The calculated amounts depend upon the assumption that 1.8 per cent. of nitrogen is dissolved in the plasma at +0. The actual values obtained in the control experiments of this series ranged between 1.46 and 2.16 per cent., a somewhat considerable variation.

In an experiment of v. Schrötter and his colleagues, a dog was exposed to +4.5 atmospheres for forty-five minutes, and the arterial blood yielded 9.2 per cent. of nitrogen as compared with a theoretical 9.9 per cent. on the former assumption. Bert's analyses are not strictly comparable with these, as he did not maintain his animals for long under a constant pressure, but they seem to suggest that the blood is not immediately saturated to the full amount. It is hard to arrive at satisfactory conclusions on this matter, because not only is the analysis of blood gases technically difficult, but the amount of nitrogen taken up by the plasma under normal circumstances is not accurately known. A less direct but simpler method of inquiry, which will be considered later, suggests that arterial blood is more rapidly saturated than the former analyses indicate, but we should be rash to assume that one circuit through the lungs necessarily equalizes the nitrogen tension of the blood with that of the alveolar air.

It is apparent that the time required to saturate the blood is not too easy to measure, but the problem is simplicity itself when compared with the more general question as to how long is required to saturate all the tissue liquids. As a matter of fact, absolutely complete saturation will not occur at all in a finite time. The reason of this is clearly explained by v. Schrötter (pp. 35-7, 1904, and p. 803, 1900).

Let us suppose that $1/p$ of the tissue liquids consists of blood, and that these liquids dissolve v volumes per cent. of nitrogen under normal conditions; let us further assume that under a pressure of n atmospheres all the blood passing through the lungs comes into gaseous equilibrium with the alveolar air at once.

Then, at the end of one complete circulation of the blood we shall have in the whole body

$$\frac{n.v}{p} + \frac{(p-1).v}{p} \text{ volumes per cent. of nitrogen.}$$

After another circulation we shall have:

$$\frac{n.v}{p} + \frac{p-1}{p} \left(\frac{n.v}{p} + \frac{(p-1).v}{p} \right) \text{ per cent. of nitrogen,}$$

and quite generally, after q circulations, we have:

$$n.v - \left(\frac{p-1}{p} \right)^q \text{ volumes per cent. of gas.}$$

Thus to attain full saturation—that is, $n.v$ volumes per cent. of dissolved nitrogen— q must be infinite.

In practice, however, the term $\left(\frac{p-1}{p} \right)^q$ diminishes rapidly at first and is small for relatively low values of q .

Thus, according to Haldane and Lorrain Smith (1900) the ratio of blood mass to body mass is about 1 to 20, and we have:

$$\frac{p-1}{p} = \frac{19}{20}$$

The value of this raised to the sixtieth power is less than 0.05. If, therefore, we assume all the blood to pass through the lungs in one minute, then at a pressure of +6 atmospheres—on the hypothesis that equilibrium is really attained in the lungs after one circuit—the body would be about 95 per cent. saturated in one hour. In other words, saturation is almost complete in a comparatively short space of time.

This investigation and the resultant formula are simple and interesting, but not very helpful in the solution of our real problem. To consider only one difficulty—the total circulation time as determined by experimental methods is misleading. Vierordt estimated (Heinz, 1906, p. 47) that the time required for the passage of a substance from one jugular vein to the other was, in the rabbit, 7.46 seconds; in a small goat, 14.14 seconds; in a dog, 16.7 seconds; in a horse, 31.5 seconds. As the pulse-rates of these animals are approximately 210, 110, 96, and 55 a minute respectively, he inferred that in each animal about the same number of pulsations is required to effect a complete circulation. This appears, at first sight, to afford a basis for calculation; but unfortunately it only gives us the time required for passing through the vascular system

by the *fastest moving* blood. For instance, if a volume equal to the total volume of the blood passes through the lungs of a man in one minute, this is *not* equivalent to saying that all the blood in his body traverses the lungs once a minute. Some portions of the blood will have made the circuit more than once, others not at all. We know roughly the circulation time of the *quickest* blood, not of the *slowest* blood, and the latter is just as important as the former. *A priori* reasoning will not, therefore, be of much assistance, and we can only have recourse to direct experiment.

PRIMARY PNEUMOCOCCIC PERITONITIS.

