INTRODUCTION

Primary brain tumors include any tumors arising in the brain. Primary brain tumors can start from brain cells, meninges, nerves, or glands [1]. Although brain tumor is a rare disease, the incidence of brain tumors is gradually increasing worldwide due to the development of diagnostic technologies and the increased frequency of imaging tests [2-4]. The prognosis of malignant brain tumors is poor due to its histologic characteristics, however, some benign tumors are located in inoperable areas, and these tumors have similar bad prognosis and require the same economic burden as malignant brain tumors.

The Korea Central Cancer Registry (KCCR) started in 1980, and they collected malignant tumors only, excluding benign and borderline tumors. In order to collect benign and borderline brain tumors, the KCCR modified their registration guideline in corporation with the Brain Tumors Registration Committee of the Korean Brain Tumor Society in 2004, and started to register non-malignant brain tumors from year 2005 [5]. The scope of brain tumors included tumors of the
meninges, pituitary gland, pineal gland and nerves, as defined in the International Classification of Diseases for Oncology, third edition (ICD-O-3). The first epidemiologic article of primary brain and central nervous system (CNS) tumors of the year of 2005 was published in 2010 [6], and the second paper of year 2010 was published in 2013 [7].

Many registries, such as the Central Brain Tumor Registry of the United States (CBTRUS) and surveillance epidemiology and end results program in USA, collect and disseminate the epidemiology of brain tumor [3,8-12]. Due to increase of screening with imaging testing, the incidence of brain tumor is increasing and the frequency of tumor diagnosis is chang-

