



## Brain and Central Nervous System Tumors in Massachusetts, 2004-2013

The Massachusetts Cancer Registry, Massachusetts Department of Public Health - May 2016

---

### PURPOSE

The purpose of this report is to present the in-depth epidemiology of both malignant and non-malignant brain and central nervous system (CNS) tumors diagnosed in Massachusetts from 2004 to 2013. This report examines the incidence, mortality, and trends of brain tumors overall and by specific histologic type in Massachusetts with some comparisons to national data.

### METHODS

#### Incidence and Mortality Data:

**The Massachusetts Cancer Registry (MCR):** All Massachusetts incidence data are provided by the MCR, which is part of the Massachusetts Department of Public Health (MDPH). The MCR is a population-based registry that began collecting reports of newly-diagnosed cancer cases in 1982. The MCR collects reports of these cancer cases from health care facilities and practitioners throughout Massachusetts. Currently, the MCR collects information on *in situ* (except cervix) and invasive cancers and benign tumors of the brain and central nervous system (CNS). There may be some confusion with the use of benign and non-malignant in relation to brain and other central nervous system (CNS) tumors in this report. Non-malignant is the umbrella term used in surveillance to clarify that tumors of the brain and other CNS tumors coded according to the International Classification of Diseases for Oncology, Third Edition (ICD-O-3) include those tumors with behavior codes of 0 (benign) or 1 (uncertain).<sup>1</sup> The North American Association of Central Cancer Registries (NAACCR) has estimated that the MCR case ascertainment is more than 95% complete.

**Surveillance, Epidemiology, and End Results (SEER) Program:** National data on cancer incidence are from the National Cancer Institute's SEER Program, an authoritative source on cancer incidence and survival in the United States that collects and publishes data from registries in selected areas. The national cancer incidence data in this report include malignant brain tumor cases from the 18 SEER areas (including Atlanta, Connecticut, Detroit, Hawaii, Iowa, New Mexico, San Francisco-Oakland, Seattle-Puget Sound, Utah, Los Angeles, San Jose-Monterey and Alaska, rural Georgia, greater California, Kentucky, Louisiana, New Jersey, and greater Georgia). SEER rates are presented per 100,000 persons and are age-adjusted to the 2000 United States standard population for ages 0-85+ years. Please note that cases diagnosed in Louisiana from July to December 2005 were excluded as a result of Hurricane Katrina.<sup>2</sup> SEER data for this report are from 2004 to 2012 since 2013 was not yet available. <http://seer.cancer.gov/registries/>

**Massachusetts Registry of Vital Records and Statistics (MVRS):** Massachusetts death data were obtained from the MDPH's Registry of Vital Records and Statistics, which has legal responsibility for collecting reports of deaths of Massachusetts residents.

**National Center for Health Statistics (NCHS):** National mortality data were obtained from the Centers for Disease Control and Prevention's National Center for Health Statistics which collects national death data from individual state vital statistics registries. In contrast to national incidence data, mortality data include the entire United States. NCHS data for this report are from 2004 to 2013.

### **Brain Tumor Reporting:**

Massachusetts has been collecting data on malignant brain tumors since the establishment of the registry in 1982. Like some other state cancer registries, it also received data on non-malignant brain tumors and later sent these data along with its malignant data to the Central Brain Tumor Registry of the United States (CBTRUS) for its statistical reports, the first of which was published as a manuscript in 1996 with data from 1985-1989.<sup>3</sup> Due to the passage in 2002 of the Benign Brain Tumor Cancer Registries Amendment Act, beginning in January 2004 state registries and hospital cancer programs were required by the National Program of Cancer Registries (NPCR) to collect data on all brain tumors, malignant and non-malignant. The rationale for including non-malignant brain tumors in reporting laws was to measure the extent of burden of these tumors which bear an 'underappreciated health and financial burden.'<sup>4</sup> Massachusetts General Law for cancer reporting was amended in 2004 to include benign brain tumors. Non-malignant cases include both benign tumors and tumors of uncertain behavior. While metastatic cancers can spread to the brain as secondary brain tumors, data are not collected on these types of tumors in Massachusetts.

### **Population Estimates:**

All of the population estimates used in this report were produced by the NCHS in collaboration with the Census Bureau's Population Estimation Program. The NCHS reallocates the multiple race categories from the Census Bureau population estimates file to create four mutually exclusive race categories that are consistent with the race categories used to collect cancer incidence and cancer mortality data for the years 2001-2010 (white, non-Hispanic (NH), black, NH, Asian, NH, and Hispanic).

### **Data Limitations:**

When interpreting the cancer data, it is important to consider certain limitations which include:

- Under-reporting in areas close to neighboring states: Although the MCR has reciprocal reporting agreements with 36 states as of April 2015, there may still be some Massachusetts residents who were diagnosed out of state and not reported to the MCR.

- Potentially misleading trends: Apparent increases or decreases in cancer incidence over time may reflect changes in diagnostic methods or case reporting rather than true changes in cancer occurrence.
- Small numbers of cases: Many of the calculations in this report involved small numbers of cases. As a result, differences in rates may be due to chance, and the data should be interpreted with caution. Due to these small numbers, data were broken down only by year and by gender for selected brain/CNS tumors but not by race/ethnicity.

## Statistical Terms:

**Age-Specific Rates** – Age-specific rates were calculated by dividing the number of people in an age group who were diagnosed with cancer or died of cancer in a given time frame by the number of people in that same age group overall in that time frame.

**Age-Adjusted Rates** – An age-adjusted incidence or mortality rate is a weighted average of the age-specific rates, where the weights are the proportions of persons in the corresponding age groups of a standard 100,000 population. The potential confounding effect of age is eliminated when comparing age-adjusted rates for populations with different age structures. The 2000 U.S. Census Bureau population distribution was used as a standard. Rates were age-adjusted using eighteen 5-year age groups. Age-adjusted rates can only be compared if they are adjusted to the same standard population. It is also important to note that differences in methodologies used in calculating rates, such as a number of age groups used, may cause slight variations in results.

**Joinpoint Regression Analysis of Cancer Trends** – The annual percent change (APC)  $= 100 * (e^m - 1)$ , where  $m$  is a slope of the linear regression line, which is an approximation of the function of the natural logarithm of the rates by the year of diagnosis. The APC is a linear approximation; therefore, it may not give an accurate picture of long-term trends. SEER provides software to calculate the number and location (in time) of points where trends change direction (joinpoints).<sup>5</sup> At each joinpoint, the trend may change in different ways. The joinpoint regression model describes the trend as a sequence of linear segments between corresponding joinpoints so that each segment has an associated APC positive trend, negative trend, or no trend.

**Proportion Comparisons** – Proportions were compared for significance using the modified Wald Method on graph pad software <http://graphpad.com/quickcalcs/confInterval1/>.

## EXECUTIVE SUMMARY:

*Data Report on Brain and Central Nervous System Tumors in Massachusetts, 2004-2013* presents in depth epidemiology of both malignant and non-malignant brain tumors diagnosed during this period. Non-malignant tumors, while reported to Massachusetts before 2004, became reportable conditions in 2004. This report examines the incidence, mortality, survival and trends of brain tumors overall and by specific histologic type in Massachusetts.

### Highlights

- Malignant brain tumors represented 1.4% of all invasive cancers diagnosed from 2004-2013 and 2.4% of all invasive cancer deaths from 2004-2013.
- There were 5,388 malignant brain/CNS tumors diagnosed from 2004 to 2013 and 8,135 non-malignant tumors.
- There were significant increases from 2004 to 2013 in the incidence rates of non-malignant brain/CNS tumors among males and females in Massachusetts. There were significant increases in rates among US males and females from 2004 to 2009, but no significant changes from 2009 to 2012.
- While the national incidence rate for malignant brain/CNS tumors decreased significantly from 2004 to 2012 for females, the rate did not change for males. In comparison, there were no significant changes in incidence among males or females in Massachusetts from 2004 to 2013.
- There were no significant changes in the mortality rates for malignant brain and CNS tumors in Massachusetts from 2004-2013. The national mortality rate for females increased significantly from 2011-2013.
- The most common tumor types (histology) for all brain tumors were non-malignant meningiomas (36.0%) and malignant gliomas (33.8%). The most common types of gliomas were glioblastomas (57.9%), anaplastic astrocytomas (6.7%), and diffuse astrocytomas (5.6%).
- The incidence rate for glioblastomas, the most common and most aggressive of malignant brain/CNS tumors, remained steady from 2004-2013 for males and females in Massachusetts.
- The incidence rate for meningiomas, the most common non-malignant brain/CNS tumor, increased significantly from 2004 to 2013 for both male and females in Massachusetts. This may be due in part to increased incidental detection of asymptomatic meningiomas through CAT scans and improved reporting as 2004 was the first year that non-malignant meningioma reporting was mandated.

