STRYCHNINE SPIKE OF CENTRAL NERVOUS SYSTEM OF LOWER ANIMAL (TOAD)

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Strychnine is a convulsant being useful in the analysis of the fiber connection in the central nervous system by the strychnine spike phenomenon discovered originally by Dusser de Barenne & Mc Culloch (strychnine neuronography). The strychnine spike is commonly employed as the probe for functional connections (1). And the strychnine spike in the cerebral cortex of cat or rabbit manifests the triphasic characteristic wave being initial positive, then strong negative and last positive phase, of which originating mechanism remains obscure in spite of its wide application in the experimental studies and of which form is usually unaltered.

The purpose of the present paper is to find out the polarity of each deflection of strychnine spike which may have a relation to the activated portion.

In an attempt to clarify this unknown correspondence between the wave form of a strychnine spike and the position originating it the nervous system which is simpler in layer architecture or cytoarchitecture such as hemisphere or spinal cord of toad is used. And the nature of strychnine spike from them, described in later, will be able to give a solution for the analysis of that in higher structure as cat cortex.

EXPERIMENTAL OBSERVATION

For the purpose mentioned above, the exposed *in situ* or isolated hemisphere and spinal cord of unanaesthetized toads which presumably had no complex fiber connection and had the simpler structure of layers were used, and the oscillographic monopolar recordings from the surface of them were done when approximately 2×2 mm filter paper soaked with 2 per cent aqueous solution of strychnine nitrite was locally placed upon them or such solution was locally dropped over them. However the diffusion of the drug must not be negligible. On the strychnine spike observed in that time the study was made.

In the following the results obtained are described. A few minutes after the application the strychnine spike begins to occur. Compared with those of cat cortex, the spikes set up by the strychninization are relatively simple in form in such central nervous system of simple structure as that in toads.

Assuming that the strychnine spike revealed at the beginning is that produced by the weak stimulus of strychnine, that spike is able to be called the elementary form of strychnine spike in the hemisphere or spinal cord of toad. In detail, at the beginning of a train of evoked strychnine spikes this elementary wave of strychnine spike is a monophasic^{negative} negative wave which is consisted of a sharp linear rising phase and a relative slow concave decaying phase when that is produced in the hemisphere by the topical strychninization, and is, in the strychninized spinal cord, a rapid or slow monophasic surface-positive deflection. This elementary wave is characterized by a monophasic wave, and that of the hemisphere is surface-negative and of the spinal cord is surface-positive, therefore the polarity of a spike seems undoubtedly to be due to the region of activation. The form of this response is usually constant (Figure 1).

Figure 1.

Ink-written strychnine spikes from toad's hemisphere (upper channel), optic lobe (second channel) and spinal cord (lower two channels).

Upward deflection indicates the electronegativity and downward the positivity.

Strychnine spike of hemisphere shown in 2nd and 4th column is electronegative and that of spinal cord (3rd column) is electropositive.

During the course of observation (up to 1.5 hr. after the topical administration) the magnitude of an elementary wave of spike potential progressively increases its amplitude in the same electrical sign. This development, the growth in size, is probably due to the increase of number of the synchronized cells by gradual increase of stimulus of strychnine if this fact is a consequence of an effect of strychnine postulated by Chang (2) that strychnine increases the chance of synchronization. This enhancement of amplitude means that more cortical neurones have activated even if the effect of strychnine may be constant. The magnitude of the amplitude of a spike indicates the involved width of the site at which convulsant activity arises. In spite of the constant stimulus the response evoked varies.

In the later stage of strychnine action, when the amplitude of an elementary wave is more and more increased by presumably the synchronization of large numbers of cells, this enlarged elementary wave begins to be followed by a more prolonged wave

of opposite sign in the polarity which is usually lower magnitude in amplitude. For example, the electrode upon the spinal cord records a diphasic wave, first positive then negative. It is correct, as described in later, each phase of this diphasic spike wave has different origins regard to the position of the firing.

In more later stage the diphasic spike becomes again the monophasic wave which is more slow and has diminished in amplitude towards the end of a train. Finally they vanish (Figure 2).

Figure 2.

