GAS CYSTS OF THE INTESTINE.*

PNEUMATOSIS CYSTOIDES INTESTINORUM HOMINIS.

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INTESTINAL pneumatosis is a chronic, probably a self-limited process, consisting of the formation of gas cysts, which may occupy any layer of the intestinal wall, the gas acting as a foreign body which gives rise to inflammatory changes and leads to the formation of giant-cells.

The views of different observers on the origin of intestinal pneumatosis vary widely, and will be considered later on under the headings of the various theories that have been advanced to explain the occurrence of the disease. The majority are in favor of a bacterial genesis, but unless the intercession of additional factors be conceded, this view is weakened by the absence of inflammatory changes, and the disappearance of the characteristic vesicles, after simple laparotomy; last, not least, by the fact that no typical bacteria have as yet been found. The assumption of a mechanical entrance of gas into the tissues presupposes the existence of gaps, or defects, passing from the epithelial layer of the bowel into the interior of the mucosa. This condition has never been positively established; at any rate, an existing communication between the epithelial gaps and the fully developed vesicles can always be constructed as a secondary process, due to the gas contained in the cysts.

In a general way, the emphysematous areas in the intestine have been remarkably free from local ulcerative processes; but practically all the reported cases of intestinal pneumatosis, with detailed clinical histories and autopsy protocols, show the presence of gastric or duodenal ulcers, or at least

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symptoms pointing to some chronic disease of the intestinal tract, which has existed for a number of years (35 out of 44). Of the other cases which we have been able to tabulate, two patients had tuberculous peritonitis, two chronic appendicitis, one carcinoma of the stomach, one pulmonary tuberculosis and emphysema, one volvulus, one post-operative peritonitis, and one suffered from chronic cardiac disease.

The following case seems to be of interest, not only on account of its rarity, but because also of the unusual opportunities afforded for bacteriological and pathological examination.

The patient, a Chinaman, fifty-seven years old, a laundryman by trade, was admitted to the service of Dr. A. B. Johnson, at the House of Relief on January 18, 1911. He gave a history of indefinite abdominal pain for several months previous. His appetite had always been good and he had never vomited; about eight o'clock in the morning on the day of admission, he was suddenly seized with a very severe cramp-like pain in the epigastric region. He vomited and his abdomen is said to have rapidly begun to swell. At three o'clock in the afternoon, he was brought to the hospital in an ambulance. When seen on admission he showed all the symptoms of a perforation of either the stomach or the duodenum, and an immediate operation was decided upon. The usual incision was made and on opening the peritoneum a large quantity of gas escaped, and the whole cavity was found to be distended with a serosanguineous fluid, almost clear. Over one and a half gallons were removed by the aspirator, and a culture was taken. It was then seen that several loops of the small intestine, lying in the right lower quadrant, were matted together and covered by hundreds of small cysts, many of them pedunculated and containing gas. When punctured these cysts promptly collapsed with the escape of air. Cultures were taken from the interior of these cysts and several vesicles were removed intact for examination. A perforated gastric ulcer was found, but as the patient was failing very rapidly, it was thought best to attempt to stop the leak in the stomach with a piece of omentum, upon which a cigarette drain was firmly placed. This was done and the wound closed. The patient grew slowly weaker, failed to respond to stimulation, and died at eleven o'clock that night.

We were fortunate to be able to obtain an autopsy, which was done by Dr. Symmers, of the New York Hospital, nine hours after death, a synopsis of which is as follows:

On opening the abdominal cavity, it was found that the parietal peritoneum was diffusely swollen and in places slightly reddish in color, but for the greater part it was pale, lustreless, and thinly covered by fibrinous exudate. There was considerable excess of cloudy fluid in the larger fossæ of the abdomen and pelvis. In the interval between the cardiac end of the stomach and the inner surface of the spleen, a number of soft rice granules were floating free in the fluid exudate. The serosa of the intestines was swollen and opaque, irregularly covered by serofibrinous exudate; and the small gut was thrown into numerous loops, which were matted together by a fibrinous substance. In the right lower quadrant of the abdomen, a dozen or more coils of the small intestine were bound together by serofibrinous exudate, forming a large, convoluted, sausage-like mass, and in the peritoneal covering were dozens of pale, tense bullæ that collapsed on section, with the escape of air. The smallest of these blebs approximated the size of a split pea, while the largest was about the size of a crab apple, and each was covered externally by peritoneum. On exposing the mucous surface of the gut corresponding to the distribution of the gaseous bullæ, large numbers of pin-head sized emphysematous vesicles were found irregularly scattered beneath the epithelial lining; otherwise the mucous membrane showed no noteworthy naked-eye changes. Large and small emphysematous blebs were also observed dispersed through the peritoneum in front of both kidneys.

The stomach was considerably distended by gas and by a quantity of semifluid material, consisting largely of macerated granules of boiled rice. The upper border of the lesser curvature in the region of the pylorus was firmly attached to the under and inner surfaces of the gall-bladder by dense, pale adhesions. In the upper border of the stomach, just to the inner side of this mass of adhesions, was a rounded perforation 1.5 cm. in diameter. The perforation involved all the coats of the stomach, and its edges were thin, pale, and smooth. On opening the stomach, an enormous ulcer came into view, involving the upper border of the lesser curvature and the posterior wall of the stomach just to the inner side of the pyloric orifice. It was irregularly rounded and approximated the size of a silver dollar. The base of the ulcer was pale and smooth. In places, the edges were composed of soft, œdematous mucous membrane, which overhung the base of the ulcer in the form of polypoid projections. In other places the edges of the ulcer were thin, smooth, and sloping. The perforation noted in the description of the external aspect of the stomach lay at about the centre of the ulcer in the lesser curvature near the pylorus.

The result of the bacteriological examination, done at the Pathological Department of the New York Hospital, is as follows: A drop of fluid taken from the peritoneal cavity at the time of the operation was inoculated into 100 c.c. of sterile bouillon. At the end of 24 hours the

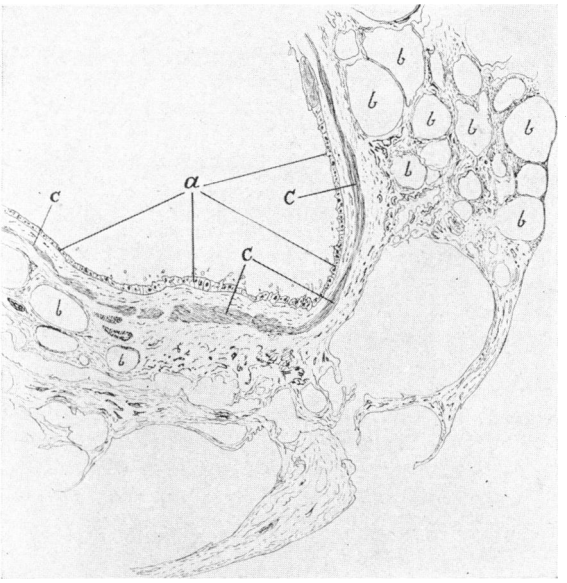
medium was diffusely cloudy. A drop of the growth was then placed on agar and streaked consecutively over the surface of three plates. After 24 hours, the plate showed a growth of *Proteus, Bacillus lactis aërogenes* and *Bacillus coli communis.*

Anaërobic cultures, taken on Loeffler's serum from the emphysematous blebs in the peritoneum of the small intestine, showed the presence of numerous large Gram-positive bacilli. The organism was slightly smaller than the *Bacillus lactis aërogenes* of Welch, but belonged to the same family (Dr. Elser). It was not practicable to establish the identity of this organism more definitely.

The outcome of the pathological examination was as follows: The mucosa was not in a perfect state of preservation. As far as could be determined, it appeared to be atrophic and very poor in lymphoid elements. The muscularis also was not well developed, and especially the circular coat was thin in places. The cystic process was situated altogether outside of the longitudinal coat and was therefore subserous (Fig. 1). The cysts were irregularly oval in shape, some considerably elongated, varying in diameter from about 1 mm. to 2 cm. The innermost layers of the wall of the cysts varied somewhat. In some of them, there was a single layer of flattened endothelial-like cells, containing one elongated spindle or ovoid-shaped nucleus; but in such cysts, probably on account of tangential section, a few of the cells presented larger, apparently swollen, nuclei, or were even multi-nuclear (Fig. 2). Such giant-cells were particularly noticeable where a slight detachment of the lining had taken place. The exceedingly sharp and linear edge along the inner aspect of the endothelial-like cells in some of the cysts, and the presence of a sharp refractive substance in others, limiting many of the cells internally in the form of short or even quite long crystal-like fascicular bodies, is a curious and unexplained feature. Possibly, the needle-like appearance is due to rupture of a continuous lining membrane.

