

PREFRONTAL LEUCOTOMY *

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THE operation of prefrontal leucotomy presents many aspects; to select one in preference to another would, we feel, do the subject an injustice. We have therefore decided to treat the subject as a whole, and thus avoid limiting the scope of the paper or of any subsequent discussion.

THE PHYSIOLOGY OF THE FRONTAL LOBES.

This operation more or less completely severs the frontal areas from the rest of the brain, and one therefore wonders what functions these perform that they can so readily be dispensed with. Purves-Stewart (1931) refers to them as the seat of the higher psychic functions, but is very vague as to what these might be exactly, and indeed, when one considers how little is known of them, it is not surprising to find one speaker at a recent American conference on neurosurgery recalling that they have been called "biological luxuries" and "parasitic growths." This speaker also stated that among 30 patients who had undergone prefrontal lobectomy, he found many who were indistinguishable from normal individuals by psychological tests, whilst others showed euphoria, facetiousness, lack of restraint and other symptoms of what has come to be regarded as the frontal lobe syndrome. One of these patients, from whom the left frontal lobe had been removed four years earlier, had an intelligence quotient of 152 on the Stanford-Binet scale. In this group of patients only one lobe had been removed and the diverse results may be compared with those of Bianchi (1922), who found no change in the intelligence of monkeys after the removal of one lobe, and the belief is generally held that both lobes must be damaged or interfered with before any changes can be detected. Our own experience with leucotomy does not, however, bear this out, as the following abstract from the case-record of a patient on whom unilateral leucotomy was performed illustrates:

CASE 1.—This patient, a male, aged 23, was admitted to the hospital in 1937 with a history of gradually progressive stupor and mutism. Despite two courses of convulsion therapy, in September, 1941, when the operation was performed, he was mute, untidy in appearance, faulty in habits and unemployable. On September 16 prefrontal leucotomy was performed on the right side, but owing to the occurrence of haemorrhage from a large cortical vein the left side was not interfered with. On the day after the operation he was able to reply when questioned that he was "feeling well." Twenty-four days later he was able to give correct answers to simple questions, such as "How many pennies in a shilling?" and from being a deteriorated patient who had to be washed and dressed by the nursing staff, he had become clean in his habits, tidy in appearance and capable of attending to his own toilet. Leucotomy was performed on the left side a month after the first operation. Soon after this he was transferred to the villas. He is now occupied at the farm as a labourer, and although mentally and physically retarded, his present condition is in marked contrast to his former state of degradation.

Moniz (1936) discusses the functions of the frontal areas at considerable length. He draws attention to the fact that the anatomical frontal lobe can be subdivided into three functionally different areas, a motor area, a pre-motor and a prefrontal area. The last is also known as the frontal association area, and sometimes owing to its large size as the frontal area. This area contains white fibres of three main types. These are, association fibres linking together areas of cerebrum on the same side, commissural fibres linking together the opposite hemispheres via the corpus callosum, and lastly projection fibres linking together areas of brain on the same side but at different levels. It is reasonable to suppose that all types of fibres are divided at the operation but, since it has been shown by Akelaitis (1941) that the corpus callosum can be divided in whole or in part without affecting personality or behaviour, it can be assumed that division of the commissural fibres plays no part in any of the results that follow the operation.

In his consideration of the physiology of the frontal areas, Moniz refers both to

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experimental work on animals, and to clinical studies purporting to show that they are concerned with the mechanisms of attention, emotion, sentiment, behaviour, and also with the synthesis of the multiple impressions arising in the environment, and with the grouping and orientating of the diverse elements of a given problem. From these and other considerations of frontal area physiology, he advanced the hypothesis that in the psychotic individual there are abnormal groupings of cells in the frontal area which have a fixed anatomical arrangement. By disturbing these abnormal cellular arrangements, Moniz argues that the patient is freed from his morbid mental activities by allowing new cellul-connective groupings to enter into action. It was this principle that guided him in undertaking the operation.

