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Brainstem Evaluation with CT Cisternography

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Seventy-eight positive contrast computed tomography (CT) cisternograms were reviewed to assess the normal anatomy of the brainstem and its surrounding cisterns. Normal brainstem and cisternal anatomy was found to be constant and symmetrical. The review included six patients with brainstem gliomas and five patients with extraaxial masses. In these patients CT cisternography accurately identified mass formation and permitted the confident distinction of extraaxial from intra-axial masses. CT cisternography is a safe and accurate method for evaluating the anterior compartment of the posterior fossa. This procedure is particularly applicable to those cases where conventional CT yields insufficient diagnostic information.

Before the advent of computed tomography (CT), patients suspected of harboring a brainstem glioma were subjected to angiography and pneumoencephalography. In most instances CT is now capable of identifying a brainstem mass [1, 2], although angiography and pneumoencephalography are frequently considered necessary to support the diagnosis [1-4]. The reports of early investigators concerning the potential value of positive contrast CT cisternography encouraged us to use this technique for brainstem evaluation [5-7]. This report discusses our experience with CT cisternography as it relates to the normal and abnormal brainstem, and the application of this technique to those cases in which conventional CT of the brainstem is negative or insufficiently diagnostic for patient management.

Materials and Methods

CT cisternography is performed by the lumbar subarachnoid instillation of 6 ml of metrizamide in a concentration of 190 mg I/ml under fluoroscopic control. A proportionately smaller volume is administered to infants and children [5]. With the patient still prone, the fluoroscopic table is tilted into a 45° Trendelenburg position with the head flexed (chin tucked) for about 2 min to allow passage of the contrast agent into the intracranial cisterns. The patient remains in a prone hanging-head position during transport to a General Electric 8800 CT scanner. CT scanning is then carried out in the supine position, parallel to the canthomeatal line. Adjacent 10 mm thick slices are obtained. When greater detail is sought, 5 mm slices are used. The use of coronal scanning varies with the individual circumstance. No attempt is made to return the contrast to the lumbar sac at the end of the examination.

During a 2 year period, 78 CT cisternograms were obtained in our radiology department for a variety of indications (table 1). All cisternograms were reviewed in order to determine the appearance of the normal and abnormal brainstem. Symmetry of the brainstem and its surrounding cisterns was noted. Where possible, the transverse diameters of the medulla, pons, and cerebral peduncles, as well as the distance from the anterior pons to the fourth ventricle, were determined from axial images. Our experience includes six intraaxial and five extraaxial masses (arachnoid cyst, cholesteatoma, chordoma, hypoglossal neuroma, and metastasis). The cisternographic distinction between these two groups was sought. In addition, a chart review was conducted for all patients who underwent CT cisternography to determine the incidence and severity of adverse symptoms attributable to the examination.

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TABLE 1: Indications for CT Cisternography

Diagnosis	No. Patients
Normal pressure hydrocephalus	15
Empty sella	17
Pituitary tumor	9
Optic chiasm lesion	7
Brainstem lesion	13
Cerebrospinal fluid leak	7
Foramen magnum lesion	3
Miscellaneous:	
Arachnoid cyst	1
Chordoma	1
Arnold-Chiari malformation, type 1	1
Cholesteatoma	1
Craniopharyngioma	1
Hypoglossal neuroma	1
Metastasis to cerebellopontine angle	1
Subtotal	7
Total	78

Results

The basal cisterns of the posterior fossa were imaged in about one-half of these cases. For this study, all patients who were examined for reasons unrelated to the brainstem or posterior fossa were considered "normal."

Normal Brainstem

The axial surface anatomy of the normal brainstem is constant and symmetrical (figs. 1–6). The posterior cerebral, basilar, and vertebral arteries are routinely identified. The posterior communicating arteries and cranial nerves 3 and 5 are often seen. Occasional scans demonstrated cranial nerves 7 and 8 (fig. 7). Usually these two cranial nerves cannot be separated.

In about 10% of normal cases, a minor degree of brainstem asymmetry was noted, particularly in the cerebral peduncles (fig. 8). In most cases the patient's head was not symmetrically positioned. Minor asymmetry or brainstem rotation in the pons and medulla may occur due to an ectatic vertebral or basilar artery (fig. 9). Minor asymmetry may also occur in the medulla without apparent explanation, but the surface anatomy is preserved (fig. 10).

