Incidence of first primary central nervous system tumors in California, 2001–2005: children, adolescents and teens

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Abstract This study used data from the California Cancer Registry to comprehensively examine first primary central nervous system tumors (PCNST) by the International Classification of Childhood Cancers (ICCC) diagnostic groups and to compare their incidence by age groups, sex, race/ethnicity, socioeconomic status and tumor behavior. The study period, 2001–2005, represents the first 5 years of benign PCNST data collection in the state. The age-adjusted incidence rates were 2.1 for malignant and 1.3 for benign per 100,000. Children younger than 5 years old had the highest incidence of malignant PCNST (2.6 per 100,000). Teens aged 15–19 had the highest incidence of benign PCNST (1.8 per 100,000). Age-specific incidence rates were nearly the same for Hispanics, non-Hispanic whites, and Asian/Pacific Islanders for malignant PCNST among children younger than 5 (2.6–2.7 per 100,000); non-Hispanic whites had the highest rates in the 5–14 year-old age group (2.5 per 100,000) and Asian/Pacific Islanders the highest among the 15–19 year old age group (2.3 per 100,000). We found no statistically significant differences in the incidence of malignant PCNST by race/ethnicity in any age group. Astrocytoma had the highest incidence for both malignant and benign histology in most age groups.

Keywords Brain and other central nervous system neoplasms · Epidemiology · Cancer incidence · Childhood cancers · Ethnic groups

Introduction

Primary tumors of the central nervous system (PCNST) among children, adolescents, and teens differ from those in adults in frequency, histological appearance, and clinical behavior [1]. PCNST are the second most common form of cancer among children aged 15 years and younger and the third most common among those 15–19 years old in California. While PCNST represent only 1.3% of incident cancers among adults 20 years and older, they represent from 26.4% (5–9 year olds) to 9.5% (15–19 year olds) of incident cancers among persons younger than 20 years old [2]. PCNST are the second leading cause of cancer deaths among children younger than 15 years old; they cause 32% (5–9 year olds) and 12.1% (15–19 year olds) of cancer deaths in children compared to 3% of cancer deaths for adults 20 years and older [2]. PCNST among children, adolescents, and teens tend to have short latent periods, often grow rapidly, and are aggressively invasive [1]. PCNST are a significant public health problem, they have a far more devastating effect on society,
communities and considering the potential years of productive life lost [3].

This study examined the incidence of malignant and benign first PCNST among children, adolescents, and teens using the population-based California Cancer Registry (CCR) from 2001 to 2005. This population is a subset of the population described in the authors’ companion publication in this edition. Since 1988, California state law mandates the reporting of all newly diagnosed malignant cancers in California [4]. An amendment to this law enacted January 2001 provides for the additional reporting of benign and borderline behavior PCNST [5]. The 2001–2005 study period represents the first 5 years of complete PCNST data collection in California. The CCR provides a robust source of epidemiologic data for a densely populous geographic area. California can be viewed as a microcosm of United States reflecting the influence of its racial, ethnic and sociodemographic diversity on overall cancer incidence. Although pediatric PCNST incidence has been relatively well studied, this is the first study to comprehensively examine PCNST incidence by patient demographics and tumor behavior among children, adolescents and teens according to the International Classification of Childhood Cancers (ICCC).

### Materials and methods

Materials and methods, including case identification, inclusion/exclusion criteria and tumor behavior assignment used in this study were identical to those described in the authors’ companion publication in this edition. For these analyses, we divided cases into 4 age groups. Patients younger than 5 and patients 5–9 years old are referred to as children, those aged 10–14 years as adolescents, and those 15–19 years old as teens. Diagnostic groups were organized using the Surveillance, Epidemiology and End Results (SEER) Program’s site/histology modification to the ICCC [6, 7]. Table 1 lists ICCC diagnostic groups by

| Diagnostic groups | ICD-O-3 code(s) | Morphology | Topography |
|-------------------|----------------|------------|------------|
| IIIA Ependymomas & choroid plexus tumor | 9383, 9390–9394, 9390 | 9383, 9390–9394, 9390 | C000–C809 |
| IIIB Astrocytomas | 9380 | 9380 | C723 |
| IIIC1 Medulloblastomas | 9470–9472, 9474, 9480 | 9470–9472, 9474, 9480 | C000–C809 |
| IIIC2 Primitive neuroectodermal tumors (PNET) | 9473 | 9473 | C000–C809 |
| IIIC9 Other intracranial & intraspinal embryonal tumors | 9501–9503, 9508 | 9501–9503, 9508 | C700–C729, C000–C809 |
| IID Other gliomas | 9380 | 9380 | C700–C722, C724–C729, C751, C753 |
| IIE Other specified intracranial & intraspinal neoplasms | 8270–8281, 8300, 9350–9352, 9360–9362, 9412, 9413, 9492, 9493, 9505–9507, 9530–9537, 9537–9539 | 8270–8281, 8300, 9350–9352, 9360–9362, 9412, 9413, 9492, 9493, 9505–9507, 9530–9537, 9537–9539 | C000–C809 |
| XA Intracranial & intraspinal germ cell tumors | 9060, 9064, 9065, 9070–9072, 9080–9085, 9100 | 9060, 9064, 9065, 9070–9072, 9080–9085, 9100 | C700–C729, C751–C753 |
| Z Other | 8000–8005, 9370, 9501–9503 | 8000–8005, 9370, 9501–9503 | C000–C809 |

**SEER** Surveillance, Epidemiology and End Results

**ICCC** International Classification of Childhood Cancers, 3rd edition

**ICD** International Classification of Diseases, Oncology, 3rd edition
Results

There were 2,096 cases of PCNST among children, adolescents, and teens (from birth to 19 years old) in California from 2001 to 2005. Of those cases, 1,114 (53.1%) were malignant, 698 (33.3%) were benign, and 284 (13.6%) were of uncertain behavior. The resultant AAIR per 100,000 was 2.1 (CI: 2.0–2.2) for malignant, 1.3 (CI: 1.2–1.4) for benign, and 0.5 (CI: 0.5–0.6) for tumors of uncertain behavior.

