Choroid plexus tumors are rare intraventricular neoplasms derived from choroid plexus epithelium, which account for approximately 2% to 4% of intracranial tumors in children and 0.5% in adults. Choroid plexus papillomas (CPPs) are more common than choroid plexus carcinomas (CPCs) in a ratio of at least 5:1; approximately 80% of CPCs arise in children, constituting 20% to 40% of all choroid plexus tumors in this age group. The average annual incidence is approximately 0.3 per 1,000,000 population inhabitants. Approximately 80% of the lateral ventricle tumors arise in patients younger than 20 years, whereas fourth ventricle tumors are evenly distributed in all age groups. Congenital tumors have been observed in utero using ultrasound technique. Presenting symptoms such as headache, diplopia, and ataxia are usually caused by hydrocephalus, regardless of tumor location. Direct mechanical obstruction of cerebrospinal fluid (CSF) flow, arachnoid granulation blockage from hemorrhage, and overproduction of CSF can contribute to hydrocephalus. Computed tomography (CT) and magnetic resonance imaging (MRI) show iso- or hyperdense, T1 isotense, and T2 hyperintense masses that appear enhanced with contrast, within the ventricles, generally associated with hydrocephalus. Macroscopic findings of CPPs include circumscribed cauliflower-like masses that may adhere to the ventricular wall, but are usually well delineated from the brain tissue, and cysts and hemorrhages may occur. CPCs are usually invasive tumors that may appear solid, hemorrhagic, and necrotic. The benign papillary tumor is composed of delicate...
fibrovascular connective tissue fronds covered by a single layer of uniform cuboidal to columnar epithelial cells with round or oval, basally situated, monomorphic nuclei. Conspicuous mitotic activity, brain invasion, and necrosis are absent.\cite{1}

In contrast to benign CPPs (World Health Organization (WHO) grade I), CPCs (WHO grade III) are characterized by frank signs of malignancy, that is, frequent mitoses, nuclear pleomorphism, increased cellular density, blurring of the papillary growth pattern, and necrosis.\cite{1,9} Histological grading is recognized as an important prognostic factor in choroid plexus tumors and also affects the decision toward adjuvant radiotherapy and chemotherapy.\cite{10,13} The distinction between CPP versus CPC is not always clear-cut, as some tumors show only one or few histological features of malignancy, for example, pleomorphism, increased mitotic activity, and invasion.\cite{14,24} Those tumors have been termed atypical CPP, but clear diagnostic criteria have not been established. In this study, the authors have analyzed clinical, pathological, and neuroradiological features of 23 cases of choroid plexus tumors.

**Materials and Methods**

All evaluable cases of choroid plexus tumors of the central nervous system from January 1997 to December 2009 were retrieved from the database files of the department of pathology. The clinical, surgical, and pathological data of the patients were retrieved from hospital information system, database files from Department of Neurosurgery and records of the Department of Pathology. The clinical data included patient age and gender, clinical presentation, physical examination, investigations (hematological, radiological), operative details, and clinical diagnosis. The pathological data included tumor location, gross appearance, tumor size (cm), and growth pattern, cellular atypia, mitosis and necrosis. A total of 19 cases of central CPP, 2 cases of atypical CPP, and 2 cases of CPC were diagnosed during this period. The formalin-fixed paraffin embedded tissue blocks and tissue sections were retrieved and reviewed. Additional sections of 3-5μ were cut and stained with hematoxylin and eosin, as and when required. Neuropathological re-evaluation of choroid plexus tumors involved assessment of histological features proposed as atypical by the current WHO classification. The presence or absence of high cellularity, solid growth, necrosis, and nuclear pleomorphism was assessed. Mitotic activity was assessed by counting mitoses in 10 randomly selected high-power fields (HPF, area of view 0.23 mm²). In line with previous studies, increased mitotic activity was defined as the presence of more than one mitosis/10 HPF. Choroid plexus tumors displaying frank signs of malignancy, defined here as the presence of at least 4 of the previously mentioned atypical histological features, were classified as choroid plexus carcinoma. Based on light microscopic examination, representative sections were selected for immunohistochemistry for cytokeratin and GFAP. All antibodies were procured from Dako Corporation, Denmark. Ki-67 proliferation index was calculated by counting 1000 cells under high power.

