Gastric Gas Analysis in the Canine Gastric Dilatation-Volvulus Syndrome

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The concentrations of N_2, O_2, CO_2, H_2, and CH_4 were measured in stomach gas samples obtained from seven clinical cases of canine gastric dilatation-volvulus. All gas concentrations except O_2 and CO_2 were similar to atmospheric air. The origin of the gastric gas, its components, and its etiological implications are discussed.

Introduction

The predisposing causes of canine gastric dilatation-volvulus remain undetermined. Many theories have been proposed to explain sources of the gas in gastric dilatation. Among these, aerophagia, fermentation-putrefaction, chemical gas genesis, and gas diffusion have been suggested.

Aerophagia was found to be the main source of gastrointestinal gas in the normal animal.[4,6,7,11,12,14,19,20] Gas ratios and concentrations from the upper gastrointestinal tract of normal dogs were similar to those of atmospheric air.[7] Evidence supporting aerophagia as the source of gastric gas has been derived from studies in intestinal obstruction. Analysis of the gas accumulating proximal to obstructed intestines revealed high concentrations of N_2 and small quantities of CO_2, H_2, and CH_4.[7] Nitrogen is not produced within the intestinal lumen and probably results from swallowing air.[7,19] Further evidence to support the aerophagia hypothesis was demonstrated by ligation of the esophagus. This prevented gas distention proximal to an obstructed intestine.[19] In man, aerophagia results from excessive air swallowing associated with emotional disturbances, nausea, rapid eating, and habitually induced belching.[14]

Fermentation-putrefaction has been suggested as the source of stomach gas observed in the gastric dilatation-volvulus syndrome.[2,4,7,17,18] Bacterial metabolism may result in liberation of CO_2, CH_4 and H_2.[3,8,9,10] Many bacteria are capable of producing these gases, but Clostridia organisms are thought to be the main source in the dog.[15] In one study, gas-producing *Clostridia sp* were isolated from the gastric contents of dogs with gastric dilatation at necropsy.[18] Hydrogen and CH_4 concentrations were not evaluated.[18]

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Chemical gas genesis and gas diffusion have not been considered causes of gastric dilatation, but these processes do contribute to concentrations of gastrointestinal gases.[1,4,7,10,18] Although the contribution is thought to be negligible, significant amounts of CO_2 can be generated by the reaction of acid and bicarbonate.

Essentially all gastrointestinal gas can be accounted for by analysis of N_2, O_2, CO_2, H_2 and CH_4.[7,8,10] It has been generally assumed that most gastric N_2 is a result of aerophagia.[7,8,10] However, an appreciable amount of N_2 could enter the gut lumen by diffusion as a result of the concentration gradient created by chemical formation of CO_2.[1,7,10,15] Present experimental techniques can not differentiate swallowed and diffused N_2.

Oxygen concentrations within the gastrointestinal tract are related to partial pressures of other gases and utilization of O_2 by bacterial flora.[8,10,16] It has been assumed that O_2 plays a passive role and its concentration is relative to the concentration of other gases. The source of O_2 is thought to be atmospheric air.[8,10,18] Oxygen concentrations are highest in the stomach and lowest in the colon.

Carbon dioxide, like H_2 and CH_4, is produced by fermentation reactions. Large quantities of CO_2 result from the chemical reaction between sodium bicarbonate and hydrochloric acid.[7,10,15] Reaction between acid and bicarbonate releases 22.4 ml of CO_2 for each mEq of bicarbonate consumed in the reaction.[15]

There is no known mammalian cellular metabolic pathway for the production of H_2 or CH_4. These gases are produced solely as the result of bacterial metabolism.[3,8,8,10] Large quantities are produced when bacteria are supplied with a fermentable substrate. Experimental studies in the dog have shown that on bean substrate diets intestinal bacterial activity can result in H_2 concentrations as high as 53%. Although intestinal CH_4 concentrations have not been measured in the dog, similar studies in man showed concentrations as high as 27% to 33.6%.[3,11]

Methods and Materials

Gas samples were obtained from dogs presented to the University of Minnesota Small Animal Clinic with gastric dilatation-volvulus. The clinical signs observed included abdominal tenderness, abdominal distention, unproductive vomiting, and shock. The diagnosis was made on the basis of history and physical findings, and in six of the seven dogs, the diagnosis was confirmed by surgery.