Much more impressive to our minds than Moniz' long discussion of the physiology of the frontal areas was the practical result arising out of the experimental work of Jacobson (1937) and his colleagues. These workers, using chimpanzees for experiments on learning, found that after a time the animals showed a tendency to develop experimental neuroses, which rendered them useless for experimental purposes. One such animal which had been friendly, co-operative, and eager to participate in the experiments was also emotionally unstable, and flew into temper tantrums whenever she made a mistake in performing the tests. Despite rest periods these tantrums returned whenever she returned to work and made an error in performance. Following bilateral prefrontal lobotomy the animal showed a profound change in her reactions to the tests, for now whenever she made an error she showed no emotional disturbance whatever, but quietly awaited the next trial, and although she made many more errors than formerly there was no reappearance of the neurosis. Fulton (1938) observes that the behaviour of the "prefrontal chimpanzee" is difficult to describe. The animal can be distinguished from the normal by its greater restlessness and a rather fatuous equanimity that one might find in a good-natured "drunk." Jacobson (1936) suggests that the behaviour of these animals is brought about by their dependence on immediate sensory experience, since they appear to have lost the faculty of recall.

Brickner (1936), summarizing the results of an exhaustive study of a patient after prefrontal lobectomy, states that while the patient's symptoms were many, none of them indicated any fundamental alteration of any mental processes, but that the main defect was one of syntheses placing a limit on the degree of abstract thought attainable.

Freeman and Watts (1941), who were first in America to adopt Moniz' technique, and who have made a fairly exhaustive study of its effects, are of the opinion that the prefrontal areas are concerned with the projection of the total individual into the future. This hypothesis assigns to the frontal areas functions of a very high order, for it regards them as being capable of foreseeing the goal, the means of attainment, and a final evaluation of the result. They state that while patients after leucotomy may be able to perform at a very high level in the spheres of art, law and mechanics, there is a disturbance in the relationship of the individual with himself, that permits certain characteristics to appear, which may or may not be offensive to others, but about which the patient is entirely unaware or unconcerned. In other words, the operation appears to cause some disturbance of the normal self-consciousness, or of the critical faculties.

From all these considerations of the physiology of the frontal areas it is clear that while a multiplicity of functions can be fairly ascribed to them, it is equally clear that they can be removed or detached from their connections without seriously disturbing intelligence, or behaviour, the main changes that result appearing to be in the conceptual, synthesizing, or reproducing processes. Perhaps the psychological tests that have so far been devised are not sufficiently delicate to detect the finer shades of deviation from the normal resulting from leucotomy, for it is very unlikely that the frontal association areas were developed simply as parasitic growths.

MONIZ' TECHNIQUE AND MODIFICATIONS.

When more is known of the more subtle effects of this operation some degree of standardization of technique may be reached. At present, however, several methods are in use. Moniz approaches the brain through trephine openings placed 3 cm. on either side of the sagittal suture on a vertical line 3 cm. in front of the tragus. When the dura has been opened the leucotome is inserted into the frontal pole. This instrument consists of a graduated hollow needle with a lateral opening at its distal end. This needle is fitted with a stylet which when fully inserted causes a

loop of steel wire to bulge through the lateral opening of the needle. Rotation of the leucotome causes the steel loop to cut a core of white matter of 1 cm. diameter. Several such cores are cut at different levels in the frontal pole.

Freeman and Watts (1938) at first adopted the Moniz technique, but later abandoned it for a method of their own. Approach to the brain is gained by laterally placed openings situated 5 cm. above the zygoma on a vertical line 3 cm. behind the orbital margin. Incision at this point down to bone usually reveals the coronal suture through which the trephine openings are made. When the dura has been exposed and opened, a hollow needle is inserted into the brain and directed

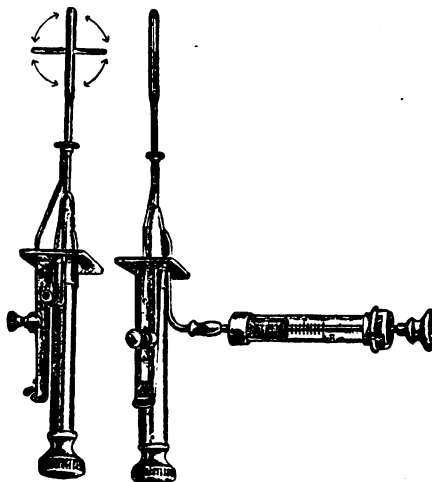


FIG. 1.—Warlingham Park leucotome No. I.

