Descriptive epidemiology of ependymal tumours in the United States

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Background: Ependymomas are rare primary gliomas that commonly affect both children and adults, but unique as survival is worse in children.

Methods: Data on brain and central nervous system primary malignant and non-malignant ependymal tumours from the Central Brain Tumor Registry of the United States analytic data set and primary malignant ependymal tumours from the SEER 13 registries research data file were used to evaluate incidence and survival, respectively.

Results: The 2004–2009 average annual age-adjusted incidence rate of ependymal tumours was 0.41/100 000. Spinal cord/cauda equina was the primary site at diagnosis for 50–60% of ependymal tumours in adult age groups in contrast to about 20% in children and adolescents. Ependymoma was the most frequent histology in all age groups; however, anaplastic ependymoma comprised about 30% in cases 0–19 years of age compared with about 3–5% in adult age groups. Overall, relative survival was favourable with rates at ~85% and 75% at 3 and 10 years post diagnosis, respectively. However, children and adolescents, the oldest adult age group, cases diagnosed with anaplastic ependymoma and/or tumour location in a brain site had lowest survival rates.

Conclusion: Paediatric cases had worse outcomes compared with adults for numerous reasons including having a higher percentage of anaplastic ependymomas and greater percentage of cases of intracranial disease.

Ependymal tumours are neuroectodermal tumours that although rare have a significant impact on the quality of life and mortality (Thuppal et al, 2006). These tumours are derived from ependymal cells that line cerebrospinal fluid (CSF)-filled ventricles, spinal canal and filum terminale (Del Bigio, 1995). A type of neuroglia, ependymal cells are essential for CSF production and have a cuboidal, multi-ciliated morphology (Brody et al, 2000). In murine studies, ependymal cells are derived from radial glial prenatally with continued differentiation and maturation of cilia during early postnatal period (Spassky et al, 2005; Taylor et al, 2005).

Ependymal tumours range in WHO grade classification from I–III (Louis, 2007). WHO grade I tumours include myxopapillary ependymoma and subependymomas. Myxopapillary ependymomas are almost exclusively located in the lower portion of the spinal cord/cauda equina, while subependymomas are often found in the ventricular wall (Scheithauer, 1978; Sonneland et al, 1985). WHO grade II tumours grouped as ‘ependymoma’ include cellular ependymoma, clear cell ependymoma, tanyctic ependymoma and papillary ependymoma. Anaplastic ependymomas are classified as WHO grade III and are commonly intracranial while WHO grade II ependymomas are found mostly in the upper spinal cord and/or are intracranial (Mork and Loken, 1977; Marks and Adler, 1982; Guyotat et al, 2002). Ependymal tumours exhibit either malignant or borderline malignant behaviour.

The goal of our study is to further characterise ependymal tumours with insights from incidence and survival data derived from population-based cancer registries in the United States.

MATERIALS AND METHODS

The study evaluated population-based registry data on cases diagnosed with ependymal tumours defined as histology codes...
9383, 9391–9394 in the brain or the central nervous system (CNS) primary sites C70.0–C72.9, C75.1–C75.3 (International Classification of Diseases for Oncology Third Edition (ICD-O-3)) (Fritz and World Health Organization, 2000). The data source for incidence was the Central Brain Tumor Registry of the United States (CBTRUS) analytic file, 1995–2009. Survival estimates were made using the SEER 13 registries research file for 1992–2009 (SEER, 2011a).

The CBTRUS analytic file consists of population-based incidence data on all primary brain and CNS tumours collected by 49 central cancer registries (Dolecek et al, 2012). Analyses were conducted using 2004–2009 data allowing the evaluation of both malignant and non-malignant ependymal tumours, given that the Benign Brain Tumor Cancer Registries Amendment Act (Public Law 107–260) was implemented in 2004. Long-term trends were assessed on a subset with primary malignant ependymal tumours for diagnosis years 1995–2009. The CBTRUS 1995–2009 analytic file captures incidence occurring over 97% of the US population.

