EFFECT OF LABYRINTHINE REFLEXES ON THE VEGETATIVE NERVOUS SYSTEM

—A REVIEW—

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Recently the interest in seasickness and airsickness has revived, in particular after the second World War. The chief symptoms of these sickness are vegetative disturbances such as vasomator reactions, pallor of the face, perspiration, nausea and vomiting. It is generally agreed that both seasickness and airsickness are due to abnormal excitation of the labyrinth because experiments on animals are able to demonstrate that the aforementioned vegetative symptoms are caused by the direct reflexeffect of excitation of the labyrinth.

1) Gastrointestinal reactions

The changes in tonus and movement of the stomach when nausea and vomiting are induced by labyrinthine stimulation are perfectly similra to those observed when these conditions are caused by other reflex stimuli.[1,2] Nausea is associated with relaxation of the fundus of the stomach, cessation of the antral waves, closure of the pylorus and duodenal antiperistalsis.[3,4,5,6] On the other hand, in vomiting the changes progress; there is not only closure of the pylorus but also contraction of the pyloric part of the stomach, relaxation of the fundus, inhibition of the cardia and esophagus, closure of the glottis with inhibition of respiration, stimulation and inhibition of the diaphragm and contraction of the abdominal muscles.[7,8] As a part of the nausea complex on caloric labyrinthine stimulation in human beings, contraction of the descending duodenum has been observed; it tends to expel the duodenal contents into the stomach.[9] According to these observations, absolute pylorospasm during nausea would be impossible.

On caloric or galvanic stimulation of the ear, the reflex effect from the labyrinth may be preceded or complicated by reflexes from sensory nerves of the external ear. Emotional influences may be an additional factor. It seems, for instance, questionable whether the hypoacidity and mucosal pallor observed in a patient with gastric fistula on the labyrinthine stmiulation were true reflex effects or emotional reactions.[10]

It seems that loss of the vagal impulses disturbs vomiting on labyrinthine stimulation for some time only. This is indicated by the observation that animals in which the vagus has been cut might still become seasick.

The reflex action of the labyrinth on the small intestine has been studied in rabbits.[11] Caloric stimulation of the labyrinth induced an increase of the pendular movements of the small intestine and of its tonus. Here two components were involved a short lasting reaction, elicited from the sensory nerve endings of the externaland the middle ear, and a long-lasting reaction, of vestibular origin, following theformer immediately or after a latent period of some seconds.[11] This reaction was retained after transection of the midbrain and was brought about by reflex stimulation of both vagal nerves. After elimination of the labyrinths, transitory reduction of the mobility of the stomach and intestine was found.[12]

The reflex action on the cranial autonomic nervous system is not limited to the intestinal vagus; it affects also the nerves that supply the salivary glands, i.e., centrifugal vegetative fibers joining the seventh and ninth cranial nerves. On excitation of the labyrinth increased secretion of saliva was found in dogs; this indicates a reflex influence on the bullar nuclei of the nerves of the salivary glands. These experiments were, however, limited to caloric stimulation, and the observed increase of the salivary glands that course through the middle ear (chorda tympani and tympanic nerve). It seems, therefore, important that potation may also elicit pronounced salivation in susceptible dogs.[13]

2) Respiratory reactions

Tonic labyrinthine reflexes on the respiration were observed in dogs.[14,15] Supine position inhibits the respiration in decerebrate animals, while extripation of the labyrinths abolishes this reaction. Linear accelerated movements produced in frogs first a rise of the intrapulmonary pressure and then an absence of pulmonary movements. In this second stage the larynx remains closed; however, the intrapulmonary pressure shows fluctuations that have been interpreted as due to contractions of the walls of the lungs.[16]

Rhythmic linear vertical movements and rythmic pitching movements induce an increase in the frequency and amplitude of respiration in cats and dogs.[17,18] These effects persist after extripation of the cerebral hemispheres, the thalamus and the hypothalamus. Thus respiratory reactions to vertical movements are at least partly due to brain stem reflexes. If the actibity of the respiratory center was depressed, an inhibitory reaction sometimes appeared.

A study of the effect of caloric stimulation of the ear on the bronchi rabbits, dogs and cats showed only in some instances a slight contraction.

During cold irrigation of the ear in human beings, the respiratory curve shows on regular alteration in length of inspiration and expiration. The ratio of inspiration to expiration is increased as a rule, owing to relative prolongation of inspiration.[19] During the appearance of nystagmus a typical alteration of the respiratory curve, of variable duration, has been found, namely, shortening of inspiration and prolongation of expiration. Eventually there may be a respiratory pause, lasting several seconds. The intensity of this reaction in independent of the intensity of the nystagmus and of the presence or absence of vertigo.

3) Pupillary reactions

Dilatation of the pupils was observed on cold irrigation of the external auditory meatus.[20] In appraisal of these observations two possibilities should be borne in mind. First, pupillodilator reflexes may be elicited by stimulation of the sensory nerve endings in the external auditory canal; second, not only in animals, but also in human beings the postganglionic fibers coursing to the dilator of the pupil from the superior cervical ganglion apparently come into relationship with the medial wall of the tympanic cavity and hence may be affected by caloric or galvanic stimulation of the ear.

