THE SURGICAL TREATMENT OF PARKINSON'S DISEASE

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Despite the frequent introduction of new drugs for the relief of the various symptoms of Parkinsonism, it must be admitted that as regards the control of tremor in particular, and rigidity to a lesser extent, the results obtained leave much to be desired. It was to be expected, therefore, in a condition apparently due to overactivity in some part of the central nervous system, that efforts would be made to influence it by destructive surgical lesions. Since the time of Sir Victor Horsley surgical lesions of the pyramidal system have been made in attempts to abolish abnormal contralateral movements, but always at the cost of a more or less complete hemiplegia. Thus Bucy² excised Brodman's cortical area 4 and a considerable portion of area 6; Browder¹ divided the fibres of the anterior limb of the internal capsule; Walker²⁶ performed lateral mesencephalic pedunculotomy; while Putnam^{19, 20} and subsequently Oliver¹⁸ sectioned the ipsilateral lateral funiculus of the cervical cord.

In 1939, Russell Meyers¹⁵ made the first attempt to influence hemiparkinsonism with a direct attack on the basal ganglia by a transventricular approach to the caudate nucleus. During the next ten years 58 patients were subjected to this operation. The surgical mortality was high (12 per cent.) but about 50 per cent. were said to be benefited. It was apparent that open surgery on the basal ganglia was not the answer to the problem of Parkinsonism, nor was the caudate nucleus the key structure. On somewhat flimsy theoretical and experimental grounds the conviction grew that more could be expected of lesions in the globus pallidus and its efferent pathway, the ansa lenticularis, and blind section of the ansa was performed by Fenelon⁶ and Guiot.⁹ This view was strengthened by experiences with ligation of the anterior choroidal artery introduced by Cooper.³ The technique of producing accurately located, discrete lesions in the basal ganglia only became possible with the development of human stereotaxic methods by Spiegel and Wycis.^{23, 24} In

essence, the stereotaxic instrument, by combined mechanical and radiological control, permits the location in the brain of an electrode point or similar device in relation to three anatomical planes. Many such instruments of varying degrees of complexity have since been constructed for the production of circumscribed lesions in the brain (Hankinson and Amador¹¹).

For the past seven years, by means of stereotaxic instruments, lesions have been made with increasing frequency in the ansa lenticularis, then in the globus pallidus and more recently, and it seems so far most effectively, in the ventro-lateral nucleus of the thalamus. Hassler and Reichert¹² have concentrated their attention and their lesions on the thalamus and Cooper⁴ in describing the implications of a five-year study of 700 basal ganglia operations found that the thalamic lesion relieved tremor which remained after rigidity had been satisfactorily reduced by a pallidal lesion. Latterly he has employed the thalamic lesion as the procedure of choice. It can now be stated with confidence that in suitably selected cases of Parkinson's disease, of whatever aetiology, tremor and rigidity in the limbs opposite from the side of operation can either be completely abolished or greatly reduced without the accompaniment of weakness, signs of pyramidal tract damage or emotional or intellectual change. In Cooper's review just referred to, in 700 cases the mortality rate was 2.4 per cent., and the hemiplegia rate was 3 per cent. Schwab and England²² report a detailed assessment of 50 cases operated on by Cooper either in the globus pallidus or thalamus and give the following classification for the selection of patients for operation:

1. *Ideal.* This is strictly a patient with unilateral disease so that the side opposite the symptoms is between 90 and 100 per cent. of normal. These patients must have good physical health, with no evidence of diffuse brain disease; be ambulatory, and have some function left on the involved side. At first it was felt that the ideal

FIG. 1.—The 'optical bench' fixes the position of the stereotaxic frame and the X-ray cassette in relation to the X-ray tube. The tube, optical bench and cassette are rotated through 90° for the antero-posterior view; the position of the head and frame is unchanged. The ventricular cannula is in position.

category should be limited to those patients whose symptoms were on the non-dominant side of the body because of the risk of a speech interference from the operative procedure. With improvement in technique due to the approach from the superior convexity such involvement is not a hazard and it does not seem to make much difference whether the dominant or other side is involved.