The transverse diameters across the medulla, pons, and cerebral peduncles were measured in all cases where possible. The distance from the anterior pons to the floor of the fourth ventricle was also measured (fig. 11). Transverse measurements were easily made except at the level of the brachium pontis, where the lateral pontine borders are not readily identified. At this location transverse measurement of the brainstem was made 5 mm posterior to the anterior pontine margin.

The various normal brainstem measurements are found in table 2. There were three normal patients under 10 years of age. Brainstem measurements in this group tended to be at the lower end of the normal range (defined as ± 2 SD from the mean). Elderly patients sometimes exhibited brainstem size at the lower end of the normal range with prominence of the surrounding cisterns. Otherwise, brainstem diameters

varied widely without regard to age. In 11 "normal" adult patients, a part of the brainstem was 1–2 mm above the 2 SD range. In each of these patients, the brainstem was generally large, but normal-appearing at all levels.

Table 2 indicates a rather large standard deviation in the measurement of each brainstem diameter among normal patients. This broad range of values is due to several factors. For practical reasons, measurements were made from hard copy and corrected for minification. The pons is best seen where its sides blend with the diverging limbs of the brachium pontis and reproducible transverse measurement is difficult. Transverse measurement of the cerebral peduncles is difficult because this dimension tends to decrease as the peduncles descend to the pons. Incomplete mixing of metrizamide with cerebrospinal fluid in the fourth ventricle prevented adequate delineation of the ventricular floor in several patients. Finally, it is difficult to precisely control the scan angulation and slice level. Despite the above technical pitfalls, we were impressed by the wide range of normal brainstem size.

Fourth Ventricular Filling

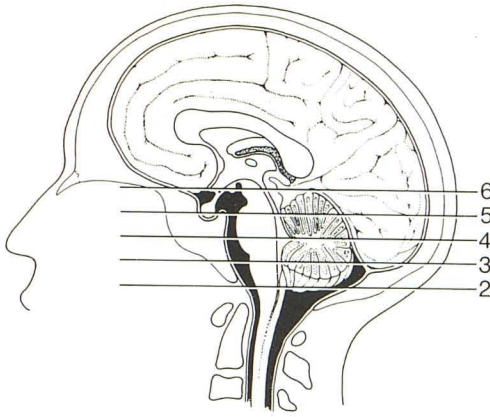
In our department metrizamide is delivered to the basal cisterns in the prone position. Nevertheless, the fourth ventricle filled with contrast material in all normal patients. Conversely, in this small series posterior fossa pathology was present in all cases where fourth ventricular filling was not achieved (table 3).

Abnormal Brainstem

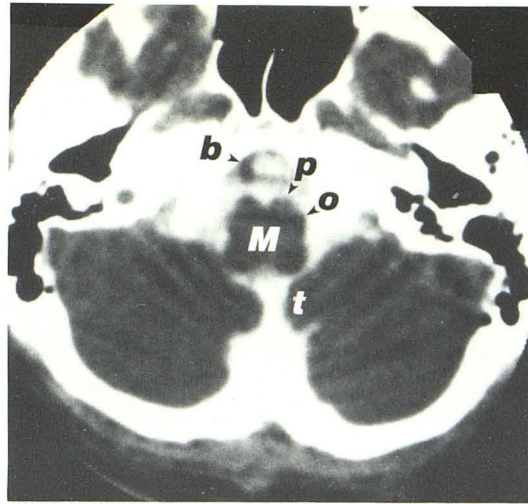
In the 2 year period of review, nine patients with progressive brainstem and/or cranial nerve disease had radiographic studies demonstrating brainstem enlargement. Brainstem masses are not biopsied at our institution so histologic confirmation is unavailable in these cases. All patients were still living at the time of this study, but the interval of follow-up was short. In most, symptoms had progressed.

Six of the nine patients were studied with CT cisternography; in two conventional CT scanning was entirely negative. The fourth ventricle failed to fill with metrizamide in two cases. In the first instance, mild hydrocephalus was present, and in the second, tumor mass went into the cisterna magna. In all six cases brainstem enlargement was recognized by disproportionate size of the affected structure and alteration of the normal symmetrical surface anatomy (figs. 12 and 13). A recognizable increase in the distance from the anterior pons to the fourth ventricle was often observed.

