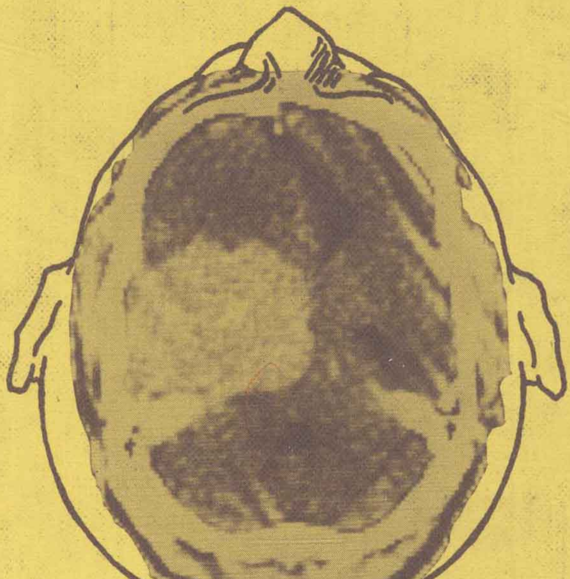
# CEREBRAL COMPUTED TOMOGRAPHY

## *A Text-Atlas*



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# Preface

The introduction of cerebral computed tomography (CT) in the investigation of suspected intracranial pathological processes has revolutionized the approach to clinical neurological practice. Since the initial description of the practical scanning apparatus by Hounsfield and the results of the early clinical studies reported by Paxton and Ambrose less than five years ago, CT has been demonstrated to be an extremely sensitive, accurate and safe technique to investigate many neurological disorders. In addition, acceptance of CT by the medical community has occurred much more rapidly than the acceptance of isotope scan, angiography and air study. Such early acceptance is a result of low patient discomfort, minimal radiation exposure comparable to that of routine skull radiogram, and the highly developed technological capability of the first generation of CT scanners, which had diagnostic sensitivity and accuracy greater than other noninvasive imaging techniques and, in some cases, equal to that of the invasive contrast procedures—air study and angiography.

The initial published studies of CT emphasized the technical aspects, including description of the apparatus, physical principles of operation and image reconstruction, computer system, specific normal anatomical details of the transverse brain tissue sections and abnormal scan findings in pathological conditions. The initial clinical and radiographic studies were retrospective analyses of findings in patients whose diagnoses had been confirmed by complementary neurodiagnostic studies and operative and necropsy examination. These studies emphasized the radiological and pathological correlation which was necessary to assess the sensitivity, validity and reliability of CT in neurological diagnosis, and also confirmed that the technique of image reconstructive tomography was a significant and dramatic advance in neurological diagnosis with possible application for the entire field of diagnostic medicine.

These early CT studies investigated the diagnostic accuracy in many specific pathological conditions, including neoplasms, intracerebral hematoma, cerebral infarction, hydrocephalus and cerebral atrophy. However, no attempt was made to undertake prospective studies of the value of this new imaging technique in the investigation of specific neurological symptoms so as to place CT scanning in appropriate diagnostic perspective relative to other currently available diagnostic studies, both noninvasive and invasive. At present, CT is accepted as a highly accurate technique, but some health care planners have suggested that over-utilization is occurring and that the technology is expanding so rapidly that it is becoming an extremely expensive procedure. In addition, in certain clinical diagnostic situations it may not be superior to less expensive conventional diagnostic studies. Rapid technological advances have been achieved, including a matrix system of finer resolution, more rapid scanning time, thinner section scans, higher contrast resolution, and multiplane scans to include coronal and sagittal sections. These improvements have required continual upgrading of the existing models to achieve greater diagnostic detail and more precise anatomical localization, but at increasing cost. Studies have not addressed the questions of how these advances have affected diagnostic accuracy, utilization of other studies and total medical costs. Furthermore, initially CT was labeled as a noninvasive study but recent changes, including widespread utilization of contrast infusion studies with material which has known neurotoxicity and has been administered intravenously, intra-arterially or intrathecally, have modified this technique so that it is becoming an increasingly invasive study.