2. *Good.* This consists of patients whose symptoms are definitely bilateral but who have objective evidence of one side being more involved than the other. In this group evidence of diffuse brain disease or mental deterioration must be absent and the patient must be in good general health as to vascular and pulmonary systems.

3. *Fair.* Such cases would be equally bilateral and would be greatly incapacitated by such bilaterality of symptoms. There would be some evidence of difficulty with speech or other midline structures and there might be evidence of diffuse brain involvement and intellectual deterioration.

4. *Poor.* These patients would have extremely advanced disease and be in rather desperate need of help with evidence that other forms of treatment had failed. The terminal invalid state would occur shortly in such cases.

5. *Contraindicated.* Patients who are obviously in such precarious physical condition that surgery would be highly hazardous, with the presence of vascular or other generalized illness, diffuse brain

disease, be totally incapacitated and invalided with many signs of midline involvement in addition.'

Patients over 60 years of age are uncertain risks and only the otherwise exceptionally fit patient over 65 years should have this operation. Patients with bilateral disease of severe degree and those who have evidence of bulbar or diffuse brain damage are poor risks regardless of age. Conversely there is no justification for withholding operation in younger patients with embarrassing unilateral tremor, even though they are far from being completely incapacitated. At this stage of the disorder a relatively large gain can be expected with minimal risk. In many such cases all forms of medication can be abandoned after operation, although in the more generalised disease skilled post-operative use of drugs is obviously indicated and operation is but one episode in the management of the case. Experience with bilateral operations is at present limited; they should be avoided in older patients and in any case, should be separated in time by at least six months. Probably also the lesions should be in different structures on the two sides; pallidal on one side and thalamic on the other.

Technique

The stereotaxic instrument designed and perfected by Dr. Lars Leksell of Lund¹⁴ has been used for all the stereotaxic operations performed in this clinic. Its advantages are lightness, ease of

FIG. 2.—(a) Lateral view of the ventriculogram and stereotaxic frame. The anterior and posterior commissures are marked by pin points.
(b) Antero-posterior view taken immediately after the lateral view.

attachment to the skull and the convenient combination of a rectangular frame for calculation of the coordinates and a semicircular electrode carrier giving a good range of movement over the head.

The degree of accuracy that can be achieved appears to be high compared with other stereotaxic methods. The whole procedure including ventriculography, the stereotaxic calculations and production of the

FIG. 3.—The head has been flexed; the semicircular electrode carrier is attached to the frame in accordance with the calculated co-ordinates and the stimulating electrode has been inserted into the thalamus through a posterior parietal burr hole.

lesion, is carried out at one session, usually under local anaesthesia, lasting between two and three hours. The main disadvantage is the difficulty of supporting and positioning the patient's head surrounded by the stereotaxic instrument.

With the patient lying supine the frame is attached to the head, its base corresponding with Reid's base-line and positive pressure air ventriculography is performed through a right frontal burr-hole. Lateral and antero-posterior views are taken, the relationship and distance between the instrument frame and the X-ray source being kept constant by the use of the 'optical bench' attachment (Fig. 1). The reference points used in this operation are the outlines of the anterior and posterior commissures as shown on the lateral view of the third ventricle (Fig. 2). The optical bench is previously arranged so that the central X-ray beam passes through the approximate target area

in the lateral projection. This greatly reduces the error of measurement due to deviation of the X-ray beam and because of the constant relationship between the instrument frame and the X-ray source a simple calculation makes allowance for the small deviation. As suggested by Guiot¹⁰ and Gillingham⁸ the electrode is directed into the thalamus from a posterior parietal burr-hole; this seems to be safer than the more anterior approaches, but necessitates changing the position of the patient's head slightly to one of greater flexion. The target point is in the ventro-lateral nucleus on the side opposite to the affected limbs, rather ventrally placed in the nucleus and as far lateral, that is as adjacent to the internal capsule, as is safe. The position of the target is calculated from the reference points on the patient's ventricular outline in accordance with anatomical information now available in stereotaxic atlases, such as

