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Bi-frontal Stereotactic Tractotomy: An Atraumatic Operation of Value in the Treatment of Intractable Psychoneurosis

By GEOFFREY C. KNIGHT

Part I. Anatomical and Surgical Observations

Stereotactic surgery has provided a means of producing accurate lesions at selected points in the nervous system where concentrations of nerve cells or fibre pathways possessing specific functions permit some small area of anatomical destruction to produce widespread physiological effects. The value of this method in relation to motor and sensory activity is illustrated by the results of thalamotomy in the treatment of Parkinsonian tremor and by stereotactic division of the spinothalamic tract in the cervical cord for the relief of incurable pain. The accuracy of approach and minimal disturbance of tissue ensures that the beneficial effects of these operations are produced in isolation without associated disfunction in the nervous system. That a similar principle can be applied in relation to the control of emotion has been shown in cases of intractable psychoneurosis treated by the operation of bifrontal stereotactic tractotomy in the substantia innominata (Knight, 1964). Owing to the influence of emotion in psychoneurotic states it is possible to influence many syndromes satisfactorily by operation at a site where connections of the limbic system concerned with instinctive and emotional activity rather than cognitive processes converge to a point beneath the head of the caudate nucleus, thereby producing a reduction in the intensity of emotional reaction without undesirable personality change or post-operative epilepsy. It is felt that it would be useful to summarize the anatomical features in order that the differences between this operation and the old leucotomy procedure can be generally appreciated. It is particularly among cases of chronic and recurrent depression that this form of surgery can be most usefully employed.

The surgical treatment of mental illness may be regarded as the surgery of the emotions. Since primitive emotions are damaging emotions, it might be deduced empirically that the interruption of connections from primitive cortical areas would contribute to the results obtained. In 1951 James Fulton, Professor of Physiology and Stirling Professor of the History of Medicine at Yale, published, in the Thomas W. Salmon Lectures, the results of animal experiments conducted on monkeys in his laboratories, which showed that lesions in relation to the neocortex in the lateral aspect of the hemispheres, the site usually assaulted by leucotomy operations, produced an intellectual deficit with little change in emotional behaviour, whereas lesions in the primitive agranular areas on the mesial surfaces of the hemispheres led to a reduction of emotional response without impairment of intellectual function. From this it could be concluded that if there was any future in the surgical treatment of psychoneurosis it would be found to lie in operations which interrupted the connections of the primitive cortex of the limbic lobe.

Fulton's experimental findings were in keeping with previous observations concerning the distribution and function of the "visceral brain". Economo (1929) held that the cingulate gyri were part of the cortical representation of the autonomic system. Papez (1937) pointed to the ensemble formed by the hippocampus, hypothalamus, and cingulate gyri and their various connections, and regarded this as a probable anatomical substratum of the emotions. In elaborating this theory he displayed the wide connections

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which exist between the hippocampus, hypothalamus, and thalamus, and between the thalamus, gyrus cinguli and frontal cortex. In discussing the hippocampus he pointed to the absence of evidence of olfactory function in this area and drew attention to the fact that in rabies the Negri bodies are most abundant in the large ganglion cells of the hippocampus and the patient shows intense emotion and hyperaesthesia to all forms of stimuli with the result that all stimulation provokes fear sometimes mingled with rage. In Papez's view somatic, including visceral, impulses entering the circuits of these basal areas may obtain emotional colour and finally reach the cortical level as a "stream of feeling" modifying the function of the cortical regions. This theory suggested that the pathways connecting the hypothalamus and frontal lobe contained the afferent projection systems for emotion, and it is noteworthy that cortical areas receiving such pathways have been described as giving rise to efferent fibres passing towards the hypothalamus which could constitute pathways for emotional reaction (Clark and Meyer, 1950). McLean (1949) developed this concept to include the posterior orbital cortex and the amygdaloid nucleus within the visceral brain.

The older parts of the neopallium or mesopallium are located in the transitional cortex of the anterior cingulate and posterior orbital gyri and in the medial and inferior parts of the temporal lobe. As Yakovlev (1948) has remarked, these areas form part of a closely integrated system which may be looked upon as part of the highest representation of visceral function. Close integration between the various areas is provided by the anatomical circuit, hippocampus → fornix, mammillary body → mammillo-thalamic tract (bundle of Vicq d'Azyr)→anterior nucleus of the thalamus from which projections pass from the antero-medial element to the anterior cingulate gyri in area 24 and from the antero-ventral element to the posterior cingulate region of area 23 (see Fig. 2). Examination of post-leucotomy material has shown that the projection from the anterior nuclei to the cingulate gyri in the human probably passes entirely through the anterior limb of the internal capsule (see Fig. 6) in a dorsal position (Meyer, Beck and McLardy, 1947). From the cingulate gyri a pathway runs posteriorly to area 29 in the retrosplenial region (Fig. 1) from which fibres may return to the hippocampus, or alternatively fibres enter the cingulum to complete a similar circuit. Fibres from the cingulate gyri also enter the fornix directly, providing a shorter path to the mammillary body (Clark and Meyer, 1950). By these means the hippocampus–fornix system maintains a constant cycle of functional relationship between the hypothalamus and limbic cortex. It should be noted, however, that an important intercortical relay exists between the anterior cingulate gyrus and the posterior orbital region.