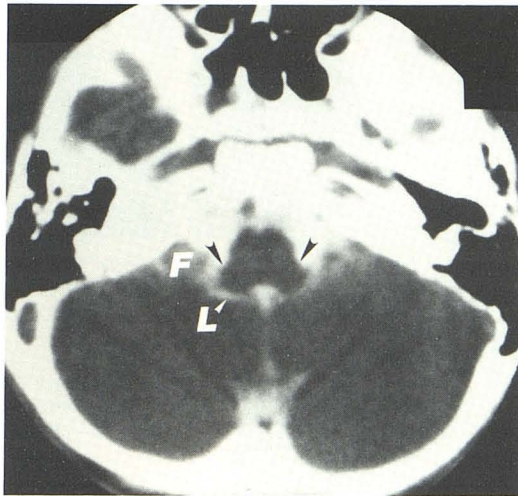
In five out of the six patients, measurements of the affected brainstem were greater than 2 SD above the mean, but in three cases the brainstem diameter exceeded the 2 SD range by less than 3 mm. In the sixth patient, the medulla was of borderline size, but quite asymmetrical. The patient's symptoms corresponded to the larger side. In each case brainstem enlargement was appreciated from simple inspection of the images.



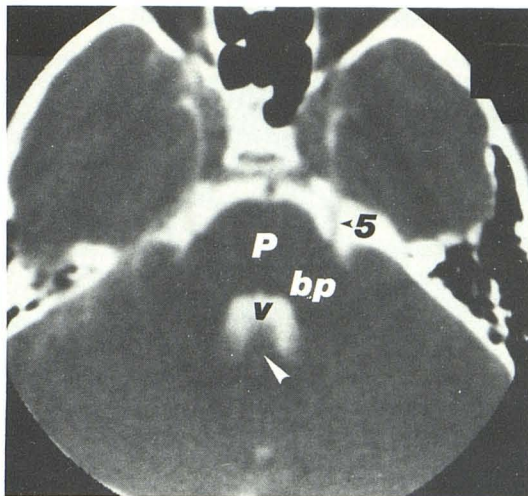
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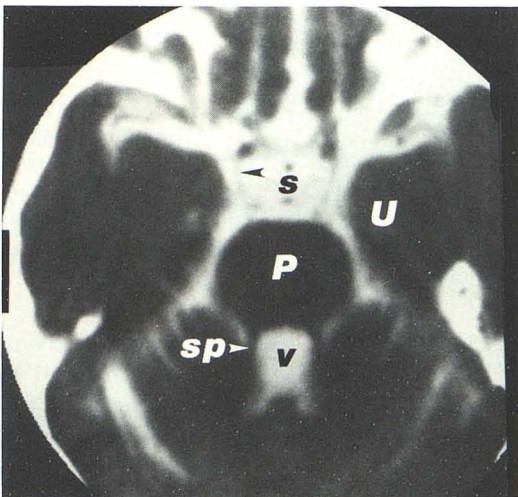
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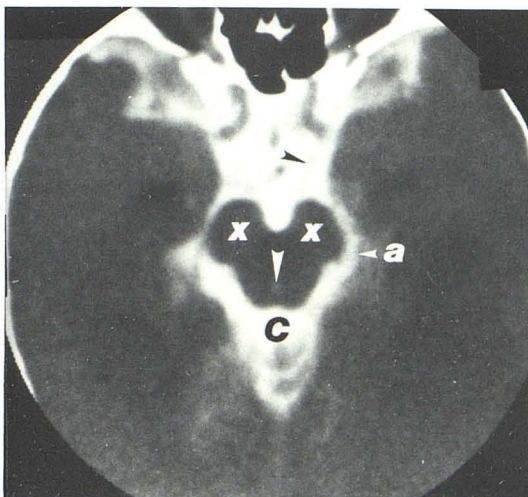
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6

Fig. 1.—Approximate levels of figs. 2–6.

Fig. 2.—Pyramids (p), olivary nuclei (o), cerebellar tonsils (t), and basilar artery (b) at level of midmedulla (M).

Fig. 3.—Rostral margin of medulla. Posterior columns (arrowheads), which contain lower cranial nerve nuclei, diverge to blend with inferior cerebellar peduncles. Foramen of Luschka (L) and laterally cerebellar flocculus (F) projecting into cerebellopontine angle cistern.

Fig. 4.—Level of midpons (P). Fourth ventricle (v), brachium pontis (bp), and often fifth cranial nerve (5) are seen. Inferior cerebellar vermis (arrowhead) indents posterior fourth ventricle.

Fig. 5.—Cut through upper pons (P) usually demonstrates temporal lobe uncus (U), suprasellar cistern (s), upper fourth ventricle (v), and superior cerebellar peduncle (sp). Posterior communicating arteries (arrowhead) are seen occasionally.

