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THE BUTTERFLY TUMOURS

RADIOLOGICAL PATHOLOGY OF BUTTERFLY TUMOURS

Butterfly tumours are defined as tumours extending bilaterally (and forming bihemispheric mirror tumours) around the ventricular system like the wings of a butterfly. Butterfly tumours are formed by primary CNS lymphomas and diffuse astrocytomas. Central primary CNS Lymphomas start bilaterally in the centrifugal subependymal microvascular system then fungate centrifugally outward along the virchow robin spaces to form the characteristic butterfly periventricular tumours. On the other hand diffuse astrocytomas commonly start focally in one hemisphere then the astrocytoma tumor cells infiltrate locally between myelinated fibers in the nondestructive manner and gradually cross through the corpus callosum to the opposite hemisphere forming the characteristic butterfly gliomas. In this chapter we will talk about the radiological pathology of primary CNS lymphomas and diffuse astrocytomas and how these tumours progress to form the characteristic butterfly tumours.
Radiological pathology of primary CNS lymphomas

Primary CNS lymphoma is an uncommon disease that historically constituted approximately 1% of primary brain tumors. Sporadic disease is most common in older adults. With the advent of acquired immunodeficiency syndrome (AIDS)-associated lymphomas, there has been a marked increase in the number of cases, particularly in younger people, in whom the disease was previously rare. There has also been a significant increase in non-human immunodeficiency virus (HIV)-associated primary CNS lymphoma among older patients. A relationship between Epstein-Barr virus and HIV-associated lymphomas has been observed. The causes of sporadic cases and their increasing incidence in the nonimmunocompromised are unknown, but viral and environmental agents have been proposed as factors. Primary CNS lymphoma occurs throughout the brain, but it is characteristically periventricular. Sporadic cases tend to be limited to one or two sites, whereas AIDS-associated tumors are commonly multifocal.

The marked shrinkage of sporadic tumors on imaging studies after initiation of steroid therapy is almost diagnostic. The initial response to radiation is also gratifying. The tumors return within several months or with the cessation of steroids, however. Modern chemotherapy has resulted in a much improved prognosis for sporadic lymphomas, with a reported median survival of about 5 years. In contrast, AIDS-associated lymphomas

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respond only transiently to therapy, and most patients die within a year of diagnosis.

![Figure 2. Gross specimen showing the butterfly lesions characteristic of lymphomas and astrocytomas. The demonstrated lesion is a highly vascular non-Hodgkin lymphoma.](image)

Circumscribed lesions may have a gray, fleshy appearance similar to systemic lymphomas or may be soft, mottled, and otherwise indistinguishable from a high-grade astrocytoma. The borders are often vaguely defined. Some lesions produce architectural distortion without a definite mass.

The defining microscopic feature of primary CNS lymphoma is angiocentricity. Tumor cells surround and infiltrate the walls of small and medium-sized blood vessels. The lamellar arrangement of the perivascular tumor cells between layers of collagen creates an onion-skin or basket-weave appearance. The involvement of the blood vessels may be destructive, producing hemorrhage or infarcts. Lymphomas tend to spread in perivascular spaces along the Virchow-Robin space.

The microscopic correlates include large cells with pleomorphic nuclei and a high mitotic rate. Primary CNS lymphoma may be subclassified by the systems used for systemic lymphomas, but this does not add prognostic information.
Primary CNS lymphomas have a characteristic topographic brain localization as follows: 

- **Topographic localization of primary CNS lymphomas**

Lymphomas start either in the subependymal tissues and the periventricular gray matter and then fungate centrifugally outward into the periventricular white matter or spread subependymally to ensheathe the ventricular system (central periventricular). The second site is the cortico-meningeal site and the disease spreads either alongside the meninges or invades the brain parenchyma in a centripetal way. (peripheral corticomeningeal)

**TOPOGRAPHIC SUBTYPES OF PCNSL**

- **Central periventricular**: Starts either in the subependymal tissues or the periventricular gray matter and then fungates centrifugally outward into the periventricular white matter or spread subependymally to ensheathe the ventricular system, although it ultimately forms extensive periventricular butterfly fungative lesions or ensheathe the whole ventricular system, it shows little tendency to encroach upon the volume of the ventricular cavity.

