Dysembryoplastic Neuroepithelial Tumor: A Case Report *

Anna Victoria M. Holgado, M.D.[1]

Abstract

This reports a case of dysembryoplastic neuroepithelial tumor (DNET) in a 5-year old male presenting with visual hallucination and seizures. Diagnostic workup revealed a homogenous cystic tumor located in the right temporo-parietal area which was considered as a low grade glioma. The patient underwent endoscopic third ventriculostomy with complete tumor excision and biopsy, revealing DNET. Findings were confirmed by immunohistochemical staining with glial fibrillary action protein (GFAP), Alcian blue and synaptophysin.

DNET is a recently described intracranial tumor under the World Health Organization classification of central nervous system (CNS) tumors. It is a unique entity of neuroglial tumors with excellent prognosis. Its worldwide incidence among all neuroepithelial tumors is 1.2% in patients under 20 years and 0.2% among patients over 20 years.

This is the first case of DNET in the country as well as in our institution. Key points on the clinical manifestation, approach to diagnosis, distinctive radiologic and histopathologic characteristics, and management are discussed.

Keywords: dysembryoplastic neuroepithelial tumor, DNET

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[1]From the Philippine Children's Medical Center

INTRODUCTION

Dysembryoplastic neuroepithelial tumors (DNET) are a group of benign mixed neuroglial tumors with 0.6% prevalence among 340 reported cases of primary CNS tumors occurring in children below 18 years of age.[1,2]

These tumors are usually found in the temporal lobe area in 84% of cases, followed by occipital and parietal areas. They are surgically curable with almost no seizure and tumor recurrence. [3]

Case Report

This presents the case of a 5 year old Filipino male from Pampanga, Roman Catholic, born on December 27, 2010; admitted for the second time in our institution on May 7, 2016 for seizure.

Five months prior to admission, the patient experienced visual hallucinations with no other associated symptoms such as headache, irritability, projectile vomiting, or seizures. He was active and had good appetite; hence no consult or any medications were taken. Four months prior to admission, he had sudden onset of seizure characterized as tonic flexion of both upper extremities, stiffening of both lower extremities, with associated upward rolling of eyeballs, circumoral cyanosis, and drooling lasting for 10-15 seconds. Seizures occurred at an average of six episodes a day, lasting for 10-15 seconds, occurring at hourly intervals. There were no consultation nor was given any medication. Seizure episodes persisted until three months prior to admission, prompted the parents to consult at a tertiary hospital. He was managed as a case of acute symptomatic seizure, and was started on valproic acid at 13 mg/kg/day with good compliance. Electroencephalogram (EEG) revealed generalized activity with right hemispheric focus, which was consistent with seizure disorder. Cranial computed tomography (CT), plain and with contrast, demonstrated a round, well defined, unilocular cystic lesion over the right basal temporal lobe, generalized activity with right hemispheric focus, which was consistent with seizure disorder. Cranial computed tomography (CT), plain and with contrast, demonstrated a round, well defined, unilocular cystic lesion over the right basal temporal lobe, effacement of the right sylvian cistern. There was no cerebral edema or midline shift. The radiologic impression was neuroglial cyst vs vs infectious cyst vs cystic astrocytoma with opacification of paranasal sinuses.(Appendix 1, Figure 1) On cranial magnetic resonance imaging (MRI), plain, and with contrast, there was a non-enhancing hyperintense mass measuring 5.4 cm x 3.6 cm x 2.7 cm over the right middle cranial fossa. Effacement of both sulci and temporal horns in this area was seen, with no radiologic findings of cerebral edema and midline shift. The radiologic impression was a non enhancing mass, right temporal lobe and hippocampus, without diffusion restriction, mild mass effect, polysinusitis. Magnetic resonant (MR) spectroscopic findings were compatible with a neoplasm, possibly low graded gliosis. (Appendix 2, Figure 2)

The patient was referred in our institution for further evaluation and management.

Review of systems showed weight gain and increase in appetite. The patient did not have any fever episodes during the course of illness. He also did not have pallor, jaundice, cyanosis, or any rashes. No eye or ear changes. No pulmonary symptoms such as difficulty of breathing, chest pain, or cough. No cardiovascular symptoms such as dyspnea, orthopnea, palpitations. No abdominal symptoms such as abdominal pain, vomiting, diarrhea or constipation. No genitourinary symptoms such as dysuria, polyuria, oliguria, or edema. He also did not present with musculoskeletal symptoms such as arthlagia and myalgia.

The patient has been admitted previously at our institution for elective craniotomy and excision of tumor; however the surgical procedure was deferred due to pneumonia. No previous surgery or any known allergies to food or medications were reported.

The patient's family history has been unremarkable for presence of malignancies, febrile convulsions, seizure or epileptic disorders, and other medical conditions such as hypertension, diabetes, thyroid disorders and bronchial asthma.

