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Amygdalotomy

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Summary

The results of a multi-disciplinary research project into the management and assessment of patients with epilepsy and behaviour disturbances are reported in eighteen patients who have undergone amygdalotomy over the past 5 years. The psychological and neuro-surgical assessments are detailed and the effects of stimulation and coagulation of the amygdala nucleus are described in six patients.

It is concluded that certain cases benefit by amygdalotomy, but that changes are not limited to a decrease in abnormal aggressive behaviour but also lead to a decrease in other areas of maladaptive behaviour. The aim of the operation is to enable the patient to respond more appropriately in a range of situations which in turn would lead to an increase in general effectiveness.

Introduction

The significance of the deep structures of the temporal lobe and the limbic system in mediating emotional responses has long been recognized (Papez, 1937; Kluver & Bucy, 1939) and the existence of a relationship between certain forms of epileptic activity and disorders of emotional reactions has also been well documented (Weil, 1959; Flor-Henry, 1969; Falconer & Taylor, 1970; Horowitz *et al.*, 1970).

Gloor (1960) suggested that certain limbic structures have a very low threshold for electrical activity, and areas of the limbic system have become particularly important in exploring the relation between neuro-physiology and behaviour. Over the past 30 years there have been two main streams in the development of neuro-surgical approaches in this field; frontal lobe lesions to modify affective states, and temporal lobe procedures for behaviour disorders associated with temporal lobe epilepsy.

The amygdala, a limbic structure within the temporal lobe, has been studied more in animals than in man (Eleftheriou, 1972). It is concerned with attention, orientation and learning as well as eating, drinking, sexual and aggressive behaviour. Many of the techniques used in animal experiments cannot be used in the exploration of the amygdala in humans. Nevertheless, the possibility that abnormal patterns of aggressive behaviour might be associated in some way with the abnormal functioning of the amygdala led to the investigation of the effects of destruction within this area (Narabayashi *et al.*, 1963; Heimburger, Whitlock & Kalsbeck, 1966). In human studies global terms such as aggression and behaviour disturbance continue to be used.

Feindel (1960), Jasper (1960), Gregory (1961) and Weiskrantz (1968) have indicated that stimulation or ablation studies do not permit valid conclusions about the function of specific brain structures. In this present study, therefore, we make no inferences from changes in behaviour pattern following partial or complete destruction of the amygdala. Vowles (1970) indicates that 23 subnuclei have been identified within the human amygdala, but we have no specified information about the facilitatory or inhibitory role of these.

The amygdalotomy project

The amygdalotomy project has developed from an isolated surgical project into a multi-disciplinary team approach, in which the neuro-surgeon, the psychiatrist and the psychologist are involved in the management and assessment of patients with epilepsy and behaviour disturbances treated by temporal lobe surgery (Hitchcock *et al.*, 1972). At the outset of the project it was felt that neither psychological nor psychiatric assessments could provide adequate selection criteria and so it was decided that within the group of cases with behaviour disorders referred to the neuro-surgeon, selection would be made by the neuro-surgeon. Thereafter, cases selected would be assessed by a psychiatrist and a psychologist and a period of detailed in-patient investigation in a psychiatric unit would be arranged for the immediate pre- and post-operative period. The patient would then be re-assessed at varying post-operative intervals, more frequently within the first year and thereafter annually. An indispensable part of the project is close liaison with the psychiatrists in the MRC Brain Metabolism Unit of the Royal Edin-

burgh Hospital. Dr George Ashcroft and his colleagues provide both out-patient and in-patient assessments and also active support during the period of post-operative rehabilitation.

Patient characteristics

The age range of the eighteen patients who have undergone amygdalotomy over the past 5 years is 8–46 years. There were five females to thirteen males. Reasons for referral all centred round behavioural disturbances in which abnormal aggressive behaviour of some description featured to a greater or lesser extent. In five cases there was a pattern of severely subnormal mental functioning (mental age 1–7 years). Behaviour in this group is described as hyperactive, destructive and rebellious. Normal patterns of emotional control have failed to develop. Their behaviour is appropriate to their mental level but physical strength greatly out-strips mental capacity and hence their behaviour, which would be acceptable in a normal toddler, has unacceptable consequences. In five adolescents, the problem behaviour centred round violent outbursts usually directed against authority, in three cases mainly against parents. The most effective group, in terms of functioning within the normal intellectual range, living at home with only intermittent hospitalization and either occasionally employed or holding down a regular job, were four male cases whose problems of aggressive behaviour were associated with alcohol. The remaining four cases were all adult and presented with a history of personality disturbance and, in three, periods of psychiatric hospitalization. Sixteen of these eighteen cases suffered from or had a history of epilepsy.