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UP to within the last few years the all-prevailing view of the origin of non-traumatic peritonitis was that it was without exception caused by some gross lesion, generally readily recognizable in the course of operation or *post-mortem* examination of one of the abdominal viscera. This opinion, held and taught dogmatically, and almost come to be looked upon as an axiom of surgery, had displaced the older conception of peritonitis as a clinical entity and a frequent primary condition. Recently it has been established beyond all doubt that cases of peritonitis do occasionally come under observation in which the most careful search, both *ante* and *post-mortem*, fails to discover the expected lesion in an abdominal viscus; and not only so, but in the majority of these cases there is no other lesion in any other organ whatever. Such a condition may justly be described as a primary peritonitis.

The cause of many such cases, though probably not all, is the organism of pneumonia, the *Pneumococcus lanceolatus*. Pneumococcal peritonitis, whether "primary" or owing its origin to the existence of some infecting focus elsewhere in the body, is at all times uncommon. It is most often met with in children, and in adults would appear to be extremely rare. Ashdowne,¹ in 1906, when recording a case of the primary diffuse form in an adult, could only find the record of 29 similar ones; while Annand and Bowen,² with 4 cases of their own in the same year collected the records of 47 primary and 44 secondary cases in children. The disease, like that caused by other infecting agents, may be diffuse or localized in the form of an intraperitoneal abscess.

During the last two years the following instances of the disease have been under my care, and their record may, in spite of their small number, help with others to elucidate the nature of these obscure and difficult cases, the existence of which will have to be borne in mind when trying to arrive at the probable cause of peritonitis, and hence to its prognosis, for the diffused forms of pneumococcal peritonitis have a very high mortality.

The first case is an example of the localized form in the adult of very rare occurrence indeed, only 8 cases having been so far recorded.

LOCALIZED PERITONITIS: ABSCESS.

CASE I.—A girl, aged 17, was admitted into hospital complaining of pain on the left side of her abdomen.

History.

Ten days before admission she began to have rather severe pain all over her abdomen, like "stomach ache"; there was no vomiting, and the bowels were regular, being open every day. The pain continued to be diffuse until three days before being seen, when it became slightly less, though still rather severe, and became more localized to the left side. The patient had never had any previous illness, and her family, with the exception of her father, who suffered from heart disease and bronchitis, was a healthy one. Menstruation was in every way regular and normal.

Condition on Admission.

An examination of the abdomen showed that the left rectus muscle was rigid, and that there was little movement of the abdomen on that side. A mass extended vertically on this side from somewhat below the crest of the ilium to slightly above the level of the umbilicus, and transversely from just without the median line into the loin. The mass was extremely tender and dull to percussion. It was apparently firmly fixed to its deeper connexions. Nothing abnormal could be made out by a rectal examination. There was a slight vaginal discharge of muco-pus, but a vaginal examination showed that the uterus and appendages were of normal size, freely movable,

and unconnected with the abdominal lesion. Swabs were taken from the vagina and cervix, and bacteriologically examined. The discharge, the girl said, had only been there since the commencement of her illness. The temperature was 100° and the pulse-rate 94. The patient looked fairly healthy and well. The thoracic organs were normal.

Operation.

Abdominal section on the following day revealed an abscess lying to the outer side of the colon and sigmoid flexure; to the inner side some coils of small intestine also helped to wall it off from the rest of the peritoneal cavity. The pus was thick, white, odourless, and contained masses of lymph suspended in it. The wall of the abscess was coated with flakes of the same lymph. No lesion of the bowel was discovered, and no glands could be felt. A small drainage tube was placed in the cavity and the rest of the wound sewn up in layers.

After-History.

Next morning the temperature was 100.6° and at night 101.6°, the pulse and respiration-rate also being quickened. The following day, with slight pain in the left lower chest, the temperature was 102.6°, the pulse-rate 132, and respirations 35 to 40 per minute. Definite signs of commencing pneumonia were present in the left base. The attack was very slight and the patient was never in great discomfort, the temperature coming finally to normal on the seventh day after operation. The abdominal wound healed soundly, and the patient left hospital well.

The examination of the pus from the abscess revealed the presence of the pneumococcus alone, without admixture with any other organism. The vaginal discharge contained no cocci of any kind, but many long rod-like bacilli, "probably urethral." "

DIFFUSE FORM.

CASE II.—A woman, aged 43, was admitted into hospital complaining of intense pain in the abdomen and vomiting.

History.