This book has been conceived and developed to serve as an introduction to the utilization of the CT scanner in evaluating neurological disorders, and is directed toward the neurologist, neurosurgeon, psychiatrist, internist, pediatrician and other physicians who will be ordering this study in the course of their investigation of a patient with neurological symptoms. It is hoped that this book will familiarize the physician with an approach to utilization of this diagnostic technique which is based upon a knowledge of its sensitivity and accuracy but also upon its limitations and an awareness of conditions in which alternative more readily available diagnostic tests will provide equivalent information. Because of limited access and high cost, there are frequently one- to five-week waiting periods for CT scans; the physician must choose those patients in whom the diagnostic yield is greatest. This can best be achieved by awareness of the CT scan's potential yield and accuracy as compared with other diagnostic procedures. The clinical neurological problems which are reported in this book are based upon over two years of clinical experience by neurologists and radiologists working together to determine the potential yield of CT scanning in specific neurological symptomatology. The organization of this book emphasizes the role of CT in specific clinical situations as they initially present to the physician, as well as the appropriate role of CT in the broad field of diagnostic evaluation.

LEON A. WEISBERG

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L.A.W.

# Contents

PART ONE

# OVERVIEW OF COMPUTED TOMOGRAPHIC (CT) SCANNING

# Chapter 1 Introduction

The impact of the CT scanner upon the traditional and conventional concepts of management of patients with neurological symptoms can best be appreciated by an analysis of the increased early diagnostic sensitivity and accuracy in many neuropathological conditions with excellent clinical pathological correlation, decrease in utilization of other invasive diagnostic procedures, and assessment of its cost effectiveness in neurological diagnosis. At the Tulane Medical Center, 5500 scans have been performed on 5000 patients with 9 percent of scans representing repeat studies. For purposes of this analysis, the scans have been divided into two groups, each representing one-half of the total number (2750 CT studies), and comparison of diagnostic trends in these two groups demonstrates several interesting patterns (Table 1–1). In the initial series, the frequency of contrast infusion was 20 percent but, with reports of increasing pathological information which may be obtained with contrast infusion, this is now being performed in 53 percent; this compares to other series in which 50 to 70 percent of scans are subject to contrast enhancement. In patients with certain neurological disorders, including neoplasms, the necessity of a prior "routine" or noncontrast infusion study has been questioned. Elimination of the plain scan would increase the number of patients who could be studied per working day.[1] This dependence upon

**TABLE 1–1.** Reason for CT Scan Referral in 5500 Patients

| *Referral* | *Initial Series (per cent)* | *Current Series (per cent)* |
|---|---|---|
| Specific Disorders | 76 | 65 |
| cerebrovascular disease | 15 | 12 |
| seizures | 10 | 8 |
| dementia | 8 | 7 |
| head trauma | 7 | 9 |
| suspected primary tumor | 12 | 11 |
| supratentorial | 10.5 | 10 |
| infratentorial | 1.5 | 1 |
| suspected metastases | 6 | 5 |
| visual or endocrine disorder and sella abnormality | 1 | 1 |
| disturbed consciousness | 2 | 1 |
| evaluation of previously documented lesion | 2 | 1 |
| post surgery or irradiation | 6 | 4 |
| orbital lesion | 2 | 2 |
| increased intracranial pressure | 1 | 1 |
| pediatric | | |
| increasing head size | 1 | 1 |
| poor development | 1 | 1 |
| hearing loss | 1 | 1 |
| Nonspecific Disorders | 24 | 35 |
| headache | 10 | 16 |
| dizziness | 8 | 10 |
| syncope | 2 | 4 |
| vague psychiatric symptoms | 1 | 2 |
| weakness | 3 | 3 |