As seen in Table 2, there was an increase in the proportion of cases by year for tumors of uncertain behavior for adolescents and teens, whereas the proportion of cases among the two groups of children, for both malignant and benign PCNST, appears to be stable over the study period. The ASIR for malignant PCNST decreased as age increased, starting from 2.6 per 100,000 among those younger than 5 years to 1.7 per 100,000 among 15 to 19-year olds. To compare with other studies, we calculated the AAIR per 100,000 for children and adolescents to be 2.2 for malignant and 1.2 for benign PCNST. The ASIR for benign PCNST fluctuated by age groups, ranging from 1.8 to 1.1 per 100,000. The incidence of tumors of uncertain behavior was very low. The pattern seen for malignant PCNST by age group was opposite that for tumors of uncertain behavior. Incident rates increased slightly as age group increased.

The highest incidence of PCNST was for malignant tumors in children and adolescents (Fig. 1). This pattern changed for teens, where incidence of benign PCNST was similar to that of malignant PCNST. The lowest incidence, at every age group, was for tumors of uncertain behavior. The ASIR for boys for malignant and uncertain behavior PCNST were higher than that for girls at all age groups. Incidence rates for girls with benign PCNST were higher than that for boys until adolescence, where they appeared

### Table 2: Number of cases, percent and age-specific incidence rate* (ASIR) of first primary central nervous system tumors by age group, tumor behavior and year of diagnosis, California, 2001–2005

| Age group | Behavior | 2001 |  | 2002 |  | 2003 |  | 2004 |  | 2005 |  | Total |  | ASIR 95% CI |
|-----------|----------|------|---|------|---|------|---|------|---|------|---|-------|---|-------------|
|           |          | n    |% | n    |% | n    |% | n    |% | n    |% |       |   |             |
| <5 years  | Malignant| 65   | 19.2 | 73 | 21.5 | 67 | 19.8 | 58 | 17.1 | 76 | 22.4 | 339 | 100.0 | 2.6 (2.4, 2.9) |
|           | Benign   | 34   | 22.1 | 29 | 18.8 | 34 | 22.1 | 33 | 21.4 | 24 | 15.6 | 154 | 100.0 | 1.2 (1.0, 1.4) |
|           | Uncertain| 11   | 20.4 | 14 | 25.9 | 7 | 13.0 | 11 | 20.4 | 11 | 20.4 | 54 | 100.0 | 0.4 (0.3, 0.5) |
|           | Total    | 110  | 20.1 | 116 | 21.2 | 108 | 19.7 | 102 | 18.6 | 111 | 20.3 | 547 | 100.0 | 4.2 (3.9, 4.6) |
| 5–9 years | Malignant| 70   | 23.6 | 59 | 19.9 | 61 | 20.5 | 53 | 17.8 | 54 | 18.2 | 297 | 100.0 | 2.3 (2.0, 2.5) |
|           | Benign   | 28   | 18.9 | 30 | 20.3 | 37 | 25.0 | 30 | 20.3 | 23 | 15.5 | 148 | 100.0 | 1.1 (1.0, 1.3) |
|           | Uncertain| 7    | 10.8 | 13 | 20.0 | 15 | 23.1 | 14 | 21.5 | 16 | 24.6 | 65 | 100.0 | 0.5 (0.4, 0.6) |
|           | Total    | 105  | 20.6 | 102 | 20.0 | 113 | 22.2 | 97 | 19.0 | 93 | 18.2 | 510 | 100.0 | 3.9 (3.6, 4.3) |
| 10–14 years | Malignant| 49   | 19.2 | 60 | 23.5 | 46 | 18.0 | 53 | 20.8 | 47 | 18.4 | 255 | 100.0 | 1.9 (1.6, 2.1) |
|           | Benign   | 23   | 14.4 | 34 | 21.3 | 33 | 20.6 | 29 | 18.1 | 41 | 25.6 | 160 | 100.0 | 1.2 (1.0, 1.4) |
|           | Uncertain| 15   | 19.7 | 11 | 14.5 | 14 | 18.4 | 12 | 15.8 | 24 | 31.6 | 76 | 100.0 | 0.6 (0.4, 0.7) |
|           | Total    | 87   | 17.7 | 105 | 21.4 | 93 | 18.9 | 94 | 19.1 | 112 | 22.8 | 491 | 100.0 | 3.6 (3.3, 3.9) |
| 15–19 years | Malignant| 37   | 16.6 | 45 | 20.2 | 34 | 15.2 | 60 | 26.9 | 47 | 21.1 | 223 | 100.0 | 1.7 (1.5, 2.0) |
|           | Benign   | 41   | 17.4 | 46 | 19.5 | 45 | 19.1 | 50 | 21.2 | 54 | 22.9 | 236 | 100.0 | 1.8 (1.6, 2.1) |
|           | Uncertain| 14   | 15.7 | 17 | 19.1 | 18 | 20.2 | 20 | 22.5 | 20 | 22.5 | 89 | 100.0 | 0.7 (0.6, 0.8) |
|           | Total    | 92   | 16.8 | 108 | 19.7 | 97 | 17.7 | 130 | 23.7 | 121 | 22.1 | 548 | 100.0 | 4.2 (3.9, 4.6) |