For the estimation of survival rates, all primary malignant ependymal tumours in brain or CNS primary sites from the SEER 13 registries research file, April 2012, were evaluated for cases diagnosed from 1992 through 2009 (SEER, 2011b). The SEER 13 registries represent ~14% of the US population.

Ependymal tumour groups were defined in accordance with the WHO Classification of Tumours of the Central Nervous Systems (Louis, 2007). Categorical classifications by ICD-O-3 histology/behaviour codes include: ependymoma (9391/3 cellular ependymoma, clear cell ependymoma and tanycytic ependymoma, and 9393/3 papillary ependymoma); anaplastic ependymomas (9392/3); myxopapillary (9394/1) and subependymomas (9383/1).

Demographic characteristics evaluated were gender; race (white; black; American Indian/Alaska Native; Asian; or Pacific Islander), ethnicity (Hispanic; non-Hispanic) and selected age groups. Age groups were based on accepted groupings, for example, 0–19 for children and adolescents, and arbitrary within adults to facilitate analysis. Tumour histology, primary site and behaviour (malignant and borderline malignant) patterns were assessed.

Frequencies, incidence rates, rate trends and relative survival rates were estimated using SEER*Stat 8.0.2 software (2011). Institutional Review Board approval was obtained under expedited review for research using the CBTRUS analytic file.

### RESULTS

Population-based incidence statistics for all primary ependymal tumours are presented in Table 1 and Supplementary Tables 1–3. A total of 7303 primary malignant ependymomas (4683 malignant and 2620 borderline malignant) were identified with an average annual

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**Table 1. Primary brain and CNS ependymal tumour incidence statistics for selected characteristics, CBTRUS analytic file, 2004–2009**

| Category                      | Count | %b | Rate | s.e. | m:b | % Tumours | Rate | s.e. | m:b | % Tumours |
|-------------------------------|-------|----|------|------|-----|-----------|------|------|-----|-----------|
| **Total**                     | 7303  | 100.0 | 0.41 | 0.005 | 1.80 | 2.0 |       |      |     |           |
| **Gender**                    |       |      |      |      |     |         |      |      |     |           |
| Male                          | 4022  | 55.1 | 0.46 | 0.007 | 1.47 | 2.6 |       |      |     |           |
| Female                        | 3281  | 44.9 | 0.37 | 0.006 | 2.35 | 1.6 |       |      |     |           |
| **Race group**                |       |      |      |      |     |         |      |      |     |           |
| White                         | 6357  | 87.0 | 0.44 | 0.006 | 1.72 | 2.1 |       |      |     |           |
| Black                         | 556   | 7.6  | 0.25 | 0.011 | 2.71 | 1.5 |       |      |     |           |
| AIAN                          | 49    | 0.7  | 0.06 | 0.038 | 1.58 | 2.5 |       |      |     |           |
| API                           | 174   | 2.4  | 0.20 | 0.016 | 3.07 | 1.8 |       |      |     |           |
| **Ethnicity**                 |       |      |      |      |     |         |      |      |     |           |
| Hispanic                      | 850   | 11.6 | 0.34 | 0.013 | 2.49 | 2.4 |       |      |     |           |
| Non-Hispanic                  | 6453  | 88.4 | 0.43 | 0.005 | 1.72 | 1.9 |       |      |     |           |
| **Age group (years)**         |       |      |      |      |     |         |      |      |     |           |
| 0–19                          | 1345  | 18.4 | 0.28 | 0.008 | 5.58 | 5.4 |       |      |     |           |
| 20–44                         | 2473  | 33.9 | 0.41 | 0.008 | 1.42 | 3.5 |       |      |     |           |
| 45–64                         | 2569  | 35.2 | 0.59 | 0.012 | 1.49 | 2.0 |       |      |     |           |
| 65+                           | 916   | 12.5 | 0.42 | 0.014 | 1.52 | 0.6 |       |      |     |           |
| **Behaviour**                 |       |      |      |      |     |         |      |      |     |           |
| Malignant                     | 4683  | 64.1 | 0.27 | 0.004 | NA   | 3.6 |       |      |     |           |
| Borderline malignant          | 2620  | 35.9 | 0.15 | 0.003 | NA   | 1.1 |       |      |     |           |
| **Histology**                 |       |      |      |      |     |         |      |      |     |           |
| Ependymoma                    | 3968  | 54.3 | 0.22 | 0.004 | NA   | NA |       |      |     |           |
| Anaplastic ependymoma         | 684   | 9.4  | 0.04 | 0.002 | NA   | NA |       |      |     |           |
| Myxopapillary ependymoma      | 1677  | 23.0 | 0.10 | 0.002 | NA   | NA |       |      |     |           |
| Subependymoma                 | 943   | 12.9 | 0.05 | 0.002 | NA   | NA |       |      |     |           |
| **Primary site**              |       |      |      |      |     |         |      |      |     |           |
| Spinal cord/cauda equina      | 3806  | 52.1 | 0.22 | 0.003 | 1.25 | 33.6 |       |      |     |           |
| Brain                         | 3381  | 46.3 | 0.19 | 0.003 | 2.78 | 2.4 |       |      |     |           |
| Brain stem                    | 980   | 13.4 | 0.06 | 0.002 | 2.64 | 16.6 |       |      |     |           |
| Brain lobes                   | 538   | 7.4  | 0.03 | 0.001 | 8.64 | 0.7 |       |      |     |           |
| Brain, NOS                    | 671   | 9.2  | 0.04 | 0.001 | 5.40 | 1.8 |       |      |     |           |
| Ventricles                    | 863   | 11.8 | 0.05 | 0.002 | 0.99 | 20.0 |       |      |     |           |
| Cerebellum                    | 265   | 3.6  | 0.02 | 0.001 | 9.31 | 2.6 |       |      |     |           |
| Other brain/CNS sites         | 116   | 1.6  | 0.01 | 0.001 | 2.77 | 0.1 |       |      |     |           |

