Psychological aspects of diencephalotomy

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The short- and long-term effects of surgery of the basal ganglia on behaviour have received relatively little attention. In previous studies emphasis has been on the more immediate post-operative changes for evaluating the effects of surgical lesions on intellectual and perceptual functions. With respect to intelligence only one aspect, intelligence quotient (I.Q.), was emphasized. The objectives in this study were to evaluate several aspects of intelligence and simple perception for relatively longer post-operative periods.

METHOD

PATIENTS This study was done on 25 patients (10 men and 15 women). Mean age was 54.2 years (range 40-70 years); mean educational level 13.8 years; mean duration of illness 5.4 years (range 1-10 years). The patients all showed some degree of generalized Parkinson involvement. The chief complaints ranged from moderate and unilateral to quite severe and bilateral tremor and rigidity. All patients were right-handed, *i.e.*, left brain dominant.

SURGERY Unilateral brain lesions were made under local anaesthesia. A 20-gauge barrel electrode with a 4 to 10 mm. non-insulated tip was inserted into the diencephalon through a frontal burr hole (Andy, 1959). The sites of coagulation were primarily in the posterior ventral thalamus-subthalamic region (Andy, Jurko, and Sias, 1963). The stereotactic atlas of Schaltenbrand and Bailey (1959) was used to determine placing of the electrodes.

PSYCHOLOGICAL TEST SCHEDULE The test used to evaluate intellectual functioning were the verbal portion of the Wechsler adult intelligence scale (Wechsler, 1955) and a visual-motor performance group consisting of the Bender-Gestalt (Bender, 1946); memory-for-designs (Graham and Kendall, 1960); and trail-making (Reitan, 1956) tests. Simple perception was followed with a group consisting of the spiral aftereffect¹ (Freeman and Josey, 1949); depth perception²; two-point discrimination³; and the memory-for-designs test oriented to evaluate perception. Testing was done during a two-day period at the

following intervals: one week pre-operatively; five days post-operatively; two months post-operatively; six months post-operatively; and one and a half to two years post-operatively. All patients were tested throughout the study by the same examiner.

EVALUATION OF DATA Since the Wechsler adult intelligence scale is a test which gives well-defined numerical scores continuously distributed, mean scores could be obtained and appropriately compared pre- and post-operatively with the parametric *t* test. However, the tests in the visual-motor performance and the simple perception groups present scoring difficulties. Tests like the Bender-Gestalt are commonly evaluated by clinical judgment and there is no widely accepted method of numerical evaluation. Observations like those made on linear deviation in the memory-for-designs test are difficult to present in numerical scores. For tests like trail making the standardized scoring is dependent upon the patient's ability easily to execute motor movements and do require modification when used on the Parkinson patient. The spiral aftereffect has such a limited spread of scores that it is usually evaluated in terms of a cut-off score (normal vs. abnormal). In view of these difficulties the most feasible presentation of the data for the visual-motor performance and simple perception groups appeared to be reduction to categorized form. Though this type of evaluation does not permit the use of the more exacting statistical methods possible with mean scores, it avoids a deceptive aura of mathematical rigour not inherent in these types of tests. Since pre-operative performance was near optimum and in only isolated instances was there a better score post-operatively, the follow-up data was dichotomized into impairment and non-impairment categories. The impairment category represented the extremes of poor performance based on criteria which pre-operatively were well within the physical and mental capabilities of the patients. The following section describes the method of evaluating impaired performance for each test in the visual-motor performance and simple perception groups. The number of patients in the impaired and the non-impaired category was compared with the non-parametric binomial expansion test.

BENDER-GESTALT These are free-hand reproduction with the test cards placed before the subjects. Impaired performance was scored if two of the following four were present: (1) deterioration in the form of the figures, (2)

¹Spiral Aftereffect Apparatus, Psychological Research and Development Corp., Tampa, Florida.

²Apparatus No. 702, Lafayette Instrument Co., Lafayette, Indiana.

³Two-point aesthesiometer (Weinstein Two-Point Type), Shaw Laboratories, Inc., Syosset Island, New York.

reversals of figures, (3) perseveration of design, and (4) marked crowding or expansion in placement of the figures. An example of expansion is demonstrated in Figure 1. The same patient displayed perseveration. He continued to draw the three rows of open circles on the desk, beyond the limits of the paper. Note that two months post-operatively both expansion and perseveration were not present.

MEMORY-FOR-DESIGNS The task consisted of drawing designs from memory after a five-second exposure. The test is scored on total number of errors. Errors were not more than four for the pre-operative group. Post-operatively eight errors or more was considered an impaired performance.