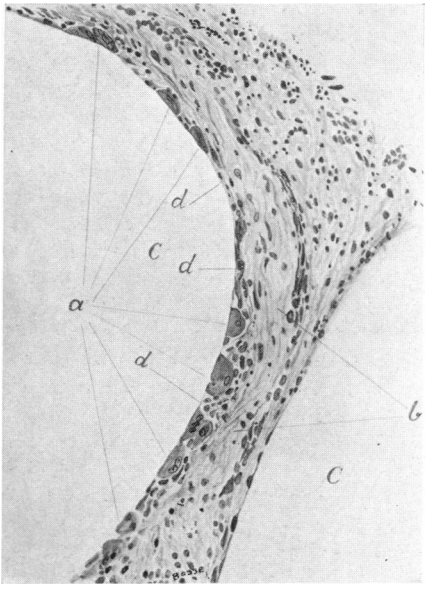
For the most part, the sections of the cysts were completely devoid of contents, except for occasional stellate and needle-like bodies (see chemist's report). In some places, however, an irregular zone of slightly granular substance, staining deeply with hæmatoxylin, adhered to the lining of the cyst, but usually occupied only a very small part of the cavity. There were no cellular elements in this substance, except those detached from the cyst wall. Another type of cysts showed a lining in which the cellular elements seemed to have suffered from marked com-

FIG. 1.



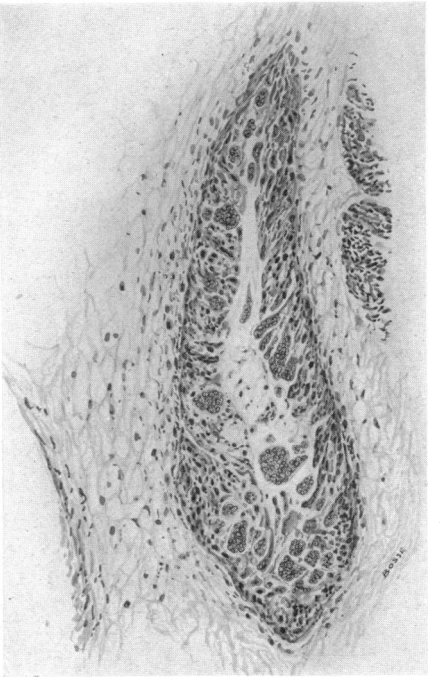
Low power. Transverse section of gut, showing subserous disposition of the gas cysts. *a*, mucous membrane; *b*, subserous cysts; *c*, attenuated muscularis.

FIG. 2.



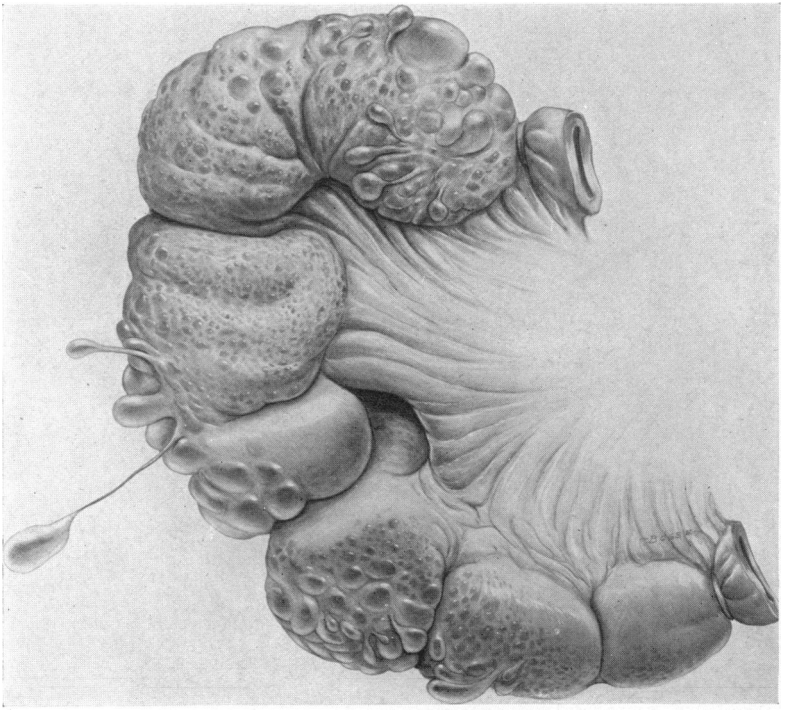
Illustrating the typical lining membrane of a gas cyst. The space to the right is bounded on the left by a connective tissue of septum bearing endothelioid and giant multinucleated cells whose flattened inner aspect is characteristic; *a*, giant-cell lining; *b*, connective-tissue septum; *c*, interior of cyst; *d*, sharp edge.

FIG. 3.



Typical giant-cell focus. Such areas may at first sight suggest a vein. Note the giant-cells in the lumen.

FIG. 4.



Showing general appearance of involved part of small intestine.

pression, so that only an occasional nucleus with a faint, long-drawn-out spindle-like body remained as evidence of the cellular nature of the lining membrane. In such cysts, however, the endothelial nature of the cells became apparent in those places where a tangential section brought more of their bodies into view. Here the atrophic effect of pressure was seen in the small size of the nuclei.

These cyst linings may be regarded as having cells of an intermediate type in which the lining is made up of elements that vary greatly in size and shape, in places being of an endothelioid type, in others having a polygonal shape, and in still others being giant-cells with two or more nuclei.

In the connective-tissue septa between the larger cysts, channels were found whose walls at first sight gave the impression of belonging to a vein or large lymphatic. These were lined with a membrane composed of a large number of giant-cells (Fig. 3). The lumen of the channel contained detached giant-cells. The mixture of small round cells, of spindle-cells, and the partial liberation of giant-cells from the walls made a somewhat confusing picture. Doubtless such appearances are due in part to tangential sectioning and to the desquamation incident upon imperfect fixation. In such channels, there is a marked proliferation of spindle- and endothelial cells, and they lie intermingled with the giant-cells.

The outer walls of these giant-cell channels, when thin, were composed of a number of layers of spindle-shaped cells simulating smooth muscle. The arrangement of the cells in a concentric fashion around the lumen of the channel, although for the most part fairly distinct and easily differentiated from the surrounding connective tissue, was not always prominent enough to warrant considering it a true theca. In many instances, the cellular elements in the surrounding connective tissue and the young connective-tissue elements, probably of an inflammatory nature, with numerous round cells and polynuclear leucocytes, encroached upon these giant-cell foci, making the recognition of a limiting wall almost impossible.

This proliferative, and in part inflammatory process had led to a marked thickening of the walls of these giant-celled channels. Here, collections of endothelial round cells and polynuclear leucocytes disposed with their long axis pointing toward the centre of

the focus were found, giving an appearance simulating the walls of a tubercle. The giant-cells can best be studied in those channels, for they often filled them, being completely detached from the walls. They presented a multitude of different shapes, there being as many as one or two dozen nuclei, usually occupying a median position in the cell. Besides this, polynuclear leucocytes were found in abundance between the giant-cells.

Where the section took in only the outer layers of these foci, the inflammatory zone can best be studied. In such places, collections of polynuclear leucocytes, round cells, plasma cells and epithelioid cells were found.

In the larger septa of connective tissue there were foci, which probably represent stages in the obliteration either of cysts or of giant-cell channels. These showed a peripheral zone of rather dense connective tissue, relatively poor in cells, the cellular elements being arranged in a radial fashion. Within this layer was enclosed an inflammatory nodule, containing numerous leucocytes, endothelioid cells, and a few giant-cells. Perhaps this is indicative of a healing process. The conversion of the loose connective tissue into dense fibrotic nodules and bands, such as form the outer zone of the focus described, was regularly seen in some of the sections; indeed, so much so, that veritable fibromata formed the striking feature of some of the sections. Thus, as an end result of the inflammatory and cicatrizing process, there were areas in which the cysts had become relatively few in number, as evidenced by the remarkable thickening of the septa. In the septa there were large fibrotic nodes made up of the connective tissue already described, in places undergoing a mucoid degeneration. A careful study reveals the fact that even these microscopic fibromata were the results of connective-tissue proliferation and obliteration of cysts, for an irregular space could often be detected in their centres. Even in the neighborhood of the nodules there were small collections of atrophic giant-cells, small polygonal cells, and endothelioid cells.

Sections of the gut taking in the mesenteric border and a portion of the mesentery showed typical cyst formation, with quite a marked inflammatory process in the connective-tissue septa. The cysts could be traced for a short distance into the mesentery, where their structure was the same as in the intestine. There was marked atrophy of the muscular coat, mucosa, and lymph follicles where cysts were present.

Examination of the gut near the termination of the cystic process, where as far as could be determined macroscopically there was a transition between minute cysts and normal intestine, showed the following pictures:

The mucosa is almost normal and the lymph follicles much larger than in the intestine heretofore described. The longitudinal and circular muscle is better preserved than in the region containing the cysts. Just outside of the longitudinal coat is new formed tissue forming a band somewhat thicker than the whole of the rest of the intestinal coats. This presents a meshwork, composed of a multitude of spaces, separated in places from the serosa by a thin layer of connective tissue, in others by dense fibroma-like tissue such as was described as forming nodes in other sections. There are areas in which the structure is that of a typical capillary lymphangioma, there being a multitude of fairly large lymphatics with thickened walls. Here and there are found marked dilatations of lymphatics, particularly outside of the muscular coats, forming cavernous spaces of considerable size, lined by endothelium and receiving or dividing into a number of lymphatic channels. Besides these spaces that are indistinguishable from capillaries, there are thin walled, irregularly shaped spaces, containing numerous bacilli, the lining being for the most part devoid of any distinct endothelial structure. In some of the cyst walls, a continuous layer of endothelial-like cells can be distinguished.

