THE EFFECT OF RADIAL ACCELERATIONS ON SALIVARY AND GASTRIC GLAND SECRETION AND ON THE PERIODIC CONTRACTIONS OF THE STOMACH

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The problem of the effect of radial accelerations on the human organism is more than 150 years old. It was first created by the use of radial accelerations in the treatment of various diseases [21], becoming a problem of great importance with the development of high-speed aviation; during both these periods, most of the research on this problem concentrated on the changes which occur in the circulatory and respiratory systems [9, 10, 12, 13, 18, 22, 23], although some research has also been done on the condition of the central nervous system [2, 14, 20]. There has, however, been hardly any investigation of the changes which occur under these conditions in the other internal organs, specifically the digestive system. There is one work [24] which indicates that certain changes in the digestive system expressed as pains in the epigastric region, loss of appetite and fatigue have appeared in many flyers who have been working for a specific period with high-speed airplanes. When these pilots were transferred to slower machines, these symptoms disappeared. No special experimental investigations have been conducted in this direction. Meanwhile, the development of jet aviation and of the problem of interplanetary communication have put the resolution of the subject problems on the agenda.

The purpose of this investigation was to study the effect of radial accelerations on secretion by the salivary and gastric glands and on the periodic contractions of the stomach.

EXPERIMENTAL METHODS

The work was performed on 6 dogs never before subjected to the action of radial accelerations. A total of 310 experiments were conducted.

We studied the effect of radial accelerations on reflex salivation induced by food (10 g of bread, 5 g of discuit) and inhibitory (10 ml of a 0.25% solution of hydrochloric acid) stimuli with three dogs (Mishka, Lis and Nochka), in which the salivary gland ducts were exposed according to D. L. Glinskii's method [3]. The unconditioned stimulus was used 4 times during the experiment at 15 minute intervals. It was used for 15 seconds each time.

Salivation was recorded for 15 minutes from the time the unconditioned stimulus was used.

Besides determining the amount of saliva secreted, we also determined the activity of the enzyme ptyalin according to the Wohlgemuth method [25] and the dense residue. The number of milliliters of a 1% solution of starch split into dextrins during a 30-minute period by 1 ml of saliva at a temperature of 38° was used as the conditional measure of amylase activity.

We used a special irrigation system (Fig. 1) to study the reflex salivation during the action of radial accelerations. When the electromagnet D was connected to the current from the accumulator A, the acid dropped from the glass vessel B into the waste pipe. It was therefore possible to regulate acid irrigation during the action of the radial accelerations.

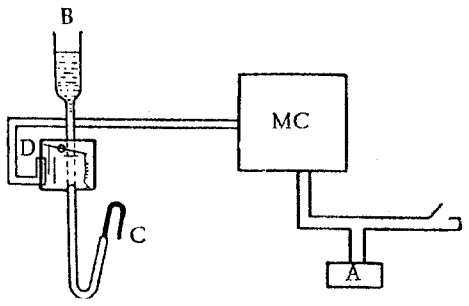

Fig. 1. Plan of irrigation system.
A) accumulator; B) glass vessel with acid; C) waste pipe; MC) mercury centrifuge receptacle.

The effect of radial accelerations on the secretion and periodic contractions of the stomach was studied on the other three dogs, two of which had Basov's gastric fistulas (Trusikha, Pegaia) and one, a Heidenhain's isolated stomach pouch (Mal'chik). The periodic contractions were recorded in the dogs with Basov's gastric fistulas by means of the usual balloon method, secretion being simultaneously observed. The experiment lasted 4 hours. Secretion was induced in the Heidenhain's isolated stomach pouch by the administration of 600 ml of milk. In this case, secretion was observed for 6 hours, starting from the time the milk was administered.

Radial accelerations were created by revolving the animals on a centrifuge 3.6 m in radius. In the experiments, we used radial accelerations * of 3-9 g in a craniocaudal direction, lasting 20 or 60 seconds and accelerations of 3-5 g in a caudocranial direction lasting 20 seconds.

