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Axial CT Recognition of Anteroposterior Displacement of Fourth Ventricle

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The recognition of anterior or posterior displacement of the fourth ventricle on axial computed tomography (CT) has proven to be difficult because the apparent position of this structure is variable and dependent on scanning angle. In most cases direct visualization of a lesion and its relationship to normal anatomic structures allows for the correct assessment. However, in some instances it would be advantageous for lesion localization to be able to identify relatively subtle displacements of the fourth ventricle. This is possible on CT by determining the position of this structure relative to Twining's line (the line between the tuberculum sellae and torcula). The position of the fourth ventricle, tuberculum sellae, and torcula relative to an arbitrary fixed point can be established in virtually all cases, and thus the position of the fourth ventricle relative to Twining's line can be determined. In a control group of 100 patients with normal CT examinations, the ratio of the distance from the tuberculum sellae to the center of the fourth ventricle and the distance from the tuberculum sellae to torcula (Twining's line) was between 0.47 and 0.53. In 66% of the cases the ratio was 0.49–0.51. There were 54 posterior fossa masses evaluated by this technique. Determination of fourth ventricular position by this method proved to be of particular value in recognizing brainstem glioma, and in determining the site of origin of laterally placed posterior fossa masses.

The position of the fourth ventricle on axial computed tomography (CT) is variable and dependent on scanning angle. This variability has made it difficult to recognize anterior or posterior displacement of the fourth ventricle, unless the displacement is extreme. In most cases, direct visualization of a mass lesion and/or identification of specific fourth ventricular distortion allow for correct assessment. In those instances in which the mass is not clearly identified, or fourth ventricular distortion is nonspecific, recognition of relatively subtle anterior or posterior displacements of the fourth ventricle is extremely important. This is especially true with lesions such as brainstem gliomas or laterally placed posterior fossa masses. The only standard neuroradiologic measurement of fourth ventricular position that can be used with axial CT, Twining's line [1], requires that the tuberculum sellae, torcula, and midportion of the fourth ventricle all be clearly identified. Using the method we describe, Twining's line can be measured and relatively subtle displacements to the fourth ventricle demonstrated.

Materials and Methods

A total of 100 normal contrast enhanced CT scans performed on the EMI 1005 scanner was used as a control in this study. In 50 cases scans were obtained at 20° to the anthropologic baseline, with contiguous 10 mm cuts. In 50 cases overlapping base cuts were obtained at 8 mm intervals through the posterior fossa at angles of 20° (20 cases), 10° (10 cases) and 0° (20 cases) to the anthropologic baseline.

The angle formed by the anthropologic baseline and Twining's line was measured in 25 normal lateral skull radiographs.

Retrospective analysis was performed on 54 posterior fossa masses. Another 40 cases of posterior fossa pathology were excluded from this study for a variety of reasons including: lack of pathologic correlation (hematomas and infarcts); technically inadequate

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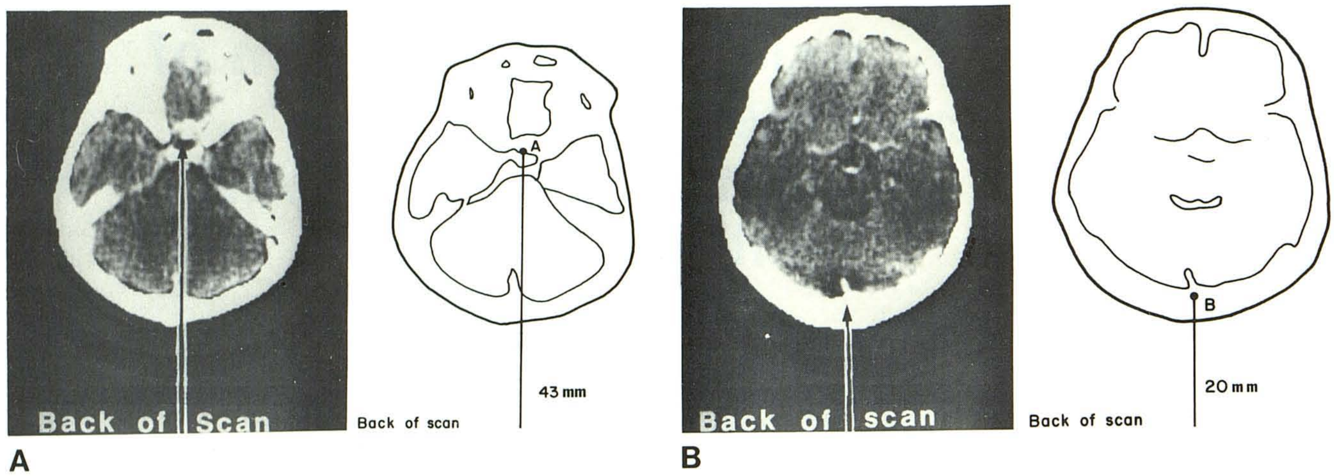


