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## Congenital Brain Tumors: A Review of 45 Cases

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Forty-five pathologically proved cases of neonatal brain tumors (diagnosed in neonates within 60 days after birth) were reviewed from the neuroradiology archives dating back to 1964. CT was performed in 24 cases, MR in five, sonography in six, and angiography in seven. Two-thirds of the lesions were supratentorial. The most common histology was a tumor composed of primitive or poorly differentiated tissues: 12 teratomas and 12 primitive neuroectodermal tumors, four of which were typical medulloblastomas. In addition, there were nine astrocytomas (grades I–III); four cases of glioblastoma multiforme (astrocytoma grade IV); three choroid plexus papillomas; and single cases each of ependymoma, medulloepithelioma, germinoma, angioblastic meningioma, and ganglioglioma. The dominant CT appearance, regardless of histology, was a large heterogeneous lesion with associated hydrocephalus. Coarse calcification was a constant feature in the teratomas. Prognosis was poor overall, with the longest survival seen in choroid plexus papilloma and astrocytoma.

Imaging studies are most valuable in identifying and distinguishing potentially curable lesions such as choroid plexus papillomas (variably sized intraventricular lesions with homogeneous enhancement) from rapidly fatal tumors such as teratomas (large heterogeneous lesions with coarse calcifications and associated hydrocephalus).

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Neonatal brain tumors are those that present clinically within the first 2 months of life [1, 2]. They are rare and represent only 0.5–1.9% of all pediatric brain tumors (those in individuals under the age of 15) [2–6].

There have been many reported cases [1–50] and numerous review articles [1, 2, 11, 14, 47, 51, 52] on neonatal brain tumors, including over 200 pathologic cases, but most lack radiologic correlation. Prior to this series, the largest radiologic study was a report of the imaging characteristics of 12 such cases [6]. Before the wide application of CT and sonography, the majority of these cases were diagnosed at autopsy. Today, the availability of noninvasive imaging of the fetus and neonate makes likely the earlier diagnosis of these tumors, perhaps at a subclinical stage [6, 33, 47]. The previously revealed prevalence, as well as our understanding of the histologic and anatomic distribution of these tumors of early life, may thus be in need of revision.

For this study, 45 cases of neonatal brain tumors were reviewed for clinical and pathologic features. In 24 cases, correlation with one or more imaging studies, including CT, MR, sonography, and angiography, was possible. The results of these analyses are discussed and compared with previous accounts documented within the literature. This is the largest series of this type yet reported and explores the usefulness and potential of imaging in diagnosis, characterization, and determination of the operability of these tumors. Specifically, the potentially resectable choroid plexus papilloma (CPP), an intraventricular mass with homogeneous enhancement, can be differentiated from the majority of other tumors, which are usually large heterogeneous masses. The teratomas classically feature coarse calcifications, and also may be differentiated.

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## Materials and Methods

From a review of our case records from January 1964 through January 1989, 45 cases of neonatal brain tumors were found. In 24 of these cases, imaging studies, including CT, had been performed. Only neonates who presented with symptoms between birth and 60 days of age were included.

The gross and histologic appearances of the tumors were correlated with the clinical findings in all cases. Files were reviewed for age at presentation, gestation and birth history, clinical symptoms and signs, association with other congenital anomalies, sex, type of surgery performed and outcome, patient survival, lesion histology and location, and imaging characteristics.

Imaging studies were evaluated for the size of the tumor and its consistency, whether cystic, homogeneous, or heterogeneous. Enhancement characteristics, presence of hydrocephalus, and tumor-related calcification were also reviewed. Twenty-four cases were complemented by CT, seven by cerebral angiography, six by sonography, and five by MR. The imaging equipment used varied according to the time and place the study was performed.

## Results

The 45 cases of neonatal brain tumors are summarized according to histology and location in Table 1.

### Birth History

The mean age at diagnosis was 10 days. Twenty-five cases were diagnosed within the first 24 hr and 39 cases within the first month. Two infants were stillborn and two were born prematurely. There were birth complications in eight, including

prolonged labor, fetal distress, and failure to progress; five of these were delivered by cesarean section. However, the majority of deliveries (27 cases) were uncomplicated; cesarean delivery was *elective* in five of these. In 10 cases adequate birth history was not available.