| Table 1. Incidence rates of primary brain and CNS tumors by histology and sex, Republic of Korea, 2013 |
|---|---|---|---|---|---|---|---|---|---|
| Histology | Male | Female | Total | | | | | | |
| | n | CR | ASR | n | CR | ASR | n | % | Age* |
|---|---|---|---|---|---|---|---|---|---|
| Tumors of neuroepithelial tissue | 848 | 3.35 | 2.98 | 761 | 3.01 | 2.98 | 1,609 | 13.6 | 52.0 |
| Pilocytic astrocytoma | 25 | 0.10 | 0.15 | 25 | 0.10 | 0.19 | 50 | 0.4 | 12.5 |
| Diffuse astrocytoma | 2 | 0.01 | 0.01 | 1 | 0.00 | 0.01 | 3 | 0.0 | 29.0 |
| Anaplastic astrocytoma | 54 | 0.21 | 0.18 | 40 | 0.16 | 0.11 | 94 | 0.8 | 53.0 |
| Unique astrocytoma variants | 18 | 0.07 | 0.07 | 16 | 0.06 | 0.08 | 34 | 0.3 | 30.5 |
| Astrocytoma, NOS | 65 | 0.26 | 0.22 | 45 | 0.18 | 0.14 | 110 | 0.9 | 47.5 |
| Glioblastoma | 344 | 1.36 | 0.99 | 285 | 1.13 | 0.78 | 629 | 5.3 | 61.0 |
| Oligodendroglioma | 47 | 0.19 | 0.15 | 40 | 0.16 | 0.12 | 87 | 0.7 | 47.0 |
| Anaplastic oligodendroglioma | 28 | 0.11 | 0.08 | 31 | 0.12 | 0.09 | 59 | 0.5 | 52.0 |
| Ependymoma/anaplastic ependymoma | 34 | 0.13 | 0.14 | 47 | 0.19 | 0.15 | 81 | 0.7 | 47.0 |
| Ependymoma variants | 11 | 0.04 | 0.04 | 15 | 0.06 | 0.05 | 26 | 0.2 | 47.0 |
| Mixed glioma | 25 | 0.10 | 0.08 | 22 | 0.09 | 0.07 | 47 | 0.4 | 44.0 |
| Glioma malignant, NOS | 84 | 0.33 | 0.32 | 76 | 0.30 | 0.25 | 160 | 1.4 | 50.0 |
| Choroid plexus | 9 | 0.04 | 0.06 | 11 | 0.04 | 0.05 | 20 | 0.2 | 33.0 |
| Neuroepithelial | 12 | 0.05 | 0.04 | 9 | 0.04 | 0.02 | 21 | 0.2 | 54.0 |
| Non-malignant and malignant neuronal/glia, neuronal and mixed | 51 | 0.20 | 0.21 | 54 | 0.21 | 0.26 | 105 | 0.9 | 29.0 |
| Pineal parenchymal | 13 | 0.05 | 0.05 | 9 | 0.04 | 0.03 | 22 | 0.2 | 37.5 |
| Embryonal/primitive/medulloblastoma | 26 | 0.10 | 0.21 | 35 | 0.14 | 0.30 | 61 | 0.5 | 5.0 |
| Tumors of cranial and spinal nerves | 674 | 2.67 | 1.95 | 780 | 3.09 | 2.10 | 1,454 | 12.3 | 54.0 |
| Nerve sheath, non-malignant and malignant | 674 | 2.67 | 1.95 | 780 | 3.09 | 2.10 | 1,454 | 12.3 | 54.0 |
| Other tumors of cranial and spinal nerves | 674 | 2.67 | 1.95 | 780 | 3.09 | 2.10 | 1,454 | 12.3 | 54.0 |
| Tumors of meninges | 996 | 3.94 | 2.77 | 3,485 | 13.79 | 8.36 | 4,481 | 37.9 | 61.0 |
| Meningioma | 954 | 3.77 | 2.61 | 3,455 | 13.67 | 8.26 | 4,409 | 37.3 | 61.0 |
| Other mesenchymal, non-malignant and malignant | 42 | 0.17 | 0.16 | 30 | 0.12 | 0.10 | 72 | 0.6 | 45.0 |
| Lymphomas and hemopoietic neoplasms | 124 | 0.49 | 0.34 | 97 | 0.38 | 0.25 | 221 | 1.9 | 63.0 |
| Lymphoma | 124 | 0.49 | 0.34 | 97 | 0.38 | 0.25 | 221 | 1.9 | 63.0 |
| Germ cell tumors, and cysts | 92 | 0.36 | 0.48 | 35 | 0.14 | 0.18 | 127 | 1.1 | 18.0 |
| Germ cell tumors, cysts and heterotopias | 92 | 0.36 | 0.48 | 35 | 0.14 | 0.18 | 127 | 1.1 | 18.0 |
| Tumors of sellar region | 911 | 3.60 | 2.68 | 1,366 | 5.40 | 4.31 | 2,277 | 19.3 | 50.0 |
| Pituitary | 835 | 3.30 | 2.42 | 1,291 | 5.11 | 4.05 | 2,126 | 18.0 | 50.0 |
| Craniopharyngioma | 76 | 0.30 | 0.26 | 75 | 0.30 | 0.26 | 151 | 1.3 | 45.0 |
| Local extensions from regional tumors | 6 | 0.02 | 0.02 | 10 | 0.04 | 0.03 | 16 | 0.1 | 44.5 |
| Chordoma/chondrosarcoma | 6 | 0.02 | 0.02 | 10 | 0.04 | 0.03 | 16 | 0.1 | 44.5 |
| Unclassified tumors | 735 | 2.91 | 2.36 | 907 | 3.59 | 2.57 | 1,642 | 13.9 | 53.0 |
| Hemangioma | 199 | 0.79 | 0.64 | 239 | 0.95 | 0.76 | 438 | 3.7 | 48.0 |
| Hemangioblastoma | 67 | 0.27 | 0.20 | 45 | 0.18 | 0.13 | 112 | 0.9 | 48.5 |
| Neoplasm, unspecified | 457 | 1.81 | 1.48 | 613 | 2.43 | 1.64 | 1,070 | 9.0 | 56.5 |
| All others | 12 | 0.05 | 0.05 | 10 | 0.04 | 0.04 | 22 | 0.2 | 55.0 |
| Total | 4,386 | 17.34 | 13.58 | 7,441 | 29.44 | 20.49 | 11,827 | 100.0 | 56.0 |

*Median age at diagnosis. CR, crude rate; ASR, age-standardized rate; NOS, not otherwise specified; CNS, central nervous system
Brain Tumors in Republic of Korea, 2013

Results with time, so the recent changes would be reflected in this paper. This report aims to provide the updated nationwide brain tumor incidence in the Republic of Korea.