The patient was born to a then 26 year old gravida 2, para 1 (1-0-0-1), non smoker, non alcoholic beverage drinker. The mother had regular pre-natal check-ups at a private clinic, with an OB-GYN, starting at three months age of gestation. She had regular intake of multivitamins and ferrous sulfate, with no known maternal exposure to radiation and viral exanthem during the course of her pregnancy. The mother had a history of palpitations occurring at five months age of gestation and was managed as a gravidocardiac

patient, functional class I. She claimed taking unrecalled cardiac medications from the 5th until 8th month gestation. During the course of pregnancy, the mother did not have any history of spotting or vaginal bleeding, and premature contractions.

The patient was delivered full term via classical cesarean section at a polyclinic, assisted by an OB-GYN. The patient had good activity and cry immediately upon delivery. There was history of meconium staining or cord coil. No signs of cyanosis or jaundice. Birth weight was 2.27 kg. Routine newborn care was done. Newborn and hearing screening tests were both normal.

The patient was started on a milk formula at 1:1 dilution, 3 ounces every 4 hours. Currently, the patient is on follow-up milk and consumes an average of 15 bottles (8 ounces) per day. Complimentary feeding started at six months of age with rice cereals. At present, he prefers having egg, chicken, and fried foods.

The patient is currently enrolled as a nursery student, and has achieved the following developmental milestones:

GROSS MOTOR: Achieved head control and rolling over to side at 3-4 months of age. He was able to walk alone at twelve months of age.

FINE MOTOR: Grasps objects at four months, and eventually able to do pincer grasp at 6-7 months of age. At six months, he started pointing at objects as a form of gesturing. At around four to five years of age, he was able to establish left handedness and was able to write his full name.

LANGUAGE: Can identify and speak out alphabets and numbers as well as primary colors. He also speaks in 4-5 sentences at a time.

SOCIAL-ADAPTIVE: Currently can feed and dress himself. Toilet training was achieved at 4 years of age.

The patient's father is a 34 year old contractual laborer, while his mother is a 31 year old house wife. He is the younger of two children. Their immediate family currently lives in a well-lit, well-ventilated concrete bungalow with two other household members. Their house is not located near any creek or factory. Garbage is collected on a weekly basis. The family purchases ready stored mineral water from their local water supplier. Currently, there are no household members who have any infectious illnesses, viral exanthem, and no known TB exposure. There is also no smoker within the household.

On admission, the patient was awake, active, and able to follow command. Vital signs were as follows: blood pressure of 90/60 mmHg; heart rate of 100 beats per minute, regular rhythm; afebrile at 36.2; respiratory rate of 20 cycles per minute. The patient weighed 36 kilograms (z score >3, overweight for age), and had a height of 106 centimeters (z score 0, normal for age). The head was normocephalic, with a head circumference of 55 centimeters (p 2 – 50). There were no palpable lesions or masses. The patient had anicteric sclera, with pink palpebral conjunctivae and no eye discharge. Ears were equal in size with no external lesions or skin tags. There was no ear discharge, with minimal retained cerumen along the external auditory canal. The tympanic membrane of both ears had no effusion, erythema, bulging, or perforation. Nasal septum was at midline. There was no nasal discharge, congestion, or polyps. There was also no alar flaring. Lips and oral mucosa were moist, with no noted external lesion or oral ulcers. No dental caries were noted. There was no tonsillopharyngeal congestion or exudates seen. No visible veins, neck mass, or cervical lymphadenopathy.

The chest had no gross deformities or lesions. It was symmetric in expansion, no subcostal or intercostal retractions. Palpation and percussion findings were unremarkable. Clear breath sounds were appreciated on all lung fields. The patient had an adynamic precordium, with no heaves or thrills. The point of maximal impulse was palpated over the 4th-5th intercostal space, left midclavicular line. Heart sounds were distinct with a regular rate and rhythm. There were no murmurs or extra heart sounds appreciated. The abdomen appeared globular, with no visible veins or other lesions. Bowel sounds were normoactive. There were no palpable masses or organomegaly. The abdomen was tympanitic on all quadrants. Genitalia were grossly male, with bilaterally descended testes. All extremities appeared symmetric. No gross deformities, joint swelling, or other lesions noted. They were warm and had full equal pulses, with capillary refill time of less than 2 seconds.

Neurologic examination upon admission was unremarkable. The patient was awake, conversant, oriented to person, place and time; and preferred to be with the mother most of the part of the

examination. Cranial nerve I was not assessed. Pupils measured 2-3 mm and were both briskly reactive to light. Accommodation to light was also noted in both pupils. Extraocular movements of both eyes were full and intact. He had good masseter tone and had no facial asymmetry. Gross hearing was also intact. He had intact gag reflex and tongue was in midline. He had symmetric tone and range of movement when he was asked to turn his head from side to side and against resistance. All extremities were equal in muscle bulk, with good tone, and a motor testing of 5/5 (able to move against gravity and against resistance). No sensory deficits were noted. No nystagmus, dysmetria, and dysdiadochokinesia. The patient was normoreflexive (+2) on all deep tendon reflexes. Autonomic functions were also intact. There was no Babinski reflex or ankle clonus elicited. No meningeal signs such as nuchal rigidity, Kernig's or Brudzinski's signs.