Fig. 6.—Appearance of cerebral peduncles (x) varies slightly with level of scan. Ambient cistern (perimesencephalic) (a) encircles midbrain to enter quadrigeminal cistern (C), the anterior boundary of which is formed by the colliculi. Aqueduct (large white arrowhead) may be seen when metrizamide enters this structure. Third cranial nerves (black arrowhead) are frequently identified.

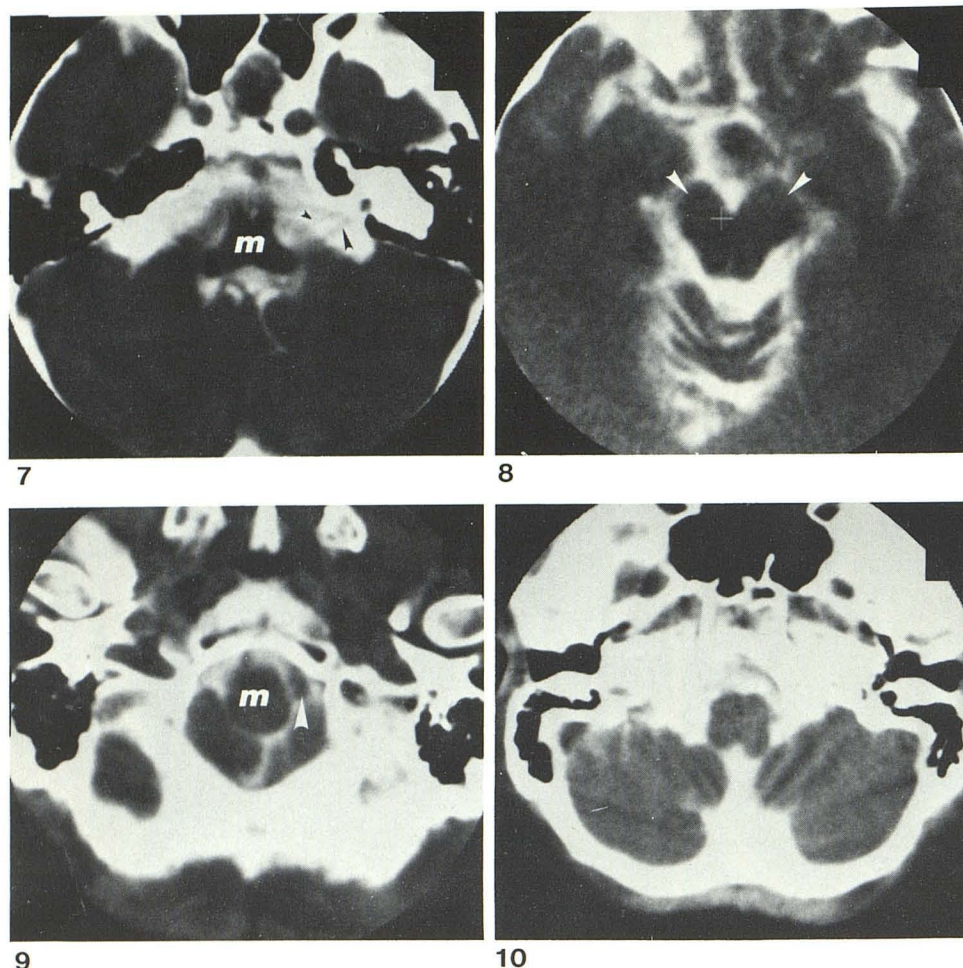


Fig. 7.—At level of upper medulla (m). Cranial nerves 7 (small arrowhead) and 8 (large arrowhead) course through cerebellopontine angle cistern to enter internal auditory canal.

Fig. 8.—Asymmetry of cerebral peduncles (arrowheads) due to positioning error.

Fig. 9.—Deformity of lower medulla (m) due to adjacent dominant vertebral artery (arrowhead).

Fig. 10.—Medulla exhibits mild asymmetry. No clinical evidence of brainstem disease.

Pneumoencephalography was not used in any of the nine brainstem glioma patients. Six patients with positive conventional CT scans were studied with angiography. Brainstem enlargement was confirmed in each case, and in one other case where conventional CT had been negative.