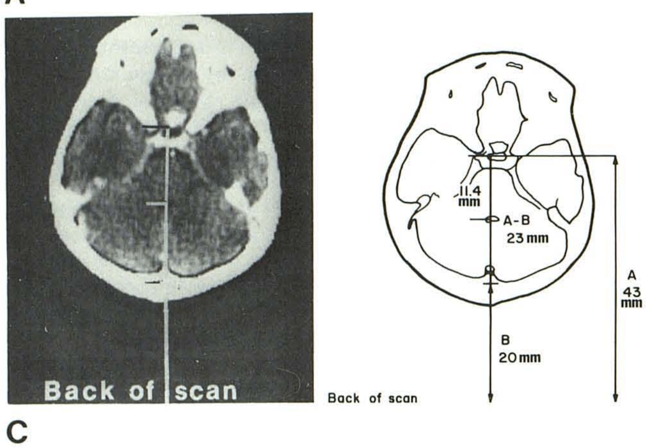


Fig. 1.—Method for determination of position of fourth ventricle relative to Twining's line (at 20° to anthropologic baseline). **A**, Distance *A*, from tuberculum sellae to back edge of scan, measured on original Polaroid image, is 43 mm. **B**, Torcula identified because of M-shaped configuration of tentorium and visualization of transverse sinuses. Distance *B*, from internal occipital protuberance at level of torcula to back edge of scan, is 20 mm. **C**, Scan through center of fourth ventricle. Lengths *A* and *B* determine positions of tuberculum and torcula relative to same fixed point. Twining's line is 23 mm. Distance from tuberculum to center of fourth ventricle is 11.4 mm. Ratio of tuberculum to fourth ventricle over Twining's line (TF/TT) is 0.50.

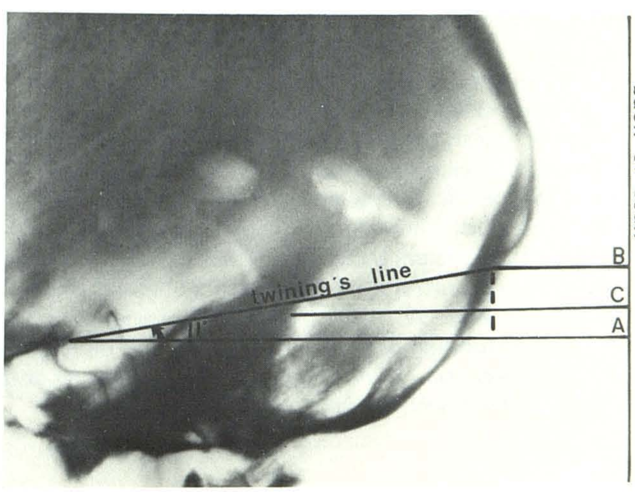


Fig. 2.—Autotomogram from normal pneumoencephalogram. *A:* line drawn in plane of CT scan from tuberculum sellae to back edge of scan. *B:* distance from internal occipital protuberance at level of torcula to back edge of scan. Broken line: intersects torcula and intersects and is perpendicular to line *A*. Distance from tuberculum to point where line *A* is intersected by broken line equals *A* − *B*, forming a right triangle with hypotenuse equal to Twining's line. Using standard trigonometric functions: Twining's line = *A* − *B*/cos ∠ (TA). In this case, Twining's line = *A* − *B*/cos ∠ (11°) = *A* − *B*/0.981 ≃ *A* − *B*.

TABLE 1: **TF/TT Ratio in 100 Normal Patients**

Ratio Criterion	Normal Scans Overlapping	Normal Scans Contiguous
Mean	0.50	0.49
Low	.48	.47
High	.52	.53
Range (%):		
0.49–0.51	72	60
0.48–0.52	100	92
0.47–0.53	100	100

Note.—TF/TT ratio = distance between tuberculum sellae and midline of fourth ventricle divided by length of Twining's line.

scans (motion artifacts, incomplete studies, no contrast scans); and inability to identify the fourth ventricle on technically adequate scans (four cases).