Methods

Psychological testing is extremely difficult since the absence of co-operation is frequently a contributory factor in referral. Personality questionnaires are appropriate for only a limited number of our population, many being too dull intellectually. In all patients, however, behaviour can be observed and can be quantified through the use of check lists and rating scales. A recent development has been obtaining measures of patient behaviour in certain standard situations designed to be mildly frustrating or stressful. The complete psychological assessment is described in the Appendix.

Because of the close association of the amygdala with the hypothalamus and its influence on the endocrine system, it is hardly surprising that hormonal disturbances were manifest post-operatively in some patients. The project has broadened, therefore, to include a biochemical study performing hormonal assay examining the continuous urinary testosterone excretion pre- and post-operatively. Biochemical analyses in the pre- and post-operative period have been confined to CSF concentrations of amines. The amygdala is rich in 5 HT and if this contributes to the 5 HIAA metabolite levels of CSF one could expect to see changes in the CSF concentration of 5 HIAA post-operatively. This aspect of the work is carried out by staff in the MRC Brain Metabolism Unit.

The neuro-surgical investigations comprised LAEG, EEG, angiography, and cerebral isotope scan. Although EEG revealed abnormalities with focal evidence of temporal lobe disturbance in some patients, the most helpful examination appeared to be LAEG. The surgical procedure involved the bilateral stereotactic placement of electrodes within the amygdala and its destruction by a radio-frequency current. The early approaches to the amygdala were transfrontal, the electrode traversing other parts of the brain than the temporal lobe. Although the damage must be small, to eliminate any possibility of damage of such structures influencing the assessment the direct transtemporal approach has been used for all but the first two or three cases (Fig. 1). A further advantage of this approach has been a shorter brain track and an opportunity to record and stimulate from temporal lobe structures en route to the amygdala. Wherever possible, procedures were performed without premedication under local anaesthesia. Nine patients have been operated on under local anaesthesia. The remaining nine patients had bilateral amygdalotomy performed under general anaesthesia because it was considered that in view of their behaviour disturbance, undergoing the procedure under local anaesthesia would be too hazardous. For six of the patients who underwent the procedure under local anaesthesia the effects of stimulation and coagulation were recorded in detail with the use of a tape recorder. Some of the case characteristics of these six patients are shown in Table 1. The age range of this group was 17–44 years. Five of the six patients were male. Our stimulus parameters are comparable with those of other studies (Chapman, 1958), 5–100 Hz, pulse width 1 msec, voltage ranging from 1 to 10 using a Radionics thermoprobe electrode with exposed tip dimensions 3 mm $\times$ 1·8 mm. Stimulation was carried out as the probe advanced towards the target at various points short of target, on target and occasionally beyond target. Where it was feasible, stimulation was repeated to ensure that the response obtained was not an artefact of the situation, but where extremely aggressive responses were being obtained and the patient was becoming disturbed it was not considered desirable to repeat these more than was absolutely necessary for localization purposes to identify the target area.

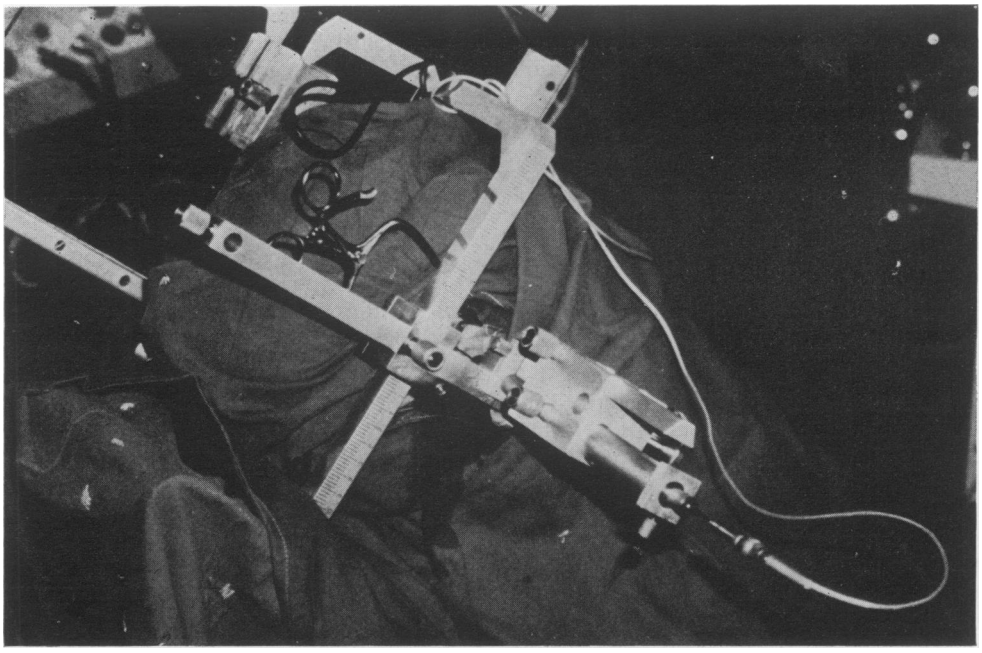


FIG. 1. Probe introduced through direct temporal route.