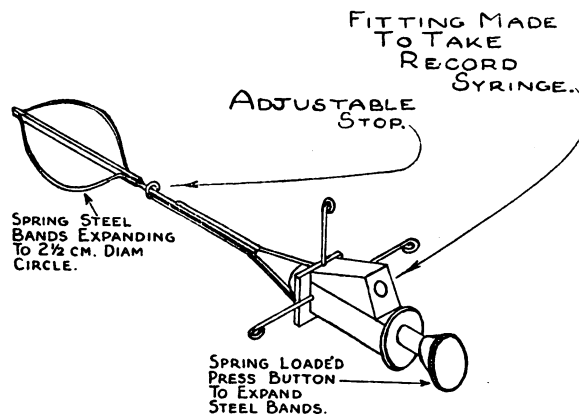


FIG. 2.—Warlingham Park leucotome No. II.

towards the opposite opening. If the ventricle is encountered the needle is re-directed in a more anterior direction. With this needle soundings are made for the falx cerebri, and the depth at which this is felt is measured. The leucotome, in this case a nasal septum elevator, is now gently inserted into the brain to a depth 1 cm. less than that at which the falx was located with the needle, and then gently moved upwards towards the vertex and downwards towards the orbital plate, thus almost completely severing the frontal pole from its connections. This procedure is more properly described as a lobotomy.

Lyerly (1938) has adopted the same approach to the brain as Moniz, but divides the fibres under direct vision. This is done by first making an incision through the cortex in an avascular area, and then inserting a lighted speculum into the brain.

The white substance is then slowly divided. This method has the advantage that any blood vessels that may be encountered can be pushed aside, or avoided; in this way the risks of cerebral haemorrhage are lessened. It is, however, open to the objection that to allow of the insertion of the speculum relatively large skull and dural openings must be made, thus increasing the risk of complications from adhesions at a later date.

We have adopted the same approach as Freeman (1939), but divide the white fibres by means of a leucotome which has a rotating blade $2\frac{1}{2}$ cm. long (Fig. 1). We decided on standardization of the blade at $2\frac{1}{2}$ cm. after examination of a great many brains in the transverse diameter between the trephine holes had revealed that in the average brain this was the maximum that could be consistently divided with safety. The trephine openings are $\frac{1}{2}$ in. in diameter and the design of the leucotome allows of very small dural openings being made.

The major catastrophe that may occur with this operation is haemorrhage from a deeply seated artery or vein. This has occurred once in our series of cases, and in an effort to obviate such occurrences in the future we have devised an instrument which it is hoped will push aside any blood-vessels encountered. This consists of twin spring bands that can be slowly expanded to form a circle with a diameter of $2\frac{1}{2}$ cm. (Fig. 2).

PREPARATION OF THE PATIENT.

Our patients undergo a three-day preparation for this operation. Deteriorated patients of doubtful habits are given enemata as required. It is probably better to shave the whole of the head, but as this is not always desirable in females, the head may be shaved as far as the ear, and the remaining hair fixed in position with collodion. The operation itself can be satisfactorily performed under local anaesthesia in co-operative patients. For this purpose we have used 1 per cent. novotox. Indeed, using local anaesthesia, some of the American workers claim that they have been able to carry on a conversation with the patient, and that coincident with the section of the fibres the patient experiences a sense of relief. We have been unable to confirm this. One of our patients, operated on under local anaesthesia, stated she felt not the slightest effect when first the one side and then the other was divided. One of the intravenous substances is probably the anaesthetic of choice in non-co-operative patients. Premedication by means of morphine and scopolamine greatly reduces the amount required, but also increases the risk of respiratory depression, and must therefore be administered with caution. Three times in our series of cases an electric convulsion was induced before the administration of the intravenous anaesthetic. This was done because the patients were so resistive that administration would otherwise have proved very difficult. In each case it proved a most satisfactory sedative, for not only was a small amount of anaesthetic required, but the carbon dioxide accumulated during the fit served excellently to regulate breathing throughout the operation. The suggestion for this came from Dr. R. M. MacFarlane.

During the operation the main difficulty that occasionally arises is bleeding from a cortical vein, or branch of the middle meningeal artery. As a rule this is readily controlled by applying a piece of the temporalis muscle to the bleeding point with firm pressure for a few minutes. On account of this difficulty we have considered the advisability of making larger trephine openings. These would allow more ready access to the bleeding, but would also increase the risk of adhesions between the meninges with, perhaps, complications at a later date. We do not make any attempt to suture the dura, the opening in which is very small, and so far this has not given rise to any trouble.