Therefore, only rotatory stimulation is appropriate for the study of vestibular pupillary reactions. During the rotation, the vestibular stimuli induce a gradually increasing constriction; after the rotation has ended, the miosis suddenly becomes well pronounced, giving way to mydriasis, followed by hippus. This could be observed by entopic subjective observations as well as by means of an apparatus permitting an investigator standing in front of the turning in front of the turning chair to observe the pupil of a human or animal subject during all stages of the turning. The pupillary changes are brought about through transmission[21,22] of labyrinthine reflex impulses to the oculomotor nerves, chiefly by way of the medial longitudinal fasciculus, each labyrinth influencing the centers of the sphincter pupillae muscle on both sides. In the production of the hippus not only vestibular reflex impulses but also other factors seem to play a part. It is interesting that in patients with Argyll-Robertson pupils there is in the majority of cases a dissociated disturbance of the vestibular reflexes to the eye-an extinction of the vestibular reaction, with preservation of the reflexes on the external muscles of the eye.[7,23]

4) Vasomotor reactions

The some evidences that stimulation of the labyrinth leads to a vasomotor reaction are furnished by experiments in which the blood pressure in rabbits was recorded during as well as after rotation. These experiments showed that a fall of blood pressure develops in some cases during rotation and in others after rotation has ceased. The depressor reaction may be preceded by a slight rise and may also be followed by a pressor reaction, so that often a multiphase reaction presents itself. Similar reactions were observed in cats, dogs and guinea pigs on rotation around the longitudinal axis of the body as well as on rotation around the dorsoventral axis.

Vasodepressor reactions could also be observed in rabbits on mechanical stimulation of the eighth nerve and on caloric and galvanic stimulation of the labyrinth and in dogs on caloric stimulation, in the latter case without proving the vestibular origin of the reaction. The nystagmus and the fall of blood pressure do not as a rule strictly coincide; the nystagmus may outlast the depression of blood pressure but may also end earlier.

It has been repeatedly confirmed by many authors that the various types of stimulation of the labyrinth such as rotatory, galvanic and caloric methods induce fall of blood pressure.[24]

5) Peripheral receptor apparatus

After paralyzing both labyrinths by local injection of a 20 per cent cocain solution, there was no nystagmus after rotatory and after caloric stimulation as well as no vasodepressor reaction on calorization, while strong galvanic stimulation acting on the trunk of the eighth nerve still had an effect.

The action of the labyrinth on the blood pressure has been compared with that of the depressor nerve of the vagus. The reflex action of the latter nerve tends to compensate for the rise of intra-aortic pressure; it has been suggested as a working hypothesis that the vestibular nerve acts in a similar way, namely, that it tends to compensate for increases of pressure caused by stimulation of other sensory nerves on brisk movements of the head.[24]

After bilateral puncture of the round windows in cats, rotatory stimulation of the labyrinth may fail to induce nystagmus during and after rotation while a reflex depression of blood pressure can still be elicited by rotation of the body.

The vestibular depression of blood pressure was retained after transection of the midbrain, but after destruction of the nucleus triangularis it could no longer be elicited by caloric stimulation on the side of the operation. Apparently the vestibular impulses are transmitted chiefly through the nucleus triangularis to the vasomotor center in the substantia reticularis.

The depressive vasomotor effect of caloric and rotatory stimulation of the labyrinth may in a group of cases be complicated by an initial rise of blood pressure. The usual phenomenon in all of Wotzilka's cases was a fall of blood pressure (uncomplicated by the initial rise in type 2). Similar observations have been made by others. The initial rise had already been observed in some of the aforementioned experiments on rabbits; as already pointed out, this phenomenon may be increased after labyrinthectomy.

On caloric stimulation, the pressure in the retinal arteries shows biphasic reaction: an initial rise may be followed by a prolonged fall, or the pressure first falls and then rises; similar changes in the cerebral arteries may be suspected, and the state of filling of the retinal vens decreases. In seasickness it has been observed that the retinal vessels have a small diameter; the choroid may show a paleness comparable to that found in persons suffering from chronic hemorrhage.

6) Uterine reactions

The reflex action of the labyrinth on the uterus has been studied in rabbits by Tanaka, one of us.

The certain evidence that caloric or rotatory stimulation of the labyrinth leads to changes in movements of the uterus was furnished by his experiments in which the curve of uterine movements was recorded during as well as after stimulation by means of detaining double balloons. These experiments showed that frequency and amplitude of uterine movements increases in most cases and decreases in a few case. The increasing reaction may be accompanied with irregular changes, so that often a multiphase reaction presents itself, particularly during calorization. The nystagmus and the changes in uterine movements do not as a rule strictly coincide; these changes lasting for 12 to 6 minutes outlast the nystagmus. These effects persisted after extripation of the cerebral hemispheres or under general anaesthesia induced with mintal, but after labyrinthectomy or destruction of the eighth nerve on both sides they could no longer appear.

Thus these changes are at least partly due to brain stem reflex. On the basis of extirpation experiments, it would be concluded that impulses mainly from the labyrinth participate in producing the changes of tone and movements of the uterus.

Conclusions

An analysis of the symptoms associated with labyrinthine stimulation must differentiate between cortical and diencephalic reactions, on the one hand, and simple reflex effects of labyrinthine origin, on the other hand. For aforementioned vegetative reactions to labyrinthine stimulation, it has been shown that they are rhombencephalic reflexes and that the higher parts of the central nervous system are dispensable. However, corticodiencephalic impulses may modify these reactions.

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