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CASE REPORT

Malignant ganglioglioma: case report and review of literature

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Abstract We report a case of de novo malignant ganglioglioma. A 61-year-old male presented with a 12-day history of headaches and general malaise. Pre-operative magnetic resonance imaging revealed an irregular enhancing mass in the left temporal lobe with associated dural enhancement and subacute subdural hematoma. The findings at surgery were of a vascular tumor intimately involving the surrounding white matter, with central necrosis. Histological and immunohistochemical studies showed an anaplastic ganglioglioma with World Health Organization grade IV characteristics. Gangliogliomas of the central nervous system are rare and are typified by a pediatric predilection and indolent behavior. A review of the de novo anaplastic and malignant gangliogliomas is presented.

Keywords Ganglioglioma · Dural enhancement · Neuroepithelial tumor · Mixed glioneuronal tumor

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Introduction

Gangliogliomas account for only about 1% of all intracranial neoplasms. They are most common in children and young adults and the most frequent clinical presentation is with seizures. The typical ganglioglioma is a benign tumor with indolent behavior [World Health Organization (WHO) grade I]. Five percent of gangliogliomas are more aggressive (WHO grade III) and usually develop after radiotherapy for a benign ganglioglioma [1]. This paper describes the rare case of an individual over 60 years of age presenting with a malignant ganglioglioma (WHO grade IV) not related to prior radiotherapy or with previous diagnosis.

Case report

History and examination

A 61-year-old right-handed male presented with a 12-day history of constant frontal headache not relieved with over the counter analgesics. There was a history of dizzy spells, decreased appetite, generalized weakness and fatigue of several weeks duration. Family members had observed episodes during which the patient would stare blankly and would not respond to verbal or physical stimuli. These lasted 5–10 s, and were not associated with other seizure activity. His past medical history was unremarkable. He was a non-smoker who took no medications and had no allergies.

Physical examination showed that the patient was afebrile, alert and oriented. His speech was normal and he was neurologically intact.

Imaging

A non-contrast cranial computed tomographic (CT) scan revealed an ill defined, left temporal, intra-axial mass with surrounding edema and mass effect. A left convexity subacute subdural hematoma was present. A magnetic resonance imaging (MRI) scan showed a left temporal mass that was hypointense on T1- and hyperintense on T2-weighted images (Fig. 1). There was surrounding hyperintensity on T2 and fluid attenuated inversion recovery images. Administration of gadolinium resulted in irregular enhancement with a non-enhancing central region. The mass abutted on the dura and there was associated dural enhancement and a subdural fluid collection.

Management

The patient was placed on phenytoin and dexamethasone. The headaches improved. The differential diagnosis included a primary high-grade astrocytic tumor, metastatic tumor or a non-neoplastic lesion such as cerebral abscess. He underwent a left pterional craniotomy and gross total resection of the mass. At surgery there was chronic subdural hematoma fluid. The tumor was adherent to the dura and fungated out of the surface of the temporal lobe. While the superficial aspects had a well defined plane between the tumor and surrounding brain, the deeper aspects infiltrated the white matter. The tumor was very vascular. A frozen section of the tumor obtained intra-operatively was interpreted as showing glioblastoma, which was consistent with the preoperative diagnosis based on imaging.

Histopathology

Paraffin-embedded sections showed an infiltrating tumor with distinct populations of ganglion and glial cells. The neuronal nature of the large ganglion cells was confirmed by immunoreactivity to anti-Hu, synaptophysin, and neurofilament. These cells had vesicular nuclei containing prominent nucleolus and ample basophilic cytoplasm. Ganglion cells showed irregular, tight clustering and were often bi- and trinucleated. The glial cell population was characterized by smaller, irregular oval nuclei, and eosinophilic cytoplasm drawn into processes. Their astrocytic