- **Peripheral corticomeningeal**: The disease spreads either alongside the meninges or invades the brain parenchyma in a centripetal way. Corticomeningeal lymphomas are probably secondary CNS lymphoma that occur from spread of systemic disease to the CNS (non-Hodgkin's more common than Hodgkin's). Secondary lymphomas typically involve the leptomeninges, and CSF with parenchymal involvement is much less common. MR imaging findings include leptomeningeal/dural enhancement and hydrocephalus.

The topographic localization of primary CNS lymphomas are best explained by considering the cellular origin of lymphoma and the brain microvascular system.

PCNSL is derived from the microglial cells and was previously called microglioma. The microglial cells are more numerous in the cortical and the subcortical gray matter. (Thalamus and basal ganglia). The microglial cells are not of neural origin. They are derived from the blood monocytes and immigrate through the small perforating blood vessels to invade the neural tissue either from the pial or the subependymal arterial system. The microglial cells lies very close to the periadventitial spaces of the small penetrating blood vessels, They are phagocytic and function as macrophages. They represent a defense mechanism and are considered as a part of the reticuloendothelial system. To sum up the microglial cells and the penetrating blood vessels are very closely coupled together.

With regard to the brain microvascular system, 2 systems were described. The centrifugal subependymal system and the centripetal pial system. The centrifugal subependymal vascular system originates from the subependymal arteries which are terminal branches of the choroidal arteries, then extends centrifugally outward into the periventricular white matter. The centripetal pial vascular system originates from the pial arteries then extends
centripetally inward towards the ventricular system. As an artery penetrates the brain it carries a sheath of pia with it resulting in a potential perivascular space called Virchow-Robin space.\(^1\)

To put things together, it is possible to state that the malignant lymphoma cells (being derived from the microglial cells) originate primarily in the periadventitial spaces of either the subependymal or the pial vascular systems, then the lymphoma cells creep alongside the penetrating arteries either centrifugally outward from the subependymal system, or centripetally inward from the pial system. This view point is consistent with the pathological findings of marked perivascular cuffing by lymphoma cells and tendency to spread along Virchow-Robin spaces. This also should support the theory that CNS lymphomas arise from the periadventitial microglial cells of the penetrating arterioles.\(^1\)

It should also be pointed out that the subependymal spread of lymphoma that is observed in some cases most probably represent either spread alongside the subependymal arteriolar system or CSF seedling.\(^1\)

Table 1. Ways of spread of primary CNS lymphomas

<table>
<thead>
<tr>
<th>Ways of Spread</th>
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<tbody>
<tr>
<td>Lymphoma cells creep alongside the penetrating arteries in the Virchow Robin spaces either centrifugally outward from the subependymal system, or centripetally inward from the pial system. Infiltration along the meninges is common in corticomeningeal lymphomas.</td>
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<tr>
<td>CSF seedling</td>
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</table>

Historical terms for cerebral lymphomas such as microglioma arose at a time when the nature of the tumor cells was uncertain. Immunohistochemical stains have clarified the origin of primary cerebral lymphomas and also are important diagnostically. Reactivity for common leukocyte antigen is used to confirm lymphoid origin and often reveals much greater parenchymal infiltration by individual cells than is apparent on routine hematoxylin and eosin staining. By far, most cerebral lymphomas are B-cell neoplasms, and monoclonal reactivity for K or k light chain may be helpful diagnostically.\(^2,6,9,12\) T-cell lymphoma occurs only rarely.\(^9,11\)

Karyotype abnormalities found in CNS tumors are similar to those found in systemic lymphomas and involve structural alterations. Molecular studies have confirmed genetic lesions involving RAS genes, CDNK2A, CDNK2B, BCL2, BCL6, and MYCC.\(^13\)

An interesting side effect of the dramatic initial response to steroids is that biopsy specimens obtained after initiation of therapy may be devoid of identifiable tumor cells. The appearance of modest perivascular and parenchymal infiltrates of small T cells and white matter changes that include myelin breakdown, edema, and gliosis has been dubbed the sentinel lesion of primary CNS lymphoma.\(^18\)
NEUROIMAGING OF PRIMARY CNS LYMPHOMAS

Neuroimaging of primary CNS lymphomas is very complex, as one must observe (1) the site, (2) the precontrast CT density, (3) the MRI T2 signal intensity, (4) the pattern of contrast enhancement, (5) the rapid changes that take place over a very short time as primary CNS lymphomas are very dynamic tumours in so far as the local spread of the disease is concerned.

