treatments

In radiotherapy, only primary diagnoses starting by C70-C72 were selected along with a primary region treated ('P', 'R', 'PR') or with procedure codes for brain or spine recorded (i.e., Z01, Z06, Z07, Z66, Z67).

Selection of appropriate major resection and biopsy

Table 1
Selection of the OPCS codes to capture major resections

Code	Label
A012	Total lobectomy of brain
A013	Partial lobectomy of brain
A018	Other specified major excision of tissue of brain
A019	Unspecified major excision of tissue of brain
A021	Excision of lesion of tissue of frontal lobe of brain
A022	Excision of lesion of tissue of temporal lobe of brain
A023	Excision of lesion of tissue of parietal lobe of brain
A024	Excision of lesion of tissue of occipital lobe of brain
A025	Excision of lesion of tissue of cerebellum
A026	Excision of lesion of tissue of brain stem
A027	Excision of transcranial dermoid cyst
A028	Other specified excision of lesion of tissue of brain
A029	Unspecified excision of lesion of tissue of brain
A073	Exploration of tissue of brain
A078	Other specified other open operations on tissue of brain
A108	Other specified other operations on tissue of brain
A118	Other specified operations on tissue of brain
A168	Other specified other open operations on ventricle of brain
A171	Endoscopic extirpation of lesion of ventricle of brain
A208	Other specified other operations on ventricle of brain
A291	Excision of lesion of optic nerve (ii)
A293	Excision of lesion of trigeminal nerve (v)
A295	Excision of lesion of acoustic nerve (viii)
A298	Excision of lesion of specified cranial nerve NEC
A381	Extirpation of lesion of meninges of cortex of brain
A382	Extirpation of lesion of meninges of sphenoidal ridge of cranium
A383	Extirpation of lesion of meninges of subfrontal region of brain
A384	Extirpation of lesion of meninges of parasagittal region of brain
A385	Extirpation of lesion of falx cerebri
A386	Extirpation of lesion of tentorium cerebelli
A388	Other specified extirpation of lesion of meninges of brain
A389	Unspecified extirpation of lesion of meninges of brain
A428	Other specified other operations on meninges of brain
A431	Extirpation of lesion of meninges of skull base
A432	Extirpation of lesion of meninges of skull clivus
A438	Other specified other extirpation of lesion of meninges of brain
A442	Extirpation of lesion of spinal cord NEC
A443	Excision of lesion of intradural intramedullary spinal cord
A444	Excision of lesion of extradural spinal cord
A445	Excision of lesion of intradural extramedullary spinal cord
A448	Other specified partial extirpation of spinal cord
A449	Unspecified partial extirpation of spinal cord
A511	Extirpation of lesion of meninges of spinal cord
A518	Other specified other operations on meninges of spinal cord
A571	Extirpation of lesion of spinal nerve root
A599	Unspecified excision of peripheral nerve
A611	Excision of lesion of peripheral nerve
B012	Trans-sphenoidal hypophysectomy
B068	Other specified operations on pineal gland
C021	Excision of lesion of orbit
E158	Other specified operations on sphenoid sinus
T962	Excision of lesion of soft tissue NEC
V031	Exploratory open craniotomy
V038	Other specified opening of cranium
V039	Unspecified opening of cranium
V051	Extirpation of lesion of cranium
V058	Other specified other operations on cranium
V431	Excision of lesion of cervical vertebra
V433	Excision of lesion of lumbar vertebra
V498	Other specified exploration of spine
V499	Unspecified exploration of spine
Y059	Unspecified excision of organ NOC

(*continued on next page*)

Table 1 (*continued*)