**Results**

The clinical, neuroradiological features, and operative findings of the 23 cases are summarized in Table 1.

During a period of 13 years, we identified 23 cases of choroid plexus tumors in the Department of Pathology at our institute. There were 11 males and 12 females. The female to male ratio was 1.09:1. The mean age of the patients in this study was 17.4 years, with a range of 6 months to 47 years. Fourteen patients were below 15 years of age. Symptoms of raised intracranial pressure were seen in all cases. In addition, one patient presented with cerebellar symptoms and one patient with gait ataxia. In all the cases, CT scan revealed isodense lobulated lesion, with homogenous contrast enhancement and MRI scan revealed isointense signal intensity on T1 weighted images, hyperintense signal intensity on T2 weighted images, and homogenous enhancement with contrast administration [Figure 1a]. In three cases, there were cystic component in the tumor. Tumor was located in lateral ventricle (n = 14; in 3 cases tumor was going into third ventricle), fourth ventricle (n = 7), and cerebellopontine angle (n = 2). Varying degree of hydrocephalus (HCP) was noted in all the cases and two cases required ventriculo-peritoneal shunt, and one case required subdural-peritoneal shunt. None of the cases underwent pre-operative embolization. Total tumor excision [Figure 1c] was achieved in 21 cases and in remaining 2 cases subtotal tumor excision was done. All patients improved in their symptoms following surgery except one who died in the postoperative period due to refractory ventricular fibrillation caused by hypokalemia. Two cases which had CPC were asymptomatic till 1.5 months follow-up, but long term outcome is not known as they were lost to follow-up after the initial follow-up of 1.5 months.

**Histopathological examination**

Grossly, the resection specimen consisted of portions of soft, friable, papilliferous pink-tan tissue [Figure 1b]. Microscopically, the architecture of CPPs resembled that of normal choroid plexus. The neoplastic villi were lined by simple epithelium, and the core consists of loose connective tissue stroma and a central blood vessel. The epithelial lining cells were uniform in size and shape, and the nuclei were round-to-oval and basally positioned. Apical cytoplasm was abundant, and cilia could be noted for some cells. No cellular atypia or mitotic figures were noted in 16 cases and were labelled as CPP [Figure 2a]. In two cases, tumor showed focal sheet pattern, with nuclear hyperchromasia, and occasional mitosis [Figure 2b]. These were labelled as atypical choroid plexus papilloma. In another two cases, tumor revealed a tumor displaying cellular pleomorphism, nuclear atypia, mitotic figures, and necrosis.
Table 1: Summary of the clinical, radiological and operative details of choroid plexus tumors

