Advances in Neuroradiology*

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The development of two new radiological techniques has significantly enhanced the performance of neuroradiological diagnostic procedures. The first of these was installed as the prototype unit at the Medical College of Virginia in November of 1972 and has marked advantages for the performance of encephalography, angiography, and air myelography. The present communication will relate the experiences of the author during the initial 15 months of clinical evaluation. The second technique is an entirely new concept of obtaining further information from the data provided by the penetration of x-ray photons. Each of these units will be discussed briefly with an outline of the principle indications and advantages of each system.

An Isocentric Diagnostic System. The principle feature of this system is a fully isocentric unit (Omnitome†) maintaining the head in alignment for filming or fluoroscopy, regardless of the patient's position during 480° of continuous rotation (Fig. 1). A C-arm rotates 300° about the isocenter. The L-arm provides 270° of rotation parallel to the wall axis with consequent alteration in the site of rotation of the C-arm. This unit was designed primarily for pneumoencephalography and enables one to obtain standard film series as well as Grossman tomography in the frontal or lateral views, as indicated, regardless of the patient's position. A unique feature is the ability to perform tomography at varying angles of incidence (Fig. 1-B). The brain stem may be tomographed coronally, therefore, relative to its vertical alignment and areas such as the temporal horns or corpus collosum may be viewed perpendicularly to their long axis without movement of the head and subsequent alteration in the position of the contrast material. There is lateral, longitudinal, and vertical adjustment of the chair relative to the isocenter, so that once the isocenter has been established, the patient may be moved to readjust as necessary throughout the procedure. An image intensifier and television system are incorporated into the C-arm, allowing constant fluoroscopy regardless of the patient's position. The Omnitome system is also equipped with a phototimed 105 mm camera providing for either single or multiple frame, up to 12 per second, with fluoroscopic control. The unit may be operated from the remote control panel or a mobile hand control may be utilized with closer observation of the patient. Television monitors are available in the control booth and adjacent to the patient. The usual encephalogram includes standard
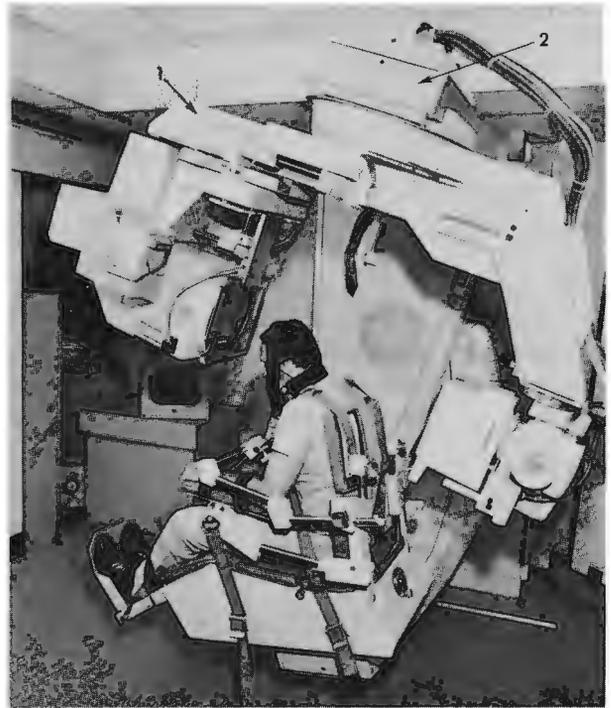
Fig. 1A.

Fig. 1B.

Fig. 1—*Omnitome-C-arm-1; L-arm-2 A*. Patient positioned for erect frontal views. *B*. Position for erect frontal view with L-arm angled. *C*. Prone, A-P view. *D*. Normal lateral encephalogram tomogram. *E*. Coronal tomogram of right acoustic neuroma. Fourth ventricle (4) compressed and rotated. *F*. Coronal tomogram 1 cm anterior to *E* with mass adjacent to pons.

films in the erect and supine position with the remainder of the film series obtained on the photospot camera. This enables one to obtain multiple different projections and angulations with a significant reduction in the time required to perform the study. Both filming and positioning are done with fluoroscopy, obviating the time required for changing film cassettes.