## **OVERVIEW OF CENTRAL NERVOUS SYSTEM:**

**The Brain** – The brain is the most complex structure in the human body, responsible for thought and emotion in addition to controlling breathing and heart rate. There are three main parts of the brain:<sup>6</sup>

- 1) The hindbrain includes the cerebellum, the upper part of the spinal cord, and brainstem, and controls the body's vital functions of breathing and heart rate.
- 2) The midbrain consists of the uppermost part of the brainstem and controls some reflex actions and voluntary movement of the eyes.
- 3) The forebrain, the largest part of the brain, consists of the cerebrum and is involved with intellectual activities. The cerebrum is divided into four lobes: the frontal, parietal, occipital, and temporal.

**The Spinal Cord** – The spinal cord runs from the brain to the bottom of the back and contains spinal nerves involved in movement, breathing, and bladder, bowel, and sexual functions.<sup>7</sup>

**The Meninges** – The meninges are protective layers that surround the brain and the spinal cord. They consist of the dura mater, the arachnoid mater, the subarachnoid space, and the pia mater.<sup>7</sup>

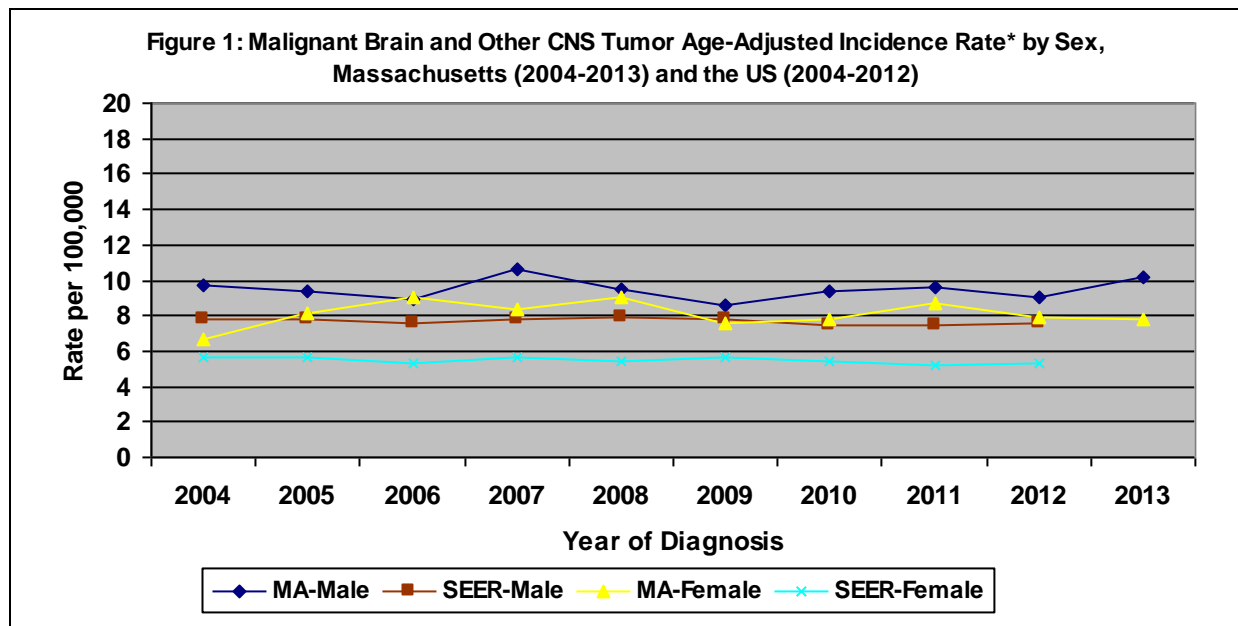
**The Ventricles** – The ventricles are spaces within the brain that are filled with cerebrospinal fluid (CSF), a clear fluid that protects the brain and spinal cord.<sup>7</sup>

**The Nerves** – The nerves consist of 13 cranial nerves, among them the olfactory, optic, and acoustic nerves controlling smell, sight, and hearing, respectively.<sup>6</sup> Neurons, the primary functional cell of the brain and central nervous system, transmit signals from the brain to various parts of the body via the cranial nerves.<sup>7</sup>

**The Glands** – There are two major glands located near the brain. The pituitary gland is involved in the secretion of several essential hormones, among them the growth hormone and prolactin, which controls milk production. The pineal gland secretes melatonin which is involved with the sleep/wake cycle.<sup>7</sup>

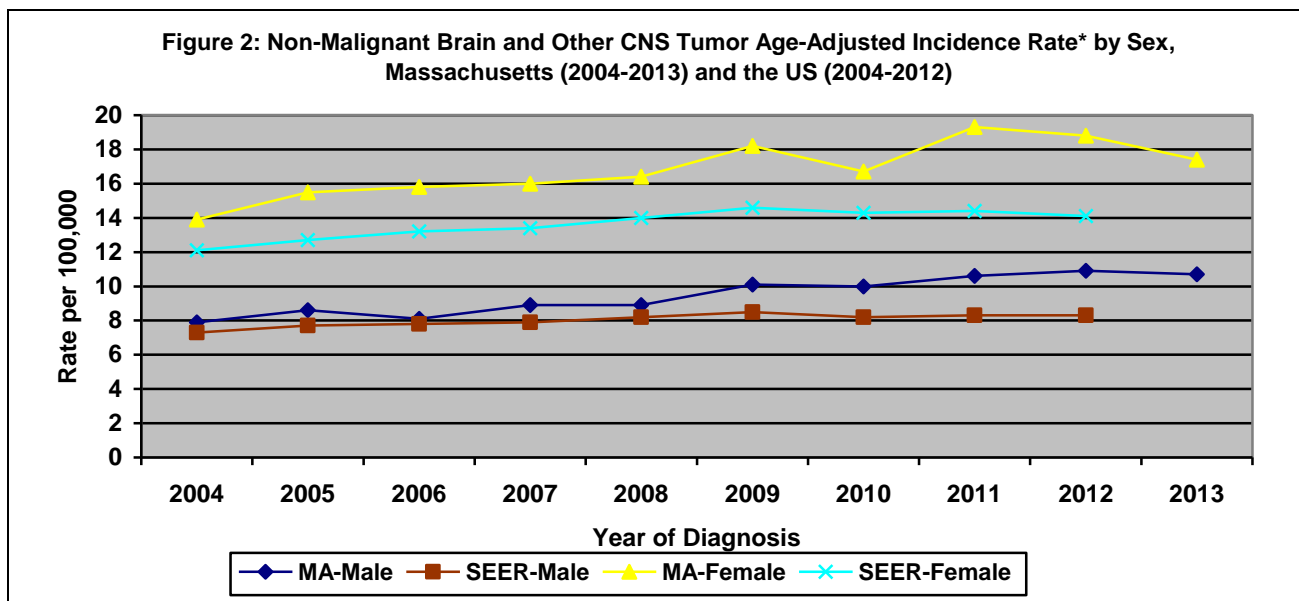
## EPIDEMIOLOGY OF HISTOLOGICAL TYPES OF BRAIN AND CNS TUMORS:

There were 5,388 cases of malignant and 8,135 cases of non-malignant brain and other CNS tumors diagnosed from 2004 to 2013. Malignant brain tumors represented 1.4% of all invasive cancers diagnosed from 2004-2013 and 2.4% of all invasive cancer deaths during the same period. The following two graphs detail the incidence of malignant and non-malignant tumors, comparing Massachusetts rates with the national SEER rates. Other than a slight though statistically significant decrease among females nationally (APC=-0.8), there were no statistically significant changes in incidence rates for malignant brain/CNS tumors for either Massachusetts or the US (Figure 1).