MATERIALS AND METHODS

Brain tumor registration

A total of 11,827 brain and CNS patients were registered in 2013 from 396 hospitals. Basic information such as the demographic characteristics of patients, date of diagnosis, tools of diagnosis, topography, and histological type according to the ICD-O-3 were collected by the KCCR [1].

Data processing

Primary brain and CNS tumors with the following ICD-O-3 codes were included in the analysis: brain (C71.0–C71.9), meninges (C70.0–C70.9), spinal cord, cranial nerves and other parts of the CNS (C72.0–C72.9), and pituitary gland, craniohypophyseal duct and pineal gland (C75.1–C75.3). Their histology code was also classified by the ICD-O-3, which are divided into 3 groups: benign, uncertain whether benign or malignant (borderline), and malignant.

Histology groupings were based on the classification of the CBTRUS [3]. These groupings were broadly based on the World Health Organization categories for brain tumors. Unclassified tumors include unspecified neoplasms and all other tumors. Unspecified neoplasms refer to cases registered based on death certificates only. The tumors which classified into all other tumors were tumors that did not meet the CBTRUS criteria.

The population size used as a denominator to calculate cancer incidence was the mid-year population on 1 July 2013 with modification of the registered population released annually from the Statistics Korea [13]. Childhood tumors were defined as those diagnosed in patients less than 19 years of age.

Statistical analysis

Incidence measures the occurrence of newly diagnosed cases of disease. Crude rate is the rate of disease in an entire population and it is frequently adjusted for age to age-standardized rate to a common standard population, which allows for comparison of rates across different countries with different age structures. We used Segi’s world standard population as a standard population in this report [14].

RESULTS

Overall incidence

There were 11,827 newly diagnosed brain tumors from a population of 50.6 million in 2013 (Table 1). The overall crude rate of brain tumors was 23.39 per 100,000 person-years in 2013.

The incidence of meningiomas was over 3.5 times higher in females than in males. Nerve sheath tumors, pituitary tumors, and ependymomas were also more common in females. On the other hand, germ cell tumors, gliomas (except pilocytic astrocytoma), and lymphomas were more common in males. Unclassified tumors accounted for 13.9% of all CNS tumors. The number of histological confirmed cases were 5,649 (47.8%) (Table 2). Pituitary tumors and nerve sheath tumors, accounted for 19.9% and 13.8% of all histologically confirmed tumors, respectively.

Incidence according to tumor biological behavior

The overall incidence according to biological behavior is shown in Fig. 1. Tumors classified as benign, uncertain, and malignant tumors accounted for 73.2%, 8.8%, and 18.0% of all primary CNS tumors, respectively. The incidence in males was 37.1% and the incidence in females was 62.9%. Benign tumors developed nearly twice more frequently in females than in males (M:F=2,786/5,877). In contrast, the incidences of borderline tumors were noted to be similar.

Distribution of tumors according to originating site

The incidence according to the originating site is shown in

Table 2. The numbers of total and histologically confirmed cases by histological group, Republic of Korea, 2013

| Histological group                                      | Total  | Histology confirmed |
|----------------------------------------------------------|--------|---------------------|
| Meningioma                                               | 4,409  | 1,708               |
| Glioma                                                   | 1,506  | 1,235               |
| Pituitary tumor                                           | 2,126  | 1,126               |
| Nerve sheath tumor                                       | 1,454  | 780                 |
| Lymphoma                                                 | 221    | 197                 |
| Germ cell tumors, cysts and heterotopias                 | 127    | 94                  |
| Craniohypophysealoma                                     | 151    | 100                 |
| Other mesenchymal, non-malignant and malignant            | 72     | 49                  |
| Embryonal/primitive/medulloblastoma                      | 61     | 59                  |
| Hemangioma                                               | 438    | 110                 |
| Choroid plexus                                           | 20     | 13                  |
| Choroid/chondrosarcoma                                   | 16     | 11                  |
| Neoplasm, unspecified                                    | 1,070  | 58                  |
| All others                                                | 156    | 109                 |
| Total                                                    | 11,827 | 5,649               |
Fig. 2. Meninges (35.2%) were the most common site of primary brain tumors, followed by the brain parenchyma (29.0%), sellar region (21.1%), and cranial and spinal nerves (14.7%). Tumors of the meninges developed more than 3 times frequently in females (Fig. 2). The sellar region tumors showed 1.5 times incidence of males than females. The other sites showed no significant differences in incidence according to sex. The overall incidence of primary brain tumors increased with age until the sixth decade. The incidence of each site specific tumor according to age is shown in Fig. 3. Tumors...
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Fig. 4. Distribution of brain and CNS tumors according to the histology, Republic of Korea, 2013. NOS, not otherwise specified; CNS, central nervous system.