Code	Label
Y068	Other specified excision of lesion of organ NOC
Y069	Unspecified excision of lesion of organ NOC
Y461	Trans-sphenoidal open approach to contents of cranium
Y463	Transoral open approach to contents of cranium
Y464	Transmastoid open approach to contents of cranium
Y465	Supratentorial open approach to contents of cranium
Y467	Craniectomy approach to contents of cranium
Y468	Other specified open approach to contents of cranium
Y469	Unspecified open approach to contents of cranium
Y470	Trans-cranial approach to contents of cranium
Y471	Trans-sphenoidal burrhole approach to contents of cranium
Y472	Frontal burrhole approach to contents of cranium
Y473	Transoral burrhole approach to contents of cranium
Y474	Transmastoid burrhole approach to contents of cranium
Y475	Supratentorial burrhole approach to contents of cranium
Y476	Infratentorial burrhole approach to contents of cranium
Y478	Other specified burrhole approach to contents of cranium
Y479	Unspecified burrhole approach to contents of cranium
Y698	Other specified harvest of other tissue

Table 2
Selection of the OPCS codes to capture biopsies

Code	Label
A041	Open biopsy of lesion of tissue of frontal lobe of brain
A042	Open biopsy of lesion of tissue of temporal lobe of brain
A043	Open biopsy of lesion of tissue of parietal lobe of brain
A044	Open biopsy of lesion of tissue of occipital lobe of brain
A081	Biopsy of lesion of tissue of frontal lobe of brain NEC
A082	Biopsy of lesion of tissue of temporal lobe of brain NEC
A083	Biopsy of lesion of tissue of parietal lobe of brain NEC
A084	Biopsy of lesion of tissue of occipital lobe of brain NEC
A085	Biopsy of lesion of tissue of cerebellum NEC
A086	Biopsy of lesion of tissue of brain stem NEC
A088	Other specified other biopsy of lesion of tissue of brain
A089	Unspecified other biopsy of lesion of tissue of brain
A104	Aspiration of lesion of tissue of brain NEC
A105	Puncture of tissue of brain NEC
A181	Diagnostic endoscopic examination of ventricle of brain and biopsy of lesion of ventricle of brain
A188	Other specified diagnostic endoscopic examination of ventricle of brain
A363	Biopsy of lesion of cranial nerve
A422	Biopsy of lesion of meninges of brain
A454	Open biopsy of lesion of spinal cord
A456	Open aspiration of lesion of spinal cord
A481	Biopsy of lesion of spinal cord NEC
A482	Aspiration of lesion of spinal cord
A513	Biopsy of lesion of meninges of spinal cord
A578	Other specified operations on spinal nerve root
A731	Biopsy of lesion of peripheral nerve
B042	Biopsy of lesion of pituitary gland
T968	Other specified other operations on soft tissue
V036	Exploratory burrhole of cranium
V052	Biopsy of lesion of cranium
Y201	Stereotactic biopsy of lesion of organ NOC
Y202	Stereotactic biopsy of organ NOC
Y208	Other specified biopsy of organ NOC
Y462	Frontal open approach to contents of cranium
Y466	Infratentorial open approach to contents of cranium
Y471	Trans-sphenoidal burrhole approach to contents of cranium
Y472	Frontal burrhole approach to contents of cranium
Y473	Transoral burrhole approach to contents of cranium
Y474	Transmastoid burrhole approach to contents of cranium
Y475	Supratentorial burrhole approach to contents of cranium
Y476	Infratentorial burrhole approach to contents of cranium
Y478	Other specified burrhole approach to contents of cranium
Y479	Unspecified burrhole approach to contents of cranium
Y698	Other specified harvest of other tissue

Complementary tables

Table 3
Number and proportion of patients diagnosed with a glioblastoma per their Indices of Multiple Deprivation (IMD) quintile

IMD quintile	Number of patients	Proportion
1 - least deprived	3724	24.5 %
2	3562	23.5 %
3	3043	20.0 %
4	2617	17.2 %
5 - most deprived	2235	14.7 %