Table 2. Radiological parameters while inspecting a study for possible primary CNS lymphoma

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comment</th>
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</table>
| Site      | 1. Central periventricular  
2. Peripheral corticomeningeal |
| The precontrast CT density | Hyperdense on unenhanced CT studies |
| The MRI T2 signal intensity | Hypointense or isointense to gray matter on T2-weighted images |
| The pattern of contrast enhancement | 1. Prominent enhancement that tends to be solid and homogeneous in immunocompetent patient  
2. Enhancement patterns in immunocompromised individuals may be irregular and heterogeneous, often with a ring pattern |
| The rapid changes that take place over a very short time as primary CNS lymphomas are very dynamic in so far as the local spread of the disease is concerned. | The rapid centrifugal periventricular spread of the central subtype forming the butterfly lesions, or the centripetal growth of the corticomeningeal type. The central subtype might spread subependymally to ensheathe the whole ventricular system. |

Table 3. Common sites for central lymphomas

<table>
<thead>
<tr>
<th>Site</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thalamus</td>
<td>100%</td>
</tr>
<tr>
<td>Parietal lobes, corpus callosum, cerebellum, brain stem, hypothalamus</td>
<td>25%</td>
</tr>
</tbody>
</table>

Primary CNS lymphoma is more common than secondary lymphomas. Most primary CNS lymphomas are high-grade non-Hodgkin's B-cell lymphomas. The site of origin is controversial because the CNS does not have endogenous lymphoid tissue or lymphatic circulation. The incidence is increasing in both immunocompromised and
immunocompetent individuals. Lesions can be multiple in up to 50% of cases, involving the basal ganglia, periventricular white matter, and corpus callosum. The lesions are very radiosensitive but frequently recur. The masses demonstrate high cellularity, with 90% isodense to hyperdense on CT, and isodense to hypointense to brain signal intensity on T2-weighted imaging. In immunocompetent individuals, there is prominent enhancement that tends to be solid and homogeneous. In these patients, lymphomas do not calcify, and hemorrhage is uncommon. Up to 75% of these masses are in contact with the ependyma or meninges. The imaging appearance is more heterogeneous in AIDS owing to hemorrhage and necrosis. Enhancement patterns in immunocompromised individuals may be irregular and heterogeneous, often with a ring pattern. In the AIDS population, CT and MR imaging cannot reliably distinguish between lymphoma and toxoplasmosis. SPECT imaging may be helpful in this setting.

Figure 3. Precontrast CT scan of a paraventricular lymphoma, each study is one week apart, notice that the lymphoma is hyperdense on precontrast scans, also notice the increase in size and the progressive periventricular fungation over a short period of time.

Figure 4. A postcontrast CT scan in a patient with central thalamic lymphoma showing dense contrast enhancement, notice the perilesional edema and the small nodules radiating from the mother lesion.
Previously an uncommon primary brain neoplasm, primary CNS lymphoma is increasing in frequency. Although the increase is most often attributed to acquired immunodeficiency syndrome (AIDS) and other immunocompromised disease states, primary CNS lymphoma is also increasing in frequency in immunocompetent patients. The periventricular butterfly lesions that are demonstrated in some CNS lymphoma cases represent centrifugal tumour cells fungation alongside the periventricular subependymal arteriolar system. It should also be mentioned that periventricular lymphoma is bilateral in 50% of cases, while most the corticomeningeal lymphomas are strictly unilateral. This probably should point to the fact that the subependymal vascular systems of both hemisphere are more richly interconnected compared with the pial vascular system. Peak incidence of primary CNS lymphoma in immunocompetent patients is in the 50s, and lesions are typically solitary; among immunocompromised individuals, it occurs at a younger age, and multiple lesions are common. It is one of two primary CNS tumors that extends across the corpus callosum with some frequency forming the bilateral butterfly lesions. (GBM is the other.) Lesions are commonly located deep within the brain substance, and T2 signal abnormality or enhancement often abuts an ependymal surface; however, primary CNS lymphoma can also occur peripherally or in the posterior fossa. On unenhanced CT studies, primary CNS lymphoma is classically hyperdense, and enhancement can be solid or ringlike.
Low signal intensity in a nonhemorrhagic tumor on T2-weighted images can be due to high cellularity, a high nuclear-to-cytoplasmic ratio, or minimal extracellular fluid. Primary tumors that are commonly lower in signal intensity on T2-weighted images include primitive neuroectodermal tumors (e.g., medulloblastoma, neuroblastoma) and lymphoma. Metastases from a systemic mucinous adenocarcinoma primary can also exhibit low signal intensity on T2-weighted images.