Fig. 5. Incidence according to sex and histology, Republic of Korea, 2013. NOS, not otherwise specified.
of the brain parenchyma reached a peak in the sixth decade. Tumors of the meninges seldom occurred in childhood, the incidence of which increased from the third decade and peaked in the sixth decade. Tumors of the nerves peaked in the sixth decade. Sellar tumors increased rapidly in late adolescents and peaked in the sixth decade, which decreased thereafter.

**Incidence according to specific histology**

Distribution of the tumors according to histology is shown in Fig. 4 and 5. Histologically, tumors of the meninges were the most common (37.9%), followed by tumors of the sellar region (19.3%) and neuroepithelial tumors (13.6%). Neuroepithelial tumors of neuroepithelial tissue were composed of astrocytic tumors, oligodendrogial tumors, ependymal tumors, choroid plexus tumors, pineal region tumors, and embryonal tumors. Most of the neuroectodermal tumors were gliomas (93.4%), which accounted for 12.7% of all primary brain tumors. Glioblastomas accounted for 5.3% of all tumors and 41.8% of all

| Table 3. The numbers of total and histologically confirmed cases by histological type in gliomas, Republic of Korea, 2013 |
|---------------------------------------------------------------|
| **Histological group in gliomas** | **Total** | **Histology confirmed** |
| | n (%) | n (%) |
| Glioblastoma | 629 (41.8) | 570 (46.2) |
| Astrocytoma, NOS | 110 (7.3) | 89 (7.2) |
| Anaplastic astrocytoma | 94 (6.2) | 88 (7.1) |
| Pilocytic astrocytoma | 50 (3.3) | 48 (3.9) |
| Ependymoma/anaplastic ependymoma/ependymoma variants | 107 (7.1) | 100 (8.1) |
| Oligodendrogioma | 87 (5.8) | 83 (6.7) |
| Anaplastic oligodendroglioma | 59 (3.9) | 58 (4.7) |
| Glioma malignant, NOS | 160 (10.6) | 32 (2.6) |
| Neuroepithelial | 21 (1.4) | 12 (1.0) |
| Mixedglioma | 47 (3.1) | 45 (3.6) |
| Pilocytic astrocytoma variants | 34 (2.3) | 23 (1.9) |
| Prottoplasmic & fibrillary astrocytoma | 3 (0.2) | 3 (0.2) |
| Non-malignant and malignantneuronal/glial, neuronal and mixed | 105 (7.0) | 84 (6.8) |
| **Total** | 1,506 (100.0) | 1,235 (100.0) |