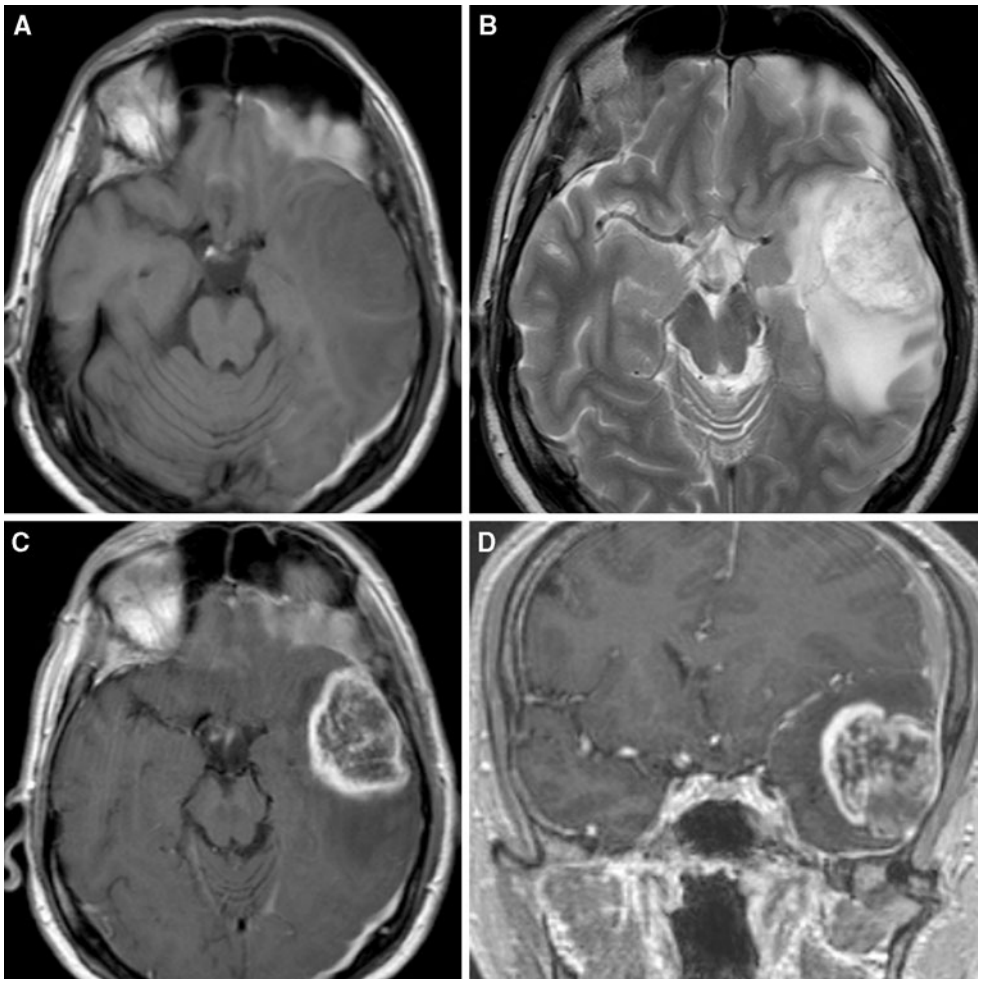

Fig. 1 Magnetic resonance images showing a left temporal lobe mass and subacute subdural hematoma. T1 (**a**) and T2 (**b**) axial images showed a dural-based mass isointense to brain on T1 and hyperintense on T2. Axial (**c**) and coronal (**d**) gadolinium-enhanced images showed an irregularly enhancing mass in the left temporal lobe with associated surrounding hypointensity. The lesion abutted on the dura and there was enhancement of the dura and associated subacute subdural hemorrhage (**d**)

nature was confirmed by positive immunostaining for glial fibrillary acidic protein (GFAP). The glial cells exhibited malignant features, consistent with a glioblastoma, including necrosis, high mitotic rate, abnormal mitoses, pseudopalisading and microvascular proliferation. The Ki-67 labeling index was 40–50% in the areas of maximal activity (Fig. 2). The diagnosis was anaplastic ganglioglioma (WHO grade IV).

Postoperative course

The patient remained neurologically intact postoperatively and was discharged home 4 days after surgery. He underwent radiotherapy that consisted of 3750 centiGray (cGy) administered in 15 fractions over 3 weeks by parallel opposed lateral brain ports followed by MRI-based conformal boost of 1750 cGy in 7 fractions to a selected isodose surface around the tumor. He received concomitant low-dose temozolamide chemotherapy for 2 months followed by six cycles of adjuvant temozolomide given once a month. Fifteen months after surgery, MRI showed disease progression and carmustine monotherapy was initiated. This regimen was complicated by myelotoxicity. He was then started on etoposide, which produced similar side effects. Twenty-nine months after diagnosis the patient presented with weakness and decreased level of consciousness. Investigations showed further disease progression with a recurrent enhancing mass at the site of the initial surgery. No treatment was administered and the patient died.

Discussion

Gangliogliomas account for about 1% of all intracranial neoplasms [2, 3]. The typical ganglioglioma is a benign, calcified tumor in the temporal lobe of a child with seizures [4]. The prognosis is favorable with over 93% 5-year survival in one series [5] and 98% 7.5-year survival among 184 supratentorial cases in another [2].