On MR images, the signal intensity on T1-weighted images can vary; however, similar to other lesions that are hyperdense on unenhanced CT studies, primary CNS lymphoma tends to be hypointense or isointense to gray matter on T2-weighted images. Surrounding edema and mass effect ranges from minimal to marked. Enhancement is the norm on MR imaging; it may be homogeneous, heterogeneous or ringlike. In a patient with AIDS and an enhancing mass lesion, the primary differential diagnostic consideration is toxoplasmosis. Although lymphoma is statistically more common, primary CNS lymphoma cannot be reliably distinguished from toxoplasmosis with conventional CT or MR imaging. A variety of techniques, including thallium-201 SPECT, fluorodeoxyglucose PET, and MR spectroscopy, have been advocated to distinguish between the two diseases.
Figure 6. MRI T1 precontrast (A,B), postcontrast (C), MRI T2 (D) and MRI proton density (E,F) Notice that the periventricular lymphoma is hypointense on precontrast scans, also notice the dense contrast enhancement. Notice the densely enhanced butterfly lesions in (C), the butterfly lesions are iso-to hypointense on the MRI T2 and proton density scans (D,E,F)

Figure 7. MRI T1 postcontrast coronal scan of a patient with central lymphoma showing progressive increase in the size of the lymphoma with periventricular fungation over a short period of time. Each image was done about 5 days before the next starting from A to F, this was coupled clinically with progressive clinical deterioration. Notice the dense contrast enhancement and the well formed butterfly lesion in E,F. The lesions are surrounded with hypointense edema with positive mass effect.
Figure 8. MRI T1 postcontrast coronal scan of a patient with central lymphoma showing periventricular fungation. Notice the dense contrast enhancement and the well formed butterfly lesions. The lesions are surrounded with hypointense edema with positive mass effect.

Figure 9. MRI T1 postcontrast showing the characteristic periventricular fungation, left MRI image is one week earlier than the right image, notice the observable periventricular spread of lymphoma in such a short time.

Figure 10. Postcontrast CT scan showing a thalamic lymphoma (left image) that started to fungate centrifugally outward on follow up CT scan (middle image) forming later on the characteristic butterfly lesion (right image), these changes occurred over 2 weeks of the patient hospitalization.
Figure 11. MRI T2 images A,B and and MRI T1 postcontrast image C. A was done 5 days before B. Notice the progressive increase in size of the central lymphoma over a short period of time, also notice that the central lymphoma is markedly hypointense on the MRI T2 image (B), the central lymphoma showed marked and dense contrast enhancement. The surrounding edema is marked in this patient (the edema is hyperintense on the T2 images and hypointense on the T1 image)
Figure 12. MRI T1 precontrast image (A) and postcontrast T1 images (B,C) and MRI T2 images (D,E) in a patient with a butterfly infratentorial lymphoma around the 4th ventricle lymphoma. The lymphoma is hypointense on precontrast T1 image (A) and iso to hypointense on MRI T2 images (D,E), the peripheral part of the butterfly lymphoma is more hypointense probably it is more cellular than other parts of the tumour with dense contrast enhancement (B,C), also notice the perilesional edema.

