the substances were eluted with 70-percent ethanol containing a few drops of dilute ammonium hydroxide. Radiometric measurements were made on the air-dried residues in comparison with similarly treated but unchromatographed standards. The average counts per minute (in parentheses), corrected for background, from six replications were as follows: standard (124), Rf 0.0–0.01 (8), Rf 0.18–0.20 (13), Rf 0.4–0.5 (48), Rf 0.6–0.7 (31), Rf 0.98 (10), total recovered (110). The origin and the nature of the zones of impurities cannot be explained from the data available at the present time.

References and Notes

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30 September 1954.

Physiological Evidence Concerning Importance of the Amygdaloid Nuclear Region in the Integration of Circulatory Function and Emotion in Man

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Preliminary findings presented in this paper (*1*) suggest that in man the amygdaloid nuclear complex, situated in the temporal lobe, may play a role in circulatory regulation as well as in emotional expression. The observations were made in five epileptic patients in each of whom a multiple electrode, consisting of four parallel needles, had been implanted in the amygdaloid region of one temporal lobe by a specially modified stereotaxic apparatus. Three of the needles were of equal length and spaced 5 mm apart in the position of an equidistant triangle, while the fourth was 3 mm shorter and was located in the center of this triangle. This electrode was used to record the electric activity, to stimulate this region, and finally to coagulate this nuclear area for therapeutic purposes. The amygdaloid area was localized by measurements derived from skull x-rays of the clinoids in each patient and from air studies of the tip of the temporal horn in all except one case.

Preliminary studies with the stereotaxic instrument in 11 cadavers using the same skull landmarks revealed that our centrally placed electrode needle entered the amygdaloid nuclei in nine cases and missed this structure by 1 mm in two cases. Since we have no tissue specimens in any of our patients for the determination of the precise location of the electrodes, we have defined the area studied as the amygdaloid nuclear region, meaning thereby, the area in or near the amygdaloid nuclei.

Three patients were diagnosed as having epilepsy with assaultive behavior of such severity as to necessitate confinement in a psychiatric institution. Two patients had a diagnosis of psychomotor (temporal lobe) seizures of incapacitating severity. All had electroencephalographic abnormalities in the temporal area before operation. The amygdaloid region was coagulated in the patients with assaultiveness in an attempt to modify favorably this behavior, and in the patients with psychomotor epilepsy, to avoid greater destruction by temporal lobe extirpation, such as is used in some centers in the treatment of that condition. In each case, a group of psychiatrists had recommended surgical treatment after all attempted medical therapy had failed. The extent of the lesion caused by the current parameters used for coagulation had been previously determined in 12 cats. The results of coagulation will not be reported until sufficient time has elapsed for clinical evaluation to be meaningful. Electric stimulation was employed in an attempt to obtain a clearer understanding of the functions of the amygdaloid region, including its role in our patients' illnesses. The effects of electric stimulation of the amygdaloid region on feeling states and the continuous recording of blood pressure and heart rate were studied, and the electric activity from this region and from the scalp was recorded at various intervals during a 7 to 9 day period prior to the therapeutic electric coagulation procedure.

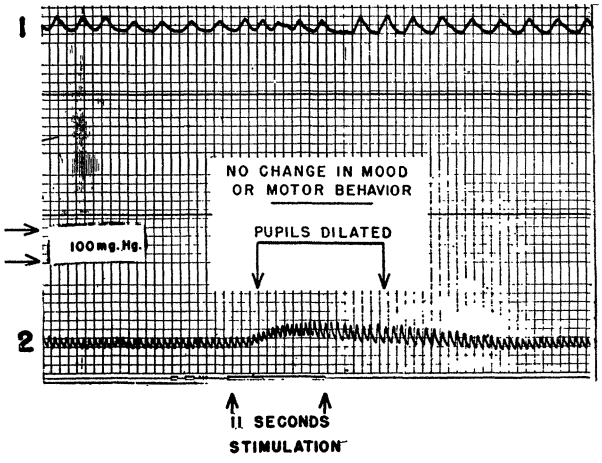

Fig. 1. Electric stimulation caused a 50 mm-Hg rise in systolic and 33 mm-Hg rise in diastolic blood pressure and pupillary dilatation without producing mood or somatic responses. (1) Respiratory tracing. (2) blood pressure tracing; 60 pulses/sec, 1 msec pulse duration, 12 v.