Gangliogliomas are defined pathologically by neoplastic astrocytes and neurons [6]. Usually the astrocytes are relatively benign and the tumor is classified as World Health

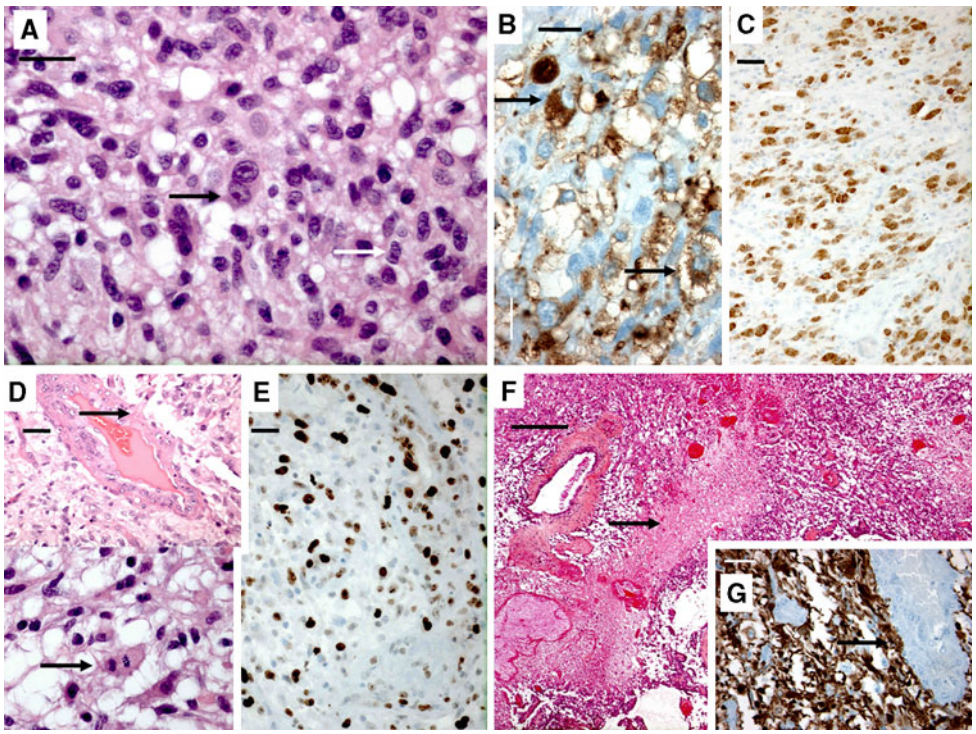

Fig. 2 Histopathology. The tumor had fine fibrillary (neuropil) background and was composed of two cell populations (**a**): glial cells (*white arrow*) and neoplastic neurons that were often binucleated (*black arrow*, hematoxylin and eosin, scale bar 25 μm). Synaptophysin immunostaining labeled the perikarya of ganglion cells, indicating their differentiated neuronal nature (**b**, scale bar 25 μm). Numerous cells contained HU immunoreactivity, demonstrating their neuronal character (**c**, scale bar 50 μm). Mitotic figures (*arrows*) were abundant, and some (*upper arrow*) were atypical (**d**, hematoxylin and eosin, scale bar 25 μm). Immunoreactivity to Ki-67 showed a high proliferation index (**e**, scale bar 50 μm). Numerous areas of necrosis were seen (**f**, hematoxylin and eosin, scale bar 400 μm). There was immunoreactivity to GFAP as well, demonstrating the glial component of the tumor (**g**). The unstained vessel on the right shows microvascular proliferation (scale bar 50 μm)

Organization (WHO) grade I or II. Some gangliogliomas, however, show anaplastic features and are considered WHO grade III (anaplastic ganglioglioma). Rarely, a newly diagnosed tumor may contain areas with mitotic activity, necrosis and microvascular proliferation that are indistinguishable from glioblastoma. These are typically classified as WHO grade IV gangliogliomas with glioblastoma changes in the glial component, or malignant gangliogliomas, as seen in the present case. Blumcke and Wiestler considered atypical gangliogliomas (WHO grade II) as tumors with cellular atypia (increased cellularity or nuclear pleomorphism in the glial component), prominent microvascular proliferation and a MIB-1 labeling index of >5%) [7]. Anaplastic gangliogliomas (WHO grade III) were required to have necrosis. Anaplasia may be present de novo or be found in recurrent gangliogliomas, usually after radiation and/or chemotherapy [1, 8].