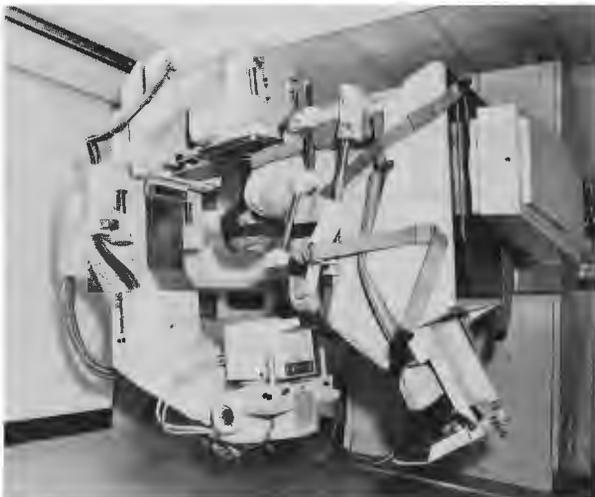An accessory table is utilized for air myelography on the Omnitome (Fig. 2). The technique
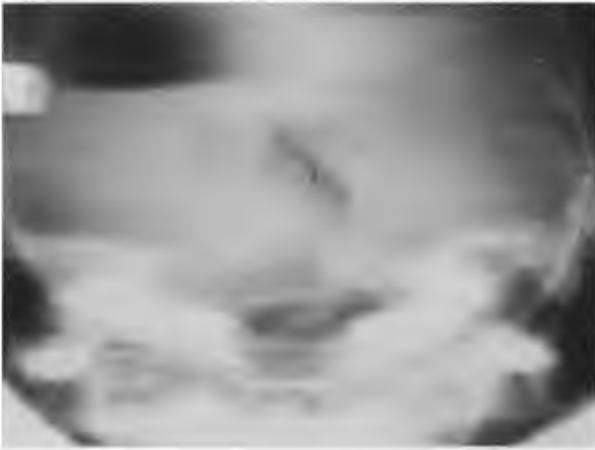

Fig. 1C.

Fig. 1D.

Fig. 1E.

Fig. 1F.

emphasized by Heinz (1) has been used primarily for study of the cervical spine. This technique is usually utilized for patients with cervical fractures or cervical spondylosis. Unstable cervical spine fractures are ideally suited for this study, allowing one to maintain adequate skeletal fixation with the patient supine. Degenerative disease of the cervical spine is also well studied by this method, since the surfaces of the spinal cord can be evaluated with tomography as well as the ventral defects associated with degenerative cervical discs. A lateral puncture of the subarachnoid space is quite easily performed under fluoroscopic control at the Cl-2 interspace. Filling of the entire subarachnoid space is obtained with the patient supine and in 20° Trendelenberg position.
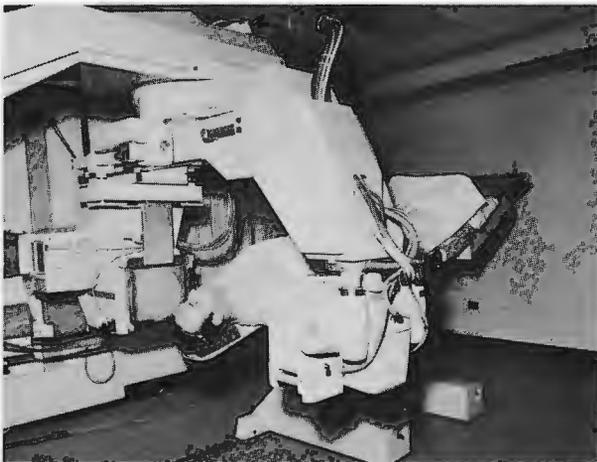
The accessory table is also utilized for angiographic procedures, with the C-arm providing fluoroscopic versatility (Fig. 2-C). Vertical height adjustment of the table of 50 cm is available for magnification studies. The table top may be motor driven or converted into a free-floating surface with a foot switch. Adequate distance is available for femoral catheterization. Filming may be obtained on the 105 mm camera or with standard film changers. The 105 mm camera again is quite beneficial, providing the capability of a "see-through" changer with rapid serial filming available at all times during fluoroscopy. The ability is also preserved to perform multiple complex angle views rapidly. A second tube may be positioned on a floor pedestal for bi-plane filming if desired.