A background of the glandular secretion and periodic stomach contractions was established for 1-1½ months before the experiments with the effect of the accelerations on the animals. The animals were fed a mixed diet during the experimental period and were starved for 18 hours before each experiment.

TABLE 1

Record of Experiment No. 87, Made July 27, 1957 on Dog Lis

Conduction time of experiment	Stimulus	Amount of saliva (in ml)	Remarks
16^{00}-16^{02}	Hydrochloric acid	1.3	Acid irrigation done before rotation was started
16^{02}-16^{15}	No stimulus	0.2	
16^{15}-16^{17}	Hydrochloric acid and influence of craniocaudally directed accelerations of 3 g, lasting 60 seconds	0.6	Acid irrigation begun the 15th second of the rotation period
16^{17}-16^{30}	No stimulus	0.1	
16^{30}-16^{32}	Hydrochloric acid	1.2	Acid irrigation done at rest
16^{32}-16^{45}	No stimulus	0.1	
16^{45}-16^{47}	Hydrochloric acid and influence of craniocaudally directed accelerations of 3 g, lasting 60 seconds	0.2	Acid irrigation begun the 15th second of the rotation period

EXPERIMENTAL RESULTS

The experiments studying parotid gland secretion showed a considerable inhibition of reflex salivation during the action of the craniocaudally directed radial accelerations. We included the record of an experiment performed on the dog Lis as a typical example (Table 1).

* In aviation medicine, the rate of radial accelerations is usually expressed in terms of acceleration of gravity (g), i. e. 9.81 meters per sec.^{2}, and the direction of their action is usually taken as the direction of the inertia forces. Thus when the direction is described as craniocaudal, it means that the action of the inertia forces is directed from the head towards the pelvis. This terminology is employed in this paper.

TABLE 2

Effect of Craniocaudally Directed Radial Accelerations on Secretion of Dogs' Parotid Glands

Experimental conditions / Indices of secretion	Dog Lis			Dog Nochka		
	30/X 1956	31/X 1956	1/XI 1956	20/XII 1956	22/XII 1956	24/XII 1956
	background	after* 7g accel 20 sec.		background	after* 7g accel / min.	
	bread	bread	bread	HCl	HCl	HCl
Amount of saliva (in ml) secreted with the 1st use of the unconditioned stimulus	0,4	0,2	0,4	0,6	0,1	0,6
Amount of saliva (in ml) secreted with the 2nd use of the unconditioned stimulus	0,4	0,2	0,4	0,7	0,6	0,9
Amount of saliva (in ml) secreted with the 3rd use of the unconditioned stimulus	0,4	0,4	0,5	1,0	0,5	0,8
Amount of saliva (in ml) secreted with the 4th use of the unconditioned stimulus	0,6	0,2	0,4	0,6	1,0	0,7
Amount of saliva (in ml - total for experiment)	1,8	1,0	1,7	2,9	2,2	3,0
Dense residue (in %)	0,52	0,50	0,65	0,70	0,86	1,18
Amylase (in conditional units)	0	2	0	0	4	2

* Investigation of saliva secretion began 3 minutes after the termination of rotation.

As the record shows, salivation to hydrochloric acid sharply decreased during the rotations. When the rotations were repeated, the inhibition of secretion caused was even more pronounced (about 0.2 ml of saliva, instead of the 0.6 ml secreted during the first rotations). Simiar results were observed with the other dogs.

There was a brief aftereffect (inhibition of reflex salivation) after the action of craniocaudally directed radial accelerations of 5-9 g for 20-60 seconds. Amylase appeared in the dogs' saliva with the first use of the accelerations (Table 2).