Abbreviations: AIAN = American Indian/Alaska Native; API = Asian or Pacific Islander; CBTRUS = Central Brain Tumor Registry of the United States; CNS = central nervous system; NA = not applicable; NOS = not otherwise specified.

aPercent ependymal tumours of all malignant and non-malignant brain and CNS tumours, CBTRUS, 2004–2009.
bPercent total cases.
cRates are per 100 000 and age-adjusted to the 2000 US standard population.
dm:b malignant to borderline malignant rate ratio.
eMalignant rate is statistically significantly different from the borderline malignant rate (P<0.05).
age-adjusted rate (AAR) of 0.41 per 100,000 (0.27, malignant and 0.15, borderline malignant). Rates were higher in males than in females, whites than in other race groups and non-Hispanics compared with Hispanics. Among age groups, the highest rates were observed in age group 45–64 years. Most notable is the incidence rate ratio (IRR) of more than five times malignant to borderline malignant tumours for child/adolescent ages 0–19 years compared with an observed IRR of about 1.5 in adult age groups.

Ependymoma had the highest count and AAR followed by myxopapillary ependymoma, subependymoma and anaplastic ependymoma. Myxopapillary ependymoma represented approximately two-thirds and subependymoma the remaining third of borderline malignant tumours, while about 85% and 15% of malignant tumours were ependymoma and anaplastic ependymoma, respectively.

About half of all ependymal tumours were diagnosed in the spinal cord/cauda equina and the remaining half in the brain and other nervous system sites. However, the proportional primary site distribution for borderline malignant ependymal tumours was 64% spinal cord/cauda equina and 35% combined brain sites (Supplementary Table 1).