Most commonly the astrocyte component of the tumor is anaplastic or malignant and the neuronal component is relatively benign [9]. Cases with malignant neuronal and astrocyte components presenting either de novo [10], after recurrence without radiation therapy [11] or after radiation treatment are extremely rare [12, 13]. Other variants occur, such as anaplastic oligodendroglial differentiation [14], combination of malignant meningioma and anaplastic ganglioglioma [15], anaplastic ganglioglioma with a sacroma component [16] and secondary appearance of neuroblastoma components [17].

Some case series report on the incidence of anaplastic gangliogliomas de novo and on followup. Among 184 patients with supratentorial gangliogliomas 1 (0.5%) was a de novo anaplastic tumor and 1 recurrent tumor was anaplastic [2]. Pathology review of 326 cases reported 17 (5%) were anaplastic, although this may have included de novo and recurrent previously treated tumors [7]. The cases in this series probably overlap with other series [4, 18]. In other series, 2 of 58 (2%) [5], 1 of 12 (8%) [19], 1 of 17 (6%) [20], 1 of 60 (1%) [21] and 1 of 18 (6%) [22] were WHO grade III at initial diagnosis [5].

Literature review found 31 anaplastic gangliogliomas not related to prior radiotherapy or previous diagnosis (Table 1) [2, 4, 5, 8, 10, 13, 16, 18–36]. This does not include a case described by Kernohan et al., that may be a anaplastic ganglioglioma or a giant cell glioblastoma [37]. A patient with a ganglioglioma with an anaplastic oligodendroglioma component and a case of a malignant meningioma with an anaplastic ganglioglioma were excluded [14, 15]. Five of these cases meet the WHO criteria for diagnosis as malignant ganglioglioma (grade IV), only 3 were patients over age 60, as in the present case [32, 34, 35]. The table summarizes cases of de novo malignant gangliogliomas identified in the literature, including the case described here.

Classification of some cases is uncertain. For example, some reported cases were not anaplastic at presentation but underwent only biopsy or subtotal resection and at recurrence after radiation had only focal areas of anaplasia [36, 38]. There are cases also of more anaplastic behavior or where there is molecular evidence for anaplasia in an otherwise benign appearing WHO grade I or II ganglioglioma [39].

There are too few reported cases of denovo anaplastic gangliogliomas to be amenable to statistical analysis but in general, review of these patients suggest the average age of patients with anaplastic gangliogliomas is older than those with typical ganglioglioma. Blumcke et al. and Schittenhelm et al. reported the average age of patients with WHO grade III anaplastic ganglioglioma was 35 years, WHO grade IV tumors was 32 years and WHO grade I and II tumors was 22–24 years [7, 34]. There is no marked gender predilection for any grade of these tumors. The anaplastic tumors are less likely to be radiologically like the typical well-defined, cystic, calcified temporal WHO grade I ganglioglioma [8]. Many anaplastic gangliogliomas were cystic, irregularly enhancing masses with edema and an appearance consistent with a malignant glioma. Only 8 of 27 (30%) were located in the temporal lobe, which is consistent with other reports that only 46% of anaplastic gangliogliomas were located in the temporal lobe compared to 71–80% of grade I and II tumors [7]. The remainder was in other areas of the cerebral hemispheres or unusual locations such as the brainstem or spinal cord [7].

There are few reports of MR spectroscopy of anaplastic gangliogliomas [10]. MR spectroscopy of WHO grade I and II gangliogliomas showed reduced ratios of choline to creatine complex and N-acetyl aspartate to creatine complex with increased choline to *N*-acetyl aspartate ratios compared with contralateral normal areas [40]. These findings were consistent with neoplasia with some neuronal component. Positron emission tomography with ^{18}F-fluorodeoxyglucose of anaplastic gangliogliomas is not reported but findings for WHO grade I gangliogliomas shows they are usually hypometabolic, while 99 m technetium hexamethyl propyleneamine oxime single photon emission CT demonstrates tumor hypo- or isoperfusion [40].

The case described here was dural-based and superficially resembled a meningioma. Siddique and coworkers reported a patient with a tumor that looked like a meningioma and was a ganglioglioma [41]. There also is one case of a 45-year-old man who had a long history of seizures and a calcified isodense parietal mass who presented 5 years later with a dural-based mass at the site of the prior calcification that pathologically was a malignant meningioma with rhabdoid features combined with an anaplastic ganglioglioma [15]. The tumor was resected and treated with radiation therapy but the patient died 4 months later with systemic metastases.