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

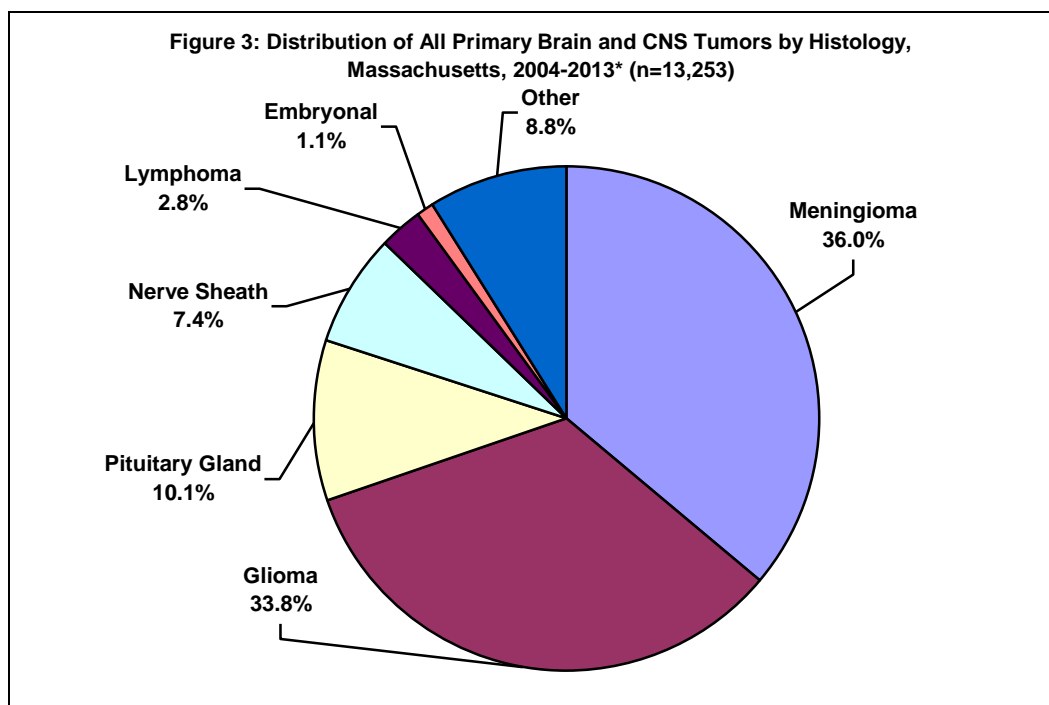
The incidence rates for non-malignant brain/CNS tumors in Massachusetts increased significantly for both males (APC=3.8) and females (APC=2.8) from 2004 to 2013. Nationally, the incidence rates increased significantly for both males (APC=2.6) and females (APC=3.6) from 2004 to 2009. The national rates for both sexes then remained stable from 2009 to 2012 (Figure 2).



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

## BRAIN AND OTHER CNS TUMOR TYPES:

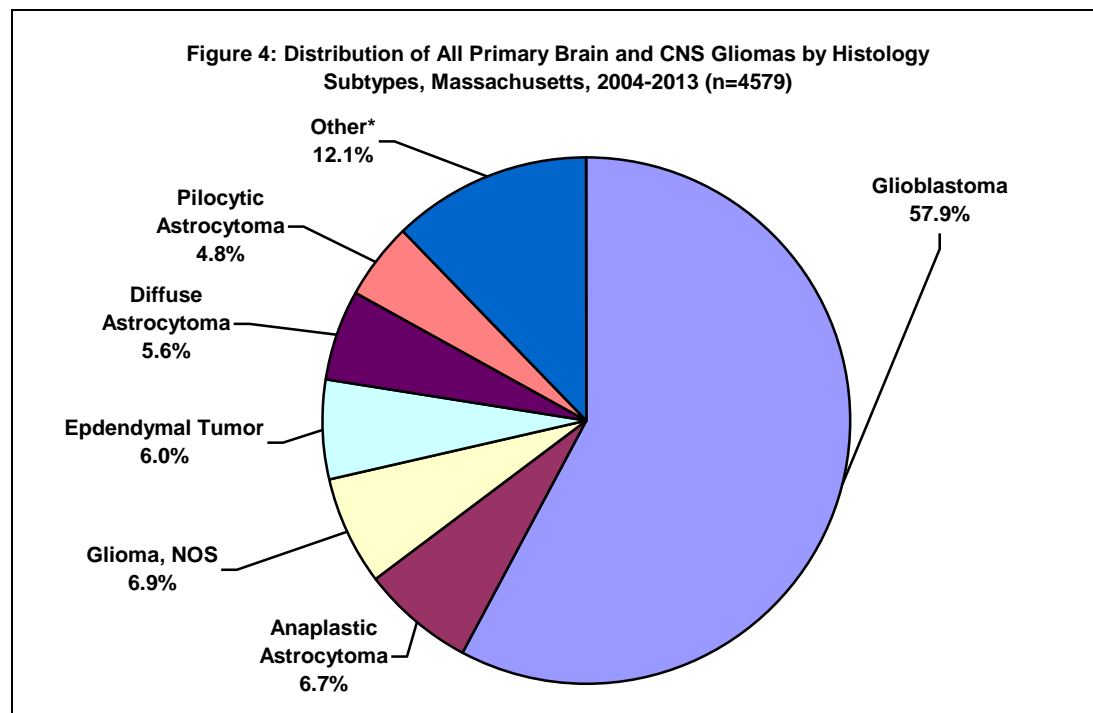
Figure 3 illustrates the distribution of the histological types of all malignant and non-malignant brain/CNS tumors. Meningiomas, nerve sheath tumors, and pituitary tumors, the majority of which are benign, represented slightly more than 50% of all histologies. The predominantly malignant gliomas (astrocytomas, glioblastomas, oligodendrogliomas) represented approximately a third of all brain tumors.



Data Source: Massachusetts Cancer Registry

## I. GLIOMAS:

Gliomas are tumors that arise from the supportive, or gluey, tissue of the brain. These supportive cells keep the neurons in place and functioning. There are three types of glial cells that can develop tumors: the astrocyte (star-shaped cell) which can become an astrocytoma, the oligodendrocyte (insulates the neuron) which can become an oligodendroglioma, and the ependymal cell (lines the fluid cavities in the brain) which can become an ependymal tumor.<sup>8</sup> The majority of gliomas diagnosed in Massachusetts from 2004 to 2013 were found in the lobes of the cerebrum. Glioblastomas, arising from the astrocytes, represented over half of gliomas diagnosed in Massachusetts from 2004 to 2013 (Figure 4).



Source: Massachusetts Cancer Registry. \*-Other includes oligodendrogliomas and oligoastrocytic tumors.

### A. Astrocytomas:

Astrocytomas are tumors that develop from astrocytes.<sup>8</sup> Nearly 100% of astrocytomas are malignant but of varying grades. The majority of astrocytomas are located in the lobes of the cerebrum.