Stimulation with a monophasic square wave at a rate of 20 to 60 pulses/sec, 1 msec pulse duration and 7 to 17 v for periods of 3 to 30 sec produced a variety of responses. In four patients, feelings of fear, anxiety, and at times a "weird" or "terrific" feeling in association with alterations in motor behavior were obtained. When the intensity of the stimulus was slightly increased or maintained for a longer period, the patients would show momentary confusion and unresponsiveness. Ability to count and the performance of a skilled act such as winding a string around a pencil would become impaired. In three patients, bilateral pupillary dilatation and a 20 to 100 percent increase in heart rate were elicited. In two patients, electric stimulation caused a 50 to 80 mm-Hg rise in systolic and a 30 to 60 mm-Hg rise in diastolic blood pressure, and, in one patient, widening of the palpebral fissure. The circulatory and pupillary responses could be obtained independently of, or in association with, alterations in mood, motor behavior, and changes in respiratory rhythm (Fig. 1). The time interval between the beginning of electric stimulation and the changes in the blood pressure or heart rate indicated that some responses were mediated directly by nervous pathways and suggested that others were perhaps mediated by the liberation of a humoral substance. All responses were readily reproducible. Voluntary motor movements simulating those induced by electric stimulation did not elicit the circulatory effects.

In the patients so far tested, stimulation that has not resulted in a psychomotor seizure has frequently been followed by increased muscle tension and eye blinking, which has obscured the electroencephalographic recording. This was found to take place even when the patient reported absence of subjective sensations.

In one patient with a diagnosis of psychomotor epilepsy who was having spontaneous seizure discharges confined to the area tapped by the deep electrodes, the only sign at the scalp electrodes was an occasional spike at the temporal tip on the same side. During these electric seizures the heart rate was augmented, and there was a great increase in blinking movements. In another patient in whom high voltage spikes were occurring randomly at the depth electrode, spikes at the temporal scalp electrodes on the same side were found but not always simultaneously with those in the depth (Fig. 2). Paillas (*2*) and Gastaut (*3*) have described similar spike activity recorded from the amygdala in two of their patients with psychomotor seizures.

The only complication known to have arisen from our use of the implanted electrodes was a temporary weakness of the contralateral facial musculature. This had disappeared by the time the electrode was removed.

The finding of striking elevations of blood pressure can now be added to previous studies in animals

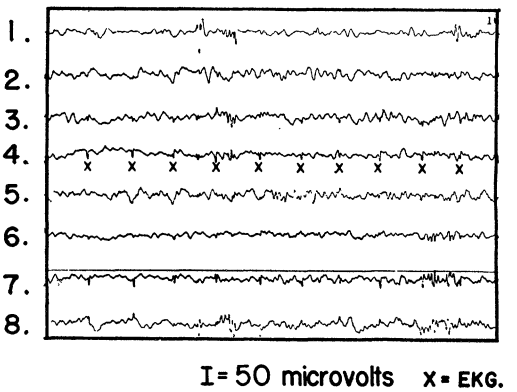

Fig. 2. Simultaneous spiking in amygdaloid region and temporal scalp. Channel 1 shows spikes occurring spontaneously in the left amygdaloid region, picked up by implanted bipolar electrode. Simultaneously, a spike appears at the scalp in the anterior temporal lead on the same side. Recorded on the third day after operation. The crosses indicate heartbeats. Scalp leads are shown as follows: channel 2, left frontal to left anterior temporal; 3, left anterior temporal to left midtemporal; 4, left midtemporal to left posterior temporal; 5, right frontal to right anterior temporal; 6, right anterior temporal to right midtemporal; 7, right midtemporal to right posterior temporal; 8, left anterior temporal to right anterior temporal.

or man of the effects of electric stimulation of the amygdaloid region. Feindel, Penfield, and Jasper have reported (*4*) that electric stimulation in the region of the claustroamygdaloid complex in the awake patient at operation frequently caused features of automatism, which probably included confusion, unresponsiveness, and abnormal motor behavior, as was noted in our patients. Pupillary dilatation, increases in heart rate, and behavior changes have been previously reported in amygdaloid studies in animals (*5*). Our observations may lend further support to the views expressed by the comparative anatomist that some portions of the amygdaloid complex may constitute a part of the brain concerned with visceral and somatic expression of internal states (*6*).

References and Notes

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