Presenting signs and symptoms most commonly included increasing head circumference, noted in 28 cases. Other presenting signs were visual changes (orbital mass, decreased visual acuity, nystagmus, proptosis, and exophthalmos) in seven cases, vomiting in five cases, seizures in three, hemiparesis in three, cranial-nerve palsy in one, lethargy in one, and skull fracture in one. Presenting signs were unknown in three cases. In one case of CPP there was an associated lumbar meningocele; no other case had an associated congenital anomaly.

### Sex

Overall there was a slight male predilection: 25 cases were male, 18 female, and two undetermined. The following distribution was noted among the major specific tumor types: teratoma (seven males, five females); astrocytoma (five males, four females); and primitive neuroectodermal tumor (four males, two females, two unknown).

### Surgery

All cases were proved pathologically. Thirty-five patients underwent surgery for tissue biopsy and the remaining 10 were diagnosed at autopsy. Surgery was performed for de-

TABLE 1: Congenital Brain Tumors Found in Neonates

Histology	No. of Cases			
	Total	Supratentorial	Infratentorial	Unknown
Neuroepithelial				
Glial				
Astrocytoma	9	8	1	0
Glioblastoma multiforme	4	4	0	0
Choroid plexus papilloma	3	3	0	0
Papillary ependymoma	1	1	0	0
Total	17	16	1	0
Neuronal				
Ganglioglioma	1	1	0	0
Primitive neuroepithelial				
Primitive neuroectodermal	8	7	0	1
Medulloblastoma	4	0	4	0
Medulloepithelioma	1	0	1	0
Total	13	7	5	1
Meningeal				
Meningioma				
Angioblastic meningioma	1	1	0	0
Germ cell				
Teratoma	12	6	5	1
Germinoma	1 <sup>a</sup>	0.5	0.5	0
Total	13	6.5	5.5	1

<sup>a</sup> Distributed equally in temporal lobe and brainstem.



bulking, partial resection, or complete resection in 17 cases. Surgery was limited to placement of a ventricular shunt in four cases; surgical history beyond biopsy was not available in four cases. Of the 21 patients who underwent major surgery (shunts and/or debulking), five (23.8%) died from postoperative complications. One patient with CPP was reported to have undergone complete resection for cure, but extended follow-up was not available. In the remaining 20 cases, resection of any kind was precluded by the size and extent of the tumor.

### Prognosis

Clinical follow-up from the time of diagnosis to the present, or until the patient's death, was available in 24 cases. Prognosis, outside of the single case of CPP noted above, was uniformly poor. Among the tumor types, astrocytomas had the most favorable outcome, with a mean survival of 26.0 months, followed by PNET, with a mean survival of 5.2 months; most lethal of all were the teratomas, with a mean survival of only 21 days. Of the 24 patients with available follow-up, one with a PNET is alive at 10 months of age but doing poorly. The mean survival for the remainder was 5.7 months; the oldest survivor, living to 4½ years, had an occipital astrocytoma, grade IV.

### Pathology

Teratoma was the most common tumor type, with 12 cases (26.7%). There was one other germ-cell tumor, a germinoma of the brainstem and temporal lobe. Neuroepithelial tumors of all histologic types accounted for 30 of 45 cases. Glial tumors included nine astrocytomas, three CPPs, four cases of glioblastoma multiforme, and one papillary ependymoma. There were 13 PNETs, including eight supratentorial PNETs, four infratentorial PNETs (medulloblastomas), and one medulloepithelioma. One neuronal tumor, a ganglioglioma, was seen. There was a single meningeal tumor, an angiolymphomatous menin-

gioma. No cases of craniopharyngioma were found among these 45 cases.

### Location

In all, two-thirds (31/45) of tumors were supratentorial, 24.4% (11/45) were infratentorial, two were unknown, and a single tumor was in both locations. Among the 24 cases with imaging studies, 19 tumors were supratentorial and five were infratentorial. Reports in the remaining 21 cases indicated that 11 were supratentorial, seven were infratentorial, two were unspecified, and one case of germinoma straddled the tentorium and involved both the brainstem and temporal lobe.