In 18 cases with cerebral angiography, the position of the fourth ventricle relative to Twining's line was determined by evaluating the position of the precentral cerebellar vein on lateral venous angiography [2, 3]. The results of these studies were correlated with CT findings.

Technique for Measuring Twining's Line

Individual scans demonstrating the tuberculum sellae (fig. 1A), torcula (fig. 1B), and center of the fourth ventricle (fig. 1C) were

TABLE 2: **TF/TT Ratio in 54 Pathologic Cases**

Pathologic Condition	No. Cases	Mean	Low	High	No. Normal Position
Brainstem Glioma	6	0.60	0.50	0.63	1
Cerebellopontine angle masses:					
Acoustic neurinoma	12	.55	.50	.61	2
Epidermoid	2	.57	.54	.60	0
Meningioma	2	.62	.58	.66	0
Ostemoa	1	.58	...	...	
Exophytic cerebellar glioma	1	.45	...	...	0
Cerebellar lesions:					
Medulloblastoma	9	.40	.33	.46	0
Astrocytoma	6	.44	.41	.47	0
Hemangioblastoma	3	.47	.45	.50	1
Metastasis	7	.44	.36	.50	1
Abscess	1	.44	...	...	0
Posterior extraaxial masses (non cerebellopontine angle):					
Arachnoid cyst	2	.44	.45	.46	0
Meningioma	2	.42	.38	.46	0

Note.—TF/TT ratio = distance between tuberculum sellae and midline of fourth ventricle divided by length of Twining's line. Normal positions had a TF/TT ratio range of 0.47–0.53.

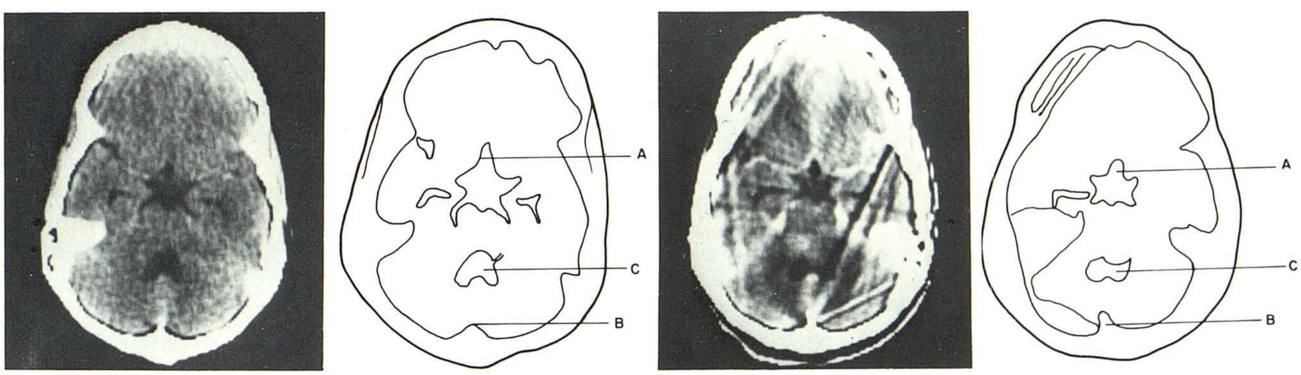


Fig. 3.—9-year-old girl with brainstem glioma. **A**, Initial scan with contrast enhancement. No abnormal densities and no subjective fourth ventricular displacement. However, TF/TT ratio, 0.61 (14/23), is indicative of marked posterior displacement of fourth ventricle by isodense nonenhancing brainstem glioma. **B**, Repeat scan 3 months later, after radiotherapy. Enhancing lesion within brainstem and nodular impression on fourth ventricle. However, lesion had slightly less mass since TF/TT ratio equals 0.59 (13/22). Therefore, changes in enhancement may represent radiation-induced tumor necrosis rather than progressive growth.