The indications for angiography on this unit are necessarily determined by the availability of other angiographic facilities. The principle advantage of angiography on the Omnitome is the 105 mm camera,
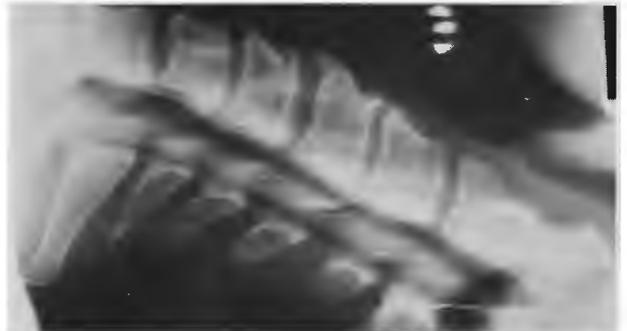

Fig. 2A—Patient positioned for air myelogram in 20° Trendelenberg.

Fig. 2B—Normal lateral tomogram.

Fig. 2C—Positioning for angiography for serial film changers cephalad to patient.

Fig. 2D—Right bracial injection (105 mm).

and therefore, cases are chosen where this would be of significant benefit. Patients studied for spontaneous subarachnoid hemorrhage or extracranial vascular disease are particularly suitable as are those patients requiring selective spinal cord angiography. Multiple views may be obtained with a significant reduction in time to perform the study and consequent reduction in patient discomfort and complications. The possibility of obtaining a standard film series in the optimal projection is available after preliminary study with the 105 mm camera. Angiotomography is also available as an ancillary procedure, since the C-arm maintains its ability to perform tomography wherever positioned.

Supplementary benefits of this system are multiple. One may obtain standard views of the skull or cervical spine utilizing the orbiting system and fluoroscopic centering. Obviously procedures requiring bi-plane fluoroscopy such as ventriculography, orbitography, or cerebral biopsies are simplified with this facility.

Computerized Axial Tomography. The second portion of this discussion will involve a new technique that has been variously compared with the discovery of penicillin or the first use of contrast material to complement standard radiographic techniques. Radiologists have long recognized that less than 10% of the information available on standard radiographs is actually interpreted by the physician. This new technique utilized computer analysis of the x-ray photon transmission, making it possible to analyze physical properties of normal cerebral tissues and a wide variety of pathological lesions.

The prototype equipment was installed in 1971, the first clinical reports appearing in 1972 by James Ambrose at the British Institute of Radiology (2). Since his initial reports, others have confirmed the importance of this unit and its acceptance throughout the world has been universal (3).

