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# PATHOMECHANISM OF INTESTINAL METEORISM

## I. THE COMPOSITION OF INTESTINAL GAS IN PARALYTIC ILEUS

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The origin of flatulence gas in paralytic ileus remains unknown till now. The composition of intestinal flatulence gas in paralytic ileus was examined and compared with the composition of the intestinal gas accumulating in mechanical ileus. An examination of the intestinal gas composition was carried out in dogs, divided into 2 groups; the first group involved animals, in which fecal peritonitis was produced; to the second group belonged animals, in which peritonitis was caused by pancreatic necrosis. The following conclusions were drawn from this experimental work: 1) the composition of intestinal flatulence gas in paralytic ileus, caused by bacterial peritonitis in dogs differs from the composition of intestinal gas in mechanical ileus; 2) intestinal gas filling the small intestine in mechanical ileus contains a strikingly high amount of carbon dioxide and hydrogen.

During the observation of patients dying of peritonitis the impression is sometimes gained that their death is equally due to peritonitis and paralytic ileus.

It is generally assumed that paralytic ileus appearing in the course of peritonitis is a result of toxic, infectious or reflexly induced irritation with stimulation of the intramural autonomic ganglia which results secondarily in a decrease of the tonus of the intestinal smooth muscles. This decrease augments the appearance of meteorism which in turn gives rise to the generally known vicious circle of disturbances.

In the mechanical ileus the gas in the distended intestine came there mainly through swallowing (8). The origin of the gas in paralytic ileus is not yet well known. It is also not known how the accumulation of gas in the intestinal lumen occurs and in connection with this the problem arises of the composition of the gas in the distended intestine in paralytic ileus and of the possible differences between this composition and that of the gas accumulating in the intestine in mechanical ileus. It was our intention to study this problem experimentally with the following methods:

a) experiments after the classical method of Wangensteen (12) with analysis of the gas in mechanical ileus;

b) studies of the composition of the gas in the distended intestine in the course of peritonitis and paralytic ileus in experimental animals.

## EXPERIMENTS

Experiments were carried out on 30 mongrel dogs of 15—22 kg body weight. All the dogs were starved for 24 hours prior to the experiment in order that on the day of the investigation their intestines should be as empty as possible. Most difficulties were encountered in the production of meteorism in dogs because in these animals, during peritonitis, meteorism most often does not appear. Only after repeated attempts did it become clear that in dog, meteorism of a degree sufficient for the study of the composition of the gas, can be evoked only in those animals in which peritonitis is produced along with vagotomy. Peritonitis was produced with 2 methods: non-bacterial peritonitis was evoked by producing acute pancreatic necrosis through injecting 5—8 ml of 96% alcohol under the capsule, and bacterial peritonitis was produced through ligating a small part of the lateral wall of the cecum with resulting necrosis. Subphrenic vagotomy was performed on all animals. Both these methods appeared effective and peritonitis with meteorism occurred already within 24 hours. During repeated laparotomy after 24—48 hours from the first operation it was found that the stomach of the operated animals was usually much enlarged and filled with liquid and gas. The amount of gas in the small intestine was always sufficient to carry out qualitative and quantitative determinations.

Our experiments were performed on 6 groups.

In group I comprising 8 dogs the experiments were carried out according to the classical method of Wangensteen these animals serving as a control group. In 4 dogs occlusion of the intestine was produced in its peripheral segment and in 4 other dogs the same procedure was preceded by ligation of the esophagus in its neck segment.

In group II meteorism was produced with vagotomy and with pancreatic necrosis in 8 dogs. Laparotomy was repeated after 24 hours and the gas present in the small intestine was taken for investigation. The amount of gas was carefully determined.

In the 6 dogs of group III meteorism was produced similarly as in group II and ligation of the esophagus was performed simultaneously to prevent the dogs from swallowing air. After 24 hours the amount of gas in the intestine was determined similarly as in group II.

In the 5 dogs of group IV meteorism was produced as in group II (with vagotomy and pancreatic necrosis). The dogs were operated upon after 24 hours and the gas was taken from the distended intestine to carry out detailed qualitative and quantitative studies.

In the 11 dogs of group V vagotomy was performed and part of the cecal wall was ligated also to cause stercoral peritonitis. Similarly as in group IV gas was taken after 24 hours and studied similarly.

In the 3 dogs of group VI meteorism was evoked similarly as in group V with simultaneous ligation of the esophagus. During the second laparotomy after 24 hours about 100 ml of gas were taken for determinations from the peripheral segment of the intestine.