From the radiological point of view, the existence of butterfly lesions and the subependymal disease are the most characteristic radiological criteria of PCNSL. In central lymphomas the thalamus is the most frequently involved site.
Table 4. The radiological characteristics of primary CNS lymphomas

1. The existence of butterfly lesions
2. The existence of subependymal lymphomatous sheath around the ventricular system, best seen in postcontrast scans
3. The lesions are hypointense on the MRI T2 images
4. The lesions are slightly hyperdense on precontrast CT scans
5. The existence of dense contrast enhancement
6. Perilesional edema is present to a variable degree
7. Lymphomas are characterized by being a very dynamic pathology with rapid increase in size and periventricular fungation over a short period of time during the hospitalization of the patient

Radiological pathology of diffuse astrocytomas

Astrocytomas are tumors predominantly composed of astrocytes. Unless otherwise indicated, the term usually applies to diffusely infiltrating neoplasms (WHO grades II through IV). The pilocytic astrocytoma (WHO grade I), pleomorphic xanthoastrocytoma, and giant cell astrocytomas have distinctly different biological, genetic, and phenotypic features. This distinction should be kept in mind during the discussion of astrocytomas.

Of the estimated 17,000 primary brain tumors diagnosed in the United States each year, approximately 60% are gliomas. Gliomas comprise a heterogeneous group of neoplasms that differ in location within the central nervous system (CNS), age and sex distribution, growth potential, extent of invasiveness, morphological features, tendency for progression, and response to treatments.

Although there are only three major tumor types recognized, corresponding to the three types of glial cells (astrocytes, oligodendrocytes, and ependymal cells), gliomas encompass a broad spectrum of histopathologic and imaging findings. The variation in the phenotype and biological behavior of gliomas likely reflects the nature of the transformation-associated genes involved in the development of neoplasia. There have been numerous classification schemes and staging criteria proposed for glial neoplasms. The WHO classification is generally used as a reference.
Primary cerebral gliomas account for up to 45% of intracranial tumors, with peak incidence in the seventh decade of life.  
In children, most (70% to 80%) of gliomas are infratentorial. In the adult, GBM accounts for more than half (55%) of all gliomas. The remaining subtypes in decreasing order of frequency include astrocytoma (20.5%), ependymoma (6%), medulloblastoma (6%), oligodendroglioma (5%), and choroid plexus papilloma (2% to 3%). Histopathology may range from benign or "low-grade" tumors to the highly malignant anaplastic astrocytoma and GBM. Glial neoplasms can be heterogeneous, with anaplasia developing focally. This can limit the diagnostic accuracy of small surgical biopsies. Furthermore, there can be significant change in the degree of malignancy over time. Morbidity and mortality of these lesions can also be significantly influenced by the location of the lesion, which may limit surgical accessibility.

All gliomas, particularly the diffusely infiltrating variety, have a tendency toward progression to more malignant forms. Genetic alterations that appear to be common across low-grade to higher-grade astrocytomas include p53 mutations. Mutations in pl6 and
CDK4 gene amplification are present in both anaplastic astrocytomas and glioblastomas, whereas loss of heterozygosity of chromosome 10 and EGF-R gene amplification are almost exclusively found in glioblastomas.

Clinical presentation includes focal neurological signs or symptoms related to increased intracranial pressure (ICP). Signs and symptoms of increased ICP include headache (typically more severe in the morning), nausea, vomiting, and visual disturbances. In GBMs and anaplastic astrocytomas, these signs can develop rapidly and are progressive. Because many of these neoplasms tend to develop and grow in the deep white matter, they can be clinically silent until achieving relatively large sizes. Patients who present with focal neurological signs or seizures tend to have a more optimistic prognosis due to an earlier presentation.

In the absence of contraindications such as pacemakers, ferromagnetic aneurysm clips, metallic foreign bodies in the eye, or cochlear implants, contrast-enhanced MR imaging is the modality of choice for the diagnosis and follow-up of brain neoplasms. MR imaging is more sensitive than CT in the detection of gliomas, in the assessment of tumor extent, and for identification of potential complications (ie, herniation syndromes, venous thrombosis, leptomeningeal and ependymal spread). Functional MR imaging can be added to the preoperative assessment of patients for identification of critical motor and language areas. This assessment is facilitated by the use of high field strength units (1.5 T) with echoplanar imaging capabilities. In addition, intraoperative interactive navigational workstations can be used to review combined functional and anatomic information during biopsy and surgical resection of tumors.