The patient lies on an adjustable couch with his head enclosed in a cap projecting into a water contained box (Fig. 3-A). He is comfortable, fully dressed, and no additional contrast materials are necessary. A slit x-ray beam scans the head using the sodium iodide crystalphotomultiplier to detect the photons. The detectors move in parallel with the x-ray tube across the patient's head with 160 readings of photon transmission during each horizontal movement (Fig. 3-B). The entire frame then rotates one degree and the horizontal movement is repeated. For each parallel movement of the unit, therefore, 28,800
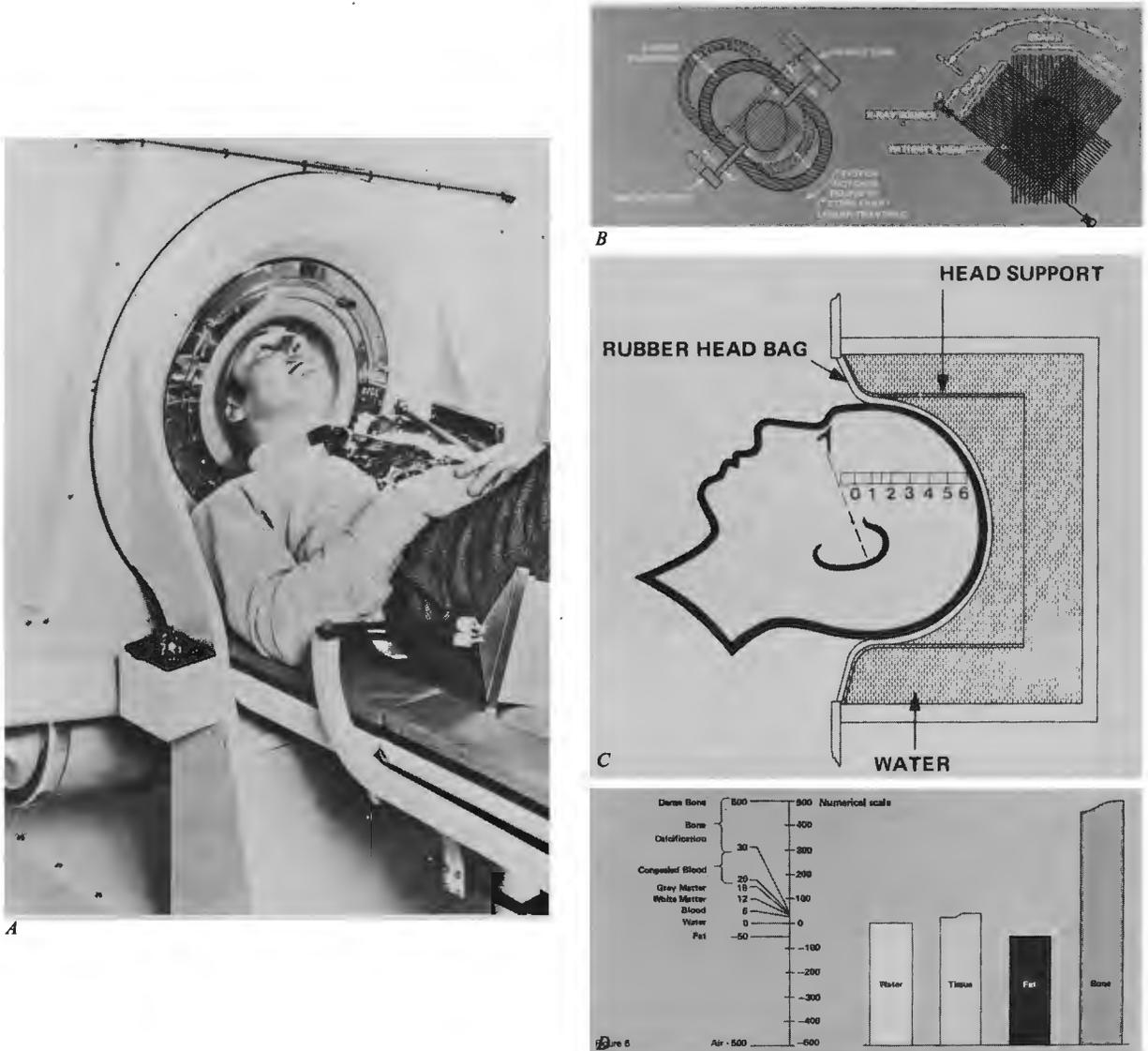
Fig. 3—*A*. The EMI scanner. *B*. Rotation sequence of scanning unit. *C*. Patient positioned for tomograms to include orbits and posterior fossa. *D*. Arbitrary scale of absorption values with air as −500 and water as 0.

absorption readings are obtained, which the computer can analyze within five-to-ten minutes. Routinely three or four axial sections are obtained with two scans of each slice. The head may be rotated to include the posterior fossa on the caudal scans if clinically indicated (Fig. 3-C). These are normally 13 mm by 2.94 mm by 2.94 mm, but an 8 mm collimator may be used if desired.

