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COMPUTED TOMOGRAPHIC ANALYSIS OF BILATERAL CINGULOTOMY FOR INTRACTABLE MOOD DISTURBANCE AND CHRONIC PAIN

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Abstract—Forty-two patients out of 300 who had undergone bilateral stereotactic cingulotomies were studied by means of computerized tomography (CT). The appearance showed bilateral encephalomalacia, measuring on the average 5 × 7 mm^2, located in the cingulate gyrus. These induced lesions had attenuation values similar to cerebrospinal fluid and did not enhance with contrast. CT is a useful technique for initial evaluation, management, and follow up of these patients.

Cingulotomy   Cingulate gyrus   Stereotactic   Intractable pain   Depression   Limbic system   Suicide

INTRODUCTION

Bilateral stereotactic frontal cingulotomy for treatment of psychiatric illness and intractable pain was initiated in 1962 at the Massachusetts General Hospital. Since that time, all patients have undergone detailed, exhaustive, medical, neurologic, psychiatric, and psychologic investigations not only prior to, but also following the cingulotomy procedures. Reports of these studies as well as technical details have been published elsewhere [1–3]. Presentation and reports of extensive neuropathologic correlations have also been performed on post mortem material in three cases [5]. Since 1974, with the availability of computerized tomography at the Massachusetts General Hospital, it has become possible to identify the stereotactic lesion in a high proportion of cases allowing the improvement in clinical status of the patient to be correlated to the size and anatomic configuration of the cingulotomy lesion during life. Computed tomography has been used in the past for preoperative localization in stereotaxis [6, 10], and mainly in connection with stereotactic biopsy of tumors [7]. Random reports of the postoperative appearance of the brain after frontal leukotomies have been published [8, 9]. To our knowledge, a detailed account of the CT scan appearance after bilateral cingulotomy (the only currently accepted procedure) has not appeared in the literature.

MATERIALS AND METHOD

Forty-two patients were studied out of 300 who had undergone bilateral cingulotomy for mood disturbance, depression and/or pain. All operations were performed by the neurosurgical team with the actual procedure being done by HTB. All patients underwent detailed, medical, neurological, psychiatric, and psychologic testing by the staff of the Massachusetts General Hospital and Massachusetts Institute of Technology. All the available CT scans were reviewed with an experienced staff neuroradiologist and the lesions measured using a conventional ruler, adjusting for magnification.

An EMI brain scanner with an 80 × 80 initially and a 160 × 160 matrix later was used. All scans were analyzed with only two showing significant movement artifacts. One patient had repeated scans because after initial procedures, the lesions were not seen on CT. However, on a repeat study, the bilateral cingulatomy lesions were clearly discernible. Three of the scans had special reconstruction

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Table 1. Postoperative psychiatric states of all patients studied

Status of patients	No. of patients	Percentage
5 (well)	8	19%
4 (marked improvement)	17	41%
3 (moderate improvement)	8	19%
2 (slight improvement)	7	17%
1 (no improvement)	2	4%
0 (worse)	0	N/A

Table 2. Postoperative psychiatric status

Number	Status
5	Free of symptomatology; not requiring medication or psychiatric care
4	Almost free of symptoms; require medication and/or psychiatric care
3	Useful improvement, able to function in society; require medication and psychiatric care
2	Not usefully improved; some relief of symptoms
1	No improvement
0	Worse

studies prepared in order to better delineate the lesions in three dimensions. "Polaroid" photographs of each slice were studied as to size and location.

All patients were carefully followed up over the years and detailed psychiatric assessments made as to clinical outcome. The psychiatric evaluations were according to a rating scale devised from previous experience in consultations with a team of psychiatrists who had examined all the patients [3]. A summary of the postoperative psychiatric status appears in Table 1.

