Sensory and Motor Responses to Stimulation of the Posterior Cingulate Cortex in Man

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The cingulate gyrus has received the attention of neurophysiologists in recent decades, and considerable information has accumulated regarding the effects of stimulation of this structure in experimental animals. Observations on humans have been less frequent, particularly concerning stimulation of the posterior part of the cingulate gyrus. The difficulty of approaching this region in humans and the infrequency of occasions when clinical factors justify surgical exploration are probably the main reasons for the small number of published reports.

During stereotaxic operations with a goniometric apparatus, we have occasionally been forced to introduce a fine electrode through the electrode holder into the brain in order to reach the basal regions. Sometimes the tip of the electrode appears beneath the cortex of the posterior part of the gyrus cinguli. This has provided us with the opportunity to explore the posterior cingulate cortex by electrical stimulation in conscious and cooperative patients.

Material and Methods

The present study utilized 27 individuals who were operated on either for treatment of parkinsonian symptoms (26 patients) or painful phantom limb (one patient); 78 points were stimulated.

The patients were fully conscious during stimulation and had only local skin anesthesia. Responses obtained from nervous, drowsy, or otherwise uncooperative patients were not used for this particular study. Stimulation never resulted in generalized or local seizures. During stimulation, patients lay on their backs with arms extended in front of them. They were questioned as to the sensations that they felt, and were asked to count in a regular manner as well as to perform voluntary movements. Care was taken to avoid suggestive questions.

Stimulation was carried out by means of a Grass C4 stimulator placed between the depth electrode and an indifferent electrode applied to the patient's back. Square wave signals were used at intensities of 1 to 3 V, depending upon the threshold of the response. Each point was stimulated at frequencies ranging from 1 to 200 cps with a pulse duration of 1 or 0.5 msec for periods of 5 to 30 sec.

A stereotaxic apparatus of the goniometric type was used for placing the electrodes. The plot of points (Fig. 1) indicates the general distribution of the stimulated areas. The position of the electrodes was established in relation to ventricular structures by means of a ventriculogram with air and a small amount of emulsified lipiodol injected into the frontal horn of the lateral ventricle. In some of the cases, small amounts of air in the cerebral sulci gave us additional evidence for determining the position of the electrodes.

The proportional method described by Talairach, et al., was used for the plotting of the stimulated points. In most instances (93%) the tip of the electrode was placed less than 15 mm from the midline. Only occasionally this distance was greater than 15 mm but never over 18 mm.

Results

Stimulation of about one-third of the 78 points failed to produce any effect. A variety of responses, including modifications of speech, activation of pupilary changes, or inhibition of resting tremor and rigidity, as well as somatic sensations and slow tonic movements, were evoked by the stimulation of the remaining points in either the cingulate gyrus or the surrounding cortex. Only those aspects of our observations relating to tonic motor and sensory activities will be
considered here. The inhibitory and facilitatory effects on the extrapyramidal symptoms have been the subject of a previous paper.3

Sensory Responses. Stimulation of 8 points in five patients evoked subjective sensations reported as "pins and needles, numbness, or electricity." No specific modality was reported. One patient only, who had been suffering for a long time from a painful phantom limb, described as "pain" the stimulation of a point located in the cingulate gyrus anterior to the region yielding the rest of the sensory responses (Case V.G.D., point 8). In this case, the chronic pain suffered by the patient might have modulated the response to stimulation. A summary of the characteristics of the sensory responses evoked during our stimulations is shown in Fig. 2.

The plot of points shown in this table indicates the distribution of those producing somatic sensations. All points but the one of the patient suffering from painful phantom limb (point 8) were located in the cingulate gyrus between the splenium of the corpus callosum and the confluence of the gyrus cinguli, the paracentral lobule, and the precuneus. Three of the points were radiographically located close to the sulcus cinguli so that the possibility of a spread of current to the sensory radiations or the primary sensory cortex has to be taken into account. The extension of paresthesias over the whole contralateral half of the body (Case N.H.S., point 2, and Case F.B.E., point 9) or the chest and the superior limb (Case F.G.B., point 1) does not seem to correspond to an excitation of the adjacent portions of the primary sensory cortex. The short distance from those three points to the midline (less than 10 mm) makes it improbable that the sensory radiations could participate in the response.

Only during the electrical stimulation of one point (Case M.C.C., point 6) was the sensory response described as confined to the contralateral hand. Stimulation of the remaining points produced paresthesias affecting the upper limb and the chest (point 1) or the whole contralateral half of the body including the limbs (points 2, 3, 4, 5, 7, 8, and 9) and sometimes also the face (points 7 and 8). In most cases stimulation at the lowest frequency necessary to evoke the sensory response produced those extensive paresthesias, but in two cases (Case A.P.P., point 4, and Case M.C.C., point 5) paresthesias were more limited but extended over the whole side of the body when the frequency of stimulation was increased.