* Age-specific incidence rates are per 100,000 population. Rates are standardized to the 2000 US population.
to be same; later ASIRs increased among teen girls, where they exceed the malignant PCNST rate in boys. Adolescents showed the widest sex-specific gulf for malignant PCNST. The ASIR among girls starts to decline dramatically from 5 to 14 years old; incidence rates for boys declined as well but not as dramatically. When PCNST incidence rates were compared by age group, sex, and tumor behavior, we found that there were no significant

Table 3 Number of cases and percent of first primary central nervous system tumors, by age group, population demographic characteristics and tumor behavior, California, 2001–2005

| Demographic Characteristics | Malignant | Benign | Uncertain | Total |
|-----------------------------|----------|--------|-----------|-------|
|                             | n   | %    | n   | %    | n   | %    | n   | %    |
| **< 5 years** | | | | | | | | |
| Sex                         |       | | | | | | | |
| Male                        | 193 | 56.9 | 72 | 46.8 | 30 | 55.6 | 295 | 53.9 |
| Female                      | 146 | 43.1 | 82 | 53.2 | 24 | 44.4 | 252 | 46.1 |
| Race/ethnicity              |       | | | | | | | |
| Non-Hispanic white          | 108 | 31.9 | 62 | 40.3 | 23 | 42.6 | 193 | 35.3 |
| Non-Hispanic black          | 21  | 6.2  | 8  | 5.2  | 7  | 13.2 | 32  | 5.9  |
| Hispanic                    | 168 | 49.6 | 69 | 44.8 | 25 | 46.3 | 222 | 41.9 |
| Asian-Pacific Islander      | 37  | 10.9 | 11 | 7.1  | 6  | 11.1 | 54  | 9.1  |
| Other/Unknown               | 5   | 1.5  | 1  | 0.6  | 0  | 0.0  | 6   | 1.1  |
| Socioeconomic Status        |       | | | | | | | |
| Low                         | 147 | 43.4 | 72 | 46.8 | 27 | 50.0 | 246 | 45.0 |
| Medium                      | 62  | 18.3 | 29 | 18.8 | 12 | 22.2 | 103 | 18.8 |
| High                        | 130 | 38.3 | 53 | 34.4 | 15 | 27.8 | 198 | 36.2 |
| Level of Urbanization       |       | | | | | | | |
| Urban                       | 325 | 95.9 | 144 | 93.5 | 50 | 92.6 | 519 | 94.9 |
| Rural                       | 14  | 4.1  | 10 | 6.5  |      |      | 24  | 5.1  |
| Total                       | 339 | 154  | 54 | 547  | | |       |
| **5-9 years**               | | | | | | | | |
| Sex                         |       | | | | | | | |
| Male                        | 155 | 52.2 | 68 | 45.9 | 39 | 60.0 | 262 | 51.4 |
| Female                      | 142 | 47.8 | 80 | 54.1 | 26 | 40.0 | 248 | 48.6 |
| Race/ethnicity              |       | | | | | | | |
| Non-Hispanic white          | 113 | 38.0 | 74 | 50.0 | 25 | 38.5 | 212 | 41.6 |
| Non-Hispanic black          | 17  | 5.7  | 9  | 6.1  | 7  | 11.7 | 28  | 5.5  |
| Hispanic                    | 138 | 46.5 | 55 | 37.2 | 30 | 46.2 | 223 | 43.7 |
| Asian-Pacific Islander      | 24  | 8.1  | 8  | 5.4  | 8  | 12.3 | 40  | 7.8  |
| Other/Unknown               | 5   | 1.7  | 0  | 0.0  | 0  | 0.0  | 5   | 1.3  |
| Socioeconomic Status        |       | | | | | | | |
| Low                         | 134 | 45.1 | 52 | 35.1 | 31 | 47.7 | 217 | 42.5 |
| Medium                      | 53  | 17.8 | 34 | 23.0 | 11 | 16.9 | 98  | 19.2 |
| High                        | 110 | 37.0 | 62 | 41.9 | 23 | 35.4 | 195 | 38.2 |
| Level of Urbanization       |       | | | | | | | |
| Urban                       | 283 | 95.3 | 138 | 93.2 | 61 | 93.8 | 482 | 94.5 |
| Rural                       | 14  | 4.7  | 10 | 6.8  |      |      | 24  | 5.5  |
| Total                       | 297 | 148  | 65 | 510  | | |       |
| **10-14 years**             | | | | | | | | |
| Sex                         |       | | | | | | | |
| Male                        | 154 | 60.4 | 82 | 51.3 | 43 | 66.6 | 279 | 56.8 |
| Female                      | 101 | 39.6 | 78 | 48.7 | 33 | 33.4 | 212 | 43.2 |
| Race/ethnicity              |       | | | | | | | |
| Non-Hispanic white          | 113 | 44.3 | 78 | 48.8 | 33 | 43.4 | 224 | 45.6 |
| Non-Hispanic black          | 10  | 3.9  | 10 | 6.3  | 8  | 10.5 | 28  | 5.7  |
| Hispanic                    | 104 | 40.8 | 61 | 38.1 | 31 | 40.8 | 196 | 39.9 |
| Asian-Pacific Islander      | 27  | 10.6 | 6  | 3.8  | 6  | 9.2  | 39  | 7.7  |
| Other/Unknown               | 5   | 1.7  | 0  | 0.0  | 0  | 0.0  | 5   | 1.2  |
| Socioeconomic Status        |       | | | | | | | |
| Low                         | 104 | 40.8 | 58 | 36.3 | 37 | 48.7 | 199 | 40.5 |
| Medium                      | 42  | 16.5 | 35 | 21.9 | 10 | 13.2 | 87  | 17.7 |
| High                        | 109 | 42.7 | 67 | 41.9 | 29 | 38.2 | 205 | 41.8 |
| Level of Urbanization       |       | | | | | | | |
| Urban                       | 243 | 95.3 | 151 | 94.4 | 69 | 90.8 | 462 | 94.3 |
| Rural                       | 12  | 4.7  | 9  | 5.6  | 7  | 9.2  | 28  | 5.7  |
| Total                       | 255 | 160  | 76 | 491  | | |       |
| **15-19 years**             | | | | | | | | |
| Sex                         |       | | | | | | | |
| Male                        | 138 | 61.9 | 101 | 42.8 | 52 | 58.4 | 291 | 53.1 |
| Female                      | 85  | 38.1 | 135 | 57.2 | 37 | 41.6 | 257 | 46.9 |
| Race/ethnicity              |       | | | | | | | |
| Non-Hispanic white          | 102 | 45.7 | 105 | 44.5 | 40 | 44.9 | 247 | 45.1 |
| Non-Hispanic black          | 12  | 5.4  | 9  | 3.8  | 7  | 7.9  | 28  | 5.1  |
| Hispanic                    | 73  | 32.7 | 103 | 43.6 | 36 | 40.4 | 212 | 38.7 |
| Asian-Pacific Islander      | 35  | 15.7 | 17 | 7.2  | 5  | 6.6  | 57  | 10.4 |
| Other/Unknown               |      |      |    |      |    |      |      |      |
| Socioeconomic Status        |       | | | | | | | |
| Low                         | 85  | 38.1 | 105 | 44.5 | 32 | 36.0 | 222 | 40.5 |
| Medium                      | 42  | 18.8 | 49 | 20.8 | 16 | 18.0 | 107 | 19.5 |
| High                        | 96  | 43.0 | 82 | 34.7 | 41 | 46.1 | 219 | 40.0 |
| Level of Urbanization       |       | | | | | | | |
| Urban                       | 207 | 92.8 | 223 | 94.5 | 81 | 91.0 | 511 | 93.2 |
| Rural                       | 16  | 7.2  | 13 | 5.5  | 8  | 9.0  | 37  | 6.8  |
| Total                       | 223 | 236  | 89 | 548  | | |       |