Were it not for the presence of the old connective tissue, one would conclude that the sections just described represent the most recent or youngest areas involved in the emphysematous process. It is more probable, however, that the lesion was inconsiderable at these sites and that absorption of the air or gas had taken place, with consequent cicatrization around the air-containing spaces.

Summary of the chief characteristics of the lesions:

1. Extensive gas cyst formation, for the most part situated outside of the longitudinal muscular coat.

2. Characteristic appearances of the gas cysts and the cyst walls, in which the presence of an endothelial-like lining and giant-cells is a feature.

3. Occurrence of spaces or channels, some of which may be lymphatics partly lined by endothelium and partly filled with giant-cells, endothelioid cells, and leucocytes.

4. Evidences of dilatation of lymphatics and of the intercommunication of large lymphatic spaces, possibly cyst spaces with undoubted lymph channels.

5. Absence of communication between cysts.

6. Inflammatory and productive processes between the cysts and under the peritoneum, resulting in the formation of connective tissue and fibromatous masses, leading to the obliteration of certain cysts and therefore to a kind of healing process.

7. Absence of bacteria in most of the cysts. (The bacteria present in some places are probably post-mortem invaders.)

8. The deposition of highly refractive needles (see chemist's report) in the interior of many of the cysts, causing a peculiar flattening of the cells belonging to the lining membrane, and the possible rôle of such crystalline matter, in the production of some of the giant-cells.

Chemist's Report.—The crystalline matter removed from the gas cysts is found composed of needle-shaped, translucent, homogeneous crystals, arranged loosely in sheaves. They are soluble in chloroform and ether, from which they readily recrystallize, assuming irregular, branched, crystalline forms. After treatment with dilute mineral acid and extraction with chloroform and ether, on evaporation of solvent the dissolved material fails to crystallize. There was not sufficient material for closer study, but the above would seem to justify the belief that the crystals represent soaps of the higher fatty acids.

The formation of small gas cysts in the intestine of animals has been known for a long time past. The disease was first described by Mayer, in 1825, in an otherwise healthy hog. The gas contained in the vesicles was found on analysis to resemble the atmospheric air. After the account of the disease by Mayer, the first description of the microscopical appearance in pigs was contributed by Roth, in 1896, who assumed a primary proliferating lymphangitis, with secondary excretion of the gas from the blood. After him, Schweitzer, in 1899, and Heydemann, in 1904, claimed that these animals always had intestinal catarrh with obstruction, causing a considerable accumulation of gas, which is under a high pressure, and is pressed into the lymphatics through small solutions in the continuity of the mucosa, thus forming cysts, and lymph-

angitis is added secondarily. A similar opinion is maintained by Kitt, in his text-book on the "Pathological Anatomy of the Domestic Animals," vol. i, 1905.

The disease had often been noted in hogs which were fed on the waste of dairies or cheese factories; and Ostertag, therefore, holds a yeast fungus responsible for its production. The culture of this fungus has not yet proven successful.

A liquefying coccus was grown in pure culture by Dupraz,[7] 1897, who explained the cysts as the result of a proliferating lymphangitis due to gas-producing bacteria, which distend the lymphatics, and he claimed to have produced the cyst formation experimentally. Jaeger (1906) isolated from gas cysts of the pig's intestine a species of the colon bacillus, *Bacterium coli lymphaticum aërogenes,* and injected this germ into the wall of animals. A number of very small gas cysts were discovered at the autopsy, in all of the layers of the gut of these animals, which died within 25 hours from general infection. The existing difference from the typical pathological picture of intestinal pneumatosis is referred by Jaeger to the very acute course of his experimental cases.

The chronic course of this affection, which in pigs is restricted to the small intestine, is illustrated by the findings of the Bureau of Animal Industry of the Department of Agriculture in Washington (Dr. J. R. Mohler). A certain importance naturally attaches to the matter from the stand-point of meat inspection, so that the process was investigated and attributed to a micro-organism of the colon group. However, the transmission of the condition by experimental introduction of the pathogenic agent has not apparently been accomplished.

In the human subject, the formation of gas cysts was observed for a long time only in the vagina and urinary bladder of females, almost without exception during pregnancy. Although the condition clinically resembles vaginal emphysema (also known as cystic colpohyperplasia), the appearance under the microscope is somewhat different. Intestinal pneumatosis does not show inflammatory changes of the same severity as those noted in cystic colpohyperplasia. The resemblance con-

sists in the benign course of the two affections, their prolonged duration, and their dependence upon predisposing factors.

The origin of gas cysts of the intestine was referred by von Winckel to hæmatomata or to follicles and small glands. Hemorrhage was considered as the cause by Lebedeff. In the opinion of Chiari and Eppinger, the air entered the cysts from the outside, whereas Bang [1] claimed that the lymph is transformed into gas under the influence of giant-cells.

After a thorough study of his personal observation, by means of all known laboratory adjuvants, and careful sifting of the available evidence derived from other cases, it appears to the author that, taken by itself alone, neither the bacterial nor the mechanical theory satisfactorily explains the formation of these gas cysts of the intestine. Acting in conjunction, it becomes more plausible that this peculiar condition might develop in consequence of bacterial invasion, supplemented by mechanical minute solutions of continuity. Reasoning along the same lines, the presence of chemical factors suggests itself as a possible ally, in the complicated pathogenesis of this interesting affection.

Bacterial Theory.—This theory is endorsed by the majority of authors, who agree in referring the formation of the cysts to the action of gas-producing micro-organisms. There is much to be said in favor of this view, although it has not yet been placed on a positive basis. Its opponents claim that the bacterial findings are always debatable, and the results either of post-mortem change, or of a secondary bacterial invasion.

The first to arraign a coccus as the originator of emphysema (vaginal) was Klebs, in 1876, and this explanation was extended to gas formation in the intestine, by Eisenlohr,[2] 1888. Three years after him, Camargo [3] reported similar bacterial findings, in a case of true pneumatosis cystoides intestinorum. The rods which Winands,[4] 1895, was enabled to demonstrate inside and outside of the cysts were not accepted by the investigator himself as satisfactory evidence of a bacterial pathogenesis.

A French observer, Dupraz,[5] claimed to have furnished the original and complete proof of the bacterial theory, through his demonstration of a microbe which presented certain resemblances to the lactic ferments

(1897). On the other hand, the bacteriological findings of Hahn,[9] in Germany (1899) were not clear but contradictory; microscopical examination showed cocci in the cyst wall, but colonies of short rods grew from sheep serum that had been inseminated with the extirpated air vesicles. Although the rest of the examination proved negative, Hahn advocated the bacterial theory and assumed the transference of the pathogenic agent from infected pigs to the human subject.

Jaboulay,[12] 1901, without submitting any evidence (the cysts in his case were not disturbed in any way) was inclined to refer the condition to a gas-producing micro-organism. In the same year, Miwa's[16] cultures from the cystic contents, on grape-sugar agar, yielded a growth of gas-forming bacteria, but no positive results were obtained in animal experimentation with these germs. He also demonstrated that a number of rods and cocci were present in the cystic walls and cavities. Another adherent of the bacterial theory is Nigrisoli,[20] 1903. Mori[29] originally inclined to the bacterial theory, although no bacteriological examination was possible in his case, 1907. In the following year, 1908, Gröndahl[32] expressed himself to the effect that the condition is probably the result of infection with a gas-forming non-pathogenic microbe, which gives rise to chronic lymphangitis and distends the lymph vessels and gaps into vesicles, causing a characteristic macroscopical and microscopical appearance. A species of gas-forming bacteria was held responsible for the genesis of the gas cysts by Jamanouchi,[40] 1909. The pathogenesis was referred to a bacterial agent, by Arzt,[43] 1910; and he also accepted the identic origin of pneumatosis cystoides and colpohyperplasia cystica. Wasiljew,[38] 1910, endorsed the bacterial theory. Sherman and Wilkie,[41] 1910, found no micro-organisms within the cysts or in their walls, and regarded some cocci and bacilli from interstices between cysts at the lower end of the ileum as the result of contamination of the specimen. A culture with the morphological and biological characters of the *Bacillus coli communis* was grown from cysts removed at the operation. The cultural findings agreed with those of Jaeger, 1906, and of the Department of Agriculture, in Washington, in cases of gas cysts of the pig's intestine. The action of germs (*Bacillus gasogenus*) resulted in the production of the gas, in the opinion of Martini,[46] 1910.