| Age(years)/Sex | Clinical presentation | Extent of excision | Location | Neuro-radiological features (CT and MRI) | Operative findings | Histopathological diagnosis |
|---------------|-----------------------|--------------------|----------|----------------------------------------|-------------------|---------------------------|
| 2.5/F         | Vomiting with persistent cry, deterioration of vision | Total | Right lateral ventricle | CT scan: Isodense, 4x4x4 cm with homogenous contrast enhancement with HCP | Tumor was well defined, reddish, irregular surface, pinkish, moderately vascular | Choroid plexus papilloma with atypia |
| 5/M           | Headache, vomiting, one episode of tonic posturing | Total | Left lateral ventricle | CT scan: Isodense to hyper dense lesion in the atrium and body of the ventricle, enhancing on contrast. HCP present | Greyish, soft, partly suckable, vascular, with plane of cleavage from the ventricular wall | Choroid plexus papilloma |
| 27/F          | Headache, gait ataxia | Total | 4th ventricle | CT: Isodense, contrast enhancement MRI: Iso on T1 hyper on T2, enhancing on contrast coming out of 4th ventricle | Soft, suckable, vascular, friable tumor with no attachment on floor of 4th ventricle | Choroid plexus papilloma |
| 15/M          | Increasing head circumference and downward gaze palsy | Total | Right lateral ventricle | CT: Isodense lesion with diffuse contrast enhancement MRI: iso on T1 hyper on T2 | Pink, frond like, vascular friable mass | Choroid plexus papilloma |
| 1.5/F         | Difficulty in walking and feature of raised ICP, progressive enlargement of head | Total | Left lateral ventricle | CT: Hyperdense enhancing mass in the left trigone, temporal, occipital horn and body of lateral ventricle MRI: iso on T1 and heterogenous on T2, lobulated brilliantly enhancing mass | Lobulated mass, very vascular, soft to firm, well defined plane of cleavage | Choroid plexus papilloma |
| 34/F          | Raised ICP, progressive diminution of vision | Total | Fourth ventricle | CT: Hyperdense mass with contrast enhancement MRI: Enhancing mass, going into the cistern magna | Very vascular, firm, cauliflower like mass | Choroid plexus papilloma |
| 45/F          | Headache, cranial nerve paresis | Subtotal left lateral | Right cerebellopontine (CP) angle | CT: Hyperdense lesion, contrast enhancement with HCP MRI: Iso on T1 hyper on T2, enhancing on contrast | Cystic mass in temporal horn, pinkish, soft and vascular | Choroid plexus papilloma |
| 25/F          | On and off holocranial headache, progressive loss of vision | Total | Fourth ventricle | CT: 2.5x2.1 cm size isodense mass with enhancement MRI: Iso on T1 and hyper on T2 enhancing on contrast with HCP | Soft suckable frond like appearance arising from choroid plexus | Choroid plexus papilloma |
| 10 month/M    | Progressive enlarging head size | Total | Left lateral ventricle also going into Third ventricle | CT: 2.5x3.6 cm size isodense mass with contrast enhancement MRI: Frond like enhancing mass in third and left lateral ventricle with calcified foci and HCP | Reddish gray frond like friable highly vascular | Choroid plexus papilloma |
| 20/M          | Headache, decrease vision | Total | Fourth ventricle | CT: 4x4 cm, hypodense with dense area of calcification with HCP MRI: Enhancing mass in fourth ventricle | Pinkish grey vascular mass attached to 4th ventricular floor | Choroid plexus papilloma |
| 13/F          | Headache, vomiting | Total | Fourth ventricle | CT: Lobulated hyperdense mass with spcoks of calcification with HCP MRI: Lobulated enhancing mass in fourth ventricle | Pink, soft, vascular fronds tumour | Choroid plexus papilloma |
| 9/M           | Altered sensorium, failure to take feeds, abnormal enlargement of head | Total | Right lateral ventricle | CT: Hyperdense lesion in the right ventricle taking up contrast MRI: Enhancing mass right lateral ventricle with calcified foci and HCP | Fronds of vascular tissue attached to choroid plexus | Choroid plexus papilloma |
| 10 month/M    | Vomiting, dullness with decreased feeding, increased head size | Total | 3rd and right lateral ventricle | CT: lobulated hyperdense enhancing mass MRI: T1 iso, T2 hyper with enhancement with contrast with HCP | Pink lobulated mass | Choroid plexus papilloma |
| 6 months/M    | Frequent upward rolling of eyes with enlargement of head | Total | Right lateral ventricle | MRI: Iso to hyper on T1 hyper on T2 lesion, with enhancement with contrast, with HCP | Tumor reddish grey highly vascular | Choroid plexus papilloma |
| 7/M           | Headache | Total | Left lateral ventricle | MRI: T1 iso- and T2 hyper lesion in trigone with contrast enhancement with HCP | Fragile, suckable | Choroid plexus carcinoma |
| 25/F          | Holocranial headache, off and on vomiting and progressive vision loss for 15 days, generalized seizure for 5 months | Total | Left lateral ventricle | MRI: Iso on T1 hyper on T2 homogenously enhancing on contrast lesion in the left lateral ventricle trigone with entrapment of the occipital horn with HCP | Tumor was greyish red, firm, moderately vascular, suckable at places | Choroid plexus papilloma with atypia |