The postoperative psychiatric status was scored according to published criteria. The maximum number was "5" and was assigned to those patients who were free of symptomatology and not requiring any medications or psychiatric care. The value "4" was assigned to those patients who were almost free of symptoms but required some medications (although reduced after the operation) and/or psychiatric care. The value "3" was assigned to those patients who showed some useful improvement and were able to function in society, but required considerable medication and psychiatric care. The value "2" was assigned to those who were not usefully improved but had some relief of their symptoms. A value of "1" was assigned to those who did not improve at all, and "0" to those who were made worse by the operation (Table 2).

RESULTS

Postoperative psychiatric status of all patients are summarized in Table 1. In all forty-two cases, the CT revealed bilateral, mostly symmetrical, well defined encephalomalacia cystic areas in the cingulate gyrus, measuring approximately $5 \times 7\ mm^2$ (Figs 1 and 2). The attenuation coefficients of these cysts were similar to CSF on the Hounsfield scale. There was no enhancement with contrast medium.

The lesions varied slightly in size but were localized to the cingulate gyrus. No meaningful correlation was found between size and shape of the lesions and clinical outcome.

DISCUSSION

It was in 1935, in London, during the Second World Congress of Neurology that Egas Moniz, a Portuguese neurologist heard Dr John Fulton, physiologist from Yale University regarding the effects of brain lesions on animal behavior [11]. Fulton and Jacobsen had found that following extensive ablations in the frontal lobes of two chimpanzees, Lucy and Becky, the animals had become less fearful and more tractable, they apparently became more placid toward environmental stimuli. Dr Moniz reasoned that the behavioral changes produced in the chimpanzees might be reproduced in humans to benefit the institutionalized psychiatrically ill. In the 1930's there was no specific treatment for the severely psychiatrically ill patient. Psychotropic drugs had not been developed, electroshock therapy was employed rarely; hypothermia was used to treat mania and hyperthermia was used to treat central nervous system syphilis. Protective custody was used for the severely depressed and suicidal patient.