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contrast infusion may alter the nature of CT scanning to that of an invasive contrast study, and attempts are therefore being made to limit its use to cases in which postinfusion information may help establish specific pathological diagnoses or to cases in which the initial scan is negative but other reported studies have indicated a high probability of positive results with infusion study of a suspected lesion. Initially, low dosage (20 cc) contrast material infusion was associated with only infrequent enhancement pattern in non-neoplastic conditions as compared with a much higher incidence of enhancement in neoplasms, but by utilizing a higher dose (50 to 100 cc) or a rapidly administered drip infusion (300 cc administered over five minutes), the frequency with which enhancement has been detected in non-neoplastic conditions has increased to the extent that differentiation now is best established by the pattern, intensity and location of enhancement rather than simply by the presence of enhancement (Table 1–2). One consequence of this higher dose infusion study was that there was an immediate and dramatic increment in the number of angiograms performed in cerebrovascular disease to differentiate infarction from neoplasm, vascular malformation or abscess, but this trend has decreased as greater clinical experience has been achieved and the temporal evolution of the enhancement pattern in non-neoplastic conditions has been documented. This trend toward increasing frequency of enhancement in non-neoplastic conditions brought with it certain associated problems in differential diagnosis, but this was later balanced by greater diagnostic accuracy, especially in the diagnosis of cerebral inflammatory disease, infarctions, and hematomas.

Of all scans performed, 44 percent were abnormal, 51 percent were normal, 4 percent were technically unsatisfactory, and 1 percent were indeterminant — that is, no specific diagnostic conclusion was possible based upon scan pattern. These indeterminant scans included studies that were technically adequate for interpretation but that showed an unusual ventricular asymmetry without accompanying distortion or displace-

**TABLE 1–2.** Enhancement in Differential Diagnosis

| | *Frequency of Enhancement* | | |
|---|---|---|---|
| *Pathological Condition* | 50 cc Bolus (per cent) | 100 cc Bolus (per cent) | 300 cc Drip Infusion (per cent) |
| cerebral infarction | | | |
| non-hemorrhagic | 5 | 10 | 60 |
| hemorrhagic | 0 | 0 | 40 |
| intracerebral hematoma | 0 | 0 | 15 |
| extradural hematoma | 0 | 0 | 15 |
| neoplasm | | | |
| meningioma | 90 | 90 | 100 |
| glioma | 85 | 85 | 95 |
| pituitary adenoma | 100 | 100 | 100 |
| craniopharyngioma | 60 | 50 | 50 |
| acoustic neurinoma | 100 | 100 | 100 |
| pinealoma | 100 | 100 | 100 |
| aneurysm | 0 | 0 | 40 |
| angioma | 10 | 10 | 100 |
| abscess | 33 | 50 | 100 |

ment, an abnormal density pattern contiguous to bone or ventricles an unexplained region of abnormal density visualized on only one section, nonvisualization or an asymmetrical basal cisternal space. In these cases subsequent contrast infusion is indicated, and if this is negative, no further studies are usually indicated, although occasionally angiography or air study has been performed, confirming the lack of pathological findings indicated by CT.

If the CT scan showed an abnormality, it was necessary to correlate the finding with the clinical disorder to determine if the reported abnormality could explain the clinical symptoms or if it was perhaps an incidental findng. In 300 consecutive abnormal scans, analysis of clinical data and results of other neurodiagnostic studies indicated that in 10 to 15 percent of cases it was highly likely that the abnormality did not explain the clinical symptoms that were the indicated reason for the scan referral. This was most frequent in cases reported as cerebral atrophy, in which there were no concomitant intellectual or psychiatric symptoms. In another 1 to 2 percent the scan showed either infarction, subdural hematoma, cystic lesion or neoplasm in patients with vague nonspecific symptoms and without focal signs, seizures or a history of sudden or progressive clinical worsening, and in whom the symptoms persisted without change following treatment of certain conditions deemed surgically remediable. In these cases, further diagnostic and therapeutic procedures after detection by CT may have been initiated by the fact that the physician is provided with more information about brain structure than ever previously available; if an abnormality is suggested by the CT scan report, there is an obligation to evaluate this finding despite a paucity of clinical symptomatology. This is the case because of the physician's training, which is directed toward completeness of evaluation and because of a defensive tendency of the physician aimed at avoiding future malpractice litigation. In addition, there have been an increasing number of recent referrals for CT scan in cases involved in litigation, such as those involving possible cerebral concussion in which the medical indication for the scan is quite limited.

