Electrical recording with micro- and macroelectrodes from the cerebellum of man

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Recently we have been exploring the therapeutic potential of stereotaxic ablation of the cerebellar dentate nucleus in man as a means of reducing hypertonicity associated with involuntary movements. At the time of the stereotaxic surgery, microelectrode recordings of the electrical activity from the cerebellar cortex and the nuclei were carried out in three patients with infantile athetosis. Recordings were also made from implanted chronic macroelectrodes prior to electrical stimulation. This report presents the method and results of recording from the human cerebellum.

Methods

Microelectrode Recording During Surgery

The patient under light flurothane anesthesia is placed in the prone position. The stereotaxic cerebellar frame is attached to the patient's head, and a pneumoencephalogram is performed to outline the fourth ventricle. A microelectrode, mounted with a micrometer, is attached to the stereotaxic frame and aligned using the stereotaxic cerebellar coordinates previously described. Movement of the micromanipulator can be read accurately to the nearest 0.5 mm. Microelectrodes (Transidyne microtrode model 405)* of 13 cm length, 0.5 mm shaft diameter, and 2μ uninsulated recording tips are used. The (direct current) resistance of the electrode dipped into a solution of 0.3 M NaCl is 100 K ohms. The electrode is connected to one side


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of the input of a Tektronix 122 preamplifier. The other side of the differential input is connected to the edge of the wound, which serves as an "indifferent" point. The output of the preamplifier is fed into a 2A63 plug-in amplifier of a Tektronix 565 oscilloscope. Recordings are stored on a magnetic tape. The passband of the amplifiers had to be limited from 80 to 6000 Hz, and additional filtering, tuned to 60 Hz, was necessary to eliminate electrical interference.

Electrical recording is started as soon as the tip of the electrode touches the cerebellar cortex. The course and position of the electrode in the cerebellum is determined by serial radiographs and by direct depth measurements from the micrometer. The electrical activity from 20 to 30 sites was recorded during two or three penetrations of the cerebellum. The same alignment used for the microelectrode can thus be directly employed for chronic electrode implantation or for the introduction of the lesion probe.

Recording from Chronic Depth Macroelectrodes

The construction, properties, and technique of the placement of the multiple contact chronic electrodes has been described in detail previously. Each electrode has six recording contacts separated by chosen distances of 1 to 3 mm. Recordings were made with the patient fully awake, asleep, and during purposeful movement of the extremities. The recordings were stored on magnetic tape, or photographed on moving film from a Tektronix 565 oscilloscope. These recordings were made in an electrically shielded room allowing a wider passband.

Results

As the microelectrode was advanced into the tissue, the recording tip regularly encountered the electrical discharge of what appeared to be clusters of several neurons. The action potentials of a single cerebellar unit were recorded less frequently. The range of amplitudes of spikes so recorded lay between 200 and 500 μV, predominantly negative. Precise measurement of voltages, or a meaningful examination of the waveform of the action potentials, was precluded by the use of filters in the recording circuit. Figure 1 A shows the electrical activity of a single cell, found close to the surface of the cerebellum. The electrode position in the cerebellum plus the large amplitude of the recorded spikes, suggested the electrical activity may be originating from a Purkinje cell. Figure 1 B illustrates the variation in the frequency of the discharge of this cell, registered with a pulse integrating rate meter. Such spontaneously occurring periodic trains of spikes were recorded from many

Fig. 1. Microelectrode recordings from the cerebellar cortex. A. Periodic bursts of unit potentials. B. Pulse integrated discharge frequency. Scale shows rate of firing as impulses/sec. Patient under fluorothene anesthesia.

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neurons of all three patients, during all four sessions of recording.

When the discharge of several cells was recorded from one site, the burst of activity in the entire cluster seemed to coincide. The periodicity did not follow either the pulse or the respiration. Some cells, however, did not show this bursting type of discharge. They fired in a more regular fashion for periods as long as 5 minutes. Movement of the extremities even under light anesthesia did not have any influence on the periodic bursting activity or the more regular continuous discharge. Bursting activity was even more pronounced in the recording shown in Fig. 2, with frequencies reaching, for brief moments, as high as 300 per sec. This cell was found at a depth of 27 mm from the surface of the cerebellum within the region of the dentate nucleus.