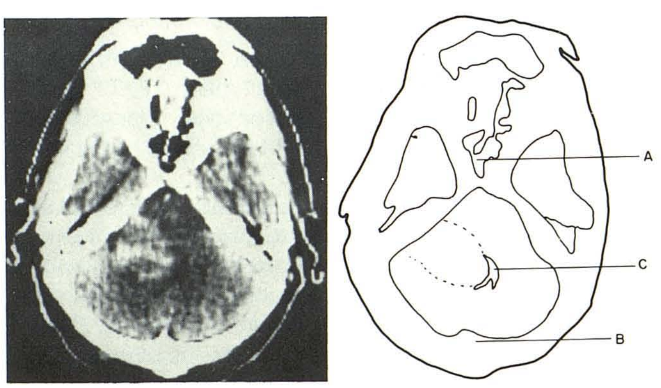
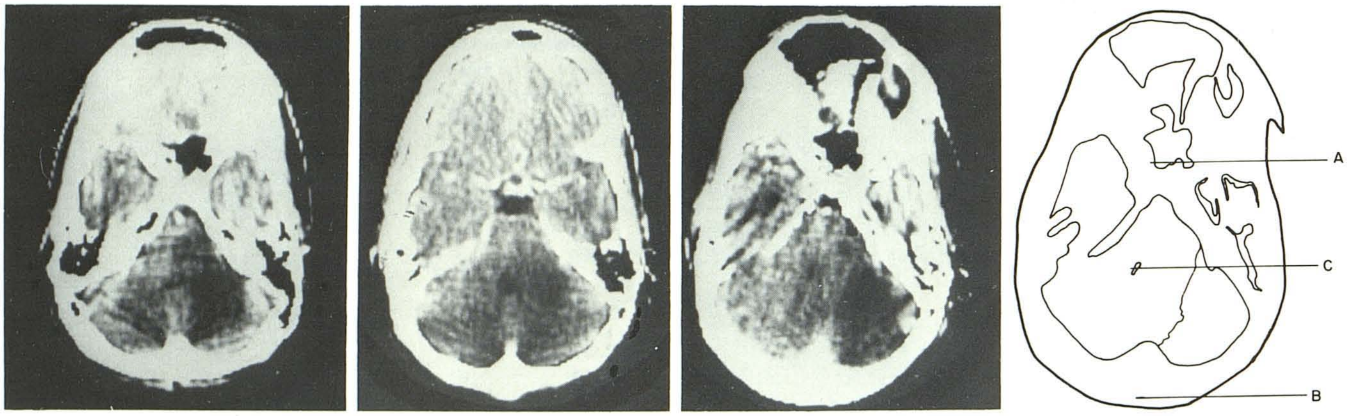


Fig. 4.—Acoustic neurinoma in 62-year-old woman. Enhancing lesion to left and slightly anterior. Fourth ventricle has typical banana-shaped deformity and posterior displacement with TF/TT ratio, 0.60 (15/25).

selected. In 36 cases each of these structures was best visualized on one scan. In 44 cases only the tuberculum sellae and center of the fourth ventricle could be identified on a single scan. In 16 cases, only the torcula and midportion of the fourth ventricle were identified on a single scan. In four patients scanned at about 10° to the anthropologic baseline, all three structures could be identified on a single scan, allowing for direct measurement of the position of the fourth ventricle relative to Twining's line.

In those cases in which all structures could not be identified on a single scan, the positions of the tuberculum sellae, torcula, and center of the fourth ventricle were determined relative to an arbitrary, easily identified fixed point. In this series an arbitrary point on the back edge of the photographed CT scan was used. Care was taken that the patient's head remained unchanged within the scanner on all scans used in computing the position of the fourth ventricle relative to Twining's line. The distance from the tuberculum sellae to the back edge of the scan was designated *A* (fig. 1A). The



A B C

Fig. 5.—Exophytic cerebellar glioma in 27-year-old man. **A** and **B**, Initial scans. Low density lesion lateral to fourth ventricle, which is displaced to left and slightly compressed. Low density area appears to involve brainstem and cerebellum. No enhancement. TF/TT ratio is 0.49, within normal limits. **C**, Repeat scan 3 weeks later. Additional compression and displacement of fourth ventricle to left. TF/TT ratio, 0.45 (13.1/29), indicates anterior ventricular displacement, key to diagnosis of exophytic cerebellar glioma.

distance from the torcula to the back edge of the scan was designated *B* (fig. 1B). (The inner aspect of the internal occipital protuberance at the level of the torcula was the actual measurement point. It was occasionally necessary to alter window width and level to distinguish the exact inner aspect of the internal occipital protuberance from the enhanced torcula.) On the scan showing the center of the fourth ventricle (fig. 1C) the lengths of *A* and *B* respectively were used to determine the relative positions of the tuberculum sellae and torcula. Twining's line was then measured and the relative position of the center of the fourth ventricle was determined.