In March, 1975, it required an initial two- to three-month period to familiarize physicians with the potential capabilities of CT scanning, but after this time our scheduling was completely saturated, with a waiting period of two days for inpatients and four to 16 days for outpatients. With increasing awareness within the medical community about the capability of the CT scanner, the opening of new installations has usually produced a saturated schedule from the onset. As the clinical demand for CT increased, the scanner was made operational for up to 15 hours per day on a five-day schedule with additional use for four to seven hours on a sixth day. This has permitted us to perform 50 to 70 scans per week, a rate which compares to the average of 58 reported by Evens and Jost.[2] With a scanning time of four minutes, this required an appointment schedule with 20 to 45 minutes allocated for each patient, depending on the need for contrast study and sedation. There may be occasional delays of one to four hours, which are usually due to technical factors or the sedation of restless and uncooperative patients, but much of this problem will be obviated with more rapid scanning time. With increasing awareness of the availability of the scanner, the scheduling delay has increased, but this has recently been balanced by an increasing number of scan installations throughout the region. Furthermore, since CT is especially valuable in head trauma, it should be available on 24-hour emergency basis; this is not presently feasible in many installations, although angiography is usually performed on an emergency basis. Careful studies will be necessary to compare the diagnostic sensitivity and accuracy of the dedicated head model with the body scanner, but with the present generation of scanners it is generally agreed that the dedicated head unit is superior in studying suspected neurological disorders. Despite this fact, one-half of referring physicians were not aware of any differences or limitations and in ordering the study opted for the facility with the shortest scheduling delay, regardless of the specific disorder to be investigated.

Our clinical data has been derived from referrals generated from multiple sources, including the Charity Hospital of New Orleans, which is a large state-run hospital, Veterans Administration Hospital and other private hospitals in the greater New Orleans regions. Of the patients studied, two-thirds were inpatients and one-third were outpatients referred either by private physicians or from multiple clinics of the Charity Hospital or Veterans Administration Hospital system. Fifty-two percent of patients studied were ambulatory, 22 percent were in wheelchairs and 26 percent were on stretchers. Following the introduction of CT scanning the number of neurological and neurosurgical inpatients at the Charity Hospital increased by 25 percent over the number in the preceding years without any possible alternative explanation, and the number of neurosurgical operations performed also increased. The number of ambulatory inpatients who were studied by CT was greater than the number of ambulatory inpatients who had EEG, skull radiogram or isotope scan, and this may reflect the need to hospitalize patients for CT. Due to certain well-conceived carefully monitored economic restraints imposed upon the physicians of the Charity Hospital and Veterans Administration Hospital, all scan requests had to be approved by a neurology or neurosurgical attending physician. In the first year of operation more than 58 percent of studies were abnormal; this was higher than in all other neurodiagnostic procedures performed during this period. With somewhat greater flexibility in the availability of the scan, the incidence of abnormal studies has decreased, but this may reflect either of two trends. Firstly, the obvious conclusion was that less care and discrimination were being employed in the selection of patients for scanning, but this was not reflected in the analysis of the clinical data available with each patient, which confirmed that there was no increase in the number of scans performed for vague and nonspecific symptoms. Secondly, the more likely explanation was that there had been a change in the approach to the selection process such that patients in whom other contrast studies had been contemplated but in whom the indications were questioned initially had CT scans and if they were normal it obviated the need for further contrast studies. If the clinical situation indicated that a preoperative angiogram would still be needed, CT was frequently not performed. In support of this approach, several angiomas, aneurysms and neoplasms were directly studied with angiography; although CT may have been valuable in their detection, subsequent preoperative contrast study was still necessary. Viewed in this perspective, a negative result of CT serves as a "positive" study, since it reduces the indication for other invasive time-consuming procedures and reduces hospital stay. This lowered incidence of positive studies reflects a change in the position of CT from that of a "revolutionary and special" procedure in which indications for its use were unsettled to one with which the clinician felt increasingly comfortable and knowledgeable about its value in the diagnosis of specific clinical problems.