Mechanical Theory.—The adherents of this theory, the most recent advocate of which is Miyake,[48] 1911, refer the origin of the disease to a process entirely analogous to that of traumatic emphysema. The following facts, according to him, go to show that the genesis of intestinal pneumatosis is referable to mechanical causes, namely, that the intestinal gas escapes from minute ruptures in the bowel wall:

1. Absence of uniform histological structure of the gas cysts.

2. Close relationship between the gas cysts and the lymphatic apparatus.

3. Absence of all inflammatory signs in the tissues or in the cysts themselves.

4. Negative bacterial findings on culture as well as in sections.

5. Combination of intestinal pneumatosis with certain chronic gastric affections, which favor meteorism and lower the resistance against the escape of intestinal gas into the bowel wall.

6. Complete disappearance of the gas cysts, after simple laparotomy or enterostomy.

7. Similarity of experimental gas cysts, in rabbits, and human pneumatosis, both in appearance and histological findings.

8. Necessity for the combined action of several causative factors, in the experimental production of intestinal pneumatosis.

Changes in the lymph vessels are undoubtedly present in practically all these cases, and were already credited with a leading part in the production of intestinal pneumatosis by Winands,[5] 1895.

Kolli,[8] 1898, explained the cysts as perhaps due to the forcing of the gases in the stomach, during the act of vomiting, through the margins of a gastric ulcer into the loose subserous cellular tissue of the intestinal canal, where, for some reason, the gas failed to become absorbed. Verebely,[17] 1901, assumed that the gas had escaped through fine solutions of continuity in the intestinal wall. For the explanation of the gas bubbles in his case, Thorburn,[19] 1903, suggested that the gas was driven from the stomach into the omentum through a perforation and for some reason became encysted instead of being absorbed. In the opinion of Simmonds,[44] 1910, a lesion of the gastro-intestinal mucosa is indispensable to the entrance of gas-forming bacteria into the bowel wall. Urban,[45] 1910, explained the condition as the outcome of cystic dilatations of the lymph gaps and vessels, but left it an open question how the air enters into the cysts; apparently through minute lesions of the intestinal wall. Mori,[20] 1908, abandoned the idea of a bacterial origin in favor of a mechanical explanation, such as circulatory disturbances. Ciechanowski[47] noted the absence of bacterial agents in his first observation, and pronounced himself more definitely in favor of the mechanical theory in his recent contribution (1911), admitting, however, that the penetration of the gases into the tissue under the action of purely mechanical factors has never been unobjectionably demonstrated.

The adherents of the mechanical theory, as was pointed out by Nowicki,[34] 1909, are found mostly among veterinarians, who believe that in animals the gas penetrates into the mucosa through solutions in the continuity of the epithelium, especially on injuries from overstraining at work or lesions due to the presence of foreign bodies. As the process is often found associated with enterocatarrh, the gas has been assumed to enter the lymph gaps in consequence of the increased pressure within the bowel. Very hot or starchy fodder has also been

held responsible for an increase of gas pressure in the intestine, with penetration of the gas into the tissue.

Neoplastic Theory.—This explanation was offered for the first authentic case on record, that of Bang,[1] in 1876. The gas cysts were interpreted by this observer as a new growth, the centre of which had undergone degeneration, followed by liquefaction and a gaseous change of the contents. Kouskow,[4] 1891, referred the cystic tumor found in his case to a congenital origin, the growth arising from the fixed elements of the connective tissue. The theory of tumor growth is strenuously supported by Mair,[30] 1908, who considers the gas cysts as analogous in structure and formation to the air bladder of fishes, and credits the cells of the tumors with the power of secreting gas. This view is endorsed by Finney,[33] 1908, who says that "the most rational explanation of the growth would seem to be that it is a definite entity, a distinct variety of tumor, the cells of which have the faculty of secreting gas."

Chemical Theory.—Taken in conjunction with Dupraz's demonstration, in a case of gastro-intestinal emphysema, of a microbe apparently related to the lactic ferments, and probably existing as a saprophyte in water, the following facts in regard to milk are very suggestive: The gases contained in milk are carbon dioxide, oxygen, and nitrogen. These gases are expelled in the course of heating; so that boiled milk has lost almost nine-tenths of its carbonic acid, and about one-half of its oxygen and nitrogen.

Dairymen are familiar with a peculiar gas-formation in milk, shown by a collection of gas vesicles under the cream; such milk is known as fermenting or framing milk. It contains large quantities of gas-producing bacteria, which do not necessarily belong to the coli aërogenous group, but include butyric acid bacteria, yeasts, and so forth. The most important gas producers are the coli aërogenes bacteria, which possess the property of decomposing lactose under the formation of carbonic acid and hydrogen; some being characterized by an especially strong capacity of gas formation. These germs live in large numbers on fodder plants, or the latter may

give rise to a marked increase of the coli aërogenes flora in the intestine, with transformation of the ordinary type into especially dangerous gas producers. It is usually a lack of lactic acid bacteria in the milk which causes a proliferation and over-activity of the ubiquitous colon bacillus. A possible formation of the gas from the blood of the vascular structures was taken into consideration by Hibler; and Deutsch, in the discussion of Verebely's [17] case, suggested that the gas might originate through the protoplasmic function of the cells, instead of coming from the bowel wall itself; as, for example, the way in which gas develops in the cells of ripening apples, while no such gas is found in unripe fruit.

Bang claimed that the lymph is transformed into gas under the influence of giant-cells. More recently the origin of the giant-cells has been sought in the local irritation of the endothelial lining, by the gas contained within the cysts (Ciechanowski,[47] 1911).

NATURE OF THE GAS CONTAINED IN THE CYSTS.

It has been pointed out by Jaeger that examinations made on specimens that are not perfectly fresh are of no value, for the reason that a gaseous exchange with the atmospheric air takes place through the vesicular walls. In order to be satisfactory, the examination must be completed within three hours at the latest. The mixture obtained by him was as follows (*Verhdlg. d. dtsch. Ges. f. path. Anatomie,* Stuttgart, 1906–1907): CO_2, 15 per cent.; O, 5.6 per cent.; H, 73.3 per cent.; N, 6.1 per cent.

The chemical analysis of the gas in Urban's case, which was made in the Vienna University Laboratory for Medical Chemistry, led to the following findings: CO_2, 5.23 per cent.; marsh gas, 7.66 per cent. Two months previously, the examination of a specimen derived from the same case, in a chemical laboratory in Luiz, Austria, had shown the following composition of the gas: CO_2, 4.5 per cent.; O, 15.4 per cent.; nitrogen and hydrogen (marsh gas?), 80.1 per cent. The gas was considered as trimethylamin, by Zweifel, whose material was derived from a case of emphysematous vaginitis (*Archiv. f. Gyn.,* vol. xii, 1877).

The first positive case was reported by Bang in 1876; this was followed by Eisenlohr's case in 1888. Hahn, after whom intestinal pneumatosis is often called in Germany, was the first to treat a case by laparotomy in 1899. Then Ciechanowski states that in 1904 he was able to find 20 cases in the literature.

At the present time we have been able to tabulate 49 cases, the present case making the fiftieth. It should be noted that the new list excludes several cases reported formerly, such as Marchiafava's, which, although of much interest as showing great similarity in cell arrangement, contained fluid instead of air. The case reported by Maass, in 1904, appears to us to have been a post-mortem change. Two or three cases, where a delayed autopsy was done, have also been excluded on the ground that the gas cysts which were found were due to putrefaction.

ABSTRACTS OF CASES REPORTED IN LITERATURE.

1. BANG (*Nordisk Medizinsk Arkiv,* vol. viii, No. 18, 1876): In a case concerning a woman 57 years of age, who had died from volvulus, the lower portion of the ileum presented a large number of small gas cysts, from the size of a pea to that of a bean; no fluid but gas escaped on puncture of the vesicles. These cysts had a smooth inner surface and were found for the most part in the muscular layer, some also in the submucosa. The wall of the cysts consisted of a layer of fibrillar connective tissue, with an endothelial lining. The endothelial cells were very large and had a finely granular protoplasm, with 30 to 40 nuclei, or over. The newly formed tissue of the intestinal serosa contained cysts of a similar character, having the identical appearance of the above-described cysts. The interstices in the newly developed tissue were lined with cells having exactly the same configuration as the endothelial cells of the cyst wall. Although all transitions were found from these interstices to the extensive cysts, there was no demonstrable connection with the lymphatic vessels.

2. EISENLOHR (*Ziegler's Beiträge zur pathol. Anatomie.,* vol. iii, 1888, p. 101): The following case of intestinal and vaginal emphysema was observed in the Zürich Pathological Institute. The patient died from valvular disease of the heart, and came to autopsy four and a half hours after death. A number of intercommunicating cysts, with thin walls, were found in the submucous muscular and serous layers. These cysts were lined with endothelium on the inner surface, and contained numerous giant-cells; they communicated with lymph gaps and lymph vessels. Numerous finely granular collections of bacteria were found in the interior of the cysts as well as in the lymph capillaries and lymph spaces.