Extraaxial Masses

This review included five patients with extraaxial masses contiguous with the brainstem. Each CT cisternogram confirmed the extraaxial location of the mass. Coronal scanning was sometimes required. The brainstem may be compressed, displaced, and sometimes rotated by an extraaxial mass. If small, an extraaxial mass tends to widen the involved cistern. If sufficiently large, the mass may entirely fill the cistern. In either event, a pointed contrast interface between the mass and the brainstem indicates the extraaxial location of the disease process (fig. 14). Bone destruction, seen in three of our five cases, also indicates an extraaxial mass. In one patient, whose conventional CT examination had demonstrated a low density prepontine mass suggestive of cholesteatoma, CT cisternography supported this preoperative diagnosis (fig. 15).

Morbidity

A retrospective review indicates that about 50% of the patients developed a headache after cisternography. About one-third developed nausea. These symptoms were generally mild and of short duration. There were no recorded seizures. This degree of morbidity is comparable with the experience of others [5, 6].

Discussion

Brainstem gliomas are most prevalent in childhood and adolescence, but they also occur during adult life [8–10]. About 50% of these are high-grade astrocytomas or glioblastomas [11]. The accepted treatment is radiation therapy, in many cases without biopsy confirmation [8]. The typical progressive symptoms of brainstem and cranial nerve disease may be mimicked by an extraaxial mass [12]. Radiographic evaluation is therefore critical to patient management in that most extraaxial masses are amenable to surgery and relatively unresponsive to radiation therapy.

CT scanning is currently the screening procedure of choice in patients with symptoms of progressive cranial nerve or brainstem symptoms. The CT findings of brainstem

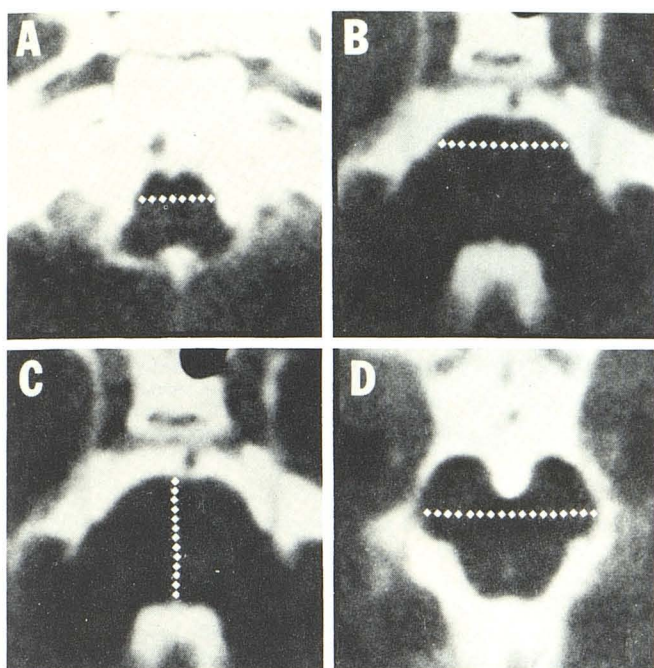


Fig. 11.—Locations at which transverse medullary (A), transverse pontine (B), pons—fourth ventricle (C), and transverse peduncular (D) dimensions were obtained.

TABLE 2: Normal Brainstem Measurements

Location	No. Cases	Mean (mm)	SD (σ)	Range ($\pm 2\sigma$) (mm)
Transverse peduncular	41	25.4	3.1	19.5–31.5
Transverse pontine	43	24.8	2.2	20.4–29.2
Transverse medullary	29	13.8	1.9	10.0–17.6
Pons—4th ventricle	39	22.8	2.3	18.1–27.4

TABLE 3: Nonfilling of the Fourth Ventricle

Diagnosis	No. Cases ($n = 78$)
Brainstem glioma	2
Hydrocephalus (communicating)	1
Chordoma	1
Arnold-Chiari malformation (type 1)	1
Hypoglossal neuroma	1
Total	6

Fig. 12.—Mass within cerebral peduncle (M) distorts normal symmetry and effaces adjacent uncus (U).