Of the initial 2750 scans performed, approximately 90 percent were referred by neurologists and neurosurgeons; of these 54 percent were abnormal. In the most recent studies, the frequency of physicians who request the CT scan but have not received specific training in neurological diagnosis has increased to 30 percent, and the incidence of abnormal studies has decreased to 38 percent. This trend appears to reflect utilization of the CT scan as an expensive triage procedure that may be used to replace the performance of a complete neurological history and examination. Analysis of the reason for referral has demonstrated an increasing number of patients who have been referred because of vague, nonspecific and poorly defined neurological symptoms. In some instances referral was directly related to an abnormality of EEG or skull radiograph which may not have always warranted further study if reviewed by a neurologist prior to availability of the CT scan. The physician may have followed the patient's clinical status, but now these patients are frequently referred for CT study to exclude any "structural" pathology, even in the absence of definite symptoms. Because of this trend, it may be prudent to have a physician who has received formal training in neurological diagnosis evaluate the patient prior to CT scan.

Initial experience in the CT era derived from the Mayo Clinic showed that, following the installation of their first scanner, the number of neurological and neurosurgical patients increased by 15 to 20 percent. Because of this, the number of EEG studies also increased, but utilization of isotope scan, echoencephalogram, and air study significantly decreased, while angiography remained at a relatively constant level.[3] At the Mallinckrodt Institute, there was a 66 percent reduction for air study, 34 percent for angiography, and 29 percent for isotope scan.[2] At Mayo, the number of negative angiograms decreased from 30 percent in 1972 to 22 percent in 1975; this 25 percent drop reflects the high sensitivity and accuracy of CT, utilized as a screening procedure. In addition, there was a marked change in the type of pathological process studied by angiography, including a 50 percent decrease in the diagnoses related to traumatic hematoma and edema; tumors increased by 50 percent and vascular lesions by 25 percent. Several other results in the diagnosis of tumors by CT are worth emphasizing. Prior to CT, the incidence of Grade I and II astrocytoma, documented by operative findings, was only 5 to 7 percent, whereas in 1975 those low-grade gliomas comprised 30 percent of all histologically proven cases, although earlier diagnosis does not appear to be associated with an improvement in prognosis.[3] Furthermore, grossly visible incidental meningiomas are not infrequently detected at the necropsy examination, but these lesions are not usually detected by isotope scan, EEG or skull radiogram. With CT, asymptomatic meningiomas have been visualized, whereas other studies were negative. Although initial studies indicated difficulties in studying posterior fossa lesions, our experience has reflected a marked increase in the early diagnosis of posterior fossa lesions prior to the development of signs and symptoms of increased intracranial pressure. There has been a marked increase in the frequency of the diagnosis of acoustic neurinoma, tentorial meningioma, and brain stem tumors; such diagnosis was quite difficult prior to CT; and the frequency of the diagnosis of porencephalic, epidermoid and arachnoid cysts in the last 18 months at several institutions is greater than that of the previous five years.