As Table 2 shows, in the October 31, 1956 experiment on the dog Lis, 0.2 ml of saliva was secreted with the first and second use of the unconditioned stimulus (3.18 minutes after rotation) after the 20-second influence

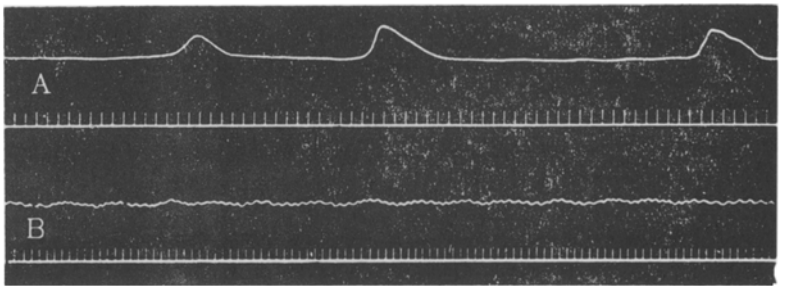

Fig. 2. Periodic contractions of the stomach in the dog Pegaia before (A) and after (B) the action of craniocaudally directed radial accelerations of 7 g for 20 seconds. Lower curves – indication of time in 3 second marks.

of 7 g radial accelerations, instead of the usual 0.4 ml observed in the experiments made before rotation. Amylase was found in the saliva. The dense residue was unchanged.

Analogous data were obtained in the experiments on the dog Nochka.

After the action of caudocranially directed accelerations, salivary inhibition was induced even by 20-second accelerations of 3 g.

Accelerations of 5 g caused a longer aftereffect (lasting about 24 hours). The duration of the aftereffect depended on the animal's type of nervous activity. The aftereffect disappeared sooner in the dogs with active nervous processes (Mishka) than in the dogs with passive nervous processes (Lis, Nochka).

Therefore, the action of radial accelerations causes acute inhibition of saliva secretion during rotation, which disappears soon after the termination of rotation. Only after the action of caudocranially directed accelerations of 5 g for 20 seconds was salivation observed to be still inhibited on the following day.

One should note that the quantitative changes in secretion caused by the first rotations were attended by the appearance of amylase in the saliva. This could indicate the presence of changes in the trophic processes. In I. P. Razenkov's laboratory, this phenomenon was observed in dogs under the influence of oxygen starvation, as when the animals were fed a primarily carbohydrate diet. It has been shown that the appearance of amylase in the saliva is connected with changes in the sympathetic innervation of the salivary glands as well as with changes

TABLE 3

Effect of Caudocranially Directed Radial Accelerations on the Secretion and Periodic Contractions of the Dog Trusikha's Stomach

Experimental conditions / Time		Background			Action of accelerations		
		date of investigation					
		14/XII 1956			19/XII 1956		
		stomach contractions	secretion from fistula (in ml)	reaction to litmus	stomach contractions	secretion from fistula (in ml)	reaction to litmus
1st hour	0—15 minutes	—	1.0	Alkali	+	0	—
	15—30 »	+	1.0	»		5 g accel/20 sec.	
	30—45 »	—	1.0	»	—	0	—
	45—60 »	—	1.0	»	—	2.5	Acid
2nd hour	0—15 minutes	—	1.0	Alkali	—	5.0	Acid
	15—30 »	—	1.0	»	—	1.5	»
	30—45 »	—	2.0	»	—	1.5	»
	45—60 »	+	0.5	»	—	1.5	»
3rd hour	0—15 minutes	—	0.5	Alkali	—	5.0	Acid
	15—30 »	—	0.5	»	—	8.0	»
	30—45 »	—	1.0	»	—	3.5	»
	45—60 »	+	1.0	»	—	3.5	»
4th hour	0—15 minutes	—	1.0	Alkali	—	5.0	Acid
	15—30 »	—	0.8	»	—	5.0	»
	30—45 »	—	0.7	»	—	5.0	»
	45—60 »	—	1.5	»	—	5.0	»

Symbols: + period of stomach contractions present; — presence of rest periods.

in the functional condition of the higher divisions of the central nervous system [5, 11, 15, 16]. One can propose that when these changes occur due to the influence of radial accelerations, they are also connected with changes in the functional conditions of the central nervous system, which are caused by hypoxia and by increased centripetal pull from various organs and tissues which are deformed during the action of the accelerations.

