Origin of Somatosensory Evoked Scalp Responses in Man*

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Because of similarities between somatosensory evoked potentials recorded from the scalp and those arising directly from the brain (animal or man), early components of the scalp response have been thought to arise from the primary sensory area, late ones to originate more diffusely in associated areas or midline cortex at the vertex. Moreover, however, whether these assumptions are correct, whether there is an ipsilateral as well as a contralateral cortical contribution, or whether the entire scalp response derives only from the contralateral primary sensory area, are questions which remain unanswered and with which this paper will deal.

The study centers on a group of patients who had selective cortical ablations for epilepsy. For our purpose they afforded a unique opportunity in that some required excision of the somatosensory hand area, either alone, or in addition to other tissue, thus enabling us to compare the effects of such ablations, on the scalp response, with that of other cerebral excisions.

Also, during surgery multiple cortical recordings were made from the entire exposed field to identify all cortical areas that are capable of generating a somatosensory response. Comparison of these cortical responses with scalp potentials that were elicited simultaneously provided additional important information.

Methods

Eleven patients who had craniotomy for convulsive disorder and tumor were studied. In seven, surgery was carried out under general endotracheal anesthesia using halothane (Fluothane) and nitrous oxide; in four, only local anesthesia was used. Prior to surgery, daily recordings (for 3 to 7 days) of scalp responses to median nerve stimulation were made for 3 to 7 days. Stimuli were square wave pulses of 20 to 40 V at 0.1 msec delivered through a General Radio Step-up (1 - 4) Transformer. They were applied transcutaneously to both right and left median nerves at the wrist, intensity being adjusted to elicit just a muscle twitch. Scalp responses were recorded between one needle electrode placed at the vertex in the midline and another just above the nasion. This single electrode arrangement permitted recording of responses to either right or left median nerve stimulation. During recordings, patients were seated comfortably in a chair, awake and with eyes closed. Responses were recorded with r-c amplifiers from which signals were led to the analog-to-digital converter of a Linc computer. Fifty responses (0.5/sec) were added and the “average” displayed on a cathode ray tube for photography. The initial 250 msec of activity following each stimulus was recorded; long latency potentials (ca 700 msec) that appear during sleep were ignored in this study. Postoperatively, several recordings were made in each patient during the first 2 to 6 weeks after surgery, and subsequent ones at 1- to 3-month intervals during the ensuing 3 to 18 months.

At surgery, we first identified motor cortex by bipolar electrical stimulation of the brain surface. This was done in patients under general anesthesia as well as those under local. The level of general anesthesia was light, stimulus intensities of 4 to 10 V and 1 msec pulse duration (60/sec) readily producing motor reactions. Averaged responses to median nerve stimulation were then recorded transcortically between a surface silver ball electrode (1 mm diameter) and a nichrome wire (200 μ diameter insulated except for the distal 1.5 mm) introduced into the immediate subcortical white matter. The silver ball and wire were at-
tached by dental cement, the end of the wire extending 5 mm beyond the silver ball. Care was always taken to insert the wire through an avascular cortical area.

A multiplexer* enabled us to record averaged responses from eight different locations simultaneously. Thus, the entire exposed brain could be canvassed in a relatively short time, about 1 hour. To determine whether potentials were actually generated between the recording electrodes, we looked for polarity reversal in monopolar records from surface and white matter (bone reference).11 In three patients cortical and scalp responses could be recorded simultaneously during surgery. Scalp electrode placements were identical to those used in the pre- and postoperative recordings, namely, vertex to nasion. In the other subjects, position of the reflected scalp flap or other technical difficulties prevented successful simultaneous recording.

Of the nine patients with intractable seizures, two had hemispherectomies, two had an anterior temporal lobectomy, two had removal of the sensory hand area, one had excision of sensory hand and face area, and one had removal of all the occipitoparietal portion of the right hemisphere posterior to the somatosensory gyrus. In the remaining patient with convulsive disorder, no tissue was removed because an epileptogenic focus could not be demonstrated by electrocorticography. The other two patients had tumors: glioblastoma multiforme of the left frontal lobe and a metastatic adenocarcinoma of the right occipital lobe. Only tumor tissue was removed in these two patients.

The study was carried out in full accord with United States Public Health Service policies governing human investigation.

Results

Distribution of Somatosensory Evoked Responses Recorded Transcortically. In eight of the patients, only the somatosensory hand area generated a response; all other areas remained silent. This was the case in the patients under local as well as those under general anesthesia (Figs. 1 and 2). Small responses recorded transcortically out-

side of the sensory hand area proved to be due to pickup of potentials generated elsewhere, probably in the sensory hand area. That is, the surface and white matter leads recorded independently against a distant electrode gave identical potentials except for minor amplitude differences (Fig. 3). In two patients both maintained under general anesthesia the motor as well as the sensory hand area yielded a response (Fig. 4). In neither of these subjects did stimulation of the sensory area at the intensities used in motor cortex elicit a motor reaction.

In all patients, responses in the sensory hand area showed an initial positive deflection with a peak latency of 25 to 30 msec (Fig. 5). To this extent there was similarity in response configuration among the patients studied. However, the components that followed varied in latency, duration, and polarity from one patient to the next. The initial positivity could be followed by a negative deflection of similar duration and nothing more (Fig. 5 A); or a series of progressively slower deflections might ensue (Fig. 5 B and F), with the late component having a peak latency of about 200 msec (Fig. 3 D and E). In other instances the initial positivity was followed by another having either the same (Fig. 5 C) or a longer duration (Fig. 5 D and E). These deflections were followed in turn by slower waves like those shown in Fig. 5 B and F.

Scalp and Cortical Responses Recorded Simultaneously. This was achieved in three patients. Each of the response components recorded transcortically could also be identified in the scalp records. The scalp potentials were of much smaller amplitude, and peak latency for each component differed from the corresponding wave in the transcortically recorded response (Fig. 6). Scalp responses recorded during surgery were essentially similar to those recorded pre- and postoperatively.

Effect of Selective Ablations on Somatosensory Evoked Scalp Responses. In all patients, except one who had infantile hemiplegia, a scalp response was elicited preoperatively to stimulation of either median nerve. As reported by others for normal subjects,13 responses to stimulation of the right and left

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† Initial minor negative deflection in Fig. 5 C is an exception.