Glees *et al.* (1950) have shown that fibres from the cingulate cortex of area 24 can be traced into the posterior part of the orbital cortex passing through the septal cortex into the posterior portion of the gyrus rectus and area 14 of Walker (1940) Fig. 3. The authors remark "in general our material suggests that the anterior part of the cingulate gyrus which includes most of area 24 has chiefly intercortical connections. The more posterior part of area 24 and adjacent regions of area 23 have thalamic connections. This finding deserves consideration as it throws doubt on the current conception that the anterior cingulate cortex has thalamic connections. If confirmed it would associate the anterior cingulate region with the orbital frontal cortex rather than with the thalamic cortical projection areas." Areas which are reciprocally connected are by inference functionally related. Smith (1945) and Livingston *et al.* (1948) have obtained respiratory and vascular responses from a continuous zone of cortex extending from the anterior cingulate gyrus to the posterior orbital surface. In monkeys, stimulation of area 24 produces autonomic responses such as are seen in association with emotion, including dilatation of the pupils, erection of the hair, change of blood pressure, pulse and respiration, and even vocalization. Two other focal regions of autonomic representation may be identified in the frontal cortex, first a zone between the motor cortex and frontal agranular area, the cortico-autonomic belt of Kennard (1944) from which fibres project through the internal capsule to the medial mammillary nucleus and to the ventro medial hypothalamic nuclei (Meyer, 1949; Clark and Meyer, 1950) (a pathway which may provide for the relationship between higher cerebral function and autonomic activity), and secondly, the posterior orbital cortex of area 13 (Walker, 1940) from which Clark and Meyer (1950) have demonstrated bilateral projections to the ventromedial hypothalamic nuclei and from which Ward and McCullough (1947), using strychnine oscillography, have fired the paraventricular and posterior hypothalamic areas. Stimulation of the posterior orbital cortex produces varying results according to the condition of experiment, for as Karda (1951) has shown, excitatory responses may be obtained from areas which under different conditions yield inhibitory results. Spencer (1894) produced vasomotor responses in the dog and monkey, Bailey and Sweet (1940) and Delgardo and Livingston (1948) observed changes in respiration and blood pressure and gastric motility. Similar effects have been obtained in the human by pre-leucotomy stimulation (Livingston, Chapman, Livingston and Kraintz, 1948). It is perhaps significant that these changes can be the accompaniments of intense emotion. Through connections with the ventromedial nuclei the orbital cortex may produce an influence upon brain-stem mechanisms which are executively concerned in the expression of rage. Wheatley (1944) showed that lesions which destroy these nuclei are invariably associated with savage behaviour, suggesting that inhibitory influences are eventually channelled through these areas. Ablation experiments confirm the influence of the visceral brain on emotional reaction. Excision of the anterior cingulate gyrus in monkeys produces alteration in the emotional reaction to environment, with loss of fear of humans, diminished aggression, increased tameness and lack of appreciation of danger. Smith (1945), Ward (1948*a*, *b*) and Glees. *et al.* (1950) have confirmed these findings. Whitty (1955) has remarked that the behavioural changes seem to be linked with the anterior part of the cingulate gyrus (that portion which possesses orbital cortical connections), because, when similar extirpations were made in area 23 more posteriorly they were not observed. He also draws attention to the similarity between certain behavioural changes and those produced by Bucy's (1941) temporal lobectomy preparations, suggesting that as far as function is concerned anterior cingulate and anterior temporal regions may be two parts of one mechanism. Excision of the orbital gyri in higher animals also produces quiescence and increased tameness (Livingston *et. al.*, 1948). Evidence, therefore, indicates that mesopallial areas of the forebrain subserving autonomic functions also form the background of emotional reaction and affective behaviour.

Pathways from the hypothalamus pass to the thalamus via the periventricular system of fibres or the mammilo thalamic tract. The dorso-medial nucleus of the thalamus is concerned in relaying to neopallial cortex impulses originating in the hypothalamus and projects mainly to the granular areas of the frontal lobe. The pars magno-cellularis of the nucleus however, projects to the mesial half of the orbital cortex chiefly anteriorally in Area 12 although Meyer, Beck, and McLardy (1947) have said that it can possibly be connected with the posterior orbital regions. Dr. N. Corsellis (personal communication) has identified neuronal loss and gliosis in the medial part of the dorso-medial nucleus of the thalamus of one patient, following a stereotactic tractotomy. In a second patient gliosis was present in the same areas but neuronal loss was not definitely established. The findings give additional support to the view that the medial part of the dorso-medial nucleus projects to the orbital cortex of the frontal lobes.

Fulton's experimental findings later received support from the results of accurate operations of undercutting or topectomy of limited cortical areas which replaced standard leucotomy.

In keeping with the effect of experimental lesions in neopallial and mesopallial areas the rostral operation which isolates the convexity and chiefly interrupts neocortical connections was found to be somewhat inconsistent, whereas operations which interrupt the connections of the agranular cortex were more successful. Cingulectomy was effective in the treatment of obsessional illness (Le Beau, 1952 and 1954) and (Lewin, 1961). Restricted orbital undercutting which isolates the agranular cortex of area 13 and part of area 14 (Fig. 3) was effective in the treatment of depression (Knight and Tredgold, 1955; and Sykes and Tredgold, 1964).

In our experience, certain cases which combined obsessional features with depression were cured of their depression by undercutting, but the obsessional features persisted and were subsequently relieved by cingulectomy. Lewin (1961) records the reverse experience. This does not necessarily mean that specific forms of psychoneurosis are related to specific cortical areas, but it does mean that in certain serious cases it is necessary to produce a greater quantitative effect upon the connections of the limbic lobe. Recently, the surgery of the limbic system has been extended towards the amygdaloid nucleu in the temporal lobe. Turner (1963) and Narabayashi *et al.* (1963) have devised methods for destruction of the amygdaloid nucleus, which have been employed with benefit by Turner for the disturbed behaviour accompanying bilateral temporal epilepsy, and in subnormal and post-encephalitic states by Narabayashi. More recently still, Turner (1967) has excised the posterior cingulate gyrus for the control of violent behaviour with some success despite the results of previously recorded experiments. These observations suggest that the maximum effect would be obtained in seriously disturbed patients by an operation which interrupts many connections of the limbic system, but the wide distribution of the limbic system on the mesial aspect of the hemisphere in the cingulate region, on the under aspect of the frontal lobe in the primitive cortex of Walker's area 13 and 14, and in the temporal lobe in the amygdaloid nucleus, has made it impossible to secure this effect by surface lesions. The operation of stereotactic tractotomy, which destroys a zone in the substantia innominata, divides fibres from certain of these areas beneath the caudate nucleus and putamen (corpus striatum).

The term substantia innominata is an accepted topographical description of the area which lies immediately beneath the striatum and overlies the posterior orbital cortex of area 13 and 14. To the naked eye, when seen under direct vision in the course of some 1,200 incursions at orbital undercutting operations, it has appeared to me white in colour, especially when compared with adjacent cortex and striatum, but in fact it contains neurons and is therefore technically grey matter. Miodonski (1967) writing on the "Myeloarchitectonics and Connections of Substantia Innominata in the Dog Brain" describes it as a strongly myelinated area containing numerous fibre tracts including connections with the amygdaloid complex, the medial forebrain bundle, and the diagonal band of Broca in addition to the adjacent cerebral cortex and fibres from the hypothalamus and thalamus.