NOS, not otherwise specified

| Table 4. Incidence rates of primary CNS tumors by histology and sex in childhood (ages 0–19), Republic of Korea, 2013 |
|---------------------------------------------------------------|
| **Histology** | **Male** | **Female** | **Total** |
| | n | CR | ASR | n | CR | ASR | n | CR | ASR |
| Tumors of neuroepithelial tissue | 113 | 1.98 | 2.09 | 110 | 2.09 | 2.27 | 223 | 2.03 | 2.18 |
| Pilocytic astrocytoma | 15 | 0.26 | 0.28 | 21 | 0.40 | 0.43 | 36 | 0.33 | 0.35 |
| Anaplastic astrocytoma | 5 | 0.09 | 0.10 | 2 | 0.04 | 0.04 | 7 | 0.06 | 0.07 |
| Astrocytoma, NOS | 6 | 0.10 | 0.10 | 4 | 0.08 | 0.07 | 10 | 0.09 | 0.09 |
| Glioblastoma | 9 | 0.16 | 0.12 | 10 | 0.19 | 0.17 | 19 | 0.17 | 0.15 |
| Ependymoma/anaplastic ependymoma | 10 | 0.17 | 0.19 | 3 | 0.06 | 0.05 | 13 | 0.12 | 0.12 |
| Glioma malignant, NOS | 14 | 0.24 | 0.28 | 9 | 0.17 | 0.20 | 23 | 0.21 | 0.24 |
| Non-malignant and malignantneuronal/glial, neuronal and mixed | 14 | 0.24 | 0.23 | 16 | 0.30 | 0.33 | 30 | 0.27 | 0.28 |
| Embryonal/primitive/medulloblastoma | 22 | 0.38 | 0.48 | 31 | 0.59 | 0.72 | 53 | 0.48 | 0.60 |
| Tumors of cranial and spinal nerves | 15 | 0.26 | 0.20 | 13 | 0.25 | 0.22 | 28 | 0.26 | 0.21 |
| Tumors of meninges | 14 | 0.24 | 0.22 | 14 | 0.27 | 0.24 | 28 | 0.26 | 0.23 |
| Lymphomas and hemopoietic neoplasms | 1 | 0.02 | 0.01 | 3 | 0.06 | 0.04 | 4 | 0.04 | 0.03 |
| Germ cell tumors, and cysts | 59 | 1.03 | 0.89 | 13 | 0.25 | 0.26 | 72 | 0.66 | 0.59 |
| Tumors of sellar region | 35 | 0.61 | 0.53 | 73 | 1.39 | 1.15 | 108 | 0.98 | 0.83 |
| Pituitary | 27 | 0.47 | 0.38 | 62 | 1.18 | 0.95 | 89 | 0.81 | 0.65 |
| Craniopharyngioma | 8 | 0.14 | 0.15 | 11 | 0.21 | 0.20 | 19 | 0.17 | 0.18 |
| Local extensions from regional tumors | - | - | - | - | - | - | - | - | - |
| Unclassified tumors | 64 | 1.12 | 1.09 | 51 | 0.97 | 0.97 | 115 | 1.05 | 1.03 |
| **Total** | 301 | 5.27 | 5.03 | 277 | 5.27 | 5.17 | 578 | 5.27 | 5.10 |

CR, crude rate; ASR, age-standardized rate; NOS, not otherwise specified; CNS, central nervous system
gliomas. Among histologically confirmed cases, glioblastomas accounted for 46.2% of all gliomas (Table 3).

**Childhood primary brain tumors according to histology**

Distribution of tumors according to histology in childhood is shown in Table 4 and Fig. 6.

Children numbering 578 under 19 years of age were diagnosed with brain tumors in 2013, and crude rates of primary brain tumors in children was 5.27 per 100,000 person-years. The incidence was slightly higher in females (5.17) than in males (5.03). The most common histology in children included neuroepithelial tumors, germ cell tumors, and tumors of the sellar region. Neuroepithelial tumors accounted for 38.6% of all tumors in children. Embryonal/primitive/medulloblastoma was the most common tumor among neuroepithelial tumors in children. Glioblastomas accounted for only 3.3% of all primary brain tumors in children.

**DISCUSSION**

This is the third nationwide report on primary brain and CNS tumors, encompassing benign, borderline, and malignant tumors in the Republic of Korea. Compared to two previous reports of 2005 and 2010, crude rates for brain and CNS tumors increased from 11.7 per 100,000 in 2005 [6], to 20.1 in 2010 [7], and 23.4 in 2013. Age-standardized rates also increased from 10.2 in 2015, to 15.7 in 2010, and 17.1 in 2010. The incidences of all histological types increased in 2013 compared to 2010, however, most of this increase was due to benign tumors, including tumors of the cranial nerves, meninges, and sellar. The increased frequency of MRI scans could be a main reason for benign tumors increase. Age-standardized rate of malignant brain tumors was 2.9 per 100,000, and slightly lower than the worldwide incidence rate (3.4 per 100,000), according to Globocan 2012 [15]. Among children, the age-standardized rate of brain tumors also increased from 3.72 in 2005 to 5.00 in 2010, and 5.10 in 2013.

In conclusion, we updated the nationwide statistics of brain and CNS tumors in the Republic of Korea. Updated incidence of brain tumors will help to assess disease burden, facilitate etiologic studies, and establish cancer prevention and control strategies.

**Conflicts of Interest**

The authors have no financial conflicts of interest.

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