those of Spiegel and Wycis,²⁴ Talairach²⁵ and Schaltenbrand and Bailey.²¹

It is realized that the variability of intracerebral anatomy, even in relation to the particular ventricular system, is the greatest potential source of error. Some additional physiological control is therefore essential—ideally in the nature of a reversible lesion. The use of ultrasonics, as described by Russell Meyers and his co-workers¹⁶ and, more simply the small distended balloon technique of Cooper⁵ and the procaine injections of Narabayashi¹⁷ are attractive for this purpose. A number of workers, notably Hassler and Reichert¹³ have described the results of thalamic stimulation during such operations. The writer is convinced of the value of this and uses stimulation in and around the target area in every case where local anaesthesia can be employed. Occasionally, as in children or where abnormal movements of the head are very troublesome, general anaesthesia is necessary. The risks of making a lesion adjacent to the internal capsule under these circumstances are greatly increased.

Dr. J. A. V. Bates suggested the method of stimulation that has been employed in the last 50 cases and this has proved most satisfactory. It is possible by using a 60 cycle square wave current of 3 volts with a 1 mm. bipolar electrode, regularly to suppress tremor and reduce rigidity in the contra-lateral limbs without producing any weakness when the electrode tip is at the target point. Leksell's instrument (Fig. 3) as used in these cases permits of stimulation at 1 mm. intervals along a line passing in the sagittal plane through the target point and directed at an angle of approximately 20° above Reid's base line. As can be seen in the records (Fig. 4) the point giving the optimum effect is very localized and therefore a relatively small lesion (5 to 7 mm. in diameter) can then be made there with confidence. Furthermore in this region the position of the internal capsule can be identified by sensory effects of stimulation. If the use of general anaesthesia is preferred the method of stimulation of the target area by low frequency impulses, as recommended by Hassler, will reproduce abnormal movements. Presumably the higher frequency stimulation mimics the effect of a subsequent lesion by 'paralysing' cells through depolarization of the cell membrane, while the lower rate discharges the cells. In the record showing modifications of tremor by stimulation the latency of the effects, suggesting the stimulation of cells rather than of nerve fibres, should be noted (Fig. 4).

There is a considerable variety in the methods employed by different workers to produce the final lesion. These include mechanical cutting devices, the 'leucotome' or 'encephalotome'; the in-

FIG. 4.—Recordings of Parkinsonian tremor and effects of stimulation in the ventro-lateral nucleus of the thalamus.

1. At calculated target point stimulus applied from 2-3.
2. Result of stimulation from 5-6 at a point 2 mm. beyond the first. This is the optimum point and the final lesion was eventually made here. Note the long latency.
3. Record of stimulation from 8-9 at a point 2 mm. proximal to the first point recorded.
4. There is no effect on stimulation from 15-16 at 2 mm. medial to the first three points.
5. This record shows the great reduction of tremor at the end of a period of stimulation and movement of the needle in the target area before the definitive lesion is produced. This is a temporary effect due presumably to trauma and is not uncommonly seen. In this case the final lesion completely abolished tremor in the opposite limbs.

jection of sclerosing fluids, such as alcohol or alcohol with myodil and some 'thickening' substance; the implantation of a small quantity of a radioactive emitter; electrolysis; thermo-coagulation by radio-frequency diathermy. The latter method has been used in this series of cases and the photograph (Fig. 5) of a coronal section through the brain of a patient who died two months after operation shows such a lesion, 7 mm. in diameter, and situated in the ventral part of the ventro-lateral nucleus of the right thalamus immediately medial to the posterior limb of the internal capsule. Finally a small stainless steel

FIG. 5.—Photograph of coronal slice of brain showing lateral and third ventricles and part of right temporal lobe together with the lesion in the ventrolateral nucleus of the right thalamus. The lateral edge of the lesion is impinging on the medial border of the posterior limb of the internal capsule.