Fibres concerned in emotional reaction passing to the hypothalamic nuclei from the posterior orbital cortex, whose presence may be inferred from the results of stimulation experiments already described, pass beneath the putamen and caudate nucleus and traverse the substantia innominata before they gain access to the third ventricular region. Fibres from the anterior cingulate region of area 24 are distributed to the subjacent gyrus rectus and area 14, and since their stimulation will produce autonomic responses they must possess further hypothalamic connections passing through this area which may be divided in this zone. Fibres ascend to the anterior cingulate region from the antero-medial nucleus of the thalamus in the rabbit and cat in front of the caudate nucleus in this region, but a similar tract has not so far been confirmed in the primate (Rose and Woolsey, 1948). Evidence concerning the precise termination of descending fibres may require reassessment, for the Glees silver technique employed for demonstrating terminal degeneration in tracing these can itself produce pseudo-degeneration in hypothalamic areas (Cowan and Powell, 1956). However, it appears that the substantia contains fibres passing from the posterior orbital cortex to the hypothalamic nuclei in addition to an important projection from the amygdaloid nucleus. Fibres from the transitional cortex of area 13 which are distributed to the ventromedial hypothalamic nuclei cross this area before being distributed bilaterally to their termination (Clark and Meyer, 1950). A projection from the amygdaloid nucleus and pyriform lobe (Nauta, 1961) sweeps up and passes into the posterior portion of the substantia before turning back and running caudally towards the hypothalamus to reach the dorso-medial nucleus of the thalamus whence it is distributed to the frontal cortex. The presence of this tract and an important return pathway from the hypothalamus to the amygdala has been confirmed (Powell, Cowan, and Raisman, 1963). Fibres pass between the orbital cortex and the thalamus (Nauta, 1962). Lesions within the substantia may possibly interrupt fibres from the anterior cingulate gyri and will undercut and isolate the posterior orbital cortex of area 13 and part of 14 and will divide a projection to and from the amygdaloid nucleus and fibres from the dorso-medial nucleus of the thalamus, a localized lesion at this point would be expected to exert an influence on the emotional activities subserved by these areas. A lesion at this site will selectively divide fibres concerned in emotional reaction whilst leaving the hippocampus fornix system and most of the thalamo-frontal pathways undisturbed for the preservation of normal emotional tone and emotional appreciation. Fibres from areas 13 and from the amygdala which lie beneath the striatum are not accessible to vertical leucotomy incisions which are more anteriorally placed, and it is interesting to speculate whether division of these fibres in the posterior part of the substantia is important in producing the successful result which can sometimes be obtained by operation in this area in cases in which leucotomy has failed.

In 1960 I selected this region for a stereotactic operation. Clinical observations and operative findings in a large series of restricted orbital undercutting operations had drawn my attention to a concentration of important fibres in this area (Knight, 1960) and had indicated that the maximum benefit of these operations was derived from the terminal 2 cm. of the narrow incision which entered the substantia innominata beneath the head of the caudate nucleus and overlay the primitive cortex of area 13 and 14 in the gyrus orbitalis and gyrus rectus (Fig. 6).

Although the restricted undercutting operation was being employed with benefit, particularly in cases of depression, it could produce certain undesirable effects (Sykes and Tredgold, 1964), far less than leucotomy but nevertheless sufficient to be weighed by clinicians before advising this procedure for their patients. There was an epileptic risk of 10 per cent., of whom half had recurrent post-traumatic epilepsy and half had only a single seizure. There was a 5 per cent. risk of personality blemish and a mortality of less than 1 per cent., particularly in hypertensive subjects. In order to avoid these effects resulting from cutting and scarring in the brain, it was decided to produce an equivalent lesion by the insertion of radioactive seeds under X-ray control into areas in the substantia innominata of both sides corresponding to the last 2 cm. of the undercutting incision. Wire markers introduced in the incision at open operation indicated the relationship of the terminal portions to skull markings as seen on X-ray. Using these points as a guide, rows of radioactive seeds were inserted stereotactically within the target area. The technique of this procedure has been described elsewhere (Knight, 1965). It was necessary to produce a lesion having length and breadth but little depth, so as to avoid damage to the striatum. I had shown (Knight, 1943) that posterior leucotomy incisions which entered this area produced harmful autonomic disturbances, an observation amply confirmed by Meyer and Beck (1945); Ziegler and Osgood (1945) and others. Meyer and McLardy (1948) had concluded that autonomic disturbances were related to bilateral damage in the region of the striatum. To produce a lesion which would not affect the striatum I employed seeds of radioactive yttrium Y.90. which would only yield a necrotic dose of beta emanation up to 2 mm. from the seeds' surface. The necrotic dose of yttrium was empirically assessed at 30,000 rads. Since the radioactive half life of yttrium is 96 hours, the necrotizing effect is produced in the early stages after operation and the seeds subsequently become inert.

Originally four rows of yttrium seeds were implanted bilaterally, but later I reduced the area of destruction by omitting the lateral rows of seeds. It was hoped that it might be possible to narrow the lesion still further, for it appeared that the main objective of operation was to destroy the inner margin of the zone in order to interrupt fibres descending into the third ventricular region which must converge towards the mesial aspect in order to do so, but this expectation has not been confirmed. In three cases where I have used only the two inner lines of seeds, the operation has not produced the expected clinical improvement in psychiatric symptoms that had occurred in comparable cases. It would therefore appear on present evidence that it is necessary to produce a lesion having a certain minimal width in order to interrupt essential pathways. We have not yet formed a lesion by electro-coagulation. The effects of electro-coagulation are sometimes unpredictable and larger lesions than intended may be produced by infarction; so for research purposes we have preferred to persevere with the use of yttrium, which produces an accurate lesion. I have matched the radioactive dosage against the results in 130 cases. My clinical impression is that better results were obtained with seeds yielding between 37½ thousand and 50 thousand rads at 1·5 mm. on the day of implantation. It is difficult to establish proof where many variables are involved, but in cases of depression in which a satisfactory result is usually achieved relapse occurred in three patients with seeds yielding less than 30 thousand rads at 1·5 mm.

