AMERICAN ACADEMY OF PEDIATRICS

Committee on Radiology

Computerized Tomography: A Perspective in the Pediatric Patient

Computerized tomography (CT), a technique conceptualized by Oldendorf in 1961[1] and developed by Hounsfield[2] of EMI-Tronics Inc. (EMI) Central Research Laboratories, has proven to be a successful innovation in neuroradiology. Reviews by Ambrose[3] in England and by Baker *et al.*[4] and by New *et al.*[5] in the United States have clearly demonstrated the value of this new modality in neuroradiological diagnosis. In 1975 Houser *et al.*[6] and Harwood-Nash *et al.*[7] provided the initial clinical and radiological data about CT in infants and children.

More recently this technique has been extended to the study of tissues and organs in the body other than those in the head. This has been accomplished by modification of the original machine into a whole-body CT system. Early reviews by Ledley *et al.*[8] and by Alfidi *et al.*[9] suggest a significant potential for diagnosis of lesions in the abdomen, pelvis, and thorax.

The advantages of CT are that it is less invasive than standard special diagnostic radiological procedures and that for the first time it provides *in vivo* information regarding the content and the characteristics of tissue composing organs and masses.

DESCRIPTION OF EQUIPMENT

In conventional radiography an image is made on radiographic film by an attenuated X-ray beam. In passing through a core of tissue, each ray of the beam is attenuated as it is absorbed and scattered by the tissue in its path. The intensity of the transmitted ray depends on the sum total of X-ray attenuation by all the different soft tissues in its path. Detailed characteristics of all the soft tissues in the core through which the ray passes are not represented; only the sum total of the attenuation of the X-ray is available. Furthermore, the relative insensitivity of radiographic film to small differences in X-ray beam intensity limits the resolution of small differences in X-ray attenuation by neighboring cores of soft tissue through which various rays pass.

CT uses X-ray beams in a fashion similar to their use in conventional radiographs.[2,10] Multiple projections are obtained through the same cross-sectional slice of tissue utilizing a highly collimated X-ray beam which passes through the slice at various angles during different intervals of time. Multiple "looks" at the same elemental volume from different angles allow an estimation of the X-ray absorption in that specific elemental volume to be made. The computer provides the means of rapid calculation of the X-ray absorption coefficients for a matrix of pixels, each pixel representing an elemental volume in the slice. The detection system utilizing crystals or a high-pressure xenon detector array has approximately 100 times the sensitivity of radiographic film.

The final data from the computer can be displayed as hard copy on a film modality and also stored on magnetic tape or disc for later retrieval. An arbitrary scale of values for absorption coefficients with dense bone or metal having the most positive values, air the most negative value, and water the value zero permits digital handling and storage. A graded gray scale from white (metal, dense bone) to black (air) provides the basis for