Again, some cells within the dentate showed just a continuous regular discharge with high frequencies (Fig. 3). Neither regularity nor the frequency of discharge was influenced by passive extremity movement. Slower waves, in the frequency range of electroencephalography, were not recorded by the microelectrodes due to the filtering used to exclude interference. These slower waves were recorded, however, with the chronic wire electrodes.

Sample recordings from the macroelectrodes are illustrated in Fig. 4. The frequency range of these waves was high, up to 150 to 300 cycles per sec (cps), as reported by others for the cerebellum of lower mammals.¹ There was no significant alteration of the wave frequency or pattern with sleep or with purposeful extremity movement. The only variation occurred with change in location of the contact point. Three distinct areas of electrical activity could be identified. The

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Fig. 2. Microelectrode recordings from the region of the cerebellar dentate nucleus. A. Periodic bursts of unit potentials. B. Pulse integrated discharge frequency. Patient under fluothane anesthesia.

Fig. 3. Continuous unit discharges from the region of the dentate nucleus. Patient under fluothane anesthesia.
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first (Fig. 4 A) was near the cortical surface, another was within what we presumed was white matter (Fig. 4 B), and the third was within the dentate nucleus (Fig. 4 C). Entrance into the region of the dentate nucleus was easily identified by the higher voltage faster activity, especially when compared to the relatively quiet preceding white matter. The cortical gray region also had much faster wave activity but this was of a lower amplitude and frequency than the nuclear region. Using several chronically implanted depth electrodes with their multiple contact points, one can plot the approximate limits of the dentate nucleus by the discrete loss of higher voltage and frequency activity of the dentate nucleus (Fig. 4 C) to a pattern we are ascribing to white matter (Fig. 4 B). The same was true with microelectrode recordings. With advancement of the electrode a long period of electrical silence presumed to be white matter was interrupted by fast unit activity similar to the pattern shown in Figs. 2 and 3. The position of the electrode on the radiograph at this point would correspond to the posterior limits of the dentate nucleus. This increase in electrical activity upon entering the dentate nucleus has been described by Zervas, et al.⁶

Electrical recording from surgical patients serves several purposes. It helps define the neuroanatomical boundaries of a specific neural region or nucleus, and becomes a diagnostic tool. Moreover, it may well contribute to basic physiological and pathological knowledge. Recordings from the macroelectrodes showed clear-cut differences in the amplitude and range of frequencies depend-

Fig. 4. Macroelectrode recordings. A. Cerebellar cortex. B. Cerebellar white matter. C. Region of the cerebellar dentate nucleus. Patient awake.
ing on the neural region under study. Exact anatomical localization of the contact points was not possible, but using stereotaxic coordinates obtained from measurements on the pneumoencephalogram a relatively precise location could be achieved. We concluded that there are two major areas of electrical activity in the cerebellum, the cortical gray and the nuclear gray. The electrical activity in the latter is of a higher frequency and voltage, which differentiates it from the region of relative electrical silence in the subcortical cerebellar white matter. By using this difference in electrical activity, the limits of the dentate nucleus can be determined.

The recording of electrical activity of individual neurons and neuron clusters was unexpectedly easy. Further information concerning neuronal activity within the cerebellum will undoubtedly aid in the understanding of dyskinetic cerebellar syndromes and the role played by the cerebellum in organizing phasic tone changes and voluntary muscle control.

We are still uncertain about the significance of the bursting activity from cerebellar neurons. Three possibilities occur to us. First, the frequency modulation may be related to the normal mode of operations of the cerebellar system. Second, it may be an expression of the pathological functioning of the cerebellum of these patients, even if the primary disease process was located elsewhere in the brain. Third, it may be the consequence of the fluothane anesthesia. Neurons in the cerebellum of healthy waking monkeys rarely exhibit similar periodicity of discharge, but regular bursting activity was seen in a special class of cells in the cerebellum of awake and freely moving cats.

Summary

We have presented a simple and successful technique for microelectrode recording within the human cerebellum. The initial results from these recordings and those from chronically implanted macroelectrodes have been shown. The recording of electrical activity is a helpful aid in confirming electrode position and will in the future provide a better understanding of normal and pathological cerebellar physiology.

References


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