### Imaging

Hydrocephalus was seen on CT in 21 of 24 cases. In 18 cases the tumor was large, occupying more than one-third of the intracranial volume. The majority of tumors, 16 of 24, were heterogeneous and partially cystic. Four of 24 cases had associated hemorrhage.

The large size and heterogeneous nature of these tumors, regardless of histology, are demonstrated in Figures 1–3: one case each of teratoma, PNET (medulloblastoma), and astrocytoma, respectively. The serial images of Figure 4, of an atypical solid PNET, highlight the potential for rapid growth seen in many of these tumors. Both CPPs presented as enhancing intraventricular masses with associated hydrocephalus. They may also infiltrate the surrounding parenchyma (Fig. 5). Their intraventricular location and homogeneous enhancement pattern distinguishes them from the other tumor types.

Tumor calcification was documented in a total of 11 cases, primarily in the teratomas, where it was noted on CT in six of seven cases and tended to be abundant and clumplike (Fig. 1). In the single case of teratoma without calcification, only a contrast-enhanced CT scan was available and calcification could not be definitely confirmed or excluded. In addition,

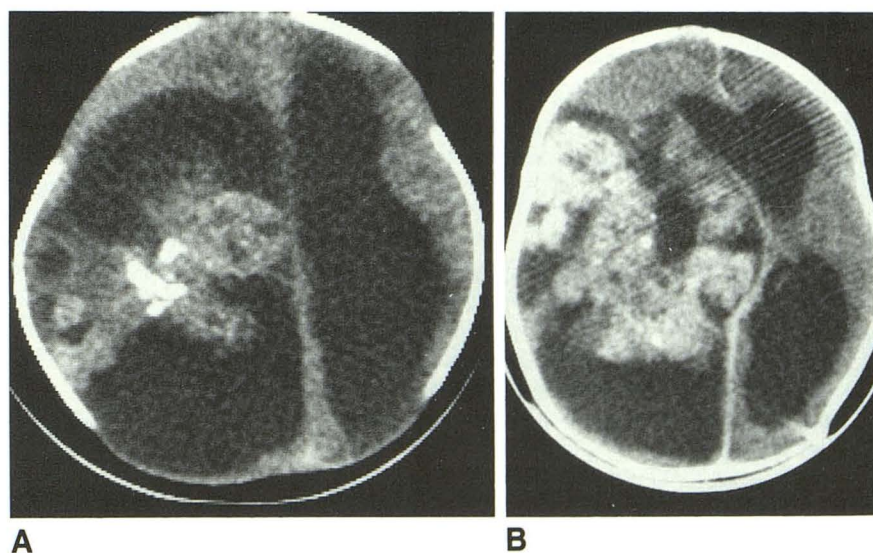


Fig. 1.—Teratoma.  
A, Unenhanced axial CT scan shows chunklike calcification within heterogeneous mass and associated hydrocephalus.  
B, After administration of contrast material there is heterogeneous enhancement.



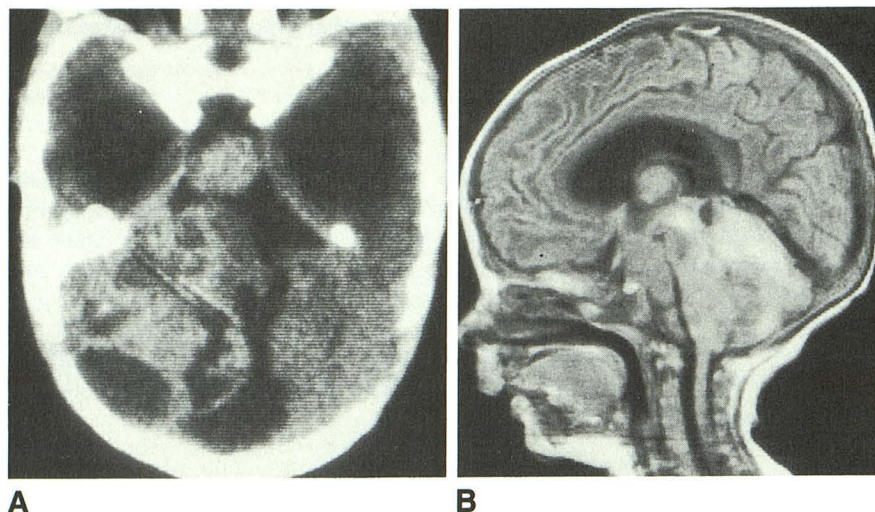


Fig. 2.—Primitive neuroectodermal tumor (medulloblastoma).