Wortzman and Holgate analyzed the cost effectiveness of a neurological evaluation utilizing the CT scan, specifically in regard to the need for contrast procedures and subsequent hospitalization.[4] They evaluated the importance of the CT findings in 203 patients in influencing the decision to perform or avoid angiography or air study; in 61 instances angiography was prevented, and air study was obviated in 89, whereas in 11 instances angiography or air study was deemed necessary because of CT findings. An additional 241 patients were analyzed in reference to the value of CT in deciding the need for subsequent hospitalization. This showed that CT prevented hospitalization in 140, prompted admission in 28, and was not a crucial factor in 73 cases. This is in agreement with the experience of other centers with CT, as it has become possible to evaluate patients with common complaints such as seizure, headache, dizziness and syncope on an outpatient basis if the CT scan is negative.

In our experience in our large ambulatory neurology clinic where patients are usually seen on a referral basis, the most common problems related to possible CNS lesions include headache, dizziness, syncope, seizures, mental change, and gait or visual disturbances. Of those patients in whom the neurological history and examination raised suspicion of specific organic neurological lesions, further neurodiagnostic studies were performed in 60 percent. Ten percent of patients had abnormal neurological signs, abnormal EEG or abnormal skull radiograph that required further investigation, and in some instances may have required delineation with contrast studies. In these patients CT confirms the presence or absence of an underlying lesion and it was on this basis that the decision for admission was then made. In the 30 percent who had negative CT, no lesion was subsequently diagnosed. Of 200 patients who were evaluated with headache only, 20 had an abnormality defined by EEG or skull radiograph; and of these 20, CT confirmed the presence of a lesion in only three, which then required inpatient hospitalization for contrast studies, whereas in 17 CT was negative. Of those 17 CT-negative patients, subsequent isotope scan, angiography or air study confirmed the negative results of CT with follow-up of 12 months or longer.

In the decade 1962–72, there was a tenfold increase in the number of isotope scans performed at the Johns Hopkins Hospital. Despite this, there was no increase in the number of brain tumors operated upon or in the mortality rate, although the interval between the onset of neurological symptoms and the time of tumor diagnosis was decreased by the use of radionuclide scanning. For example, 93 percent of meningiomas, 67 percent of astrocytomas and metastases had positive scans at onset of symptoms, whereas 100 percent of meningiomas and 87 percent of astrocytomas had positive scans by 28 months, and 100 percent of metastatic lesions had positive scans by eight months.[5] Furthermore, isotope brain scan was the most sensitive screening procedure to detect the presence of potentially operable and remediable neurosurgical lesions, and negative studies frequently obviated the need for hospitalization and invasive contrast procedures, but it was recognized that low-grade and small-sized lesions were not always detected by isotope scan. In one study comparing the results of isotope and CT scan in 297 patients it was shown that they were frequently in agreement but CT was more sensitive; they provided similar results in 185 (both positive in 52 and negative in 133), whereas in 87 cases CT was positive but isotope scan was negative; in only nine cases was isotope scan positive but CT negative.[6] Of 25 patients who had CT scan performed primarily because of positive isotope scan, CT demonstrated single or multiple lesions in 10 but was negative in 15 cases. The impression of a falsely positive isotope scan was confirmed by subsequent angiography or air study. In the study of patients with suspected cerebrovascular disease, isotope and CT scan were complementary, as isotope scan is more sensitive in detecting abnormalities of cerebral blood flow but less sensitive than CT in differentiating uptake in normal and infarcted tissue. In the diagnosis of suspected neoplasms, isotope scan is much less effective as a sensitive screening procedure because contrast discrimination between normal parenchyma and neoplastic tissue must be quite pronounced before it can be detected, but more subtle differences may be defined by CT. In the evaluation of cerebral atrophic and hydrocephalic conditions, intravenous use of gamma-emitting radionuclide has little place; although isotope cisternography may demonstrate abnormalities of CSF flow patterns, CT directly visualizes enlarged ventricular and subarachnoid spaces. The value of the combined negative results of these two studies is that there have been no cases in which both isotope scan and CT are negative and subsequent studies have detected a pathological lesion, with a follow-up of 12 to 18 months.

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