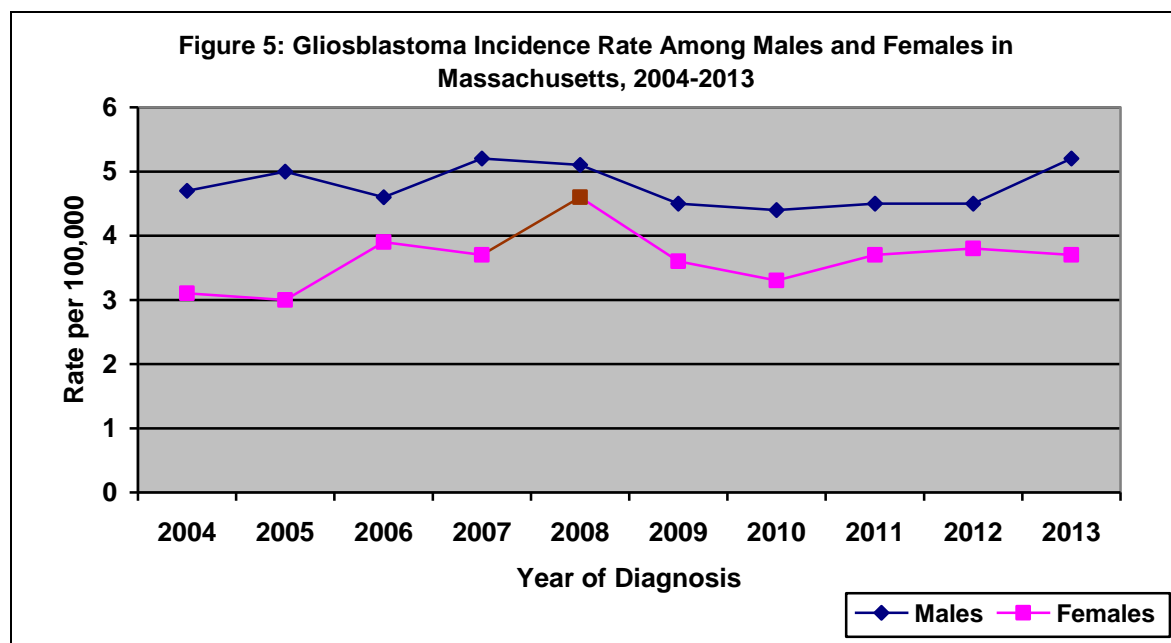
**1. Pilocytic Astrocytomas** are low grade gliomas that do not infiltrate surrounding tissue. Their behavior is usually benign, but they are classified in the ICD-O-3 manual as uncertain or borderline malignant. They usually form cysts or are enclosed within a cyst. Although slow-growing, they can grow to be quite large.<sup>8</sup> From 2004 to 2013, there were 222 cases diagnosed among Massachusetts residents. The majority (71.2%) were diagnosed among children and adolescents up to age 19. They were, in fact, the most common brain tumor

among this age group, representing 17.2% of all pediatric and adolescent brain tumors. The incidence of pilocytic astrocytomas has remained stable in Massachusetts from 2004 to 2013.

**2. Diffuse Astrocytomas** are also low grade tumors but are able to grow into surrounding tissue. They are, however, slow-growing. After treatment, they are capable of recurring as a higher grade tumor.<sup>8</sup> From 2004 to 2013, there were 256 cases diagnosed among Massachusetts residents. There was no predominant age group. The incidence of diffuse astrocytomas remained stable in Massachusetts from 2004 to 2013.

**3. Anaplastic Astrocytomas** are higher grade (III) tumors with tentacle—like projections that grow into surrounding tissue making them difficult to remove. Treatment is more aggressive with surgery performed to remove most of the tumor and radiation to control the rest of the tumor. These tumors tend to recur and may regrow as a higher grade tumor.<sup>8</sup> From 2004 to 2013, there were 307 cases diagnosed among Massachusetts residents. There was no predominant age group. The incidence of anaplastic astrocytomas remained stable in Massachusetts from 2004 to 2013.

**4. Glioblastomas** are the highest grade of tumor. A glioblastoma is graded based on the most malignant cell found in the tumor. Any astrocytoma that contains dead cells and an extensive network of blood vessels is generally classified as glioblastoma. It can either be a primary glioblastoma manifesting rapidly or a secondary glioblastoma, developing slowly from diffuse astrocytoma or anaplastic astrocytomas.<sup>9</sup> Its lack of uniformity from end to end of the tumor makes the glioblastoma one of the most difficult brain tumors to treat, with some cells responding to and other cells resisting treatment.<sup>8</sup> From 2004 to 2013, there were 2,653 cases diagnosed among Massachusetts residents. Glioblastomas were the second most common brain tumor over the age of 40. The incidence trend in Massachusetts remained stable for both males and females (Figure 5).



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

## **B. Ependymal Tumors:**

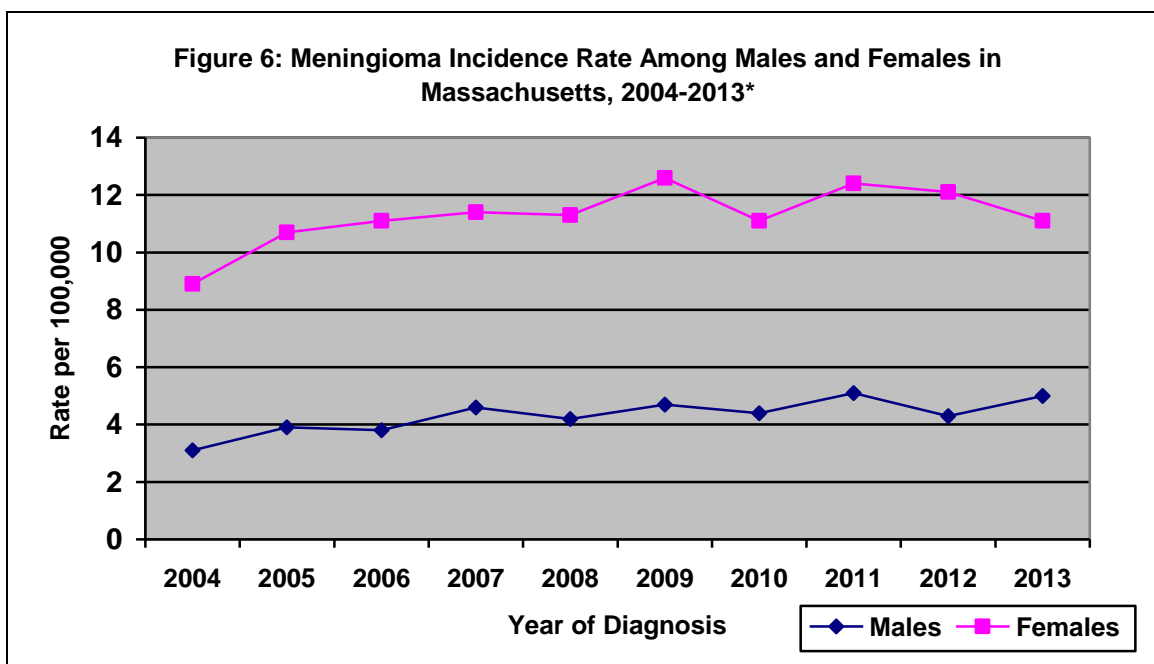
Ependymal tumors arise from the ependymal cells, neuroglial cells that line the ventricles of the brain and spinal cord and secrete cerebrospinal fluid (CNS).<sup>8</sup> Although they tended to be evenly distributed among the age groups, 21.5% occurred among those under the age of 20. There were no significant changes in the incidence rate of ependymal tumors from 2004 to 2013 in Massachusetts.

## **C. Glioma, NOS:**

This is a general term for any tumor that develops from the glial cells. These gliomas are defined by their anatomical location.<sup>8</sup> Of the 317 cases diagnosed from 2004 to 2013, 23.7% were found in the brain stem and 16.1% in the optic nerve. Most of the others (42.3%) were found in the lobes of the cerebrum. Overall, 49.5% of gliomas, NOS were diagnosed in those under the age of 20. There was no significant trend in incidence rate from 2004 to 2013 in Massachusetts.

## **II. TUMOR OF THE MENINGES:**

These are protective layers that surround the brain and the spinal cord. They consist of the dura mater, the arachnoid mater, the subarachnoid space, and the pia mater.<sup>7</sup> Meningiomas arise from the arachnoid mater. They are primarily found in the brain but can also occur in the spinal cord. They are nearly always benign and slow growing with symptoms usually occurring as the result of the tumor compressing against the brain.<sup>8</sup> From 2004 to 2013, meningioma was the most common brain tumor starting at age 20 years (N=4,863). Nearly all meningiomas (97.4%) were non-malignant. There were significant increases in the incidence rate from 2004 to 2013 for both males (APC=4.0) and females (APC=2.1) (Figure 6).



