Impedance and Phase Angle as a Locating Method in Human Stereotaxic Surgery*

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ROBINSON et al. have recently shown that measurement of brain tissue impedance and phase angle by means of a roving electrode is a useful method in locating deep cerebral structures in laboratory animals. They also recorded impedance and phase angle in the dead human brain. They considered the method safe and useful for human stereotaxic use.

During 1965, we recorded the impedance and phase angle of brain tissue in 65 patients undergoing stereotaxic surgery for various conditions. In this paper we report our technique and discuss the results and value of this method as a locating aid in stereotaxic surgery.

Methods

Impedance and phase angle measurements were taken in 65 patients during stereotaxic operations. Of these, 49 had Parkinson's disease, 6 had infantile cerebral palsy, 3 had myoclonic epilepsy, 2 had hemiballismus, and 2 had hereditary intention tremor. Three patients were operated upon for intractable pain. The ages of the patients varied between 8 and 69 years. The children were operated upon under general anaesthesia; the others had local anaesthesia (Citanest®). As premedication for the latter group, 5 mg. perphenazine (Trilafon®) and 50 mg cyclazine lactate (Marzine®) were administered intramuscularly 1 hour before surgery.

We used a Mundinger-Riechert stereoecephalotome. The electrode was introduced through a frontal burr hole that lay on the corona suture or slightly in front of it, and about 4 cm. lateral to the midline. The electrode was aimed at a target 15.0 to 16.5 mm. posterior to the anterior commissure, 11.0 to 12.0 mm. lateral to the midline of the 3rd ventricle, and at the level of the intercommissural line. This target corresponds to the ventral margin of the thalamus, just dorsal to the subthalamic nucleus.

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Impedance and Phase Angle Recording. The impedance and phase angle were recorded with a monopolar electrode that was constructed from a straight stimulation electrode of Mundinger-Riechert. The tip of the electrode was shortened and made thinner. It was then coated with platinum and chlorided to prevent polarization. The chloridization procedure was repeated regularly. The calotte-shaped bare tip was 0.5 mm. long and its base diameter was 1.15 mm. The area of the bare-tip surface was 1.8 mm². As an indifferent electrode we used the 4 insertion screws of the stereoecephalotome and a big lead plate which was attached to the patient's leg.

The electrode was driven into the target with a small electric motor at a constant rate of 0.47 mm./sec (Fig. 1). During the whole time of entry, the impedance and phase angle were continuously measured by means of a General Radio Company Type 1065-A impedance comparator (Fig. 2).

This apparatus is completely self-contained and it indicates directly on 2 panel meters the difference in impedance and phase angle between the unknown and a standard element. The basic circuit of the comparator is a bridge circuit with the unknown and the standard impedances serving as 2 of the bridge arms and the halves of a center-tapped transformed secondary winding serving as the other 2 arms. The bridge unbalance voltage, resulting from inequality of the standard and unknown impedances, is separated into in-phase and out-of-phase components, which are amplified and indicated directly by 2 meters reading, respectively, impedance magnitude difference in per cent and phase angle difference in radians. The apparatus makes possible the measurement of differences of 0.01%. Four different sine wave frequencies are possible, 0.1, 1, 10, and 100 kc.

Voltage across the standard and unknown in our measurements was 180 mV as read on the oscilloscope. This made a peak current density of about 42 μA/mm² of the electrode tip surface.

Both the impedance difference and the phase angle difference were continuously recorded by a Honeywell Electronik 19 recorder.

Results

Fig. 3 shows the typical impedance and phase angle records obtained with a 10 kc. frequency. The first part of the curve, corre-
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Fig. 1. Impedance and phase angle recording. The electric motor is in the surgeon's hand.

sponding to the subcortical white matter and the deep grey sulci, shows irregular variations. A fairly constant decrease of impedance and phase angle is seen where the electrode passes the caudate nucleus (c). Here the electrode may on occasion penetrate the wall of the later ventricle ("v" in Fig. 5) and the impedance abruptly decreases to the minimum. While the electrode is passing the middle of the anterior branch of the internal capsule, the impedance and phase angle rise to a maximum level. We call this peak Laitinen's peak ("ic" in the illustrations). From this point while the electrode is being introduced into the thalamic grey matter ("th"), the impedance shows a characteristic decrease that starts rising again when the electrode approaches the subthalamic white structures. In the subthalamus no general pattern of changes could be detected. With a 10 kc. frequency the impedance and phase angle curves are very similar to each other. The maximum difference in impedance magnitude between the white and grey matter was 15 to 45% and that of the phase angle 0.002 radians.

Figs. 4 and 5 show the impedance and phase angle records obtained with a 100 kc. frequency. The impedance curve is very similar to that of a 10 kc. frequency, but the phase angle record differs strikingly from the corresponding record with a 10 kc. frequency. The phase angle no longer follows the impedance variations, except where these are very abrupt, as for example when the electrode penetrates the ventricular wall (Fig. 5). The impedance magnitude variations at 100 kc. are approximately as large as those at 10 kc., while the phase angle differences usually do not exceed 0.002 radians.

Complications

Although one of the patients in this series died, no complications were noticed that could be attributed to the impedance recording procedure. The sine wave current of 10 or 100 kc. did not produce any noticeable stimulation of cerebral structures. We had earlier shown, in experiments with eggs, that this amount of current did not have any effect of heating. The time required for impedance recordings was approximately 5 minutes, so