TRAIL MAKING This test is a paper-pencil maze consisting of two parts. Part A has the less difficult all-number pathway and part B the more difficult alternating number-letter pathway. Post-operative impairment was the inability to perform part B.

SPIRAL AFTEREFFECT This is a test of apparent (illusory) motion. When rotation of the spiral ceases the normal response is one of apparent movement of the spiral in the opposite direction. The maximum score in our use of the test, after Blau and Schaffer (1960), was 8 points representing four clock-wise and four counterclockwise trials. All patients pre-operatively had a score of 6 or better. Because of the stability of the illusion in most subjects over time, a score of 5 or less was treated as impairment in performance (failure of the test). This cut-

off score is also in accord with the findings of Blau and Schaffer (1960) in which a score of zero through 5 was shown to be a highly predictive abnormal.

MEMORY-FOR-DESIGNS This test was used in our test battery to evaluate intellectual function after diencephalotomy with a minor alteration in instructions to indicate changes in perception. The subject was required to draw each figure from memory after a five-second exposure. He was asked to place the figures in columns down the page rather than across the sheet as is usually done. The test was scored for the presence of obvious linear deviation of the columns to the left or right. Note the marked deviation to the left five days post-operatively (Fig. 2).

DEPTH PERCEPTION In the performance of the test the subject aligned two rods suspended in an illuminated box devoid of cues. Twenty randomized trials were given, 10 trials with a 3 cm. misalignment and 10 trials with a 7 cm. misalignment. Impaired depth perception was scored when there was a decrease of one-third or more in both of the distances compared with pre-operative skill.

TWO-POINT DISCRIMINATION The threshold was tested for two areas of both hands, the thenar and hypothenar eminences. Four descending trials (starting with a separation that was easily discriminated and gradually reduced) and four ascending trials (starting with a separation that was not discriminated and gradually increased) were randomly given and averaged. Pre-operative thresholds ranged from a 6 to 18 mm. separation. Post-operative

FIG. 1. Pre-operative and post-operative (five days and two months) Bender-Gestalt protocols.

Note the marked tremor in the pre-operative drawings and the absence of tremor after surgery. The small size of the pre-operative figures relative to post-operative size can be accounted for, in part, by restrictions imposed by the motor disorder. Note that five days post-operatively, perseveration is evident in the drawing of the three rows of open circles. The patient continued to draw more open circles on the desk beyond the limits of the paper. Also, the same three rows of open circles are erroneously connected by vertical lines in the pre-operative and again in the post-operative drawings two months later. This visual defect was not present in the post-operative period of five days.

FIG. 2. Memory-for-designs test modified to evaluate linear deviation as a test of perception. Note the extreme deviation to the left five days post-operatively which tends to persist two years later.

impairment of sensitivity was scored if there was an increase in point separation of 5 mm. or greater for both test areas.

RESULTS

INTELLECTUAL FUNCTIONS A decrease in verbal I.Q. was apparent in the testing interval of one and a half to two years (mean decrement, 10 points). This represents a loss of 8 to 14 points in six out of eight patients (75% of the subjects). In contrast, there was no significant change in the acute post-operative period (five days) nor in the testing intervals of two months and six to eight months. The verbal I.Q. and the subtests comprising the Wechsler adult intelligence scale, which reveal significant or relatively consistent increased or decreased trends, are given in Table I. It is to be noted that the decrease in

verbal I.Q. was mainly due to poor performance in one subtest, similarities. The similarities subtest evaluates abstract thinking by requiring the subject to discriminate between essential and superficial likenesses. No statistically significant changes were present in the remaining subtests. The comprehension subtest, which depends on the possession of a certain amount of practical information and a general ability to evaluate past experience, showed little decline. On the other hand, performance in digit span, a test of attention and retentiveness, was consistently higher post-operatively. This was thought to reflect the effect of practice. The remaining subtests—information, arithmetic, and vocabulary—showed no significant changes.

Unlike the I.Q., which showed little change early post-operatively, maximal decrement in all of the visual-motor performance tests occurred in the acute (five days) post-operative period (Table II). Greatest impairment was in the Bender-Gestalt

TABLE I

PRE- AND POST-OPERATIVE WECHSLER VERBAL I.Q. SCORES

Time of Test	No. of Patients	Subtests (scaled score) ¹			Verbal I.Q.
		Digit Span	Similarities	Comprehension	
Pre-operatively	25	10.0	19.6	24.6	114
Post-operatively					
5 days	21	10.9	18.6	23.2	110
2 mth.	14	11.1	17.1	24.3	114
6-8 mth.	13	10.9	16.0	23.2	112
1½-2 yr.	8	10.4	12.2 ²	22.2	104 ²

¹The remaining subtest (information, arithmetic, and vocabulary) showed no consistent trends.