Shaded cells categories with less than 5 cases were omitted
differences except among adolescents. The ASIR for malignant PCNST for adolescent boys was 2.2 (CI: 1.9–2.6) and for adolescent girls was 1.5 (CI: 1.2–1.8). Malignant PCNST incidence among teen boys and girls was 2.1 (CI: 1.7–2.5) and 1.4 (CI: 1.1–1.7), respectively. Benign PCNST among teen boys and girls was 1.5 (CI: 1.2–1.8) and 2.2 (CI: 1.8–2.6), respectively.

Table 3 shows the study population by age groups, demographic characteristics, and tumor behavior. For nearly all age groups, boys were more often diagnosed with malignant PCNST and tumors of uncertain behavior; girls, proportionally, had more benign PCNST. The exception was for adolescents, where boys were proportionally diagnosed more often with benign PCNST.

Hispanic children, younger than 5, had proportionally more PCNST. Non-Hispanic white adolescents and teens had proportionally more PCNST. In the 5–9 age group, Hispanic children had more malignant and uncertain behavior PCNST while non-Hispanic white children had more benign PCNST.

Among children younger than 5, more cases were from lower socioeconomic status (SES) regardless of tumor behavior. For children 5–9, more cases of malignant and uncertain PCNST were in low SES, while benign cases were from high SES. For adolescents and teens, all cases of malignant PCNST were from high SES. For adolescents, more benign cases were from high SES while uncertain cases were from low SES. For teens, the opposite was seen—more uncertain cases were from high SES while more benign cases were from low SES. Lastly, overwhelmingly, more cases, regardless of tumor behavior were from urban areas of California than from rural.

Incidence rates were calculated for race/ethnic groups by tumor behavior in Table 4. For many subgroups by age, race/ethnicity, or tumor behavior, incidence rates could not be calculated due to the small number of cases. Where incidence rates could be calculated and compared, we found no statistically significant differences by race/ethnicity for any age group by tumor behavior. Incidence rates for all tumor behaviors were highest in non-Hispanic white children aged 5–9 years and in adolescents with the exception of malignant tumors, which were highest in Asian/Pacific Islander children younger than 5 and teens.

