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Chemopallidectomy and Chemothalamectomy for Parkinsonism and Dystonia[1]

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IN this paper I shall review our investigation into the effects of 850 globus pallidus and thalamic lesions in humans afflicted with parkinsonism and diverse involuntary movement disorders.

This series of cases commenced in 1952 with our investigation of the procedure of anterior choroidal artery occlusion for parkinsonism and was actually initiated by observation of the effects of a surgical accident. During the course of a craniotomy and pedunculotomy for uncontrollable tremor, I divided and was obliged to sacrifice the left anterior choroidal artery. Because of this occurrence, the operation was terminated in order to observe the effects of the occlusion of this vessel. The most notable post-operative finding was the virtual disappearance of tremor and rigidity of the opposite extremities without any loss of motor or sensory function of the arm or leg.

On the basis of this observation and earlier anatomical studies [1, 2] of the anterior choroidal artery a working hypothesis was developed to the effect that occlusion of the anterior choroidal artery had caused an infarction of several anatomical structures which had evolved as a physiological unit [3, 4]. It was further suggested that this unit consisted essentially of the mesial portion of the globus pallidus and the ventrolateral region of the thalamus as well as the connexions between these structures. Considerable evidence exists to support this hypothesis [5–15]. On that basis we proceeded to carry out an investigation of the effects of anterior choroidal artery occlusion in patients with parkinsonism (Fig. 1).

Between 1952 and 1955 selective anterior choroidal artery occlusion was performed in 55 patients. Follow-up examination of these 55 cases of anterior choroidal artery occlusion for a period ranging from two to six years following surgery demonstrates that in the successful cases this operation provided the most complete and lasting relief of far-advanced incapacitating rigidity, tremor and deformity that has been reported anywhere in the literature up until that time. Many of the patients who were completely relieved of tremor, rigidity and deformity from the side of the body contralateral to surgery have remained not only relieved of these symptoms for the intervening period up to the present time but have also become ambulatory and independent in their daily life.

Two cases with more than five-year follow-up studies are cited to demonstrate the complete and lasting nature of the effects of anterior choroidal artery occlusion in selected instances. These two cases are purposefully selected from among those originally described in my earliest reports.

Case I.—W. D., a 41-year-old white male, referred by Dr. Walter Friedman for occlusion of the anterior choroidal artery. This patient contracted epidemic encephalitis at the age of 15 and was in coma for six weeks. Parkinsonism developed within one year and by age 17 he was completely incapacitated by bilateral tremor and rigidity as well as the other manifestations of parkinsonism. At the time of operation he demonstrated masked facies, marked diminution of the spoken voice, a violent bilateral resting tremor, severe cog-wheel rigidity of all four extremities and inability to turn in bed, rise from a chair or stand or walk alone unaided. Of particular note at that time was the presence of a marked, apparently fixed deformity of the left wrist and hand of a dystonic nature. This had been present in this fixed form for eighteen years prior to operation.

On September 2, 1953, the right anterior choroidal artery was occluded by silver clips. This failed to obliterate the vessel completely. Therefore, re-operation was performed and the artery was coagulated so as to interrupt its blood supply completely.

From the time of surgery this patient has had complete relief of tremor and rigidity of the left extremities. However, even more remarkable was the reversal and disappearance of the dystonic deformity of the left

[1]From St. Barnabas Hospital and Division of Neuromuscular Diseases New York University Post-Graduate School of Medicine. Supported by Sister Elizabeth Kenny Foundation and Allen P. and Josephine B. Green Foundation.

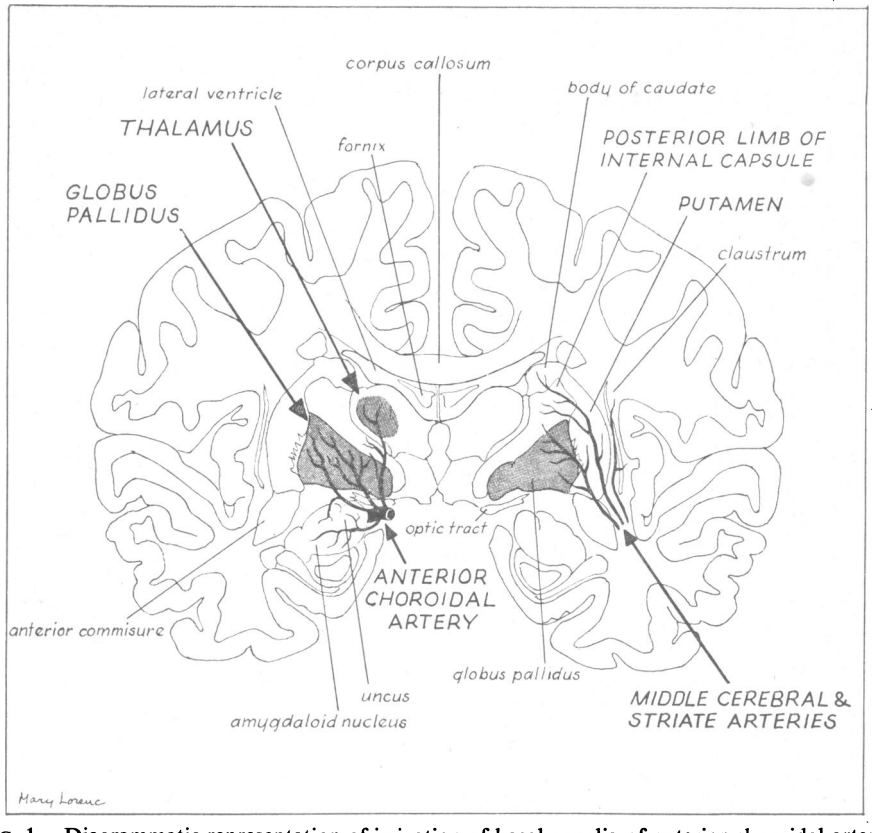

FIG. 1.—Diagrammatic representation of irrigation of basal ganglia of anterior choroidal artery.

hand. The patient became ambulatory and independent in all activities of daily living as a result of this operation. Relief of tremor, rigidity and deformity of the left extremities have persisted up to the present time.

Case II.—L. D., a 48-year-old white man, presented with marked tremor and rigidity present only in the left extremities of seven years' duration. Although still ambulatory and independent in his daily life, he was unable to work.

Anterior choroidal artery occlusion was performed in June 1953. Since that time the patient has had complete relief of tremor and rigidity of the left extremities with normal function of these extremities.

Complete relief of tremor and rigidity in this case is documented by a report of Dr. Christian Keedy who wrote in December 1956: "This patient has had a very excellent result from ligation of the right anterior choroidal artery. There is no evidence of any tremor or rigidity of the left extremities." An additional follow-up report from Dr. I. Perlmutter in October 1958 stated that the condition of the left side remains perfect. However, tremor and rigidity had slowly developed on the non-operated side.