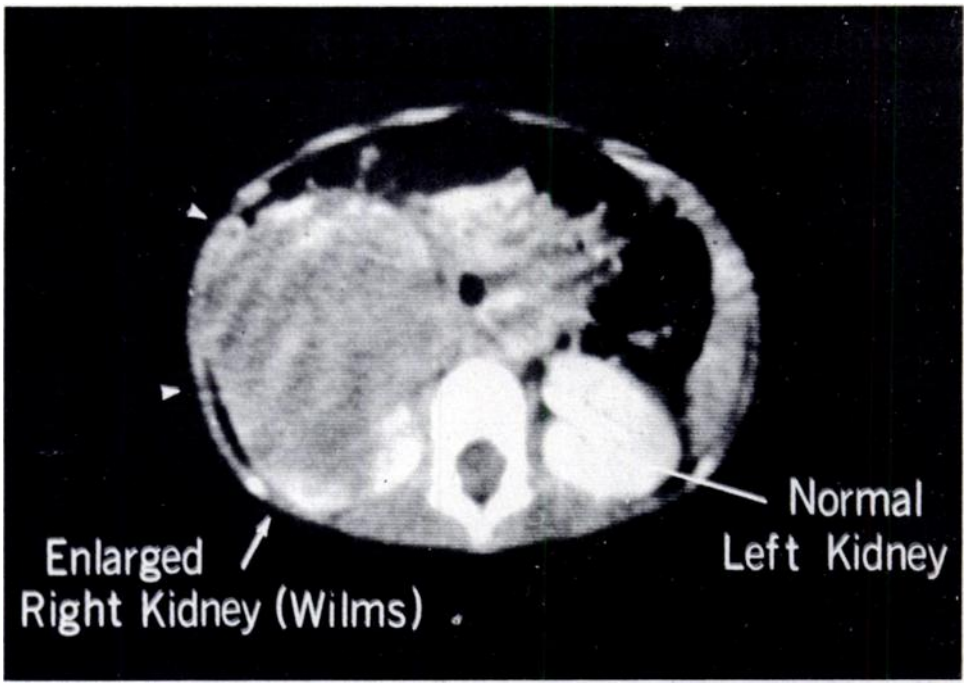

FIG. 1. A huge right renal Wilms' tumor. Note the normal kidney on the left (courtesy of Dr. R. J. Alfidi, Cleveland, Ohio).

the cathode ray tube and hard copy display. The window level and width for a gray scale display may be varied. The retrieval capability permits data from tape or disc to be reviewed. The presentation may be altered by changing the window level and width, allowing analysis and display of different characteristics of the tissue slice.

CT thus combines the features of viewing an image in multiple projections with more sensitive X-ray detection and computer reconstruction of the image, as well as greater information retrieval capability, all in a noninvasive procedure.

At present, radiation dosages vary from 1 to 4 rads per slice depending on the particular unit. This radiation dose compares favorably with a radiation dose equivalent to that of a single skull roentgenogram of 2.5 rads;[11] the gonadal dose with shielding is less than 0.1 millirads per complete scan. Precise beam collimation has reduced scatter into adjacent slices to as little as 10% in some models.

THE PEDIATRIC PATIENT

The initial EMI units employed a water bag which enclosed the head and provided a system whereby the abrupt change and attenuation of X-ray beams between the skull and air was shortened by this bone-water interface. This bag presented a considerable problem *vis-a-vis* infants.[7] The latest machines have, fortunately, no water bag, and the patient therefore rests quietly on a padded board within the large orifice of the gantry.

Any motion will destroy the fine detail of a CT scan; therefore, heavy sedation and often general anesthesia is necessary in order to obtain a satisfactory image in children under 3 years of age. A compromised picture obviously leads to a compromised diagnosis. Most present CT units perform one tomogram in 2½ to 4 minutes. The latest units, however, have dramatically decreased this to as little as four seconds. The problem of motion is, therefore, diminishing. Experience will diminish the need for general anesthesia. General anesthesia, however, is better than heavy sedation in the neurologically compromised child. Respiration rates and excursion in such a child can, together with heavy sedation, decrease to a critically low level. It is recommended that this age group be investigated by CT in a pediatric hospital or a large pediatric unit in a general hospital.

Most older children can be examined with or without mild sedation. Very ill or mentally disturbed children may need a general anesthetic.

TECHNIQUE

Eight "slices" or tomograms of the head will normally suffice to visualize all the structures of the head. Note that each of the four gantry rotations provides two slices. The time taken for these to be produced is now a total of 20 minutes. New units acomplish this in four to six minutes.

Insufficient world-wide experience with CT in the abdomen and chest in children does not permit a description of this technique in detail. However, the definition of organs in children is not thought to be inferior to that in adults[9] (Fig. 1). The greatest difficulty will be the recognition of normal anatomy and its normal variations in the growing child. New equipment requires less than 30 seconds per tomographic cut.

Contrast enhancement by water-soluble contrast material such as Renographin 60 and Hypaque 60 at a dose of 4 cc/kg to a maximum of 90 cc is injected as a bolus via an intravenous needle. This is essential in examination of most mass lesions or suspect neoplasms.[12-14] The CT detection of the I_2 molecule within vascular tissues or subsequently in the extravascular interstitital spaces of normal and altered tissues, is most precise and will enhance many neoplasms that remain latent on the standard CT examination. This enhancement of the *latent* image occurs in the majority of CNS neoplasms. The mass effect on ventricles is discernible on standard CT, and the actual neoplasm containing I_2 within its interstitial spaces is seen on the enhanced CT. This enhancement necessitating administration of a drug (Hypaque 60) intravenously converts CT to a certain extent into an invasive examination and hence one with potential morbidity (even though this is very unlikely). Morbidity is no greater than that with an intravenous pyelogram.

INDICATIONS

Depending on the organ to be examined, the availability of recent skull, chest, and IVP roentgenograms is essential. A close clinical liaison between the referring physician and the radiologist both before and after CT is desirable and necessary for optimal correlation of the CT and the clinical findings and history.