3. DE CAMARGO (*Thèse de Doctorat,* Geneva, 1891): At the autopsy of a man 60 years of age, who had died from pulmonary consumption, the cæcum and the ascending colon were found to be much contracted, and thickly studded on the serous surface with a mass of large and small cysts. The cysts occupied exclusively the submucosa. The septa between the individual cysts were in part very delicate but in part quite thick;

they were infiltrated with round cells. The inner surface of the cysts was provided with a lining of flattened endothelial cells; multinuclear giant-cells were also found scattered about. A connection of the cysts with the lymph vessels or lymph spaces could not be demonstrated. Numerous bacteria were found throughout, both inside and outside of the cysts.

4. KOUSKOW (*Boln. Gaz. Botkina Russ.*, October 7, 1891): At the autopsy of a man 57 years of age, who had suffered for years from symptoms of gastric ulcer and intestinal obstruction, several coils of the small bowel were found to be covered with a transparent cyst-like tumor. Gas escaped on incision of the membranous lining, which was found to be the shell of a number of separate cysts, varying in shape and size. Each small vesicle had a connective-tissue wall, lined by a membrane made up of flattened multinuclear giant-cells.

5. WINANDS, M. (*Ziegler's Beiträge zur Pathol. Anat. u zur allgem. Pathol.*, vol. xvii, 1895, p. 38): The observation concerned a woman 49 years of age, who was for six years an inmate of the Marburg Clinic, under the diagnosis of chronic ulcer of the stomach. Intestinal puncture was performed on one occasion, on account of persistent obstipation and associated extremely severe tympanites; after temporary improvement, the patient succumbed to progressive exhaustion. At the autopsy (44 hours postmortem), a very peculiar change was found in the abdominal cavity, aside from the fundamental disease. The intestinal wall contained countless numbers of gas cysts, which were likewise scattered over the lining adhesions.

6. ORLANDI, E. (*Gazzetta Med. di Torino*, No. 40, 1896, p. 781): The patient, a man 33 years of age, was admitted to the hospital with symptoms of intestinal occlusion and alcoholic delirium. Temporary improvement was followed three days later by peritonitis and death. The autopsy showed, aside from fibrinous peritonitis, a number (7–9) of irregularly arranged swellings, up to the size of a nut, at Bauhin's valve. These cysts had the appearance of submucous neoplasms, and were of an elastic consistence; a large quantity of gas, without offensive odor, escaped on incision of the swellings. The intestinal mucosa presented no special changes.

Cultures were prepared from all these gas cysts, and a bacterium was obtained, in one instance even in pure culture, which gave rise to gas development also outside of the body. Rabbits, mice, and guinea pigs were killed by injections with this bacterium, but the autopsy yielded no characteristic findings, and no gas formation in the animal body was demonstrable in further experimentation.

7. DUPRAZ, A. (*Archiv. de Méd. Expérim.*, vol. ix, 1897, p. 282): The observation concerned a woman 29 years of age, at whose autopsy (36 hours after death) the stomach was found to contain submucous vesicles in the large cul-de-sac, while other emphysematous vesicles covered the jejunum for some distance, as well as the ileum. The microscopical findings showed a dilatation of the lymphatic system, with formation of alveoli, with gaseous contents. The smaller alveoli presented

remnants of cellular necrosis on their wall, while the lymphatics of normal calibre were in a state of endothelial proliferation (proliferative chronic lymphangitis).

8. KOLLI (*Russki Vratch,* September, 1895; *Lubarsch-Ostertag,* vol. v, 1898, p. 212): In a fatal case of gastric ulcer, numerous vesicles filled with air, and varying in size from a pin's head to a walnut, were found under the serosa of the duodenum and the adjacent coils of small intestine.

9. HAHN (*Deutsche med. Wchschrft.,* 1899, p. 657): The patient was a man 35 years of age, who after suffering for two years from a stomach disease supposed to be gastric ulcer, began to present symptoms of intestinal trouble, in form of prolonged diarrhœa, later on replaced by persistent obstipation; there was also a sensation of fulness with anorexia and progressive emaciation. Soft, elastic, painful resistances could be felt under the sternum and in the abdomen. Operative interference finally became necessary, and the laparotomy showed the larger part of the small intestine as well as the entire colon to be closely studded with countless cysts, from the size of a pea to that of a bean, partly pedunculated, partly attached by a broad base to the serosa. The cysts contained exclusively a non-combustible gas, but no fluid; compression caused them to burst, with an audible noise. As the cysts could not be radically removed, a number were compressed and burst open between the fingers.

The patient visibly improved after the simple laparotomy, and was discharged in good condition, at the end of about seven weeks.

10. KORTE (*Discussion of Hahn's paper, Dtsch. med. Wchscrft., 22,* 1899, p. 255): At the autopsy of a woman 62 years of age, who had died under symptoms of peritonitis seven days after a hernia operation, the walls of the small intestine were found to contain a number of sharply outlined cystic tumors, from the size of a pea to that of a cherry. Bubbles of air escaped from these cysts when they were cut open under water. The microscopical examination showed the site of the cysts to be the intestinal submucosa.

11. WIKERHAUSER (*Centralblatt für Chirurgie,* 1900, No. 37, p. 938): In the case of a patient 35 years of age, who had suffered for ten years from gastro-intestinal disturbances, laparotomy showed beside pyloric stenosis, a number of globular clusters of cysts, from the size of a hempseed to that of a small cherry, studding the small intestine. The vesicles were either attached separately by a small pedicle opposite to the mesentery, or they were arranged in large or small groups, surrounding almost the entire periphery of the bowel. In color these cysts were reddish or bluish, transparent or white, traversed by fine capillaries. They crepitated under the finger, and were inflated with air. Some of the growths were extirpated for microscopic examination, which showed that the internal surface was mostly lined with normal endothelial cells, hypertrophied, and arranged in two to three layers. When the patient came to autopsy, having succumbed to peritonitis about two months after the operation, not a trace was left of the pneumatosis in the entire abdominal cavity.

12. JABOULAY (*Lyon Médical,* vol. xcvi, 1901, p. 753): In the course of operation upon a man 50 years of age, with a history of eight years'

gastric dilatation, due to cicatricial pyloric stricture, the small intestine was found to be covered with numbers of gas cysts, from the size of a pinhead to that of a hazel-nut. Another cluster of gas cysts was seen on the diaphragm near its centre. The cysts were neither removed nor interfered with in any way by the operator.

13. TOLOT (*Lyon Médical,* 1901, vol. xcvi, p. 955): In the course of a laparotomy on a man 52 years of age, with cicatricial pyloric stenosis, a large number of cysts were discovered on the peritoneal surface of the small intestine. No cysts were seen on the transverse colon, but several vesicles, some of them with a pedicle, appeared on the lower surface of the diaphragm. The intestinal cysts varied in size between that of a currant and a gooseberry; they were transparent and apparently situated underneath the serosa. Notable improvement followed upon the simple exposure of the cysts to the air, combined with digital dilatation of the pylorus.

14. VALLAS-PINATELLE (*Lyon Médical,* vol. xcvii, 1901, p. 215): The patient, a man 48 years of age, was operated upon as an emergency procedure under symptoms of acute intestinal obstruction or perforative peritonitis; death on third day following operation. The autopsy, 30 hours after death, showed the presence of a peculiar tumor, the size of two fists, a polycystic structure resembling a hydatid mole, which occupied a circumscribed segment of the jejunum. Clusters of cysts were found arranged along one metre's distance, followed by isolated cysts on the next metre of the bowel; the remainder of the ileum and the entire large intestine were normal. The vesicles varied from the size of a pea to that of a large nut. An odorless gas escaped on puncture or compression. The walls were thin and transparent, but continuous, and the gas could not be squeezed into the intestine, nor from one cyst into another. There was no cadaveric putrefaction. Some of the cysts were also noted on the parietal peritoneum and on the diaphragm.

Histological examination showed that the cysts were subserous and had very thin walls, made up of a connective-tissue stroma apparently devoid of endothelium, and with a very variable vascularization.

15. PELNAR (*Bull. Int. de l'Acad. de Méd.,* vi. 1901): This observation was made in a case of chronic tuberculous peritonitis. The cysts were mostly found in the intestinal submucosa, and were without an endothelial lining. The peritoneum presented no gas-cyst formation.

16. MIWA (*Centralblatt für Chirurgie,* No. 16, 1901, p. 427): At the autopsy of a man 42 years of age, countless vesicles were noted on the ileum, as the most noteworthy change; a segment of bowel about 30 cm. in length was studded with a number of gas cysts, from the size of a hempseed to that of a pigeon's egg, considerably narrowing the lumen of the intestinal canal. These cysts were all attached by a broad base; on compression they burst with a loud report. The gas contained in the cysts was odorless and non-combustible.

Microscopical examination showed no characteristic bacteria in the vascular contents. Although gas was formed in sugar cultures, animal

experiments (intraperitoneal cultures in two rabbits and two dogs) had a negative outcome.