²Significant at 0.05 level (t test).

TABLE II

NUMBER OF PATIENTS WITH POST-OPERATIVE IMPAIRMENT IN VISUAL-MOTOR PERFORMANCE TESTS OVER A TWO-YEAR PERIOD

Time of Test	Test			
	Total No.	Bender-Gestalt	Memory-for-Designs	Trail Making
Post-operatively				
5 days	24	20 (83%) ¹	11 (46%)	11 (46%)
2 mth.	14	7 (50%)	5 (36%)	4 (30%)
6-8 mth.	13	2 (16%)	4 (30%)	2 (15%)
1½-2 yr.	8	3 (38%)	4 (50%)	3 (38%)

¹Significant at 0.001 level (binomial expansion test).

test. Evidence of continuing impairment, one and a half to two years post-operatively, was seen for all of the tests. In the trail-making and memory-for-designs tests, subjects with left brain operations appeared to be more frequently impaired than those with right brain lesions (Table III). Though this trend did not reach the level ($p = 0.05$ or better) usually taken as significant for our small sample, it is suggestive of a laterality difference and should be pursued in a larger sample.

TABLE III

IMPAIRED VISUAL-MOTOR PERFORMANCE RELATED TO LATERALITY OF BRAIN LESIONS FIVE DAYS POST-OPERATIVELY

Test	Left Operation (12 patients)	Right Operation (12 patients)
Trail-making	8 (67%) ¹	3 (25%)
Memory-for-designs	7 (60%)	4 (33%)
Bender-Gestalt	11 (90%)	9 (75%)

¹Significant at 0.10 level (Chi-square test).

SIMPLE PERCEPTION There was impairment in all of the simple perception tests in the acute (five days) period (Table IV). The greatest declines were in depth perception and two-point discrimination tests, with decrement present in over 50% of the patients.

TABLE IV

NUMBER OF PATIENTS WITH POST-OPERATIVE IMPAIRMENT IN SIMPLE PERCEPTION TESTS OVER A TWO-YEAR PERIOD

		Test				
Time of Test	Total No.	Spiral After-effect	Linear Deviation (MFD)	Depth Perception	Two-point Discrimination	
Post-operatively						
5 days	24	10 (42%)	10 (42%)	15 (75%) ^{1,2}	12 (60%) ^{1,3}	
2 mth.	14	2 (14%)	4 (30%)	2 (14%)	5 (36%)	
6-8 mth.	13	0	4 (30%)	1 (7%)	2 (15%)	
1½-2 yr.	8	0	2 (25%)	0	1 (13%)	

¹Based on 20 patients.

²Significant at 0.02 level (binomial expansion test);

³Significant at 0.06 level.

Two-point discrimination remained impaired in a significant number of subjects two months post-operatively, and there was continuing deficit in one patient two years after surgery. Among the 12 patients with decrement in two-point discrimination, six had contralateral decrement, three had ipsilateral, and three had bilateral. Two of the three patients with ipsilateral deficits were operated on the left brain. Linear deviation also gave evidence of long-range impairment. Figure 2 illustrates extreme deviation to the left five days post-operatively and deviation still apparent two years later. There was a trend for a greater number of subjects oper-

TABLE V

IMPAIRED SIMPLE PERCEPTION RELATED TO LATERALITY OF BRAIN LESIONS FIVE DAYS POST-OPERATIVELY

Test	Left Operation (12 patients)	Right Operation (12 patients)
Spiral after-effect	3 (25%)	7 (60%)
Linear deviation	6 (50%) (8 patients)	4 (33%) (12 patients)
Depth perception	3 (38%)	10 (83%) ¹
Two-point discrimination	3 (38%)	9 (70%)

¹Significant at 0.10 level (Chi-square test).

ated on the right brain to show impaired simple perception than those operated (Table V) on the left brain.