Table 1 Anaplastic ganglioglioma cases not related to previous radiation therapy or prior diagnosis

Author	Age	Gender	Clinical presentation	Imaging findings	Pathology	Treatment	Outcome
Hall et al. [28]	6 months	Female	Increased head circumference	Calcified, enhancing cystic temporal lobe mass on CT scan, no MRI	NSE-positive ganglion cells, GFAP-positive astrocytes, areas of necrosis, calcification and vascular proliferation, probably a WHO grade IV tumor	Surgery	No recurrence at 12 months after diagnosis
Rodewald et al. [23]	17 years, Martin Bell syndrome	Male	Paraparesis	Thoracic intradural extramedullary mass on myelography	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Recurrent at 1 year, undergoing further treatment
Haddad et al. [20]	10 years	Male	Strabismus	Cervicomedullary junction mass	Ganglioglioma with anaplastic astrocytoma	Surgery, radiation	Died 1.5 years after diagnosis
Lang et al. [5]	Not reported	Not reported	Not reported	Cerebral hemisphere	WHO grade III (anaplastic) ganglioglioma	Surgery, radiation, chemotherapy	Not reported
Lang et al. [5]	Not reported	Not reported	Not reported	Spinal cord	WHO grade III (anaplastic) ganglioglioma	Surgery, radiation, chemotherapy	Not reported
Prayson et al. [21]	Not reported	Not reported	Not reported	Not reported	WHO grade III (anaplastic) ganglioglioma	Not reported	Died of recurrent tumor
Campos et al. [25]	13 years	Male	Seizures	Cystic enhancing temporal lobe mass on CT and MRI	WHO grade III (anaplastic) ganglioglioma	Surgery	No recurrence at 6 months after diagnosis
Isimbaldi et al. [19]	18 years	Female	Seizures, increased intracranial pressure	Enhancing temporal lobe mass on CT	WHO grade IV ganglioglioma with glioblastoma	Surgery, radiation	Alive with stable disease 5.5 years after diagnosis
Hakim et al. [22]	45 years	Male	Seizures	Not reported	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Died 14 months after diagnosis
Nakajima et al. [13]	7 years	Female	Increased intracranial pressure	Cystic enhancing parietal mass, isointense on T1, hyperintense on T2	WHO grade III (anaplastic) ganglioglioma, MIB-1 8%	Surgery, chemotherapy, radiation	Died 15 months after diagnosis
Dash et al. [27]	6 years	Female	Increase intracranial pressure	Cystic enhancing frontal mass on CT	WHO grade IV ganglioglioma with glioblastoma	Surgery, chemotherapy, radiation	Died 18 months after diagnosis
Araki et al. [24]	53 years	Female	Seizures	Cystic enhancing frontal mass on MRI	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Died 26 months after diagnosis
Danjoux et al. [26]	26 years	Male	Seizures, acute hemorrhage	Hemorrhagic enhancing temporal lobe mass on CT	WHO grade III (anaplastic) ganglioglioma	Surgery, radiation	Died 2 months after diagnosis
Suzuki et al. [16]	59 years	Male	Focal neurological deficit	Cystic enhancing temporal lobe mass on MRI	WHO grade III (anaplastic) ganglioglioma with sarcomatous features	Surgery	Not reported