17. VEREBELY (*Wiener mediz. Wchschrft.*, No. 47, 1901, p. 2218): Pneumatosis cystoides of the intestine, involving four coils of the ileum and the entire cæcum, was discovered as accidental findings in the autopsy of a man 30 years of age, who had died from pulmonary consumption and also had tuberculous abscesses in the intestine. The vesicles were in part attached by a pedicle, and in part with a broad flattened base. The mucosa was likewise infiltrated by innumerable vesicles, which contained an odorless, non-combustible gas. The microscopical examination showed the main seat of the cysts to be in the intestinal submucosa.

18. KADYAN (*Russ. Chir. Archiv.*, H. 6, 1902; *Centralblatt f. Chirurgie*, No. 10, 1903, p. 300): The following case was observed by the author in 1893. The patient, a woman 31 years of age, had been suffering for two years from abdominal pains, vomiting, alternate diarrhœa and constipation, and ascites. At the time of the laparotomy the intestinal serosa, especially of the small gut, was seen to be irregularly studded with tubercles of variable size, as well as air-containing vesicles up to the size of a plum. The condition was at first improved, but the operation had to be repeated about two and a half months later; the solid tubercles had disappeared, but there were again many air-containing vesicles, which were punctured and emptied or cut off after ligature of the pedicle, as at the first operation. At the third laparotomy, two months later, whitish spots were seen instead of the tubercles; again, there were numerous air-containing vesicles and a large amount of ascitic fluid. Considerable improvement again followed upon the operation.

Microscopical examination of the cysts showed fibrous walls lined with one or more layers of large endothelioid cells.

19. THORBURN, W. (*Med. Chronicle*, Manchester, vol. iv, 1902–3, p. 255): Gas-containing cysts were found in the omentum of a woman 42 years of age, who had suffered for ten years from dyspepsia and recurrent vomiting. At the operation were found gastric ulcers, perigastric adhesions, an enormous dilatation of the stomach, and two collections of rounded cystic masses, lying like saddlebags across the omentum, and extending into the right hypochondrium, or beneath the spleen, respectively. The numerous cysts varied in size from that of a small pea to that of a walnut, and were closely packed together in form of a cone, resembling a cluster of hydatids. Each little cyst had a thin, transparent but well-defined wall; some contained a thin, almost colorless fluid, but the majority were filled with an inodorous gas. The first mass which came into view was excised, but the collection on the left side was left behind, as there was evidently no malignancy. The patient recovered from the operation, but died about ten days after her discharge, presumably as the result of hemorrhage from an unhealed ulcer.

20. NIGRISOLI (*Nuovo Raccoglitore medico*, Sept., 1902): Gas cysts were discovered in the course of gastro-enterostomy upon a young man, aged 25 years, on account of cicatricial pyloric stenosis. Numerous

vesicles, round or oval, from which escaped an odorless non-combustible gas, were found on the mesentery and on a coil of small intestine, about 30 inches long. At the autopsy, three weeks later, no trace of the cysts was left on the intestine or on the mesentery.

The microscopical examination showed that the cysts had a connective-tissue wall and an endothelial lining.

21. v. HACKER (*Wiener klin. Wchschrft.*, Nos. 12, 14, 1903, pp. 368, 430): Before the Innsbruck Scientific Medical Society, meeting of January 17, 1903, was shown a man 42 years of age, upon whom an exploratory laparotomy had been performed on account of obscure intestinal disturbances. Aside from a gastric ulcer at the fundus, multiple gas cysts, from the size of a hempseed to that of a pigeon's egg, were found on several portions of the small bowel, chiefly occupying the convexity. Individual groups of these partly pedunculated structures were removed for examination. The vesicles burst on pressure with a slight report, and contained a colorless, odorless gas.

The histological examination, by Hibler, showed that the gas cysts were lined with a single layer of endothelial cells; similar layers were likewise found in gas-free serum-filled spaces. There were no recent inflammatory changes, no giant-cells, and no necrotic areas.

22. CIECHANOWSKI (*Wiener med. Wchschrft.*, No. 1, 1904, p. 24.): Gas cysts of the intestine were found at the autopsy of a woman 24 years old, who had died from gastric hemorrhage. The ileocæcal region was occupied by three swellings, attached to the side of the ileum opposite the insertion of the mesentery, and composed of numerous large and small gas cysts. The vesicles were filled with a colorless and odorless gas; in size, they varied from that of a pinhead to a pea. The inner surface was smooth and glistening; there was no apparent communication between the cysts.

Histological examination showed the cysts to be mostly situated in the thickened subserous tissue, in part outside of the external elastica of the bowel wall, which presented gaps in these localities. The submucosa contained cysts in only a few isolated areas. Careful microscopical and bacteriological examinations served to show that no etiological part was played in this instance by bacterial agents.

23, 24. STORI (*Clinica Moderna*, Pisa, x, 1904, p. 481): Case I: In the course of operation upon a woman 38 years of age (gastro-enterostomy for pyloric stenosis and gastric dilatation) a round mass consisting of transparent cysts from a pinhead to a bean in size was found lying above the gastrohepatic ligament. The cysts contained an odorless non-combustible gas. Part of the mass was removed for examination, and the cystic walls were found to be made up of connective tissue lined with a layer of endothelial cells.

Case II: In the course of operation upon a man 30 years of age (gastro-enterostomy for pyloric stenosis) the ileum near the cæcum was found to be surrounded for about a metre's length by a greyish lobulated mass, springing from the mesentery, and made up of separate transparent cysts, from the size of a pinhead to a small hazel-nut. The cysts con-

tained an odorless, non-inflammable gas. Part of the mass was removed for examination, with the same findings as in the first case.

25. VISCONTINI (Gazz. degli Ospedali, No. 118, 1904, p. 1249): Transparent gas-containing cysts were found on the intestine, mesentery, and parietal peritoneum of a girl 13 years of age, in the course of a second laparotomy on account of dilatation of the stomach after pyloric stenosis. New vesicles were seen to form as the hand was passed over the peritoneum, while some of the cysts coalesced into a tumor the size of a hen's egg. The gas had no odor of hydrogen sulphide. Microscopical examination of the excised specimens showed a solid layer of connective tissue, with a few endothelial cells at the inside of the cysts. Recovery.

26, 27, 28. LUBARSCH (*Verhdlg. d. dtsch. Pathol. Geselschaft*, x, 1906, p. 256): *Three cases* of gas cysts of the large and small intestine in human beings, which were carefully examined, presented the typical histological findings of lymph cysts with giant-cell formations. Bacteria were not demonstrable by means of any method.

29. MORI (*Dtsch. Ztschrft. f. Chir.*, vol. xxxviii, 1907, p. 553; vol. xci, 1907–8, p. 620): The patient, a man 37 years of age, was operated upon under the diagnosis of gastric dilatation beside which the following condition was discovered along the entire course of the small intestine: Except the first portion of the ileum and the terminal portion of the jejunum, the intermediate segment was studded with countless air vesicles, from the size of a hempseed to that of a hazel-nut, partly attached by a broad flattened base, partly suspended from a pedicle. The cysts were arranged in groups or scattered separately. A segment of intestine with gas cysts was reserved for histological examination, which showed the absence of an endothelial lining to the cysts.

After being considerably improved by the gastro-enterostomy and enterostomy, the patient had a relapse of his old disturbances, and returned for operation eight months later. At this time, all the innumerable cysts had disappeared absolutely, except two small hydatid vesicles with serous contents.

30. MAIR, W. (*Medical Chronicle*, March, 1908, p. 422): In the course of operation upon a young man (gastro-enterostomy for pyloric stenosis) the small intestine was found to be covered with a cystic tumor mass, for a distance of about nine inches; these cysts were separate from each other and varied from a barely visible size to that of a walnut. On puncture most of the cysts collapsed, under escape of an odorless gas. A few vesicles contained a small amount of fluid. The microscopical examination showed an endothelial lining in a number of the cysts, with multinuclear giant-cells lying free in the cyst cavity and also in the cyst walls.

31. MITCHELL (Quoted by Mair, *Med. Chronicle*, xiv, 1907–8, p. 422): Gas-containing cysts were found in the performance of a gastro-enterostomy for pyloric obstruction on a young man. Resection of the affected segment of small intestine was followed by recovery.

32. GRÖNDAHL, N. B. (*Dtsch. med. Wchschrft.*, No. 21, 1908, p. 913): The patient was a man 31 years of age, healthy until six years ago, when

dyspeptic symptoms developed and became gradually worse, leading to marasmus and death after protracted gastric hemorrhage of several days' duration. At the autopsy the ileum was seen to be covered for about the distance of one metre with innumerable cysts, up to the size of a bean, forming grape-clusterlike projections or floating like simple vesicles on a long slender pedicle. The cysts were all attached to the free margin of the bowel as far as the mesenteric insertion, but without involving the mesentery.

The microscopical examination showed the absence of gas cysts from the intestinal mucosa, which was unchanged; whereas the submucosa and also the thickened serosa contained numerous gas cysts, lined with a more or less distinct endothelium and surrounded by a layer of connective tissue. The submucosa also contained collapsed cysts with numerous enclosed cells, mostly lymphocytes, and many large multinuclear giant-cells. Apparently a communication existed between the lymph vessels and the cysts.