TABLE 1. Details of six cases undergoing amygdalotomy under local anaesthesia

Patient	Sex	Age at operation (years)	Operation	Date	Seizure type	EEG focus	Main presenting complaints	Intelligence
W.L.	M	34	Bilateral	14.7.71	? Psychomotor	No EEG abnormality	Aggressive behaviour and drinking problem	Average
H.F.	M	42	Unilateral left (previous right-sided lesion)	4.5.70 24.6.67	Focal	Bilateral temporal abnormality (pre first operation)	Aggressive behaviour and drinking problem	Average
W.G.	M	29	Bilateral	23.10.70	Major+ temporal lobe fits	No significant abnormality	Aggressive behaviour and drinking problem	Average
D.G.	M	17	Bilateral	26.8.71	Jacksonian +major	Left occipital focal disturbance	Aggressive behaviour (to parents only)	Severely subnormal
G.M.	M	44	Bilateral	27.1.70	Temporal lobe	Sphenoidal EEG Right inferior temporal disturbance	Aggressive behaviour (self-reported, never observed) and drinking problem	Average
E.M.	F	18	Bilateral	18.5.72	None	None	Behaviour disturbance (with violent and self-mutilative behaviour	Severely subnormal

Results

Before dealing with the long-term results for the whole group we will describe some of the results obtained for the six cases for whom detailed records of responses during stimulation and coagulation under local anaesthesia are available. These are recorded in Table 2.

The most significant (and the most dramatic) effect of stimulation has been the eliciting of a range of aggressive responses from coherent, appropriately directed verbal responses (speaking to surgeon, 'I feel I could get up and bite you') to uncontrolled swearing and physically destructive behaviour. While all these patients had a history of abnormally aggressive behaviour, during in-patient investigations, psychological testing, etc., such behaviour as occurred during stimulation was not observed at all. In four patients a similar pattern of restless behaviour was obtained which included tearing at drapes and clothes, moving hands up towards the stereotactic frame and trying very forcibly to remove this frame. This characteristic pattern occurred during coagulation as well as during stimulation in two of these four patients. It appeared purposive but had an automatic quality. It was not susceptible to modification as a result of external stimulation, i.e. verbal commands to move the hands from the frame or not to tear off the gown, and force was required in two cases to prevent the stereotactic frame being removed by the patient who before and after

TABLE 2. Tabulated results of behaviour during stimulation and coagulation in six patients

Description of behaviour	No. of patients in whom this response was obtained	
(1) Aggressive behaviour		
(a) Swearing	2	
(b) Shouting, sounding angry	3	
(c) Threat of violence	1	
(d) Restless, destructive behaviour	4	
(2) Emotional, upset, tearfulness	1	These expressions of emotions were all associated with periods of confusion
(3) Other expressed emotions		
(a) Anxiety	1	
(b) Guilt	2	
(c) Embarrassment	1	
(d) Jealousy	1	
(4) Verbalized desire for 'flight', 'escape'	3	
(5) Expressed fatigue	2	
Signs of fatigue	4	
(6) Confusion	3	
(7) Disorientation		
(a) Place	1	
(b) Time	1	
(8) Unresponsiveness	5	
(9) Incoherent speech	4	
(10) Automatic speech	2	
(11) Automatic behaviour	4	
(12) Autonomic/visceral		
(a) Flushing	4	
(b) Thirst	2	
(c) Butterflies in stomach	1	(normal seizure pattern)
(13) Motor		
(a) Upper limb movement	3	
(b) Jaw movement	2	
(c) Slurring of speech	3	
(14) Sensory		
(a) Visual		
(i) Diplopia	2	
(ii) c/o everything going black	1	
(b) Smell/taste	1	
(c) Feeling of electric shock, tingling	1	
(15) Seizures		
(a) Typical	3	
(b) Atypical	0	

these episodes appeared fully aware of the situation and refrained from touching the frame or from interfering with the operative procedure in any way or from interfering with the drapes, etc.