from the seeds' surface. Bilateral lesions are essential. In the early cases the implants were inserted on one side at a time at separate operations. Unilateral implantation produced little effect, but the full effect appeared when the second side was completed, indicating how easily open operations and blind operations can miss their effect should deviation of the forceps cause an incision to miss a target area on one side only. In one post mortem it has been shown that a three-line implantation produces an area of necrosis measuring 1 cm. in width, ½ cm. from above downwards, and 2 cm. in antero-posterior extent. The edge of the necrotic area consisted of softened cerebral tissue to a depth of a few millimetres, but beyond this there was no macroscopic abnormality. Post mortem examination has been obtained in a man of 70 who obtained relief from chronic depression for two years and then died from natural causes. Three rows of seeds had been inserted bilaterally. Section at 4 cm. from the frontal pole showed an area of necrosis measuring 1 cm. from side to side, and ½ cm. from above downwards, subjacent to the gyrus rectus and adjacent orbital gyrus, the lesion contained yttrium implants firmly embedded in greyish connective tissue. Section a few millimetres anteriorly showed no evidence of any damage except for the three puncture wounds produced by the inserting needle. At 6 cms. from the frontal pole, the lesion in the right hemisphere had deviated a little to the right and showed an area of brownish degeneration, presumably due to slight haemorrhage subjacent to the medial gyrus and lateral to the gyrus rectus. The lesion on the left was similarly placed. The cerebral tissue surrounding the necrotic area was softened to a depth of 1–3 mm., the softening extending to immediately below the tip of the caudate nucleus which was not involved in the necrotic process. Section of the necrotic area showed a chronic glial reaction with demyelination for a few millimetres in the surrounding myelinated areas. (I am indebted to Dr. Corsellis for information concerning these post mortem findings.)

Routine follow-up has shown that this small lesion has prevented the harmful effects, whilst at the same time preserving the benefits produced by open operation. There has been no mortality in a series of 200 cases; there has been one example of recurrent epilepsy in 120 patients observed up to four years from the date of operation, a woman of 65 with cerebral atrophy in whom recurrent right-sided Jacksonian epilepsy commenced two and a half years after operation and was satisfactorily controlled with phenobarbitone. This patient has now been investigated. EEG shows no disturbance in the region of the cortical punctures, and it seems improbable that this disturbance of the motor cortex could be causally related to an operation at the frontal pole. With this one exception, six patients had a single fit or repeated fits in the first 24 hours as a result of operative disturbance, but these ceased spontaneously. One patient of 79 had a single fit eight months after the operation, which was not repeated. Anti-convulsive therapy has not been employed, and recurrent fits have not been observed. Although final conclusions as to the production of personality change must await the outcome of the current psychiatric review, it does not appear that persistent changes in personality occur. In certain cases there may be a temporary phase following operation in which personality defects are apparent, but these settle well with appropriate rehabilitation. In cases studied personally at an interval of three months or longer after operation, defects of inhibition, lack of restraint, inappropriate or anti-social behaviour, excessive volubility, excessive eating and excessive sexual demands have not been observed, nor has adiposity been a consequence of the operation, possibly because excessive eating does not occur and there is not any reduction in activity, which was a feature of some leucotomized cases. There seems to be no evidence of the diminution in capacity for enjoyment seen after leucotomy to which Ström-Olsen and Tow (1949) have drawn attention, and which was thought to be due to destruction of the thalamo frontal pathway. Patients retain or regain their capacity for the enjoyment of work and leisure, and those improved by operation resume a normal occupation appropriate to their age and physical condition. Many complain of a temporary feeling of fatigue which occurs as a phase lasting some weeks and sometimes for several months, which has to be overcome by rehabilitation. In elderly patients there is sometimes a complaint that memory is less reliable than it was, but this is by no means universal. My overall impression is that any defect which exists is slight and does not constitute a handicap or blemish to the patient. There is certainly a total absence of the so-called leucotomy syndrome. Incontinence, which was a frequent and troublesome feature following leucotomy, has been observed as a temporary defect only in three elderly patients in whom cerebral atrophy was present, in these urinary incontinence persisted for three weeks to two months. It was felt that the probable reason for this temporary complication was that the atrophic process had altered the anatomical dimensions of the brain, so that the centres concerned in bladder control which lie immediately behind the target area (Andrew and Nathan, 1964) had come to lie more anteriorly in relation to the skull and were therefore affected by the activity of the posterior seeds; in order to avoid this complication we now place the seeds slightly further forward when cerebral atrophy is revealed.

The position appears to be that this operation can do no harm but it may do a very great deal of good, and it is hoped, therefore, that it may be accepted as a helpful adjunct to the work of a psychiatric team, providing a useful next stage in treatment which can be used with confidence when required after conservative measures reach an impasse in certain potentially curable cases. In successful cases clinical improvement may be observed immediately after operation, or a slow, gradual recovery may continue with increasing benefit over a period of months. The results are influenced by many factors, but I would wish particularly to emphasize the great importance of psychiatric supervision and rehabilitation after operation. Many patients who have suffered from depression respond quickly, but prolonged and careful rehabilitation is required in other cases, particularly in patients suffering from chronic anxiety states and obsessional illness and those of poor personality. Satisfactory results can only be obtained by team work in which operation is one stage which must be supported later by psychiatric rehabilitation.

Owing to the elimination of major surgical trauma, this operation can be performed with success in patients of advanced years and poor physical condition, including hypertensive subjects and sufferers from cardiac conditions. Numerous successes have been obtained in patients in the oldest age groups, from 70–86 years (Knight, 1966), a point of significance in view of the large and increasing number of geriatric patients confined in mental hospitals as the result of depressive illness (Herbert and Jacobson, 1966).

Because physical methods can cure certain patients in a particular category it is not reasonable to expect that all are necessarily curable, but in those who do well the effect of operation is to reduce the intensity of emotional reaction to a degree which is either adequate to relieve symptoms entirely, or to render patients accessible to psychiatric treatment which was ineffectual before. They are still capable of feeling normal fear, grief, and tension, but no longer react excessively, so that the stresses do not excite excessive reaction.

A housewife aged 37, following the death of her father, had for ten years exhibited depression, involving as many as ten suicidal attempts of which seven had occurred in the last five years, the last had resulted in a temporary paralysis of her left arm from cerebral anoxia. She stated quite definitely that she intended to kill herself, and that she would do so because she was convinced that she could obtain no help from existing methods of treatment. Following operation she made a satisfactory recovery and became once again a happy married woman, deeply interested in the running of her house and in her family, and warm and normal in emotion. A particularly gratifying feature was her emotional reaction to her young son who had been growing up during the ten years of her illness. During that time she had had no feeling towards him, but after operation she developed a normal maternal love. Two years after operation she discovered that she had developed cancer of the breast. She held an objective discussion with the surgeon as to whether she should have an amputation or deep X-ray therapy, choosing deep X-ray therapy in order to avoid mutilation, as she had already been sterilized as part of her psychiatric treatment. She has satisfactorily withstood the impact of this serious stress, exhibiting no more than the normal anxiety of any woman, and has obtained an excellent clinical result in so far as this second illness is concerned. The pre- and post-operative psychometric assessment of this case is of interest, and I am indebted to Mr. A. S. Presly of the Clinical Psychological Department of Bexley for the following details, and for his personal comments on the results.