Site and histology patterns differed by age at diagnosis as shown in Figure 1. Whereas 50%–60% of ependymal tumours in adult ages were located in the spinal cord/cauda equine, only about 20% were found in the spinal cord/cauda equine primary site for children/adolescents. As shown in Supplementary Figure 1, the proportions of ependymal tumours diagnosed in the brain sites for the age group 0–19 years substantially exceeded those observed for adult age groups with the exception of ventricle. Among adult age groups, ventricle and cerebellum were the brain sites where

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### Table 2. Relative survival rates* of primary malignant brain and CNS ependymal tumours for selected characteristics, SEER 13 registries research data, 1992–2009*

|                  | N  | %  | s.e. | %  | s.e. | %  | s.e. | %  | s.e. |
|------------------|----|----|------|----|------|----|------|----|------|
| **Gender**       |    |    |      |    |      |    |      |    |      |
| Male             | 805| 92.7| 0.97 | 83.5| 1.46 | 79.4| 1.68 | 72.3| 2.08 |
| Female           | 717| 94.1| 0.92 | 86.1| 1.44 | 82.6| 1.67 | 78.9| 2.04 |
| **Race group**   |    |    |      |    |      |    |      |    |      |
| White            | 1260| 93.7| 0.72 | 85.1| 1.12 | 81.6| 1.28 | 76.1| 1.58 |
| Black            | 127 | 92.4| 2.49 | 80.5| 3.90 | 72.7| 4.60 | 68.9| 5.47 |
| AIAN             | ~   | ~   | ~    | ~   | ~    | ~   | ~    | ~   | ~    |
| API              | 110 | 88.7| 3.14 | 83.5| 3.83 | 81.1| 4.16 | 72.5| 5.80 |
| **Ethnicity**    |    |    |      |    |      |    |      |    |      |
| Hispanic         | 268 | 92.1| 1.72 | 82.7| 2.58 | 78.6| 2.97 | 71.4| 3.60 |
| Non-Hispanic     | 1254| 93.6| 0.73 | 85.1| 1.12 | 81.4| 1.29 | 76.3| 1.61 |
| **Age group (years)** | | |      |    |      |    |      |    |      |
| 0–19             | 429 | 91.9| 1.34 | 77.9| 2.12 | 71.0| 2.39 | 62.5| 2.76 |
| 20–44            | 502 | 95.2| 0.98 | 91.4| 1.35 | 89.8| 1.51 | 86.5| 1.89 |
| 45–64            | 454 | 94.0| 1.19 | 87.8| 1.76 | 83.7| 2.15 | 81.8| 2.50 |
| 65+              | 137 | 87.6| 3.11 | 72.2| 4.75 | 70.6| 5.00 | 53.2| 7.46 |
| **Histology**    |    |    |      |    |      |    |      |    |      |
| Ependymoma       | 1312| 93.9| 0.70 | 88.0| 1.01 | 84.7| 1.19 | 79.3| 1.54 |
| Anaplastic ependymoma | 210 | 89.3| 2.22 | 63.5| 3.68 | 55.5| 3.96 | 50.4| 4.28 |
| **Primary site** |    |    |      |    |      |    |      |    |      |
| Spinal cord/cauda equina | 660 | 98.5| 0.58 | 96.1| 1.01 | 94.3| 1.32 | 91.0| 1.92 |
| Brain            | 845 | 89.1| 1.11 | 76.0| 1.58 | 70.7| 1.75 | 63.6| 2.05 |
| Brain stem       | 277 | 91.5| 1.73 | 81.5| 2.53 | 76.1| 2.96 | 65.1| 3.73 |
| Brain lobes      | 165 | 92.7| 2.13 | 76.3| 3.58 | 67.5| 4.09 | 60.3| 4.64 |
| Brain, NOS       | 165 | 86.8| 2.69 | 75.3| 3.59 | 70.0| 3.91 | 64.7| 4.38 |
| Ventricle        | 134 | 85.4| 3.11 | 69.7| 4.24 | 68.9| 4.28 | 63.8| 5.06 |
| Cerebellum       | 86  | 89.5| 3.40 | 75.4| 4.94 | 69.5| 5.50 | 65.6| 6.18 |
| Other brain/CNS sites | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

*The cohort analysis of survival rates was utilised for calculating the survival estimates presented in this table. Long-term cohort-based survival estimates reflect the survival experience of individuals diagnosed over the time period, and they may not necessarily reflect the long-term survival outlook of newly diagnosed cases.

