EFFECTS OF STIMULATION OF THE PHRENIC NERVE ON THE MOVEMENTS OF THE STOMACH AND SMALL INTESTINE

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In our previous investigation (NAKAYAMA and MORI, 1967) on the reflex responses by distention of the gall bladder and biliary tracts on the movements of the stomach and small intestine, it was reported that afferent pathways from the gall bladder and biliary tracts may be contained in the thoracic and lumbar splanchnic nerves. Recently HAZARIKA et al. (1964) have found that the sensory nerve fibers from the gall bladder enter the spinal cord not only through the dorsal roots of the 2nd to the 10th thoracic segments but also through the phrenic nerves. It has been verified by some investigators that the phrenic nerve receives the sensory nerves from the diaphragmatic peritoneum (DAVIS and POLLOCK, 1936; LITTLE and MCSWINEY, 1938; HINSEY and PHILLIP, 1940), and the reflex responses to stimulation of the phrenic nerve on the pupils (LITTLE and MCSWINEY, 1938), bronchus (THORNTON, 1937), blood vessels or blood pressure (SCHREIBER, 1883; GREENE, 1935) were investigated.

The present communication deals with the reflex responses on the movements of the stomach and small intestine produced by electric stimulation of the central cut end of the phrenic nerve.

METHODS

Dogs anesthetized by intravenous injection of pentobarbital sodium (15-25 mg/kg) were used and a few of animals were decerebrated at the level of the midcolliculus. The movements of the stomach and the small intestine (duodenum or jejunum) were recorded by means of the balloon-water manometer system on a smoked paper. The right phrenic nerve was cut at the neck or just above the diaphragm under artificial respiration and its central cut end was electrically stimulated. The parameters of the electric stimulus were the square wave of 2 msec in duration, 10 to 20 c/sec in frequency and 5 to 10 volts in intensity. To prevent motions of animals produced by stimulation of the nerve, gallamine (1-2 mg/kg) was intravenously administered and throughout the experiment the artificial respiration was persisted.

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RESULTS

The electric stimulation of the central cut end of the phrenic nerve caused an augmentation of the gastric movements (Fig. 1A), which was in general more remarkable at the initial stage of the stimulation or was transient (Fig. 4A), while the augmentation of the movements of the small intestine was generally less remarkable than that of the stomach or not always observable.

Fig. 1. Effects of stimulation of the phrenic nerve on the gastric and jejunal movements. The tracings from above downwards are the gastric (S), jejunal movements (J), signal of stimulation and time in 6 sec. In A, the vagus and splanchnic nerves were intact, in B, bilateral cervical vagi were cut and in C, bilateral thoracic splanchnic nerves were severed in addition.

After severing the bilateral cervical vagus nerves the augmentation of the movements of the stomach and small intestine was not abolished, although it became less marked than that before the severance (Fig. 1B). When, after the vagotomy, the bilateral thoracic splanchnic nerves were severed the augmentation due to the stimulation of the phrenic nerve was completely abolished (Fig. 1C).

In one case of the experiments, after cutting the bilateral thoracic splanchnic nerves the stimulation of the phrenic nerve produced an augmentation of the gastric and duodenal movements (Fig. 2B) and the augmentation was completely abolished by severing the bilateral cervical vagus nerves in addition (Fig. 2C). Such excitatory effects were also observed in the decerebrated dogs (Fig. 3A and 6A).

From the results described above it is evident that the efferent pathways
FIG. 2. Effects of stimulation of the phrenic nerve on the movements of the stomach and duodenum. In A, all nerves were intact, in B and C, bilateral thoracic splanchnic and cervical vagus nerves were severed respectively. S: gastric movements; D: duodenal movements. Time in 6 sec.

responsible for the excitation of the gastrointestinal movements to the stimulation of the phrenic nerve pass through the vagus as well as the thoracic splanchnic nerves, and that the excitatory center responsible for the splanchnic excitatory response is located below the inferior colliculus of the midbrain. But after the spinal cord was transected at the level of the C3, the excitatory response via the splanchnic nerves was completely abolished (Fig. 4). It is supposed that the afferent impulses of the phrenic nerve enter the spinal cord via the dorsal roots of the 5th and 6th cervical segments and ascend up to the medulla oblongata, without descending directly down to the thoracic segments.