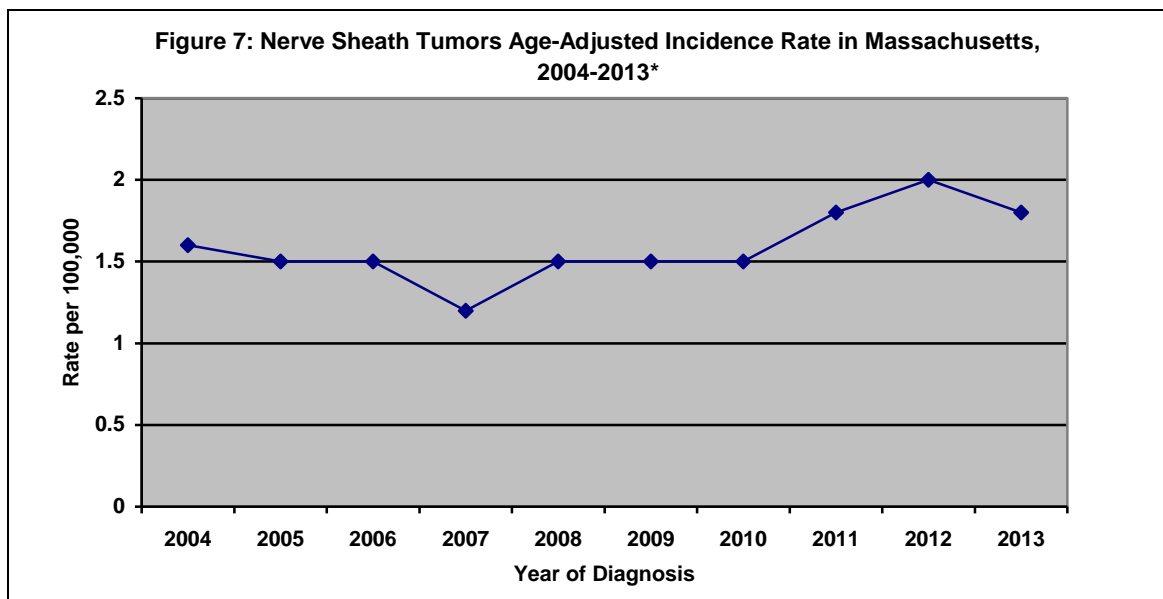
\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

### III. EMBRYONAL TUMOR:

These tumors begin in the embryonic (fetal) cells in the brain and spinal cord. There are six types of embryonal tumors: medulloblastoma, CNS primitive neuroectodermal tumors, medulloepithelioma, and ependymoblastoma.<sup>10</sup> There were 152 embryonal tumors diagnosed from 2004 to 2013, 95% being malignant. Of the embryonal tumors, 70% were diagnosed in people under the age of 20 and only 13% were diagnosed beyond the age of 40. There were no significant incidence trends in Massachusetts from 2004 to 2013.

### IV. TUMOR OF CRANIAL AND SPINAL NERVES:

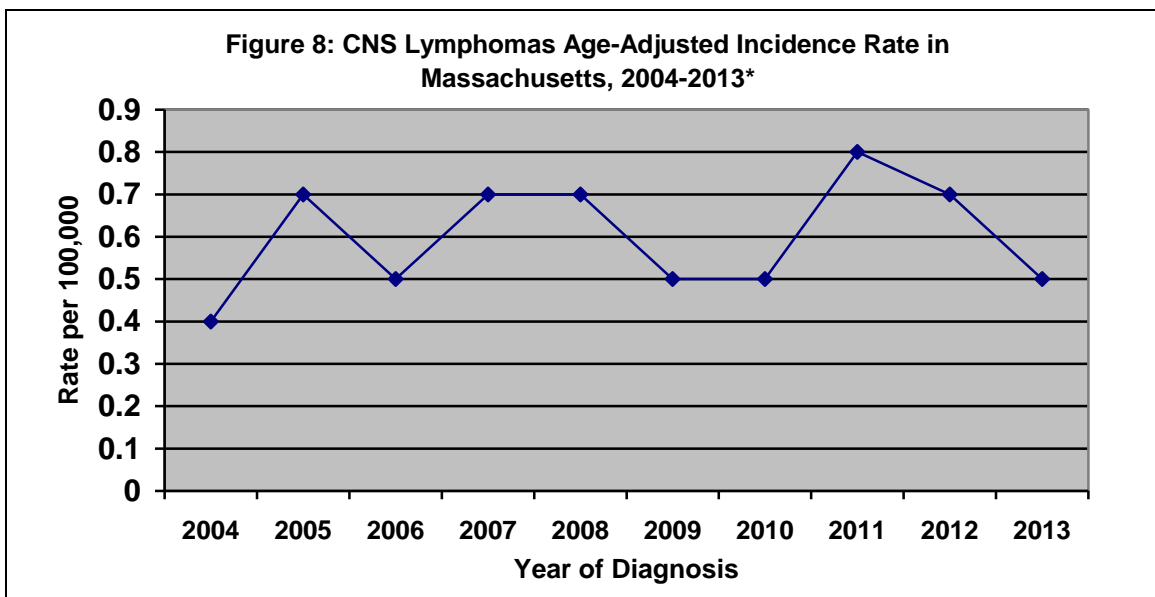
Nerve sheath tumors are primarily schwannomas which are slow growing benign tumors located in the acoustic nerve, one of the cranial nerves. There were 1,008 nerve sheath tumors diagnosed from 2004 to 2013, nearly 100% of them were benign. While there were no significant incidence trends from 2004 to 2007, the incidence rate did significantly increase from 2007 to 2013 (APC=6.6) (Figure 7).



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

## V. CENTRAL NERVOUS SYSTEM (CNS) LYMPHOMA

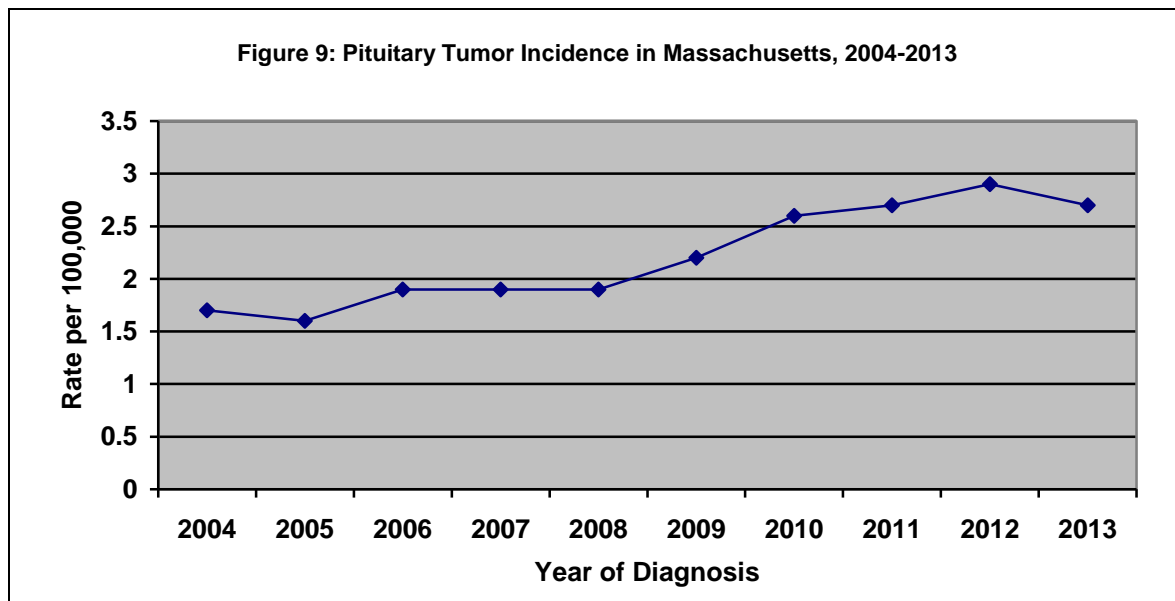
Lymphomas are cancers that develop in cells called lymphocytes, which are located in the lymph nodes and lymphoid tissue (such as the spleen and bone marrow) and used in the fight against infections and disease.<sup>9</sup> Lymphomas can occur anywhere in the central nervous system but are most common in the lobes of the cerebrum. There were 378 CNS lymphomas diagnosed from 2004 to 2013. There were no significant incidence trends in the incidence rate from 2004 to 2013 (Figure 8).



