CENTRAL REGULATION OF VESTIBULAR FUNCTION

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1. Introduction

The normal overall function of the vestibular system can be considered as the result of at least three interdependent activities:

1. Afference generated in the peripheral organ by mechanical stimulation of the hair cells which activate the afferent neurons.

2. Inhibition of the afference by efference generated in the central nervous system, to a degree depending upon the afference. The efference is transmitted along the Rasmussen bundle, terminating upon the hair cells of the peripheral organ, so reducing the transfer function between hair cell and neuron.

3. Pattern center activity generated in the central nervous system when labyrinthine stimulation has a repetitive character.

2. Afference

In the laboratory, the isolated peripheral organ shows a resting activity measurable with an electrode as a constant stream of action potentials in the transected vestibular nerve. When this isolated preparation is stimulated, as for example, on a torsion swing, the resting activity in the ampullar nerve of the lateral canal is modulated sinusoidally (Figure 1). The frequency of the action potentials rises and falls rhythmically with the movement of the swing. This response will stay the same for hours on end. There is neither adaptation nor fatigue (Groen et al., 1952; Ledoux, 1958).

3. Inhibition

If the test animal is left intact and alive, adaptation of the peripheral organ to constant stimulation can be demonstrated (Figure 2). An electrode is brought into contact with the ampullar nerve from which the nerve sheath has been partially removed, saving the artery which serves the labyrinth. If lidocaine is applied to the nerve at a point between the electrode and the central nervous system, adaptation disappears and unbridled peripheral activity, as in an isolated preparation, will be recorded. As soon as the lidocaine blockade wears off, adaptation reappears, reducing activity to its former magnitude (Goetmakers, 1968). In the frog, this reduction is considerable; the normally adapted state has one-third of the maximum, unadapted sensitivity. Under constant stimulation, sensitivity is still further reduced within two minutes to even one-tenth of its maximum value. If left alone, this extra adaptation will return to its normal value in about 5 min (Figure 3). From this, it may be concluded that there
Fig. 1. Frequency of the action potentials of a single nerve fiber preparation of the ampullar nerve of the lateral canal of a ray during a sinusoidal stimulation on a torsion swing with a period of 18.4 sec. The dotted lines represent the turning points of the swing.

Fig. 2. Adaptation phenomenon (lower trace) in the ampullar nerve of the lateral canal of a frog during sinusoidal stimulation on a torsion swing with a period of 2.5 sec (upper trace).

is an efference activity which inhibits the peripheral organ to a degree depending upon the intensity and duration of the stimulation.

Similar phenomena have been observed in the human test subject. The human appears to be in a constantly adapted state, the degree of adaptation among others depending upon previous vestibular experience (Figure 4). The inhibition responsible for this adaptation shows itself among others in shortening of duration of post-stimulatory phenomena such as nystagmus and sensation; the shorter they last the more adapted he is. Figure skaters, ballet dancers, fighter pilots and all those who submit themselves daily to intense rotational stimulation have attained the highest degree of adaptation (Figure 5). In contrast to the frog’s recuperation time of 5 min, man needs days, even weeks, to regain the normal state of adaptation. This condition