Pulsatile Blood Flow of Gliomas Studied with Implanted Impedance Electrodes*

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Measurement of the regional blood flow through a brain tumor and the brain tissue that surrounds it is a difficult task with conventional methods. Recently, it was found that pulsating cerebral impedance recorded through intracerebral electrodes reflects cerebral circulation.1,2,4 Since April, 1966, we have implanted permanent steel wire electrodes into inoperable gliomas and surrounding tissue in seven patients. Through these electrodes it was possible to follow intracerebral impedance changes daily during the time when the patients were receiving irradiation therapy, usually a 3-month period. In this paper we shall report our recording technique, show some preliminary findings, and discuss them briefly.

Material and Method

Stereotaxic biopsy was carried out on seven patients with inoperable brain tumors. Three of these tumors were classified as astrocytomas, two as multiform glioblastomas, and one a less well-defined glioma. The biopsy specimen was aspirated through a 2.5-mm-thick cannula introduced stereotaxically. Thereafter an enamel-insulated steel wire electrode 80 µ thick was introduced through the cannula into the tumor tissue. The bare tip of the electrode was 1 mm long. The cannula was withdrawn. A similar electrode was introduced by free hand into the cortical tissue to a depth of 5 to 10 mm. Both electrodes were attached to the burr hole margin with a silk suture. Their ends emerged through the skin outside the incision wound and were left dangling on the scalp (Fig. 1). Before closure of the wound, the burr hole was covered with gelfoam or tissue cement. Usually no impedance measurements were made until 4 days later when it was assumed that electrode impedance was well stabilized.

Impedance measurements were carried out monopolarly by means of a modified Wheatstone bridge (Impedance Comparator, Type 1605-A, General Radio Company). This bridge gives a direct reading of the impedance difference between the standard and unknown circuit as a percentage of the total impedance magnitude. An oscillator frequency of 10 kc was used. As reference electrode we used two silver plates attached to the scalp. The total surface of these plates was 2500 mm. Since the tip of the intracerebral measuring electrode was only 0.25 mm, it seems justified to assume that impedance measurements refer to the immediate vicinity of the measuring electrode.

The electrodes were left in place for about 3 months during the irradiation. The patients were transported twice a week from the radiological to the neurosurgical department for impedance recordings. The electrodes caused slight crust formation at their points of exit from the skin, but no deeper

Received for publication December 4, 1967.

* This work was supported by grants from the Sigrid Jusélius Foundation and the Finnish State Medical Commission.
tissue irritation. The patients did not suffer from the electrodes in any way. At the end of the radiotherapy the electrodes were removed.

The bridge used in these recordings did not allow a simultaneous 2-channel impedance recording. Therefore all recordings shown here are consecutive. With a mechanical shift, however, it was easy to change over the recording channel at any time. At the moment we are constructing a 4-channel bridge which will make simultaneous recordings possible.

**Preliminary Findings**

We studied both impedance baseline changes and pulsatile impedance. The baseline impedance of the tumor varied from 1 to 6 kOhms. The impedance was lowest in highly vascularized malignant tumors and highest in fibrillary astrocytomas. Cortical impedance also showed large variations partly dependent on individual and localization factors, but mostly on pressure conditions exerted on the surrounding tissue by the tumor, as will be shown later. On the basis of a single measurement it seems impossible to know whether recordings come from the tumor or from the surrounding tissue. Cysts and abnormally hard tumors may constitute an exception.

The pulsatile impedance, which is caused by the pulsatory blood flow in the vicinity of the electrode tip, was found to give much information on the circulatory conditions in the tumor and the tissue around it. Normally, the intracerebral impedance pulse wave consists of a rapidly falling phase corresponding to the systole, and a rising phase corresponding to diastole. The average time lag between the R-peak of the electrocardiogram and the start of the descending phase is 213 msec. The same time lag is usually found in brain gliomas, while outside the tumor it is greatly increased (Fig. 2). Here, impedance starts rising when it should fall, and the descending phase starts about 200 msec later than in the tumor tissue. This paradoxical impedance pulse wave is a very constant finding in the brain tissue surrounding a tumor. Its cause is presumably an intracranial hypertension. The arterial ventricular cerebrospinal fluid (CSF) pressure wave arrives 70 to 100 msec after the R-peak of the electrocardiogram. If the static intracranial pressure is very high, the CSF pressure wave compresses the capillaries and empties them, as is shown by the rising impedance. The blood flow cannot begin until the pressure wave starts declining, which is about 400 msec after the R-peak. The fact that this paradoxical impedance wave was never seen inside the tumor may be because of the higher mechanical resistance of the tumor vessels. We have not yet measured experimentally what pressure is needed to produce this paradoxically delayed pulsation. The mechanism of retarded flow in the brain under high intracranial pressure may possibly be explained on the basis of our present findings.

Figure 3 shows an example of the mutual

![ECG Tumor Cortex Reg Subcut](image)

**Fig. 2. Left:** Consecutive impedance recordings from brain tumor, cerebral cortex, extracranial subcutaneous tissue, and rheoencephalography. **Right:** Recording in same patient 5 weeks later. Note the paradoxical impedance wave from the cortical tissue.