Date of Operation, 20 September, 1965.
Date of Post-Operative Test, 5 November, 1965.

1. *Wechsler Bellevue Form I*

	Pre	Post
Comprehension ..	14	13
Digit Span	11	6
Similarities	10	11
Vocabulary	12	11
Verbal Scale IQ ..	116	107

The falling off in intelligence on the post leucotomy test is more apparent than real. It is solely due to the poor score on the Digit Span subtest, where the patient found it difficult to concentrate. This may be a result of the operation, but is more probably a chance variation

2. *M.P.I.*

	Pre	Post
Neuroticism	33 (high)	6 (very low)
Extraversion	18 (low)	26 (average)

There are significant changes on both personality dimensions on this test. The patient now has an average score on extraversion, and a very low neuroticism score. These changes are in the direction one would expect following leucotomy, but the degree of change is rather surprising.

3. *Taylor Manifest Anxiety Scale*

	Pre	Post
Score	28 (high)	18 (average)

The patients' retest score on this test shows a decrease of 1·5 standard deviations, indicating a marked reduction in anxiety level.

4. *Foulds Punitiveness Scales*

	Pre	Post
Acting out Hostility ..	23%	16%
Criticism of others ..	8%	8%
Delusional Hostility ..	11%	0%
Self Criticism	82%	55%
Delusional Guilt ..	28%	14%

The only significant change on this test is a marked reduction in self criticism, showing the patient to be much less self-punishing than before. There has been no change in the opposite direction, i.e. there is no increase in outwardly expressed hostility.

5. *Rozenzweig Picture Frustration Test*

	Pre	Post
Extrapunitiveness ..	17%	33%
Impunitiveness ..	33%	42%
Intropunitiveness ..	50%	25%

Changes on this test are again in the predicted favourable direction. The patient appears to be less inclined to take the blame upon herself in frustrating situations (i.e. to be intrapunitive) and more inclined to express her aggression outwardly (i.e. to be extrapunitive).

6. *M.M.P.I.*

Validity Scales	Pre	Post
?	50	50
L	60	70
F	64	53
K	55	51
Clinical Scales		
Hypochondriasis ..	68	50
Depression	105	78
Hysteria..	73	52
Psychopathic	60	50
Paranoid	62	41
Phobic/Compulsive ..	81	58
Schizophrenia	89	51
Hypomania	35	30
Masc./Fem. Interest ..	55	59
Social Introversion ..	72	65

This test shows the most dramatic changes of all. It shows a marked decrease in severity of depressive, phobic anxiety and social withdrawal features, and apart from the Depressive scale score, all scores are now within normal limits. The Validity scales show an interesting change in the patient's attitude. Previously, she showed a tendency to show herself in an unfavourable light, but on the second occasion the high L score indicates that she has tried to appear as "normal" as possible. Thus, the changes shown on the test may be again more apparent than real.

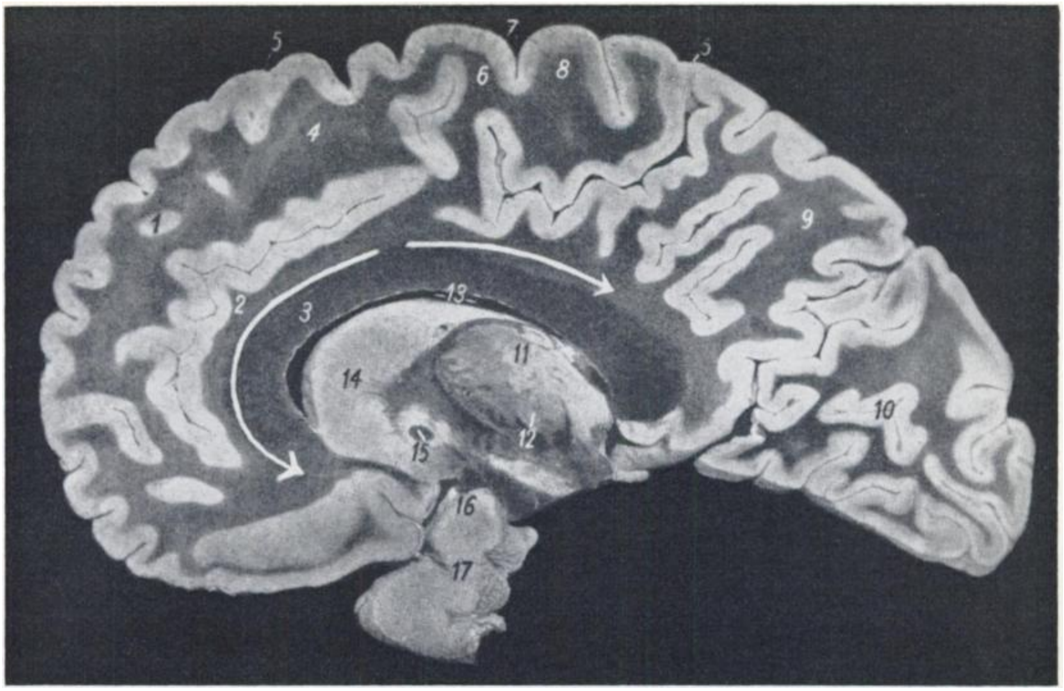

FIG. 1.—Sagittal section of left cerebral hemisphere showing position of cingulate gyri (2) and corpus callosum (3). Arrows indicate the intercortical radiation from the anterior part of area 24 to posterior orbital cortex and a posterior projection from areas 24 and 23 to the retrosplenial region.