The data may be stored in two forms for recall when desired. A paper printout is available with numerical values of the relative absorption

coefficients. There is also a cathode ray tube display of the information in an 80 by 80 matrix form. A Polaroid® camera is used for photographic records of the cathode ray tube display.

The absorption values are a normal function of the physical density and the atomic numbers of the tissue analyzed. The relative absorption values are illustrated in Figure 3-D. Water is used as a reference (i.e., water = 0) and the scale of relative percentage of absorption of intracranial tissues is expanded several times for convenience. Utilizing a gray scale picture
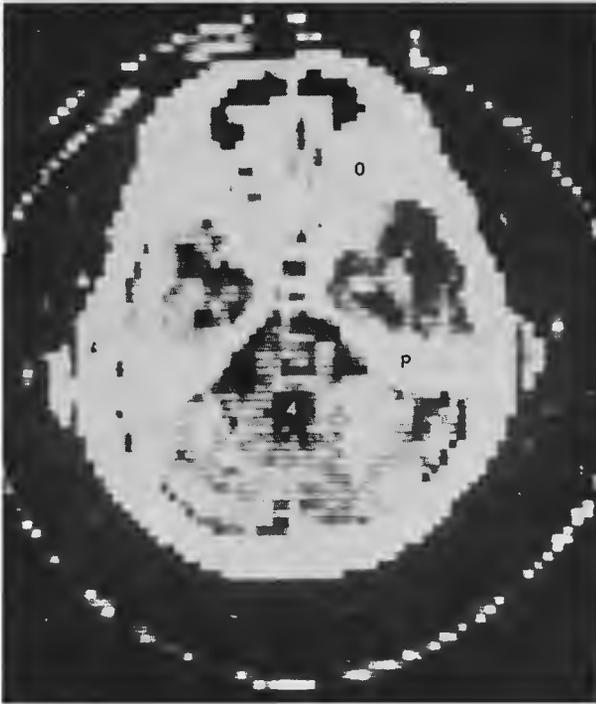
Fig. 4—Normal axial tomograms beginning caudally (A) and progressing superiorly. *A*. Caudal section. Broad white outer zone is the skull. Petrous temporal bone (p) and orbits (0). Fourth ventricle is black area posteriorly (4).
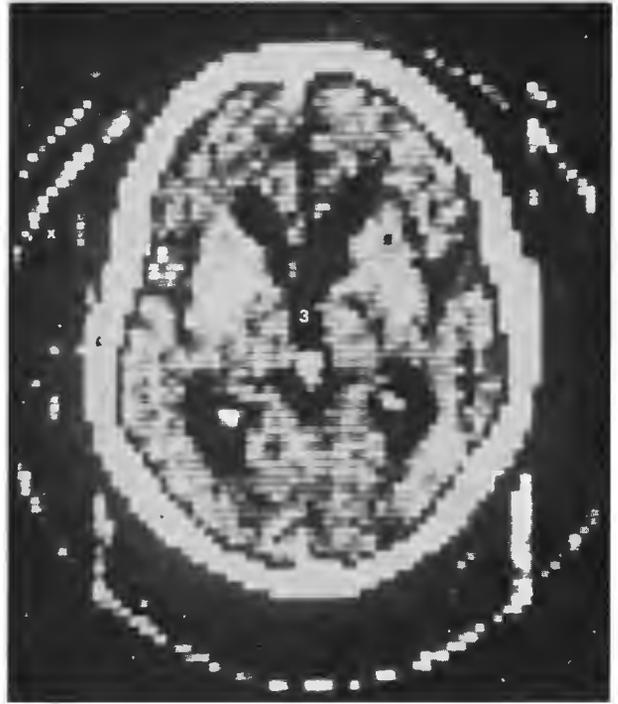