Despite the exquisite sensitivity of MR imaging for identifying alterations in water content, it lacks specificity in the determination of histological grade. In general, the presence of contrast enhancement and hemorrhage correlate with increasing grade of tumor. However, the presence or pattern of contrast enhancement or degree of T2-prolongation cannot be used to grade these lesions. In addition, it has been well recognized that regions of "normal-appearing brain" in patients with infiltrative or anaplastic astrocytomas and GBMs can harbor malignancy.
Figure 16. A, Glioblastoma multiforme with necrosis and haemorrhage, glioblastomas are often multicolored on cross section due to hemorrhage and necrosis.

MR spectroscopy has long held the promise of in vivo histopathologic specificity. Preliminary work indicates that N-acetylaspartate (NAA) and gamma-amino butyric acid are decreased in brain tumors, whereas choline is elevated. Lactate levels may correlate with histologic grade, and alanine may be associated with benign tumors. NAA is found primarily in neuronal cells. Any process that either replaces normal neurons, or causes neuronal loss, can be expected to decrease the NAA level. For example, meningiomas are reported to have low NAA, low creatine, a prominent choline peak, and a mild elevation in lactate. The H spectrum of gliomas appears to be dependent on the grade of the tumor, with higher grade lesions having lower levels of creatine and more significant elevations of lactate and choline. Currently, MR spectroscopy may be useful in distinguishing tumor from other lesions that may mimic a neoplasm, such as encephalitis. However, the histopathologic specificity has been predominantly anecdotal, and its clinical usefulness has been limited by long imaging times and limited voxel resolutions. This may change with improvements in imaging hardware and novel imaging pulse sequences.
Common pathological characteristics of diffuse astrocytomas

- Diffuse astrocytomas are tumors predominantly composed of astrocytes. Unless otherwise indicated, the term usually applies to diffusely infiltrating neoplasms (WHO grades II through IV).
- Diffuse astrocytoma is unusual in the first decade of life and most commonly presents in older children or young adults up to the age of 40 to 45.
- All diffuse astrocytomas, particularly the diffusely infiltrating variety, have a tendency toward progression to more malignant forms. Diffuse astrocytomas have a peculiar tendency to change its grade over time into the next higher grade of malignancy and the condition is age dependant. A change in the grade of diffuse astrocytoma is more likely to occur in the older age group.
- Diffuse astrocytomas commonly start as grade II at a younger age group then gradually change its grade over time into the next higher grade until they ultimately dedifferentiate into glioblastomas (secondary glioblastoma multiforme), on the other hand, glioblastoma multiforme in older patients are usually primary-that is, they occur as glioblastoma multiforme from their inception, without progression from a lower-grade tumor.
- Diffuse astrocytomas appear to form a continuum of both biological and histological aggression. They vary from lesions with almost normal cytology (grade I and grade II astrocytomas) through intermediate stages (grade III, anaplastic astrocytomas) and up to the most aggressive of all human brain tumours (grade IV astrocytomas or glioblastoma multiforme).
- Diffuse astrocytoma often spreads widely through the brain but without destruction and also without interruption of normal function. Microscopically, tumor cells infiltrate between myelinated fibers in a nondestructive manner. The local spread of diffuse astrocytomas (forming gliomatosis cerebri and butterfly gliomas) does not mean that the tumour grade is grade IV (glioblastoma multiforme), local spread can occur in grade II and grade III and in the author experience gliomatosis cerebri and butterfly gliomas are much more commonly seen in grade II astrocytomas and has not been encountered in grade III (anaplastic astrocytomas) and grade IV (glioblastoma multiforme). It takes a long time for a diffuse astrocytoma to cross the corpus callosum to the opposite hemisphere to form a butterfly glioma. Patients harbouring glioblastomas have a much shorter life span for their tumours to form butterfly gliomas, however cases were reported for glioblastomas forming butterfly tumours.
- In practice considerable histological heterogeneity in astrocytic tumours is found (i.e., low grade areas with Rosenthal fibers and calcification can be intermixed with with frankly malignant ones).
- The differences in histologic features, potential for invasiveness, and extent of progression likely reflect genetic differences acquired during astrocytoma growth.
- Grade IV astrocytomas (glioblastoma multiforme) differ from diffuse astrocytoma grade II and grade III (anaplastic astrocytomas) in the presence of gross necrosis, and microscopically in the presence of vascular endothelial hyperplasia and tumour hemorrhage.
Figure 17. Astrocytoma grade II showing diffuse infiltration of the left temporal lobe with gray and white matter involvement (arrowhead). Note the relative lack of mass effect for the degree of infiltration. The white matter infiltration extends across the corpus callosum (white arrow) and involves bilateral deep white matter tracts (double arrow) forming the characteristic butterfly glioma.