Table 1 continued

Author	Age	Gender	Clinical presentation	Imaging findings	Pathology	Treatment	Outcome
Nair et al. [33]	60 years	Male	Seizures	Cystic right parietal calcified enhancing mass on CT	WHO grade III (anaplastic) ganglioglioma, MIB-1 6%	Not reported	Not reported
Luyken et al. [2]	Not reported	Not reported	Not reported	Not reported	WHO grade III (anaplastic) ganglioglioma, MIB-1 6%	Surgery, radiation and/or chemotherapy	Alive 11 years after diagnosis
Matsuzaki et al. [32]	64 years	Female	Focal neurological deficit	Mixed intensity on T1 and T2 MRI, cystic enhancing cerebellopontine angle mass	WHO grade IV ganglioglioma with glioblastoma, MIB-1 50%	Surgery, radiation	Died 12 months after diagnosis
Mekni et al. [29]	25 years	Female	Increased intracranial pressure, neurofibromatosis type 1	Cystic enhancing cerebellar mass on CT	WHO grade IV ganglioglioma with glioblastoma	Surgery	Died 1 month after diagnosis
Karabekir et al. [30]	2 years	Female	Paraparesis	Solid intramedullary lower thoracic mixed intensity on T1, hyperintense on T2, enhancing mass	WHO grade III (anaplastic) ganglioglioma	Surgery, radiation	Alive with stable disease 22 months after diagnosis
Kang et al. [31]	45 years	Female	Headaches	Solid hypointense on T1, hyperintense on T2, enhancing frontal mass	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	No recurrence 35 months after diagnosis
Schittenhelm et al. [34]	77 years	Male	Seizures, focal neurological deficit	Cystic enhancing parietal mass on CT and RI	WHO grade IV ganglioglioma with small cell glioblastoma	Surgery, radiation	Stable 1 year after diagnosis
Rogojan and Olinici [35]	60 years	Male	Not reported	Not reported	WHO grade IV ganglioglioma with glioblastoma, MIB-1 29%	Not reported	Not reported
Karremann et al. [8]	16 years	Female	Seizures	Temporal lobe lesion	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Stable disease 25 months after diagnosis
Karremann et al. [8]	10 years	Female	Headaches	Cerebral hemisphere	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Complete remission at 42 months after diagnosis
Karremann et al. [8]	10 years	Female	Not reported	Spinal cord	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Stable disease 61 months after diagnosis
Karremann et al. [8]	2 years	Male	Seizures	Frontal lobe lesion	WHO grade III (anaplastic) ganglioglioma	Surgery	Complete remission at 31 months after diagnosis

Table 1 continued

Author	Age	Gender	Clinical presentation	Imaging findings	Pathology	Treatment	Outcome
Karremann et al. [8]	10 years	Male	Headaches	Cerebral hemisphere	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Died 6 months after diagnosis
Karremann et al. [8]	3 years	Male	Seizures	Frontal lobe lesion	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Complete remission at 44 months after diagnosis
Karremann et al. [8]	10 years	Male	Back pain, bladder dysfunction	Spinal cord	WHO grade III (anaplastic) ganglioglioma	Surgery, chemotherapy, radiation	Progressive disease 7 months after diagnosis
Karremann et al. [8]	14 years	Male	Vomiting, ataxia	Pons and 4th ventricle	WHO grade III (anaplastic) ganglioglioma	Surgery, radiation	Stable disease 8 months after diagnosis
Kawataki et al. [10]	34 years	Male	Seizures	Cystic enhancing temporal lobe mass on MRI	WHO grade III (anaplastic) ganglioglioma, neuronal component also malignant	Surgery, chemotherapy, radiation	Died 6 months after diagnosis

Histopathology of anaplastic gangliogliomas shows that the neuronal component is almost always benign and characterized by neoplastic neurons. The neuronal stem cell marker, CD34, is typically present in the neurons but this may be less common in anaplastic tumors [2]. There is usually immunoreactivity to synaptophysin and neurofilament [7]. The astrocyte component is malignant and GFAP- and vimentin-positive. The Ki-67 index usually is greater than 10% in the anaplastic areas, consistent with a malignant glial tumor [34].

Treatment for all grades of gangliogliomas is gross total resection when judged to be technically feasible without undue surgical risk. Adjuvant radiotherapy and/or chemotherapy are generally not recommended after gross or subtotal resection of WHO grade I and II gangliogliomas [42]. The indications for and timing of radiation therapy for anaplastic or malignant gangliogliomas are not well defined but would seem to be warranted at initial diagnosis [2, 5, 43]. Prognostic factors have been difficult to define using survival analysis due to small numbers of patients [2, 18, 40]. Some studies suggest favorable prognostic factors are temporal lobe location, long-standing epilepsy, gross total resection [2] and absence of cellular atypia [22]. 23 of 28 (82%) anaplastic gangliogliomas underwent surgery plus radiation and/or chemotherapy with 9 patients (32%) dead an average of 13 months after diagnosis. 12 patients were alive a mean of 37 months after diagnosis. Of 5 patients treated only with surgery, survival was not reported in one, was greater than 6 and 12 months in 2 and death in 1 month in the remainder (Table 1). This outcome is much worse than for WHO grade I and II tumors.