The patient was worked up for possible causes of seizure. EEG prior admission showed generalized activity with right hemispheric focus. Cranial CT scan and MRI plates showed the presence of a non enhancing tumor at the right temporo-parietal area.

The patient underwent endoscopic third ventriculostomy of the right temporoparietal area, with complete tumor excision and biopsy (Appendix 3, Figure 3). Histopathology showed findings suggestive of dysembryoplastic neuroepithelial tumor (Appendix 4, Figure 4). Immununohistochemical staining with glial fibrillary acidic protein (GFAP), Alcian blue, and synaptophysin confirmed the diagnosis (Appendix 5, Figure 5). No post operative complications were observed, and the patient was discharged stable after a week. He is on regular follow-up with Child Neurology and Neuro-Oncology services upon discharge.

Case Discussion

Our patient came in with a chief complaint of an unprovoked seizure. The presence of associated signs and symptoms may help determine whether this is a primary seizure disorder, or a seizure with an underlying cause. Visual hallucination was noted prior to the unprovoked seizure. In addition, seizure episodes presented in a stereotypical manner, suggesting there may be an underlying cause. The physical and neurologic examination findings did not present any signs of deficit, indicating the need for ancillary work up to narrow our differential diagnoses.

In order to determine if the underlying cause of a seizure is metabolic or structural, we use the aid of laboratory workup. Metabolic causes may be due to hypoglycemia, or electrolyte imbalances. In our patient, no derangements from these parameters were noted based on the pre-operative workup. Structural causes may branch out into the following: 1) congenital malformations; 2) hydrocephalus; and 3) tumor growth. Diagnostic imaging confirmed the presence of a tumor, located approximately at the right temporoparietal area. Temporal lobe tumors are difficult to diagnose and localize. These tumors present with a variety of clinical presentation as compared to other intracranial lesions. Nonetheless, tumors arising from the temporal lobe area commonly present with seizures as recorded in 80% of primary CNS tumors.[4] Other associated symptoms arising from temporal lobe tumors include auras, somatosensory and other special senses phenomena which may include visual hallucinations, especially when the tumor compress or arise from the inferior temporal gyrus.[4] Visual hallucinations arising from occipital lobe lesions may produce sharper images as compared to that of the temporal gyrus. This finding gave us an impression that the possible tumor found in our patient may still be temporal in origin, more than occipital.

Common primary CNS tumors that have a temporal lobe predilection include ependymomas and gangliogliomas. Ependymomas in the pediatric population often occur in the supratentorial region, arising from the lateral or third ventricles. Most common clinical presentation include headache, nausea, vomiting or vertigo, secondary to increased intracranial pressure (ICP) from obstruction of cerebrospinal fluid flow through the ventricles or brain stem. In our patient, signs of increased ICP were not noted, hence ruling out this diagnosis. Gangliogliomas are a mixed type of tumor generally occurring during the first three decades of life. They are commonly found in the medial temporal lobe described as well circumscribed masses that have calcium-containing cystic structures which enhance on neurologic imaging. Seizure is the most common presenting symptom due to its medial temporal lobe predilection. This diagnosis was ruled out in our patient, on the basis of a non enhancing lesion appreciated on neuroimaging.

Other possible differential diagnosis would be astrocytomas since they make up 25% of low-grade CNS tumors in the pediatric age group.[5] Clinically, it is difficult to deduce the presence of DNET from common low-grade gliomas, such as pilocytic

astrocytomas and fibrillary astrocytomas, since they generally present with localizing symptoms depending on the tumor location. The aid of histopathology and immunochemical staining comes into play in arriving at the diagnosis. In our patient, the gross characteristic of the resected tumor did not have a clear delineation between the intracranial mass and normal brain parenchyma. The mass seemed to have expanded the temporal gyrus, with the adjacent gray matter thickened. These gross pathologic findings are common features for DNET.[1,5] On further microscopic findings, mixed neuroglial elements that gave an appearance of "floating neurons" were appreciated, hence guiding which immunohistochemical staining will be appropriate to utilize. A positive Alcian blue, synaptophysin, and glial fibrillary acidic protein (GFAP) confirmed the diagnosis of DNET.

Dysembryembryoplastic neuroepithelial tumors are a rare, slow-growing group of CNS tumors recently categorized under neuronal and mixed neuronal-glial type in the 2007 and 2016 World Health Organization (WHO) tumor classification of primary CNS tumors. Worldwide, it only occurs in about 0.2 - 1.2% among children and young adults below 20 years of age.[1] In our country, no data regarding this case has been recorded.