Radiologically the tumor is usually identified by a combination of brain asymmetry, enlargement of a portion of the brain, or abnormal signal intensity on MR or abnormal attenuation on CT. The lesions typically have precontrast CT attenuation and MRI signal changes suggesting increased water content and lower than normal specific gravity (diffuse low CT scan densities with MRI T1 hypointensities and diffuse MRI T2 hyperintensities).

Figure 18. Butterfly glioblastoma multiforme

It is tempting to consider that these changes represent edema. The question then arises: Is this vasogenic edema or cytotoxic edema? Because the blood-brain barrier is intact in these tumors, vasogenic edema is unlikely. The cells are not dead or dying, so that cytotoxic edema is also unlikely. Perhaps the edema results from the increased number of astrocytic cells that spread apart the normal myelinated axons of the white matter. The presence of significant amount of normal appearing astrocytes (hyperplasia), with marked cytoplasmic hypertrophy and low nuclear to cytoplasm ratio result in total increase in the water content.
of the brain. These cells may merely have different physical and chemical properties than the normal tightly packed bundles of axons that traverse through the brain. Astrogliosis is commonly associated with widened fluid filled extracellular spaces (microcavitations) which definitely increase tissues water content resulting in the characteristic CT scan/MRI picture. Absence of significant edema coupled with the very slow growth rate of these tumours result in minimal mass effect.

Astrocytes have extensive vascular foots, Astrogliosis (astrocytic hyperplasia) commonly results in the formation of a mesh with enlargement of extracellular spaces and extensive fluid-filled microcavitations. This, coupled with marked cytoplasmic hypertrophy of astrocytes-that results in low nuclear to cytoplasm ratio- are responsible for the neuroimaging picture of low grade astrocytomas

**THE BUTTERFLY TUMOURS**

In the author experience, the progressive centrifugal butterfly fungation of primary CNS lymphomas is something that can be observed clinically. When successive flow up neuroimaging studies are done (on several days) to a patient with CNS lymphoma during hospitalization, it was possible, in the author experience, to observe the progressive centrifugal butterfly fungation of the lymphoma. This is probably due to the rapid growth of the neoplasm (see figures 7,8,9,10,11), this is in sharp contrast with the butterfly bihemispheric spread of astrocytomas which has never been observed "taking place" in action in a single patient by the author, this is probably because the growth and the local spread of astrocytoma cells is slower compared with that of lymphoma cells.
Figure 20. Precontrast CT scan, (A), astrocytoma grade II and (B), lymphoma. Notice that astrocytoma grade II is hypodense on precontrast scans, while lymphoma is hyperdense on precontrast CT scan. Lymphoma is also surrounded by edema (B) while edema is absent in astrocytoma (A).

The spread of lymphoma cells is different from that of astrocytoma cells. Lymphoma cells spread locally along the periarteriolar spaces in the Virchow-Robin spaces, while astrocytoma tumor cells infiltrate locally between myelinated fibers in the nondestructive manner. Spread of lymphoma cells along the Virchow Robin spaces is probably faster than the spread of astrocytoma cells by infiltration between myelinated fibers (probably Virchow Robin spaces facilitate spread of lymphoma cells) and this is probably another reason that explains the more rapid local spread lymphoma cells compared with that of astrocytoma cells.

Figure 21. MRI T2, (A), astrocytoma grade II and (B), lymphoma. Notice that astrocytoma grade II is hyperintense on the T2 MRI scan, while lymphoma is hyperintense on the T2 MRI scan. Lymphoma is also surrounded by edema (B) while edema is absent in astrocytoma (A).