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

## **VI. TUMOR OF THE PITUITARY GLAND:**

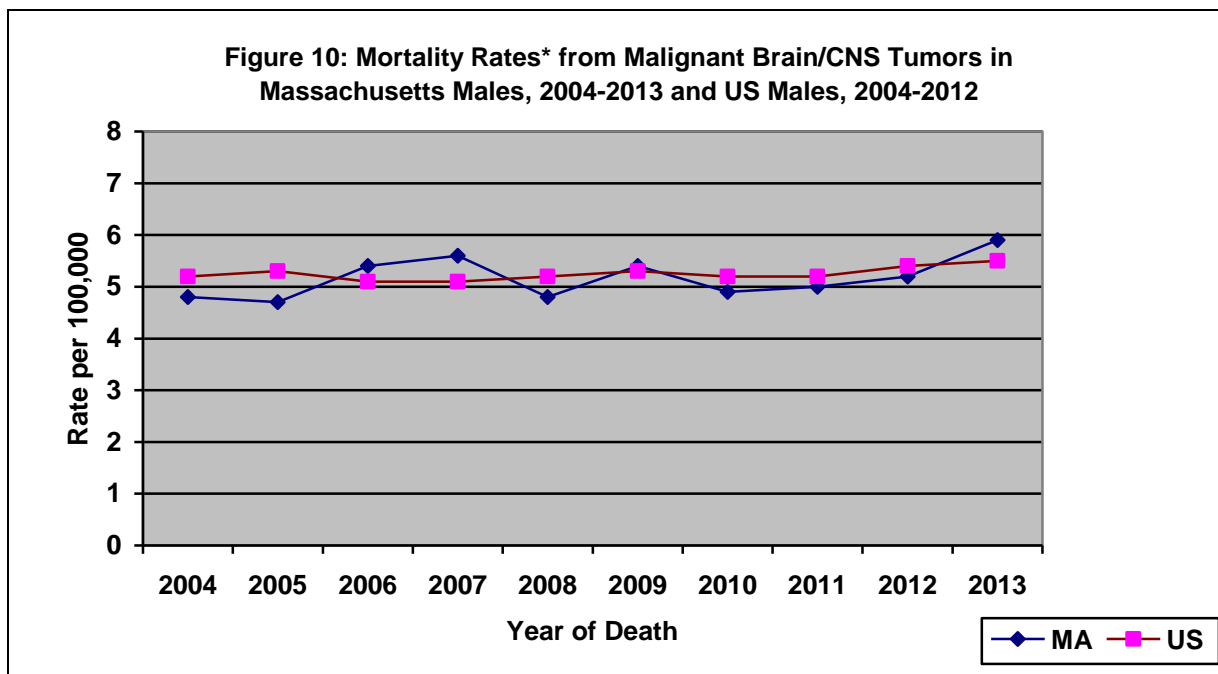
The pituitary gland, sometimes referred to as the ‘master gland’, produces hormones which sends signals to other endocrine glands to stimulate or inhibit their own hormone production. These glands include the ovaries, testes, thyroid, adrenal, and mammary. Nearly 100% of tumors arising from the pituitary gland are benign and slow growing and grow in the front two-thirds of the gland. Symptoms of a tumor include excessive hormone production.<sup>8</sup> There were 1,367 pituitary tumors diagnosed from 2004 to 2013. Pituitary tumor was the most common brain tumor among people age 20-29 years, representing 21% of tumors in this group. The incidence rate increased significantly from 2004 to 2013 (APC=7.0) (Figure 9).



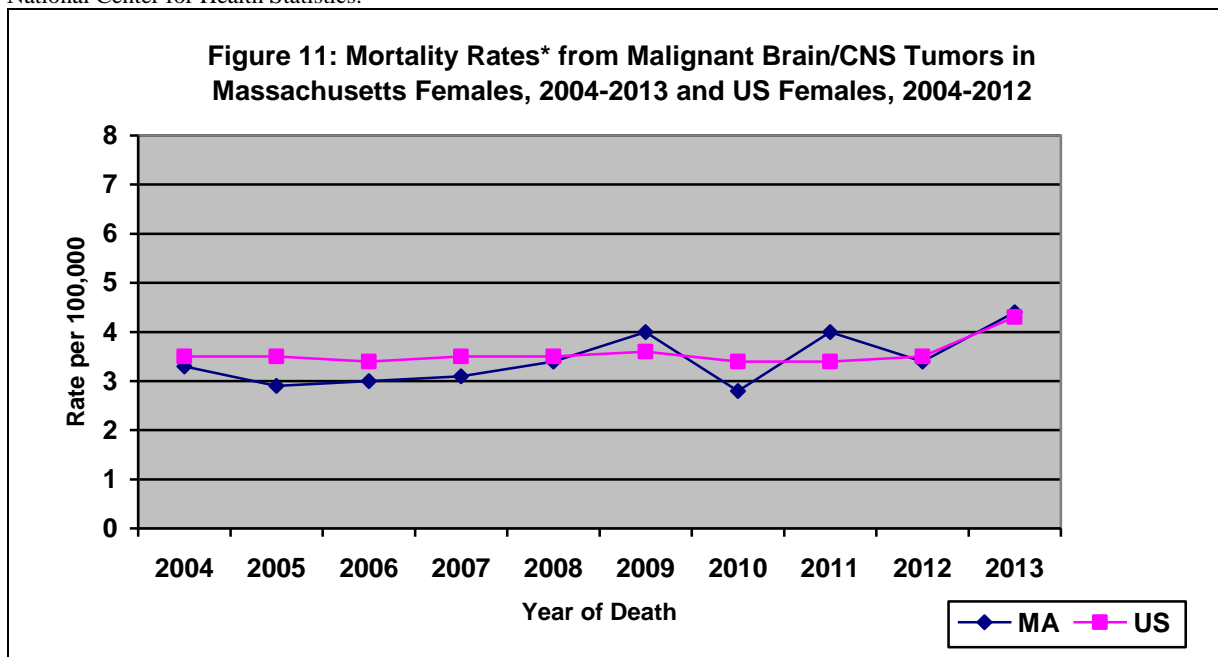
\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population. Data Source: Massachusetts Cancer Registry

## **MORTALITY FOR MALIGNANT BRAIN/CNS TUMORS:**

The mortality rates presented in the following two figures are from the Massachusetts Vital Statistics Registry. They represent deaths from malignant brain and CNS tumors. Among males, the mortality rates from malignant brain/CNS tumors did not change significantly from 2004 to 2013 in Massachusetts or the US. While the mortality rates did not change significantly among Massachusetts females, there was a significant increase from 2011-2013 (APC=10.5) among females in the US. The rates among Massachusetts males and females were comparable to the US rates throughout the ten-year period.



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population Data Source: Massachusetts Vital Statistics and National Center for Health Statistics.



\*-rates per 100,000 were age-adjusted to the 2000 US Standard Population Data Source: Massachusetts Vital Statistics and National Center for Health Statistics.

## DISCUSSION:

Meningioma was the most common non-malignant brain tumor diagnosed from 2004 to 2013, representing 58.4% of all non-malignant brain tumors. While the data for this report did not include race/ethnicity, other studies have shown significantly higher incidence rates for females and for black, non-Hispanics.<sup>11</sup> Previous studies have found a link between

breast cancer and meningioma among females<sup>12</sup> and hormone (estradiol only) therapy among females.<sup>13</sup> Exposure to dental x-rays in the past when radiation exposure was greater than the present has been shown to be associated with intracranial meningioma.<sup>14</sup> The increased use of CAT scans for screening of other conditions has led to the increased diagnosis of asymptomatic meningiomas. Most of these incidental meningiomas either remain stable in size or grow very slowly over time.<sup>15</sup>

Other studies have also found that the incidence rate for pituitary tumors, the second most common non-malignant brain tumor, was also significantly elevated for black, non-Hispanics.<sup>16</sup> Possible explanations cited include naturally occurring racial differences, differing clinical presentations of pituitary tumors for blacks that draw attention to the condition, or incidental findings from stroke rates, which are higher among blacks.<sup>16</sup> It is not possible, however, to determine the reasons for the differences from the MCR data.