Our technique is an adaption of one initially developed to allow for accurate localization of intracranial lesions on CT relative to osseous landmarks identified on plain film tomography. (D. O. Davis, personal communication) [4]. The validity of the adaption of this method to determination of fourth ventricular position is demonstrated in figure 2, a lateral autotomogram from a normal pneumoencephalogram.

Findings

Evaluation of lateral skull radiographs in 25 normal adults demonstrated that the angle between Twining's line and the anthropologic baseline range was 8.8°–12° with a mean angle of 10.8°. All scans in this series were 0°–20° to the anthropologic baseline and therefore the maximal angulation between Twining's line and the plane of the scan was about 12°. The cosine of 12° is 0.979 and the small error introduced by using this method, 2% or less, may be ignored for practical purposes.

Visualization of the tuberculum sellae, torcula, and fourth ventricle was an obvious prerequisite to accurate measurement of Twining's line. The tuberculum sellae was directly visualized in 46 of 50 cases scanned with overlapping technique and in 42 of 50 cases scanned with contiguous scan technique. In the other cases in which the tuberculum sellae could not be visualized, the anterior margin of the sella turcica was used. The center of the fourth ventricle was visualized in all cases in which overlapping scan technique was used and in 48 cases in which contiguous scan technique was used. The internal occipital protuberance (torcula) was seen in all cases. The torcula was visualized on enhanced scans by the M-shaped configuration of the tentorium at the level of the torcula [5] and/or visualization of the transverse sinuses.

The results of the determination of fourth ventricular position relative to Twining's line in the 100 normal control examinations are summarized in table 1. In the 50 cases with 8 mm overlapping base scan technique, the mean ratio of the distance of the tuberculum sellae to fourth ventricle over the distance of the tuberculum sellae to torcula (TF/TT) was 0.50. The values ranged from 0.48 to 0.52. In the 50 cases in which a contiguous scan technique was used, the mean value was 0.49 with a range of 0.47–0.53. With overlapping base scan techniques, 72% of the scans had a TF/TT ratio of 0.49–0.51, whereas with the contiguous scan technique, 60% fell within this range.

Observations from applying this method in 54 pathologic cases are presented in table 2. The fourth ventricle was regarded in an abnormal position if the TF/TT ratio was greater than 0.53 or less than 0.47.

In five of six brainstem gliomas the fourth ventricle was displaced posteriorly, with an overall mean TF/TT ratio of 0.60. Two of these lesions were isodense, nonenhancing, and showed no definite distortion of the shape of the fourth ventricle (fig. 3).

There were 18 cerebellopontine angle masses evaluated. In two of 12 patients with surgically proven acoustic neurinomas, the fourth ventricle was not displaced along its anteroposterior axis. In 10 cases, posterior displacement of the fourth ventricle was identified with a mean TF/TT ratio of 0.55 (fig. 4). In no case was the ratio less than 0.50. In each instance there was direct visualization of the lesion in the cerebellopontine angle on CT. Six other cerebellopontine angle masses were identified, including two epidermoid tumors, two meningiomas, and one osteoma. In each case the diagnosis rested primarily on direct visualization of the