Although both astrocytomas and lymphomas are hypercellular neoplasms, however their MRI T2 signal intensity is different (astrocytomas are hyperintense on the MRI T2 images while lymphomas are hypointense on the MRI T2 images). The cells of lymphomas have a high nuclear to cytoplasmic ratio with minimal extracellular water, resulting in T2 shortening (hypointense on the T2 MRI images), while astrocytoma cells have a low nuclear to cytoplasmic ratio with increased extracellular fluid resulting in T2 prolongation (hyperintense on the T2 MRI images). For the same reasons lymphomas are hyperdense.
on precontrast CT scan (because of hypercellularity with high nuclear to cytoplasmic ratio), while astrocytomas are hypodense on precontrast CT scan because of hypercellularity with a low nuclear to cytoplasmic ratio associated with increased extracellular fluid.

Figure 22. (A), A patient presented with a clinical picture resembling Alzheimer dementia, post contrast CT scan revealed a butterfly tumour, The tumour is hypodense, with absence of mass effect, edema, or contrast enhancement, histopathology revealed an astrocytoma grade II. (B,C), belongs to a patient with butterfly CNS lymphoma, notice that the tumour is hyperdense on noncontrast CT scan (B), with patchy, ring like enhancement. The lesion has a positive mass effect, and surrounded by massive edema.

Mass effect, perilesional edema and contrast enhancement are very prominant in lymphomas and in the author experience all butterfly gliomas were astrocytomas grade II. Edema, mass effect and contrast enhancement is not a feature of astrocytoma grade II and many of these tumours were initially mistaken with old infarctions, see table 5. Butterfly tumour was seen by the author infratentorially around the 4th ventricle in one case if primary CNS lymphoma, see fig 12, while it has however been observed infratentorially by the author in case of astrocytomas.
Figure 23. A, Glioblastoma involving the corpus callosum. Axial postcontrast CT image in young male patient presenting with psychosis. Note the huge mass in the genu and anterior body of the corpus callosum with enhancement at the margins. Note dilatation of the lateral ventricles caused by obstructing mass. B, Lymphoma of the corpus callosum. Axial postcontrast CT image in young male patient presenting with psychosis. The tumor crossed the corpus callosum and involved both frontal lobes.

Table 5. Comparison between the astrocytoma butterfly tumours and lymphoma butterfly tumours

<table>
<thead>
<tr>
<th></th>
<th>Astrocytoma grade II</th>
<th>Lymphomas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site of origin</td>
<td>Diffuse astrocytomas commonly start focally in one hemisphere</td>
<td>start bilaterally around centrifugal subependymal microvascular system</td>
</tr>
<tr>
<td>Pattern of spread</td>
<td>The astrocytoma tumor cells infiltrate locally between myelinated fibers in the nondestructive manner and gradually cross through the corpus callosum to the opposite hemisphere forming the characteristic butterfly gliomas.</td>
<td>The lymphoma cells fungate centrifugally outward along the virchow robin spaces to form the characteristic butterfly periventricular tumours.</td>
</tr>
<tr>
<td>Rate of spread</td>
<td>Very slow</td>
<td>Very rapid</td>
</tr>
<tr>
<td>Precontrast CT scan</td>
<td>Hypodense</td>
<td>Hyperdense</td>
</tr>
<tr>
<td>MRI T2 signal intensity</td>
<td>Hyperintense</td>
<td>Hypointense</td>
</tr>
<tr>
<td>Edema</td>
<td>Not a feature</td>
<td>Very prominent</td>
</tr>
<tr>
<td>Mass effect</td>
<td>Not present</td>
<td>Very prominent</td>
</tr>
<tr>
<td>Contrast enhancement</td>
<td>Not present</td>
<td>Very prominent</td>
</tr>
</tbody>
</table>
In the author experience, all butterfly gliomas were astrocytoma grade II except in one case where the histopathology was glioblastoma multiforme. When the histopathology is glioblastoma multiforme one should expect mass effect, patchy enhancement, the presence of edema and the presence of tumour necrosis. Local spread in case glioblastoma multiforme will be much more rapid with extensive tissue destruction and marked clinically disability within a very short time.

**REFERENCES**