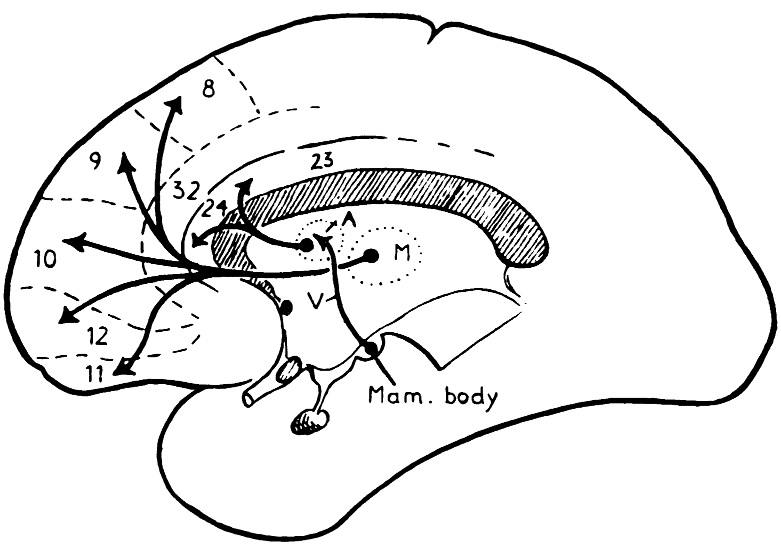

FIG. 2.—Right cerebral hemisphere showing major afferent projections to the cortex of the frontal lobe from the dorso-medial nucleus of the thalamus to areas 8–11 and from the anterior nucleus of the thalamus to areas 24 and 23. The mammillary body and mammillo-thalamic tract are also figured (modified from Le Gros Clark (1948) and reproduced by kind permission of the *Lancet* and Sir Wilfred Le Gros Clark).

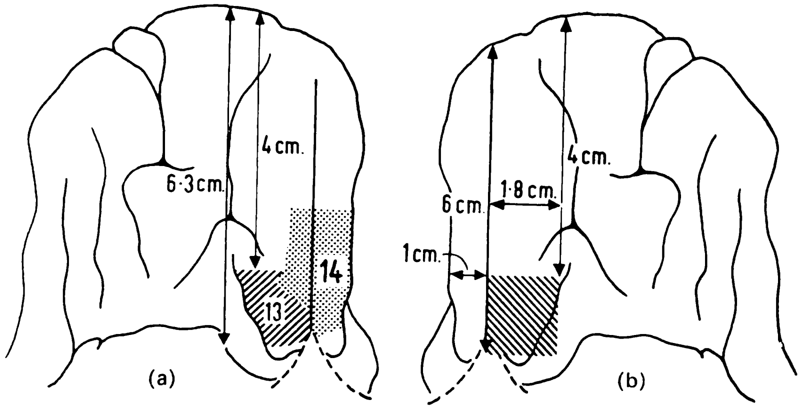

FIG. 3.—(a) Orbital aspect of the left frontal lobe showing Walker's area 13 in cross hatch and area 14 in stipple. Elizabeth Beck (1949) has shown that in man the change to agranular cortex of area 13 takes place about 4 cm. from the frontal pole and thereafter extends to 6·3 cm. from the tip of the pole. Area 14 receives intercortical fibres from the anterior cingulate region.

(b) Orbital aspect of right frontal lobe showing extent of restricted orbital undercutting incision situated 1 cm. from the midline and extending to 6 cm. from the frontal pole. Sir Wilfred Le Gros Clark has pointed out that the posterior 2 cm. of the incision will undercut areas of the human cortex corresponding to area 13 and 14 as described by Walker, and more particularly the former (personal communication).

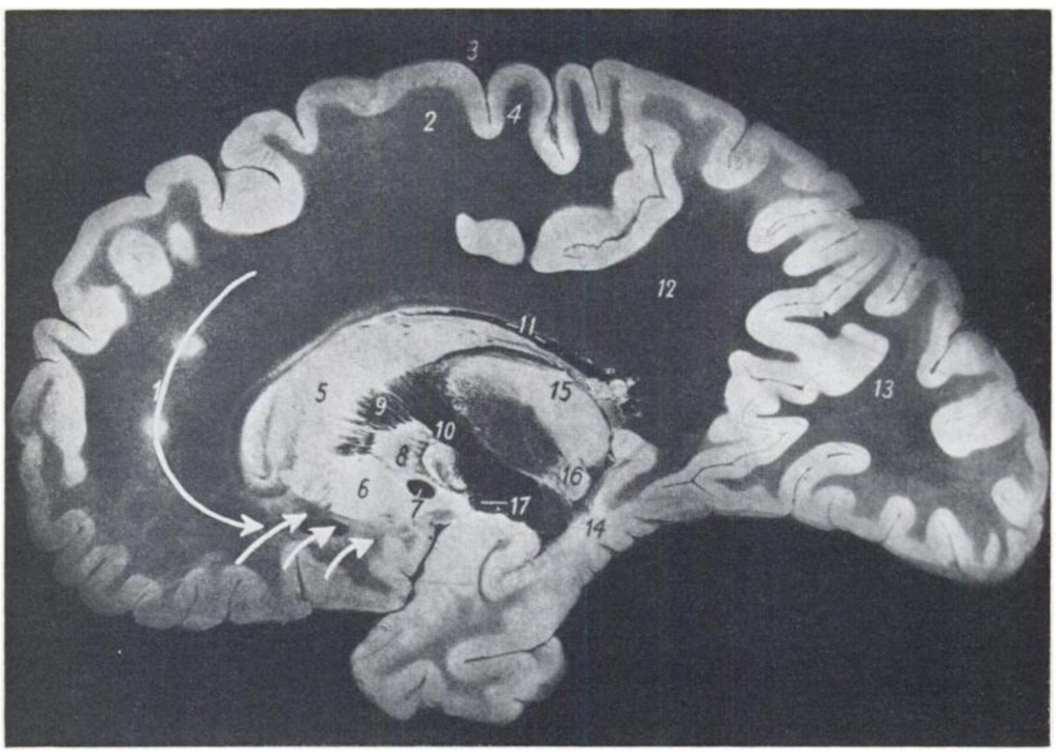

FIG. 4.—Saggital section of hemisphere showing caudate nucleus (5) and putamen (6) and the subjacent substantia innominata. Arrows indicate projections from the anterior cingulate gyri and posterior orbital cortex. Figs. 1, 4 and 5 reproduced by kind permission of Professor Stelmasiak and the Polish State Medical Publishers from the *Anatomical Atlas of the Human Brain and Spinal Cord.*