Table 4
Number of cases per year and sex

	2013	2014	2015	2016	2017	2018	Total	Mean
Female	971	922	1019	1022	1075	1034	6043	1007
Male	1534	1408	1504	1566	1610	1516	9138	1523
Total	**2505**	**2330**	**2523**	**2588**	**2685**	**2550**	**15181**	**2530**

Table 5
Breakdown of the ethnicity recorded in Gliocova versus the ONS classification

ONS classification	Ethnicity recorded in Gliocova	Number of patients
White	WHITE	2
White	WHITE BRITISH	13085
White	WHITE IRISH	92
White	WHITE GYPSY IRISH TRAVELLER	0
White	WHITE OTHER WHITE	0
White	ANY OTHER WHITE BACKGROUND	560
Mixed / Multiple ethnic groups	MIXED WHITE AND BLACK CARIBBEAN	12
Mixed / Multiple ethnic groups	MIXED WHITE AND BLACK AFRICAN	5
Mixed / Multiple ethnic groups	MIXED WHITE AND Asian	9
Mixed / Multiple ethnic groups	MIXED OTHER MIXED	0
Mixed / Multiple ethnic groups	ANY OTHER MIXED BACKGROUND	27
Asian / Asian British	Asian INDIAN	199
Asian / Asian British	Asian PAKISTANI	90
Asian / Asian British	Asian BANGLADESHI	21
Asian / Asian British	Asian CHINESE	0
Asian / Asian British	CHINESE	15
Asian / Asian British	ANY OTHER Asian BACKGROUND	95
Asian / Asian British	Asian OTHER Asian	0
Black / African / Caribbean / Black British	BLACK AFRICAN	55
Black / African / Caribbean / Black British	BLACK CARIBBEAN	74
Black / African / Caribbean / Black British	BLACK OTHER BLACK	0
Black / African / Caribbean / Black British	ANY OTHER BLACK BACKGROUND	32
Other ethnic group	OTHER ARAB	0
Other ethnic group	ANY OTHER ETHNIC GROUP	234
Other ethnic group	TURKISH	0
Excluded	(blank)	192
Excluded	NOT KNOWN	79
Excluded	NOT STATED	303

Table 6
Incidence of glioblastoma per ethnicity ("Other ethnic group" captures Arab, Turkish groups and any other ethnic group)

Ethnicity	Specific incidence (mean)
Asian / Asian British	2.13
Black / African / Caribbean / Black British	1.88
Mixed / Multiple ethnic groups	1.20
Other ethnic group	8.88
White	6.13
All	**5.63**

Table 7
Breakdown of number of patients as per their diagnosis and sex

ICD-10 code diagnosis	Female	Male	All
C71: Malignant neoplasm of brain	6036	9129	15165
C72: Malignant neoplasm of spinal cord, cranial nerves and other parts of central nervous system	7	9	16
All	**6043**	**9138**	**15181**

Table 8
Number and proportion of patients who had a histological confirmation of their diagnosis

Age	Histology	Total	Proportion
18–19	28	29	97 %
20–24	56	57	98 %
25–29	124	129	96 %
30–34	203	210	97 %
35–39	257	264	97 %
40–44	444	467	95 %
45–49	747	798	94 %
50–54	1164	1243	94 %
55–59	1523	1647	92 %
60–64	1868	2070	90 %
65–69	2296	2620	88 %
70–74	1783	2299	78 %
75–79	955	1672	57 %
80–84	248	1013	24 %
85–89	39	466	8 %
90 +	6	197	3 %
All	11741	15181	77 %

Table 9
Proportion of patients treated per age and sex (in %)

Age at diagnosis	Female	Male	All
18–19	100	100	100
20–24	96.3	96.7	96.5
25–29	90.5	98.5	94.6
30–34	93.5	95.7	94.8
35–39	96.2	95.6	95.8
40–44	98	93.7	95.1
45–49	95.8	93.9	94.6
50–54	91.8	94.7	93.6
55–59	92.1	93	92.7
60–64	90.8	91.7	91.4
65–69	88.5	90.3	89.6
70–74	77.3	80.3	79.2
75–79	57.6	64.1	61.4
80–84	25.7	32.5	29.5
85–89	9	11.6	10.3
90 +	1.8	3.4	2.5
All	**75.9**	**81**	**78.9**