According to Suh, DNETs were initially believed to be a hamartoma grossly in nature but recent identification of genetic altinerations in DNETs indicate that this tumor is more of a neoplastic condition.[2] The histogenesis of DNTs still remains unknown. The developmental origin from the secondary germinal layer has been proposed by Daumas-Duport and colleagues, based on the mixed cellularity of DNETs, their prevalence in the temporal lobe, and their association with focal cortical dysplasia.[6] Another study by Bodi, et al suggested that DNETs could have originated from pluripotent precursor cells based on ultrastructural findings of oligodendrio-like cells showing neuronal and glial differentiation. This hypothesis is supported by the immunoexpression of both nestin and MAP-2 in these cells. These markers have also been identified early in neural and glial precursor cells during human development, hence a predilection for the younger age group.[7]

Chassoux, et al as well as Devaux, et al. further discussed that DNETs are found in approximately 17.8%–20% of patients who undergo surgical resection for chronic epilepsy.[8,9] They are actually the second most common tumors in surgically resected cases for intractable epileptic seizures. DNETs comprised 87% of 31 cases with tumor-associated, temporal lobe epilepsy, as discussed by Kirkpatrick, et al.[10] Among the pediatric age group, the frequency of DNETs was reported to be 0.6% among 340 primary CNS tumors and an estimated prevalence of 0.8% in 233 children with hemato-oncologic problems, in general, as discussed by Suh.[1]

Chang et al stated that among patients found to have DNETs, partial complex seizures are the most common clinical manifestation, followed by generalized tonic-clonic, simple partial, and partial seizures with secondary generalization.[11] An additional neurologic symptom is headache only. Over 90% of patients with DNETs have epilepsy before the age of 20 years.[11] Patients generally do not have neurological deficits or evidence of elevated intracranial pressure. Males are more frequently affected, and tumors have a predilection for the temporal lobe, followed by the frontal and parietal or occipital lobes. Multifocal DNETs affecting the different sites in the CNS have also been reported in other studies. There have also been unusual locations for DNETs, which include the septum pellucidum, caudate nucleus, thalamus, pons, cerebellum, brainstem, and ventricles as described in surgical studies by Cervera-Pierot et al and Onguru et al.[12,13]

Though a rare type of tumor, dysembryoplastic neuroepithelial tumors are part of the top three differentials causing seizures. On neuroimaging, DNETs have distinct features that would give clue to the diagnosis. According to Fernandez, et al, these tumors usually present with "septated" appearance best seen on high resolution MR imaging. Another distinct radiologic feature that may aid in the diagnosis is the "comical tail" which denote the involvement of epithelial tissues with neuroglial component.[14] In our patient, the tumor presented as a non-enhancing lesion, both on cranial CT scan and MRI, hence it was initially considered as a low-grade glioma.

The clincher to the diagnosis, however, is still the histopathologic and immunohistochemical findings. Dysembryoplastic neuroepithelial tumors are usually described as complex multinodular lesions, consisting of glial nodules, associated with a specific glioneuronal element with or without focal cortical dysplasia.[15] In the case of our patient, microscopic examination showed hypercellular lesions with a multinodular architecture, and a low- to high- cellularity gradient. Neurocytic-like cells with axon bundles are found bordering

the microcytic spaces, hence giving a "floating neuron" look. Confirmation is made by immunohistochemical staining with Alcian blue, Synaptophysin, and GFAP. "Floating neurons" found within the glioneuronal element of the tumor have been found out to express neuronal markers such as the synaptophysin neurofilament. However, majority of oligodendriolike-cells have been found strongly positive for S-100 protein and Oligo-2 markers, but are generally negative for glial fibrillary action protein (GFAP). Hence, other histopathologic clues that would aid in clinching the diagnosis would also be the predilection of other glial nodules to GFAP since a number of these structures contain GFAP-positive astrocytes.[1,2] In our patient, immunohistochemical results were positive in all immunohistochemical staining.

The importance of early identification and diagnosis of the disease is of high value, since timely surgical intervention lead to an excellent outcome. Surgery, alone leads to an almost 95% excellent prognosis, with no seizure recurrence within 5 years, postoperatively.[16] The revised WHO tumor classification categorizes central nervous tumors according to grading and staging in order to guide practitioners in the diagnosis and management of these tumors (Appendix 6). Tumor grading is usually based on the degree of endothelial proliferation, mitotic changes, presence of necrosis, and presence of giant cells, hyperchromic nuclei, and pleomorphic cells. In addition, staging CNS tumors utilizes postoperative MRI of the tumor resection site, done within 24-48 hours after surgery. Postoperative imaging is necessary to determine the extent of resection and to discern any residual tumor. Generally, tumor dissemination and leptomeningeal involvement are also investigated as part of staging after resecting primary CNS tumors. If these are suspected, MRI of the entire spine and cerebrospinal fluid (CSF) analysis are considered.[5] Tumor seeding and leptomeningeal involvement are usually uncommon in DNET. Being classified under Grade I, dysembryoplastic neuroepithelial tumors can be treated by surgery alone. The need for chemotherapy or short course radiation therapy is of little value to the contribution of the overall survival of the patient, as compared to other intracranial lesions.[6,16]

Dysembryoplastic neuroepithelial tumors have an overall excellent prognosis. Among the cases reported by Chang et al and Ranger and Diosy, seizure episodes did not recur during the postoperative period. No malignant transformations or metastasis were observed after complete tumor resection. [10,11,16] In our patient, no seizure recurrence was observed during the immediate post-operative period, as well as on follow-up. No significant signs of developmental delay or regression were also observed. Currently, the patient is back to his hometown, and has been doing his regular routine of activities.