COMMENT

Riklan, Diller, Weiner, and Cooper (1960) reported significant impairment in the Wechsler verbal I.Q. in the 'immediate' (8 to 43 days) post-operative period. In the 'long-range' period (4 to 13 months) there was no significant difference compared with post-operative performance. Our patients, in contrast, showed no impairment in the Wechsler verbal I.Q. immediately post-operatively. Deficit was only found one and a half to two years after operation. Furthermore, the decrement was due to a decline in one specific subtest, similarities. It should be noted that in the series of Riklan *et al.* (1960) patients represent a mixture of chemothalamotomy and chemo-pallidotomy testable 'usually between two and four weeks subsequent to surgery depending upon the clinical condition of the patient.' This implies that the post-operative morbidity was pronounced in some patients which may account for the early impairment, especially in those who could not be tested within five days after surgery. The technique utilized in our study consisted of electrolysis of diencephalic structures and 21 out of 25 patients could be so tested within five days after surgery. In addition, our long-range testing period was 18 to 24 months in contrast to theirs which was four to 13 months.

Our observations of delayed impairment in verbal I.Q. are in accord with a recent case report by Watkins and Oppenheimer (1962). They described late decline in the Wechsler-Bellevue intelligence scale after an apparently good recovery from unilateral chemothalamotomy. The Wechsler verbal I.Q. was 114 pre-operatively, 100 at one month post-operatively, 109 at five months, and 98 at 18 months. No information was given on their subtest scores. It is of interest to note that studies in lobotomy patients also revealed decrements which were specific for only some Wechsler subtests (de

Mille, 1962; Smith and Kinder, 1959). In addition, the changes were not present immediately after surgery, but became evident eight years later (Smith and Kinder, 1959).

The question arises as to whether the delayed post-operative decrement in the (Wechsler) verbal I.Q. can be attributed to deterioration associated with Parkinsonism. Riklan *et al.* (1960) reported no significant change in Wechsler I.Q. scores in their unoperated Parkinson patients in a mean test-retest of nine months. Machover (1957) used the Rorschach test to evaluate intellectual function in two groups of Parkinson patients, each representing a relatively short and long period of illness. A comparison of the short duration group (mean, 2.5 years) with the long duration group (mean, 19.6 years) showed 'no really significant difference in degree or kind of impairment in cognitive integrity or efficiency'. In view of these observations, it would appear unlikely that the long-term impairment found in our study is due to the natural course of Parkinson's disease. In contrast to the lack of impairment in verbal I.Q. immediately after surgery, maximal decrement in the visual-motor performance tests occurred in the acute period after operation. These skills obviously implicate a different aspect of intellectual function than the Wechsler I.Q.

There are many reports of impairment in perception following cortical lesions but only a few following subcortical lesions. In a recent study Proctor, Riklan, Cooper, and Teuber (1963) reported decrement in two-point discrimination and punctuate pressure thresholds immediately after chemothalamotomy. Significantly higher thresholds for punctuate pressure were still evident five months post-operatively. These findings parallel our observations of maximal number of patients showing decrement in somesthesia in the acute (five days) period following diencephalotomy. There was little long-range deficit; only one patient still had impairment one and a half years post-operatively. It should be noted that Teuber (1962) found decrement in two-point discrimination 10 years after penetrating missile wounds of the cortex. The above investigators also found that impairment was greatest contralateral to the lesion and ipsilateral impairment was more frequent in the group with lesions of the left brain. Our observations on diencephalic lesions are in accord with those findings.

Two-point discrimination and depth perception tests showed impairment in more patients after diencephalic lesions than did spiral aftereffect and linear deviation tests. It is of interest that the former tests are to a large degree tactile-spatial in contrast to the latter which are visual-spatial. This difference may be due to the greater involvement of the primary

sensory relay nuclei of the thalamus consequent to the diencephalic lesions. It must also be noted that the impaired perception was not accompanied by general intellectual deficit. Disturbed perception without involvement of general intellect has also been reported by Denny-Brown, Meyer, and Horenstein (1952), Gerstmann (1958), and others.

The laterality of the lesion appears to affect intelligence and simple perception differentially. This is now quite well documented for cortical representation but has received little attention in relation to diencephalic function. Greater impairment of simple perception appeared among our patients with right subcortical operations. Recently Piercy, Hécaen, and Ajuriaguerra (1960) reported on 67 patients who had constructional apraxia associated with unilateral cerebral lesions. The deficit was measured by having the patients draw a house and a cube. They concluded 'that, in general, constructional apraxia associated with right hemisphere lesions involves greater impairment of perceptual functions than is the case in the left hemisphere syndrome'. In contrast to simple perception, impairment of intelligence was more frequent among our patients with left diencephalic lesions. This is in accord with laterality effects noted on patients with cortical lesions. Reitan (1955) in a carefully controlled study of 14 patients with surgical verification of pathology, found impairment of verbal intelligence (Wechsler-Bellevue) more frequently in patients with left-side cortical lesions.