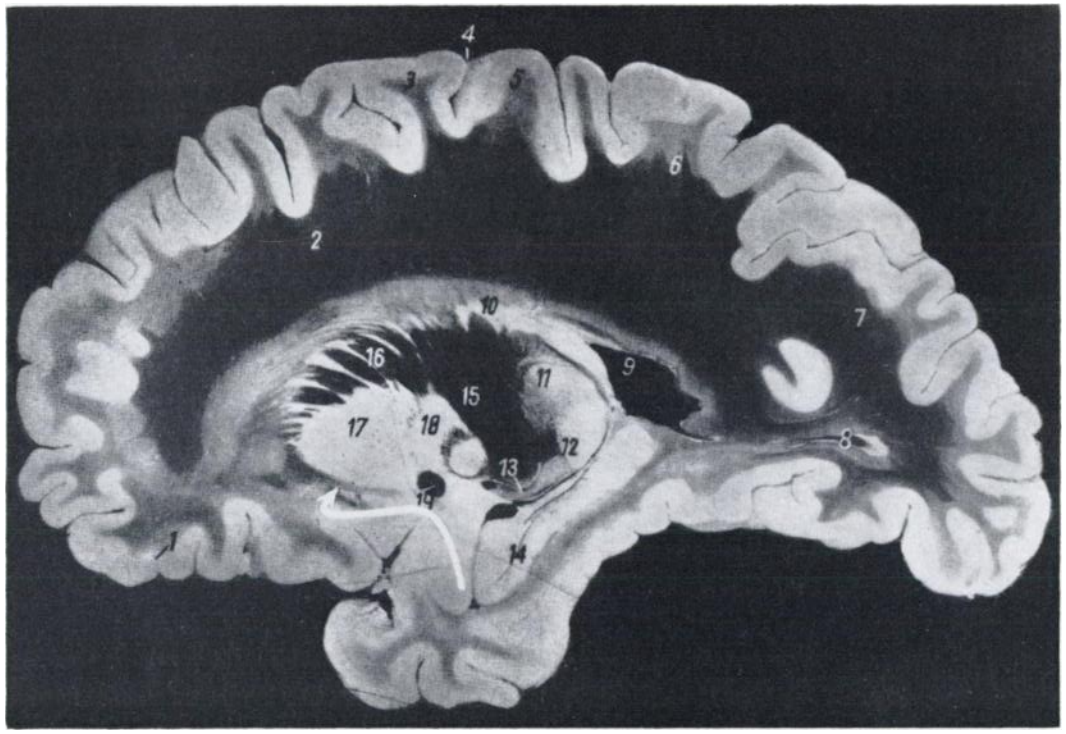

FIG. 5.—Section approximately 1 cm. further laterally showing putamen (17) and hippocampus (14) and arrow indicating projection from the amygdaloid nucleus to the hypothalamus via the substantia innominata.

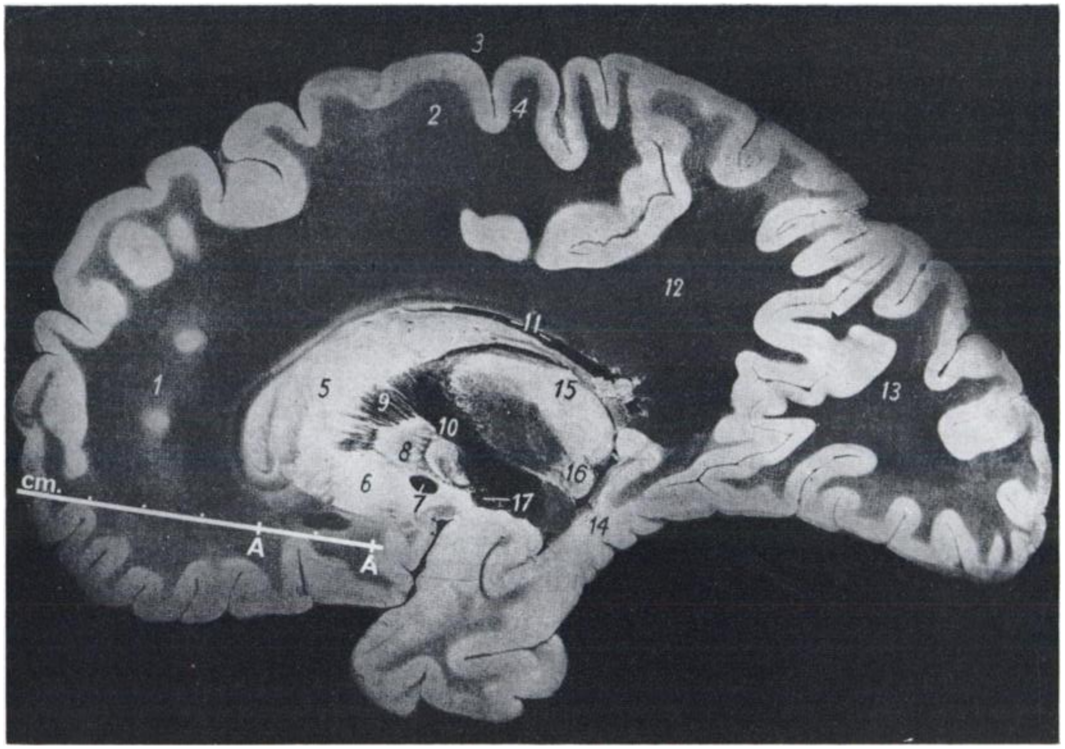

FIG. 6.—Saggital section of left frontal lobe showing the situation of the 6 cm. orbital undercutting incision and A–A the last 2 cm. of that incision in the substantia innominata. The ascending thalamo frontal radiation passes between the caudate nucleus (5) and putamen (6). Also figured are anterior limb of internal capsule (9), gyrus hippocampus (14) and pulvinar of thalamus (15).