The second part of the work was dedicated to the study of the effect of radial accelerations on the secretion and periodic contractions of the stomach. The experiments performed for this purpose showed that the changes observed took the same general course as those observed for the salivary glands. Thus, the complete disappearance of 1-2 periods of stomach contractions was observed after the 20-second action of craniocaudally directed radial accelerations of 5-7 g (Fig. 2).

Figure 2, B, shows a typical curve recording gastric motility in the dog Pegaia after the action of 7 g acceleration.

The repeated action of accelerations of this force usually caused only a decrease in the amplitude of the stomach contractions in the first period after the rotation.

Analogous changes were observed with the action of caudocranially directed accelerations of 3 g. In these conditions, there was no change in the secretion of the empty stomach. However, 20-second, caudocranially directed accelerations of 5 g and 60-second, craniocaudally directed accelerations of 7-9 g caused the spontaneous secretion of gastric juice (Table 3).

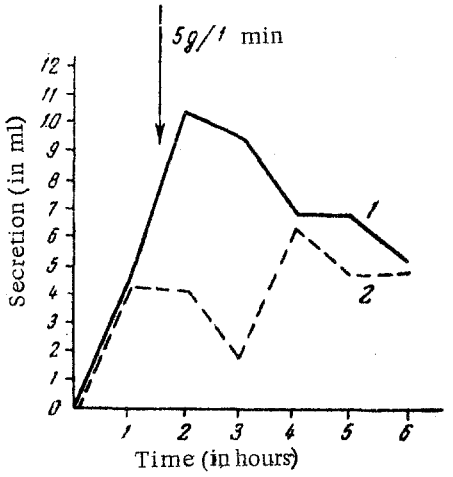

Fig. 3. Effect of 1-minute, craniocaudally directed radial accelerations of 5 g on secretion in a Heidenhain's isolated stomach pouch in an experiment on the dog Mal'chik.
1) control, 2) experiment.

As Table 3 shows, after the action of caudocranially directed accelerations of 5 g, the periodic contractions of the stomach disappeared, while profuse secretion of acid gastric juice was observed after 15 minutes. Analogous results were obtained with the 60-second action of craniocaudally directed accelerations of 7 g. Therefore, although craniocaudally directed accelerations cause hemodynamic changes opposite to those caused by caudocranially directed accelerations [19, 23], the two types of accelerations cause similar changes in the secretory and periodic activity of the stomach. The same was observed to be true of saliva secretion. This fact shows that the changes observed in the secretory and periodic activity of the stomach must be primarily due to changes in the regulatory mechanisms. The main secretory nerve of the stomach is known to be the vagus nerve [7, 8, 17]. Therefore, the development of spontaneous secretion observed with the action of the accelerations could be due primarily to stimulation of the vagus nerves. We studied the secretion in a Heidenhain's isolated stomach pouch in order to verify this proposal. We did not observe the appearance of spontaneous secretion in these experiments. Only a prolonged inhibition of juice secretion (lasting $1\frac{1}{2}$-$2\frac{1}{2}$ hours) was observed (Fig. 3).

Therefore, these results confirm the above proposal concerning the role of the vagus nerves and also indicate the presence of changes in the sympathetic nervous system (prolonged inhibition of secretion in the Heidenhain's stomach pouch); the latter also concurs with the data of other authors [1, 4, 6].

SUMMARY

The author studied the effect of radial accelerations on the secretion of parotid glands, gastric glands and on the periodic stomach contractions. Radial accelerations in the craniocaudal and caudocranial direction caused inhibition of reflex salivary secretion and of the periodic stomach contractions. A spontaneous secretion of the gastric juice was noted in high accelerations in dogs with a Basov stomach fistula. Disturbance

of the parasympathetic innervation in a dog with an isolated Heidenhain's stomach pouch resulted in the absence of spontaneous gastric secretion. However, a prolonged inhibition of gastric secretion was noted in these conditions. It is assumed that the changes described above are connected with changes in the nervous system, particularly in its parasympathetic and sympathetic portions.

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