A, Postcontrast axial CT scan shows heterogeneously enhancing mass within posterior fossa with extension into brainstem.

B, Sagittal T1-weighted MR image shows mixed-signal-intensity mass extending from cerebellum into brainstem and associated hydrocephalus. Note extension ventral to basilar artery and in interpeduncular and suprasellar cisterns.

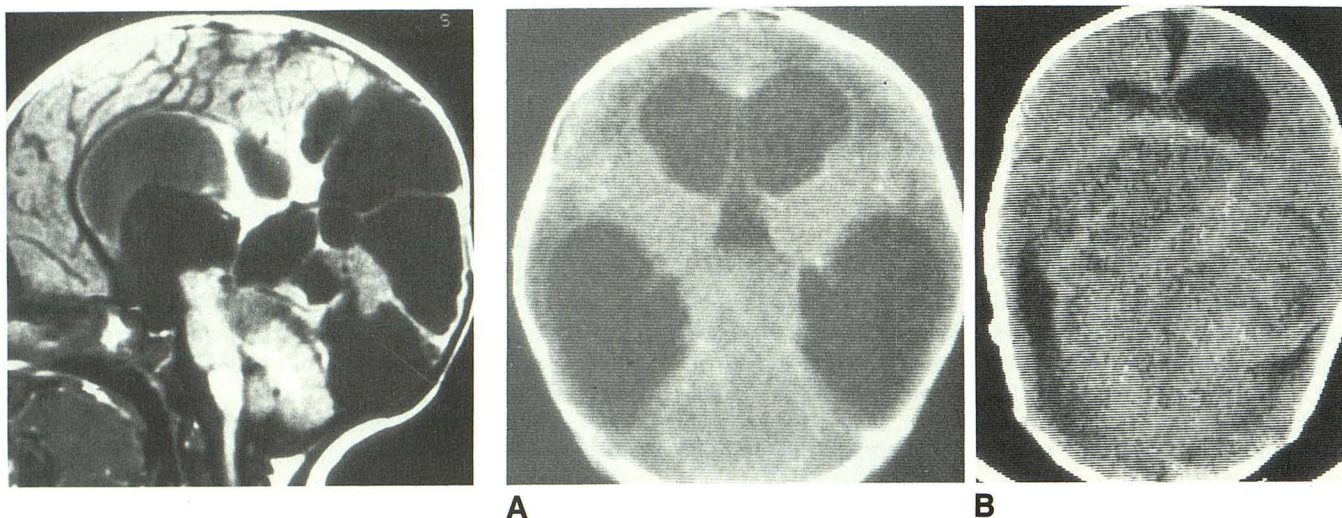


Fig. 3.—Grade IV astrocytoma, glioblastoma multiforme. Sagittal T1-weighted MR image shows mixed-signal-intensity mass around choroid plexus. High signal represents area of hemorrhage. Note associated hydrocephalus.

Fig. 4.—Primitive neuroectodermal tumor.

A, Axial CT scan shows a midline solid mass in region of quadrigeminal plate with associated hydrocephalus.

B, Follow-up scan 10 weeks later reveals marked enlargement of tumor mass.

tumor calcification was noted on plain radiographs in one case of teratoma in which CT was not performed. A single focus of thin curvilinear calcification was noted in two cases of supratentorial PNET. In one case of ganglioglioma, calcification was noted microscopically, but imaging had not been performed.

MR showed heterogeneous signal intensity on T1- and T2-weighted images accompanied by hydrocephalus in cases of glioblastoma multiforme (Fig. 3), PNET (Fig. 2), and teratoma. In contrast, homogeneous intermediate T1 signal and high T2 signal were noted in CPP (Fig. 5). Angiography showed marked intraventricular tumor blush fed by branches of the anterior choroidal (Fig. 5) and medial posterior choroidal arteries in two cases of CPP; two astrocytomas demonstrated a slight tumor blush with mass effect, but cases of glioblastoma multiforme (Fig. 3), PNET, and ganglioglioma presented

as avascular masses. Sonography, when performed, was usually the first examination performed. Echo texture varied from hypoechoic (medulloepithelioma) to hyperechoic (angio-blastic meningioma), but most tumors were complex echo-genic masses (teratomas); hydrocephalus was identified when present, and calcification was demonstrated in a case of teratoma.