At every age group, astrocytomas (IIIB), ependymomas, and choroid plexus (IIIA) predominated (Table 5). For both malignant and benign PCNST, at nearly every age group, astrocytoma had the highest incidence. Among children younger than 5 years old, the primary malignant diagnoses were ependymomas and choroid plexus (IIIA), while for children 5–9 years old, other gliomas (IID) was

| Age Group | Race                  | Malignant | Benign |
|-----------|-----------------------|-----------|--------|
|           | ASIR 95%CI            | ASIR 95%CI|
| < 5 years | Non-Hispanic White    | 2.6 (2.2, 3.2) | 1.5 (1.2, 1.9) |
|           | Non-Hispanic Black    | 2.3 (1.4, 3.5) |        |
|           | Hispanic              | 2.6 (2.2, 3.0) | 1.1 (0.8, 1.4) |
|           | Asian-Pacific Islander| 2.7 (1.9, 3.8) |        |
|           | **Total**             | 2.6 (2.4, 2.9) | 1.2 (1.0, 1.4) |
| 5-9 years | Non-Hispanic White    | 2.5 (2.1, 3.1) | 1.7 (1.3, 2.1) |
|           | Non-Hispanic Black    | 1.7 (1.0, 2.8) |        |
|           | Hispanic              | 2.2 (1.9, 2.6) | 0.9 (0.7, 1.2) |
|           | Asian-Pacific Islander| 1.8 (1.1, 2.6) |        |
|           | **Total**             | 2.3 (2.0, 2.5) | 1.1 (1.0, 1.3) |
| 10-14 years | Non-Hispanic White  | 2.3 (1.9, 2.7) | 1.6 (1.2, 1.9) |
|           | Non-Hispanic Black    |          |        |
|           | Hispanic              | 1.7 (1.4, 2.1) | 1.0 (0.8, 1.3) |
|           | Asian-Pacific Islander| 1.8 (1.2, 2.7) |        |
|           | **Total**             | 1.9 (1.6, 2.1) | 1.2 (1.0, 1.4) |
| 15-19 years | Non-Hispanic White | 2.0 (1.6, 2.5) | 2.1 (1.7, 2.5) |
|           | Non-Hispanic Black    |          |        |
|           | Hispanic              | 1.4 (1.1, 1.8) | 2.0 (1.6, 2.4) |
|           | Asian-Pacific Islander| 2.3 (1.6, 3.2) | 1.1 (0.7, 1.8) |
|           | **Total**             | 1.7 (1.5, 2.0) | 1.8 (1.6, 2.1) |

* Age-specific incidence rates are per 100,000 population. Rates are standardized to the 2000 US population. Shaded cells rates could not be calculated if number of cases were less than 15 and/or the underlying population was less than 100,000
Table 5  Number of cases, percent and age-specific incidence rate* (ASIR) of first primary central nervous system tumors by diagnostic group, age group and tumor behavior, California, 2001–2005

| Diagnostic Groups | <5-9 years | 10-14 years | 15-19 years |
|-------------------|------------|-------------|-------------|
|                    | Benign     | Uncertain   | Total       | Benign     | Uncertain   | Total       | Benign     | Uncertain   | Total       |
| Malignant          | n %        | ASIR 95% CI | n %        | n %        | ASIR 95% CI | n %        | n %        | ASIR 95% CI | n %        | ASIR 95% CI | n %        | n %        | ASIR 95% CI | n %        | ASIR 95% CI | n %        | ASIR 95% CI |
| Ependymomas &     | 23.0%      | 0.2 (0.1, 0.3) | 5.1%       | 0.2 (0.1, 0.3) | 12.1%      | 0.2 (0.1, 0.3) | 40.1%      | 0.2 (0.1, 0.3) | 12.1%      | 0.2 (0.1, 0.3) | 40.1%      | 0.2 (0.1, 0.3) |
| Choroid Plexus Tumor | 66.2%      | 0.5 (0.4, 0.6) | 89.7%      | 0.5 (0.4, 0.6) | 21.2%      | 0.5 (0.4, 0.6) | 152.2%     | 0.5 (0.4, 0.6) | 21.2%      | 0.5 (0.4, 0.6) | 152.2%     | 0.5 (0.4, 0.6) |
| Medulloblastomas   | 28.1%      | 0.2 (0.1, 0.3) | 5.6%       | 0.2 (0.1, 0.3) | 17.2%      | 0.2 (0.1, 0.3) | 42.1%      | 0.2 (0.1, 0.3) | 17.2%      | 0.2 (0.1, 0.3) | 42.1%      | 0.2 (0.1, 0.3) |
| PNET               | 17.6%      | 0.1 (0.1, 0.2) | 6.4%       | 0.1 (0.1, 0.2) | 17.2%      | 0.1 (0.1, 0.2) | 42.1%      | 0.1 (0.1, 0.2) | 17.2%      | 0.1 (0.1, 0.2) | 42.1%      | 0.1 (0.1, 0.2) |
| Other Intracranial & Intraspinal | 51.0% | 0.0% | 0.0% | 0.0% | 51.0% | 0.0% | 0.0% | 0.0% | 51.0% | 0.0% |
| Other Gliomas      | 10.0%      | 0.0 (0.0, 0.3) | 5.1%       | 0.0 (0.0, 0.3) | 12.1%      | 0.0 (0.0, 0.3) | 40.1%      | 0.0 (0.0, 0.3) | 12.1%      | 0.0 (0.0, 0.3) | 40.1%      | 0.0 (0.0, 0.3) |
| Specified Intracranial & Intraspinal | 41.2% | 0.2 (0.2, 0.4) | 6.0% | 0.2 (0.2, 0.4) | 16.0% | 0.2 (0.2, 0.4) | 44.0% | 0.2 (0.2, 0.4) | 16.0% | 0.2 (0.2, 0.4) |
| Other Germ Cell Tumors | 59.3% | 0.4 (0.3, 0.6) | 0.0% | 0.4 (0.3, 0.6) | 2.0% | 0.4 (0.3, 0.6) | 13.0% | 0.4 (0.3, 0.6) | 2.0% | 0.4 (0.3, 0.6) |
| Other Tumors       | 7.7%       | 0.0 (0.0, 0.3) | 3.8%       | 0.0 (0.0, 0.3) | 11.1%      | 0.0 (0.0, 0.3) | 31.1%      | 0.0 (0.0, 0.3) | 11.1%      | 0.0 (0.0, 0.3) | 31.1%      | 0.0 (0.0, 0.3) |
| Total              | 100.0%     | 1.2 (1.0, 1.4) | 100.0%     | 1.2 (1.0, 1.4) | 100.0%     | 1.2 (1.0, 1.4) | 100.0%     | 1.2 (1.0, 1.4) | 100.0%     | 1.2 (1.0, 1.4) | 100.0%     | 1.2 (1.0, 1.4) |