These two cases demonstrate complete relief of intense tremor, rigidity, deformity and incapacity of parkinsonism achieved by occlusion of the anterior choroidal artery. It is stressed that the relief of contralateral tremor and rigidity obtained in these cases was complete, and that this fact is attested by disinterested examination of these patients by various objective neurological examiners. Moreover, the persistence of relief of tremor, rigidity and deformity in these cases for more than five years is noteworthy.

Conclusions which we reached as a result of the follow-up studies in these 55 cases of anterior choroidal artery occlusion are as follows: (1) The effectiveness of anterior choroidal artery occlusion, in those cases in which it was successful, was due to infarction of more than a single small anatomical structure and probably involved a physiological unit of 2 or more intercerebral structures; principally, the mesial part of the globus pallidus and the ventrolateral region of the thalamus. (2) Complete relief of tremor, rigidity, incapacity and deformity is possible by neurosurgical means without inflicting any neurological deficit upon the patient. (3) Objective evidence of five-year relief of the parkinsonian symptoms of tremor, rigidity and deformity has been achieved by anterior choroidal artery occlusion. (4) The dystonic deformities seen in some parkinsonians are not actually fixed

deformities but represent forced postures which are reversible even after many years' standing. (5) The so-called syndrome of the anterior choroidal artery is not invariable and in many cases this vessel may be occluded completely without producing any observable neurological deficit. However, anatomical variations of the vessel and particularly the lack of collateral blood supply to the posterior limb of the internal capsule in the aged would make routine employment of anterior choroidal artery occlusion unwise. (6) The ability of this procedure to relieve tremor and rigidity without inflicting any neurological deficit warranted further steps to develop neurosurgical techniques which might be more universally applicable to a broader spectrum of the parkinsonian population. This led us to the development of chemopallidectomy and thalamectomy which was commenced on our service in 1953 [11, 12, 13].

The techniques of chemopallidectomy and chemothalamectomy [14, 15] combine roentgeno-anatomical methods of lesion placement deep in the brain, with clinical physiological confirmation of the results in a conscious, co-operative patient. As presently performed the technique consists of the following basic steps: (1) Pneumo-encephalography with 30 c.c. of air in order to visualize the anterior portion of the ventricular system, especially the foramen of Monro. (2) Introduction of a polyethylene brain cannula through a small skull trephine. This cannula is placed under roentgenographic control into the region of the globus pallidus or ventrolateral nucleus of the thalamus. (3) Distension of a small balloon at the tip of the cannula in order to provide a clinical physiological test of the effects of a lesion in this region (*see* Fig. 2). In addition to providing such a physiological test, the balloon produces a cavity in the desired region of the brain for subsequent injection of absolute alcohol and Pantopaque in order to produce a circumscribed and localized permanent lesion. (4) The cannula remains indwelling in the brain for several days following surgery so that the lesion may be enlarged if necessary in order to produce lasting relief of the contralateral hyperkinetic symptoms. The anatomical landmarks used in the production of these lesions are summarized in Figs. 3 and 4.

The production of a large lesion in the globus pallidus by the technique of chemopallidectomy proved to be a relatively simple procedure with a small morbidity and mortality rate and favourable results were obtained in 70% of cases. However, although rigidity could be relieved in 80% of such cases, tremor was relieved only in 60%. In such cases the tremor would respond favourably when we placed a second lesion on a plane approximately 10 mm. behind the original globus pallidus lesion or approximately 15 mm. behind the posterior margin of the foramen of Monro. Anatomical studies permitted us to identify the second area as a zone which included the pallidothalamic connexions with the anteroventral portion of the thalamus. In some instances the second lesion was localized within the ventrolateral region of the thalamus itself.

In subsequent experience with several hundred cases this latter lesion in the region of the ventrolateral nucleus of the thalamus proved to be so successful for cases that had been incompletely relieved of tremor by the pallidal lesion alone, that it gradually became our practice to produce a thalamic lesion primarily as the lesion of choice. We have learned that when this thalamic lesion is properly placed, virtually complete relief of

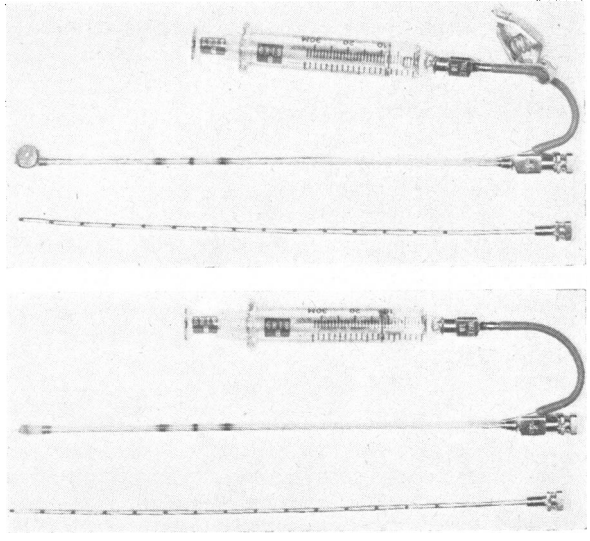

FIG. 2.—Special chemopallidectomy cannula, before and after inflation of balloon.

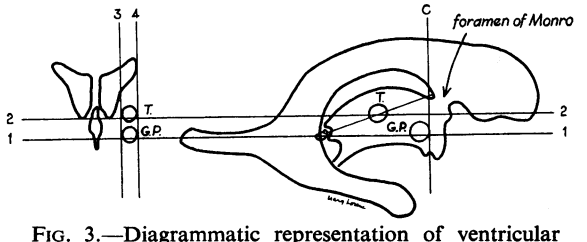

FIG. 3.—Diagrammatic representation of ventricular landmarks used for chemopallidectomy and chemothalamectomy.

tremor is obtained in 90% of cases of properly selected patients. Moreover, this relief is complete and is lasting.

There is no question but that a lesion in the region of the ventrolateral nucleus of the thalamus has a more certain, complete and absolute effect on contralateral resting tremor than does the pallidal lesion alone. It is now our lesion of choice for relief of tremor and rigidity.

From a surgical standpoint one must perform the technique meticulously, with accuracy in placement of the cannula and with persistence in production of an adequate sized, properly developed basal ganglia lesion.

From a clinical standpoint excellent relief of tremor and rigidity can be produced in more than 80% of properly selected cases. However, proper selection of cases is as important as correct surgical technique. The principal contra-indications to these operations at the present time are as follows:

(1) Organic mental deterioration.

(2) Psychosis.

(3) Pseudobulbar palsy.

(4) A preponderance of vegetative and akinetic symptoms as opposed to a preponderance of tremor or rigidity.