Indications can be summarized as follows:

(1) *Confirmation of a Clinically Established Lesion*—CT of the head is the diagnostic examination for tuberous sclerosis[7,15] and hydrocephalus (Fig. 2) and its attendant complications. Sturge-Weber syndrome, mass lesions, whether cysts, neoplasms, or focal infections,[16] or gross geographic congenital abnormalities such as an absent corpus callosum are all delicately detailed.

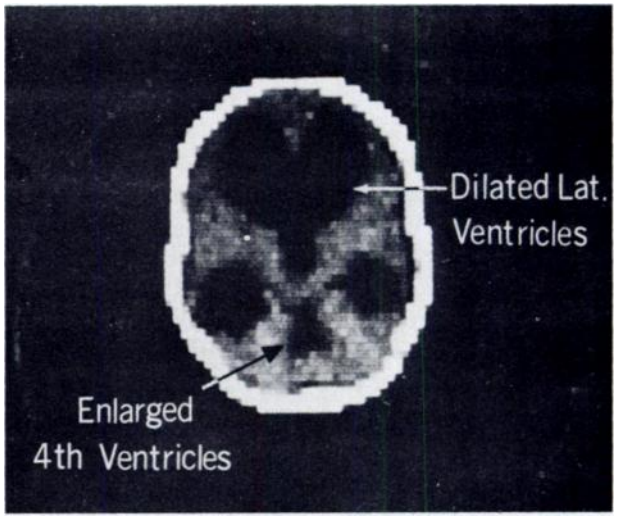

FIG. 2. Marked hydrocephalus in an infant due to obstruction at the foramen of Magendie. Note the large fourth ventricle (*arrow*).

(2) *Detection of the Content of Mass Lesions*—The presence of cerebral edema, be it due to trauma, infection, neoplasm, or infarction,[17-19] the presence of clotted blood as in a hematoma[20] or flowing blood in a Galenic varix,[7] the CSF content of arachnoid cysts,[7] Dandy-Walker cysts, calcium in a neoplasm or teratoma, and fat in a lipoma are all well shown by CT.

(3) *Demonstration of the Cause of a Nonspecific Clinical Sign or Symptom*—The etiology of seizures from a neoplasm,[10] arteriovenous malformation,[21] or tuberous sclerosis,[15] the cause of subarachnoid hemorrhage such as arteriovenous malformation,[21] large aneurysms,[22] and intracerebral or intraventricular hemorrhage[20] will be shown by CT. The cause of macrocrania, usually hydrocephalus (caused by neoplastic obstructive lesions), large chronic hygromas, or merely anatomic or metabolic megalencephaly is readily evaluated by CT. Subependymal or intracerebral hemorrhage, leucomalacia, or even gross cerebral atrophy in premature infants is best detected by CT.

(4) *Post-therapeutic or Natural Course of Diseases*—CT will detect the presence of neoplastic recurrence, secondary spread, post-traumatic sequelae, effect of radiotherapy, or the complications thereof as in the treatment and natural history of hydrocephalus.

(5) *Tumor Delineation for Determination of Radiation Therapy Portals.*

PERSPECTIVE

Where do we go from here? CT provides a simple and increasingly accurate diagnostic technique for examining most structural abnormalities or organ systems. It is safer than most angiograms and pneumoencephalograms but must not be used as an apology for poor technique. Many abnormalities such as intracranial congenital anomalies, or mass lesions in and about the third ventricle and sella,[23] and intravascular abnormalities, are at the present time better examined by pneumoencephalography and cerebral arteriography. These latter techniques often provide better definition of abnormalities if they are bounded by CSF or within the vessel lumen or wall. CT is, however, rearranging diagnostic priorities.[24]

One certain fact is that CT false-negatives (2%) and false-positives (3%) are low. CT used as a screening procedure in suspect diseases will, if normal, obviate further studies. CT does not provide a histological diagnosis but does show the geography of most lesions.

The complexity of pediatric diseases and the precision of infant care will necessitate a hospital CT practice both for inpatients and outpatients rather than an isolated CT diagnostic unit. It is likely that for a pediatric hospital or division with over 100 beds, a total-body CT system can be utilized full time.

With the technical advances now in progress, the scope and extent of the imagination and ingenuity of the radiologist and his clinical colleagues appear to be the only limiting factors.

COMMITTEE ON RADIOLOGY

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