* Age-specific incidence rates are per 100,000 population. Rates are standardized to the 2000 US population

PNET: Primitive Neuroectodermal Tumors

Shaded cells rates could not be calculated if number of cases were less than 15 and/or the underlying population was less than 100,000.
ranked first only slightly ahead of astrocytomas (IIIB), which was followed closely by medulloblastomas (IIIC1). For adolescents, germ cell tumors (XA) ranked a close second to astrocytomas (IIIB). Among teens, benign PCNST classified as other specified intracranial and intraspinal tumors (IIIE) were ranked first; the majority of patients in that sub-category were diagnosed specifically with pituitary adenoma (66.7%). Overall, pituitary adenoma comprised 20.1% of all diagnoses in teens. In all age groups, the majority of tumors of uncertain behavior were classified as other specified intracranial and intraspinal tumors (IIIE) classification. In nearly every age group, the majority of those patients were diagnosed specifically with gangliogliomas, representing between 37.0% (5–9 year olds) and 47.8% (10–14 year olds) of those cases. Among children younger than 5 years old, nearly an equal number of patients were diagnosed with craniopharyngiomas and gangliogliomas (36.1 and 38.9%, respectively).

Table 6 shows the distribution of astrocytomas; both malignant and benign numbered nearly the same for boys and girls younger than 15 years old, while among teens, they predominated in boys. Further, boys had the most ependymomas and choroid plexis tumors, medulloblastomas, and PNET. Although astrocytomas and PNET tumors were distributed nearly equally among non-Hispanic white and Hispanic children; all other histologies were more frequently seen in adolescent and teen non-Hispanic whites. In the low SES group, ependymomas and choroid plexis tumors, medulloblastomas, and PNET were found most often among children younger than 10 years old. Astrocytomas were found mostly among low SES children younger than 5, with a near even distribution among those 5–9 and among high SES adolescents and teens. Furthermore, benign astrocytomas were found mainly in the low SES group for children younger than 5 and in teens. In high SES groups however astrocytoma were found mainly among those 5–14 years old.

Discussion

This is the first study to examine both malignant and benign PCNST among children, adolescents, and teens in California. Fifty-three percent of PCNST among those younger than 20 years old were malignant, 33.3% benign, and the remainder was of uncertain behavior. The AAIR of malignant PCNST in this age group was 2.1 cases per 100,000 persons and for benign PCNST, 1.3 per 100,000. Among children and adolescents younger than 15 years old, the malignant PCNST was 2.2 per 100,000 and for benign PCNST, 1.2 per 100,000.

In the present study, the incidence of malignant tumors decreased with increasing age. The highest incidence for malignant PCNST was found among children younger than 5 years old [8–11], whereas teens had the highest incidence of benign and uncertain behavior PCNST. Post-mortem studies on younger brains have found a higher relative concentration of neural stem cells [12, 13], which suggests that the immature brain might possess an increased capacity to generate malignant neuroepithelial tumors through increased populations of neural stem and progenitor cell types, supporting the stem cell hypothesis for tumor formation [14].

Consistent with results found for adults, boys at every age group had a higher incidence of malignant tumors, while girls generally had a higher incidence of benign tumors [11, 15]. Significant sex-specific differences were not found for malignant PCNST in the 5–9 year age group or for benign PCNST among adolescents. The incidence of malignant PCNST in girls dropped sharply starting in the 5–9 year old age group while the incidence of benign PCNST rose just as dramatically starting in the adolescence. Age- and sex-specific tumor frequency and tumor behavior transition are postulated to be hormone-related, coinciding with the onset of puberty, although the specific mechanism has yet to be determined [16]. For example, in a case report, the growth and regression of a pilocytic astrocytoma was found to be related to exogenous human growth hormone (hGH) [17].

In our study, astrocytomas were the prominent diagnoses for malignant PCNST in most age groups, which is consistent with other national and international studies [8, 10, 11, 15, 18–29]. Ependymomas and choroid plexus tumors were highest among children younger than 5 years old [19, 20, 26, 27], while other gliomas and medulloblastomas had a similar incidence to astrocytomas in the 5–9 age group [11, 20]. We noted a surge in germ cell tumors for adolescents, which declined for teens concurrent with an increase in pituitary tumors [16, 30, 31]. The proportional incidence of pituitary adenomas in our study population was similar to that reported by CBTRUS, although our methods varied [21].