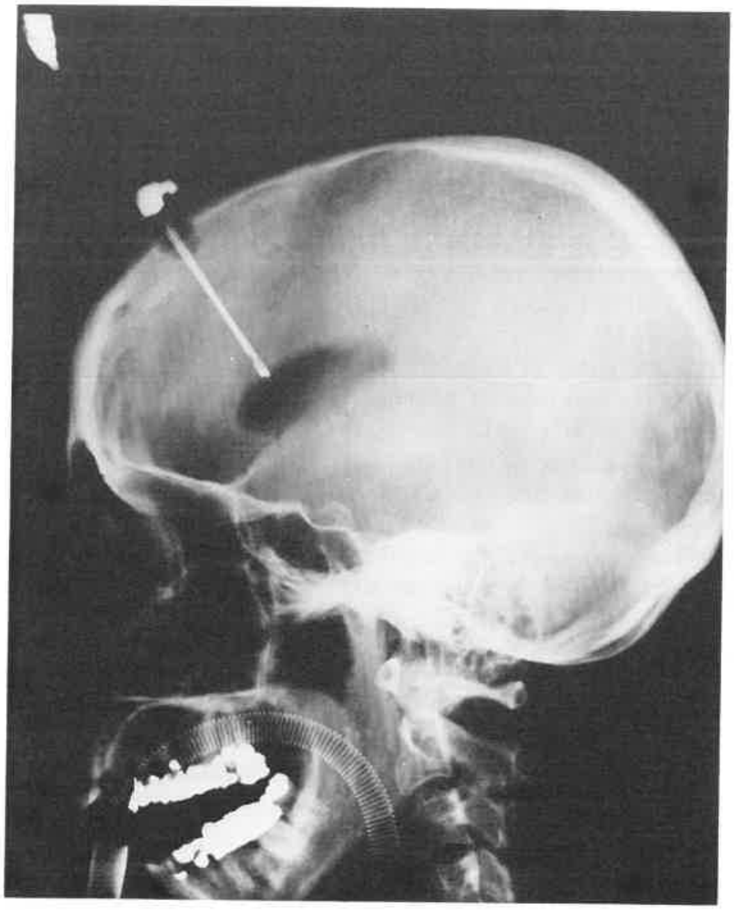

Fig. 1

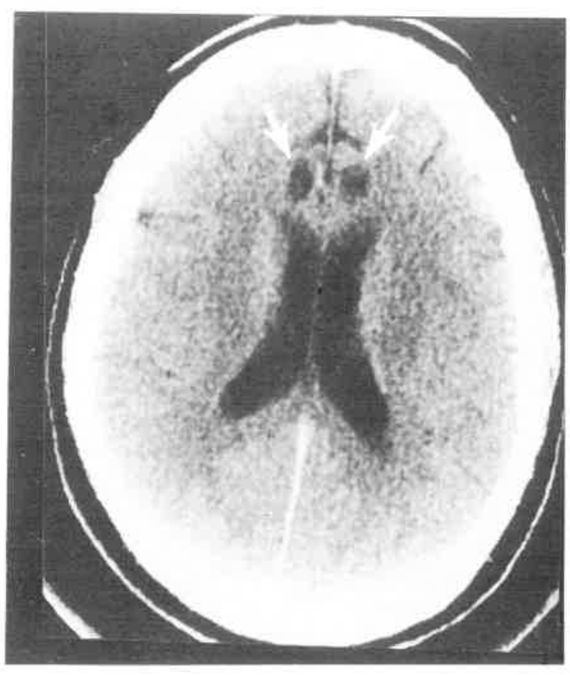

Fig. 2

Frontal lobotomies were started by Drs Moniz and Lima in 1935. The results were reviewed and the therapeutic approach was enthusiastically embraced by Dr Walter Freeman working at George Washington University Hospital. Thus began the first systematic investigation of the safety and efficacy of neurosurgical interventions for the treatment of the psychiatrically ill. One useful way of dividing this kind of surgery is to consider the prestereotactic and poststereotactic era. The major concern in this paper is to address the poststereotactic era and the era of computerized tomographic scanning. In the early stages of radical frontal lobotomies the safety factor was questioned. Tooth and Newton reviewed 10,365 operations performed between 1942 and 1954 [12]. 75% of the patients were said to have shown postoperative improvement however, the mortality rate was 6% and 1.5% of the patients had undesirable sequelae severe enough to prevent hospital discharge. The surgically induced epilepsy rate was 1%.

Most distressing was the group of patients who were made worse by leucotomy with loss of social control which was characterized in some patients by inappropriate and occasionally obscene speech and behavior. These complications led to a search for safer procedure. The original operation devised by Moniz was abandoned in favor of restricted frontal leucotomy, three of which (bilateral inferior leucotomy, bimedial leucotomy, and orbital gyrus undercutting) were done most frequently, see diagram. There were gradual improvements in the surgical procedures and modifications of the lobotomy procedures over time including Sir Hugh Cairns at Oxford and Professor Jacques LeBeau in Paris. Cairns removed 4 cm of the anterior cingulate gyrus under direct vision and reported his various experiences with his operation in 1952. Lewin reported in 1961 the postoperative status of 37 patients who had various psychiatric disorders [13]. There were no severe postoperative sequelae, no deaths and no adverse personality changes. Two patients had postoperative epilepsy. In the late 1940's Spiegel and Wycis used intracranial stereotaxy and performed thalamotomy for psychiatric illness [11]. Knight in London used a modification of Scoville's orbital undercutting, beginning in 1950 [11], Sykes and Tredgold reported the postoperative status of 350 of these patients in 1964 [14]. Knight concluded that successful outcome depended upon interrupting those fibers of the orbital fasciculus lying beneath the caudate nucleus [15]. In 1965 he reported initial results from the implantation of radioactive yttrium 90 seeds to produce a subcaudate tractotomy. Stereotactic bilateral anterior cingulotomy for the relief of chronic pain was introduced by Foltz and White at the 1961 meeting of the Harvey Cushing Society in Mexico City [16]. Dr Ballantine was present at the meeting and in 1962 began his clinical investigation of the method. In 1965 he reported on a series of 15 patients followed from 3 months to 3 years after bilateral stereotactic anterior cingulotomy [17]. In 1973 Richardson described the procedure of "stereotactic limbic leucotomy," which is essentially a combination of stereotactic subcaudate tractotomy and anterior cingulotomy [18]. Stereotactic capsulotomy has been employed intermittently by Leksell and Kullberg since the 1950's [19]. These researchers report improvement in patients with disabling obsessive–compulsive neurosis. Data are now available relative to the postoperative status of more than 1500 patients who have undergone various operations which may be grouped under the rubric of "limbic system surgery for limbic system dysfunction" [11].