(5) Physiological old age. Although many cases have been operated upon successfully in the seventh and even in the eighth decade of life, one must select patients in this age group who are physiologically well preserved, do not show organic mental deterioration, and who have much more involvement of tremor and rigidity on one side of the body than on the other.

(6) General medical contra-indications such as severe hypertension.

Complications

The incidence of mortality in these 850 operations of chemopallidectomy and thalamectomy has been 2·4%. There has only been one post-operative death in the last 200 operations for parkinsonism on our service.

The incidence of lasting hemiplegia or hemiparesis has been 3%. Transient motor or sensory signs, disappearing during the first three post-operative weeks, have been observed in 6% of cases.

Some degree of somnolence, mental confusion or obtunding has been observed during the first post-operative week in 8% of cases; it may last several weeks in aged patients. However, this has invariably been transient, and in almost each instance has been an exaggeration of abnormalities noted during the pre-operative psychological work-up.

Speech disturbances, varying from dysphonia, to slurring of speech to mutism or aphasia have been observed in 7% of cases. They have been more common following operations on the dominant hemisphere but not limited to the dominant hemisphere operations. These disturbances have tended to clear within two weeks in practically every instance.

Excessive drowsiness, hyperpyrexia, hypokinesia, dysphagia, aspiration pneumonitis, and urinary retention are seen post-operatively in the far advanced post-encephalitic cases, but have responded to meticulous nursing measures.

Transient hyperkinetic states varying from slight fleeting choreic movements of one hand to hemiballismus have been seen 18 times. In three cases these were very severe but all disappeared spontaneously. One case, however, lasted four months.

Except for the isolated surgical complications such as deep hæmorrhage or infarction which account for our mortality rate of 2·4% and hemiplegia or hemiparesis of 3%, these transient post-operative problems seem to be directly related to the pre-operative condition of the patient, and can almost be predicted by the pre-operative evaluation. Although they are trying and often difficult to deal with in some instances, they do not affect the long range favourable effect of the operation on the patient or his symptoms.

In my experience the incidence of post-operative morbidity and complications is directly proportional to the condition of the patient pre-operatively. A patient who has unilateral parkinsonism, without other stigmata of far advanced disease, may be subjected to one of these procedures and have a reasonable expectation of having an excellent result and being discharged ambulatory from the hospital within ten days. A patient who is physiologically aged or who has far advanced bilateral disease, who has been bedridden or incapacitated for a prolonged period, and who has difficulties with salivation, speech, temperature control, swallowing, and other vital mechanisms, will often encounter transient difficulties which prolong hospitalization. It is in this latter group that one may expect to see transient confusion, hypopyrexia, bladder difficulties, and other post-operative abnormalities. These are of significance during the post-operative course but do not affect the long range favourable results of this type of basal ganglia surgery upon tremor and rigidity.

If these patients are on a post-operative ward which can supply meticulous, constant, interested nursing care and are under the control of medical attendants who have informed themselves of the protean nature of this syndrome and the various pitfalls which may be encountered post-operatively,

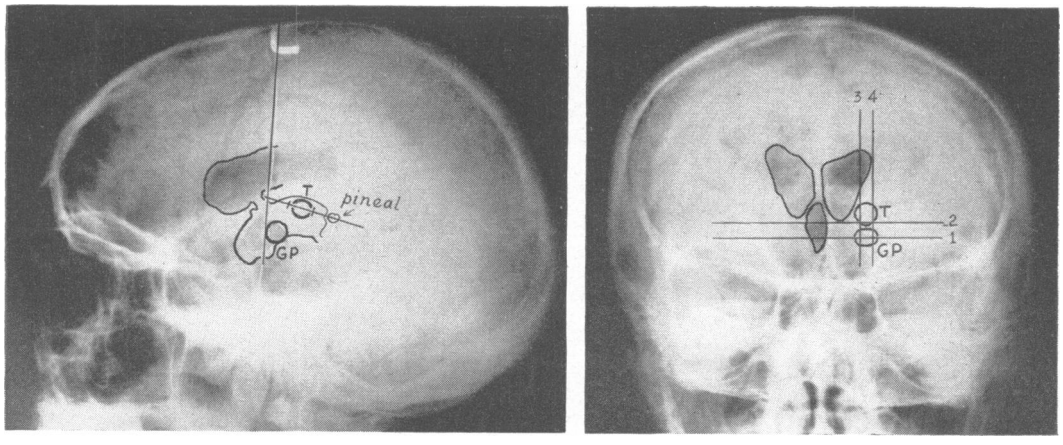

FIG. 4.

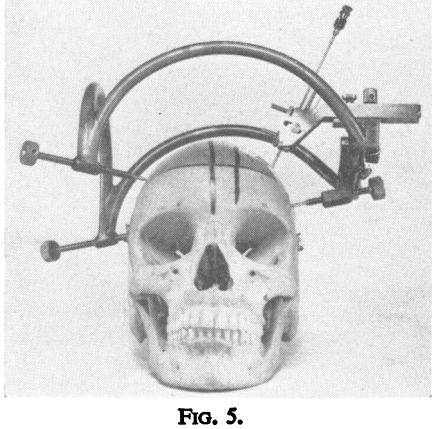

FIG. 5.

FIG. 4.—Landmarks of pallidal and thalamic lesions superimposed upon pneumoencephalogram.

FIG. 5.—Basal ganglia guide and holder employed in chemopallidectomy and thalamectomy.

FIG. 6.—Roentgenogram demonstrating balloon inflated within the region of mesial globus pallidus. Inflation of the balloon when correctly localized is followed by cessation of contralateral tremor and rigidity. This provides a physiological test essential to the technique of chemopallidectomy and thalamectomy.

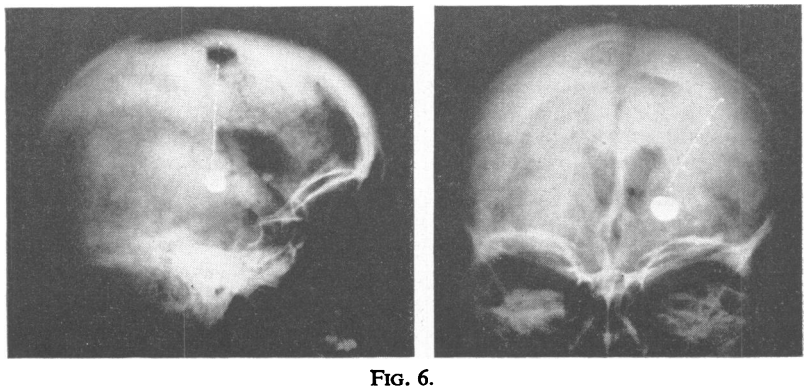

FIG. 6.