## Discussion

Ainstein et al. [1] first reviewed congenital brain tumors presenting in the neonates, and defined them as limited to tumors presenting within 60 days after birth. Congenital brain tumors represent only 0.5–1.9% of all pediatric brain tumors [2–6].



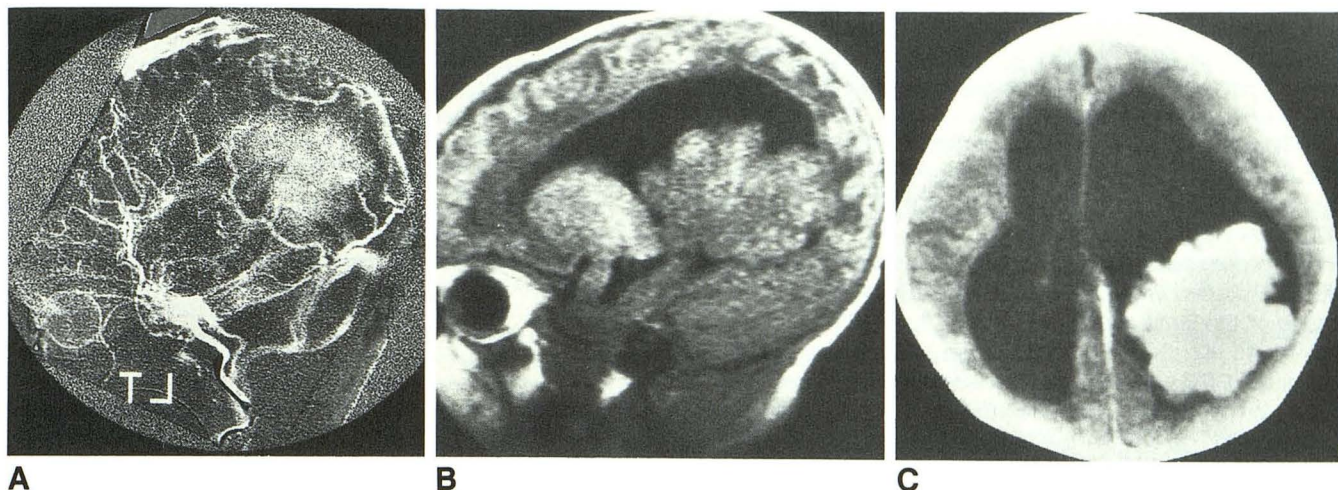


Fig. 5.—Choroid plexus papilloma.

A, Angiogram of left internal carotid artery shows dense vascular blush supplied by anterior choroidal artery.

B, Sagittal T1-weighted MR image shows lobulated homogeneous mass in region of trigone with hydrocephalus.

C, Postcontrast axial CT scan reveals an enhancing intraventricular mass with hydrocephalus.

Later, in 1964, Solitare and Krigman [14] reviewed 45 cases of neonatal brain tumors and classified them into three categories: (1) definitely congenital, those presenting or producing symptoms at birth; (2) probably congenital, those presenting or producing symptoms within the first week; and, (3) possibly congenital, those presenting or producing symptoms within the first few months. Wakai et al. [2] modified this categorization by limiting the last group to neonates presenting within 2 months of life [2]. Conversely, broader modifications have included infants older than 1 year of age, provided symptoms began in the first year [3]. Although such divisions are arbitrary, there is no doubt that tumors presenting at birth are congenital. Thereafter, confidence about their congenital origin wanes with increasing time between birth and symptoms. The present study included only neonates aged 2 months or less, over half of whom presented at birth.

The most frequent initial symptom reported in the literature, as in our study, is an enlarged head [3]. Signs of increased intracranial pressure such as vomiting and papilledema were noted infrequently, because in neonates a freely expanding calvaria can accommodate the increased volume [6]. Despite increased head circumference, 27 of 35 births were complicated. Only two were stillborn and two premature, suggesting that these tumors do not interfere severely with normal gestation or parturition.