Two days before admission she had felt very tired, slightly shivery, but had gone about her household work in the usual way. Late at night, twenty-four hours exactly before admission, she was seized with intense pain in the upper part of the abdomen, with frequent vomiting and diarrhoea; this continued until her admission to hospital. She had never suffered from indigestion, nor had previous attacks of pain in the abdomen. There had been no sore throat. She put the onset of the pain down to having eaten at supper some chipped potatoes.

Condition on Admission.

The patient looked extremely ill. The face was pinched and cyanosed; the tongue brown and dry. The pulse feeble, 120; the temperature 101.6°. The abdomen was distended, its walls rigid, and very tender to touch. There was shifting dullness in the flanks, and absence of movement on respiration—in short, all the signs of a bad general peritonitis. Menstruation was regular and normal. There had been no previous illnesses. In view of the very sudden onset in the epigastrium of the pain, it was considered that the most likely diagnosis was that of a perforated gastric ulcer, although it was recognized that the case was anything but clear.

Operation.

Abdominal section revealed general peritonitis. The abdomen seemed to be full of a thin, absolutely odourless, yellowish-brown pus, somewhat like thin beef-tea, in which were floating numerous masses of a curdy lymph. The stomach showed no trace of disease either back or front; the lesser sac of the peritoneum was opened up, but only showed a quantity of the all-pervading pus. The wound was continued downwards, and the appendix and the uterus and appendages examined, but no lesion could be found. Indeed, a careful search everywhere showed no breach of surface. As this case, which happened two years ago, was my first experience of this class of peritonitis, I was considerably perturbed by not finding the expected visceral point of infection, but could see nothing else to do but to follow the fashion of that time—flush out the abdomen, and place drains in the pelvis and abdomen. Some of the pus was kept for examination, and showed that the organism present was the pneumococcus.

After-History.

The patient was very dull and apathetic, saying very little for many days afterwards, but otherwise made a slow but sure recovery. I saw her a short time ago, and she assured me that she had never felt better in her life.

CASE III.—A woman, aged 39, was admitted into hospital complaining of intense abdominal pain, worse in the lower half and in the right iliac fossa.

History.

Two days before admission she was suddenly seized with severe pain in the abdomen. The pain was bad all night, though there were slight intermissions in its severity. She vomited several times, and her bowels, usually constipated, were open several times, the motions being like diarrhoea. The pain, vomiting, and diarrhoea continued through the next day, and she got steadily worse. The patient up to this attack

had always had good health, with the exception of typhoid fever fifteen years ago. She had not suffered from indigestion, menstruation was regular and normal, and there had been no uterine trouble. She had had a child ten months ago.

Condition on Admission.

The patient seemed to be almost moribund. The face was cyanosed, pinched, and looking very distressed. The hands were cold, the pulse 120, and temperature 102.2°; the abdomen was distended, and its walls rigid, especially in the lower half. There was very slight movement on respiration. The abdomen was very tender to palpation. There was shifting dullness to percussion in both flanks, otherwise the abdomen was resonant. Nothing further could be made out in the abdomen. The pelvic organs on examination appeared to be normal. There was nothing abnormal in the lungs or heart. The patient's tongue was dry and coated. A diagnosis of peritonitis of unknown origin was made.

Operation.

Abdominal section showed that the peritoneal cavity was full of a thin, brown, odourless pus, containing very numerous flakes of lymph, and other flakes attached to the abdominal viscera. A careful search of all the usual sites of infection revealed no visceral lesion. A drainage tube was placed in the abdomen and the rest of the abdominal wound sutured. The patient was put back to bed, placed in a reclining position, and the constant rectal saline given.

After-History.

Next morning she appeared to be slightly better; there was no vomiting, the distension was less, and the abdomen soft. The tongue also was cleaner and moist. Towards evening, however, vomiting came on again, together with increase in abdominal distension and pain. The patient rapidly became worse and died early on the following day.

Pus taken at the time of the operation showed the pneumococcus in pure culture, no other organism being present.

Necropsy.

A complete post-mortem examination showed a general peritonitis, the abdominal viscera healthy, the stomach and bowel mucous membranes being healthy. The thoracic and pelvic organs were normal.

CASE IV.—Whether this case should be included as one of pneumococcal peritonitis is doubtful. Unfortunately no bacteriological examination of the pus was made, and when ultimately the patient died no post-mortem examination was allowed; but a consideration of the appearances found at operation and the after-course of the case makes me believe that we had here to deal with pneumococcus infection.

History.