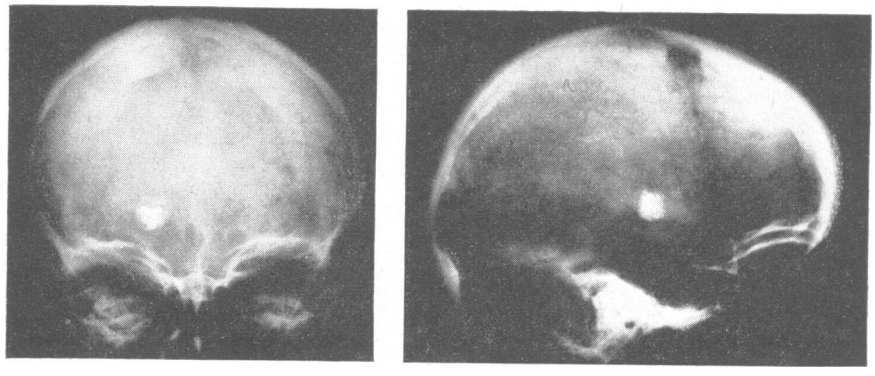

FIG. 7A.—Final alcohol-Pantopaque lesion produced by injection of this mixture into cavity formed by balloon distension demonstrated in Fig. 6.

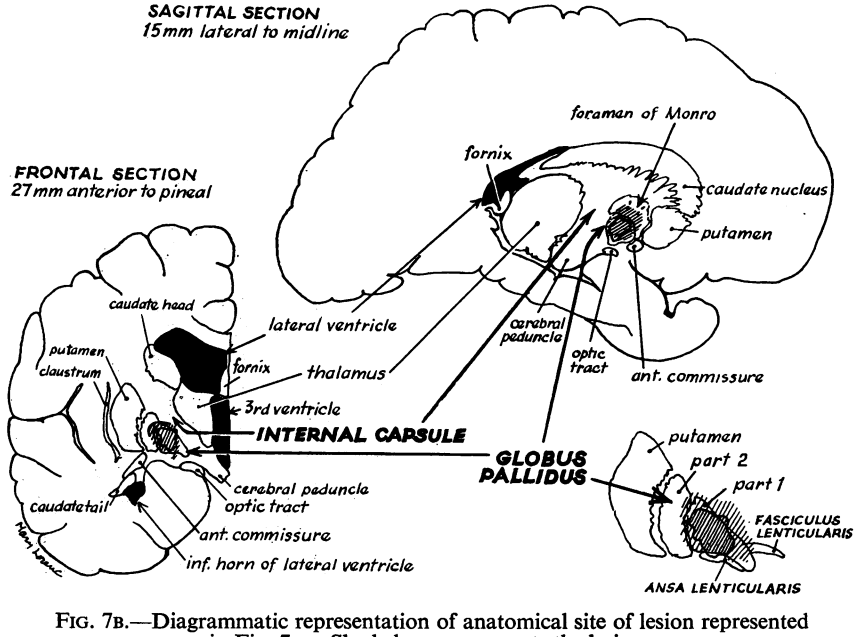

FIG. 7B.—Diagrammatic representation of anatomical site of lesion represented in Fig. 7A. Shaded area represents the lesion.

practically all of these trying post-operative complications can be either obviated or relieved. In surveying the statistics of this large series, in retrospect one is gratified at the fact that the trying and difficult post-operative manifestations referred to above have disappeared and that the overall rate of complications is minute compared to the lasting benefit which has been achieved in this group of chronically ill patients.

THE HYPER-PARKINSONISM CRISIS

From time to time during the post-operative period a patient will demonstrate a marked accentuation of all of the well-known features of the parkinsonian symptom complex. For example, we have seen on many occasions, during the first post-operative week, a patient, who has been successfully relieved of tremor and rigidity of the extremities contralateral to operation, manifest an exaggeration of all of the other symptoms of parkinsonism which he demonstrated prior to surgery. Such a patient may have increased difficulty in speaking, dysphagia, marked perspiration, hyperpyrexia, difficulty in voiding, increased tremor and rigidity of the non-operated extremities, hypersalivation with danger of

aspiration of saliva, and a marked increase in general helplessness.

This post-operative picture lasts about two weeks and clears gradually. However, during this crisis of hyper-parkinsonism, meticulous and constant nursing attention is necessary if one is to avoid aspiration pneumonia, decubital ulcers, urinary infection, and other complications that may ensue as secondary phenomena.

It seems at first glance paradoxical that one might encounter a transient marked exaggeration of so many parkinsonian symptoms in a patient who has actually been operated successfully for relief of tremor and rigidity of the extremities of one side of the body. However, one may see this same example of a crisis of hyper-parkinsonism in many non-operated parkinsonian patients who are subjected to a violent physical or emotional stress. For example, the elderly advanced bilateral parkinsonian who may fall and fracture his femur, often becomes totally helpless during the post-traumatic period as a result of exaggeration of all parkinsonian symptoms. Similarly, many patients with advanced parkinsonism do not become bedridden and helpless until subjected to the psychological stress of the death of a member of their family or some similar emotional duress.

This post-operative hyper-parkinsonism crisis seems to be related to the mental and physical stress of undergoing surgery plus the direct effect upon the brain. It is most commonly seen in post-encephalitic parkinsonians who present advanced symptomatology including symptoms of the vegetative variety as well as tremor and rigidity. One may see it as well in the aged parkinsonian. In the latter group, if this hyper-parkinsonism crisis is manifested post-operatively it is usually accompanied by transient mental confusion and disorientation.

We have commented in earlier publications on the importance of evaluating the effect of stress on each individual case of parkinsonism. It is our policy to insist on a period of hospital observation in any case of advanced parkinsonism in an aged patient in whom we suspect that stress might possibly precipitate exaggeration of the parkinsonian symptom complex. By so doing, we have found many cases of aged parkinsonians who, under the stress of strange hospital surroundings, manifest nocturnal hallucinations, confusion and disorientation. Such a patient, in our opinion, should no longer be considered as a candidate for surgery.

Similarly, we have found many patients, particularly in the far advanced post-encephalitic group, who, under the duress of frequent examinations and testing in a hospital environment become hyperpyretic, incontinent or retentive of urine, dysphagic, and generally helpless. Such a patient must be evaluated very stringently before making a final decision for or against surgery. If surgery is decided upon, one should anticipate the possibility of encountering this hyper-parkinsonism crisis as a transient complication during the first two post-operative weeks.

Many of the transient complications referred to above are actually seen to be features of this hyper-parkinsonism crisis which is a peculiar reaction of the parkinsonian to stress. In its extreme form it may change a previously compensated far-advanced bilateral parkinsonian into a hyperpyretic, dysphagic, speechless, motionless mass of protoplasm of a most frightening variety. Although such symptoms are reversible and will respond to good care, in many cases it is best to avoid these by a searching clinical inquiry prior to selecting any particular patient as a candidate for surgery.