Focal neurologic changes were absent in most cases of neonatal brain tumor despite the large head size and hydrocephalus [2, 3, 6]. Clinical diagnosis is often difficult owing to nonspecific signs; some tumors are detected incidentally [2–4, 6, 8, 12, 13, 15–18, 20, 23, 27, 30, 38, 46, 53, 54]. In our study one case of PNET was discovered incidentally after a skull fracture.

Teratoma is the most common tumor in the neonatal period, representing about one-third to one-half of all cases [2, 3, 23, 34]. They occur supratentorially in at least two-thirds of cases and less commonly infratentorially [1–4, 6, 11, 13, 19, 23, 32–34, 40, 47, 50]. In our series they were also the most

common tumor, accounting for 12 of 45 cases. Tumor calcification was noted on CT in all six cases in which unenhanced studies had been performed and tended to be clump-like (Fig. 1). In only two other tumors, both PNETs, was calcification noted on CT; however, it was curvilinear and sparse. Calcification and its appearance, therefore, may prove to be a specific and sensitive sign suggesting the diagnosis of congenital CNS teratoma. Perhaps this is because teratomas can produce a calcified matrix. The other tumor types calcify dystrophically, requiring time to develop. Radkowski et al. [6] reported tumor calcification in two of three teratomas; however, they also noted calcification in four of five cases of CPP and one case of PNET. That calcification can be seen in various tumor types suggests that only the type and quantity of calcification may be useful distinguishing features.

The prevalence of tumor hemorrhage in this series was 18%, much higher than the rate seen in children and adults [55], and agrees with the high 14% prevalence previously reported [2]. This has been attributed to the rapid growth of the neonatal tumors.

Neuroepithelial tumors constituted 69% of the tumors of this series. The prevalence of these tumors was about 50% in the largest previous study [2], but varied slightly from study to study [1–4, 8, 10, 12, 13, 19, 25, 34, 53, 56]. Seventeen (56.7%) of 30 neuroepithelial tumors were glial in origin, of which nine (29%) were astrocytomas. Supratentorial PNETs followed with eight cases; medulloblastomas represented four cases. If medulloblastomas are grouped with other PNETs, then they would collectively account for 12 cases, equaling the prevalence of teratomas. The increasing prevalence of the diagnosis of PNET may be due to the relatively recent origin of this new classification, reported by Hart and Earle [57] in 1973. The difficult histology of these tumors may make them more likely to be referred for secondary consultations as well. There were no cases of craniopharyngioma, a tumor common in children and young adults but not found frequently in neonates [1–4, 6, 8, 10, 13, 14, 16, 18, 39, 42, 56]. It is



certain, nevertheless, that the apparent prevalence and age distribution of CNS tumors are changing with the earlier referral and diagnosis made possible with the advent of CT [35].

In agreement with most previous reports [1–9, 13, 19, 22, 23, 27, 34, 35, 38, 54, 56, 58], the majority of our cases were supratentorial (two-thirds) and there was no statistically significant sex predilection.

The prognosis is guarded in all neonates with brain tumors, despite modern imaging methods and surgery, probably because of the large size (2, 3, 7, 10, 19, 22, 23, 26, 31, 32, 38, 40, 45, 47, 54, 58, 59). However, survival is significantly better for CPP and astrocytoma than for other tumor types [3, 6]; in this series one of the patients with CPP underwent resection for cure while the mean survival time for astrocytoma was 26 months.

CT was superior to MR in the detection of calcifications, but MR, through its multiple imaging planes and absence of bone artifact, better delineated the extent of the tumor, especially within the posterior fossa. Angiography was most useful in the cases of CPP, in which it revealed a vascular blush and the supplying vessel(s). In some cases sonography may have been the first examination to demonstrate the tumor mass, but it was not specific and CT was essential for further clarification.

Imaging studies are helpful in determining the suitability for surgery and, perhaps, in the detection and diagnosis of teratoma and CPP. The dominant CT and MR appearance, however, regardless of histology, was that of a large heterogeneous mass with associated hydrocephalus. For the neonate with a brain tumor, imaging studies are invaluable in the early detection of CPP, a variably-sized intraventricular lesion with homogeneous enhancement, which is particularly amenable to surgical resection before it extends into the parenchyma.

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