IMMEDIATE EFFECTS OF THE OPERATION.

The immediate post-operative course is usually uneventful. Headache is the most frequent complaint made by patients, but it appears to be slight and is readily relieved by codein. The temperature is usually elevated to $101-102^{\circ}$ F. for three or four days. There may also be incontinence of urine during this time. In a few cases circum-orbital ecchymoses have made their appearance in the first post-operative days. They appear to be due to gravitation of blood into the loose periorbital tissues, as a result of interference with the venous drainage at the operation sites. There is frequently some disorientation for a few days, but this has been most noticeable in deteriorated patients in whom clouding of consciousness

was present before operation. Two of our patients showed gross behaviour disorder about the third post-operative day when they became aggressive, destructive, obscene and abusive to the nursing staff. Both episodes occurred in agitated depressed males aged 47, were of short duration, and quite foreign to their usual conduct. Both patients have since returned to their usual occupations in civil life. The sutures may be removed from the 7th-10th day and the patient allowed out of bed. In this series of cases there have been no late complications, although Freeman (1939) reported the occurrence of a monoparesis in one case, and Strecker (1939) and his colleagues report the death of a patient in the 7th week after the operation. In this case, however, a right-sided hemiplegia occurred 48 hours after the operation. Occasionally there may be marked mental improvement almost from the time of recovery from the anaesthetic. The following abstract from one of our case-histories well illustrates this:

CASE 2.—The patient, a well-educated young woman with a history of schizophrenia of four years' duration, at the time of operation in May, 1941, was solitary, self-absorbed and heedless of her surroundings. She was poorly oriented in time, place and person, and her judgment and memory appeared to be impaired. She said her thoughts were interfered with, and she suffered from auditory hallucinations. At times her behaviour was impulsive and shameless. In this case there was marked improvement from the time of recovery from the anaesthetic. She conversed intelligently with the staff, and all evidence of hallucinations had gone. Her progress was uninterrupted, and she has now been at home for more than a year. Her relatives report that she is sociable in every respect, and we last heard from them when they wrote to inquire whether she should join one of the Services or go into munition work.

This patient had previously undergone treatment by insulin and induced convulsions, the latter by means of both cardiazol and electricity, and although she improved under these she always relapsed within a few days of their discontinuance.

LATE EFFECTS OF THE OPERATION.

Turning now to consider the psychic changes that follow the operation, it is not surprising to find that these are of a subtle nature, for we have already noted that at least one observer found it difficult to distinguish all cases of frontal lobectomy from normal individuals. Freeman and Watts (1937) reporting on six cases, operated on by the Moniz technique, recorded that while hesitating to use the word "cure," they were of the opinion that the "sting" had been taken out of the psychosis. Later, Hunt, reporting on 20 cases operated on by Freeman (1939), stated that the patients, after operation, were more co-operative, showed less distractibility, but that they also showed less initiative in starting the tests. She found no evidence of impaired intelligence, while accuracy was on the whole improved. To illustrate this point Freeman (1939) records that one patient was able to resume her mathematical studies after three years of disability. Another, after operation, conceived and patented an engineering device. This patient was later (Freeman and Watts, 1941) taken before the Harvey Cushing Society, where he exhibited a drawing of his machine, and showed clear judgment and understanding of its implications. When, however, he had finished expounding his device, he entered upon a discussion of a health system for rational living, and despite the laughter his sallies provoked among his audience, he seemed unaware of the position that he had placed himself in, and later boasted of the attention that he had received. This case serves to illustrate the lack of self-consciousness that Freeman and Watts believe to be a function of the normal intact frontal area. Amplifying their statement that the operation takes the "sting" out of the psychosis, these workers state that there is a marked attenuation of the psychotic ideas on the subject; that although the ideas persist of their own momentum, the patient is no longer interested in them, whether delusional, hallucinatory, or otherwise. Our own experience agrees with the view of Freeman and Watts in this respect. One of our patients recently operated on, and not included among the results of this series, still confesses to bizarre hallucinations of a visual kind, and also to delusions of persecution, but while before the operation he had been violent and aggressive, he is now well behaved and co-operative, it appearing as if his hallucinated and persecuted personality exists beside the normal personality without interfering, the one with the other.