These symptoms of hyper-parkinsonism are not precipitated following surgery on a case of unilateral parkinsonism or in those cases of parkinsonism who are not yet far advanced and do not show any evidence of mental deterioration. Therefore, as our experience has increased and we have been able to select patients more wisely than we did during the early years of this investigation, there are fewer patients on our wards manifesting this post-operative storm, and thus the incidence of transient complications on our post-operative wards has been commensurately decreased. At times it is just and wise to accept the calculated risk of producing this transient post-operative crisis because of the knowledge that it can be managed and that the patient will ultimately be benefited by the surgical treatment. However, by being aware that this hyper-parkinsonism crisis is practically a predictable sequence in certain types of cases the surgeon can either entirely avoid producing this post-operative storm or else knowledgeably risk its production because of the possible gains of surgery in a particular case.

Neurological Observations

A five-year study of all cases from a clinical psychological standpoint before and at various follow-up periods after operation has been carried out by our clinical psychologists. They have found that in no case has a lesion which has been circumscribed in the mesial globus pallidus or the ventrolateral region of the thalamus produced any lasting intellectual or emotional deficit.

In many instances large lesions have been placed on the same side of the brain in both the

globus pallidus and the ventrolateral portion of the thalamus. In such cases there has been no observable motor, sensory, or intellectual deficit. Thus, one may conclude that in selected cases relatively large portions of these structures in the basal ganglia may be sacrificed without interfering with voluntary motor movements or intelligence. The quantitative limits within which such procedures can be performed on both sides of the brain has not yet been established.

The placement of lesions in the thalamus is potentially more hazardous, because of the surrounding structures, than the placement of lesions within the pallidal complex. If one places the lesion inferior to the ventrolateral nucleus of the thalamus, the corpus luysii and its environs are penetrated and the possibility of production of hemiballismus is present. Immediately lateral to the properly placed thalamic lesion is the internal capsule, involvement of which will produce hemiparesis. Theoretically, placement of a lesion posterior to the ventrolateral nucleus of the thalamus should result in sensory loss because of involvement of the sensory area of the thalamus. However, in only two instances have we observed any gross sensory defect post-operatively in this group of patients. Moreover, in not a single instance have we observed the so-called thalamic pain syndrome following placement of thalamic lesions.

It is our impression that interruption of cerebello-thalamic as well as other afferent systems to the thalamus, including pallido-thalamic and rubro-thalamic connexions, contributes to the relief of tremor and rigidity following placement of a lesion in this region.

Documentation

In 1955 Doctors Robert S. Schwab and Albert England of the Massachusetts General Hospital in Boston instituted an objective evaluation of our cases of anterior choroidal artery and chemopallidectomy. Later, a mutual study was initiated in which long-term cases from their clinic in Boston were operated upon by us and were re-evaluated post-operatively by Schwab and England. Their study of our cases corroborated the fact that lasting complete relief of tremor, rigidity and deformity is achieved by these techniques without necessarily inflicting any neurological or emotional deficit. Further, during the week of May 12, 1958, we brought back to New York University 100 follow-up patients who had gone from one to more than five years following operation for parkinsonism on our service. These patients were made available with their complete objective investigative records and cinematographic records for disinterested follow-up evaluation.

One other clinical reference may be indicated at this time. In view of the possibilities of surgical therapy in certain varieties of parkinsonism, a re-classification of this syndrome might be considered. The therapeutic possibilities which currently exist in many cases of the shaking palsy require intensive clinical study and selection by the clinician if the proper therapy is to be utilized. A re-study and re-classification of the various types of parkinsonism and the subdivisions of this syndrome would be useful both therapeutically and in an enhancement of our ultimate physiological understanding of the disease process. The following are some representative cases:

Case III.—Dr. N. A., a 63-year-old chemistry professor, was referred by Dr. Albert England of Boston. This patient had a four-year history of tremor of the left side of the mouth, left upper extremity and left lower extremity. He dragged the left leg when walking. He demonstrated a violent tremor with marked rigidity of the left extremities but only a trace of tremor in the right upper extremity. On June 14, 1957, chemothalamectomy was performed. The roentgenographic appearance of the Pantopaque-stained, chemically induced thalamic lesion is seen in Fig. 8A. An approximate anatomical interpretation of this lesion based upon our own anatomical researches as well as reference to the atlases of others is provided in Fig. 8B. This demonstrates what we consider to be the lesion of choice for treatment of tremor and rigidity of parkinsonism. In this regard it is interesting to note the follow-up report of Dr. England, the referring neurologist, who also examined the patient at various intervals post-operatively. Dr. England reported: "This is a grade A perfect result. I think this complete functional result without any trace of either tremor, rigidity or loss of co-ordinated movements is very important. It has apparently gone beyond controlling tremor or rigidity and approached the so-called perfect result."

This case is cited as an example of complete relief of tremor and rigidity by a chemically induced thalamic lesion.

Case IV.—Reverend N. T., age 51, noted onset of tremor in the right upper extremity four years prior to admission to our service. Tremor and rigidity of the right extremities had progressed rapidly during these four years and became violent under emotional duress. These symptoms made it impossible for him to continue his calling as a minister.

On October 31, 1957, chemopallidectomy was performed. At this time a lesion was made at the level of the posterior border of the foramen of Monro. However, slight tremor of the right upper extremity persisted, particularly during emotional duress.

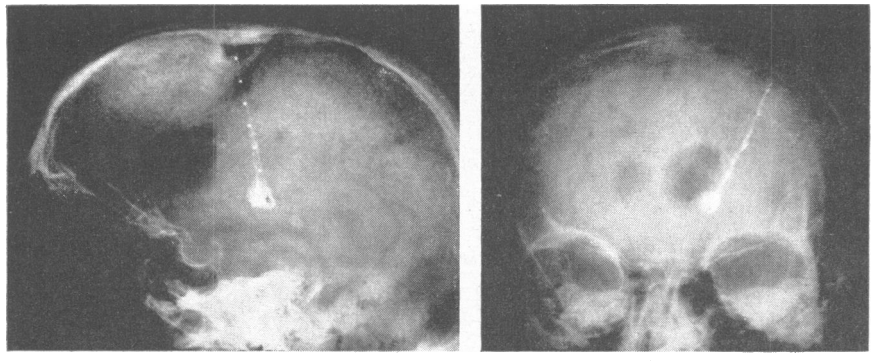

FIG. 8A.—Roentgenographic appearance of thalamic lesion produced in Case II. In our experience this is the lesion of choice for complete alleviation of tremor and rigidity.