SUMMARY

We report a case of dysembryoplastic neuroepithelial tumor in a 5-year old male who initially presented with visual hallucination and seizure. Neurologic examination findings were unremarkable. Radiologic and histopathologic work ups are indeed crucial in clinching the diagnosis. Timely surgical management is still the definitive management with 95% excellent prognosis and no seizure recurrence.

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APPENDIX

APPENDIX 1: Plain and Contrast, Cranial CT Scan Imaging of the Patient

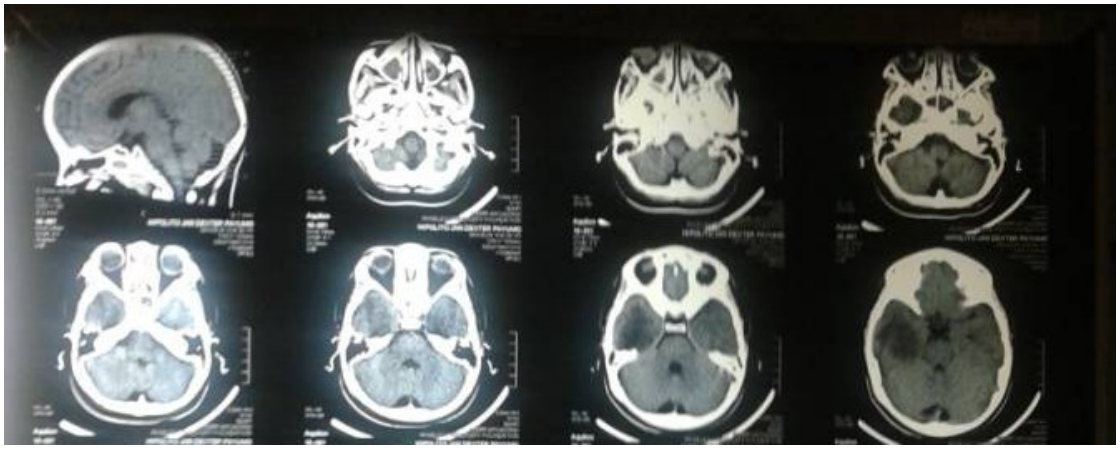

Figure 1a - Plain cranial CT images of our 5-year old patient showing a non enhancing lesion over the right temporo-parietal area as identified by the red arrows.

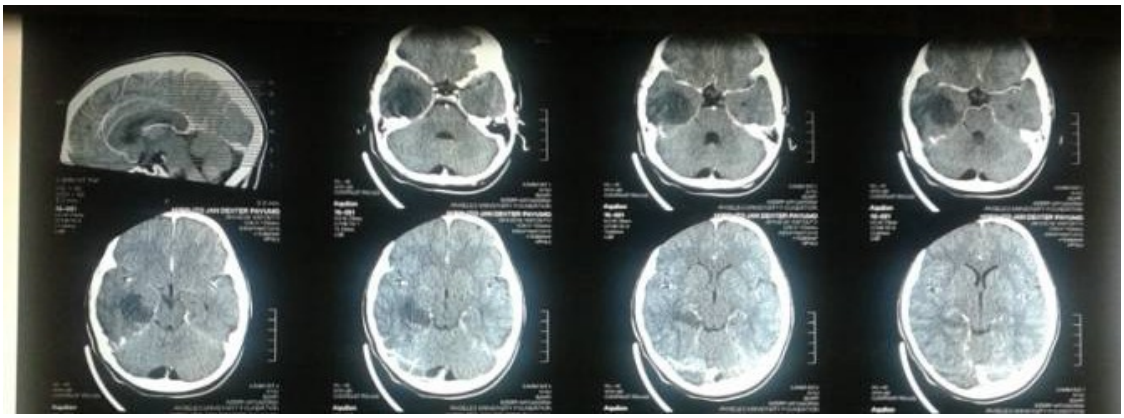

Figure 1b - Contrast cranial CT images of our 5-year old patient showing a non enhancing lesion over the right temporo-parietal areas identified by the red arrows.

