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Tomographic Imaging in Nuclear Medicine

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Chapter 19

Computerized Transverse Axial Tomography with X-Rays

Leonard M. Freeman

The principle of computerized transverse axial tomography with x-rays was conceived by Godfrey Hounsfield of EMI Electronic and Industrial Operations in Hayes, Middlesex, England. After some initial success in EMI’s central research laboratory, a clinical prototype was built and, in October 1971, was installed in a site adjacent to the x-ray department at Atkinson Morley Hospital in Wimbledon. The clinical evaluation is still continuing under the direction of James Ambrose.

The high radiation output flux of x-rays and high sensitivity of scintillation detectors is combined with the speed and accuracy of the digital computer in this system. This enables about 100 times more information to be extracted from the x-ray photon compared with conventional radiographic methods. The method probably represents the first major fundamental advance in the use of x-rays since their initial discovery by Roentgen in 1895.

Operation of the System

The patient’s head is immobilized and surrounded by a water bath which in turn constitutes the central portion of a large circular yoke (Fig. 19-1). The entire machine rotates around the yoke at 1-deg intervals over a total of 180 deg in about 4 min. During this time interval the EMI system constructs two adjacent tomographic slices of
the brain, each approximately 1–1.3-cm thick. The total examination, consisting of three such rotations at different levels, takes approximately 12 min.

At each 1-deg rotation, a pair of narrow x-ray beams rapidly pass through the head in the two adjacent tomographic planes and are detected at each point by two scintillation detectors which always re-

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**Fig. 19–1.** Photograph of patient positioned in EMI tomographic system. Head is immobilized in rubber head cap.

**Fig. 19–2.** Schematic drawing showing rotary motion of central yoke at 1-deg intervals around patient's head (right) as well as transverse motion of paired x-ray sources and detectors across head at each interval (left).
main in alignment with the x-ray sources. Both the x-ray tube and the detectors scan across the patient’s head in a linear fashion taking 160 readings (80 from each adjacent tomographic plane) of transmissions through the head (Fig. 19-2). The information is then transmitted to a digital computer where the absorption values of the material within each slice are calculated. During each 4-min cycle (180-deg rotation), the machine (paired detectors together) takes 56,000 readings. The computer then solves 28,000 simultaneous equations from these readings and calculates 6,400 absorption values of the material within each slice. These absorption values are then assembled by the computer to form a transverse section image.

The machine sensitivity may be set by a “window-width” switch so that the absorption coefficient range (about 2–6%) of different tissues within the head can be represented as the full black to peak white seen on the cathode-ray tube. Within this relatively small density range, differences will appear as dramatic changes on the CRT (see Figs. 19-3 and 19-4).

The results can be displayed in three ways:

![CT Image]

**Fig. 19-3.** Obstructive hydrocephalus caused by acoustic neuroma. Dilated ventricles are easily delineated because of difference in density from surrounding tissues.
Fig. 19-4. Craniopharyngioma is clearly delineated as circumscribed black area in middle of head.

1. A pictorial cathode-ray tube display of the processed magnetic tape information. This may take the form of a $160 \times 160$-picture matrix which provides maximal clarity or an $80 \times 80$-point matrix which appears to be adequate for most diagnostic clinical studies performed by Ambrose.

2. A Polaroid exposure made from the cathode-ray tube.

3. A full computer paper printout providing detailed information concerning the absorption characteristics of the tissue in each picture matrix point.

Early Clinical Results

In the first 59 cases of proven intracranial disease studied at Atkinson Morley, the system produced pictures that were diagnostic in 54. In general, one may differentiate specific anatomic structures such as the gray and white matter, the sinuses, ventricles (Fig. 19-3), median fissure between the hemispheres, pineal body, and other areas where the density is sufficiently different from that of surrounding tissues. Calcification not
yet radiographically evident may be detected. Because of their different
densities, ischemic and hemorrhagic infarcts may be identified with ap-
parent ease as well. Neoplasms generally are easily diagnosed (Fig.
19-4)—even those in areas often escaping detection on routine brain
scintigraphic studies.

It is clear from the completed preliminary work that computerized
axial tomography represents a striking and significant advance in neuro-
logic diagnosis. The developers of the apparatus feel that it is of sound
design and construction. Their hope is that an increasing number of pa-
tients requiring neuroradiologic examinations will be adequately studied
with the innocuous, painfree combination of plain skull x-rays, radio-
uclotide brain scan and computerized axial tomography.

This author looks forward to the application of the technique to other
organ systems with great interest and enthusiasm.

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