‘marker’ is deposited at the site of the lesion and post-operative X-rays are taken (Fig. 6).

Results

Sixty-one cases have required 68 lesions as follows:—

Medial globus pallidus	15
Thalamus (ventro-lateral nucleus)..	46
Combined thalamic and pallidal lesions	7
	68
	—

Seven patients have been operated on twice. The ages of the 61 patients ranged from 36 to 68 years. The great majority were in the 45 to 55 age group. No more than 15 per cent. of the cases considered for operation were rejected on the grounds of old age, senility or severe bilateral involvement and profound akinesia. Undoubtedly there had been a significant degree of selection before cases were referred to the neurosurgeon and probably not many more than half of all unselected cases would prove suitable for operation. Even so some very unpromising cases have been improved from being almost helpless to being able to get around the house and dress and feed themselves. But the combination of advanced bilateral disease and advanced age must be recognized as a contra-indication. Thus the poorest result was in a badly disabled woman of 68. On the other

hand a well-preserved man of 67, engaged in his profession, with severe unilateral tremor and minimal rigidity was completely relieved of his symptoms. However, the risks of operation are small and therefore operation should not be denied a patient able to continue his occupation but suffering embarrassment and limitation of his social activities on account of a noticeable unilateral tremor. There were no operative deaths, one very debilitated woman of 52 died two months after operation following an anaesthetic for the incision of an abscess. Such a patient would now be refused operation. The lesion in this case in the right thalamus (Fig. 5) completely abolished tremor and rigidity in the left hand, arm and leg and despite its close proximity to the posterior limb of the internal capsule caused no signs of pyramidal damage, although it was noted that after operation dorsi-flexion of the ankle was weaker on the left than on the right. One patient with bilateral symptoms was rendered hemiplegic on the left side at a second operation, the result of the first operation on the right side having been very satisfactory. Another, a woman of 65, following a pallidal lesion lost her tremor and rigidity but 48 hours after operation developed a hemiplegia. Five patients show mild pyramidal signs but only two of these are aware of any weakness and this is of a minor degree.

About 30 per cent. of the patients in this series have complained of subjective sensory changes at

FIG. 6.—(a) Post-operative lateral view of steel marker at site of lesion.
(b) Antero-posterior view of marker in ventro-lateral nucleus of left thalamus.

the moment the lesion is made or during the first few days after operation. They have described tingling and numbness, practically always confined to the hand, and occasionally in the face.

Rarely this can be confirmed by objective evidence of loss of sensation in the hand or face and in one case only this has persisted now for four months. Similarly joint position sense has been found to be

impaired on occasions for a few days. In ten cases a mild degree of cerebellar ataxia occurred in the affected arm, and also a tendency to veer to the side opposite from the lesion. These side effects also have usually disappeared rapidly, although in three cases tendency to veer in walking persists. It is clear that with the posterior approach such sensory effects, almost always of a temporary nature, follow trauma or spread of heat during coagulation to the adjacent posterior ventral group of nuclei receiving impulses from the spinothalamic tract and the posterior columns. Similarly afferents from the cerebellum through the superior cerebellar peduncle may be damaged by a lesion placed in too ventral a position. On the other hand the risks of motor disturbances, psychic changes and somnolence appear to be much less than is the case with the more anterior lesions in the vicinity of the medial globus pallidus. Only one patient showed any visual disturbance. He complained of blindness in one eye immediately after operation and was found to have a homonymous hemianopia which recovered in three days.