APPENDIX 2: Plain and Contrast, Cranial MRI Imaging of the Patient

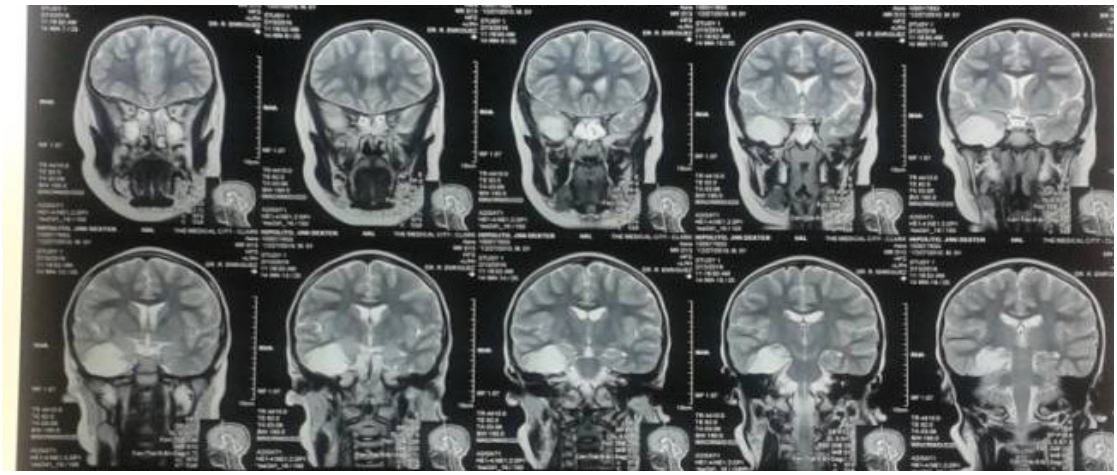

Figure 2a - Plain cranial MRI images of our 5-year old patient showing a non enhancing lesion over the right temporo-parietal area as identified by the red arrows.

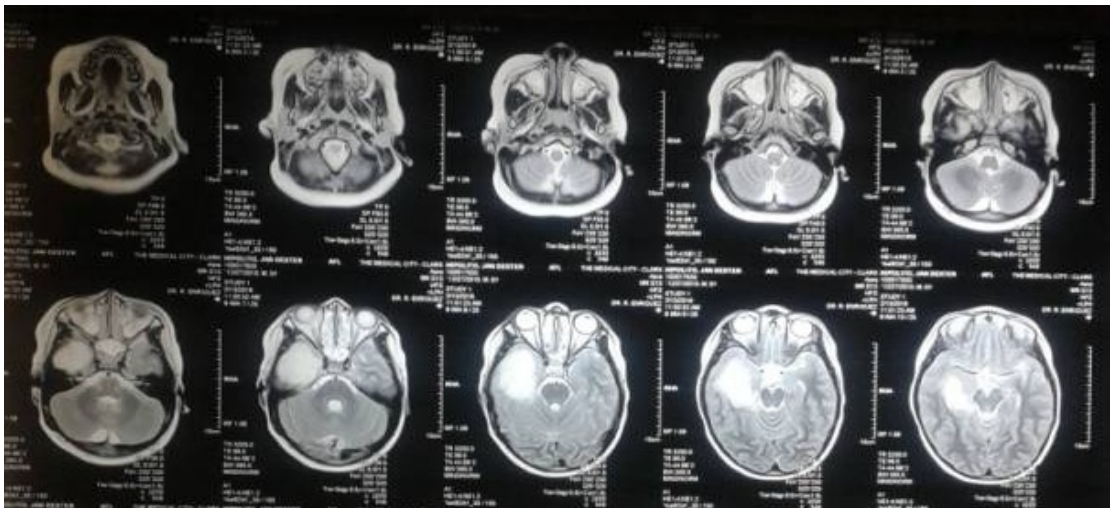

Figure 2b - Contrast cranial MRI images of our 5-year old patient showing a non enhancing lesion over the right temporo-parietal area as identified by the red arrows.

APPENDIX 3: Gross Finding of the Tumor Resected from the Right Intracranial Temporoparietal Area

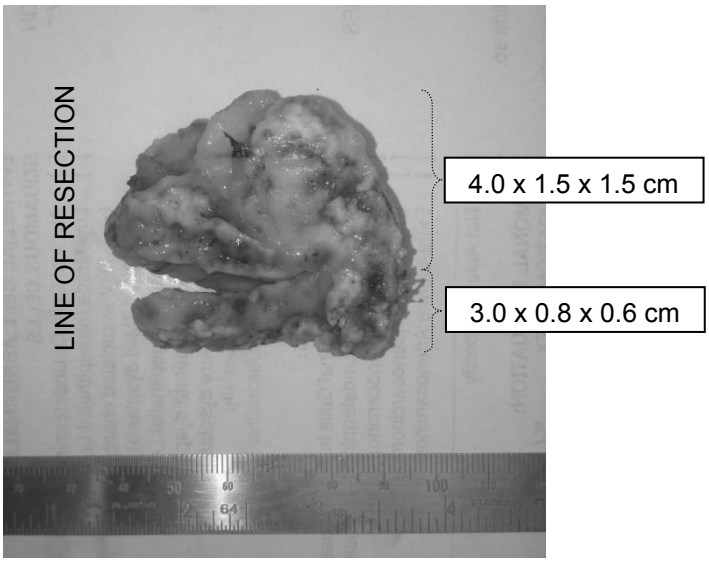

Figure 3 – Tumor resected from the right intracranial, temporoparietal area. The tumor was divided in a sagittal direction from the midline. It grossly appears as a yellowish, L-shaped intracortical mass measuring 4.0 x 1.5 x 1.5 cm along the longer arm and 3.0 x 0.8 x 0.6 cm along the shorter arm. Along the line of resection, a smooth, cream white surface is appreciated.