Two patients expressed other emotions during what appeared as periods of confusion. Three patients expressed a desire to get away. The significance of this, which might be termed 'flight' behaviour, in relation to known patterns following amygdaloid stimulation in animals in whom distinct patterns of flight, defence and attack responses have been observed (Kaada, 1972) is of some interest. No pleasurable emotional feelings and no responses connected with sexual behaviour were identified in any of our patients during stimulation or coagulation.

A comparison of the effects obtained during stimulation and coagulation of the amygdala with the features of psychomotor seizures (Chatrian & Chapman, 1960) shows them to be very similar. Where seizures occurred during the stimulation procedure these were of a similar nature to the patients' current seizure pattern (D.G., W.G., G.M.). Two of the patients reported these as identical and in the third patient they were observed to be identical. The question of whether the unresponsiveness noted in five of our patients was in fact no more than the occurrence of seizures was raised, but there were several instances of unresponsiveness in the two patients in whom there was no history of clinical seizures. During some of these periods of unresponsiveness the patient would at some times respond to non-verbal commands. At other times there was no response and not even an orienting to the source of the stimulus. These aspects ruled out the possibility that we were seeing no more than speech arrest frequently reported during stimulation of the periamygdaloid area. It is of some interest that the unresponsiveness occurred in two patients at exactly the same location at which verbal aggression and restlessness were previously or subsequently elicited. No clearcut pattern has as yet emerged between the onset of the stimulus and the occurrence of the response, or of persistence of response after cessation of stimulus. Some responses occurred within 3 sec of the onset of the stimulus and some responses persisted 1 min after the cessation of the stimulus.

In one of the two cases in which vehement swearing occurred, this was of sudden onset, 30–45 sec after stimulation commenced, on three separate occasions. The disturbance lasted for 15–30 sec and the patient became placid 5–30 sec after cessation of stimulation. On one occasion the patient was asked, 30 sec after cessation of the stimulus, if he had felt angry. He agreed that he had been angry, but that he no longer was, and he sounded very surprised (Table 3).

Although in the post-operative period some patients were so disturbed that they removed their dressings and fingered their wounds, post-operative infections were minimal and no serious infection arose.

TABLE 3. Record of stimulation responses: Stimulation of amygdala (patient W.L.; date, 13 July 1971; side, right)

Time	On/off	Frequency (Hz)	Voltage	Comments made and questions put to patient	Patient's responses	
					Verbal	Observations
	At target					
0	On	50	3	Tell us if you feel anything.		7 sec delay—incoherent response.
0·12				What's happening?		6 sec delay.
					Yes.	
0·22				Mr L.	Yes.	
				Are you awake?	Yes.	
				How are you feeling?	OK.	
				Any funny feeling?	Yes, just	3 sec pause.
0·30				Just what?		3 sec pause. Long sigh.
					Just I'm getting sick of all this.	
0·35	Off			How are you now?	Just the same.	Still sounds angry.
0.40	On	5	4·5		My leg.	2 sec delay and then face flushing.
0.43					I can hardly speak*****	Patient swearing.
0.55				What's the matter?		10 sec delay.
					Everything going black.	
				What do you feel now?		3 sec delay.
1.10			5		I just want to get***** out of here.	Patient swearing, shouting very angrily.
1.20				That's OK.		
	Off			All right?	Yes.	
1.50				Did you feel angry?	Aye, I did.	Patient sounds surprised.
				Do you feel that now?	No, I don't feel that now.	

The surgical procedure is relatively simple and although we have had no pathological verification, radiological verification indicates that target siting was accurate. The amount of destruction necessary, however, is less well known. Some of the lesions made have been small and no attempt has been made to destroy the whole amygdala, the surgical target being the most medial nucleus of the amygdala. Complications have been small and largely related to immediate post-operative difficulties of management. In one patient, however, as the result of an injury sustained during the removal of an indwelling electrode inserted via the transfrontal approach, a severe right hemiplegia was produced which has resulted in a considerable disability in one arm. The original lesions were small because of the fear of complication but increasingly we have tended to make larger lesions in an attempt to destroy a major part of the medial nucleus of the amygdala. To date we have had no complications from these large lesions.