What is the limbic system?

Anatomically there is the mesial surface of the cerebral hemispheres which have two large circumferential convolutions that blend into one another, the cingulate and parahippocampal gyri. These structures form a border, or limbus, within which are found the rostral brain stem and the interhemispheric connections and commissures (Fig. 3). In 1878, Broca described this region as "le grande lobe limbique," or limbic lobe [20]. He included within it the corpus callosum, the subcallosal and parahippocampal gyri, the hippocampal formation, and the dentate gyrus.

In 1937, James Papez published his classic paper, "A Proposed Mechanism of Emotion," and one of his important remarks was, "Is emotion a magic product or is it a physiological process which depends on an anatomic mechanism?" An attempt has been made to point out various anatomic structures and correlated physiologic symptoms which, taken as a whole, deal with the various phases of emotional dynamics, consciousness and related functions. It is proposed that the hypothalamus, the anterior thalamic nuclei, the gyrus cinguli, the hippocampus and their interconnections constitute a harmonious mechanism which may elaborate the functions of central emotion as well as participate in emotional expression [21].

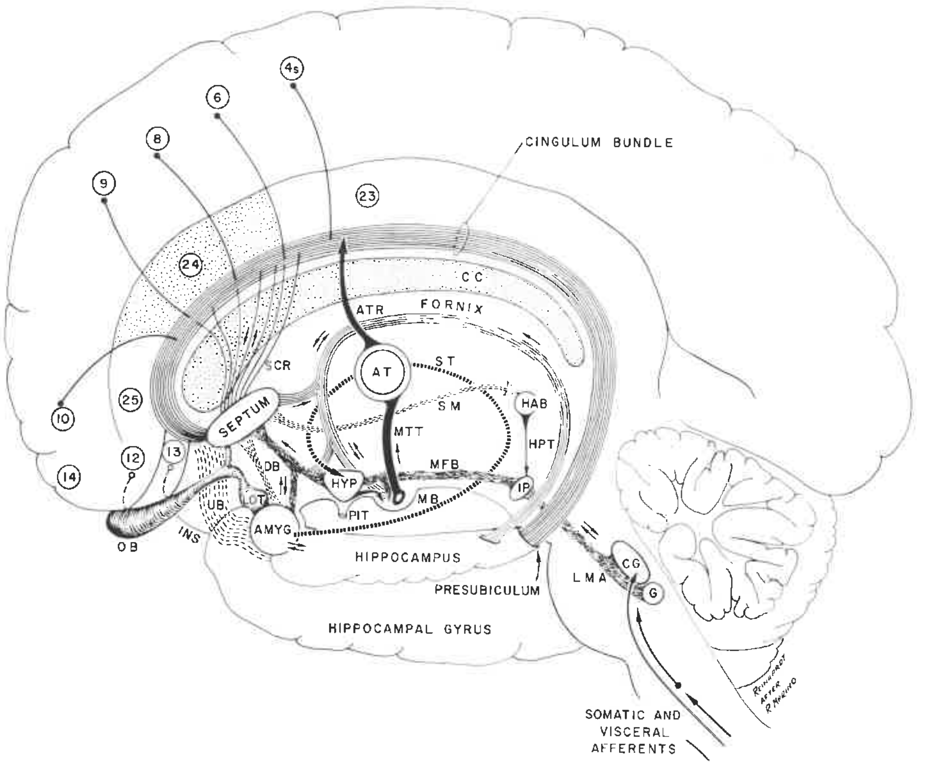

Fig. 3. Schematic model of the limbic system. *Legend*: OB—Olfactory Bulb; LOT—Lateral Olfactory Striae; INS—Insula; UB—Uncinate Bundle; DB—Diagonal Band of Broca; AMYG—Amygdala SCR-Subcallosal Radiations; HYP—Hypothalamus; AT—Anterior Thalamus; MB—Mamillary Body; MTT—Mamillo-thalamic Tract (Vicq D'Azyr's Tract); ATR—Anterior Thalamic Radiations; ST—Stria Terminalis; HAB—Habenula; MFB-Medial Forebrain Bundle; SM—Stria Medullaris; HPT-Habenulointerpeduncular Tract (Fasciculus Retroflexus of Meynert); IP-Interpeduncular Nucleus; LMA-Limbic Midbrain Area of Nauta; G-Nucleus of Gudden; CG—Central Gray; CC-Corpus Callosum. (From H. T. Ballantine and R. Marino Jr *CINGULOTOMY for Chronic Neuropsychiatric Illness and Intractable Pain*.)

Subsequently, other investigators linked structures outside of the limbic lobe of Broca with the functions of that region, and in 1952 MacLean wrote of the "limbic system." This latter term now encompasses the limbic lobe, the medial tegmental region of the midbrain (Nauta), the anterior thalamic nuclei, the hypothalamus, the septal nuclei, the amygdaloid nuclei, and the posteroinferomedial region of the frontal lobes—the "zona innominata" of Knight (Fig. 3).