The patient, a woman, was admitted into hospital complaining of great pain in the abdomen. With the exception of slight discomfort and pain after food, she had been quite well up to twenty-four hours before admission. The illness commenced with sudden and severe pain in the abdomen, she had to go to bed, and could scarcely turn over on account of the pain. She felt sick, but did not vomit.

Condition on Admission.

The patient was obviously very ill, and appeared very near death. Her face was slightly flushed and cyanosed; her hands and feet cold and clammy. She was restless, and the respirations hurried and inclined to be irregular. The abdomen was distended, tense, and rigid, not moving with respiration. The abdomen was generally tender to touch all over, but perhaps more so in the epigastrium. The liver dullness was present, but its edge did not come quite to the costal edge, perhaps from the distension of the intestines present. The temperature was 99°, and the pulse-rate 136 and hardly perceptible.

Operation.

A provisional diagnosis of perforate gastric ulcer was made, and in view of the patient's serious condition it was decided that the abdomen should be rapidly opened above the pubes, the pus present allowed to escape, and a drain placed into the pelvis. This was done, and at the same time the patient was infused. On opening the abdomen a large quantity of clear brownish fluid was evacuated. In the fluid were a quantity of clots like curdled milk. A drain was introduced and the patient put back to bed, the head of the bed raised, and saline injections by the bowel instituted.

After-History.

For the next ten days the patient steadily improved. The abdominal condition rapidly cleared up; the drain was removed, and the wound completely healed. No tenderness was present anywhere, and the condition of the thoracic organs was normal. All the time it was noticed that the patient was very quiet, almost apathetic, and after the first five days she became more so. On the seventh day after the operation the pulse-rate began to increase, on that day being 112 at night. The temperature was normal, and the patient was taking food well. On the eleventh day after the operation the patient became somewhat drowsy, the temperature rose to 101.8°, and

she had three epileptiform fits. The urine was normal. The next day there were nine fits, the patient was more drowsy, was not taking nourishment, she scarcely moved or spoke, and the head was retracted. She became totally unconscious, had many fits, and died on the fourteenth day after operation. The temperature varied between 99° and 102°, and the pulse-rate between 120 and 164.

From a consideration of the cause of death, meningitis, the presence of the liver dullness area, the curious torpor of the patient, and the character of the fluid in the abdomen, I came to the conclusion that the case was probably one of pneumococcic infection, though unfortunately, this could not be proved.

CASE V.—One further case has come under my notice of pneumococcic peritonitis; it occurred in a man. Cultures of the pus showed the presence of the pneumococcus, but unfortunately, owing to the man being seen in a moribund condition, and dying within a few hours, no notes were taken of the history. My remembrance of it is that the pain occurred suddenly two days before, that it was accompanied with vomiting, that there had been no previous history of ill health. The patient was cyanosed, had a greatly distended and rigid abdomen, a high temperature, and a very rapid pulse. The pus, of which there was a great quantity, was thin, and contained masses of white lymph unusually large and numerous. All the fat of the mesentery, especially the appendices epiploicae, were stuffed as it were with small foci of this white lymph. No *post-mortem* examination was allowed.

Pneumococcic peritonitis in its primary form seems to have, if we may judge from the reports of published cases, a symptom complex which in some cases, at any rate, should allow the surgeon to make a probable diagnosis of the disease. The majority of the patients are suddenly seized with severe abdominal pain. The pain from the first is generalized, remains so, and is accompanied more often than not by marked diarrhoea and vomiting. There has not usually been any previous ill health, abdominal or otherwise. The march of events is very rapid in the diffuse forms; the patients quickly have the aspect of intense poisoning, great prostration, rapid pulse, cyanosed face, and pinched expression. The abdominal condition rapidly assumes an advanced and severe form. The presence of free fluid in the peritoneal cavity seems to be an early sign. In many cases the presence of restlessness has been remarked, but this was absent in the patients I have observed, who were particularly quiet and indeed apathetic. The girl with the localized abscess was the most alert of all, for although she did not volunteer any information about herself, yet she briefly answered questions.

A peculiarity about the character of the pus in these cases, which is practically always noticeable, is the presence of a large quantity of coagulated lymph like curdled milk. The fluid portion may be plentiful and make up the bulk of the pus; when the curd-like masses are very much in evidence, or when the pus is thick and white, as in the localized forms, the lymph masses make up the bulk of the exudate.

The most common causes, excluding trauma, of peritonitis from which these cases will have to be distinguished are appendicitis, perforation of gastric and duodenal ulcers, and infection through some disease of the female pelvic organs.