These patients have been observed after operation for periods of up to two years only, and with the possible exception of the postencephalitic cases, they must be regarded as suffering from a progressive disease. All of the latter group are maintained subsequently on adequate drug treatment. Tremor is not so well controlled by the pallidal lesion and four such patients subsequently required a second lesion in the thalamus, when tremor had recurred. The first two thalamic lesions were much smaller than those now made and the tremor recurred within a few days, necessitating further operation. The thalamus is therefore preferred both as a site for preliminary stimulation and for the lesion, although in some clinics a pallidal or a combined lesion is favoured. Forty-eight (80 per cent.) of these patients (who were not selected by the strictest criteria) had an excellent result from operation. This implies a complete or virtually complete loss of tremor and rigidity and improvement of deformities when present. For practical purposes the other manifestations of Parkinson's disease are little affected by operation, although occasionally the voice is undoubtedly increased in power. Eight patients benefited to a lesser extent, two were apparently unchanged and two were definitely made worse by operation.

Discussion

The theoretical implications of the successful surgical treatment of the motor manifestations of Parkinson's disease are of the greatest importance in casting light on the control of movement in general and the mysterious workings of the

extra-pyramidal system in particular. Such aspects cannot be considered here in any detail but it should be appreciated that these operations can have a symptomatic effect only and that this effect is achieved by damage to neuronal systems which have escaped the original pathological process. The most effective therapeutic lesion in Parkinson's disease appears to be one situated in the ventro-lateral nucleus of the thalamus. Here the medial lemniscus, conveying posterior column sensation, and a significant portion of the cerebellar peduncle relay to both precentral and postcentral areas of the cortex and also connect across the internal capsule with the lentiform nucleus. Michael Foster,⁷ in his textbook of physiology of 1879 remarked 'It cannot be too much insisted upon that for every bodily movement of any complexity afferent impulses are as essential as the executive efferent impulse.' In Parkinson's disease a normal afferent stream of impulses is influencing an extra-pyramidal system disorganised by damage in one or more of its many component parts. A tentative explanation of the effects described in this paper is that the ventro-lateral nucleus is an area where the sensory side makes contact with both the lentiform nucleus and the cerebral cortex; a lesion suitably placed in this part of the circuit may reduce the afferent impulses to a level more appropriate to the abnormal thresholds of the damaged extra-pyramidal nuclei. Possibly the operation varies in success in a quantitative way according to the amount of functional damage inflicted in the ventro-lateral nucleus. This would be influenced by the position and size of the lesion in any particular case and by the production of the minimal unavoidable destruction of sensory and cerebellar relay systems.

Summary

This paper describes the development of the surgical treatment of Parkinson's disease, the indications for operation, the technique and results of a stereotaxic procedure which has been performed on a series of 61 patients. Possible physiological mechanisms are briefly discussed.

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that areas of lung which appear normal on bronchography are frequently as seriously damaged as areas with dilated bronchi, so that the bronchogram can prove an unreliable guide to the extent of the condition. Most of the poorer results of surgery can certainly be attributed to the persistence of abnormal areas and it is doubtful if surgery is justified at the present time unless the whole of the diseased lung can be excised.

Diffusing Capacity

Our experience shows that a simple method of measuring diffusing capacity is practicable in children, and the normal limits have been defined. At least one example of a severe diffusion defect has been detected and there will doubtless prove to be some others. These, however, are likely to be rare and because of this, the measurement of diffusing capacity will have only a very limited application in children. The finding of lower than normal values in bronchiectasis is not particularly helpful as the defects are slight. They may be, in fact, due to inequalities of ventilation and blood-flow, rather than to impairment of diffusion as usually understood. Any steady state method for measuring diffusing capacity will be affected by this even when no obstacle to diffusion exists in any individual part of the lung.⁹ Bronchiectasis is often diffuse and patchy and might be expected to be associated with these inequalities. An investigation of this possibility might be rewarding.

Conclusions

Measurements of ventilatory capacity are useful and practicable in children. Measurements of pulmonary diffusing capacity are practicable but

of limited usefulness. A great deal of work still remains to be done in extending these investigations to states of pulmonary insufficiency in acute respiratory disease in young children.

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