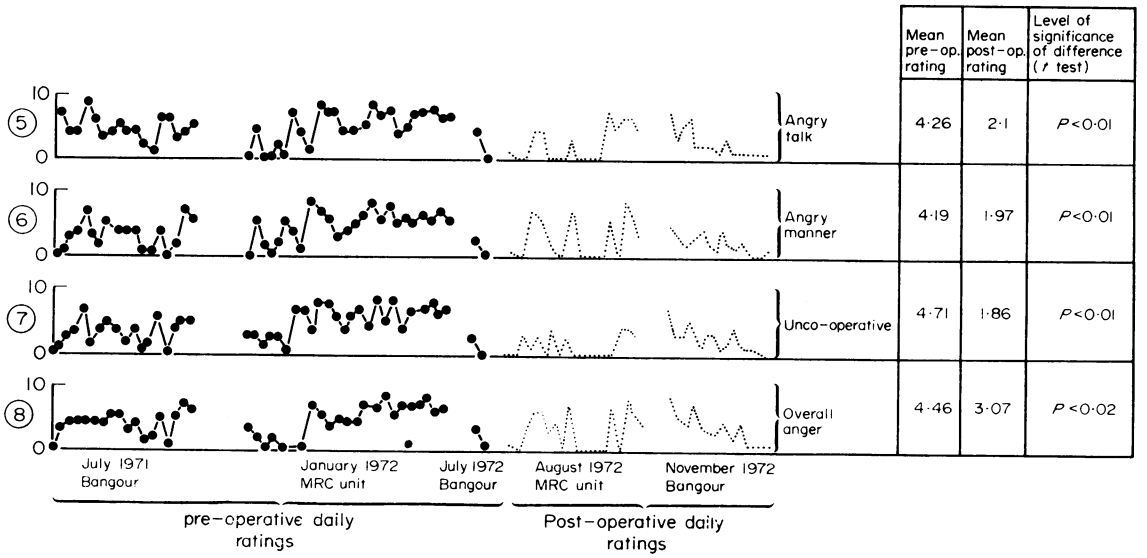
Frequency and severity of fits have been notably reduced in three cases (D.G., J.S., W.G.), with consequent reduction in anticonvulsants. Apart from in the immediate post-operative period, in no case has there been an increase in frequency or severity.

Tests of intellectual function showed no post-operative impairment. A subtle deficit in the recognition of faces has been reported in one or two recent cases. Perceptual and memory aspects of this are now being investigated.

The major psychological assessment, however, is of personality and behaviour. Five cases have completed Cattell's 16 PF Questionnaire pre- and post-operatively. The group personality profile indicates minor changes on a number of factors. Of particular interest is the post-operative decrease to a normal level on the factor related to suspiciousness. Total level of hostility (as measured by the Hostility and Direction of Hostility Questionnaire) remains high. These test results have been reported in detail elsewhere (Hitchcock *et al.*, 1973).

Observational methods have provided results on a larger number of patients. The Hargreaves Nursing Rating Scale provides a detailed record of patient behaviour, as shown in Fig. 2. It can be seen that although the mean level on item 7, for example, has dropped significantly, there are still marked day-to-day fluctuations.

In addition to the use of this rating scale, we have also made use of a checklist. The Adaptive Behaviour Scales, although devised for use with institutionalized retardates, are proving very useful for the majority of our cases. Figure 3 gives results for twelve patients on four of the areas covered by the scales. In four males the scores indicated a drop in violent and destructive behaviour, but in only one female. Three females remain more violent and destructive than 90% of an equivalent population. In all four females there was a high level of self-abusive behaviour which was reduced post-operatively in only one case, the same patient in whom there was a decrease in violent



	Mean pre-op. rating	Mean post-op. rating	Level of significance of difference (*t* test)
Angry talk	4·26	2·1	$P<0.01$
Angry manner	4·19	1·97	$P<0.01$
Unco-operative	4·71	1·86	$P<0.01$
Overall anger	4·46	3·07	$P<0.02$

FIG. 2. Hargreaves Nursing Rating Scale. Results for one patient (G.C.) on four of the total of twenty-four items, rated daily on a 10 point scale (from 0=no disturbance, to 9=extreme disturbance).