The composition of the intestinal gas was studied at the Department of Inorganic Chemistry Technology of the Warsaw Polytechnic School. The method of investigation was adapted to the simultaneous presence of the following components in the gas: $H_2S$, $CO_2$, CO, $O_2$, $H_2$, $CH_4$, $N_2$. An apparatus was devised to make possible two manipulations: 1. absorption, 2. combustion. The components $H_2S$, $CO_2$, CO, $O_2$ were determined with absorption in the following fluids: $H_2S$ in 0·05 n $I_2$ solution, $CO_2$ in 28% water solution of KOH, $O_2$ in a solution of pyrogallol: 1 g of pyrogallol, 1·5 g of KOH, 5 g of water. CO was determined in a ammoniacal solution of $Cu_2Cl_2$.

The components $H_2$, CO, $CH_4$ were determined by means of combustion on CuO at 600°. Trace amounts of $H_2S$ were additionally determined with lead paper. The combustion gases containing carbon atoms in their molecule were determined by means of absorption of their remnants after combustion in a 28% KOH solution. Mercury was used as the closing fluid. The accuracy of the determination with this method and this apparatus was $\pm 0{\cdot}5\%$. The minimal amount of gas taken for analysis was 40 ml.

## RESULTS

In group I, in the dogs with mechanical occlusion caused by simple ligation of the peripheral part of the intestine without ligation of the esophagus fairly large amounts of gas were found in the intestine (40—250 ml) together with a certain amount of fluid (50—350 ml). In the dogs with mechanical occlusion with preceding ligation of the neck portion of the esophagus a small amount of gas (20—60 ml) and fairly much fluid (320—500 ml) were found in the post-mortem examination.

In group II in which the mean volume of gas appearing in our experiments was determined its total volume ranged from 60 to over 2000 ml, averaging 200—400 ml.

In group III in the dogs with experimentally induced paralytic ileus and with a ligated esophagus this volume ranged from 40 ml to 90 ml, on the average 66 ml.

In group IV (pancreatic necrosis with vagotomy) the analysis of gases from the distended intestine showed on the average trace amounts of $H_2S$, 5·46% of $CO_2$, 8·96% of $O_2$, 4·1% of $H_2$, 8·37% of $N_2$.

Table I

| Mean | Amount of gas | Amount of fluid |
|---|---|---|
| Mechanical ileus (ieiunum) esophagus non-ligated | 40—250 ml | 50—350 ml |
| Mechanical ileus (ieiunum) esophagus ligated in cervical portion | 20— 60 ml | 320—500 ml |

Table II (group II and III)

| | Amount of gas in ml |
|---|---|
| Paralytic ileus | 60—2000 |
| (pancreatic necrosis) | mean 200 |
| Paralytic ileus | 40—90 |
| (pancreatic necrosis with ligation of esophagus) | on the average 66 ml |

Table III

Composition of gas in the intestine in group IV

| No. | Dog No. | $H_2S$ | $CO_2$ | $O_2$ | $H_2$ | $CH_4$ | $N_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 98 | trace | trace | 17·0 | — | — | 83·0 |
| 2 | 34 | — | 1·5 | 18·5 | — | — | 80·0 |
| 3 | 198 | 0·55 | 7·9 | 7·0 | 0·7 | — | 83·9 |
| 4 | 199 | trace | 7·8 | 2·3 | 18·3 | — | 71·6 |
| 5 | 206 | — | 10·1 | — | 1·5 | — | 88·4 |
| On the average | | trace | 5·5 | 9·0 | 4·1 | — | 81·4 |

In group V (Table IV) an unexpectedly large amount of $H_2S$ (1·27%) was found, a markedly larger amount of $CO_2$ (13·47%) than in group IV and a smaller amount of $O_2$ (1·79%). The $H_2$ content was also very high (9·09%).

In group VI (Table V) in dogs with bacterial peritonitis and vagotomy and with a ligated esophagus the composition of the gases differed markedly from

Table IV

Composition of gases in the intestine in group V

| No. | Dog No. | $H_2S$ | $CO_2$ | $O_2$ | $H_2$ | $CH_4$ | $N_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 131 | 1·4 | 30·1 | 1·0 | 3·6 | 0·45 | 63·45 |
| 2 | 144 | 1·6 | 17·3 | 3·6 | 7·2 | — | 70·3 |
| 3 | 151 | 1·0 | 12·8 | 1·4 | 5·9 | — | 78·9 |
| 4 | 152 | 0·95 | 8·35 | 1·85 | 17·9 | — | 71·15 |
| 5 | 168 | 1·6 | 8·67 | 3·39 | 4·2 | — | 82·14 |
| 6 | 167 | 0·4 | 10·9 | — | — | — | 89·1 |
| 7 | 146 | 0·6 | 8·06 | 2·5 | 4·4 | — | 84·5 |
| 8 | 192 | 1·5 | 19·7 | — | 42·0 | — | 36·8 |
| 9 | 193 | 0·5 | 10·1 | 5·9 | 9·2 | — | 74·3 |
| 10 | 196 | 0·9 | 10·5 | — | 3·8 | — | 84·8 |
| 11 | 197 | 0·85 | 8·4 | — | 0·75 | — | 90·0 |
| On the average | | 1·27 | 13·47 | 1·79 | 9·09 | — | 71·41 |