Hutton (1942), who made personality studies on patients after leucotomy, has recorded her belief that as a result of some defect in reproductive memory, these patients live in a perpetual present that is dependent on associative memory. This dependence may be the cause of the apparent lack of initiative noted by Hunt.

Personally we have not resorted to any special behaviour or personality tests on our patients, but have been content for the most part with clinical observation for the interpretation of results. In those of our patients on whom it was possible to perform intelligence tests there was no noticeable impairment after the operation. One of our patients had no difficulty in solving problems in higher mathematics some weeks after operation. We have noticed, as have some of the American workers, a striking change in the facial appearance of two of our patients. The face appears to have lost all its natural mobility, and to have assumed a mask-like appearance very similar to that seen in Parkinson's disease, and like the victims of that condition they also feel emotion, but appear to have lost the faculty for expressing it.

With regard to the anatomical basis of these changes nothing is known with any degree of certainty. It is fairly certain that the frontal areas have projection systems to the thalamus and to the hypothalamus, but the precise details of these connections have not yet been worked out. Severance of these may be the cause of the apathy and emotional blunting seen in some cases after the operation, and also of the mask-like expression, for several authorities believe that the Parkinsonian mask is due to a lesion of the bundle of Vicq d'Azyr, which arises from the mammillary portion of the hypothalamus. It is also possible that it might be caused by slight haemorrhage into the bundle for with the passage of time the mask becomes less noticeable. This can be correlated with recovery of function in the bundle as the haemorrhage is absorbed. The more subtle changes in the psychic spheres are no doubt due to severance of the frontal pole with its connections. Freeman (1941) has observed degeneration of the nucleus medialis dorsalis of the thalamus as a result of the operation, and it is possible that a slow degeneration of this structure is responsible for the slow and progressive improvement sometimes seen after the operation. The following illustrates this point:

CASE 3.—The patient, a male, aged 26, was first admitted to the hospital on a voluntary basis in 1937. He was auditorily hallucinated and confused with ideas of reference at this time. He departed after a few weeks, but was readmitted in 1940, having been discharged from the Army as unfit for further service. At this time he was worried, restless and excited. After a course of insulin treatment he made a partial adjustment and departed in December, 1940. He was again readmitted in August, 1941, this time as a temporary patient. His condition was one of stupor with mutism, and heedlessness of his appearance, and his surroundings. After the operation he recovered his volition and signed a voluntary application form. Since then his progress has been gradual, and he is now in the villas, where he is friendly, co-operative, and mixes freely with his fellow patients. His conversation is intelligent, and he looks forward to his return to home and his former occupation.

In this case, although the initial improvement was slight, his gradual and steady progress leaves one with the hope that he may yet make a complete adjustment.

INDICATIONS AND RESULTS OF THE OPERATION.

Moniz reported that tension, apprehension, anxiety and agitation disappeared as a result of leucotomy, and Freeman and Watts (1938) employ these symptoms as indications for the operation. They have confined their attention almost entirely to cases of melancholia, and report (Freeman, 1941) that 72 of 80 patients operated on were able to return to their homes. In view of this very high figure we feel that many of these patients would have recovered on some less radical treatment. Freeman, however, does not consider the hazards of leucotomy as great as those of cardiazol treatment. We cannot concur with him in this. Strecker (1942) and his colleagues state that the main effect of the operation is to "relieve apprehension," and observe that if the "mental condition is produced, or aggravated by fear, then this factor can be relieved by prefrontal lobotomy." They record that 12 melancholics and 2 schizophrenics of a total of 22 patients operated on made a complete adjustment. Cohen (1942) and his co-workers report clinical improvement in 6 cases of what they describe as "chronic overactivity." In one of these, the improvement was at the cost of almost complete apathy.

A study of the literature makes it clear that good results are to be had from this operation in cases of melancholia, and here we would state unreservedly our opinion that it should only be resorted to in such cases after convulsion therapy has been given a full trial, and that it is our practice only to operate in every case after other methods of treatment have been given a full trial and have failed. With this in mind, it is our opinion that the best results are to be obtained from among those cases who show by their response to other treatments that they are potentially

capable of recovering although not of maintaining normality by those means. To illustrate this we describe briefly one such case from our records :

CASE 4.—The patient, a male, aged 47, was admitted to the hospital as a voluntary patient in July, 1940. On admission he presented all the appearances of profound depression with agitation. He had ideas of guilt, stating that he had been unfaithful to his wife and country. He was poorly oriented in time, showed marked psychomotor retardation, and lack of interest in himself or surroundings. Electric convulsion therapy was started soon after admission, but had to be discontinued for a time as he developed broncho-pneumonia and had a long convalescence. When treatment was resumed he made an excellent adjustment, but relapsed soon after it was stopped. Repetition of treatment was followed by the same result whenever it was discontinued. At the time of operation in December, 1941, he was very agitated, restless, anxious, worried and depressed. In this case a complete adjustment followed the operation and he left the hospital in January, 1942. Since then he has been in continuous employment.