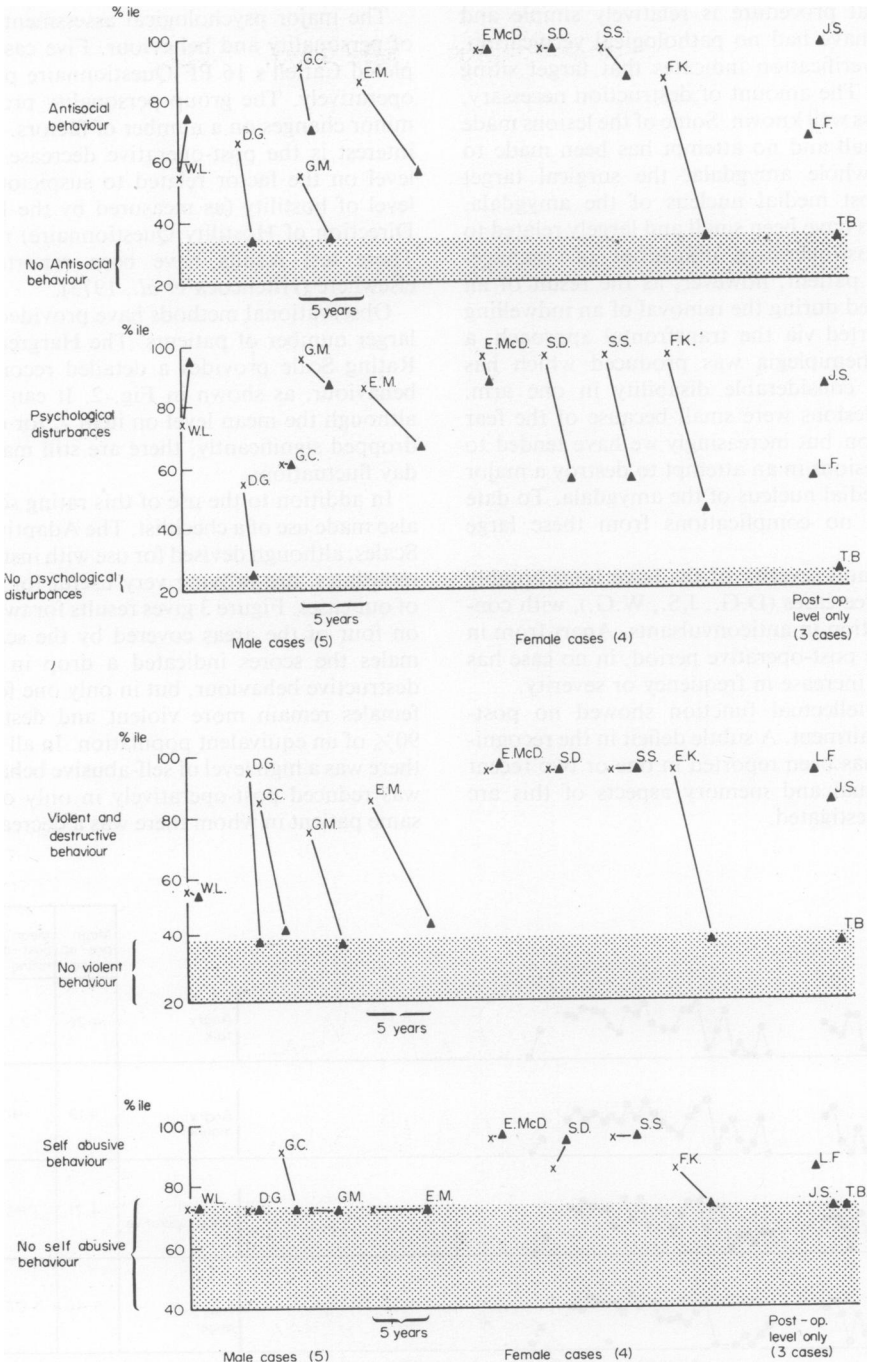


FIG. 3. Adaptive Behaviour Scales. Pre- and post-operative levels in four areas of maladaptive behaviour, derived from raw scores. The vertical axis indicates percentile rank, the stippled area the percentage of an equivalent population obtaining zero scores. Length of follow-up is indicated along the horizontal axis, each case being plotted separately. ×, pre-operative level; ▲, post-operative level.

and destructive behaviour. A range of behaviour, such as reaction to frustration, mood changes and hypochondriacal tendencies, are covered in the area labelled psychological disturbances. All cases show some degree of such disturbance pre-operatively and ten cases post-operatively. Six cases show a decrease (improvement) post-operatively, one an increase in level and two no real change. Three of the four cases (D.G., E.M., G.M. and F.K.) showing greatest overall improvement could be described as having adolescent problems pre-operatively and in the fourth there was a change in domestic circumstances. It would appear from these results that the cases where there is a decrease in violent, destructive behaviour and antisocial behaviour also show an all-round improvement in general effectiveness.

Of the fifteen cases on whom data is currently available, the five cases hospitalized pre-operatively remain in hospital. One patient who was at home pre-operatively is now in hospital, but hospitalization was imminent pre-operatively. As far as occupational activity is concerned, four of the nine patients previously incapable of any form of occupational activity are now either employed or attending occupational therapy units. A further four patients continue to be in either regular or occasional open employment post-operatively. From these figures we cannot claim, as other authors have done, that post-operatively a majority of patients become capable of effective functioning in a social context.