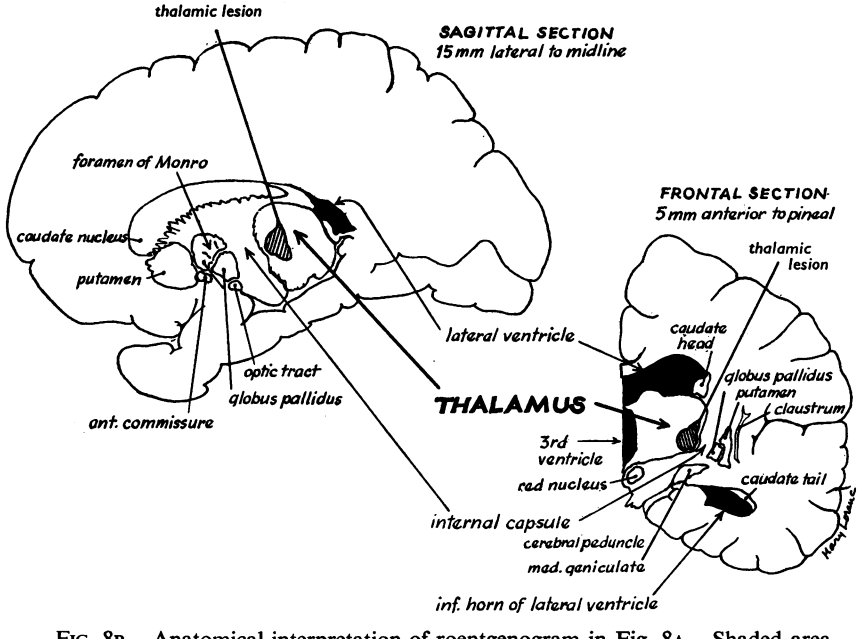

FIG. 8B.—Anatomical interpretation of roentgenogram in Fig. 8A. Shaded area represents the lesion.

Therefore, on November 15, 1957, a second lesion was placed in the region of the ventrolateral nucleus of the left thalamus. From that time to this there has been no further tremor or rigidity of the right extremities. The patient is now once again engaged in his profession as a minister and is in charge of the parish which he had previously been obliged to relinquish. He has not taken any anti-parkinson medication since operation. The patient, his family, and the referring neurologist all state that he appears completely normal.

The lesions of the globus pallidus and thalamus are shown in Fig. 9A. Our approximate anatomical interpretation of this roentgenogram is demonstrated in Fig. 9B.

This case is cited to demonstrate a perfect result regarding relief of tremor and rigidity induced by a combined pallidal and thalamic lesion. This combined lesion did not result in any motor, sensory, intellectual or psychological deficit. As a result of these lesions this patient who was disabled by violent unilateral tremor and rigidity now appears as a normal individual. The operation was performed in the dominant hemisphere without any adverse effect upon speech. This patient now regularly addresses his congregation each Sunday without difficulty.

One should note in this case the value of persistence in production of basal ganglia lesions.

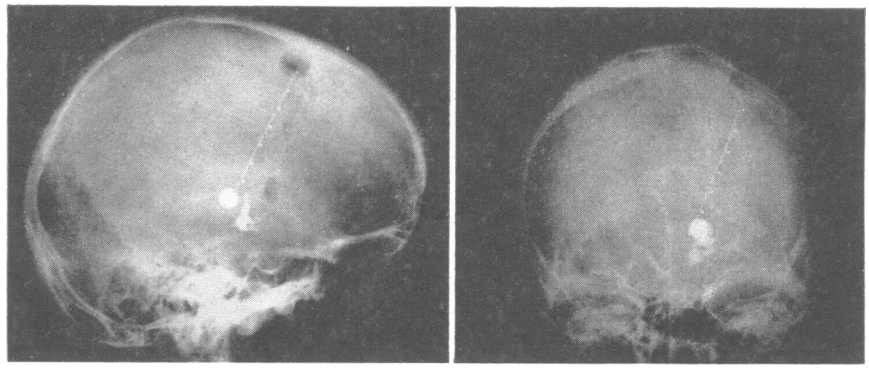

FIG. 9A.—Roentgenographic demonstration of alcohol-Pantopaque pallidectomy lesion followed by insertion of balloon cannula into the thalamus in Case IV.

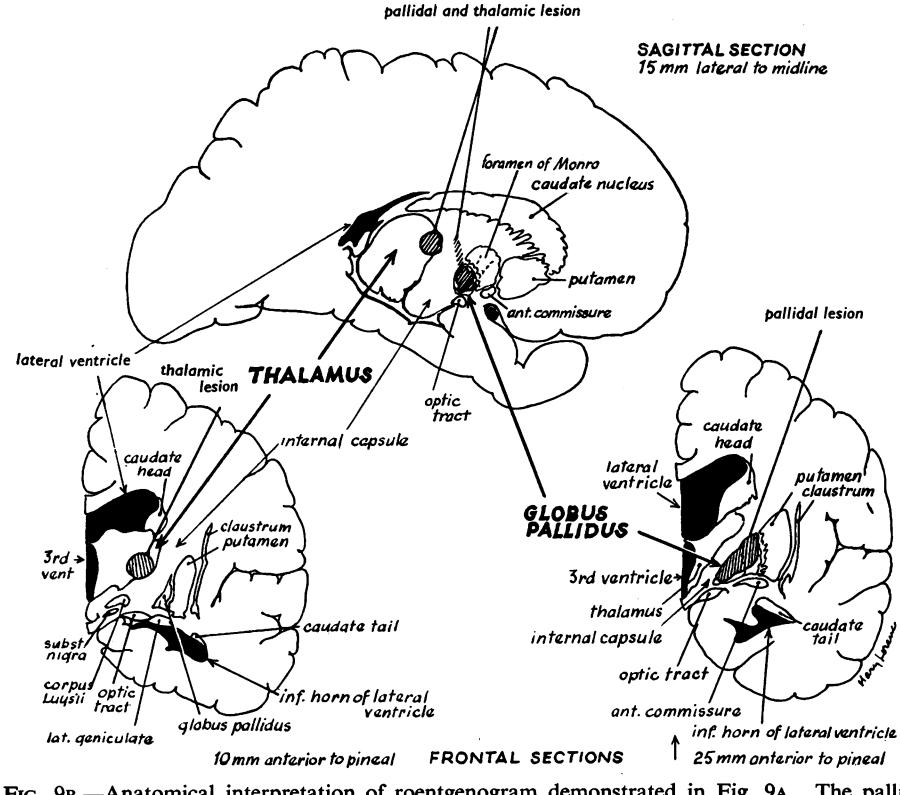

FIG. 9B.—Anatomical interpretation of roentgenogram demonstrated in Fig. 9A. The pallidal lesion and thalamic balloon placement are indicated by shaded areas.

We have constantly stressed that if a globus pallidus lesion renders an incomplete result, it should be followed by a thalamic lesion as illustrated by this case. This type of case would now receive a thalamic lesion as the primary one on our service.