SUMMARY

Intellectual function and simple perception were evaluated before and during a two-year period after placement of lesions in the diencephalon of 25 Parkinson patients.

Psychological tests employed were verbal I.Q. (Wechsler) and visual-motor tests: Bender-Gestalt memory-for-designs, and trail-making tests. Tests of perception consisted of spiral aftereffect, memory-for-designs, depth perception, and two-point discrimination threshold.

Immediate impairment was verified in all the tests comprising the motor performance battery, and recovery was present within six months. However the verbal I.Q. was not immediately impaired.

Delayed impairment of verbal I.Q. appeared one and a half to two years post-operatively. It should be noted that the decrement was confined to one subtest only, similarities (a test of abstract thinking).

All perception tests revealed immediate post-operative impairment. Only one (linear deviation) showed decrement at two years.

Right diencephalic lesions produced greater impairment of simple perception and left diencephalic lesions produced greater impairment of intellectual function.

REFERENCES

- Andy, O. J. (1959). Globus pallidus coagulation technique. *Surg. Forum*, 1958, 9, 698-700.
- , Jurko, M. F., and Sias, F. R. Jr. (1963). Subthalamotomy in treatment of Parkinsonian tremor. *J. Neurosurg.*, 20, 860-870.
- Bender, L. (1946). *Bender Visual Motor Gestalt Plates*. Amer. Orthopsychiatric Ass. Inc., New York.
- Blau, T. H., and Schaffer, R. E. (1960). The spiral aftereffect test (SAET) as a predictor of normal and abnormal electroencephalographic records in children. *J. con. Psychol.*, 24, 35-42.
- de Mille, R. (1962). Intellect after lobotomy in schizophrenia: A factor-analytic study. *Psychol. Monogr.*, 76, No. 16, pp. 1-18. [Whole No. 535].
- Denny-Brown, D., Meyer, J. S., and Horenstein, S. (1952). The significance of perceptual rivalry resulting from parietal lesion. *Brain*, 75, 433-471.
- Freeman, E., and Josey, W. E. (1949). Quantitative visual index to memory impairment. A preliminary report. *Arch. Neurol. (Chic.)*, 62, 794-797.
- Gerstmann, J. (1958). Psychological and phenomenological aspects of disorders of the body image. *J. nerv. ment. Dis.*, 126, 499-512.
- Graham, F., and Kendall, B. (1960). *Memory for Designs Plates*. Psychological Test Specialists, Missoula, Montana.
- Machover, S. (1957). Rorschach study on the nature and origin of common factors in the personalities of Parkinsonians. *Psychosom. Med.*, 19, 332-338.
- Piercy, M., Hécaen, H., and De Ajuriaguerra, J. (1960). Constructional apraxia associated with unilateral cerebral lesions—left and right sided cases compared. *Brain*, 83, 225-242.
- Proctor, F., Riklan, M., Cooper, I. S., and Teuber, H. (1963). Somatosensory status of Parkinsonian patients before and after chemothalamectomy. *Neurology (Minneap.)*, 13, 906-912.
- Reitan, R. M. (1955). Certain differential effects of left and right cerebral lesions in human adults. *J. comp. physiol. Psychol.*, 48, 474-477.
- (1956). *Trail Making*. Mimeographed. Indiana University Medical Center, Indianapolis.
- Riklan, M., Diller, L., Weiner, H., and Cooper, I. S. (1960). Psychological studies on effects of chemosurgery of the basal ganglia in Parkinsonism. *Arch. gen. Psychiat.*, 2, 22-32.
- Schaltenbrand, G., and Bailey, P. (1959). *Introduction to Stereotaxis, with an Atlas of the Human Brain*. Grune and Stratton, New York.
- Smith, A., and Kinder, E. F. (1959). Changes in psychological test performances of brain-operated schizophrenics after 8 years. *Science*, 129, 149-150.
- Teuber, H. L. (1962). Effects of brain wounds implicating right or left hemisphere in man: Hemisphere differences and hemisphere interaction in vision, audition, and somesthesia. In *International Symposium on Cerebral Dominance*, edited by Vernon B. Mountcastle, pp. 131-157. Johns Hopkins University Press, Baltimore.
- Watkins, E. S., and Oppenheimer, D. R. (1962). Mental disturbances after thalamolysis. *J. Neurol. Neurosurg. Psychiat.*, 25, 243-250.
- Wechsler, D. (1955). *W.A.I.S.* Psychological Corporation, New York.