California’s unique race/ethnic population allows analyses of the distribution of cancer incidence in groups that might otherwise be overlooked or inaccurately counted. California’s younger population (<20 years old) is predominantly Hispanic (45.8%). Hispanics represent 50.2% of children younger than 5 years old, 47.8% of those in the 5–9 age group, and 44.3% of the adolescent group. However, in the teen group, the Hispanic population is nearly equal to the non-Hispanic white population (40.9 and 39.5%, respectively) [32]. Therefore not surprisingly, in our study the highest proportional incidence of malignant PCNST was among Hispanic children younger than 10 years old; non-Hispanic whites had the highest incidence among 10–19 year olds. The ASIR reported for
Table 6  Number of cases and percent of first primary malignant and benign central nervous system tumors by age group, population demographics and diagnostic group, California, 2001–2005

| Demographic Characteristics | Malignant | Benign |
|-----------------------------|-----------|--------|
|                             | IIA Ependymomas & Choroid Plexus Tumor | IIB Astrocytomas | IIIC Medulloblastoma | IIIC2 PNET | IIID Other Gliomas | XA Intracranial & Intraspinal Tumor | Germ Cell | Z Other | Total |
|                             | n        | %       | n        | %       | n        | %       | n        | %       | n        | %       |
|                             | n        | %       | n        | %       | n        | %       | n        | %       | n        | %       |
|                             | n        | %       | n        | %       | n        | %       | n        | %       | n        | %       |
|                             | n        | %       | n        | %       | n        | %       | n        | %       | n        | %       |
| Sex                         |         |         |         |         |         |         |         |         |         |         |
| < 5 years                   |         |         |         |         |         |         |         |         |         |         |
| Male                        | 41       | 55.4%   | 40       | 59.7%   | 43       | 67.2%   | 26       | 55.3%   | 17       | 45.0%   |
| Female                      | 33       | 44.6%   | 27       | 40.3%   | 21       | 32.8%   | 21       | 44.7%   | 22       | 55.0%   |
| Race/ethnicity              |         |         |         |         |         |         |         |         |         |         |
| Non-Hispanic white          | 22       | 29.7%   | 24       | 35.8%   | 20       | 31.3%   | 13       | 27.7%   | 12       | 30.0%   |
| Hispanic                    | 41       | 55.4%   | 25       | 37.3%   | 38       | 59.4%   | 24       | 51.1%   | 19       | 47.5%   |
| Other/Unknown               | 11       | 14.9%   | 18       | 26.9%   | 6        | 9.4%    | 10       | 21.3%   | 9        | 19.2%   |
| Socioeconomic Status        |         |         |         |         |         |         |         |         |         |         |
| Low                         | 26       | 35.1%   | 29       | 43.3%   | 23       | 35.9%   | 17       | 36.2%   | 14       | 35.0%   |
| Medium                      | 12       | 16.2%   | 13       | 19.4%   | 14       | 21.9%   | 10       | 21.3%   | 5        | 12.5%   |
| High                        | 8        | 28.6%   | 11       | 15.3%   | 15       | 22.1%   | 13       | 24.5%   | 13       | 17.8%   |
| 5-9 years                   |         |         |         |         |         |         |         |         |         |         |
| Male                        | 13       | 46.4%   | 36       | 50.0%   | 42       | 61.8%   | 16       | 55.2%   | 35       | 47.9%   |
| Female                      | 15       | 53.6%   | 36       | 50.0%   | 26       | 38.2%   | 13       | 44.8%   | 38       | 52.1%   |
| Race/ethnicity              |         |         |         |         |         |         |         |         |         |         |
| Non-Hispanic white          | 6        | 21.4%   | 32       | 44.4%   | 28       | 41.2%   | 12       | 41.4%   | 26       | 35.6%   |
| Hispanic                    | 14       | 50.0%   | 34       | 47.2%   | 36       | 52.9%   | 13       | 44.8%   | 30       | 41.1%   |
| Other/Unknown               | 8        | 28.6%   | 6        | 8.3%    | 17       | 23.3%   |          |         | 7        | 25.9%   |
| Socioeconomic Status        |         |         |         |         |         |         |         |         |         |         |
| Low                         | 17       | 60.7%   | 30       | 41.7%   | 28       | 41.2%   | 14       | 48.3%   | 34       | 46.6%   |
| Medium                      | 11       | 15.3%   | 15       | 22.1%   | 13       | 18.7%   |          |         | 21       | 20.6%   |
| High                        | 8        | 28.6%   | 31       | 43.1%   | 25       | 36.8%   | 11       | 37.9%   | 26       | 35.6%   |
| 10-14 years                 |         |         |         |         |         |         |         |         |         |         |
| Male                        | 34       | 51.5%   |          |         |          |         | 25       | 49.0%   | 48       | 53.8%   |
| Female                      | 32       | 48.5%   |          |         |          |         | 26       | 50.0%   | 10       | 16.9%   |
| Race/ethnicity              |         |         |         |         |         |         | 24       | 47.1%   | 19       | 32.7%   |
| Non-Hispanic white          | 33       | 50.0%   |          |         |          |         | 21       | 41.2%   | 27       | 45.8%   |
| Hispanic                    | 24       | 36.4%   |          |         |          |         | 21       | 41.2%   | 27       | 45.8%   |
| Other/Unknown               | 9        | 13.6%   |          |         |          |         | 12       | 17.2%   | 10       | 14.7%   |
| Socioeconomic Status        |         |         |         |         |         |         |         |         |         |         |
| Low                         | 30       | 45.5%   |          |         |          |         | 17       | 33.3%   | 21       | 35.6%   |
| Medium                      | 10       | 15.2%   |          |         |          |         | 13       | 25.5%   | 9        | 15.3%   |
| High                        | 26       | 39.4%   |          |         |          |         | 21       | 41.2%   | 29       | 49.2%   |
| 15-19 years                 |         |         |         |         |         |         |         |         |         |         |
| Male                        | 44       | 62.0%   |          |         |          |         | 17       | 46.8%   | 42       | 56.8%   |
| Female                      | 27       | 38.0%   |          |         |          |         | 18       | 51.4%   | 8        | 18.6%   |
| Race/ethnicity              |         |         |         |         |         |         | 17       | 46.8%   | 15       | 34.9%   |
| Non-Hispanic white          | 30       | 42.3%   |          |         |          |         | 11       | 27.9%   | 27       | 36.5%   |
| Hispanic                    | 23       | 32.4%   |          |         |          |         | 18       | 41.3%   | 7        | 18.7%   |
| Other/Unknown               | 18       | 25.4%   |          |         |          |         | 7        | 17.5%   | 16       | 27.3%   |
| Socioeconomic Status        |         |         |         |         |         |         |         |         |         |         |
| Low                         | 33       | 46.5%   |          |         |          |         | 15       | 42.9%   | 23       | 31.1%   |
| Medium                      | 12       | 16.9%   |          |         |          |         | 8        | 22.9%   | 9        | 20.9%   |
| High                        | 26       | 36.6%   |          |         |          |         | 12       | 34.3%   | 20       | 46.5%   |