Table 1

Clinical Data

Case	Breed	Sex	Age	Gastroesophageal Rotation at Surgery
A	Great Dane	F	8 yr	180°
B	Great Dane	F	5 yr	180°
C	Great Dane	F	9 yr	*
D	Great Dane	F	5 yr	90°
E	Great Dane	M	2 yr	360°
F	Great Dane	F	4 yr	90°
G	French Briard	M	7 yr	90°

**Decompression and correction by stomach tube.*

Gas samples were obtained by percutaneous aspiration. A small area was clipped and the skin was surgically prepared on the left side behind the last rib. A 50 cc plastic syringe with attached three-way stopcock and 18 gauge 1½ inch needle was used. The three-way stopcock was closed to seal the syringe while the needle was still in the stomach. All samples were refrigerated and analyzed within an eight-hour period.

All samples were passed through an anhydrous calcium sulfate gas drying unit[a] for dehydration prior to analysis. Analysis of all gases, except CO_2, was performed with a gas chromatograph[b] equipped with a molecular sieve column and automatic sampler. Methane was identified using a hydrogen flame detector. The instrument was standardized with room air for O_2 and N_2. A special tank standard was used for H_2 and CH_4. A thermal conductivity detector was used to identify N_2, O_2 and H_2 concentrations. Carbon dioxide values were determined on a blood gas analyzer.[c] Values were reported as pCO_2 and converted to percent CO_2 by the equation

$$\frac{pCO_2}{\text{Atmospheric Pressure (mmHg)}} \times 100.$$

Results

Our findings are based on evaluation of gas samples taken from clinical cases with acute gastric dilatation and tympany [Table 1]. Seven stomach gas samples were analyzed and concentrations of N_2, O_2, CO_2, H_2 and CH_4 were obtained [Table 2]. The sum of

[a] Drierite, W.A. Hammond Drierite Co., Xenia, OH.

[b] Gas chromatograph model GC-5, Beckman Instruments, Inc., Palo Alto, CA.

[c] Blood gas analyzer model 113, Instrumentation Laboratories, Inc., Watertown, MA.