It is important to add to the neuroanatomical descriptions the physiologic underpinnings and starting in the 1960's the exciting new neurotransmitter and neuropharmacologic connections. It is of fundamental importance to realize the neurons communicate with each other. Histochemical fluorescent techniques for the study of minute discrete volumes of brain led to the discovery that neurons contain various neurotransmitters including catecholamines and serotonin. Radioenzymatic techniques brought forth understanding of other neurotransmitters including dopamine, norepinephrine, acetylcholine, gamma-aminobutyric acid and other related biochemical structures. New peptides including endorphins, substance P and somatostatin have also been identified. It is quite clear that there is an interrelationship between the anatomic, physiologic, and the neuropharmacologic aspects of the brain which ultimately give rise to emotion which is acted upon by the procedure of stereotactic neurosurgery for behavioral disorders. This paper addresses only one aspect and that is the evaluation of patients using modern techniques such as computed tomographic analysis.

In terms of selection of patients, in 1981, Bartlett published a statement regarding the criteria for referral of patients and the choice of surgical approach. The operative techniques have been well addressed by Ballantine *et al.* [11]. The neuropathologic analysis has also been addressed elsewhere. [4, 5].

During the initial evaluation of a patient who is considered a potential candidate for the cingulotomy procedure, it is necessary to be certain that there is no structural central nervous system pathology that would be an absolute contradiction to proceed with surgery. Computed tomography is a useful technique to improve the precision of stereotactic operations. This method of localization has been applied to capsulotomy and may become an important adjunct in preoperative planning of all stereotactic procedures, including cingulotomies. After the procedure, CT may be used to study *in vivo*, the results of stereotactic cingulotomy as a quality control on the accuracy of the technique. The ability to determine the exact size and location of the lesion may help the neurologist and neurosurgeon particularly in those patients in whom the initial response is poor and is not maintained and in whom extension of the original lesion is contemplated. Finally, *in vivo* studies could be correlated to neuropathologic sections at post mortem.

The findings on CT after bilateral stereotactic cingulotomy are pathognomonic. The CT scan shows bilateral well defined encephalomalacia cystic areas in the cingulate gyri, measuring $5 \times 7\ \text{mm}^2$. Their attenuation coefficients on the Hounsfield scale are similar to CSF and they are not contrast enhanced. Three dimensional analysis of the surgical lesions will further help to evaluate cingulotomies in order that tissue destruction be minimized while maximizing clinical benefit to the patient.

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