Table 10
Distribution of the tumour location

Tumour location	Number of patients	Percentage (%)
Frontal lobe	4286	28
Temporal lobe	3982	26
Brain	2688	18
Parietal lobe	2435	16
Cerebrum	896	6
Occipital lobe	664	4
Cerebellum	102	1
Brain stem	59	0
Ventricle	53	0
Spinal cord	13	0
Optic nerve	2	0
Cranial nerve	1	0

Table 11
Pairwise combination of treatments

Combination of two treatments	None	Major resection	Biopsy	Radiotherapy
None	3197	-	-	-
Major resection	1370	-	-	-
Biopsy	1233	0	-	-
Radiotherapy	390	1974	1040	-
Chemotherapy	44	223	114	1099

Table 12
Description of patients' age at the time of the labour, when they were admitted, and how long they stayed in the hospital

Statistics	Age at the childbirth	Time of admission post-diagnosis (in months)	Length of stay (in days)
Count	13	13	13
Mean	31	26.4	13.2
Standard deviation	5.7	19.4	22.5
Minimum	22	0	1
First quartile	27	8	1
Median	32	29	4
Third quartile	35	42	6
Maximum	40	58	79

Table 13
Breakdown of the location of death of patients who died, per sex at diagnosis

Location of death	Female	Male	Total
Private Home	37.6 %	36.9 %	37.1 %
Hospital	21.3 %	25.4 %	23.8 %
Hospice NOS	15.8 %	16.6 %	16.2 %
Unknown	12.7 %	10.5 %	11.4 %
Nursing Home	9.0 %	7.4 %	8.0 %
Other	3.7 %	3.2 %	3.4 %

Table 14
Breakdown of the location of death of patients who died, per age at diagnosis

Age band	Private Home	Hospital	Hospice NOS	Unknown	Nursing Home	Other
18–19	20.0 %	45.0 %	25.0 %	5.0 %	0.0 %	5.0 %
20–24	41.9 %	35.5 %	12.9 %	6.5 %	0.0 %	3.2 %
25–29	26.7 %	32.0 %	29.3 %	12.0 %	0.0 %	0.0 %
30–34	28.8 %	30.9 %	21.6 %	14.4 %	1.4 %	2.9 %
35–39	27.7 %	33.5 %	25.7 %	9.4 %	2.1 %	1.6 %
40–44	33.2 %	25.8 %	26.4 %	9.2 %	3.5 %	1.9 %
45–49	32.0 %	26.1 %	26.5 %	9.9 %	3.7 %	1.7 %
50–54	38.3 %	24.6 %	20.4 %	9.3 %	4.6 %	2.9 %
55–59	39.8 %	24.0 %	19.1 %	8.9 %	5.6 %	2.6 %
60–64	39.5 %	23.7 %	17.7 %	10.7 %	5.8 %	2.7 %
65–69	39.5 %	23.2 %	15.8 %	10.7 %	7.7 %	3.1 %
70–74	39.1 %	22.3 %	13.7 %	11.2 %	9.6 %	4.1 %
75–79	36.8 %	23.9 %	11.8 %	12.3 %	10.6 %	4.6 %
80–84	33.5 %	22.6 %	10.1 %	16.6 %	12.4 %	4.9 %
85–89	28.0 %	21.5 %	7.7 %	16.6 %	20.2 %	6.0 %
90 +	23.9 %	20.8 %	6.6 %	20.8 %	21.3 %	6.6 %
Total	**37.1 %**	**23.8 %**	**16.2 %**	**11.4 %**	**8.0 %**	**3.4 %**

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