Fig. 4C—Frontal horns, third ventricle (1), and trigone of lateral ventricles. Pineal calcification behind third ventricle and glomus calcifications in trigone.
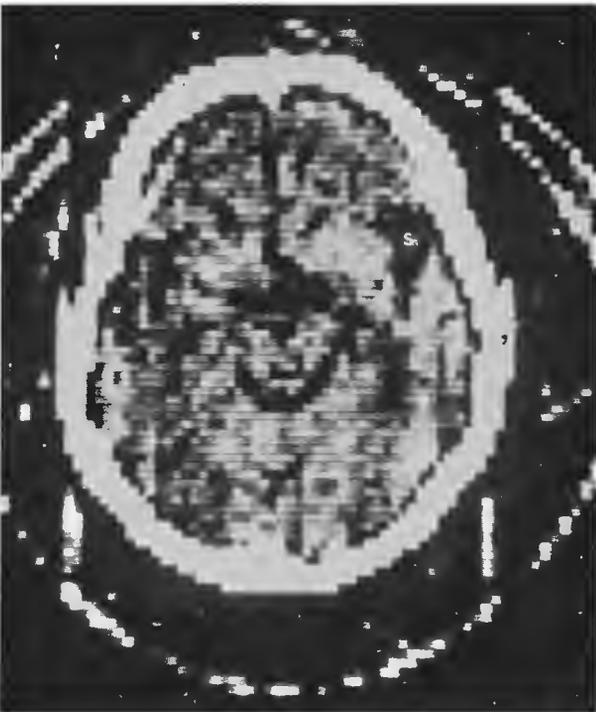

Fig. 4B—Ambient, interpeduncular and sylvian (s) cisterns.

of each tomographic section, water density would be black with increasing grayness-to-white at the bone level. It can be seen that water density is adequately separate and allows the basal cisterns and ventricular system to be visualized with ease (Fig. 4). Likewise, calcifications are very clearly delineated, such as in the pineal gland or glomus of the choroid plexus. It must be emphasized that this technique utilizing absorption coefficient differences and computer analysis is much superior to the previously used photographic methods and computer enhancement processing of photographic images. Preliminary data indicate that all of the cerebral tissue, cerebrospinal fluid, and coagulated blood are very easily distinguished. The matrix actually allows for analysis of individual 3 mm lesions at any point of each tomogram.

The preliminary results obtained in this country have confirmed the reasons for the rapid acceptance of this dramatic new technique. The most striking pathological change is with an intracerebral hematoma (Fig. 5-A). The clotted blood is quite easily seen, with its absorption coefficient in the 20 to 30 range, and extension into the ventricles or the cortex is easily delineated. Cerebral infarcts must be

Fig. 4D—Lateral ventricles.

Fig. 4E—Lateral ventricles.

differentiated during their various pathological stages. The early lesion may be patchy with decreased absorption and much larger definition occurring in seven-to-ten days as the necrotic area becomes sharply defined with the onset of phagocytosis.

Gliomas are highly variable not only from case to case, but in different parts of the same tumor (Fig. 5-B). Cystic areas within the neoplasm may be seen by the decreased absorption with areas of more dense and compact tumor delineated by an increased absorption value. More importantly, one is able to evaluate deep infiltration of a portion of tumor into the critical deeper structures.

Metastatic neoplasms tend to be more circumscribed than the primary gliomas (Fig. 5-C). The center may be necrotic and cavitated with a decreased absorption or may be dense and compact with a large surrounding area of cerebral edema and consequently with decreased absorption.