When atropine was intravenously administered to dogs whose vagus nerves had previously been severed, the excitatory effect produced by stimulation of the phrenic nerve was remarkably reduced (Fig. 5) or completely abolished (Fig. 6). These facts reveal that the augmentation of the gastrointestinal movements is associated with the cholinergic fibers contained in the thoracic splanchnic nerves.
FIG. 3. Effects of stimulation of the phrenic nerve on the gastric and duodenal movements in the decerebrated dog. In A, all nerves were intact and in B, severing bilateral vagi did not abolish the reflex effect, while the stimulation of the phrenic nerve did not cause the change of the blood pressure of femoral artery. S: gastric movements; D: duodenal movements; B.P.: blood pressure of femoral artery. Time in 6 sec.

DISCUSSION

It has been supposed that the phrenic nerve contains the sensory nerves from the gall bladder, pancreas, diaphragmatic peritoneum. From the results described above it may be concluded that the stimulation of these sensory nerves affects the vagus nuclei in the medulla oblongata and an unknown excitatory center located between the inferior colliculus and medulla oblongata, resulting in the excitation of movements of the stomach and small intestine via the vagus as well as the thoracic splanchnic nerves.

Many investigators have presumed that the thoracic splanchnic...
Fig. 4. Effects of transection of the spinal cord on the excitatory response of the gastric movements to stimulation of the splanchnic nerve. In A, the spinal cord, vagus and splanchnic nerves were intact, in B, bilateral cervical vagus nerves were cut and in C, after the spinal cord was transected at the level of C3, the excitation of the gastric movements was completely abolished. Time in 6 sec.

Fig. 5. Effects of stimulation of the phrenic nerve on the gastric movements. In A, all nerves were intact, in B, bilateral vagi were severed and atropine sulphate (0.4 mg/kg) was intravenously injected (At), and in C, 4 minutes after atropinization the excitatory effect was remarkably reduced. Time in 6 sec.
FIG. 6. Effects of stimulation of the phrenic nerve on the gastric movements. Decerebrated dog. In A, the bilateral cervical nerves were severed, in B, 4 minutes after intravenous injection of atropine (0.2 mg/kg) the excitatory effect was completely abolished. Time in 6 sec.

nerves contain the inhibitory as well as the excitatory nerve fibers to the movements of the stomach and small intestine. In the present experiments it has been demonstrated that the administration of atropine reduced or abolished the excitatory effect. Therefore, it may be presumed that the splanchnic excitatory effect produced by stimulation of the phrenic nerve is due to the cholinergic fibers contained in the thoracic splanchnic nerves.

SUMMARY

1. Effects of stimulation of the central cut end of the phrenic nerve on the movements of the stomach and small intestine were investigated in dogs anesthetized with pentobarbital sodium and in the decerebrated or spinal dogs. The movements of the stomach and small intestine were recorded by means of the balloon method. The right phrenic nerve was electrically stimulated at the neck or just above the diaphragm under artificial respiration.

2. The stimulation of the phrenic nerve produced an augmentation of the gastrointestinal movements. The excitatory effects still persisted even after severing the bilateral vagus nerves, and after the severance of the bilateral thoracic splanchnic nerves, the excitatory effects were completely abolished.
In one case, the severance of the bilateral thoracic splanchnic nerves did not much change the excitatory effect, but on cutting the bilateral cervical vagus nerves they were completely abolished.

3. In dogs decerebrated at the level of the midcolliculus, the excitatory effects similar to those observed in (2) were also obtained. These effects were abolished when the spinal cord was transected at the level of C3 following the severance of bilateral cervical vagi.

4. It may be concluded that the excitation of the gastrointestinal movements produced by stimulation of the phrenic nerve is elicited via the vagus as well as the thoracic splanchnic nerves, and that one of the reflex centers is the vagus nuclei in the medulla oblongata and another is an unknown excitatory center located between the inferior colliculus and medulla oblongata.

REFERENCES


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