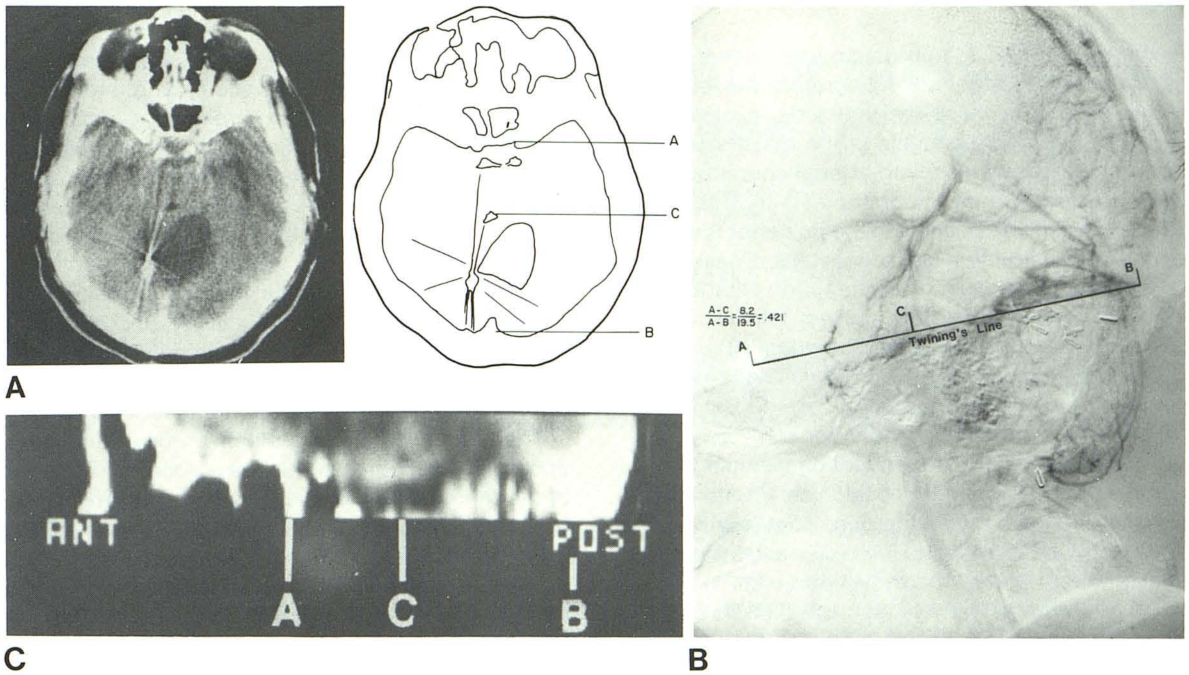


Fig. 6.—Recurrent cerebellar hemangioblastoma in 32-year-old man. **A**, Contrast scan. Large cystic lesion in midline and slightly to right within cerebellum. Surgical clip in left part of lesion. Fourth ventricle displaced to left and anteriorly with TF/TT ratio, 0.39 (12.5/32). **B**, Lateral venous phase film from vertebral angiogram. Precentral cerebellar vein displaced anteriorly. Ratio of tuberculum sellae to precentral cerebellar vein divided by Twining's line equals 0.42. **C**, Reconstruction sagittal scan through midline. Anterior displacement of fourth ventricle. Artifacts from previously identified surgical clips seen as is cystic component of lesion. TF/TT ratio, 0.39, confirms axial CT findings.

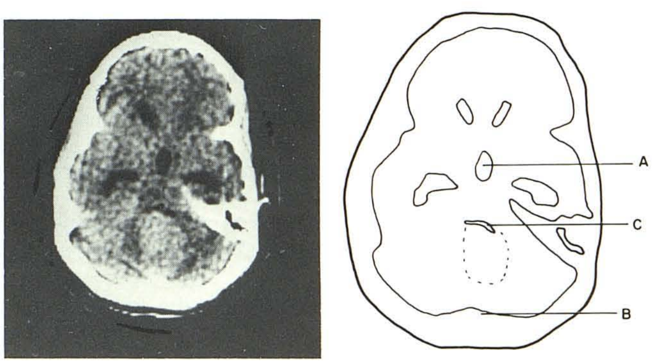


Fig. 7.—Medulloblastoma in 12-year-old boy. Fourth ventricle compressed and distorted from behind with marked anterior displacement. TF/TT ratio, 0.40 (8.0/20).

mass rather than identification of the displaced fourth ventricle, but in each case posterior displacement of the fourth ventricle was clearly documented.

The sixth case was an exophytic cerebellar glioma seen clinically as a cerebellopontine angle mass (fig. 5). The internal auditory meatus was normal on both plain films and multidirectional tomography, but a Pantopaque cisternogram demonstrated a large extracanalicular mass occluding the orifice of the internal auditory canal. Angiography demonstrated an avascular and apparently extraaxial mass in the cerebellopontine angle. The ratio of tuberculum sellae to precentral cerebellar vein over Twining's line, 0.48, was considered within normal limits. Initial CT 2 weeks before angiography (figs. 5A and 5B) demonstrated a low density nonenhancing lesion in the right cerebellopontine angle with displacement of the fourth ventricle to the left. The TF/TT ratio was 0.49. Repeat CT 1 week after angiography demonstrated increase in size of the low density lesion. At this time the fourth ventricle was anteriorly displaced with a TF/TT ratio of 0.45 (fig. 5C). This was the key finding indicative of the surgically proven diagnosis of exophytic cerebellar glioma.