33. FINNEY, J. M. T. (*Jour. Am. Med. Assoc.*, Oct. 17, 1908, p. 1291): In the course of operation upon a man 60 years of age (gastro-enterostomy as a palliative procedure for the relief of suspected carcinoma), "a curious soft multinuclear cystic tumor, 15 cm. (6 inches) long by 8 cm. (3¼ inches) wide at its widest point, was found attached to the free border of a loop of ileum about one foot above the ileocæcal valve." The cysts were very numerous and varied from microscopical size to that of grapes; each cyst seemed to have a thin fibrous wall of its own, which burst on puncture with an audible noise, indicating considerable pressure. The gas contained in the cysts was odorless and non-combustible. Portions of the mass were removed for histological examination, and were found to be composed of a loose fibrous tissue surrounding spaces of very irregular size, part of which were provided with an endothelial lining and multinuclear giant-cells. The endothelial cells as well as the cells of the adventitia presented swelling or ballooning, and numerous cells apparently belonging to the connective tissue were similarly enlarged and filled with great vacuoles, lending a very loose appearance to the entire tissue.

34, 35, 36. NOWICKI (*Virchow's Archiv.*, vol. cxcviii, 1909, p. 143): (1) At the autopsy of a man 22 years of age, who had died from valvular disease of the heart and chronic gastro-enteritis, the following condition was noted in the large intestine: The mucosa of the transverse and descending colon showed transverse elevations up to the size of a nut, separated by deep furrows; these elevations, to some extent also the smooth mucosa, were studded with greyish, transparent, round gas vesicles, of an average size of 3 mm. A characteristic crepitation was heard on compression or incision. The vesicles did not change in position under pressure. On removal of a slice of the uppermost layer, the bowel presented a sponge-like appearance, while the outer surface, *i.e.*, the intestinal serosa, was smooth and free from visible changes.

(2) At the autopsy of a man 41 years of age, who had died from chronic myocarditis and chronic gastro-enteritis, similar findings were noted as in the preceding case, in form of cystoid pneumatosis of the

cæcum and ascending colon. The elevations as well as the interstices presented an enormous number of uniformly scattered round vesicles, which contained gas and had a diameter up to 5–6 mm.

(3) Kucera's case: This observation was made on a man 39 years of age, who had died from pulmonary tuberculosis. The process was limited to the transverse and descending colon; the vesicles were located in the mucosa and submucosa, reaching an average diameter of 4 mm. The serosa presented no visible changes.

37. HERMAN (*Lek. Gal. Tyg. lekarski,* No. 8, 1908, p. 118): In this case, which is quoted by Nowicki as having been demonstrated before the Przemyszlau Galicia Medical Society, the intestinal pneumatosis had developed as a sequel to gastric ulcer.

38. VASLYEFF (Wasiljew) (*Centralblatt f. Chirurgie,* No. 16, 1910, p. 594): The patient, six months after appendectomy for acute appendicitis, began to suffer from pain in the cæcal region and intestinal disturbances. Laparotomy was performed, under the assumption of adhesions; none were found, but the lower end of the small intestine was distended by numerous gas cysts, lined with peritoneum, which burst and disappeared on pressure. Resection of the affected segment, 7 cm. in length, was followed by recovery.

The mucosa of the resected intestinal segment was unchanged; the submucosa was thickened and interspersed with gas-filled cavities; the muscular layer was fairly unaltered; the bulk of the gas cysts occupied the serous layer (lymphangitis proliferans).

39. WOLTMANN, A. N. (*Centralblatt f. Chirurgie,* No. 17, 1909): The patient was a man 37 years of age, who presented the symptoms of chronic appendicitis. The appendix was removed, but five months later the pain returned and remained constant. Laparotomy showed the absence of adhesions. A tumor, consisting of gas vesicles, was found on a coil of small intestine, at the side opposite the mesentery. The vesicles were separated from one another by peritoneal septa, and communicated in such a way as to give the tumor the appearance of a hydatid mole. An isolated vesicle was found higher up on the peritoneum. The affected segment of intestine was resected, and the isolated vesicle was crushed.

40. JAMANOUCHI (*Verhdlg. d. Japan. Geselschaft f. Chir.,* 1909): Laparotomy was performed upon a patient 29 years of age, who since his seventeenth year had suffered from gastric disturbances, leading to the diagnosis of pyloric and intestinal stenosis. In addition to gastric dilatation, due to cicatricial pyloric stenosis, a number of gas cysts were found in two segments of the small intestine, one 100 cm. and the other 70 cm. in length.

41. SHENNAN, TH., WILKIE, D. P. D. (*Jour. of Pathology and Bacteriology,* vol. xiv, 1910, p. 259): At the operation of a man 32 years of age, masses of gas cysts springing from the wall of the ileum were observed, besides pyloric stenosis, with a dilated and hypertrophied stomach; the patient died 30 hours later. The post-mortem examination showed a mass of closely set, thin-walled, transparent cysts, varying in size from

that of a hempseed to that of a hazel-nut; some were sessile, others were pedunculated; all were tense, and their contents were evidently gaseous, the cysts collapsing on puncture. None of them contained fluid, but one or two were filled with altered blood clot. The cysts occupied altogether about 54 inches of the ileum; a line of similar but smaller cysts was found on the under surface of the transverse mesocolon, in the hepatic flexure; a few cysts were scattered over the under surface of the transverse colon about its middle; the jejunum was free from cysts and so was the large intestine, except the parts mentioned. The cysts in the lower end of the ileum were evidently of longest duration, the vesicles becoming less numerous, less prominent, and apparently of more recent age, in an upward direction.

On microscopic examination, the cysts were found to have developed in the submucous coat and on the serous surface. Large giant-cells were observed in the innermost layer of the cyst wall, with fairly distinct margins and many nuclei.

42. WIESINGER (*Centralblatt für Chirurgie*, No. 16, 1910, p. 577): A specimen of gas cyst of the bowel wall, obtained at an operation for ileus, from a woman 67 years of age, was presented before a surgical society. A movable tumor the size of a small fist had been palpable above the umbilicus, and was found connected with the ileum at the operation. Another coil of small intestine was adherent to the tumor and was bent at a sharp angle. One coil was resected, and the other had a piece excised from its wall. The tumor was found to be cystic but contained air instead of fluid. Recovery.

43. ARZT, L. (*Frankfürter Zeitschrift f. Pathologie*, vol. vi, Feb. 1, 1910, p. 85): The patient was a man 30 years of age, who had suffered from gastric disturbances since 1906. The condition gradually became aggravated, and laparotomy was performed in January, 1909. After the peritoneum had been opened in the middle line between the xiphoid process and the umbilicus, the entire visible portion of the abdominal cavity was seen to be filled with large and small vesicles, between the size of a cherry and that of a hen's egg, studding the great omentum. Vesicles of the same character were seen also in the serosa of the small intestine, being especially numerous at the side of the coils opposite the insertion of the mesentery. These vesicles, which were filled with gas, could be removed by blunt dissection. After the ablation of a large number of the vesicles, a posterior retrocolic gastro-enterostomy was performed, and the abdominal wound was closed. The further course was unimportant; the patient was discharged cured three weeks after the operation; the improvement persisted one year later.

Principal results of the histological examination: (1) formation of cysts, single or multiple, in the intestinal wall, in the subserous tissue, with transformation of the endothelial lining into giant-cells in isolated areas; (2) undoubted lymph capillaries, with the lumen almost entirely obliterated by numerous giant-cells, developed in part at least from the endothelium of the lymph capillaries; (3) slit-like or rounded cavities

lined with peritoneal epithelium and communicating with the peritoneal cavity.

44. SIMMONDS (Discussion of Arzt's case at the fourteenth meeting of the German Pathological Society, Erlangen, April, 1910): A similar observation was referred to in a patient suffering from gastric ulcer.

45. URBAN, K. (*Med. Wchschrft.*, No. 30, 1910, p. 1750): The patient was a girl of 13 years, and the diagnosis of tuberculous peritonitis was rendered on the basis of the clinical findings. At the time of the laparotomy, half a litre of clear serous fluid escaped. No nodules were seen on the bowel or peritoneum, but the entire small intestine, the cæcum, and a piece about 20 cm. in length of the ascending colon were much distended, and the wall was interspersed with countless transparent, not communicating, vesicles, from the size of a pea to that of a hazel-nut, which caused the serosa to bulge, and gave it a roughened appearance. The vesicles collapsed on puncture, with escape of an odorless gas, apparently non-combustible. Lit in the dark, in larger quantities, this gas was seen to burn with a faint blue flame. The mesentery as well as the parietal peritoneum were entirely free from vesicles. The mesenteric glands were enlarged but not caseated.

Further intervention, such as enterostomy or resection, was omitted, in view of the extensive distribution of the process. At the relaparotomy, seven weeks later, nothing remained of the vesicles, but the serosa was covered with an enormous mass of light nodules, resembling millet seeds, which occupied the place of the former vesicles. Only a piece about 50 cm. in length of the lower jejunum was closely studded with cysts and very sharply outlined from the rest of the bowel. This segment was excluded by entero-anastomosis.