Table V

Composition of gases in the intestine in group VI

| No. | Dog No. | $H_2S$ | $CO_2$ | $O_2$ | $H_2$ | $CH_4$ | $N_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 137 | — | 13·8 | — | 18·0 | — | 68·2 |
| 2 | 207 | — | 16·1 | — | 26·6 | — | 57·3 |
| 3 | 209 | — | 31·0 | 1·5 | 17·0 | — | 50·5 |
| On the average | | — | 20·26 | 0·5 | 20·5 | — | 58·7 |

Table VI

Composition of gases in intestine in cases of paralytic ileus (means from tables III—V)

| | $H_2S$ | $CO_2$ | $O_2$ | $H_2$ | $CH_4$ | $N_2$ |
|---|---|---|---|---|---|---|
| Fecal peritonitis | 1·27 | 13·47 | 1·79 | 9·09 | — | 71·41 |
| Peritonitis in pancreatic necrosis | trace | 5·5 | 9·0 | 4·1 | — | 81·4 |
| Fecal peritonitis in dogs with ligated esophagus | — | 20·26 | 0·5 | 20·5 | — | 58·7 |

that of the other groups. Even trace amounts of $H_2S$ could not be found, and the content of $O_2$ was minimal (0·5%). On the other hand almost half these gases formed $CO_2$ (20·26%) with $H_2$ (20·5%).

## DISCUSSION

In 1931 *Wangensteen* carrying out experiments on the systemic disturbances developing during experimental mechanical intestinal occlusion suggested that the most important or one of the most important causes of death of the animal is meteorism. He thought that the gas (and afterwards also the fluid) accumulating in the distended intestine gives rise to the development of a vicious circle of disturbances with compression of the vessels in the intestinal wall, which in turn causes edema, increased exudation, increasing meteorism and progressively impaired trophic condition of the intestine. Studies on the gas causing meteorism in experimental mechanical intestinal occlusion showed (*Hibbard* 1936) that this gas has, on the average, a fairly characteristic composition.

Table VII

| Small intestine | |
|---|---|
| $N_2$ | 70·0% |
| $CO_2$ | 6— 9% |
| $O_2$ | 10—20% |
| $H_2$ | 1— 3% |
| $CH_4$ | 0— 1% |
| $H_2S$ | 1—10% |

Table VIII

| Large intestine | |
|---|---|
| $N_2$ | 80·0% |
| $O_2$ | 30·0% |
| $CO_2$ | 7·5% |
| $CH_4$ | 0·8% |

Such investigations were also carried out by other authors (8, 2). Their results are in general approximately the same as the ones presented above and in all investigations the composition of the gas present in the intestine during ileus closely resembles that of air. A striking finding, similarly as in the investigations of *Wangensteen*, was the presence of some $H_2$ (up to 5%) and very small amounts of $CH_4$ along with varying amounts of $H_2S$ little of which, however, was found in most investigations. $H_2S$ is an easily soluble gas and its concentration in the blood is very slight, possibly it is so swiftly removed from the blood that it is impossible to be found in large concentrations.

Taking into consideration the composition of the gases in the intestine during ileus *Wangensteen* supposed that it was mostly the composed of air which had been swallowed by the animals. He was able to prove it with generally known experiments which permitted him to establish that the gas causing the distension of the intestine above the occlusion was in 68% the gas which had been swallowed into the esophagus, in 22% it penetrated from the blood and in 10% was formed within the intestine due to fermentation and putrefaction.

The gases penetrating into the intestine from the blood and the gases formed within the intestine (up to 32%) may have a different origin. They may be the products of the action of the intestinal succus, of the enzymatic digestion of food and bacterial fermentation and of the putrefaction of foodstuffs. $CO_2$ appears from the bacterial fermentation of starch, sugars and cellulose in the terminal part of the intestine, so that for example 100 g of cellulose give 19 l of $CO_2$, 7·5 l of $CH_4$ and 4l of $H_2$. $H_2S$ and $NH_3$ are formed in only minute amounts and mainly in the large intestine depending on the diet.