It is difficult to say what symptoms or what order of symptoms may be safely relied upon as pointing to the presence of any one of these causes in a given case of peritonitis; indeed, in some cases it is quite impossible to make a diagnosis previous to operation.

Speaking generally, diffuse cases of peritonitis depending upon disease of the appendix have usually a history of abdominal discomfort, slight or severe localized pain, extending over several days or periods, before the severe symptoms come on. The abdominal tenderness, although it may be widely diffused, is most marked over the lower part of the abdomen, and often more marked still over the seat of the original mischief. Here, too, the rigidity of the muscles is apt to be more marked than elsewhere. Vomiting is common, but diarrhoea in this form, as it is in most forms of peritonitis, is rare. Pneumococcic peritonitis seems to start suddenly. The pain from the first is intense; it is generalized, more marked if anywhere in the epigastric region, not particularly marked in the right iliac fossa. Many of the patients have not previously had any form of abdominal trouble. Diarrhoea is a common symptom.

I have the impression, though it is difficult to be sure from the small experience I have had, that the actual rigidity of the abdominal walls in these cases is not so

great as it usually is in an appendix peritonitis of the same severity.

In diffuse peritonitis due to the perforation of a gastric ulcer there is, as is well known, more often than not the history of previous indigestion, pain and vomiting after food. The onset of perforation is usually heralded by the occurrence of sudden acute pain in the abdomen and severe shock, often by the sensation of something having given way or burst.

The pain at first is referred to the epigastric region—indeed, often to that portion of the parietes actually overlying the ulcer. It then, though never disappearing, may moderate for a short time, to be often referred to the lower part of the abdomen, where the peritoneum is becoming irritated by the gravitating stomach contents. The tender, often acutely tender, spot over the stomach lesion, however, remains, and can be made out by gentle palpation. The warning signs at this time, if the condition of shock is moderating, are the stiffly-contracted abdominal muscles, the tenderness on touch, and the rising pulse-rate, and, after the initial fall, rising temperature. Vomiting in the early stage of perforation is extremely rare. Generally, too, there is the important sign of the disappearing liver dullness, though in some cases this may not appear for some hours after the onset of the disease.

The separation of pneumococcic peritonitis from these cases will in many cases be difficult. The two have many signs and symptoms in common. The history of the presence or absence of stomach trouble, of the situation of the first pain, whether localized or general, the presence of vomiting, and more particularly of diarrhoea, will have to be utilized to help in arriving at a correct conclusion.

As the majority of cases of pneumococcic peritonitis occur in women, the question of disease of the pelvic organs as the cause of a given case will have to be considered. History of present or previous disease in these parts and a careful pelvic examination will probably enable the question to be settled.

One of the theories of the origin of pneumococcic peritonitis, based upon this frequency of occurrence in women and girl children, is that the organism finds an entrance by way of the vagina. But this does not seem to be borne out by any clinical facts. Another theory is that the onset of the disease is preceded or accompanied by the presence of gastro-enteritis which allows of the passage of the micro-organism through the walls of the bowel; this idea, which might be supposed to be countenanced by the frequent occurrence of diarrhoea, does not find any great support from *post mortem* findings, whether in adults or children.

The most likely theory, though it still leaves unsolved the question of the point of entrance of the coccus, is that the peritonitis is but the localized expression of a general blood infection. It is well known that the organism can be isolated from the blood of patients suffering from pneumonia. The onset of pneumonia in the case of the girl with the localized abscess, twelve days after the commencement of the abdominal disease, would seem to support this theory. So, too, does the onset of meningitis ten days after laparotomy in Case IV. The aspect of extreme poisoning, the cyanosis, the early occurrence of diarrhoea, and vomiting, may also be used to support this view.

CONCLUSIONS.

The conclusions to which a study of these cases leads are briefly these:

That an acute diffuse or localized peritonitis may be the sole symptom of a pneumococcic infection.

That such cases possibly form a considerable proportion of those anomalous cases of peritonitis without visible lesion of any of the abdominal viscera.

That their sudden onset after previous freedom from abdominal trouble, together with the frequent accompaniment of diarrhoea, and signs of early systemic poisoning, may perhaps serve to assist in differentiating them from peritonitis caused by other infection.

That they may be followed by pneumococcic lesions in other organs of the body.

That their prognosis is extremely grave.

REFERENCES.

¹ *Lancet*, vol. i, 1906. ² *Ibid.*