The histological examination of several extirpated cysts showed the vesicles to lie in the submucosa, pushing apart the mucosa on the one hand and the annular and longitudinal muscle on the other; they were lined with flattened endothelial cells or giant-cells.

46. MARTINI, E. (*Giornale della R. Accad. di Medicina di Torino*, Nos. 3, 4, 1910, p. 129): In the course of an operation for supposed benign pyloric stenosis, a new formation of cystic appearance came into view, covering a large portion of the intestine. The findings consisted in soft greyish or pearly masses of variable size, more or less pedunculated, and crepitating on pressure; these masses consisted of a variable number of light round cysts, transparent like soap-bubbles, from the size of a millet seed to that of a pea. The cystic new formation occupied only the convex portion of the bowel, and involved the entire length of the ileum; the calibre of the intestine was unchanged.

Macroscopical examination of some excised masses showed these to be formed of a conglomeration of thin-walled vesicles, which were united by highly vascularized connective-tissue septa. These vesicles floated on water, and an odorless, non-inflammable gas escaped when they were incised.

Microscopical examination showed a supporting connective-tissue framework, containing numerous enlarged capillaries, with the character-

istics of simple as well as cavernous angioma. Beside and between the blood lacunæ were seen cavities of variable size, rounded shape, and cystic appearance, lined with a layer of flattened endothelial cells. These cavities were for the most part empty; some contained individual more or less well-preserved blood elements and blood pigment.

47. CIECHANOWSKI (*Virchow's Archiv.*, vol. cciii, 1911, p. 170): The patient was a woman 46 years of age, who died in the hospital under the diagnosis of pulmonary tuberculosis and emphysema, without having presented any special symptoms on the part of the intestine. The autopsy showed pneumatosis cystoides, limited to the large intestine; the changes began directly at the ileocæcal boundary, comprising without interruption the entire cæcum, ascending and transverse colon, reaching as far as 10 cm. below the splenic flexure, where they terminated very abruptly. The colonic mucosa in the affected segments was uniformly bloated by gas cysts in the submucosa, which was interspersed with innumerable vesicles from the size of a pinhead to that of a pea. The contents of the cysts consisted of a colorless and odorless gas.

The microscopical examination confirmed in a general way the macroscopical findings, showing the submucosa to be the main seat of the gas cysts, whereas the subserosa was unchanged. Collections of giant-cells, surrounded by cellular connective tissue, were found in cyst-free upper layers of the submucosa, above the deeper cystic layers.

48. MIYAKE (*Archiv. f. klin. Chir.*, vol. xcv, 1911, p. 437): The patient was a physician 45 years of age, who during the last seven years had four attacks of acute and very severe pain in the ileocæcal region, and two similar attacks in the left iliac fossa. Radical operation was performed under the diagnosis of chronic recurrent appendicitis. Beside this disease, pneumatosis was discovered, affecting a coil of the ileum, and exactly corresponding to a resistant spot in the umbilical region which had been found tender on pressure in the preceding examination. The coil of ileum, about 10 cm. long and at a distance of 338 cm. from the duodenojejunal fold, was studded with a mass of gas vesicles, from the size of a lentil to that of a pea, arranged like grape clusters, mostly attached with a broad flattened base, in part pedunculated. The vesicles were either transparent, bluish, or pinkish in color, in part traversed by a fine vascular network. Beginning at the insertion of the mesentery the conglomeration of gas cysts covered about three-fourths of the circumference of the intestinal tube, leaving one-fourth of the bowel uninvolved, on the side opposite the insertion of the mesentery. The vesicles burst on compression with an audible report; the gas contained in them was odorless and non-combustible. The remaining intestinal segments were found to be free from vesicles on careful inspection of the exposed coils. The coil of ileum affected with the pneumatosis was resected to a length of about 10 cm.; this was followed by circular junction of the two stumps. The patient made a prompt and very good recovery.

49. ELSE PHILIP (Inaugural Dissertation, Leipzig, 1911): The patient, a carpenter 23 years of age, was under conservative treatment two years ago for perityphlitis. Eight days before admission to the clinic he was

suddenly attacked by severe abdominal pains in the right side; the condition became worse, and an operation was performed, which showed a peculiar configuration of the cæcum. The wall was made up of masses of globular structures, from the size of a sand grain to that of a hazel-nut; they appeared semi-transparent and filled with gaseous contents. Puncture of the cysts caused the gas to escape with a hissing noise, followed by collapse of the vesicles, which covered the entire cæcum and the lowermost segment of the ileum, terminating without a distinct boundary about 3 cm. above Bauhin's valve. A segment of omentum near the cæcum, but not adherent to it, was likewise interspersed by gas cysts of variable size, so as to form a tumor the size of an apple, which crepitated on contact. The mesocolon was swollen and emphysematous; it contained numerous swollen glands, one of which was removed for examination. A piece of omentum was likewise ligated and resected. The affected parts presented no signs of recent or chronic inflammation. The appendix was similarly emphysematous and infiltrated; it was resected, and the stump was buried through circular suture of the cæcum. Further surgical treatment seemed impossible, in view of the great extent of the gas infiltration, and was not attempted. As there was no trace of exudate and the appendix showed no gangrenous spots on macroscopical examination, the wound was closed by primary sutures. Next day, the patient complained of pain and pressure in the abdomen; the wound looked well and was not opened. The abdominal walls "crackled" very extensively, but inflammatory phenomena were absent. This crackling subsided promptly, the wound healed by first intention, and the patient was dismissed in excellent condition on the twelfth day after the operation. He was reexamined six months later, at which time he felt and looked perfectly well.

The report on the excised tissues and the appendix, from the Pathologico-Anatomical Institute of the University of Marburg, was as follows: The appendix shows a local, rather extensive necrosis, and in the surroundings of the necrotic area and the hæmatomata bacteria are demonstrable. The adjacent lymph vessels are much dilated, apparently through gas or air infiltration. Bacteria cannot be positively demonstrated in the lymph gaps themselves. The piece of omentum presents the same pneumatic dilatations of lymph vessels, likewise without demonstrable bacteria; remnants of a fibrinous exudate are found in certain areas in the dilated lymph vessels of the omentum.

The following observation of Duverney, 1747, quoted by Combalusier (*Pneumo-Pathologia*, 1747, p. 17), should be interpreted as a post-mortem gas formation, *i.e.*, a putrefactive emphysema, in the opinion of Winands (*Ziegler's Beiträge zur pathol. Anat.*, vol. xvii, 1895, p. 38):

At an autopsy, a large portion of the intestinal tube was found to be studded with broad, long, annular swellings upon the outer membrane. These swellings seemed to be filled with a whitish substance, and on digital pressure yielded a crackling noise, like small air-filled vesicles. When opened, they were seen to be entirely filled with white, perfectly empty cells. On turning the bowel inside out, the same swellings were

likewise found on the internal side. Some of these swellings were so tensely stretched as to obliterate the lumen of the bowel. These swellings were therefore true emphysemata.

The observation of Cloquet (*Bulletin de la Fac. de Méd.*, vii, quoted by Andral, *Anatomie Pathol.*, ii, p. 175) can likewise not be admitted as a true case of intestinal pneumatosis:

A scrofulous patient, 20 years of age, died from vertebral caries in a state of extreme marasmus. At the autopsy soon after death, the cadaver presented no evidence of putrefaction. The cellular tissue between the various layers of the stomach was found to be very emphysematous; its walls appeared to be inflated, and in several places were nearly as thick as the thumb. The roughened mucosa was pale, and without a demonstrable lesion. The two anterior layers of the great omentum which are inserted at the greater curvature of the stomach were likewise separated by air. Similar conditions prevailed in the two layers of the lesser omentum. Collections of gas resembling the above were noted in other portions of the submucous cellular tissue, especially in the wall of the gall-bladder.

The treatment of this condition is the treatment of the fundamental or predisposing disease. Hahn, at the time of operation on his case, found the involvement of the ileum and colon so extensive that removal of the diseased bowel was considered impossible, so a number of the cysts were compressed between the fingers and ruptured. The patient made a good recovery after simple laparotomy and was considered cured seven weeks later. Mori states that in his case the patient after gastro-enterostomy was considerably improved, but suffered a relapse of his symptoms eight months later, which necessitated a second operation. At this time, the large number of cysts observed at the first operation had entirely vanished, except two small hydatid vesicles with serous contents. Kadyan had the opportunity of two secondary laparotomies on his case, the first two and a half months, the second four and one-half months after the first operation. At each time he noticed the number of cysts to be greatly diminished, practically none remaining at the third operation. Nigrisoli in the course of an operation for pyloric stenosis found many cysts on the small intestine. These were not interfered with, and at the autopsy three weeks later they had entirely disappeared.

Thus it would appear, concluding from the reported cases, and from the examination of our own pathological specimen in which obliteration of the cysts can be seen in many areas, that the condition is self-limiting, with a tendency to spontaneous cure. Therefore, if the predisposing cause be treated, there is no indication for resection of the affected bowel or even an attempt at removal of the cysts.

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