**Estimated using SEER Program (www.seer.cancer.gov) (SEER, 2011a).

**Rates are an estimate of the percentage of patients alive at 1, 2, 3 and 10 year, respectively. ~ Rates were not presented for categories with 50 or less cases and were suppressed for rates where <16 cases were surviving within a category.
proportional increases were observed with increasing age. The brain lobes site showed progressively lower proportions of cases with advancing age group.

The distribution by histology also differed by children/adolescent and adult age groups. While ependymoma was the most frequent histology in all age groups, anaplastic ependymoma was about six times more frequent in children and adolescents than adults, while the reverse pattern was apparent for subependymomas and myxoepipapillary ependymomas. For adult age groups, the proportional distribution pattern for subependymoma increased with advancing age, whereas decreases with age were observed for myxoepipapillary ependymoma.

Ependymal tumours exhibit a bimodal age distribution showing a peak in the 0–4 year age group declining through the early adolescent years and then rising to a second peak in the 55–59 year age group with the oldest age groups. Supplementary Figure 2 graphically shows the bimodal age distribution.

Supplementary Table 3 shows findings from the analysis of malignant ependymal tumour incidence for CBTRUS, 1995–2009. Trend analyses showed primary malignant ependymal tumour incidence rates to increase and in most instances significantly for most categories in gender, race, age, histology and primary site groups.

Relative survival estimates were made for a total of 1522 malignant ependymal tumour cases reported to the 13 SEER registries during 1992–2009 (Table 2). Overall, relative survival was ~93%, 85%, 80% and 75% at 1, 3, 5 and 10 years post diagnosis, respectively. Poorer relative survival was observed for the youngest and oldest age groups, cases diagnosed with anaplastic ependymoma and/or tumours located in the brain sites. Additional relative survival estimate comparisons are graphically presented in Supplementary Figures 3–5.

**DISCUSSION**

Our comprehensive evaluation reaffirms findings from previous studies (Rodriguez et al, 2009; McGuire et al, 2009a,b; Amirian et al, 2012; Bishop et al, 2012; Crocetti et al, 2012; Dolecek et al, 2012). Outcomes were generally favourable except for age groups 0–19 years and 65+ years, anaplastic ependymomas and tumour location in the brain site.

Children are more often diagnosed with anaplastic ependymomas and with tumours located in the brain sites. Furthermore, when the diagnosis is WHO grade II ependymoma, children fare worse than adults in the 20–44 and 45–64 year age groups. This is uncommon as most cancers of the same type and grade have improved outcomes in children compared with adults (Dolecek et al, 2012). Potential explanations include: (1) paediatric and adult cases having different biologically based tumours with gain of chromosome 1q and the absence of chromosomal imbalances as a marker for more aggressive disease (Korshunov et al, 2010; Wani et al, 2012), (2) although morphologically similar systematic bias by pathologists to report a better tumour grade/histology in paediatric cases, which has been demonstrated for classification of oligodendrogliomas (McCarthy et al, 2008); (3) differences in treatment, such as less radiation use in children (Koshy et al, 2011); and (4) differences in tumour biology based on location–genetic testing demonstrate subsets of ependymomas exhibit distinct patterns of chromosomal mutations and gene expression based on anatomical site (Spassky et al, 2005; Taylor et al, 2005).

The poorer relative survival for elderly cases may, in part, be explained by the fact that proportionately more diagnoses occurred in the brain sites among elderly than younger adult age groups (Supplementary Tables 2b, c and d). Our study has limitations, including the lack of detailed clinical data that may impact survival which, if available, could also shed light on this observation.

Insights from population-based incidence and survival analyses afford an opportunity to better understand the impact of site and histology patterns on outcomes associated with ependymal tumours and inform future research.

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