Cerebellar masses resulted in anterior displacement of the fourth ventricle in 25 of 27 cases (figs. 6 and 7). In one hemangioblastoma and in one cerebellar metastasis the fourth ventricle was not displaced. Anterior displacement of the fourth ventricle was also observed in four extraaxial posterior compartment posterior fossa masses.

Comparison of CT results with posterior fossa angiography for determination of fourth ventricular position was possible in 18 cases. In 15 of 18 cases there was agreement on both type and degree of fourth ventricular displacement. In two cases of cerebellar masses, displacement of the fourth ventricle was diagnosed by CT only. In one instance of brainstem glioma, the fourth ventricular position was equivocal by CT, but there was posterior displacement of the fourth ventricle by angiography. In one case of cerebellar hemangioblastoma (fig. 4) anterior fourth ventricle displacement was documented on axial CT, sagittal reconstruction CT, and angiography. The TF/TT was virtually identical for all methods (fig. 6).

Discussion

Before the advent of CT, neuroradiologic evaluation for posterior fossa masses required angiography and/or pneumoencephalography. In these two methods, evaluation of displacement of the fourth ventricle or the vessels adjacent to it (precentral cerebellar vein and arterial choroidal point) is considered of paramount importance [1-3]. The fourth ventricle occupies a fixed position in the posterior fossa and displacement of this structure is a key for lesion localization. On CT, evaluation of the position of the fourth ventricle may be less important since, in most cases, lesions can be directly visualized and their relation to anatomic landmarks clearly defined. Furthermore, it has been difficult to identify anything but the most massive of anteroposterior displacement of the fourth ventricle since the apparent position of this structure is variable and dependent on scanning angle.

Evaluation of fourth ventricular position on 100 normal CT scans demonstrated that the midportion of the fourth ventricle lies at virtually the midpoint of Twining's line (mean ratio of tuberculum to fourth ventricle over tuberculum to torcula is 0.50). The range of normal values, 0.47–0.53, is consistent with both pneumoencephalography [1] and cerebral angiography [2, 3] findings. When overlapping scan technique was used the range decreased and more normal cases were 0.49–0.51. This decrease in variability is probably due to better localization of anatomic landmarks. Using our method, fourth ventricular displacement can be accurately recognized even when subjectively this structure appears to be in normal position. This information may be valuable even when lesion identification or localization is not a problem since it may be helpful in planning therapeutic approaches and judging their effectiveness (fig. 3).

In some clinical situations, recognition of anterior or posterior displacement of the fourth ventricle on CT may be of paramount importance. This is particularly true for brainstem gliomas which may be isodense and nonenhancing. In many cases angiography air studies and positive contrast ventriculographic studies must be performed to document displacement of the fourth ventricle. With our method unequivocal evidence of displacement of the fourth ventricle was noted in five of six brainstem gliomas. In two cases this was the only clear-cut finding at the time of initial diagnostic workup. In both cases, follow-up CT scans several months later (after radiotherapy) showed abnormal density and enhancement within the tumor and marked distortion of the fourth ventricle (fig. 3).

Demonstration of anterior fourth ventricular displacement proved to be the key diagnostic finding in one patient with an exophytic anterolateral cerebellar glioma, and clinical appearance suggestive of acoustic neurinoma (fig. 5). True cerebellopontine angle masses generally produce posterior displacement of the fourth ventricle, and even in those instances when the fourth ventricle was determined to be nondisplaced, the TF/TT ratio was never less than 0.50. By contrast, anterior cerebellar masses produce anterior displacement of the fourth ventricle [3], and thus documentation of this type of displacement in a patient with a lesion in the area of the cerebellopontine angle cistern should be considered strong evidence of its cerebellar origin.

The qualitative and quantitative correlation between CT and cerebral angiography in the recognition of displacement of the fourth ventricle was excellent, confirming the validity of CT. In the three of 18 cases with some disagreement between methods, in each case the tests were complementary rather than contradictory, since one test was equivocal and the others positive and correctly diagnostic.

In one case, sagittal reconstruction CT was performed, with good correlation between axial and sagittal CT. In the future, expanded use of sagittal reconstruction may allow for direct visualization of the fourth ventricle and its position relative to Twining's line. However, the time required and the added radiation dose with overlapping techniques for sagittal reconstruction may not be warranted in all cases.

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