Contd...
Table 1: Summary of the clinical, radiological and operative details of choroid plexus tumors

| Age(years)/ Sex | Clinical presentation | Extent of excision | Location | Neuro-radiological features (CT and MRI) | Operative findings | Histopathological diagnosis |
|-----------------|-----------------------|--------------------|----------|-----------------------------------------|--------------------|----------------------------|
| 1.5/F | Progressive increase in size of head, recurrent vomiting, with developmental delay | Total | Right lateral ventricle | MRI: T1 iso, T2 hyper with contrast enhancing lesion with HCP | Reddish, soft to firm frond like moderately vascular lesion | Choroid plexus papilloma |
| 1/M | Progressive increase in size of head | Total | Left lateral ventricle | CT: Isodense, lobulated enhancing mass in trigonal area of left lateral ventricle MRI: Lobulated mass T1 iso, T2 hyper and homogeneously enhancing with contrast with moderate HCP | Lobulated, vascular frond like mass | Choroid plexus papilloma |
| 40/M | Raised ICP, right cerebellar symptoms | Total | Right CP angle | CT: Hyperdense with cystic component, mass with hydrocephalus MRI: Right CP angle extraxial lesion, iso to hypo in T1, and heterogenous hyperdense on T2 with HCP | Reddish, soft to firm frond like moderately vascular lesion | Choroid plexus papilloma |
| 32/F | Holocranial headache, vomiting, diminution of vision, altered sensorium | Subtotal | Right CP angle | CT: Enhancing brain stem exophytic mass on right CP angle, MRI: Lobulated enhancing mass on right CP angle, coming out of foramen of Luschka | Grey white friable vascular frond like tumor | Choroid plexus papilloma |
| 14/M | Headache and vomiting | Total | Right lateral ventricle and third ventricle | CT: Hyperdense mass, enhancing on contrast MRI: lobulated with both cystic and solid component | Tumor in right lateral ventricle and extending to into third ventricle. cyst has multiple septae | Choroid plexus papilloma |
| 22/F | Headache and swaying while walking for, progressive diminution of vision | Total | Fourth ventricle | CT: Irregular frond like mass in fourth ventricle, mildly enhancing on contrast, with HCP | 5×4 cm tumor reddish yellow fleshy | Choroid plexus papilloma |
| 1.5/F | Vomiting, headache and visual deterioration | Total | Fourth ventricle | CT: Contrast enhancing lesion MRI: Small iso to hypo mass with contrast enhancement with HCP | Reddish pinkish lobulated mass | Choroid plexus carcinoma |

The epithelial sheath overlying the papillae exhibited areas of stratification, and the stroma was edematous. The epithelial cells were columnar and tightly stacked in some areas, with high nucleus/cytoplasm ratios and hyperchromatic nuclei. They were labelled as CPC [Figure 2c]. Clear cell areas were identified in three cases [Figure 2d]. Foci of calcification were identified in five CPP, including Psammoma bodies in two cases and were located either in fibrovascular core and also lying in the stroma. Hemorrhage was identified in five tumors and hyalinization was identified in two tumors. Oncocytic changes in the tumor cells were identified in one tumor.

Discussion

CPPs are intraventricular papillary neoplasms derived from the choroid plexus epithelium, that account for 2% to 3% of intracranial tumors in children.[9] Benign papillomas are reported to account for approximately four-fifth of the neoplasms and carcinomas one-fifth.[10] On MRI scans, papillomas tend to appear as lobulated, homogeneous, enhancing masses, whereas carcinomas appear more heterogeneous because of areas of necrosis, calcification, or hemorrhage. The advantage of using MRI in the diagnosis of choroid plexus neoplasms lies in the fact that the multiplanar view facilitates surgery as well as postoperative evaluation.

Clear cells are common in all choroid plexus tumors, benign, and malignant. As they are also very frequent in the fetal choroid plexus, they may suggest similarities between the neoplastic cells and immature related tissue. Psammoma bodies (PBs) are more frequent to be secondary to hypoxia or ischemia. They are found in normal meninges, choroid plexus.[25,26] PBs are more frequent in choroid plexus of healthy older people, and during aging, they obtain larger dimensions more irregular contours, which is the result of their mutual merging.[25,27] Amyloid deposition can also be incidentally observed in choroid plexus and choroid plexus tumors without clinical significance.[28] Other unusual histological feature include mucinous degeneration, melanization, and tubular glandular structures.
Primary CPP may also arise in cerebellopontine angle from embryonic remnant of choroid plexus anlage. CPP of cerebellopontine angle may present as direct extension from primary intra fourth ventricular CPP or from choroid tuft projecting from the formen of Luschka, referred to as Bochdalek’s flower basket.