APPENDIX 4: Histopathology of the Tumor

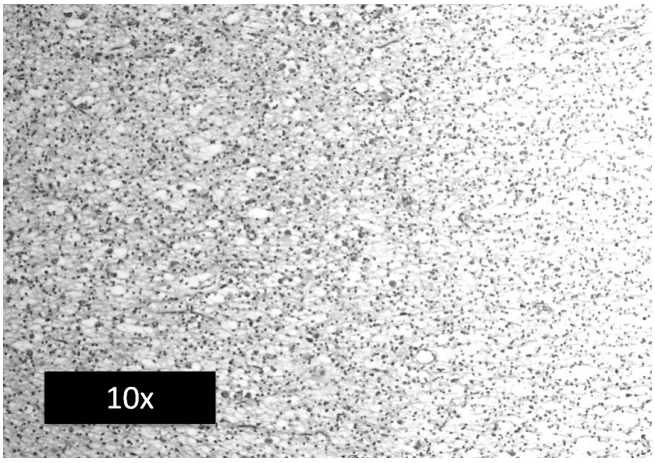

Figure 4a - Microscopic examination shows a nodular intracortical lesion, showing a low- to high-cellularity gradient, which is more evident with 10x magnification

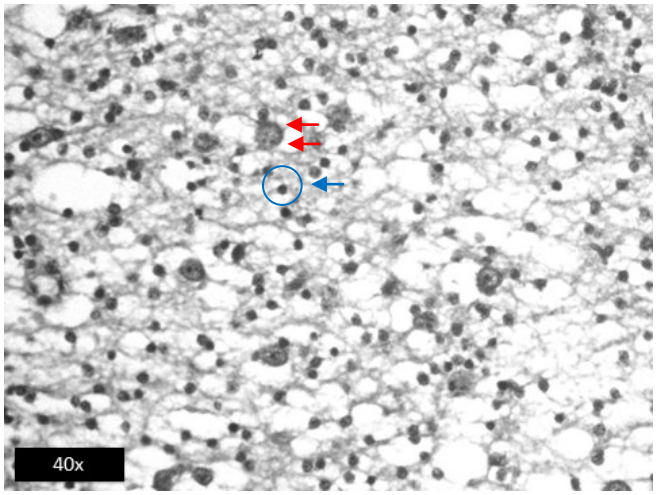

Figure 4b- Showing neurocytic-like cells (red arrow) with axon bundles bordering microcystic spaces in which larger ganglion cells lie, giving it a "floating neuron" effect.

Showing the nuclei of the tumor cells (blue arrow) show no pleomorphism, atypia, or hyperchromasia.

APPENDIX 5: Immunohistochemical Staining of the Tumor

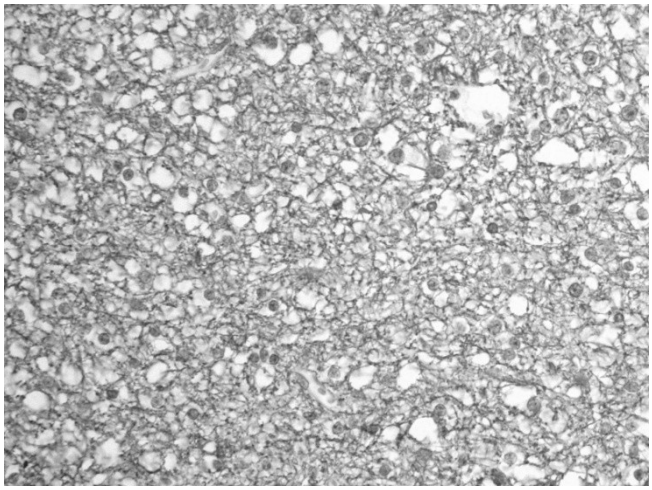

Figure 5a – The following sample has been stained with **glial fibrillary acidic protein** (**GFAP**).

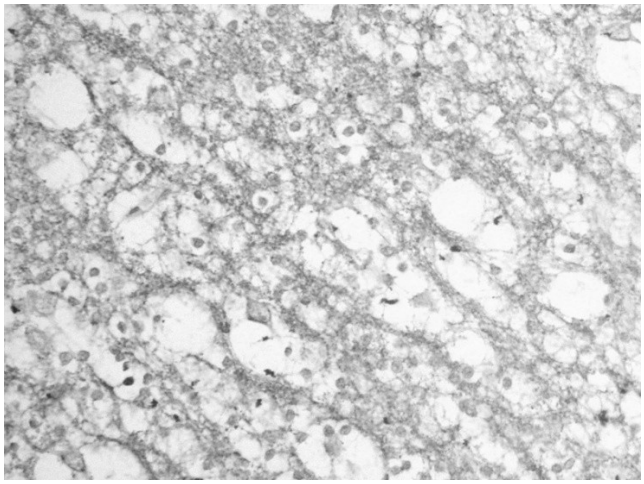

Figure 5b – The following sample has been stained with **synaptophysin**. This immunohistochemical stain highlights oligodendrocyte-like cells, neurons, and parenchyma showing off a granular cytoplasmic pattern