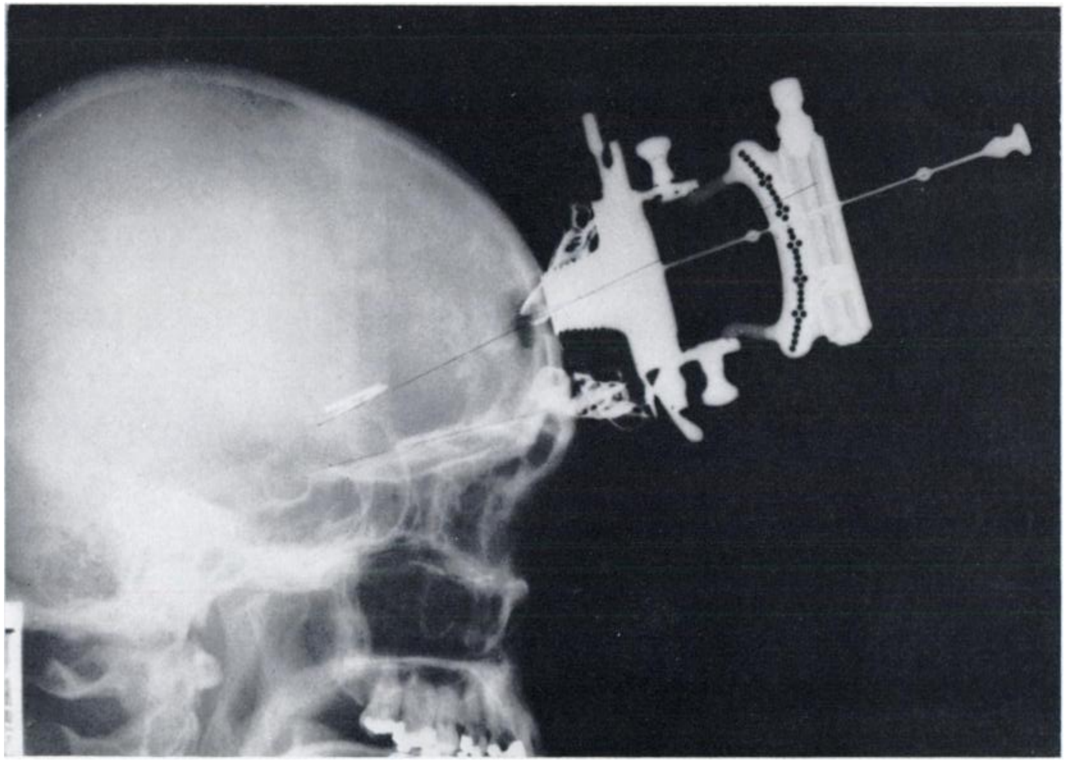

FIG. 7.—Stereotactic device *in situ*. One set of seeds has already been inserted. The distance between the two spheres on the aiming needle corresponds to the distance between the lower sphere and the centre of rotation of the instrument. The site of the target area is marked on the radiograph and a line projected from this point through the centre of rotation to cross the perforated scale will indicate the site of the target in this plane.

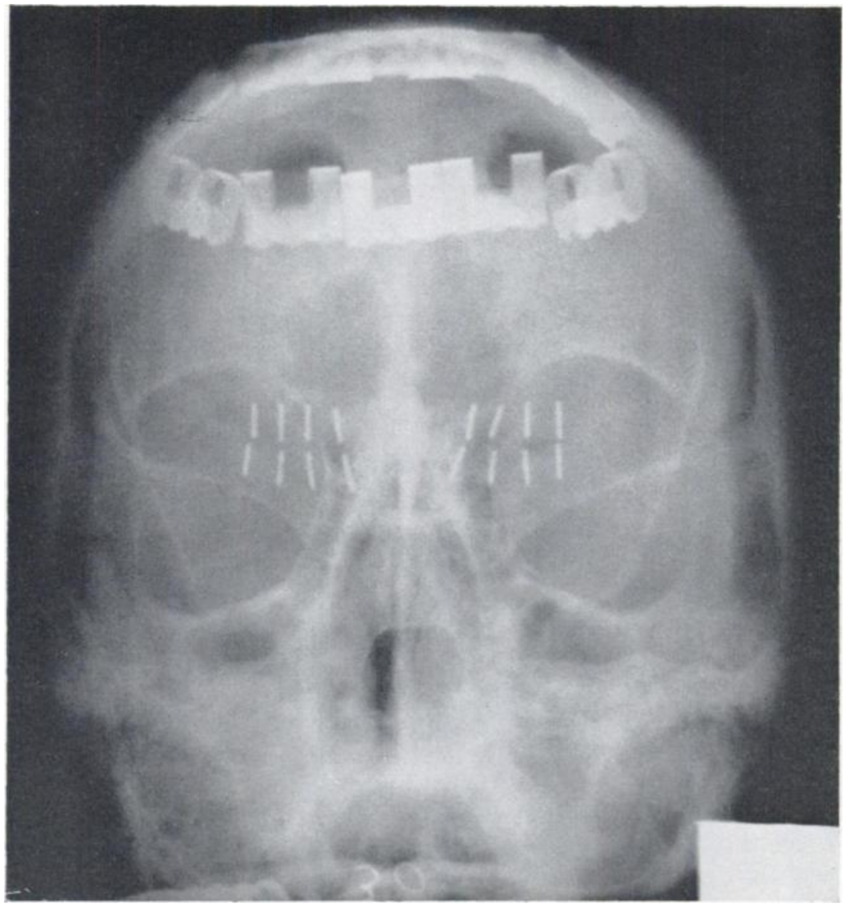

FIG. 8.—Antero-posterior X-ray view of yttrium seeds irradiating a plane 1·8 cm. wide by 2 cm. long.

Conclusions. The post-leucotomy test results all indicate a marked improvement in this patient. Her intelligence level is unaffected, apart from some difficulty in concentration. Her personality now appears less neurotic, more extraverted, and less intropunitive. There has also been a change in her attitude to her illness in that she now wishes to appear as "normal" as possible, as opposed to the severely self-critical attitude she adopted previously.

The changes on the tests are so marked that one suspects they may be due, in part, to her change in attitude rather than to a basic change in her personality.

(*Signed*) A. S. PRESLY.

All of the patients treated in the series had received prolonged psychiatric treatment for a period of years before being referred for operation. In successful cases, the results, in the words of one experienced psychiatrist, "can be impressive, especially when we have done everything that we can think of to help these patients without success". I have from time to time published statistics based upon repeated follow-up studies and the reports from referring psychiatrists (Knight, 1964, 1965, 1966). My clinical impression in this highly selected series has been that the measure of success in different categories is comparable to that obtained by orbital undercutting. A retrospective study based upon the first 200 cases is now being conducted as a Mental Health Research Fund Survey by Dr. Rolf Ström-Olsen. A full psychiatric assessment of this method will, therefore, appear as a separate communication when this survey is complete.

SUMMARY

1. Two hundred patients have been treated by stereotactic implantation of radioactive yttrium Y.90 in the substantia innominata under X-ray control.

2. The operation is harmless in that there is no mortality, no definite post-operative epilepsy, and no serious personality change.

3. Many patients suffering from depression can be improved by this operation when psychiatric treatment has failed.

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