Case V.—Miss A. B., a 60-year-old nurse, was referred by Dr. James Cooney of Florida. She had

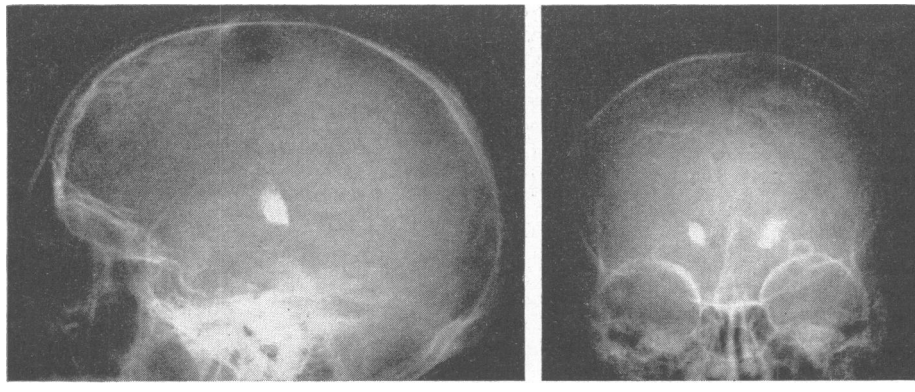

FIG. 10A.—Roentgenographic appearance of bilateral thalamic lesions produced by alcohol-Pantopaque injections in Case V.

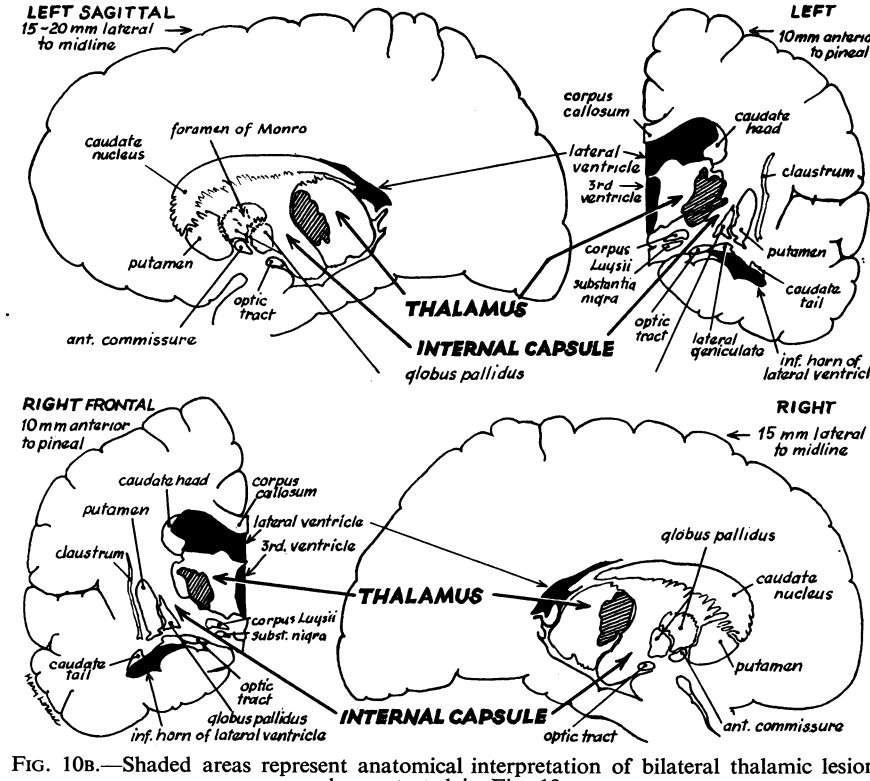

FIG. 10B.—Shaded areas represent anatomical interpretation of bilateral thalamic lesions demonstrated in Fig. 10A.

a six-year history of tremor and rigidity of the left extremities. Progression of her symptoms made walking difficult and finally made it impossible for her to continue her work as a nurse. During the year prior to admission there had been onset of symptoms in the right extremities. Right chemothalamectomy was performed October 24, 1957. This resulted in complete relief of tremor and rigidity of the left extremities which has persisted to date. In May 1958 a left chemothalamectomy was performed for relief of tremor and rigidity of the right extremities. This operation was also successful. Therefore, the patient

has had complete relief of tremor and rigidity of all four extremities as a result of bilateral chemothalamectomy (*see* Fig. 10A, B).

This case demonstrates bilateral thalamic lesions inflicted in a 60-year-old female with complete lasting relief of tremor and rigidity on both sides of the body, and shows the possibility of carrying out chemothalamectomy on each side of the brain. However, experience with the bilateral operation is still limited and requires further experience and investigation before the quantitative limitations of this type of surgery can be explicitly stated.

Case VI.—K. K., a 14-year-old boy from Chicago, Illinois, was referred because of a confirmed diagnosis of dystonia musculorum deformans of three years' duration. The illness began with an abnormal involuntary turning motion of the left ankle. By the time of admission the patient had a marked opisthotonic deformity of the neck and trunk. The left extremities had typical torsion movements and deformities. There was flexion and adduction of the left hip with exacerbation of the lumbar lordosis. The right extremities were involved to a lesser extent as regards deformity but had rather marked involuntary movement disorders. It was impossible for this patient to sit unsupported or to lie comfortably in bed. He often had to sleep on the floor. He could not walk without support. It was impossible for him to attend school.

On September 7, 1957, the patient had a right chemopallidectomy. This was followed on October 1, 1957, by right chemothalamectomy. This produced marked alleviation of the symptoms and deformities of the left extremities. The marked torticollis and opisthotonus of the back continued. Symptoms progressed in the right extremities. In February 1958 a left chemothalamectomy was performed. Following this procedure the patient had marked improvement in movements of the right extremities and also had alleviation of the dystonic deformities of the neck and trunk.

From that time to this there has been marked progressive improvement in this boy's condition as illustrated in Fig. 11.

The patient appears virtually normal at this time. He now rides a bicycle, plays golf, has returned to school and engages in all academic and extracurricular activities which are normal for a boy of his age. His parents report that he is completely independent in all of his activities and is able to travel about town alone without difficulty.

His parents have written on many occasions stating that they now consider him to be returned to normal. Dr. Joshua Spiegel of Chicago has recently examined this boy as an objective observer and reports: "This is a splendid result. During the 45 minutes that this boy was in my office I did not find any evidence of deformities or involuntary movements of any kind."

This case is cited as an example of the reversibility of dystonic deformities and movements by chemopallidectomy and thalamectomy.

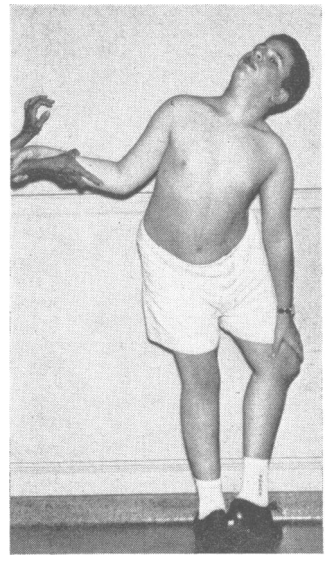

FIG. 11A.—K. K. (Case VI) prior to bilateral operation showing deformities of dystonia musculorum deformans.