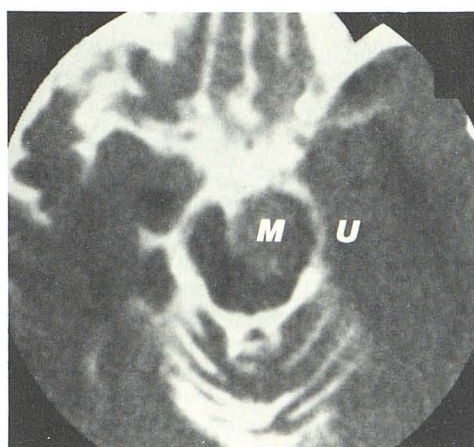
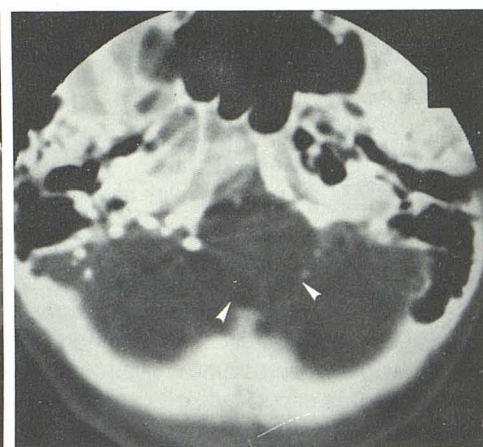


Fig. 13.—Metrizamide outlines enlarged medulla (arrowheads). (Conventional CT scan was negative.)

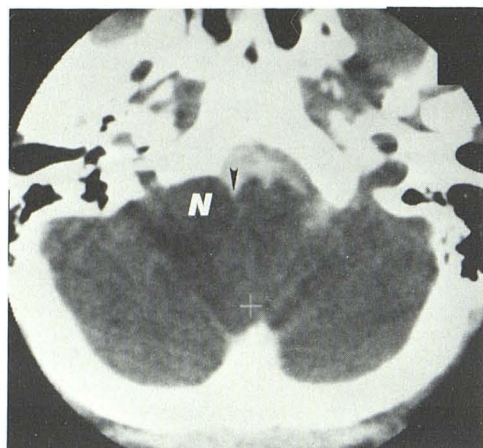


gliomas are quite variable [1–3, 13]. They may appear isodense, hyperdense, or hypodense on noncontrast CT. If isodense, the tumor may indicate its presence by obliteration or displacement of the fourth ventricle and compression of the adjacent cisterns. Low-density lesions are seen, in some cases indicative of cyst formation [13]. High density lesions most likely indicate foci of hemorrhage although calcification has been reported [14]. Hydrocephalus, usually mild, is present in one-third to one-half of cases. Contrast enhancement may or may not occur. A definite relation between enhancement and tumor grade has not been established, although an early trend has been reported [3].

Despite its efficacy in the diagnosis of brainstem masses, sometimes conventional CT is falsely negative, equivocal, or unable to distinguish between an intra- and extraaxial pro-

cess [5, 13, 15–17]. Most authors have recommended angiography or pneumoencephalography for such circumstances.

Initial experience has documented the safety and efficacy of CT cisternography for imaging the basal cisterns [6, 7]. Brainstem gliomas have been diagnosed [5, 18], but a discussion of normal high-resolution CT cisternographic anatomy of the brainstem has not been published. Our experience suggests that this procedure is the safest and most accurate means of brainstem evaluation. CT cisternography in combination with a current generation CT scanner can match or exceed the precision of pneumoencephalography. The brainstem and fourth ventricle can be precisely imaged, and cranial nerves often seen without thin collimation or special gantry angulation. Focal and diffuse



14



15

Fig. 14.—Hypoglossal neuroma (N). Contralateral displacement of medulla and pointed contrast interface (arrow-head), indicating extraaxial location of mass.

Fig. 15.—Diagnosis of cholesteatoma (verified at surgery) made preoperatively with CT cisternography when contrast was demonstrated within interstices of mass.

brainstem enlargement can be appreciated readily from simple inspection of the images. Borderline cases are more easily evaluated by visual assessment than by brainstem measurement. CT cisternography is also of benefit in those circumstances where conventional CT is unable to distinguish between an intra- and extraaxial mass. In the case of cholesteatoma, CT cisternography offers a specific diagnosis.

CT cisternography promises to further reduce the need for angiography. Nevertheless, angiography retains legitimate indications. If clinical or conventional CT findings suggest the possibility of a vascular lesion (aneurysm, arteriovenous malformation, hemangioblastoma) angiography should be performed. The neurosurgeon may find it useful to know the extent of displacement or involvement of major vessels by an extraaxial mass. Occasionally angiography may be necessary to distinguish an intra- from an extraaxial mass.

The high accuracy and low morbidity of CT cisternography should render pneumoencephalography obsolete for the detection of brainstem enlargement except for unusual circumstances. As with any new technique one must approach minimal findings with caution. Minor asymmetry is not rare. Pending further experience one must also assume that such nonneoplastic processes as inflammatory disease, multiple sclerosis, and Leigh disease, may cause brainstem swelling sufficient to be detected by CT cisternography.

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