The progressive variation of wave form of strychnine spike.
Ink-written tracings from medulla (upper channel) and spinal cord
(lower three channels). Calibration: 0.3 mV.

DISCUSSION

It is obvious that the present report does not reveal the mechanism underlying the synchronization due to the individual impulse discharge but discloses the relation of the polarity of a spike to the site of firing of certain cells group.

Initially the effect of strychnine applied to the surface will activate less numbers of neurones of circumscribed region than those activated in later, and the recording of strychnine spike at the same time illustrates the monophasic negative wave from the surface of hemisphere and the monophasic positive one from spinal cord. It is significant that the difference of the region of nerve cells affected by strychnine reveals the difference of polarity of the basic wave. Up to the present this idea based upon the view of the position of firing is not able to be found in spite of many descriptions of the fact (1).

A general assumption in the electrophysiology that the activated region manifests more negativity of electrical potential than that in the inactive region seems to fail to explain this result since the strychnine spike is, of course, the consequence of excitation of large numbers of synchronous nervous cells.

However this difference of polarity may be determined by the anatomical relation. It is able to be supposed that when the firing nerve cells exist direct under the recording electrode the elementary wave appears as the excitation of a monophasic electronegative wave, and when the firing cells are separated by the inactive region (e.g. white matter in the spinal cord) the surface recording of the spike of spinal cord illustrates electropositive.

This conception will also be supported by the following experimental observation. As shown in Figure 3 when the spinal cord and the spinal ganglion (both are adjacent each other.) are independently recorded monopolarly, an electropositive spike of spinal cord is noticed as an electronegative (the opposite sign) monophasic spreading potential by the recording electrode placed on the spinal ganglion. And at the same time the relative size of potential diminishes. In other words the recording from the inactive region being apart from the firing region has an opposite electrical sign of activity to that of the firing region.

Figure 3.

Electropositive strychnine spikes (downward deflection) in 1st and 3rd trace illustrate the synchronous activation of spinal cord and the electronegative deflection (2nd and 4th trace) is merely the potential picked up the spinal firing at the distant spinal ganglion.

That the momentary firing of the spinal cord (strychnine spike) is recognized as an electropositive change may also be supported by the experimental observation of the steady potential of the spinal cord surface carried out by the author (3). According to that, I know a fact that the steady potential of spinal cord of lumbar portion increases its electropositivity when that portion is activated by the descendently indirect chemical stimulation. Moreover the conceptions to interpret their own results proposed by Chang (4), Tasaki et al. (5), and Sano et al. (6) support my decision of the results of polarity of activation that, in the recording by the surface electrode, the elementary wave of firing of hemisphere is electronegative and that of spinal cord is electropositive.

The fact that the elementary wave of strychnine spike is followed by the opposite phase after the development of it reveals the successively spreading of excitatory process to wider region of firing under the electrode. The enhancement of the basic wave followed by the phase of an opposite sign discloses the spreading of fired region from initially activated region to deeper or transverse region. The position of an exploring electrode related to the active-inactive region determines the polarity of the basic response. Thus the polarity of the spike potential produced by strychninization is explained with sufficient accuracy on the basis of the assumption of position of activated state to a recording electrode.

The two phases of a spike occasionally shift a little in time each other.

SUMMARY

The report on the observaion of strychnine spike in the simpler structure of lower animal like central nervous system of toad may be suggestible to the interpretation of the analysis of a characteristic triphasic spike of cat cortex.

(1) The elementary wave of strychnine spike manifests an electronegative monophasic wave where the activated region is placed directly under a recording electrode, and shows an electropositive monophasic wave where the inactive region is placed between the recording electrode and the activated region.

This elementary wave develops, and the increase in amplitude may be due to an increase in the number of cells excited, even if the stimulus with strychnine solution is constant.

(2) Accordingly when the recording electrode has picked up successively two phases of a spike of different polarities it reveals the firing of nerve cells occurred initially has spread to wider region.

(3) The developed elementary wave of strychnine spike is followed by a wave of opposite sign because of the increase of number of synchronized cells.

(4) The polarity of activation is determined by the relative position of the exploring electrode to the firing region.

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