A study by Jeibmann et al. examined a series of 164 choroid plexus tumors for the presence of atypical features and correlated these features with prognosis in an effort to create criteria for the diagnosis of atypical CPP.[29] They showed that mitotic activity is the only feature that impacted the probability of recurrence inpatients diagnosed with CPP. The group proposed that a mitotic count greater than or equal to 2 per 10 high-power fields could define a choroid plexus tumor as atypical, and the same study suggested that if at least two of the following histological features are seen, including increased cellularity, nuclear pleomorphism, solid growth pattern, and/or necrosis, a diagnosis of atypical CPP would be warranted. Using these criteria, the study examined a series of 124 previously diagnosed CPPs, and 15% of these were atypical CPPs. Malignant evolution of a CPP which recurred as CPC has been reported in two patients, but documented transition from benign to malignant histology is extremely rare.

In comparison with the papilloma, the diagnosis of CPC is rendered in the setting of increased cell density, increased mitotic figures (usually greater than 5 per 10 high power fields), nuclear pleomorphism, and necrosis.[1] Diffuse invasion of the adjacent brain parenchyma is often present. While distinct papillary configuration is a hallmark of low-grade CPP, in CPC the papillary features are blurred or can be lost in the sheets of epithelial tumor cells, and this ill-defined growth pattern can make diagnosis challenging.[30] Proliferation indices such as Ki-67/MIB-1 can be useful in the diagnosis of CPC, with reported mean nuclear labelling rates of 1.9% for CPP and 13.8% in CPC. Choroid plexus carcinoma is classified as a WHO grade III tumor.[1]

Differential diagnosis of an intraventricular papillary tumor includes several possibilities. Villous hypertrophy of the choroid plexus which is a benign proliferation causing enlargement of the choroid plexus in the ventricles is one such possibility. These lesions have normal choroid plexus microscopically, and can also be distinguished from a neoplastic lesion using proliferation markers.[31] Papillary variant of ependymoma, is an additional consideration; however, characteristic cytological and morphological features on histological examination, including monomorphic cuboidal cells with a flattened surface, indistinct nucleoli, granular chromatin, ependymal rosettes, and perivascular pseudorosettes consisting of tapered cell processes oriented toward a central blood vessel can...
Another tumor to consider as differential diagnosis is myxopapillary ependymoma, a tumor that is usually located at the spinal cord; it is formed by papillae within a myxoid matrix and PBs, surrounded by cuboidal epithelial cell, and has GFAP-and CK-positive reaction. Papillary meningioma, a rare high grade (WHO grade III) variant of meningioma, can arise in the choroid plexus, especially in patients in the pediatric age group. This tumor is described histologically as having a pseudopapillary or perivascular pattern impart of the tumor, which makes this meningioma a WHO grade III neoplasm.\textsuperscript{31,32} In infants, PNET (primitive neuroectodermal tumors) can occur in the same area. Apart from all these, atypical teratoid/rhabdoid tumor (AT/RT), due to its aggressive nature, deserves a special mention. Histologically, AT/RT usually has groups of rhabdoid cells with eccentric, pleomorphic nuclei, and abundant eosinophilic cytoplasm. These tumors are high grade, with increased mitoses and necrosis. Atypical teratoid/rhabdoid tumor can be somewhat challenging to distinguish from CPCs that are poorly differentiated with foci of epithelial differentiation. In immunohistochemistry, CPCs stained positively for INI1, whereas the majority of AT/RTs are negative. This immunostain could help in distinguishing between a poorly differentiated CPC and an AT/RT with extensive epithelial differentiation. Finally, metastatic neoplasms to the choroid plexus, especially in the adult population, are possible. The reported incidence of solitary metastases to the choroid plexus with no evidence of tumor in the brain parenchyma is rare, accounting for 0.14% of all cerebral metastases, the most common in adults being renal cell carcinoma. Metastases of papillary carcinomas to choroid plexus occur in 10% of the patients; hence, we should consider them as a differential diagnosis because they may have identical histological appearance. There are some markers that have been used to distinguish them, such as BerEP4 and CEA, which are positive in metastatic carcinomas and negative in CPPs.

Total excision by surgical extirpation is expected to be curative, with infrequent recurrences.\textsuperscript{33} However, a gross total resection sometimes may not be feasible because of the deep intraventricular location of lateral ventricular tumors and the proximity of third and fourth ventricular tumors to critical brain-stem structures.\textsuperscript{34}

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