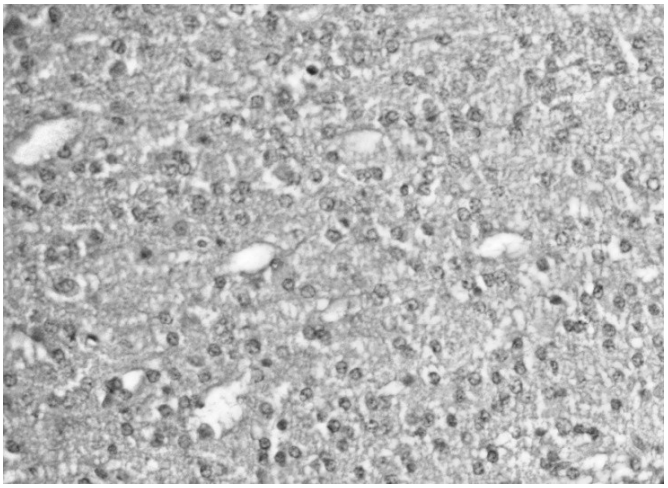

Figure 5c **–** The following sample has been stained with **Alcian blue.** It highlights mucin-filled cysts. This slide shows uniform oligodendroglioma-like cells in a mucin-rich background.

APPENDIX 6: WHO Classification and Grading of Selected CNS Tumors

WHO grades of select CNS tumours	
Diffuse astrocytic and oligodendroglial tumours	
Diffuse astrocytoma, IDH-mutant	II
Anaplastic astrocytoma, IDH-mutant	III
Glioblastoma, IDH-wildtype	IV
Glioblastoma, IDH-mutant	IV
Diffuse midline glioma, H3 K27M–mutant	IV
Oligodendroglioma, IDH-mutant and 1p/19q-codeleted	II
Anaplastic oligodendroglioma, IDH-mutant and 1p/19q-codeleted	III
Other astrocytic tumours	
Pilocytic astrocytoma	I
Subependymal giant cell astrocytoma	I
Pleomorphic xanthoastrocytoma	II
Anaplastic pleomorphic xanthoastrocytoma	III
Ependymal tumours	
Subependymoma	I
Myxopapillary ependymoma	I
Ependymoma	II
Ependymoma, *RELA* fusion–positive	II or III
Anaplastic ependymoma	III
Other gliomas	
Angiocentric glioma	I
Chordoid glioma of third ventricle	II
Choroid plexus tumours	
Choroid plexus papilloma	I
Atypical choroid plexus papilloma	II
Choroid plexus carcinoma	III
Neuronal and mixed neuronal-glial tumours	
Dysembryoplastic neuroepithelial tumour	I
Gangliocytoma	I
Ganglioglioma	I
Anaplastic ganglioglioma	III
Dysplastic gangliocytoma of cerebellum (Lhermitte–Duclos)	I
Desmoplastic infantile astrocytoma and ganglioglioma	I
Papillary glioneuronal tumour	I
Rosette-forming glioneuronal tumour	I
Central neurocytoma	II
Extraventricular neurocytoma	II
Cerebellar liponeurocytoma	II
Tumours of the pineal region	
Pineocytoma	I
Pineal parenchymal tumour of intermediate differentiation	II or III
Pineoblastoma	IV
Papillary tumour of the pineal region	II or III
Embryonal tumours	
Medulloblastoma (all subtypes)	IV
Embryonal tumour with multilayered rosettes, C19MC-altered	IV
Medulloepithelioma	IV
CNS embryonal tumour, NOS	IV
Atypical teratoid/rhabdoid tumour	IV
CNS embryonal tumour with rhabdoid features	IV
Tumours of the cranial and paraspinal nerves	
Schwannoma	I
Neurofibroma	I
Perineurioma	I
Malignant peripheral nerve sheath tumour (MPNST)	II, III or IV
Meningiomas	
Meningioma	I
Atypical meningioma	II
Anaplastic (malignant) meningioma	III
Mesenchymal, non-meningothelial tumours	
Solitary fibrous tumour / haemangiopericytoma	I, II or III
Haemangioblastoma	I
Tumours of the sellar region	
Craniopharyngioma	I
Granular cell tumour	I
Pituicytoma	I
Spindle cell oncocytoma	I

Source: Louis DN, Ohgaki H, Wiestler OD, Cavenee WK (2016). World Health Organization Histological Classification of Tumors of the Central Nervous System. France: International Agency for Research on Cancer. Retrieved from http://braintumor.org/wp-content/assets/WHO-Central-Nervous-System-Tumor-Classification.pdf