Glioblastoma was the most common malignant brain tumor diagnosed from 2004 to 2013, representing 49.2% of all malignant brain tumors. This is similar to percentages from CBTRUS (46%)<sup>11</sup> and SEER (49.4%).<sup>2</sup> The incidence rate for glioblastoma has remained constant from 2004 to 2013 for both sexes. It is the brain tumor with the poorest prognosis. For adults with more aggressive glioblastoma, treated with concurrent temozolamide and radiation therapy, median survival is about 14.6 months and two-year survival is 30%. However, a 2009 study reported that almost 10% of patients with glioblastoma may live five years or longer. Children with high-grade tumors (grades III and IV) tend to do better than adults; five-year survival for children is about 25%.<sup>17</sup>

According to the American Cancer Society (ACS), most brain tumors are not associated with any particular risk factor.<sup>7</sup> The only known environmental risk factor for brain tumors is radiation exposure, most often from some type of radiation therapy.<sup>18</sup> Most radiation-induced brain tumors are caused by radiation to the head given to treat other cancers. They occur most often in people who received radiation to the brain as children as part of their treatment for leukemia and usually develop around 10 to 15 years after the radiation. Radiation-induced tumors are still fairly rare, but because of the increased risk (as well as the other side effects), radiation therapy to the head is only given after carefully weighing the possible benefits and risks. For most patients with other cancers involving the brain or head, the benefits of radiation therapy far outweigh the risk of developing a brain tumor years later.<sup>7</sup>

Additionally, there are rare genetic disorders that can be associated with brain tumors such as neurofibromatosis type 1 (NF1), neurofibromatosis type 2 (NF2), tuberous sclerosis, Von Hippel-Lindau disease, and Li-Fraumeni syndrome.<sup>7</sup> People with impaired immune systems are at an increased risk for CNS lymphoma.<sup>7</sup>

According to the ACS, ‘some studies have suggested a possible increased risk of brain tumors or of vestibular schwannomas with cell phone use’, but most of the larger studies done so far have not found an increased risk, either overall or among specific types of tumors.<sup>6</sup> An international case control study found no increased risk of glioma or meningioma among mobile phone users, but felt that the possible effects of long-term heavy use of mobile phones required further investigation.<sup>19</sup>

## **ADDITIONAL RESOURCES:**

While this report presented national data on brain tumor incidence and mortality overall, please refer to the following document for the most recent national statistical data on types (histologies) of all primary brain tumors, including incidence, mortality, and survival.

‘CBTRUS Statistical Report: Primary Brain and Central Nervous System Tumors Diagnosed in the United States in 2008-2012’

Quinn T. Ostrom et al, *Neuro-Oncology* 17:iv1–iv62, 2015.doi:10.1093/neuonc/nov189

## **ACKNOWLEDGMENTS**

This report was prepared by Richard Knowlton, an epidemiologist at the Massachusetts Cancer Registry (MCR). Thanks are given to Susan Gershman for her review of initial drafts of the report and to consultant Nancy Weiss for her editing efforts. Special thanks are given to Carol Kruchko, the President and Administrator of CBTRUS, for her review of a final draft of this report and her insightful edits and comments.

## **REFERENCES:**

<sup>1</sup> International Classification of Diseases for Oncology (ICD-O3), Third Edition, 2000

<sup>2</sup> Surveillance, Epidemiology, and End Results (SEER) Program, SEER\*Stat Database: Incidence - SEER 18 Regs Limited-Use, Nov 2011, 2009 Pops(2000-2009) <Katrina/Rita Population Adjustment> - Linked To County Attributes - Total U.S., 1969-2010 Counties, National Cancer Institute, DCCPS, Surveillance Research Program, Cancer Statistics Branch, released April 2012, based on the November 2011 submission.

<http://seer.cancer.gov/registries/>

<sup>3</sup> Davis FG, Malinski N, Haenszel W, Chang J, Flannery J, Gershman S, Dibble R, Bigner DD. Primary brain tumor incidence rates in four United States regions, 1985-1989: a pilot study. *Neuroepidemiology*. 15(2):103-112, 1996.

<sup>4</sup> Centers for Disease Control, Data Collection of Primary Central Nervous System Tumors, 2004

<sup>5</sup> Joinpoint Regression Program [computer program]. Version 3.0. Bethesda, MD: National Cancer Institute; April 2005. Available at: <http://srab.cancer.gov/joinpoint/>. Accessed November 26, 2008.

<sup>6</sup> National Institute of Neurological Disorders and Stroke. Brain Basics: Know Your Brain. [http://www.ninds.nih.gov/disorders/brain\\_basics/know\\_your\\_brain.htm?css=print](http://www.ninds.nih.gov/disorders/brain_basics/know_your_brain.htm?css=print) Accessed: January 10, 2014.

- <sup>7</sup> American Cancer Society. Brain and Spinal Cord Tumors in Adults. <http://www.cancer.org/cancer/braincnstumorsinadults/index>
- <sup>8</sup> American Brain Tumor Association (ABTA), About Brain Tumors: A Primer for Patients and Caregivers, 2012, [www.abta.org](http://www.abta.org)
- <sup>9</sup> Louis, DN, Ohgaki, H, Wiestler, OD, Cavenee, WK, WHO Classification of Tumours, Volume 1, IARC WHO Classification of Tumours, No 1, 2007.
- <sup>10</sup> American Cancer Society. Brain and Spinal Cord Tumors in Children. Available at: <http://www.cancer.org/acs/groups/cid/documents/webcontent/003089-pdf.pdf>
- <sup>11</sup> Ostrom, Q, Gittleman, H, Farah, P, et al. CBTRUS Statistical Report: Primary Brain and Central Nervous System Tumors Diagnosed in the United States in 2006-2010, Neuro-Oncology, 15:ii1-ii56, 2013.
- <sup>12</sup> Rao, G, Giordano, S, Liu, J., and Ian, E. 'The Association of Breast Cancer and Meningioma in Men and Women'. Neurosurgery: September 2009: 65 (3), p. 483-489.
- <sup>13</sup> Korhonen, K, Auvinen, A, Lyytinen, H, Yikorkala, O, and Pukkala, E. 'A Nationwide Cohort Study on the Incidence of Meningioma in Women Using Postmenopausal Hormone Therapy in Finland'. American Journal of Epidemiology, 2012;175(4):309-314.
- <sup>14</sup> Claus, E, Calvocoressi, L, Bondy, M et al. Family and personal medical history of meningioma, Journal of Neurosurgery, 115:1072-1077, 2011.
- <sup>15</sup> Chamoun, R, Krisht, K, Couldwell, W. Incidental Meningiomas, Neurosurgery Focus, 31 (6): December 2011.
- <sup>16</sup> McDowell, B., Wallace, R., Carnahan, R., et al. 'Demographic Differences in Incidence for Pituitary Adenoma'. Pituitary: 2011 March;14(10):23-30.
- <sup>17</sup> American Brain Tumor Association (ABTA), Information on Brain Tumors, <http://www.abta.org/brain-tumor-information/types-of-tumors/glioblastoma.html>
- <sup>18</sup> Sadetzki, S et al. 'Long-Term Follow-up for Brain Tumor Development after Childhood Exposure to Ionizing Radiation for Tinea Capitis'. Radiation Research: April 2005, Vol. 163, No. 4, pp. 424-432.
- <sup>19</sup> The INTERPHONE Study Group. 'Brain tumor risk in relation to mobile telephone use: results of the INTERPHONE international case-control study'. International Journal of Epidemiology, 2010;39:657-694.