The development of this procedure has significantly altered the evaluation of patients with cerebral dysfunction. One is now able to selectively choose which patients will require the more invasive but precise technique of pneumoencephalography
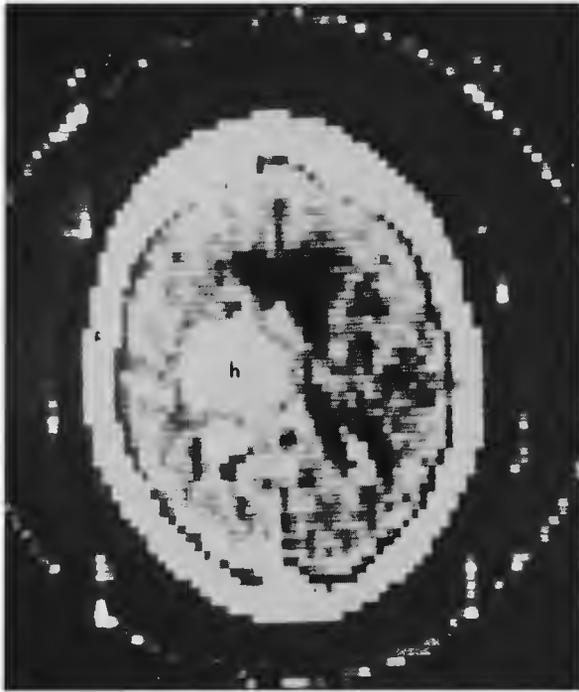

Fig. 4F—Cortical sulci.

Fig. 5A—Left thalamic hemorrhage (h) with frontal horn compression and shift.

Fig. 5C—Deep right thalamic metastases with a cavitated center.

Fig. 5B—Left frontal astrocytoma extending deep into basal ganglia. A large cyst (c) is also present.

and angiography. There will also be fewer negative results with these studies. The tomographic study enhances other techniques and will enable isotope brain scanning techniques to become more specific with the development of tissue specific radionuclides. The results from one center (3) indicate that of the first hundred patients that underwent computer assisted tomography, 71 of them required one or more neuroradiological procedures for diagnosis. In the fifth group of 100, however, only 34 required further study.

The expertise required to interpret this tomographic study is somewhat more than one would anticipate. One must not only interpret the pathophysiological data, but he must also know the associated features and types of mass effect created by different lesions. He must understand not only the occurrence of a glioma but its typical pattern and course of infiltration as well as the types of cerebral infarction and their sequential pathological development in time. He must also know what pathological conditions are associated with cerebral edema or necrosis, and how this may modify the absorption values. Likewise, the initial feeling that differentiation of the gray and white matter could be attained

with ease has been less commonly observed in practice. The technical limitations in the evaluation of the base of the skull and particularly the cerebellopontine angles has been less impressive. Most investigators, however, have now shown that with care this area can be seen with certain limitations. Extracerebral hematomas were also considered to be a significant problem with the use of this unit. Extradural hematomas with their larger portion of congealed blood have easily been seen; however, subdural hematomas have varied considerably and require care of the observer in interpreting the results. Since the hematoma may be totally liquid and therefore of water density, the absorption may be considerably different from a hematoma that is mixed in character or contains more clotted blood and is more dense than the surrounding cortex. Frequently there is also adjacent cerebral edema which limits the exact differentiation between the borders of the hematoma and the cortex. Even with this limitation, however, it is considered that with careful evaluation of the edges of the lesion, the hematoma may be ascertained with a high degree of accuracy. Even if the hematoma is not delineated fully, the shift of the ventricular system and cerebral structures is quite easily seen and accurately indicates a source of the cerebral dysfunction.

There is no question that the avenues for research and further investigation available through this technique are unlimited. Most importantly it is a functional and clinically useful tool that can be performed safely on inpatients or outpatients with no morbidity. The procedure may be conducted by an experienced neurotechnologist after a short period of familiarization with the method and equipment. The limitations of this technique are negligible in view of its outstanding advantages. There is clear indication that there will be a significant reduction in the number of pneumoencephalograms, and in select cases, angiography will also be omitted from the diagnostic evaluation. Carotid angiography will no longer be necessary to evaluate an intracerebral hematoma or hydrocephalus. Radionuclide brain scanning will have a limited place in the diagnostic evaluation. These are immediate benefits and only the future will ascertain the long-term alterations in the evaluation of patients with disease of the central nervous system.

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