References

1. Rumana CS, Valadka AB (1998) Radiation therapy and malignant degeneration of benign supratentorial gangliogliomas. Neurosurgery 42:1038–1043
2. Luyken C, Blumcke I, Fimmers R, Urbach H, Wiestler OD, Schramm J (2004) Supratentorial gangliogliomas: histopathologic grading and tumor recurrence in 184 patients with a median follow-up of 8 years. Cancer 101:146–155
3. Mclendon RE, Enterline DS, Tien RD, Thorstad WL, Bruner JM (1998) Tumors of central neuroepithelial origin. In: Bigner DD, Mclendon RE, Bruner JM (eds) Russell and Rubinstein's pathology of tumors of the nervous system. Arnold Publishing, London, pp 308–309
4. Zentner J, Wolf HK, Ostertun B, Hufnagel A, Campos MG, Solymosi L, Schramm J (1994) Gangliogliomas: clinical, radiological, and histopathological findings in 51 patients. J Neurol Neurosurg Psychiatry 57:1497–1502
5. Lang FF, Epstein FJ, Ransohoff J, Allen JC, Wisoff J, Abbott IR, Miller DC (1993) Central nervous system gangliogliomas. Part 2. Clinical outcome. J Neurosurg 79:867–873
6. Nelson JS, Burger JM, Wiestler OD, VandenBerg SR (2000) Ganglioglioma and gangliocytoma. In: Kleihues P, Cavenee WK