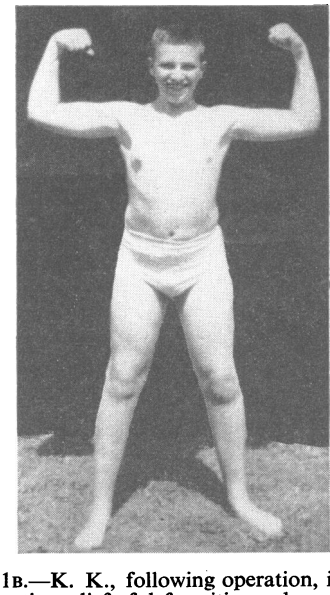

FIG. 11B.—K. K., following operation, illustrating post-operative relief of deformities and movements of dystonia musculorum deformans.

DISCUSSION

A perusal of the representative cases cited above and an examination of the roentgenographic appearance of the basal ganglia lesions produced as well as the anatomical interpretation of these lesions demonstrate that it has been possible to relieve tremor, rigidity, deformity, bradykinesia

and incapacity by lesions placed within a complex consisting of the ventrolateral nucleus of the thalamus, the ansa and fasciculus lenticularis, and the mesial globus pallidus. Such lesions are capable of completely alleviating a contralateral tremor and rigidity without infliction of any observable motor, sensory, intellectual or psychological deficit.

Until it becomes possible to examine many of the brains in which such successful lesions have been inflicted, the exact nuclei and pathways which are principally involved by these successful lesions cannot be stated with certainty. However, it is our impression at this time that the lesion of choice for relief of tremor and rigidity is one placed in the region of the ventrolateral nucleus of the thalamus. Further, we believe that it is the interruption of the pallido-thalamic, cerebello-thalamic, and rubro-thalamic impulses which are principally responsible for the complete relief of tremor and rigidity produced consistently by this lesion. That is not to say that other pathways and impulses may not be involved. However, the confluence of these particular pathways upon the ventrolateral nucleus of the thalamus and their interruption by the lesion of chemothalamectomy lends itself to this interpretation.

The size of the lesion which one should inflict in order to obtain relief of symptoms must be decided in each individual case. Obviously, the lesion must be large enough to relieve the symptoms completely, but should not encroach on any structures which will produce undesirable sequelæ. In our opinion the ability to graduate this lesion in small increments in a conscious, co-operative patient, as is done in chemopallidectomy and thalamectomy, is logical, effective and rewarding. Many academic objections can be posed to chemical lesions as well as to other types of destructive brain surgery, but the ultimate proof remains the relief of disabling symptoms in a human being without inflicting any undesirable side-effects. The method of lesion production employed in our service in more than 850 operations fulfils these criteria and provides complete relief of tremor and rigidity in a singularly successful manner.

In this respect I must insist that it has been our goal during this six-year investigation to study the problem of parkinsonism and its surgical treatment. Consequently we have attached ourselves to the problem including the important, basic investigation of the syndrome and its manifestations. Those who attempt to master a single surgical technique rather than to understand every possible ramification of the disease process will not achieve consistently beneficial results from surgery. Because of our basic interest in the problem rather than in a single surgical technique, there has been at least one major change in our surgical technique during each of the six years of this investigation. Modifications have ranged from occlusion of the anterior choroidal artery, to the free-hand method of globus pallidus injection, to the technique of use of an indwelling cannula, to development of the chemopallidectomy cannula guide, to use of a balloon to provide a physiological test and create a basal ganglia cavity, and finally a modification of the surgical target from the globus pallidus to the thalamus as the lesion of choice.

It is my hope, and I believe that our cases and the end-results in our patients bear out this aim, that the gradual modification of chemopallidectomy and thalamectomy reflects our insistence upon the necessity of modifying any technique with increasing knowledge and insight into the problem, to which the technique is only an accessory. In this regard, I feel strongly that the performance of this type of surgery under modified local anæsthesia, so that the surgeon may obtain clinico-physiological verification of the result of cannula placement and balloon insufflation, is a *sine qua non* of consistently good results with complete relief of contralateral tremor and rigidity.

Anatomical verification by X-ray, no matter how accurate, cannot by itself supplant the usefulness of this physiological test at the time of surgery and during gradual infliction of the lesion. I believe that it is this physiological test, originally performed by procaine injection and more recently by balloon insufflation in the globus pallidus or thalamus, that is the singular feature of chemopallidectomy and thalamectomy which distinguishes it from techniques solely dependent upon anatomical localization. Important as accurate anatomical identification may be, the ultimate result of relief of tremor and rigidity is even more important both to the patient and to the surgeon. Physiological verification by the cannula balloon technique helps immeasurably to assure this desired result.

Conclusions

A five-year follow-up study of more than 850 operations of anterior choroidal artery occlusion, chemopallidectomy and chemothalamectomy leads to the following conclusions:

(1) This investigation has resulted in a practical roentgeno-anatomical-physiological method of basal ganglia surgery which can relieve tremor and rigidity of parkinsonism in more than 80% of properly selected cases with a risk of mortality of 2·4% and a risk of hemiparesis of 3%.

(2) Tremor, rigidity, deformity and incapacity of

parkinsonism can be relieved without the infliction of any neurological or psychological deficit.

(3) Five-year cures of the symptoms of tremor, rigidity, deformity and incapacity can now be documented in this series of cases.

(4) Parkinsonism can no longer be considered as a hopeless, progressive, incurable disease. Inasmuch as the incapacitating symptoms of tremor, rigidity, and deformity have been alleviated for as long as five years without recurrence by surgery of the globus pallidus and thalamus, a more hopeful and optimistic viewpoint can be adopted concerning this disease. The therapeutic implications of this statement apply not only to surgical therapies but to the future development of medical treatment as well. Moreover, the symptoms of dystonia musculorum deformans have been alleviated during the course of this study for periods up to three years without recurrence.

(5) The treatment of choice of many cases of parkinsonism and of dystonia musculorum deformans is surgery of the globus pallidus and thalamus. The thalamus is the surgical target of choice.

(6) Lesions confined to the globus pallidus and/or ventrolateral region of the thalamus on one side of the brain do not result in any motor, sensory, intellectual or psychological deficit. The degree to which such lesions can be inflicted on both sides of the brain requires further elucidation.

(7) Clinical studies leading to a more physiological classification of the subdivisions of the overall parkinsonism syndrome are required if therapy and further basic investigations are to be conducted intelligently and fruitfully.

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