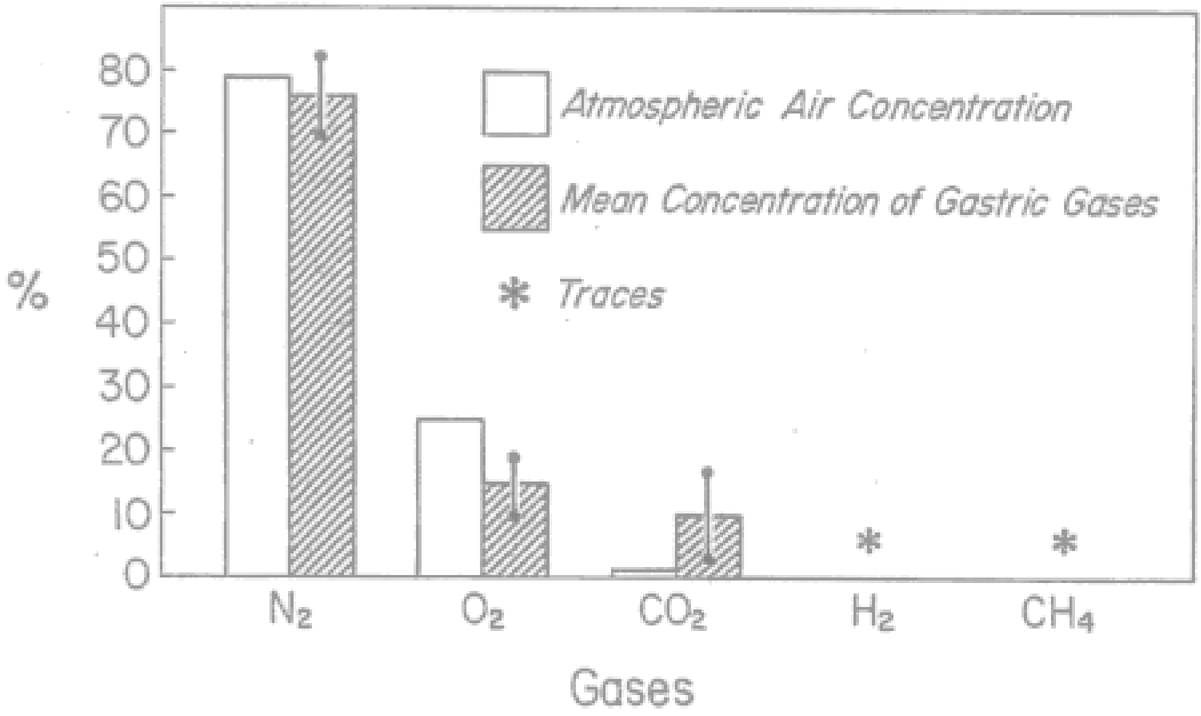

Figure 1— The mean concentration of gastric gases from seven dogs with gastric dilatation-volvulus compared to atmospheric air.

the gas concentrations varied from 100% in each dog. This has been attributed to the independent analysis of CO_2 and instrument error. The mean values of stomach gas concentrations were compared with normal values of atmospheric air [Table 2 and Figure 1]. Although all stomach gas concentrations varied slightly from air concentrations, O_2 and CO_2 varied significantly in several animals. The O_2 concentrations varied from 9.3% to 21.8% with a mean value of 14.9%. The stomach CO_2 concentrations also varied among individual samples from 1.0% to 24.0% with a mean value of 10.1%. Hydrogen and CH_4 concentrations were negligible [Table 2].

Discussion

A previous post-mortem study evaluating gas samples of dogs with gastric dilatation attributed the gas source to bacterial fermentation.[18] This assumption was based on high CO_2 concentrations and the isolation of Clostridia organisms from gastric contents.[18] Hydrogen and CH_4 concentrations were not evaluated.[18] In our study, fermentation was not the source of CO_2. Hydrogen and CH_4 concentrations in the gastric gases were negligible. Bacterial fermentation is the only source of H_2 and CH_4 production.[3,8,9,10] Stomach contents were cultured at surgery for three of the seven dogs. Anaerobic and aerobic bacterial cultures did not yield Clostridia organisms.

Table 2

Relative Concentration of Gastric Gases (%)

Case	N_2	O_2	CO_2	H_2	CH_4
A	82.4	19.1	5.8	0.003	0.0040
B	68.7	9.3	24.0	0.050	0.0060
C	77.0	17.0	5.1	0.008	0.0003
D	84.0	12.0	7.0	0.007	0.0004
E	72.0	14.0	14.0	0.070	0.0005
F	79.8	21.8	1.0	0.029	0.0010
G	68.4	11.6	13.6	0.015	0.0009
Mean Concentration (M.C.) and Standard Deviation (S.D.)					
M.C.	76.0	14.9	10.1	0.026	0.0019
S.D.	±6.42	±4.49	±7.7	±0.025	±0.0022
Atmospheric Air Concentration					
	79.2	24.8	1.0	0.0009	0.009

It has been suggested that gases may enter the stomach from the blood,[22] and that venous stasis may enhance diffusion.[1] However, the increased intragastric pressure seen with gastric dilatation-volvulus may prevent gas diffusion into the gastric lumen. Future experimental studies are needed to determine if gas diffusion is significant in the pathogenesis of gastric dilatation.

Chemical CO_2 formation could have accounted for the CO_2 concentrations measured. Canine saliva contains between 34.7 and 69.1 mEq of bicarbonate per liter.[5] Increased salivation and swallowing associated with gastric hypersecretion could increase the bicarbonate acid reaction, resulting in significant CO_2 production.

Oxygen concentrations within the gastrointestinal tract are related to the partial pressures of other gases.[8,10,16] Our data is consistent with this finding. The low stomach O_2 percentage appeared to be inversely related to the CO_2 concentration. The O_2 percentages were lower when CO_2 percentages rose [Table 2].

Our data supports the concept that swallowed air is the major source of stomach gas in the canine gastric dilatation-volvulus syndrome. This assumption is based on the similarity of gastric gas concentrations to atmospheric air. The possibility of aerophagia causing gastric distention, allowing the progression to torsion, and finally volvulus, is consistent with clinical and experimental studies.[20,21,22]

The causes of canine gastric dilatation-volvulus are unknown. Present knowledge is primarily confined to the pathophysiology of the disease. There is a need for future clinical and experimental investigations of the etiopathogenesis of gastric dilatation.

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