Certain authors believe that the gases may be actively secreted by the intestinal mucosa and may penetrate into the intestinal lumen according to the physical properties of the gases. A mixture of these gases was introduced intraperitoneally, intrapleurally or into the intestine and after a certain time it was found that for example the concentration of $CO_2$ and $O_2$ balanced the concentration of these gases in the blood (5, 2). The only gases which could penetrate from the blood into the intestine were $CO_2$, $O_2$ and $N_2$. However, the partial pressure of oxygen and carbon dioxide is so small and the rate of diffusion of nitrogen is so low that it is difficult to suppose from a physical standpoint that the diffusion of these gases could play a role in the pathomechanism of meteorism. Because of this the mechanism of the penetration of gases from the blood into the intestine in ileus must be different.

In this work the problem of the paralytic ileus was studied in a more detailed fashion because a method was sought which would diminish the meteorism in this condition. Clinical experience shows that relieving the distended intestine in the paralytic ileus through an intestinal fistula or through Miller-Abbott's tube does not interrupt the vicious circle. There is also no relief after the administration of drugs stimulating the motor function of the intestine (physostigmine). In this state of affairs the idea was conceived that if external measures cannot remove the gas as long as the motor function of the intestine is not restored the intestinal gas might possibly be exchanged for another which could more easily diffuse from the occluded intestine. Judging by the experimental investigations carried out so far this assumption seems possible because the diffusion of gases from the intestine into the blood is relatively well known at present. It has been shown on animals that twenty times more intestinal gas in excreted through the lungs than through the rectum. The solubility of various intestinal gases was also studied (5, 2) and their absorption coefficients were determined. In an isolated closed intestinal loop of the experimental animal these coefficients according to *Mc Iver* are: $N_2$ 1·5 ml/hour, $CH_4$ 5 ml/hour, $H_2$ 7 ml/hour, $O_2$ 18 ml/hour, $H_2S$ 69 ml/hour, $CO_2$ 160 ml/hour. The speed of diffusion of these gases into the blood according to *Anderson* is (adopting $N_2$ as 1): for $O_2$ 1·8, $CH_4$ 2·5, $H_2$ 5, $CO_2$ 35, $H_2O$ 130.

The diffusion of hydrogen, methane and hydrogen sulfide from the healthy intestine into the blood and air is very rapid because the partial pressure of the gases in the blood is very low. On the other hand nitrogen and carbon dioxide diffuse more rapidly than would result from the laws of physics because these gases are not only soluble in the blood but have their place into chemical reactions with hemoglobin.

Practically the most important is nitrogen because of its large particle, its small diffusibility and its high partial pressure in the blood into which it penetrates slowly. Our studies only answer the question, whether the composition of gases in paralytic ileus is the same as in mechanical ileus and whether the composition of this gas resembles that of air.

Group IV of our studies shows that the gas present in the intestine of the animals with paralytic ileus due to pancreatic necrosis and to vagotomy very much resembles air because its average composition is: $CO_2$ 5·42%, $O_2$ 8·96%, $H_2$ 4%, $H_2S$ — trace amount, $N_2$ about 81·37%. This gas closely resembles the gas encountered in the experimental investigations on mechanical ileus.

In group V (fecal peritonitis) the gas taken from the distended intestine contained much more $CO_2$ than that in mechanical ileus, the hydrogen content was also greater. The average composition of this gas was: $CO_2$ 13·4%, $H_2$ 9·1%, $H_2S$ 1·3%, $O_2$ 1·8%. This composition differed considerably from that of the gas in paralytic ileus. Our studies have given no answer to the question, what is the cause of this composition of the gas. Possibly it was the highly increased activity of the bacteria whose growth under the influence of an inflammatory process on the outside of the gut caused such distinct changes in the composition of the gases. This requires further investigation in future work.

In group VI in which the experimental procedure was the same as in group V and in which the esophagus had been ligated to prevent swallowing gas, the composition of the gas in all the experiments differed greatly, from $H_2$ and $CO_2$ over 20%. This shows that in meteorism due to paralytic ileus in bacterial peritonitis the prevention of air flow from outside causes the composition of the gases to differ distinctly from the one in mechanical ileus.

## CONCLUSIONS

1. In meteorism present in paralytic ileus due to bacterial peritonitis in the dogs the composition of the gases in the distended intestine differs from the one in mechanical ileus.

2. In paralytic ileus the gas filling the smal intestine contains strikingly much $CO_2$ and $H_2$.

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