(eds) World Health Organization Classification of Tumours. Pathology and genetics of tumours of the nervous system. IARC Press, Lyon, pp 96–98
7. Blumcke I, Wiestler OD (2002) Gangliogliomas: an intriguing tumor entity associated with focal epilepsies. J Neuropathol Exp Neurol 61:575–584
8. Karremann M, Pietsch T, Janssen G, Kramm CM, Wolff JE (2009) Anaplastic ganglioglioma in children. J Neurooncol 92:157–163
9. Kitano M, Takayama S, Nagao T, Yoshimura O (1987) Malignant ganglioglioma of the spinal cord. Acta Pathol Jpn 37:1009–1018
10. Kawataki T, Sato E, Sato T, Kinouchi H (2010) Anaplastic ganglioglioma with malignant features in both neuronal and glial components—case report. Neurol Med Chir (Tokyo) 50:228–231
11. Mittelbronn M, Schittenhelm J, Lemke D, Ritz R, Nagele T, Weller M, Meyermann R, Beschorner R (2007) Low grade ganglioglioma rapidly progressing to a WHO grade IV tumor showing malignant transformation in both astroglial and neuronal cell components. Neuropathology 27:463–467
12. Hirose T, Kannuki S, Nishida K, Matsumoto K, Sano T, Hizawa K (1992) Anaplastic ganglioglioma of the brain stem demonstrating active neurosecretory features of neoplastic neuronal cells. Acta Neuropathol 83:365–370
13. Nakajima M, Kidooka M, Nakasu S (1998) Anaplastic ganglioglioma with dissemination to the spinal cord: a case report. Surg Neurol 49:445–448
14. Allegranza A, Pileri S, Frank G, Ferracini R (1990) Cerebral ganglioglioma with anaplastic oligodendroglial component. Histopathology 17:439–441
15. Chau HL, Chan CM, Pong WM, Tan TC, Cheung JY, Chan SC (2001) Coexistence of malignant meningioma and anaplastic ganglioglioma. J Hong Kong Coll Radiol 4:297–301
16. Suzuki H, Otsuki T, Iwasaki Y, Katakura R, Asano H, Tadokoro M, Suzuki Y, Tezuka F, Takei H (2002) Anaplastic ganglioglioma with sarcomatous component: an immunohistochemical study and molecular analysis of p53 tumor suppressor gene. Neuropathology 22:40–47
17. David KM, de Sanctis S, Lewis PD, Noury AM, Edwards JM (2000) Neuroblastomatous recurrence of ganglioglioma. Case report. J Neurosurg 93:698–700
18. Wolf HK, Muller MB, Spanle M, Zentner J, Schramm J, Wiestler OD (1994) Ganglioglioma: a detailed histopathological and immunohistochemical analysis of 61 cases. Acta Neuropathol 88:166–173
19. Isimbaldi G, Sironi M, Tonnarelli GP, Roncoroni M, Declich P, Galli C (1996) Ganglioglioma: a clinical and pathological study of 12 cases. Clin Neuropathol 15:192–199
20. Haddad SF, Moore SA, Menezes AH, VanGilder JC (1992) Ganglioglioma: 13 years of experience. Neurosurgery 31:171–178
21. Prayson RA, Khajavi K, Comair YG (1995) Cortical architectural abnormalities and MIB1 immunoreactivity in gangliogliomas: a study of 60 patients with intracranial tumors. J Neuropathol Exp Neurol 54:513–520
22. Hakim R, Loeffler JS, Anthony DC, Black PM (1997) Gangliogliomas in adults. Cancer 79:127–131
23. Rodewald L, Miller DC, Sciorra L, Barabas G, Lee ML (1987) Central nervous system neoplasm in a young man with Martin-Bell syndrome—fra(X)-XLMR. Am J Med Genet 26:7–12
24. Araki M, Fan J, Haraoka S, Moritake T, Yoshii Y, Watanabe T (1999) Extracranial metastasis of anaplastic ganglioglioma through a ventriculoperitoneal shunt: a case report. Pathol Int 49:258–263
25. Campos MG, Zentner J, Ostertun B, Wolf HK, Schramm J (1994) Anaplastic ganglioglioma: case report and review of the literature. Neurol Res 16:317–320
26. Danjoux M, Sabatier J, Uro-Coste E, Roche H, Delisle MB (2001) Anaplastic temporal ganglioglioma with spinal metastasis. Ann Pathol 21:55–58
27. Dash RC, Provenzale JM, McComb RD, Perry DA, Longee DC, Mclendon RE (1999) Malignant supratentorial ganglioglioma (ganglion cell-giant cell glioblastoma): a case report and review of the literature. Arch Pathol Lab Med 123:342–345
28. Hall WA, Yunis EJ, Albright AL (1986) Anaplastic ganglioglioma in an infant: case report and review of the literature. Neurosurgery 19:1016–1020
29. Mekni A, Chelly I, Haouet S, Zitouna M, Kchir N (2006) Malignant cerebellar ganglioglioma. A case report and review of the literature. Neurochirurgie 52:119–122
30. Karabekir HS, Balci C, Tokyol C (2006) Primary spinal anaplastic ganglioglioma. Pediatr Neurosurg 42:374–378
31. Kang DH, Lee CH, Hwang SH, Park IS, Han JW, Jung JM (2007) Anaplastic ganglioglioma in a middle-aged woman: a case report with a review of the literature. J Korean Med Sci 22(Suppl):S139–S144
32. Matsuzaki K, Uno M, Kageji T, Hirose T, Nagahiro S (2005) Anaplastic ganglioglioma of the cerebellopontine angle. Case report. Neurol Med Chir (Tokyo) 45:591–595
33. Nair V, Suri VS, Tatke M, Saran RK, Malhotra V, Singh D (2004) Ganglioglomas: a report of five cases. Indian J Cancer 41:41–46
34. Schittenhelm J, Reifenberger G, Ritz R, Nagele T, Weller M, Pantazis G, Capper D, Beschorner R, Meyermann R, Mittelbronn M (2008) Primary anaplastic ganglioglioma with a small-cell glioblastoma component. Clin Neuropathol 27:91–95
35. Rogojan L, Olinici CD (2008) Ganglioglioma with glioblastoma component. Rom J Morphol Embryol 49:403–406
36. Wacker MR, Cogen PH, Etzell JE, Daneshvar L, Davis RL, Prados MD (1992) Diffuse leptomeningeal involvement by a ganglioglioma in a child. case report. J Neurosurg 77:302–306
37. Kernohan JW, Learmonth JR, Doyle JB (1932) Neuroblastomas and gangliocytomas of the central nervous system. Brain 55:287–310
38. Hirose T, Scheithauer BW, Lopes MB, Gerber HA, Altermatt HJ, VandenBerg SR (1997) Ganglioglioma: an ultrastructural and immunohistochemical study. Cancer 79:989–1003
39. Jay V, Squire J, Becker LE, Humphreys R (1994) Malignant transformation in a ganglioglioma with anaplastic neuronal and astrocytic components. Report of a case with flow cytometric and cytogenetic analysis. Cancer 73:2862–2868
40. Im SH, Chung CK, Cho BK, Wang KC, Yu IK, Song IC, Cheon GJ, Lee DS, Kim NR, Chi JG (2002) Intracranial ganglioglioma: preoperative characteristics and oncologic outcome after surgery. J Neurooncol 59:173–183
41. Siddique K, Zagardo M, Gujrati M, Olivero W (2002) Ganglioglioma presenting as a meningioma: case report and review of the literature. Neurosurgery 50:1133–1135
42. Selch MT, Goy BW, Lee SP, El-Sadin S, Kincaid P, Park SH, Withers HR (1998) Gangliogliomas: experience with 34 patients and review of the literature. Am J Clin Oncol 21:557–564
43. Liauw SL, Byer JE, Yachnis AT, Amdur RJ, Mendenhall WM (2007) Radiotherapy after subtotally resected or recurrent ganglioglioma. Int J Radiat Oncol Biol Phys 67:244–247