<b>Appendix A:Top Ten Brain Tumors by Age Group, Massachusetts, 2004-2013</b>				
<b>0-19:</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Pilocytic astrocytoma	158	17.2	1.0	(0.8,1.1)
Glioma malignant, NOS	157	14.4	1.0	(0.8,1.1)
Embryonal tumors	107	12.3	0.7	(0.5,0.8)
Neural/mixed neuronal glial cells	84	8.4	0.5	(0.4,0.6)
Pituitary tumors	62	6.8	0.4	(0.3,0.5)
Ependymal tumor	53	6.2	0.3	(0.2,0.4)
Diffuse astrocytoma	40	4.0	0.3	(0.2,0.3)
Germ cell tumors	36	2.6	0.2	(0.1,0.3)
Nerve sheath tumors	34	3.6	0.2	(0.1,0.3)
Hemangioma	27	1.8	0.2	(0.1,0.2)
<b>20-29:</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Pituitary tumors	130	18.7	1.5	(1.2,1.7)
Meningioma	83	15.0	0.9	(0.7,1.1)
Nerve sheath tumors	45	7.6	0.5	(0.4,0.6)
Glioblastoma	36	5.8	0.4	(0.4,0.5)
Neural/mixed neuronal glial cells	34	4.7	0.4	(0.3,0.5)
Diffuse astrocytoma	32	6.1	0.4	(0.2,0.5)
Oligoastrocytic tumors	32	5.3	0.4	(0.2,0.5)
Pilocytic astrocytoma	29	4.5	0.3	(0.2,0.4)
Ependymal tumor	28	5.3	0.3	(0.2,0.4)
Anaplastic astrocytoma	26	3.2	0.3	(0.2,0.4)
<b>30-39:</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Meningioma	251	27.9	2.9	(2.5,3.3)
Pituitary tumors	161	15.8	1.9	(1.6,2.1)
Nerve sheath tumors	84	8.3	1.0	(0.8,1.2)
Glioblastoma	71	7.7	0.8	(0.6,1.0)
Oligoastrocytic tumors	53	6.1	0.6	(0.4,0.8)
Anaplastic astrocytoma	41	4.8	0.5	(0.3,0.6)
Ependymal tumor	37	3.5	0.4	(0.3,0.6)
Diffuse astrocytoma	36	4.8	0.4	(0.3,0.5)
Oligodendroglioma	32	3.7	0.4	(0.2,0.5)
Other meningeal lesions	22	2.6	0.2	(0.1,0.4)
<b>40-49:</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Meningioma	619	34.0	6.2	(5.7,6.7)
Glioblastoma	263	15.8	2.6	(2.3,2.9)
Pituitary tumors	253	12.7	2.5	(2.2,2.8)
Nerve sheath tumors	211	11.5	2.1	(1.8,2.4)
Ependymal tumor	61	3.7	0.6	(0.5,0.8)
Oligodendroglioma	50	3.0	0.5	(0.4,0.6)
Anaplastic astrocytoma	48	2.6	0.5	(0.3,0.6)
Diffuse astrocytoma	46	3.1	0.5	(0.3,0.6)
Oligoastrocytic tumors	43	2.0	0.4	(0.3,0.6)

Anaplastic oligodendroma	29	1.5	0.3	(0.2,0.4)
<b>50-59</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Meningioma	971	38.2	10.8	(10.0,11.4)
Glioblastoma	576	23.8	6.4	(5.9,6.9)
Pituitary tumors	311	10.9	3.4	(3.1,3.8)
Nerve sheath tumors	267	9.1	3.0	(2.6,3.3)
Lymphomas	60	2.5	0.7	(0.5,0.8)
Anaplastic astrocytoma	55	2.5	0.6	(0.4,0.8)
Oligoastrocytic tumors	46	1.9	0.5	(0.4,0.7)
Ependymal tumor	42	1.5	0.5	(0.3,0.6)
Oligodendroglioma	35	1.4	0.4	(0.3,0.5)
Diffuse astrocytoma	32	1.4	0.4	(0.2,0.5)
<b>60-69</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Meningioma	1091	41.9	18.4	(17.2,19.4)
Glioblastoma	695	26.4	11.7	(10.8,12.5)
Pituitary tumors	231	8.0	3.9	(3.4,4.4)
Nerve sheath tumors	204	7.9	3.4	(3.0,3.9)
Lymphomas	109	3.7	1.8	(1.5,2.2)
Anaplastic astrocytoma	61	2.2	1.0	(0.8,1.3)
Neoplasm, NOS	48	2.0	0.8	(0.6,1.0)
Ependymal tumor	35	1.4	0.6	(0.4,0.8)
Diffuse astrocytoma	29	1.2	0.5	(0.3,0.7)
Oligoastrocytic tumors	23	0.8	0.4	(0.2,0.5)
<b>70-79</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Meningioma	909	42.0	25.1	(23.4,26.7)
Glioblastoma	624	29.9	17.2	(15.8,18.5)
Pituitary tumors	149	6.1	4.1	(3.5,4.8)
Nerve sheath tumors	97	4.2	2.7	(2.1,3.2)
Lymphomas	95	4.7	2.6	(2.1,3.1)
Neoplasm, NOS	67	4.1	1.9	(1.4,2.3)
Anaplastic astrocytoma	45	2.2	1.2	(0.9,1.6)
Diffuse astrocytoma	29	1.7	0.8	(0.5,1.1)
Glioma malignant, NOS	29	1.4	0.8	(0.5,1.1)
Ependymal tumor	17	0.7	0.5	(0.2,0.7)
<b>80+</b>	<b>Count</b>	<b>% Age Group</b>	<b>Rate*</b>	<b>95% CL+</b>
Meningioma	916	46.8	32.5	(30.3,34.5)
Glioblastoma	366	20.3	13.0	(11.6,14.3)
Neoplasm, NOS	267	16.0	9.5	(8.3,10.5)
Lymphomas	77	3.9	2.7	(2.1,3.3)
Pituitary tumors	70	3.8	2.5	(1.9,3.1)
Nerve sheath tumors	66	3.1	2.3	(1.8,2.9)
Glioma malignant, NOS	48	2.8	1.7	(1.2,2.2)
Anaplastic astrocytoma	20	1.1	0.7	(0.4,1.0)
Diffuse astrocytoma	12	0.6	0.4	(0.2,0.7)
Other meningeal lesions	5	0.4	0.2	(0.0,0.3)

-\*Rates are age-specific per 100,000. +-95% confidence limits for the rate.

## **APPENDIX B: Brain Tumor Incidence and Mortality Codes:**

Brain tumor types are based on the site in the brain and the histology (cell and tissue structure). The histology groupings for this report were based on definitions by the Central Brain Tumor Registry of the United States (CBTRUS). CBTRUS focuses on providing quality statistical data on brain and CNS cases in the United States. The data come from the National Program of Cancer Registries (NPCR) and SEER. The following details the CBTRUS primary site and histology definitions for brain tumors in this report:

### **Primary Site:**

### **Site Code:**

Cerebral meninges	C70.0
Spinal meninges	C70.1
Meninges, NOS	C70.9
Cerebrum	C71.0
Frontal Lobe	C71.1
Temporal Lobe	C71.2
Parietal Lobe	C71.3
Occipital Lobe	C71.4
Ventricle, NOS	C71.5
Cerebellum, NOS	C71.6
Brain Stem	C71.7
Overlapping Lesion of Brain	C71.8
Brain, NOS	C71.9
Spinal Cord	C72.0
Cauda Equina	C72.1
Olfactory Nerve	C72.2
Optic Nerve	C72.3
Acoustic Nerve	C72.4
Cranial Nerve, NOS	C72.5
Overlapping Lesion of Brain/CNS	C72.8
Nervous System, NOS	C72.9
Pituitary Gland	C75.1
Craniopharyngeal Duct	C75.2
Pineal Gland	C75.3

### **Brain Tumor:**

### **Histology Codes:**

pilocytic astrocytoma	9421
diffuse astrocytoma	9400,9410,9411,9420
anaplastic astrocytoma	9401
unique astrocytoma variants	9381,9384,9424
glioblastoma	9440,9441,9442
ependymal tumor	9383,9391,9392,9393,9394

glioma malignant, NOS	9380
embryonal tumors	8963,9364,9470,9471,9472,9473, 9474 9480,9490,9500,9501,9502,9508
nerve sheath tumors	9540,9541,9550,9560,9561,9570,9571
meningioma	9530,9531,9532,9533,9534,9537,9538,9539
lymphomas	9590,9591,9596,9650,9651,9652, 9653,9654,9655,9659,9661,9662, 9663,9664,9665, 9667,9670,9671, 9673,9675, 9680,9684,9687,9690,9691, 9695,9698,9699,9701,9702,9705,9714,9719, 9728,9729
germ cell tumors	8020,8440,9060,9061,9064,9065, 9070,9071,9072,9080,9081,9082, 9083,9084,9085,9100,9101
pituitary tumors	8040,8140,8146,8246,8260,8270,8271, 8272,8280,8281,8290,8300,8310,8323, 8334,9492,9582

#### **Brain Tumor ICD-10 Mortality Codes:**

Malignant neoplasm of the meninges (C70-C70.9)

Malignant neoplasm of brain (C71-C71.9)

Malignant neoplasm of spinal cord, cranial nerves, and other parts of the central nervous system (C72-C72.9)

Malignant neoplasm of pituitary gland (C75.1)

Malignant neoplasm of pineal gland (C75.3)

Benign neoplasm of the meninges (D32-D32.9)

Benign neoplasm of brain and other parts of the CNS (D33-D33.9)

Benign neoplasm of the pituitary gland (D35.2)

Benign neoplasm of the pineal gland (D35.4)