Discussion

It might be argued that this series of cases has no control group matched in terms of behaviour patterns and other variables. In view of the variation of individual patterns of maladaptive behaviour within our group, it is felt that this would not provide such valid information as our current design, in which each patient is used as his own control and the results are evaluated in terms of checklists for which age norms are available.

Long term assessments are more relevant than evaluation of the effects immediately post-operatively. However, during such long term observation variables other than the surgical procedure itself result in behavioural changes and it is important that such long term evaluation also considers the effects of maturation, domestic changes, occupational status and other factors. It is also difficult to determine how far changes in social factors are a cause of, or a result of, changes in behavioural patterns.

The study of behavioural responses occurring during stimulation of localized areas of the brain has been criticized in that such responses are artefacts which do not yield valid results (Mark, Sweet & Ervin, 1972) and even more so when these studies are carried out in the operating theatre (Sem-Jacobsen, 1970). In monkeys aggressive responses were elicited only in the appropriate social situation (Rosvold, Mirsky & Pribram, 1954). An operating theatre might be regarded as an inappropriate situation for the expression of emotional reactions.

The only aim of stimulation at surgery was in physiological localization prior to coagulation. In all of these patients the main, or one of the main, presenting complaints was a pattern of abnormal aggressive behaviour and hence we were particularly interested in the aggressive responses which were elicited. In our one-stage bilateral operations it may not even be possible to specify exactly that responses obtained during stimulation of the second side definitely are such, or no more than the delayed effect of stimulation and coagulation of the contralateral amygdala. Further objection to describing the functions of the amygdala in terms of results obtained during stimulation and coagulation at surgery is that we were not able to allow sufficient intervals between one stimulation and another or between stimulation and coagulation to extrapolate adequately the after-effects of one stimulation from the direct effects of the next. Again studies using chronic implanted electrodes, those of Sweet, Ervin & Mark (1969), King (1960) and Sem-Jacobsen (1970), with intervals of 5 to 10 min between stimulations, do enable more exact analysis to be made. However, with our patients it was not considered a necessary part of the pre-operative investigations to have implanted electrodes and it was not considered justifiable to use these merely for research purposes.

Many studies mention that negative emotions can be elicited by electrical stimulation (Heath & Mickle, 1960; Gloor, 1960) but few describe in detail the behaviour elicited. One exception to this is the work of Sweet *et al.* (1969) who do provide detailed description of telemetric stimulation in several patients. Comparison of our results with these published studies indicates that we were eliciting certain responses at surgery which had not been recorded previously.

Horowitz *et al.* (1970) described a turbulent period of post-operative re-adjustment and it is during this period, sometimes prolonged, that we have been very dependent on the support provided for the patient and the family by our psychiatric colleagues. Aspirations are frequently unrealistic and while pre-operatively the aims of surgery and the limitations have been carefully explained, patients and their relatives often expect the patient to be able to return to normal independent functioning, living at home, in the immediate post-operative period.

The neuro-surgeon's criterion for accepting a patient for surgery is based on a judgment; the judgment that the pattern of aggressive behaviour is

detrimental to the patient's well-being, not that it is detrimental to society. The aim of surgical intervention has been to render the individual more effective rather than more manageable.

As with any therapeutic technique, there is the risk of misuse, but it is felt that non-surgical techniques (such as conditioning and drug therapy) may come under less careful scrutiny than psychosurgical procedures and hence may very well be more liable to misuse.

Conclusion

In view of the indications of abnormal epileptic activity in the majority of our cases it is not possible to generalize from our results to a non-epileptic population, but within our group in certain cases in certain situations behaviour after amygdalotomy is less disturbed. Results to date indicate that where this is so changes are not limited to a decrease in abnormal aggressive behaviour but there is also a decrease in many other areas of maladaptive behaviour. Human behaviour is extremely complex and to date it has not been possible to establish whether the decreases in aggression and other maladaptive behaviour occur simultaneously or whether, as initially hypothesized, the effect of a discrete lesion in the amygdala is to increase level of tolerance for frustration and increase inhibition of aggressive responses, thus enabling the patient to respond more appropriately in a range of situations which in turn would lead to an increase in general effectiveness.

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Appendix

Summary of psychological assessment

(A) *Tests of cognitive function*
- (i) General intellectual level
- (ii) Memory
- (iii) Miscellaneous

(*B*) *Personality and behavioural assessment*
- (i) Questionnaires
- (ii) Self-rating
- (iii) Rating Scales and Checklists
- (iv) Objective Measures

Patients are tested* pre-operatively, and at 1 month, 3 months, 6 months, 1 year, and subsequently annually.