We have no extravagant claims to make for this operation. Of the 20 cases under consideration in this series 6 were suffering from melancholia, 12 from schizophrenia, and 2 from non-systematized delusional insanity. Of these, 3 of the melancholics and 2 of the schizophrenics have made a complete adjustment and have resumed their former activities. Since all had previously undergone intensive treatment of one kind or another, these results must be regarded as encouraging. We certainly did not expect more, for the schizophrenics were for the most part institutionalized and deteriorated and had made no response to shock therapy.

MORTALITY.

With regard to the mortality that may attend this operation, it varies from none in 39 cases operated on by Lyerly (1941) to 20 per cent. in 10 cases operated on by Tarumianz (1941). In this series of 20 cases the mortality was 10 per cent. The first death was that of a melancholic male subject, aged 53, and was caused by bronchopneumonia following secondary cerebral haemorrhage. The second was that of a schizophrenic woman, aged 32, whose illness was of 12 years' duration. In this case, death resulted from cerebral softening following ligation of the left internal carotid artery for deep-seated cerebral haemorrhage. The bleeding must have occurred at the time of operation, but this was not apparent when the wounds were sutured. Post-mortem revealed that the frontal lobes were abnormally short, and the leucotome incision was situated close to the basal ganglia. A branch of the anterior cerebral artery had been severed.

In conclusion, we repeat that this operation appears to offer the hope of a return to a more or less normal life in certain selected cases. We would not speak of cure where brain tissue has been interfered with, for we cannot believe that Nature has endowed us with too much brain, and left it to the surgeon to correct this error.

We would like to express our indebtedness to Dr. T. P. Rees, Medical Superintendent of Warrlingham Park Hospital, for his active interest in this work, and for his ever-ready help and support in carrying it out. To Mr. J. W. Pearson, Assistant Clerk of Works at the Hospital, we also owe thanks for the clever way in which he made the original leucotome, and for many helpful suggestions.

REFERENCES.

- AKELAITIS, A. J. E. (1941), *Amer. J. Psychiat.*, **98**, 409.
 BIANCHI, L. (1922), *The Mechanism of the Brain and the Function of the Frontal Lobes*. Edinburgh.
 BRICKNER, R. M. (1936), *The Intellectual Functions of the Frontal Lobes*. New York.
 COHEN, L. H., NOVICK, R. G., and ETTLESTON, A. (1942), *Psychosom. Med.*, **4**, 96.
 FREEMAN, W. (1939), *Med. Ann. Dist. Columbia*, **8**, 345.
Idem (1941), *J.A.M.A.*, **117**, 517.
Idem and WATTS, J. W. (1938), *J. Nerv. Ment. Dis.*, **88**, 589.
Idem (1941), *Psychosom. Med.*, **3**, 111.
 FULTON, J. F. (1938), *Physiology of the Nervous System*. London.
 HUTTON, E. L. (1942), *J. Ment. Sci.*, **88**, 19.
 JACOBSON, C. F. (1936), quoted by Fulton, 1938.
Idem, WOLFE, J. B., and JACKSON, T. A. (1935), *J. Nerv. Ment. Dis.*, **82**, 1.
 LYERLY, J. G. (1938), *J. Fla. med. Ass.*, **25**, 203.
Idem (1941), *J.A.M.A.*, **117**, 517.
 MONIZ, E. (1936), *Tentatives opératoires dans le traitement de certaines psychoses*. Paris.
 PURVES-STEWART, Sir J. (1931), *The Diagnosis of Nervous Diseases*. London.
 STRECKER, E. A., PALMER, H. D., and GRANT, F. C. (1942), *Amer. J. Psychiat.*, **98**, 524.
 TARUMIANZ (1941), *J.A.M.A.*, **117**, 517.