PNET Primitive Neuroectodermal Tumors

Shaded cells categories with less than 5 cases; age groups that represented less than 25 of a histology group and/or no meaningful information could be gleaned due to small case numbers, were omitted.
malignant PCNST for children younger than 5 (2.6–2.7 per 100,000) was nearly the same for Hispanics, non-Hispanic whites, and Asian/Pacific Islanders. Non-Hispanic whites had the highest incidence among 5–14 year olds (2.5 per 100,000) and Asian/Pacific Islanders had the highest incidence among teens (2.3 per 100,000). The differences in these incidence rates were not statistically significant.

This is the first study to examine the proportions of PCNST incidence by SES in this age group. We found that children younger than 10 years old in the lowest SES group had a higher proportional incidence of malignant PCNST, while children and adolescents 5–19 years old in the highest SES group had a higher incidence of benign PCNST compared to other SES groups. This finding may be related to unique class level exposures or indirectly related to race/ethnicity population distribution, specifically those groups that are more likely at the lower SES levels and/or differential healthcare coverage [33]. Cancer incidence has been found to be highest among those with more education, greater income, and with private insurance [34, 35]. Reasons for this are unclear. Some have advanced the theory, least in childhood leukemia, that higher SES groups are immunologically shielded by hyperhygienic environments, leading to naïve immune systems which are more prone to cancer development [36, 37].

Common causes for differences in CNS tumor incidence statistics between epidemiologic studies were discussed at length in the authors’ companion publication in this edition. Unique to comparisons of pediatric CNS tumor incidence statistics is the variation in the selection of age groupings across sources and the use of the ICCC. The ICCC was designed specifically for childhood cancers and is based on tumor morphology in conjunction with primary anatomical site, rather than histology and anatomical site separately as is common [6, 7]. Additionally, SEER created a recode system for the ICCC [6, 7], as it did for the ICD-O [38]. The ICCC SEER site recode is used by the CCR, all North American central cancer registries, NPCR and SEER to organize histologies but not by CBTRUS or in international studies. Even when the ICCC was used, valid comparisons between studies and statistical sources could not be made because many of those studies used cases from a single institution or if population-based, did not calculate incidence rates [39–41]. When rates were available, the detail necessary for valid comparison was not the same [18, 42]. We found the use of the ICCC to have limitations. Although appropriate for showing transitioning tumor occurrence by age groups, the ICCC was inadequate for delineating PCNST among teens. For example, 20% of benign PCNST among teens were pituitary adenomas, which were otherwise hidden in the category of “other intracranial and intraspinal”, since they are nearly nonexistent among children and adolescents younger than 15 years old.

Our study’s strengths and weaknesses have been discussed in the authors’ companion publication in this edition. Specific to this study, even though 5 years of benign data had been collected, due to the small numbers of cases, stable and accurate incidence rates could not be calculated for many sex-race/ethnic-age group combinations among children, adolescents, and teens.

Primary central nervous system tumors are a major source of cancer morbidity and mortality among children, adolescents, and teens. While PCNST incidence has been relatively well-researched, this is the first study to comprehensively examine benign PCNST by ICCC diagnostic groups and age groups, and to compare them to malignant PCNST. In addition, this is one of the few studies to examine PCNST among adolescents [22, 24, 30, 43]. This study of California PCNST among children, adolescents, and teens provides a basis for future basic, translational and clinical brain tumor research and for both healthcare and public health in California.

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