(A) Tests of cognitive function

(*i*) *General intellectual level*
- (a) Raven's Progressive Matrices. A test of non-verbal reasoning ability.
- (b) Mill Hill Vocabulary Scale. A test of ability for verbal communication.
- (c) Stanford Binet Intelligence Scale. An age scale, measuring intelligence.
- (d) Wechsler Adult Intelligence Scale (WAIS). Measure of intelligence.
- (e) Porteus Maze Test. A paper and pencil performance test of foresight and planning capacity.

(*ii*) *Memory function*
- (a) Graham Kendall Memory for Designs. Test of ability to reproduce simple, geometric designs from memory, immediately after recall.
- (b) Sentence Repetition (Stanford Binet XI year Item). Test of short term memory for verbal material.
- (c) Williams' Memory Scale:
  - (1) Digit Span. Test of short term memory.
  - (2) Non-verbal Learning (Rey-Davis). This task requires the patient to learn the position of one fixed peg on each of four boards containing nine pegs.
  - (3) Verbal Learning. The patient has to learn the meanings of eight new words.
  - (4) Delayed Recall. The patient is required to recall pictorial material seen 10 min previously.
- (d) Photo Recognition (Modification of Milner's test). Test of ability to select, from twenty-four photographs of faces, the twelve which the patient was shown 1½ min previously.
- (e) Orientation Questionnaire.

(*iii*) *Miscellaneous*
- (a) Word Fluency (Stanford Binet X year Item). To pass this item the patient must say twenty-eight words in 1 min.
- (b) Perseveration. The patient is asked to draw two circles, a cross and a square.
- (c) Reaction Time. A measure of time to react to a light stimulus, by depressing a switch.
- (d) Educational Attainments.
  - (1) Burt–Vernon Reading Age.
  - (2) Vernon Arithmetic Test.

(B) Personality and behavioural assessment

(*i*) *Questionnaires*
- (a) Cattell's 16 Personality Factor Questionnaire. A multidimensional measure of sixteen distinct primary personality factors.
- (b) Personality and Personal Illness Questionnaire (Foulds). Questionnaires measuring three levels of psychological functioning—symptoms, attitudes and personality.
  - (1) Symptom Sign Inventory.
  - (2) Hostility and Direction of Hostility Questionnaire.
  - (3) Hysteroid–Obsessoid Questionnaire.
- (c) Scales designed to measure the two major personality variables of neuroticism (or emotionality) and extraversion/introversion.
  - (1) Eysenck Junior Personality Inventory.
  - (2) Eysenck–Withers Personality Inventory.

(*ii*) *Self-rating—Visual Analogue Scale*

The patient completes the scale daily, thus providing an index of change in self-rating, on such continua as Happy–Depressed and Well–Ill.

(*iii*) *Rating Scales and Checklists*
- (a) Hargreaves Nursing Rating Scale. Designed for daily use by psychiatric nurses, covering a wide range of psychopathology, with twenty-four items each rated on a 10 point scale.
- (b) Adaptive Behaviour Scale (American Association on Mental Deficiency). A behaviour rating scale for mentally retarded and emotionally maladjusted individuals, completed by nursing staff, teachers (and also by parents). Part 1 covers the individual's skills and habits in areas important in the maintenance of personal independence. Part 2 provides a measure of maladaptive behaviour, related to personality and behaviour disorders.

* Not all assessment methods are applicable to all patients.

(c) Checklist of observation of 10 min samples of behaviour. The patient is observered for a 10 min period, once or more daily. Items of aggressive, destructive behaviour are checked off, and overactive behaviour is rated.

(*iv*) *Objective measures*

(a) Mirror Drawing. This task is designed to provide a measure of tolerance of frustration. (Time spent on task, and number of items attempted.)

(b) Pursuit Rotor. On this tracking task, the patient has a number of trial runs, at different speeds. Then, he is encouraged to adjust the speed himself (providing a measure of choice of level of difficulty).

Next, the speed is fixed at a moderate rate, and the buzzer switched off (feedback). A series of false 'success' readings are given, followed by a series of 'failure' readings. This is alternated for dominant/non-dominant hand and for several different patterns.

This provides a differential measure of the patient's persistence when succeeding and failing.

(c) Gibson Spiral Maze (Modification). The patient is required to trace a path through this circular maze, using his non-dominant hand. The test is administered under three conditions: (1) the patient is left alone to complete the task; (2) the patient is stressed every 15 sec, to increase his speed; (3) the patient is stressed every 15 sec, to increase his accuracy.

Variation in time taken and number of errors provides a measure of reaction to a mildly stressful situation.